UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C., 20460

OFFICE OF
CHEMICAL SAFETY AND
POLLUTION PREVENTION

DP Barcode: D418317
PC Code: 080803
Date: April 12, 2016

MEMORANDUM

Subject: **Refined Ecological Risk Assessment for Atrazine**

To: Marianne Mannix, Chemical Review Manager
Kelly Sherman, Branch Chief
Risk Management and Implementation Branch 3
Pesticide Re-evaluation Division (7508P)

From: Frank T. Farruggia, Ph.D., Biologist
Colleen M. Rossmeisl, D.V.M., M.S., Biologist
James A. Hetrick, Ph.D., Senior Science Advisor
Melanie Biscoe, M.E.M., Physical Scientist
Rosanna Louie-Juzwiak, Risk Assessment Process Leader
Dana Spatz, M.S., Branch Chief
Environmental Risk Branch III
Environmental Fate and Effects Division (7507P)

Attached is the preliminary ecological risk assessment conducted by the Environmental Fate and Effects Division for the Registration Review of Atrazine.

REFINED ECOLOGICAL RISK ASSESSMENT FOR ATRAZINE

This refined assessment presents the ecological risks posed by the use of the herbicide atrazine. Based on the results from hundreds of toxicity studies on the effects of atrazine on plants and animals, over 20 years of surface water monitoring data, and higher tier aquatic exposure models, this risk assessment concludes that aquatic plant communities are impacted in many areas where atrazine use is heaviest, and there is potential chronic risk to fish, amphibians, and aquatic invertebrates in these same locations. In the terrestrial environment, there are risk concerns for mammals, birds, reptiles, plants and plant communities across the country for many of the atrazine uses. EPA levels of concern for chronic risk are exceeded by as much as 22, 198, and 62 times for birds, mammals, and fish, respectively. For aquatic phase amphibians, a weight of evidence analysis concluded there is potential for chronic risks to amphibians based on multiple effects endpoint concentrations compared to measured and predicted surface water concentrations. The breadth of terrestrial plant species and families potentially impacted by atrazine use at current labeled rates, as well as reduced rates of 0.5 and 0.25 lbs. a.i./A, suggest that terrestrial plant biodiversity and communities are likely to be impacted from off-field exposures via runoff and spray drift. Average atrazine concentrations in water at or above 5 µg/L for several weeks are predicted to lead to reproductive effects in fish, while a 60-day average of 3.4 µg/L has a high probability of impacting aquatic plant community primary productivity, structure and function.

Frank T. Farruggia, Ph.D.
Colleen M. Rossmeisl, D.V.M., M.S.
James A. Hetrick, Ph.D.
Melanie Biscoe, M.E.M.

Environmental Risk Branch III
Environmental Fate and Effects Division
Office of Pesticide Programs
U.S. Environmental Protection Agency

April 12, 2016

The authors would like to acknowledge the following people who contributed to and/or reviewed portions of this risk assessment.

Contributors:
Jonathan Becker, Ph.D. (OPP/BEAD)
Russell Erickson, Ph.D. (ORD/NHEERL/MED)
Matthew Etterson, Ph.D. (ORD/NHEERL/MED)
Kevin Flynn, M.S. (ORD/NHEERL/MED)
James Hook, M.S. (OPP/EFED)
Rodney Johnson, Ph.D. (ORD/NHEERL/MED)
Steven Lennartz, M.S. (OPP/EFED)
Charles Peck, M.S. (OPP/EFED)

Reviewers:
Catherine Aubee, M.S. (OPP/EFED)
Amy Blankinship, M.S. (OPP/EFED)
Rochelle Bohaty, Ph.D. (OPP/EFED)
Sigmund Degitz, Ph.D. (ORD/NHEERL/MED)
Kris Garber, M.S. (OPP/EFED)
Dale Hoff, Ph.D. (ORD/NHEERL/MED)
R. David Jones, Ph.D. (OPP/EFED)
Brian Kiernan, M.S. (OPP/EFED)
Rosanna Louie-Juzwiak (OPP/EFED)
Patricia Schmieder, Ph.D. (ORD/NHEERL/MED)
Dana Spatz, M.S. (OPP/EFED)
Nelson Thurman, M.S. (OPP/EFED)

ABSTRACT

This refined assessment presents the ecological risks posed by the use of the herbicide atrazine. Based on the results from hundreds of toxicity studies on the effects of atrazine on plants and animals, over 20 years of surface water monitoring data, and higher tier aquatic exposure models, this risk assessment concludes that aquatic plant communities are impacted in many areas where atrazine use is heaviest, and there is potential chronic risk to fish, amphibians, and aquatic invertebrates in these same locations. In the terrestrial environment, there are risk concerns for mammals, birds, reptiles, plants and plant communities across the country for many of the atrazine uses. EPA levels of concern for chronic risk are exceeded by as much as 22, 198, and 62 times for birds, mammals, and fish, respectively. For aquatic phase amphibians, a weight of evidence analysis concluded there is potential for chronic risks to amphibians based on multiple effects endpoint concentrations compared to measured and predicted surface water concentrations. The breadth of terrestrial plant species and families potentially impacted by atrazine use at current labeled rates, as well as reduced rates of 0.5 and 0.25 lbs. a.i./A, suggest that terrestrial plant biodiversity and communities are likely to be impacted from off-field exposures via runoff and spray drift. Average atrazine concentrations in water at or above 5 µg/L for several weeks are predicted to lead to reproductive effects in fish, while a 60-day average of 3.4 µg/L has a high probability of impacting aquatic plant community primary productivity, structure and function.

Table of Contents

LIST OF TABLES

Table of Figures

Table of Appendices

1. EXECUTIVE SUMMARY

1.1. Nature of Chemical Stressor

Atrazine is a triazine herbicide first registered by USDA in 1958. Atrazine is registered for use to control broadleaf and some grassy weeds in corn, sweet corn, sorghum, soybeans, sugarcane, wheat, oats, macadamia nuts, guava, turf grass, range grasses, switchgrass, fallow land, roadsides, conservation reserve programs, Christmas tree plantations and conifer forests. On the basis of total pounds of atrazine used in the United States, over 90% of atrazine is applied to corn; however upwards of 65% of sorghum and sugarcane acres are also treated. The non-agricultural uses of atrazine, such as turf and conifer forests, are not well characterized. This refined risk assessment evaluates the risks of all registered atrazine uses to non-target species of animals and plants in terrestrial and aquatic environments, as well as the potential impacts of atrazine on aquatic plant communities.

Triazine herbicides such as atrazine bind with a protein complex of the Photosystem II in chloroplast photosynthetic membranes (Schulz *et al.,* 1990). The result is an inhibition in the transfer of electrons that in turn inhibits the formation and release of oxygen. Atrazine shares a common mechanism of toxicity with 5 other chlorinated triazine compounds. Atrazine, simazine, propazine, and the 3 chlorinated degradates common to these compounds all exhibit neuroendocrine effects seen across mammals and can alter hormone levels in rats that may result in developmental and reproductive consequences. In addition to this primary effect in mammals, acute and chronic exposure of animals to each of these chlorinated triazine compounds has shown significant reduction in body weight and organ weights across multiple mammal and bird species. Because of atrazine's structural similarity to simazine and propazine, atrazine is considered to be of equal potency to simazine and propazine and the chlorinated degradates with respect to their common mechanism of toxicity. It was concluded that data from these chlorinated triazines can be used in the assessments collectively to characterize potential ecological risks.

1.2. Environmental Exposure Assessment

Atrazine is mobile and persistent in the environment; the main routes of dissipation are microbial degradation under aerobic conditions, runoff, and leaching. Because of its persistence and mobility, atrazine has the propensity to move into surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water.

The major degradates of concern for ecological risk of atrazine are deethylatrazine (DEA), deisopropylatrazine (DIA), diadealkylatrazine (DACT) and hydroxyatrazine (HA). Scientific open literature indicates that atrazine and these degradates have similar toxicity to terrestrial animals and that these effects are manifested at low exposure concentrations. However, in the aquatic environment, hazard from parent atrazine is the greater concern.

For terrestrial exposure, this assessment considered dietary exposure to atrazine and its degradates to animals on-field as well as off-field as a result of spray drift. Atrazine alone was evaluated for potential risks to terrestrial plants through off-field exposure from drift and runoff. Maximum labeled rates according to the currently registered labels were assessed for all uses. As a refinement, two reduced rates (0.5 lbs a.i./A and 0.25 lbs a.i./A) for corn scenarios were included. These refinements were selected based on reported use data discussed in **Section 5**.

The aquatic exposure assessment (see **Sections 7.3** and **7.4**) includes standard ecological modeling (*i.e.*, Surface Water Concentration Calculator [SWCC]), surface water monitoring data, as well as geospatial modeling using the USGS Watershed Regressions for Pesticides (WARP) model. Although each of the exposure assessment methods have limitations in estimating environmental exposure concentrations (EECs) of atrazine, the combination of the modeling approaches and monitoring data, taken together, provides a comprehensive depiction of atrazine occurrence in surface water at various spatial scales.

Maximum labeled rates were assessed with the SWCC for all registered uses. As refinements, two reduced rates (0.5 lbs a.i./A and 0.25 lbs a.i./A) for corn scenarios were included, and the impact of soil incorporation (0 to 15 cm) on SWCC predicted EECs was evaluated. These refinements were selected based on reported use data discussed in **Section 5**.

To characterize the geospatial extent of atrazine in surface water, surface water monitoring data were evaluated (see **Section 7.4**). This data set includes over 20 years of ambient surface monitoring data for atrazine and its degradation products. Because the various atrazine monitoring programs were designed with different objectives, it is generally difficult to directly evaluate atrazine occurrence data in the context of exact atrazine use rates, application timing, and source of atrazine for a specific monitoring site. In order to address the uncertainty in atrazine occurrence data due to sample frequency, bias factors were developed from the Atrazine Ecological Exposure Monitoring Program (AEEMP), Atrazine Monitoring Program (AMP), and National Center for Water Quality Research (NCWQR) (see **Section 7.4**). These monitoring programs were selected for determination of bias factors because they have high sampling frequencies, from daily to 7-day sampling intervals, and the sites are associated with atrazine use areas. The bias factors normalize atrazine occurrence data to account for the impact of sampling frequency on capturing peak or high-end atrazine concentrations. Monitoring data, including those that were adjusted with a bias factor, are used for the identification of aquatic environments where the ecological levels of concern (LOC) may be exceeded (see **Section 15**).

1.3. Risk to Terrestrial Animals and Plants

Atrazine is slightly toxic to birds and mammals and is practically non-toxic to terrestrial invertebrates on an acute exposure basis. In most terrestrial animal species, chronic effects are

the predominant concern and are discussed further below. Based on the mechanism of action, *i.e.*, disruption of photosynthesis, atrazine is toxic to most photoautotroph organisms including unicellular algae, and flowering plants.

When estimates of atrazine exposure in terrestrial environments are compared to the available ecotoxicity data, the results indicate potential risk to birds, mammals and plants (see **Section 14**). Risk to birds and mammals is primarily through chronic exposure, although some LOCs are exceeded for acute risk to birds under scenarios involving higher use rates. Levels of concern for terrestrial plants are exceeded following spray drift and/or runoff after applications according to all currently labeled maximum application rates, as well as rates as low as 0.25 lb a.i./A.

1.3.1. Birds, Mammals, Reptiles and Terrestrial Phase Amphibians

The most sensitive acute endpoint for birds (LD_{50}) is 783 mg a.i./kg-bw for the northern bobwhite quail. The most sensitive chronic endpoint for birds is reported in reproduction studies in the mallard duck at atrazine concentrations of 75 mg a.i./kg-diet. Decreased hatchling weight was significant at all concentrations tested, with decreases ranging from 5.3 to 12.3% at 75 to 675 mg a.i./kg-diet, respectively. At a concentration of ≥225 mg a.i./kg-diet, there were effects on egg production and mean food consumption while live embryos and hatchlings per eggs set and male weight gain were affected at 675 mg a.i./kg-diet. A limited number of additional studies are available in the open literature on chronic effects of atrazine in birds and are also considered in this assessment.

On an acute exposure basis, atrazine is slightly toxic to mammals (LD_{50} = 1,869 mg/kg-bw). The most sensitive chronic endpoint in mammals is reported in a reproductive study in the Norway rat. The reported NOAEL was 50 mg/kg-diet (3.7 mg/kg-bw) based on decreases in body weights, body weight gains and food consumption. A number of additional mammalian toxicity studies are available in the open literature and are also considered in this assessment.

Based on available toxicity data for birds and mammals, the primary degradates of concern for atrazine (DEA, DIA, DACT and HA) are generally of equal toxicity or slightly more toxic than atrazine. In order to account for this toxicity, a default upper bound foliar dissipation rate of 35 days is assumed in terrestrial exposure modeling, allowing the assumed persistence of atrazine to serve as a surrogate for degradate toxicity.

For birds, acute and chronic levels of concern are exceeded for a number of uses. Maximum RQs occur for the small bird with short grass as the primary food item and the sugarcane and macadamia nut use scenarios (RQs range from 20.5 to 22.5). For corn, RQs range from 0.01 – 3.41 for acute risks and 0.2- 22.5 for chronic risks across the range of application rates, sizes and dietary items of birds. Although acute risks are of concern, for most use scenarios, chronic risks pose the greater concern in birds.

In order to refine the risk analysis for birds, higher tier modeling was performed using the Terrestrial Investigation Model (TIM) and the Markov Chain Nest Productivity model (MCnest). At 2/0.5 lb a.i./A with a 14 day application interval, the maximum labeled rate for corn, the probability distributions from the TIM model predicts there is a 95% chance that between 5 and 14 birds out of the flock of 25 will die, with the greatest likelihood of 9 deaths, for the on field small insectivore group. Based on the same application rate, out of the 59 species modeled using MCnest, impacts to reproduction were predicted for 88% of those species modeled. Additional sensitivity analyses for TIM and MCnest are contained in **Section 14.1.3.2**.

In addition to modeling with the TIM and MCnest stand-alone models, the integrated TIM-MCnest model (Beta version) was used to simulate effects to specific species. Use of this model allowed for the incorporation of more species specific parameters and acute mortality data as inputs into the MCnest model. In addition, the combined model allowed for the incorporation of species known to frequent corn fields. Similar to the results of the separate TIM and MCnest analyses, reproductive output and mortality were impacted in the five species modeled to varying degrees, with reproductive output predicted to be reduced in all species modeled. **Figure 1** below depicts the predicted impact to reproduction on the five species simulated with the combined model. These outputs represent a greater refinement to the model and are indicative of impacts to species that are known to frequently visit the corn fields in the geospatial area of heaviest atrazine use.

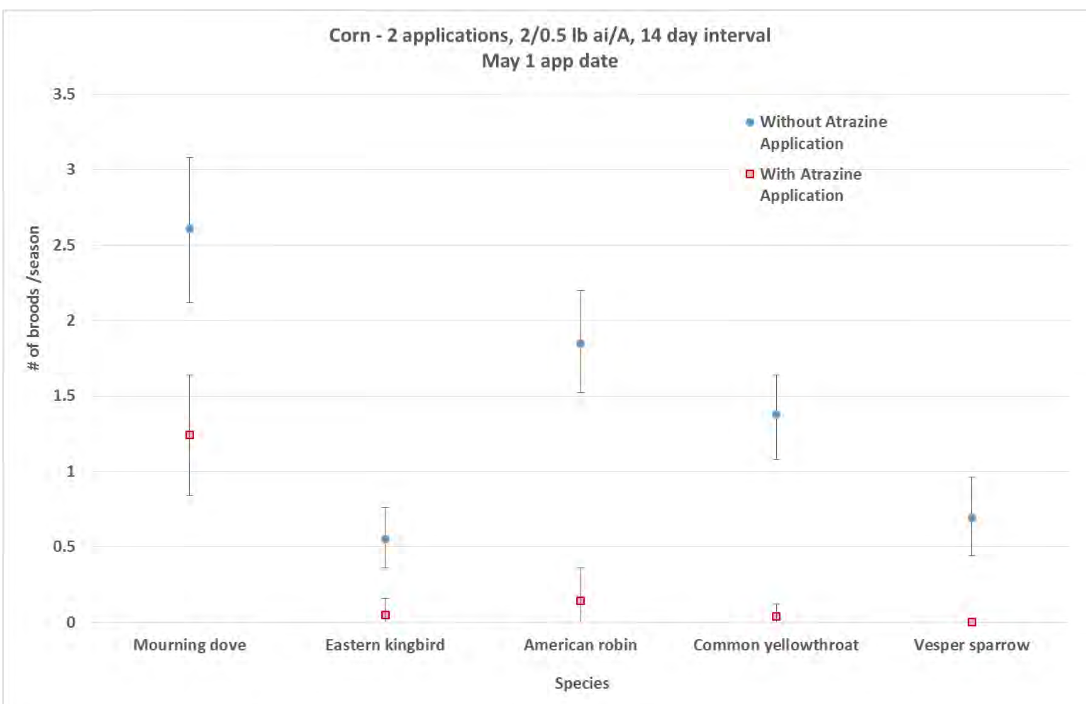


Figure 1. **Reproductive impacts (number of broods per season) with and without atrazine application for several bird species known to frequent corn fields in Midwestern states (Iowa and Illinois).**

For mammals, chronic levels of concern are exceeded for a number of uses while acute RQs only exceed the listed species LOC. Maximum RQs occur in the small mammal with short grass as the primary food item and the sugarcane and macadamia nut use scenarios (RQs range from 180 to 198). For corn, RQs range from 0.0 – 0.4 for acute risks and 0.1- 198 for chronic risks across body sizes and dietary items.

As illustrated in **Figure 2,** based on upper bound dietary EECs the LOC for chronic risk to mammals is exceeded for 80 to 130 days out of the year across 4 different dietary items. Although not shown graphically, when the same analysis is completed for sugarcane, the highest labeled use rate, the LOC is exceeded for approximately 70 to 210 days out of the year across 5 dietary items.

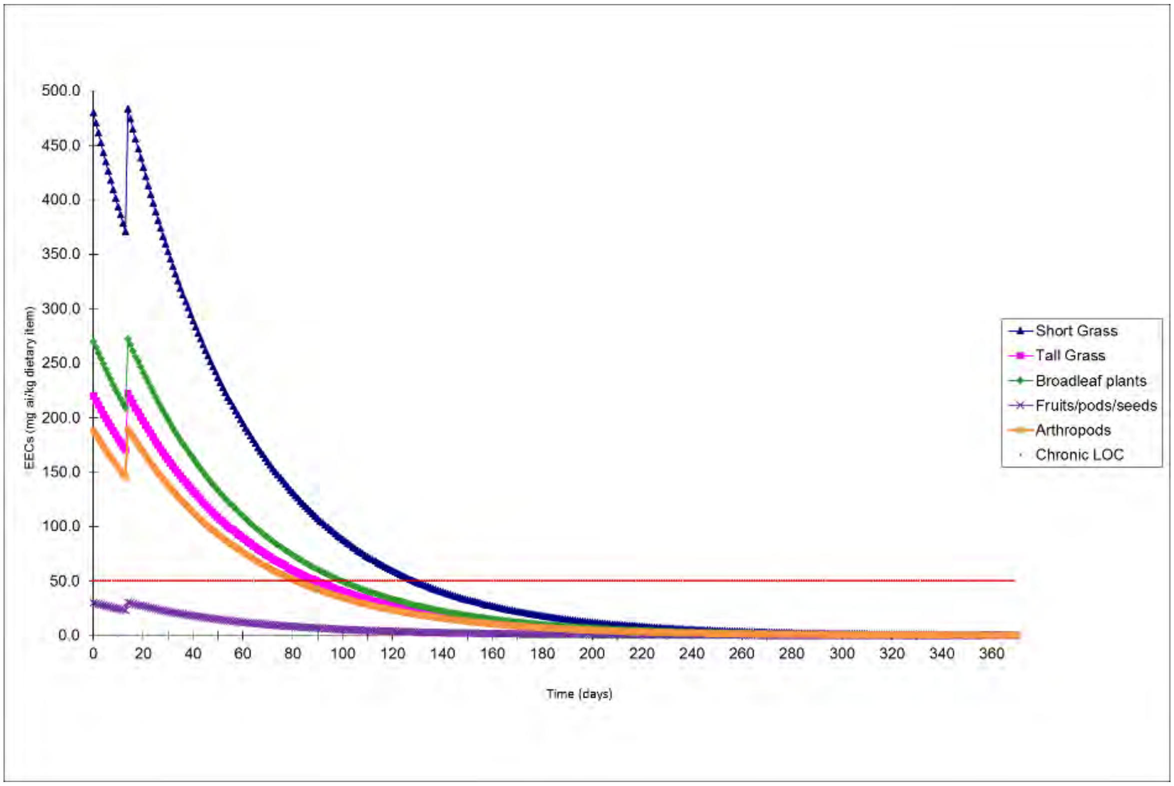


Figure 2. Terrestrial dietary EECs for atrazine applied at 2/0.5 lbs a.i/A with a retreatment interval of 14 days (maximum labeled corn use rate). Day 0 = date of first application.

Based on a tier I terrestrial spray drift analysis, chronic risk LOCs for mammals are exceeded at distances of 25 to 250 feet off the field following ground spray application at 4 lb a.i./A, with the distance depending on particle size and spray-boom application height. The distance off the field for risk to birds is less than the distance for mammals.

T-Herps was used to provide refined EECs and RQs for reptiles and terrestrial-phase amphibians using bird toxicity data (**Sections 11.1.1**). Modeled rates included 2 and 4 lb a.i./A as single applications and a reduced single application rate of 0.5 lb a.i./A. RQ values exceeded LOCs

primarily for those herpetofauna consuming herbivore mammals but included groups with other dietary items for higher rates (insectivore mammals and broadleaf plants/small insects; **Section 14.1.5**). Consistent with the calculated RQs for birds, the primary risk concerns for herpetofauna were associated with chronic risk, with RQs ranging from 1.2 to 22.6.

1.3.2. Terrestrial Invertebrates

Atrazine is practically non-toxic to honey bees (*Apis mellifera L.*) based on acute contact toxicity. The reported LD_{50} value is >97 µg/bee with 5% mortality reported at the highest dose tested. Additional studies on honey bees were not available. Studies available on beetles and earthworms generally indicated no effects within the range of application rates for atrazine. Effects were reported for springtails within the range of application rates, with 18% mortality reported at approximately 1 lb a.i./A application rate.

Using the new pollinator guidance (USEPA et al. 2014) to estimate terrestrial invertebrate risk, an RQ value for acute contact toxicity in the honey bee was calculated as 0.11; less than the LOC of 0.4 for acute exposure. No data on oral or larval honey bee exposure with atrazine are available for additional RQ calculations. Based on toxicity studies in other terrestrial invertebrates and the range of application rates, risk to most tested species is not anticipated. One exception is the springtail, where mortality was seen in one study at an application rate of 1 lb a.i./A, which is within the range of application rates for atrazine.

1.3.3. Terrestrial Plants

Terrestrial plant toxicity studies are available in the open literature as well as through registrant submitted data (see **Section 10.1**). These studies provide a number of endpoints showing that atrazine and atrazine formulations are highly toxic to both monocot and dicot terrestrial plants from the onset of seed germination through plant maturation phases captured in the seedling emergence and vegetative vigor studies. The most sensitive seedling emergence phase IC_{25} endpoints for dicots and monocots are 0.003 and 0.004 lbs a.i./A respectively. The most sensitive vegetative vigor IC_{25} endpoints for dicots and monocots are 0.008 and 0.61 lbs a.i./A respectively.

The levels of concern for terrestrial plants are exceeded for all atrazine labeled uses and application rates. Refinements of the application rate down to 0.5 and 0.25 lbs a.i./A reduced risk quotients; however, the levels of concern are exceeded for all runoff and runoff+spray drift conditions.

Because of the rich dataset available for atrazine, separate species sensitivity distributions (SSDs) were developed for the seedling emergence and vegetative vigor endpoint data based on the reported concentrations that cause a 25% inhibition (IC_{25}) in growth. A comparison of the SSDs indicates that the seedling emergence data is approximately one order of magnitude more sensitive than the vegetative vigor data. These SSDs are used to discuss potential risks to

non-target off-field species of plants that are exposed to atrazine through runoff and/or spray drift.

The seedling emergence and vegetative vigor SSDs, when compared to the EECs from TerrPlant modeling, indicate that terrestrial plants exposed to atrazine from spray drift following aerial application, and runoff with and without spray drift following either ground or aerial applications are at risk (see **Section 14.2.2**). The percent of the SSD exceeded by the TerrPlant EECs is interpreted as the percent of species that will have a 25 percent or greater reduction in growth. As an example, based on the seedling emergence SSD and TerrPlant estimated EECs following a ground application of atrazine at 2 lb a.i/A on corn, a 25% or greater reduction in growth for 71% of plant species is predicted based on spray drift exposure alone. For semi-aquatic habitats and plants that receive run-off from the field, 98% of species are predicted to be impacted by survival and/or growth reductions of 25% or greater.

Seedling emergence endpoints reflect the most sensitive data, but also the most likely stage of plant development during the corn application season. Under the reduced application rate scenario of 0.25 lb a.i./A, and assuming ground application, 88% of species are estimated to incur a 25% or greater reduction in survival and/or growth when exposed as developing seedlings in semi-aquatic habitats.

With a ground application to corn at 2.0 lb a.i./A, drift concerns for non-target plants span from 100 to 400 feet for 50% of tested terrestrial plants. For more sensitive taxa, distances extend to between 300 and 600 feet for the coarsest droplet spectra with a low boom release height. All other modeled scenarios extend this distance out to beyond 1000 feet for the very-fine to fine droplet spectra and a high-boom release height.

The diversity of species that are included in the SSDs for both vegetative vigor and seedling emergence data suggests that a broad diversity of plants are sensitive to atrazine exposure. The breadth of species and families of plants potentially impacted by atrazine use at current maximum labeled rates, as well as following application at reduced rates of 0.5 and 0.25 lb a.i./A suggest that terrestrial plant biodiversity and communities are likely to be impacted from off-field exposures via runoff and spray drift.

1.4. Risk to Aquatic Animals, Plants and Plant Communities

Atrazine is moderately toxic to freshwater and estuarine/marine fish, highly toxic to freshwater aquatic invertebrates and very highly toxic to estuarine/marine aquatic invertebrates on an acute exposure basis (see **Section 11.2**). Chronic exposure studies for freshwater and estuarine/marine fish, aquatic phase amphibians and aquatic invertebrates resulted in significant effects on survival, growth or reproduction, with freshwater fish having the most sensitive reported chronic endpoint due to reproductive effects.

Based on available toxicity data for aquatic organisms, including fish, aquatic invertebrates, aquatic phase amphibians, and aquatic plants, the primary degradates of atrazine (DEA, DIA, DACT and HA) are less toxic than the parent compound, with reported toxicity levels often exceeding the maximum solubility of the compound. For these reasons, aquatic exposure modeling was based on atrazine only.

1.4.1. Fish

The most sensitive freshwater fish acute study is the rainbow trout with a 96-hour LC_{50} of 5,300 µg a.i./L. The most sensitive chronic endpoint in fish was for total egg production in the Japanese medaka (*Oryzias latipes*) in a 38 day study. Fish were exposed to atrazine concentrations of 0.5, 5 and 50 µg/L. Total egg production was lower (36-42%) in all atrazine-exposed groups compared to the controls. Based on EPA's review of the study, the NOAEC for freshwater fish was established at 5 µg/L and the corresponding LOAEC at 50 µg/L based on statistically significant reductions in cumulative egg production. A similar study is not available for saltwater fish and, although significant differences in toxicity to freshwater and saltwater fish were not necessarily observed, differences exist between freshwater and saltwater invertebrates. This is an area of uncertainty in the assessment and thus, the chronic freshwater fish endpoint was also applied to saltwater fish. A number of other open literature studies are available for chronic effects in fish and are included in the analysis.

Levels of concern are exceeded for freshwater and estuarine marine fish based on chronic exposures to atrazine through runoff and spray drift following labeled applications for all registered uses (RQs = 0.94 to 61). Estimated RQs following the modeled refinements, reduced application rates and soil incorporation, exceed levels of concern for all modeled corn scenarios.

1.4.2. Aquatic Phase Amphibians

An extensive review of the available literature was previously conducted for amphibian species and presented at FIFRA Scientific Advisory Panel (SAP) meetings (2003, 2007, and 2012). For each of these SAPs, studies were reviewed for scientific validity and quality with criteria largely based on OPP's open literature guidance (*e.g.*, USEPA 2011c). Reported effects in amphibians included mortality, growth/developmental alterations, reproductive/sexual trait alterations, endocrine mediated and immunologic effects. Studies were classified as quantitative, qualitative or invalid based on these reviews.

Based on feedback from the 2012 SAP, those studies that were classified as qualitative were added to a pool of literature reviewed since the 2012 SAP and were included in a weight of evidence analysis. The weight of evidence analysis involved grouping data based on major effects groups, including amphibian survival, growth, development and reproduction, and determining the amount of confidence in these data. The effects data were then compared to anticipated exposure concentrations based on surface water monitoring and modeling.

The weight of evidence analysis concluded there is possible risk to amphibians as there is significant overlap of multiple effects endpoints and the EECs estimated with modeling, as well as surface water monitoring results. This is consistent with the results found for all other aquatic organisms, including fish, invertebrates and plants. Due to the variability in the reported amphibian endpoints, establishment of a definitive quantitative value for RQ calculations was not possible. Instead, chronic endpoints for fish and plants are considered acceptable surrogates for protection of aquatic amphibian species.

1.4.3. Aquatic Invertebrates

On an acute exposure basis, the most sensitive aquatic invertebrate organism tested was the juvenile estuarine/marine shrimp, *Neomysis integer* with an LC_{50} of 48 µg a.i./L. For freshwater aquatic invertebrates, the most sensitive acute toxicity value is for the midge, *Chironomus tentans*, with a 48-hour LC_{50} value of 720 µg a.i./L. Chronic toxicity endpoints for aquatic invertebrates are 60 µg/L and 3.8 µg/L for freshwater (Scud, *Gammarus fasciatus*) and saltwater (Opposum shrimp, *Neomysis integer*) species, respectively. Chronic effects observed were reduction in growth and survival, and relied upon an Acute to Chronic Ratio for the estuarine/marine endpoint. A number of other chronic endpoints are reported in the open literature and were included in this analysis (see **Section 11.2.2**).

There are risk concerns to listed freshwater invertebrates from acute exposures (RQs = 0.2 - 0.3 and to non-listed and listed species from chronic exposure (RQs = 0.5 - 3.3). Estuarine/marine invertebrates are more sensitive than freshwater species on both an acute exposure and chronic exposure basis and result in risk conclusions for all uses and modeled rate reduction scenarios (RQs = 0.5 – 4.3 for acute risk and 6.2 – 52 for chronic risk).

1.4.4. Aquatic Plants

The most sensitive aquatic non-vascular plants tested with atrazine are the chlorophycean “green” algae, *Stigeoclonium tenue*, and the cyanobacterium “blue-green algae” *Oscillatoria lutea* with 67% and 93% reductions in chlorophyll production at 1 ug a.i./L. Results from many other single species toxicity tests on aquatic plants representing all major lineages of photoautotrophic organisms derived similar endpoints (see **Section 10.2**). Vascular aquatic plant endpoints are also similar to those of the non-vascular aquatics with the most sensitive taxon being *Elodea canadensis* at 4.6 ug a.i./L based on reduced growth (see **Section 10.3**).

The non-listed LOCs for aquatic non-vascular and vascular plants are exceeded for all uses, rates and SWCC scenarios including those evaluating exposures following reduced rates and soil incorporation (RQs = 5.2 – 316 and 1.1 – 68.7 respectively).

1.4.5. Aquatic Plant Communities

In addition to reviewing the aquatic plant toxicity data for individual species, the toxicity of atrazine to aquatic plant communities was evaluated (see **Sections 10.4** and **12.2**). The focus on toxicity to the plant community is necessary to ensure that the atrazine concentrations in watersheds do not cause significant changes in plant community structure, function and productivity and thus put at risk the food chain (*e.g.*, reducing food for fish, invertebrates and birds) and ecosystem integrity (*e.g.*, erosion control and animal habitat). In this approach, single-species plant toxicity data and microcosm/mesocosm (cosm) studies are used to determine what atrazine exposure patterns and concentrations are likely to result in changes to the productivity, structure and/or function of aquatic plant communities. From these data, a level of concern was developed, which together with monitoring data is used to identify watersheds where atrazine levels pose a concern for these communities. This level of concern is referred to as the Concentration Equivalent Level of Concern (CELOC). The aquatic plant community CELOC of 3.4 ug a.i./L can be compared to 60-day average concentrations of atrazine to identify watersheds that warrant further attention.

The CELOC is exceeded for all labeled uses and for 100% of the modeled scenarios for these uses. The evaluation of lower application rates down to 0.5 lb a.i./A results in reduced RQs; however, risk to the aquatic plant community is still predicted, with all scenarios exceeding the CELOC. EECs following a reduced application rate of 0.5 lb a.i./A, and soil incorporation to depths greater than 6 cm, begin to fall below the CELOC for some scenarios.

Exceedances of the CELOC are considered far more meaningful than exceedances for any single aquatic plant species. Because of the dependence of the entire aquatic ecosystem on the plant community, negative impacts on the plant community are expected to cascade through the ecosystem. Potential impacts on the entire aquatic ecosystem include reduced biological diversity, reduced food items for fish, birds and mammals (e.g., drifting insects; benthic organisms, and emerging insects), reductions in spawning and nursery habitat, increased erodibility, and reduction in overall water quality. Impacts on smaller scale communities such as headwater streams, ponds, and wetlands could carry over to larger rivers, lakes, and reservoirs which contain organisms that depend on the headwaters and microhabitats the CELOC is intended to protect for refuge (e.g., during high flow events, thermal events, predation and competition) and rich feeding sites for spawning and nursery habitat

1.5. Geographic Distribution of Risk to Aquatic Animals, Plants and Aquatic Plant Communities

A highly refined geographic depiction of the predicted risk to aquatic species and aquatic plant communities was developed using USGS's Watershed Regressions for Pesticides (WARP) model and the vast amount of atrazine monitoring data. WARP provides a base map for predicted atrazine concentrations that helps to highlight waters across the atrazine agricultural use area that may contain atrazine concentrations above the aquatic levels of concern. These base maps

are presented with the available georeferenced monitoring data results. The combination of the WARP model estimates, together with monitoring data and SWCC EECs, provides multiple lines of evidence in terms of atrazine exposure across the landscape. A full discussion of the geographic distribution of the risks to aquatic animals, plants and aquatic plant communities is provided at the national and state levels (see **Section 17**).

The map presented below (**Figure 3**) provides an example of how the WARP model and georeferenced monitoring data are used to describe the landscape where risk to aquatic taxa is expected. Evident in this map is the expanse of watersheds that have been identified as having 60-day maximum average atrazine exposure concentrations (modeled and measured) which result in potential risk to amphibians, fish, and aquatic plant communities. The overlay of georeferenced monitoring data supports the model estimates and corroborates the geographic extent of potential atrazine risks to these taxa and communities.

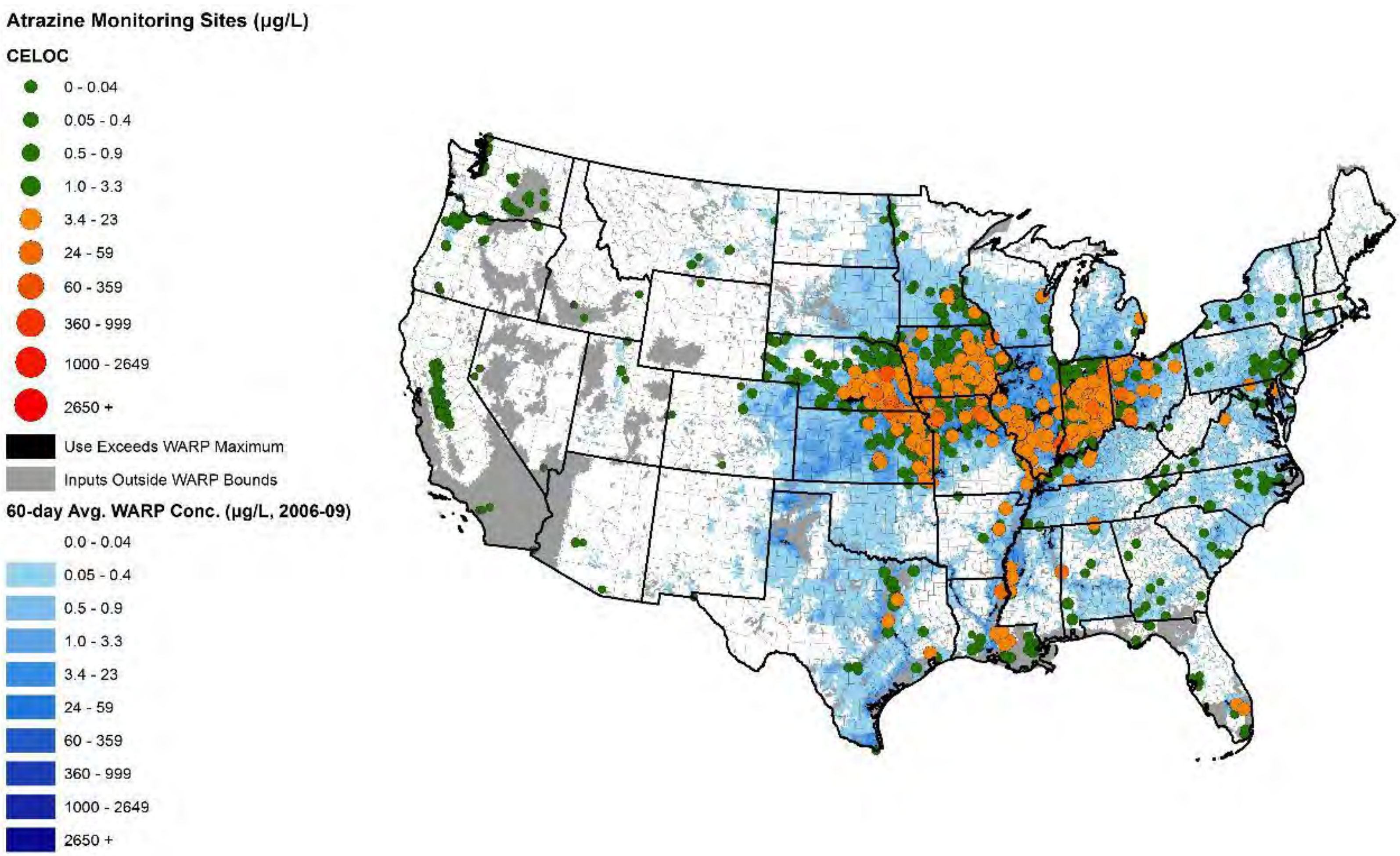


Figure 3. Predicted and measured 60-day average atrazine concentration (µg/L) using WARP and the available georeferenced monitoring data illustrate the national risk picture for amphibians, fish, aquatic plants and communities. WARP generated concentrations (blue shading) represent the average predicted 60-day concentration based on agricultural use and weather input data for 2006-2009. Available georeferenced monitoring data with 12 or more samples are identified as green when the 60-day maximum average concentration is below the CELOC (3.4 µg/L) and orange to red when exceeding the CELOC and also represents risk to amphibians and fish.

2. INTRODUCTION

Atrazine is registered as an herbicide in the U.S. to control annual broadleaf and grass weeds primarily in corn, sorghum, and sugarcane. In addition to food crops, atrazine is also used on a variety of non-food crops, forests, residential, commercial, and industrial lawn uses, golf course turf, recreational areas, and rights-of-way. It is one of the most widely used herbicides in North America (USEPA, 2003a).

The purpose of this risk assessment is to provide an understanding of what is currently known about the environmental fate and ecological effects of atrazine, in relationship to its registered uses, and describes EPA's approach for analyzing data relevant to atrazine and its degradates and for conducting the environmental fate and ecological risk assessment for atrazine's registered uses. This document also provides ecological risk conclusions based upon currently available data, the herein described modeling approaches, and the extensive national monitoring data. The assessment describes the ecological risk picture on a national scale and then identifies within states the regions with the highest potential risk to aquatic organisms.

3. BACKGROUND

Atrazine was first registered by the United States Department of Agriculture (USDA) in 1958 as a broad spectrum residual herbicide. Atrazine is used both at plant and post-plant, and is primarily used in corn, sweet corn, sorghum, and sugarcane production. Additional uses include soybeans, wheat (stubble only), oats, macadamia nuts, guava, range grasses, conifer forests, Christmas tree farms, sod farms, ornamental grasses, ornamental plants, ornamental turf, residential lawns, schools, parks, playgrounds, athletic fields, roadsides, rights-of-ways, airfields, vacant lots, roadsides, lumber yards, agricultural buildings, industrial sites and storage sites.

Atrazine is mobile and persistent in the environment. The main routes of dissipation are microbial degradation under aerobic conditions, runoff, and leaching. Because of its persistence and mobility, atrazine will move into surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water.

In June, 2012, the EPA presented the agency's problem formulation for this ecological risk assessment to the Scientific Advisory Panel, which focused on three major topic areas:

1. the evaluation of the atrazine amphibian toxicity data,
2. the method for determining the level of concern for aquatic plant communities, and
3. the development and implementation of methods for a quantitative interpretation of atrazine occurrence data in surface water.

A refined methodology for determining the magnitude and frequency of atrazine exposures below which significant changes in aquatic plant community structure, function and productivity are not expected was presented. EPA's review of atrazine studies with amphibians published in the open literature since 2007 was also presented. The Panel recommended that EPA further analyze existing ecological data and proposed that additional studies be conducted to further refine the environmental fate and ecological risk assessment for atrazine. The Panel also recommended some refinements and alternative approaches for consideration when interpreting uncertainty in atrazine water monitoring data. EPA responded to the 2012 SAP recommendations in an addendum document (USEPA 2013) and used the feedback in part to guide the amphibian and aquatic plant community portions of this risk assessment.

4. MECHANISM OF ACTION

Triazine herbicides such as atrazine bind with a protein complex of the Photosystem II in chloroplast photosynthetic membranes (Schulz *et al.,* 1990). The result is an inhibition in the transfer of electrons that in turn inhibits the formation and release of oxygen. Atrazine shares a common mechanism of toxicity with 5 other chlorinated triazine compounds. Atrazine, simazine, propazine, and the 3 chlorinated degradates common to these compounds all exhibit neuroendocrine effects seen across mammals and can alter hormone levels in rats that may result in developmental and reproductive consequences. In addition to this primary effect in mammals, acute and chronic exposure of animals to each of these chlorinated triazine compounds has shown significant reduction in body weight and organ weights across multiple mammal and bird species. Because of atrazine's structural similarity to simazine and propazine, atrazine is considered to be of equal potency to simazine and propazine and the chlorinated degradates with respect to their common mechanism of toxicity. It was concluded that data from these chlorinated triazines can be used in the assessments collectively to characterize potential ecological risks.

5. OVERVIEW OF PESTICIDE USE AND USAGE

Information on use sites, formulations, application methods, and application timing has been obtained from various EPA sources, including databases such as OPPIN and the Label Use Information System (LUIS), and confirmed through a review of label information (USEPA, 2012a). A summary of the currently registered product labels was provided by the atrazine registrants (Atrazine Registrant Use Matrix, 10/23/2013). This information was used to identify the application rates for assessing risk in this assessment and is provided in **Table 1** and **Table 2**.

Table 1. Maximum Application Rates, Maximum Applications, Minimum Application Intervals, and Application Methods for Section 3 Atrazine Labels

Crop	Max App Rate (lbs/A)	Max Apps	Min App Interval (days)	Max Annual Rate (lbs/A)	App Method	Geo Restriction	Label Numbers
Corn[1]	2(1.6)[2]/0.5	2	14	2.5	Air/Ground		100-497 35915-4 66222-36 100-585 35915-3
Sorghum[3]	2(1.6)[2]/0.5	2	14	2.5	Air/Ground		
Sugarcane	4/2/2/2	4	14	10	Air/Ground		
Turf-Bermudagrass	1	2	30	2	Ground	Do not use north of NC or west of eastern OK and eastern TX	
Turf-St Augustine grass	4	2	14	6	Ground	Do use north of NC or west of eastern OK and eastern TX	
Fallow-Winter Weed Control-Prior to planting corn and sorghum	1[4]	1	NA[5]	2.5	Ground	Gulf Coast and Blacklands of TX	
Fallow- post wheat harvest	1[4]	1	NA	2.5	Ground	Use in CO, KS, ND, NE, SD, and WY	
Fallow- Prior to planting corn and sorghum	2.25[4]	1	NA	2.25	Ground	Soil restrictions per soil pH in ND and SD	
Roadside	1	1	NA	1.0	Ground	CO, KS, ND,NE, SD, and WY	
CRP	2.0	1	NA	2.0	Air/Ground	OK, NE, TX, OR	
Macadamia Nuts	4	4	14	8	Ground		
Guava	4	4	120	8	Ground		
Conifers	4	1	NA	4	Ground		

1-Field, sweet, and pop-corn.
2-Application rate on highly erodible soils
3-Sorghum and Sorghum-Sudan Hybrids
4-Application rate needs to be considered in allowable annual rate on corn or sorghum
5- Applied in November and December

Table 2. Maximum Application Rates, Maximum Applications, Minimum Application Intervals, and Application Methods for Section 24c Atrazine Labels

Crop	Max App Rate (lbs/A)	Max Apps	Min App Interval (days)	Max Annual Rate (lbs/A)	App Method	Label Numbers
CRP	2.0	1	NA	2	Air/Ground	MN-000004 IA-970001
Fallow- Sorghum/Corn	2.0	1	NA	2.5	Ground	KS-030003
Fallow-Winter Wheat	1.0	1	NA	1.0	Air/Ground	OK-830029 OK-830030
Fallow-Winter Wheat	0.5	1	NA	0.5	Air/Ground	OK-830024 OK-830030
Fallow-Wheat	0.4	1	NS	0.4	Ground	ID-830009 OR-040008
Sorghum	1.2	1	NA	1.2	Ground	OK-910003 OK-910001
Sorghum	1.25(1)[1]	1	NA	1.2	Air/Ground	TX-920005 TX-920006
Roadsides	2.0	1	NA	1.0	Ground	OK-920007 OK-920008
Switchgrass	2.0	2	14	2.0	Ground	TN-080010

1-Fall and Winter Application

5.1. Formulations

Atrazine is available in many formulations, including granular, wettable powder, water dispersible granules, emulsifiable concentrate, flowable concentrate, soluble concentrate, ready-to-use solution, and water soluble packs. There are approximately 200 formulated product registrations. Atrazine is the single active ingredient in 148 formulations, and is co-formulated with 22 different active ingredients in 52 formulated products. The most common chemicals co-formulated with atrazine are acetochlor, S-Metolachlor, metolachlor, dimethenamid-P, and mesotrione (**Table 3**).

Table 3. List of Chemicals Co-Formulated in Atrazine Formulated Products.

Co-Formulated Active Ingredients	Number of times co-formulated with atrazine
2,4-D, 2-ethylhexyl ester	1
Acetochlor	31
Alachlor	2
Bicyclopyrone	1
Bifenthrin	3
Bromoxynil octanoate	3
Dicamba	1

Co-Formulated Active Ingredients	Number of times co-formulated with atrazine
Dicamba, potassium salt	5
Dimethenamid	1
Dimethenamid-P	8
Fluthiacet-methyl	1
Glyphosate	1
Glyphosate-isopropylammonium	3
Isoxaflutole	1
lambda-Cyhalothrin	1
Mesotrione	8
Metolachlor	9
Nicosulfuron	2
Pyroxasulfone	1
Rimsulfuron	2
Simazine	2
S-Metolachlor	20

5.2. Application Methods

Atrazine may be applied by groundboom sprayer, aircraft, tractor-drawn spreader, rights-of-way sprayer, low pressure handwand, backpack sprayer, lawn handgun, push-type spreader and belly grinder (hand-crank spreader).

5.3. Application Timing on Crops with the Highest Use

Corn: Applications to corn are most often preemergence (mid-April through mid-May in the major corn-growing areas). Postemergence applications are most likely to occur up to the end of June, until corn reaches 12" in height. There is some variability in timing based on geographical regions.

Sorghum: Applications to sorghum are most often preemergence (mid-May to mid-July in the major sorghum-growing areas). Postemergence applications are most likely to occur up to the end of August. There is some variability in timing based on geographical regions.

Sugarcane: Applications to sugarcane are usually at planting (fall), in the spring after emergence, and an additional postemergence application (often at layby). Since ratoon crops may face heavier weed pressure, additional applications are more likely in sugarcane ratoon crops.

5.4. Non-Agricultural Use Sites

Atrazine is registered for use in conifer forests, Christmas tree farms, sod farms, ornamental grasses, ornamental plants, ornamental turf, outdoor residential, lawns mostly confined to Florida and the Southeast, schools, parks, playgrounds, and athletic fields. Atrazine can also be used on roadsides, rights-of-ways, airfields, vacant lots, roadsides, lumber yards, agricultural buildings, industrial sites and storage sites. The amount of atrazine applied to non-agricultural sites is not known.

5.5. Agricultural Usage Data

Based on private market survey data from 2000-2010, the annual agricultural use of atrazine averaged approximately 72 million pounds of active ingredient for 71 million acres.

5.5.1. Screening Level Usage Analysis Data

Table 4 provides the most recent Screening Level Usage Analysis (SLUA), which was prepared in May, 2015 (USEPA 2015). The SLUA provides available estimates of pesticide usage data for atrazine on agricultural crops in the United States. The reported usage data in the SLUA are obtained from various sources and are merged, averaged and rounded so that the presented information is not proprietary, or business confidential.

Limitations to the data include the following:

- Additional registered uses for certain crops may exist but are not included because the available surveys do not report usage (*e.g.*, small acreage crops).
- Lack of reported usage data for the pesticide on a crop does not imply zero usage.
- Usage data on a particular site may be noted in data sources, but not quantified. In these instances, the site would not be reported in the SLUA.
- Non-agricultural use sites (*e.g.*, turf, post-harvest, etc.) are not reported in the SLUA.

Some sites show use even though they are not on the label. This usage could be due to various factors, including, but not limited to data collection or reporting errors, or application errors.

Table 4. Screening-Level Estimates of Agricultural Uses of Atrazine (2004-3013) (USEPA, 2015)

Crop		Annual Average lbs. a.i.	Percent Crop Treated	
			Average	Maximum
1	Almonds +	<500	<1	<2.5
2	Apples +	<500	<1	<2.5
3	Barley +	9,000	<2.5	<2.5
4	Beans, Green +	<500	<2.5	<2.5
5	Caneberries +	<500	5	5
6	Corn	60,100,000	60	70

Crop		Annual Average lbs. a.i.	Percent Crop Treated	
			Average	Maximum
7	Fallow	400,000	5	5
8	Pasture	40,000	<1	<2.5
9	Peaches +	1,000	<2.5	<2.5
10	Pecans +	2,000	<1	<2.5
11	Sorghum	5,300,000	65	70
12	Soybeans	500,000	<1	<2.5
13	Sugarcane	1,900,000	65	80
14	Sunflowers +	6,000	<1	<2.5
15	Sweet Corn	400,000	70	75
16	Watermelons +	4,000	<1	<2.5
17	Wheat	80,000	<1	<2.5

All numbers are rounded. <2.5: less than 2.5 percent of crop is treated; <1: less than 1 percent of crop is treated.
+: Crops not known to be listed on active end use product registrations when this report was run.
SLUA data sources include: USDA-NASS (United States Department of Agriculture's National Agricultural Statistics Service); Private Pesticide Market Research

5.5.2. Typical Use Patterns (2006-2013)

For the timeframe of 2006-2010, usage averaged approximately 66 million pounds a.i. for 67 million acres. Atrazine is typically applied at a rate of 0.3-2.3 lbs a.i./A, depending on the crop as shown in **Table 5** (Proprietary Data, 2006-2010).

In addition to the average application rate data, a rate distribution was generated to calculate an upper bound rate for each crop. The upper bound rate in this analysis is defined as the rate at which 90% (or as close to 90% as possible) of the acres treated with atrazine were treated at, or below that rate, as shown in **Table 5**.

Table 5. Typical Use Patterns for Atrazine Used on Selected Crops (2006-2010).

Crop	Average Application Rate (lbs ai/A)	Average number of Applications Per Year	Upper bound rate* (lbs ai/A) *percentile in parenthesis*
Corn	1.0	1.2	1.60 (89%); 1.75 (92%)
Sorghum (Milo)	1.0	1.2	1.5 (85%); 1.60 (90%); 1.75 (93%)
Sugarcane	2.3	1.4	3.75 (82%); 4.0 (100%)
Fallow	0.9	1.1	1.25 (79%); 1.45 (85%); 1.5 (95%)
Sweet Corn	0.8	1.1	1.5 (91%)
Wheat, Spring (stubble)	0.3	1.0	0.25 (67%); 0.45 (68%); 0.5 (100%)
Wheat, Winter (stubble)	0.7	1.0	0.75 (83%); 0.90 (91%); 1 (100%)

Source: Proprietary Data, 2006-2010

*The upper bound rate (90th percentile) is defined as the rate at which 90% (or as close to 90% as possible) of the acres treated with atrazine were treated at or below that rate. For example, in the above table, for sugarcane, 82 percent of the acres are treated at 3.75 lbs a.i./A or less, while the remaining 18 percent are all treated at 4.0 lbs a.i./A.

A more refined typical use rate distribution, including only recent reported use data (2009-2013), was evaluated for corn, sorghum and sugarcane**. Table 6, Table 7, and Table 8** describe the percent of national atrazine use as a function of different application rate ranges, as well as identifying the percent of national acres of these crops treated within the intervals. What can be derived from these distributions is that for corn and sorghum applications, roughly 85% of atrazine use (pounds used nationally) was applied at a rate less than 1.75 lb a.i./A, and that only 8% of national use was applied at rates lower than 0.5 lb a.i./A. The percent of acres treated in the intervals is fairly similar between the two crops as well with 92-94% of total acres treated having an application rate of 1.75 or less, and 19-21% of acres having an application rate of less than 0.5 lb a.i./A.

Table 6. Percent of Pounds of Atrazine Applied and Total Treated Acres of Corn by Application Rate, based on 2009-2013 Proprietary Survey Data.

Rate Range (lbs a.i/Acre)	Percent of Atrazine Pounds in Interval	Cumulative Percent	Percent of Total Acres Treated in Interval	Cumulative Percent
AI 0 to 0.25	0.7%	0.7%	2.9%	2.9%
AI 0.25 to 0.5	8.1%	8.8%	17.7%	20.6%
AI 0.5 to 0.75	11.5%	20.3%	17.0%	37.6%
AI 0.75 to 1	28.3%	48.6%	29.2%	66.8%
AI 1 to 1.25	10.0%	58.6%	8.5%	75.4%
AI 1.25 to 1.5	15.8%	74.4%	10.8%	86.2%
AI 1.5 to 1.75	9.6%	84.0%	5.8%	92.0%

Rate Range (lbs a.i/Acre)	Percent of Atrazine Pounds in Interval	Cumulative Percent	Percent of Total Acres Treated in Interval	Cumulative Percent
AI 1.75 to 2	14.9%	98.9%	7.4%	99.5%
AI 2 to 2.25	1.1%	100.0%	0.5%	100.0%

Table 7. Percent of Pounds of Atrazine Applied and Total Treated Acres of Sorghum by Application Rate, based on 2009-2013 Proprietary Survey Data.

Rate Range (lbs a.i/Acre)	Percent of Atrazine Pounds in Interval	Cumulative Percent	Percent of Total Acres Treated in Interval	Cumulative Percent
AI 0 to 0.25	0.5%	0.5%	2.2%	2.2%
AI 0.25 to 0.5	7.5%	8.0%	16.3%	18.5%
AI 0.5 to 0.75	9.0%	17.0%	13.4%	31.9%
AI 0.75 to 1	30.0%	47.0%	31.6%	63.5%
AI 1 to 1.25	13.1%	60.0%	11.6%	75.1%
AI 1.25 to 1.5	18.0%	78.0%	12.5%	87.6%
AI 1.5 to 1.75	10.3%	88.3%	6.4%	94.1%
AI 1.75 to 2	11.5%	99.8%	5.8%	99.9%
AI 2 to 2.25	0.2%	100.0%	0.1%	100.0%

For sugarcane, roughly 48% of the total atrazine use on this crop were applied at a rate of 3.75 to 4 lbs a.i./A. Another 47% of the use was applied at rates 2 lbs a.i./A or less. Percent of acres treated at these different rates correspond to 31% of total sugarcane acres being treated at rates of 3.75 to 4 lbs a.i./A and 58% of the acres treated at 1.75 to 2 lbs a.i./A.

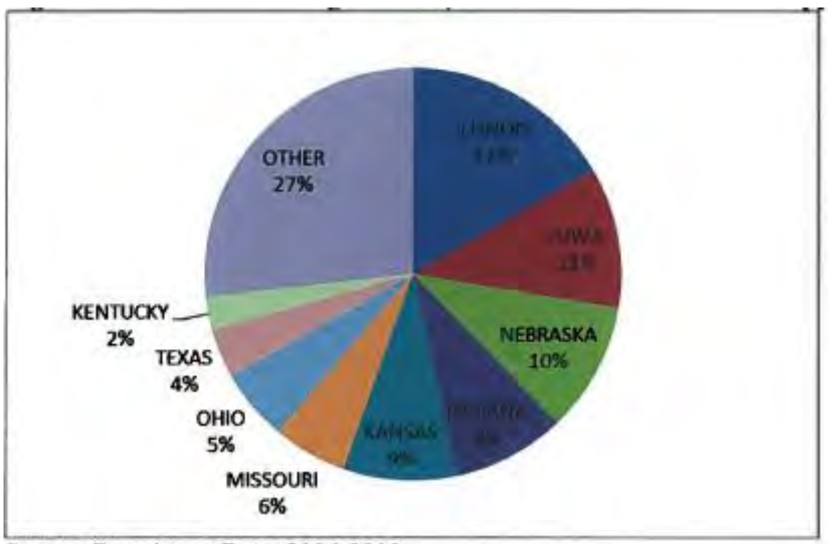
Table 8. Percent of Pounds of Atrazine Applied and Total Treated Acres of Sugarcane by Application Rate, based on 2009-2013 Proprietary Survey Data.

Rate Range (lbs a.i/Acre)	Percent of Atrazine Pounds in Interval	Cumulative Percent	Percent of Total Acres Treated in Interval	Cumulative Percent
AI 0.75 to 1	1.7%	1.7%	4.5%	4.5%
AI 1.25 to 1.5	0.9%	2.6%	1.6%	6.1%
AI 1.75 to 2	44.6%	47.2%	58.4%	64.5%
AI 2.25 to 2.5	1.5%	48.6%	1.5%	66.0%
AI 2.5 to 2.75	0.0%	48.7%	0.0%	66.1%
AI 2.75 to 3	2.6%	51.3%	2.2%	68.3%
AI 3.5 to 3.75	0.6%	51.8%	0.4%	68.7%
AI 3.75 to 4	48.2%	100.0%	31.3%	100.0%

5.5.3. Top Crops and States with Highest Use (2006-2010)

For 2006-2010, the top crop in terms of average annual pounds of active ingredient applied was corn (88%), followed by sorghum (8%), and sugarcane (2%) and sweet corn and fallow (1 % each). Spring and winter wheat stubble accounted for less than one percent of total pounds a.i. used during this period.

As shown in **Figure 4** between 2006-2010, the states with the most agricultural usage in terms of pounds a.i. applied were Illinois (17%), Iowa (11%), Nebraska (10%), Indiana and Kansas (9% each), followed by Missouri, Ohio, Texas, and Kentucky with less than 6% each. The "other" category includes 29 other states with Minnesota, Michigan and Wisconsin having the most usage among those states.



Source: Proprietary Data, 2006-2010

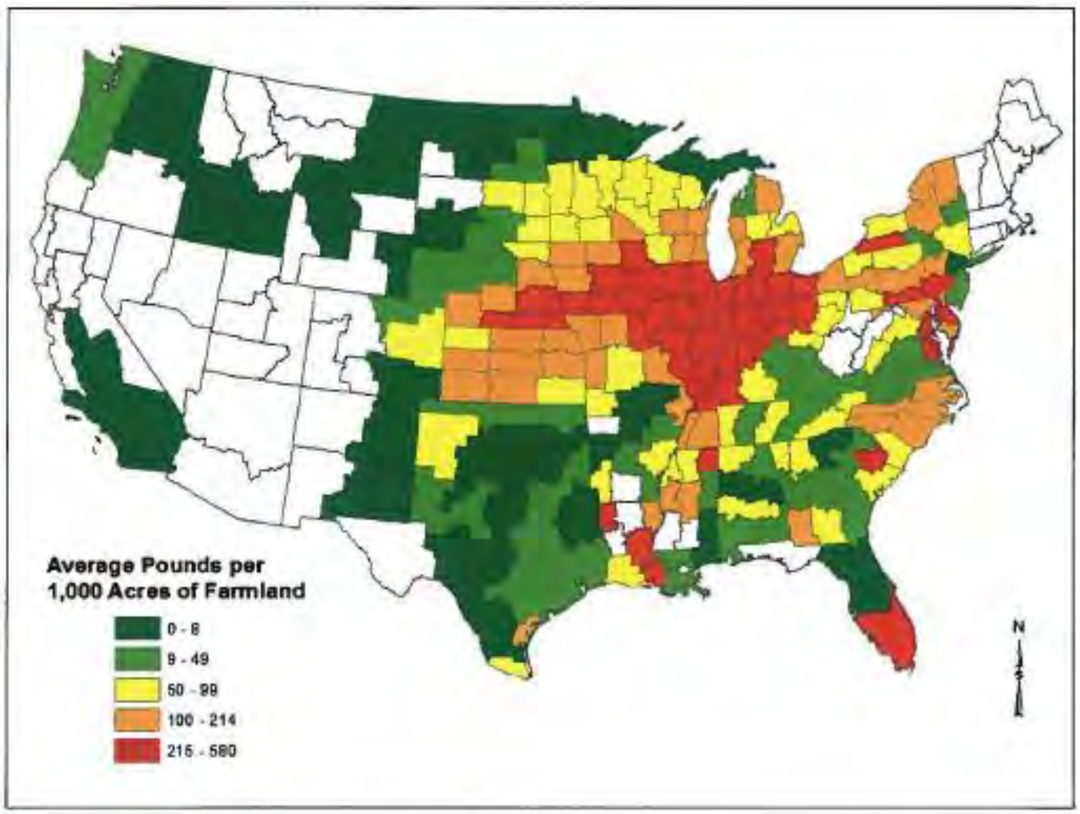
Figure 4. States with the Highest Use (Percent of Total Pounds A.I. Applied) 2006-2010.

5.5.4. National Mapping of Use Data

Another measure of usage is the use intensity. In this analysis, the use intensity is expressed as the pounds a.i. applied per acre of farmland. This differs from the application rate, which is expressed as the pounds a.i. applied per treated acre. **Figure 5** is a map of agricultural pesticide usage at the Crop Reporting District (CRD) level that spatially represents atrazine use intensity in the US. As shown, areas such as Florida and the corn producing states (colored in red) have the highest use intensity.

CRDs are districts created by USDA NASS which include aggregations of counties (USDA, 2010). Pesticide usage is displayed as average pounds (for the years 2006-2010) per 1,000 acres of farmland in a CRD to normalize for the variation in farmland between CRDs. Farmland acreage was obtained from USDA (2007).

Usage is based on private market surveys of pesticide use in agriculture (Proprietary Data, 2006-2010). The survey data are limited to the states that represent the top 80-90 percent of acreage for the individual crops, and do not include non-agricultural uses; therefore, use may be occurring in regions outside the scope of the survey. CRDs showing no usage of pesticides may be due to either the lack of pesticide use in the region or non-participation in the agricultural surveys. In addition, across the years, there may be variations in the specific crops included in the CRD survey. This may result in a lower annual average for the CRD.



Sources:
Proprietary Data. 2006-2010
USDA, 2006-2010. NASS Crop Reporting Districts.
USDA, 2007. Census of Agriculture.

Figure 5. Atrazine Usage by Crop Reporting District (2006-2010)

5.6. Non-Agricultural Usage

Information on non-agricultural usage in this section of the document has been obtained from available private market survey data from Kline & Co. The information provided on atrazine use in this section is for select non-agricultural use sites and does not represent all non-agricultural usage since data were not available for all non-agricultural use sites.

Non-agricultural usage data for professional applications to turf and ornamentals are available for 2002, 2004, and 2006 (**Table 9**). Over this time period, there was a notable increase in use by lawn care operators and on golf courses, institutional turf, and turf farms (Kline & Co., 2002, 2004, 2006).

Table 9. Atrazine Select Non-Agricultural Usage (Pounds A.I.) (2002, 2004, 2006).

Site	2002	2004	2006
Golf Courses	N/A	3,085	6,431
Institutional Turf	3,493	11,479	152,079
Landscape	593	41,978	204
Lawn Care Operators	211,561	97,095	686,107
Turf Farms	145,013	269,829	302,636
Nursery/Greenhouse	N/A	7,029	7,824
TOTAL Reported (lbs. a.i.)	360,660	430,495	1,155,281

N/A= no atrazine use was reported in the 2002 reports
Source: Kline & Co., 2002, 2004, and 2006

6. ANALYSIS PLAN

6.1. Conceptual Model

For a pesticide to pose an ecological risk, it must reach ecological receptors in biologically significant concentrations. An exposure pathway is the means by which a pesticide moves in the environment from a source to an ecological receptor. For an ecological pathway to be complete, it must have a source, a release mechanism, an environmental transport medium, a point of exposure for ecological receptors, and a feasible route of exposure.

The conceptual model for atrazine provides a written description and visual representation of the predicted relationships between atrazine, potential routes of exposure, and the predicted effects for the assessment endpoint. A conceptual model consists of two major components: risk hypothesis and a conceptual diagram (USEPA, 1998).

Based on the submitted environmental fate data, atrazine is expected to leach to ground water and move to surface water through runoff and spray drift.

Based on previous ecological risk assessments for atrazine, there is the potential for risk for federally listed threatened/endangered (hereafter referred to as "listed") and non-listed birds, mammals, plants and aquatic species from labeled atrazine uses. Because of the potential risk for direct effects to taxa (both listed and non-listed) described above and in the previous assessments, listed species in all taxa may potentially be affected indirectly due to alterations in their habitat and prey items (*e.g.*, food sources, shelter, and areas to reproduce). These conclusions are used to derive the risk hypothesis and conceptual diagram discussed below.

6.2. Risk Hypothesis

A risk hypothesis describes the predicted relationship among the stressor, exposure, and assessment endpoint response along with the rationale for their selection. For atrazine, the following ecological risk hypothesis is being employed for this ecological risk assessment:

> *Based on the application methods, mode of action, fate and transport, and the sensitivity of non-target aquatic and terrestrial species, atrazine has the potential to reduce survival, reproduction, and/or growth in non-target terrestrial and aquatic animals and plants as well as negatively affect the structure, productivity, and function of aquatic plant communities when used in accordance with the current labels. These non-target organisms include listed and non-listed species.*

6.3. Conceptual Diagram

The environmental fate properties of atrazine indicate that runoff, leaching, spray drift and direct spray represent potential transport mechanisms to aquatic and terrestrial habitats where non-target organisms may be exposed. Additional pathways are considered for the evaluation to identify other potential routes of exposure that may be of concern. These transport mechanisms (*i.e.*, sources) are depicted in the conceptual diagrams below (**Figure 6, Figure 7** and **Figure 8**) along with the receptors of concern and the potential attribute changes in the receptors from exposures to atrazine.

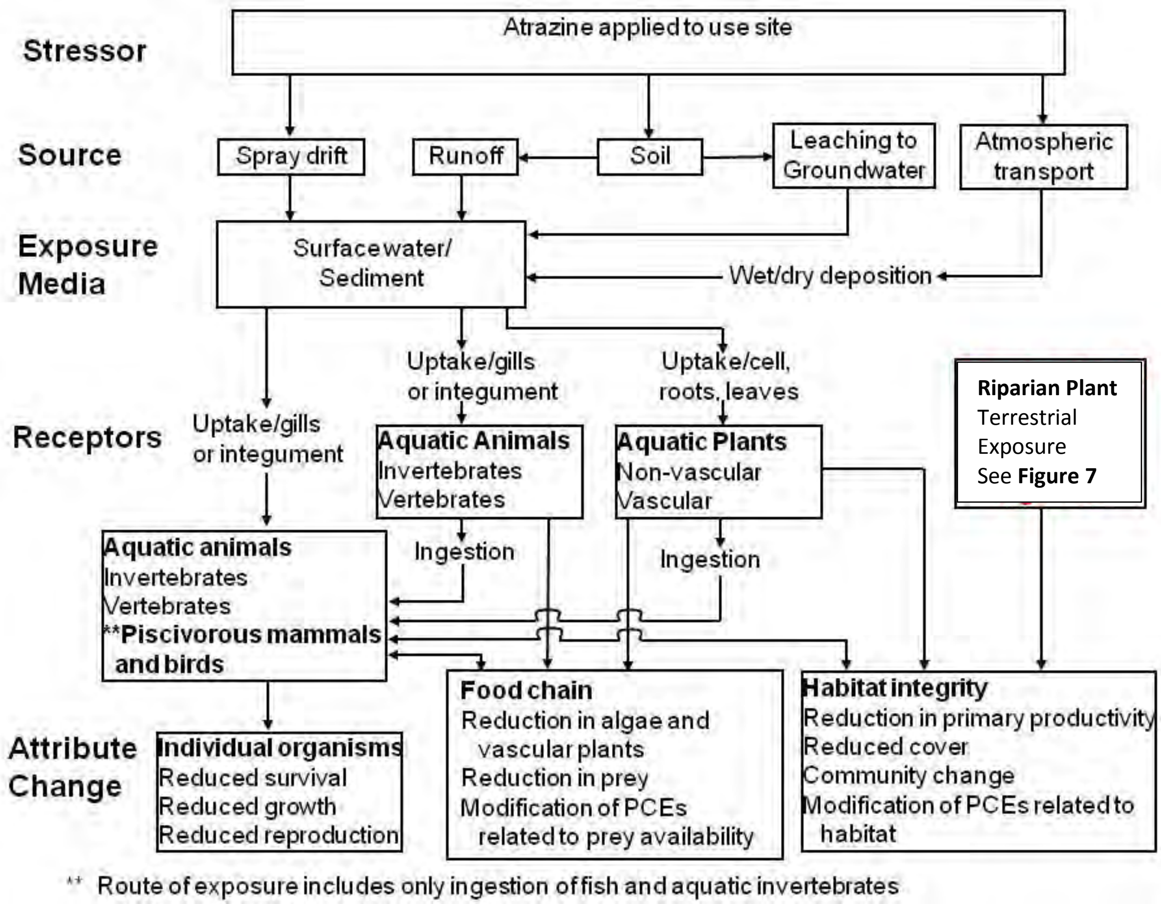


Figure 6. Conceptual Model for Atrazine Effects on Aquatic Organisms.

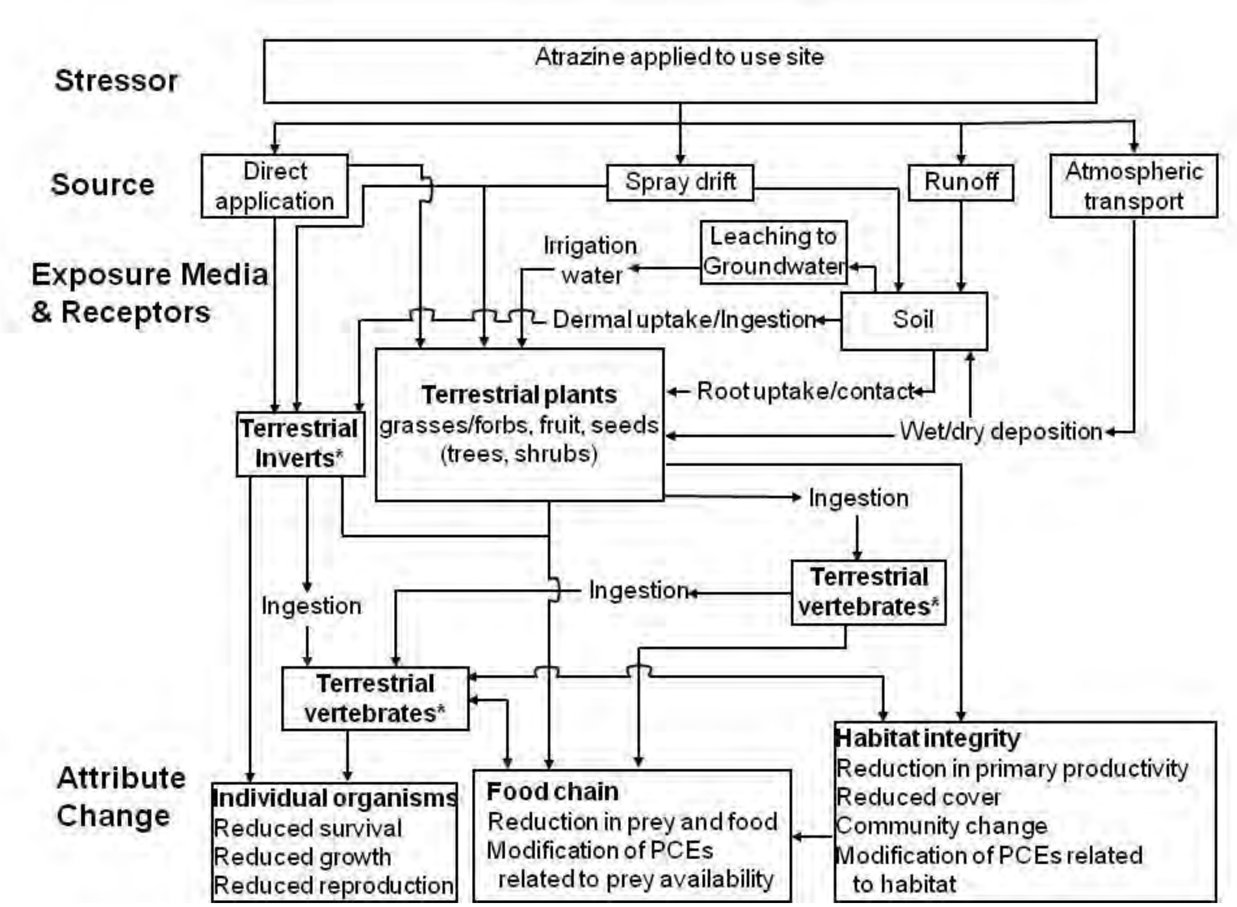


Figure 7. Conceptual Model for Atrazine Effects on Terrestrial Organisms.

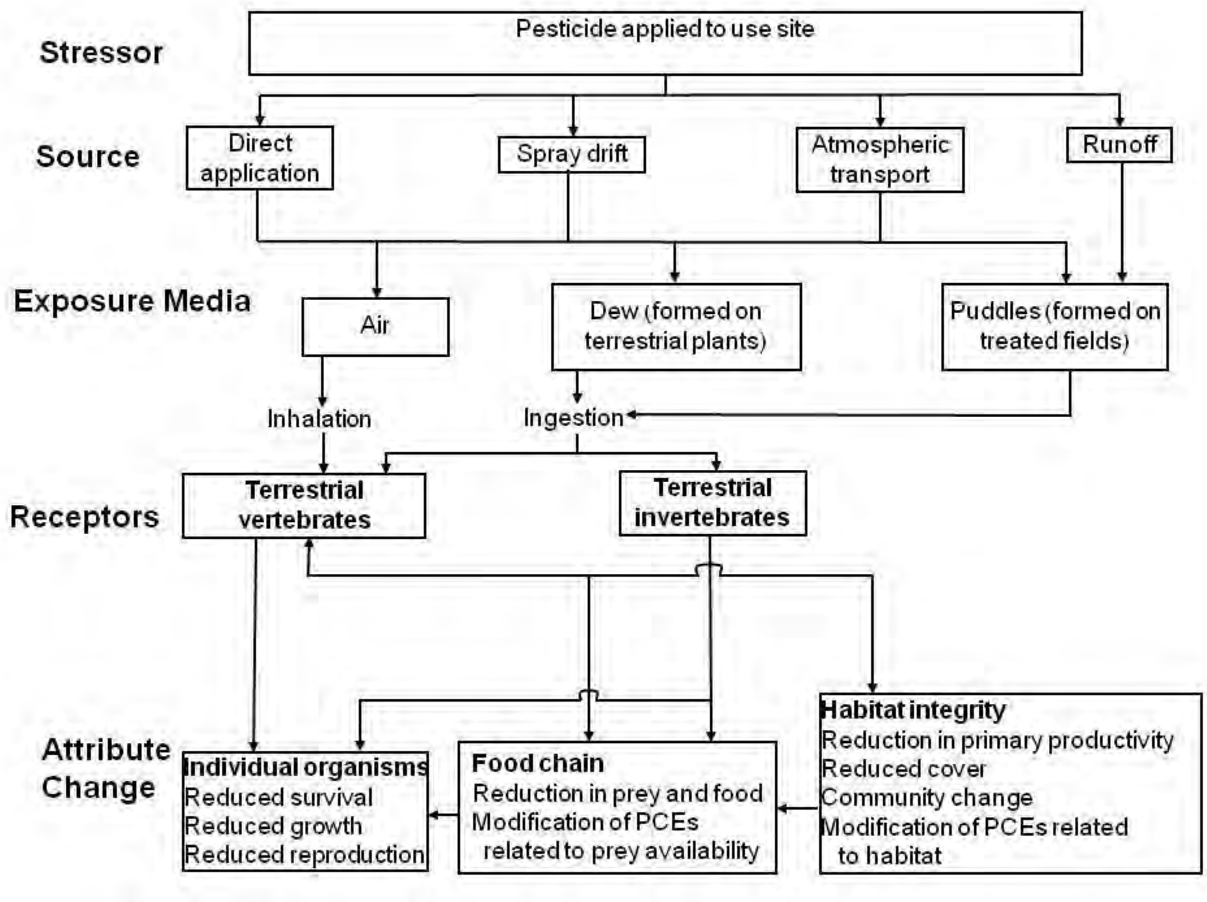


Figure 8. Conceptual Model for Atrazine Routes of Exposure for Terrestrial Animals.

In order to address the risk hypothesis, the potential for adverse effects on the environment is estimated. The use, environmental fate, and ecological effects of atrazine is characterized and integrated to assess the risks. For most taxa risk characterization is initially based on a deterministic approach using the risk quotient (RQ) method which compares exposure over toxicity. For the toxicity value component, the lowest toxicity value (*e.g.*, LC_{50} or NOAEC) that is deemed appropriate for quantitative use is chosen from the available atrazine toxicity dataset. Additional characterization of the risk to terrestrial and aquatic organisms and communities rely upon a more comprehensive inclusion of the available literature combined with the use of higher tier modeling, comparison to environmental monitoring data and reduced rates analyses.

6.4. Measures of Exposure

In order to estimate risks of atrazine exposures in aquatic and terrestrial environments, all exposure modeling and resulting risk conclusions were initially made based on maximum

application rates for the currently registered uses as discussed in **Section 5**. Measures of exposure were based on aquatic and terrestrial models that estimate environmental concentrations of atrazine using maximum labeled application rates and application methods that have the greatest potential for off-site transport of the chemical. Additionally, the measures of exposures were based on the USGS Watershed Regressions for Pesticides (WARP) and ambient surface water monitoring data.

The Surface Water Concentration Calculator (SWCC version 1.106) model was used to generate EECs. Model input values were selected consistent with the most recent version of the Input Parameter guidance (current version 2.1). Additional information on this model can be found at: http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

The SWCC generates daily exposures and 1-in-10-year EECs of atrazine that may occur in surface water bodies adjacent to application sites receiving atrazine through runoff and spray drift. SWCC simulates pesticide application, movement and transformation on an agricultural field and the resultant pesticide loadings to a receiving water body via runoff, erosion, and spray drift, and then simulates the fate of the pesticide and resulting concentrations in the water body. The standard watershed geometry used for ecological pesticide assessments assumes application to a 10-hectare agricultural field that drains into an adjacent 1-hectare water body that is 2 meters deep (20,000 m^3 volume) with no outlet. The SWCC is used to estimate screening-level exposure of aquatic organisms to atrazine. The measure of exposure for aquatic species is the 1-in-10-year peak or rolling mean concentration. The 1-in-10-year peak is used for estimating acute exposures of direct effects to aquatic organisms. The 1-in-10-year 60-day mean is used for assessing the effects to fish and aquatic-phase amphibians from chronic exposure. The 1-in-10-year 21-day mean is used for assessing the effects on aquatic invertebrates from chronic exposure. Surface water monitoring data will also be considered in the aquatic exposure assessment.

The USGS WARP model is a set of multiple regression statistical models that utilizes five input variables to predict pesticide concentrations. The input parameters include pesticide use intensity (USEINTL), total May/June precipitation (PMAYJUN), percent Dunne overland flow (PERDUN), R factor (RFACTOR; the rainfall and runoff factor used in the Universal Soil Loss Equation), and the presence of a soil restrictive layer (SRL25) (Stone, et al. 2013). The USGS WARP models for predicting the 4 day average atrazine concentration, 21-day average atrazine concentration and 60-day average concentration were used to predict EECs in flowing waters for Hydrologic Unit Code 12 (HUC12) from 2006 to 2009. The exposure estimates from WARP represent the average predicted EEC over a four year period.

Monitoring data for atrazine occurrence in surface waters were obtained from federal, state, registrant, and university monitoring programs. The monitoring data represent atrazine occurrence data from 1975 to 2014 in streams, rivers, lakes, and reservoirs. The monitoring data were analyzed by site-year to obtain a maximum daily concentration, maximum 4-day

average concentration, maximum 21-day average concentration, maximum 60-day average concentration, and maximum 90-day average concentration. Average atrazine concentrations for each site-year were estimated from simulated chemographs by stair-step imputation between measured monitoring data. In order to address uncertainty in quantification of monitoring data due to low sampling frequency, linear regression equations were developed to allow estimation of sampling bias factors (BFs; see **Section 7.4.1** for estimation of peak, 21-day average, and 60-day average atrazine concentrations.

The model used to produce terrestrial EECs on food items is T-REX, while the model used to derive EECs relevant to terrestrial and wetland plants is TerrPlant. The AgDRIFT spray drift model (v2.1.1; December 2011) is used to assess exposures of organisms to atrazine deposited on terrestrial or aquatic habitats by spray drift. Detailed information about the models T-REX, T-Herps, TerrPlant and AgDrift, can be found on the EPA's website at http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

The Screening Imbibition Program (SIP v.1.0, Released June 15, 2010) was used to calculate an upper bound estimate of exposure to wildlife via drinking water using atrazine's aquatic solubility limit (33 mg/L), and the most sensitive acute and chronic avian and mammalian toxicity endpoints. Drinking water exposure alone was determined to be a potential pathway of concern for avian or mammalian species on a chronic basis but not on an acute basis. Detailed information about the SIP v.1.0, as well as the tool, can be found on the EPA's website at http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

The Screening Tool for Inhalation Risk (STIR v.1.0, November 19, 2010) was used to calculate an upper bound estimate of exposure to atrazine through inhalation. This calculation used atrazine's vapor pressure (2.89 x 10^{-7} torr) and molecular weight (215.69 g/mole) for vapor phase exposure, the maximum single application rate (4 lb a.i./acre) and method of application for spray drift, and acute and chronic avian and mammalian toxicity values. Results of the model run indicated that inhalation exposure via spray drift and/or vapor-phase of atrazine alone did not appear to be a concern. Detailed information about STIR v.1.0, as well as the tool, can be found on the EPA's website at: http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

6.5. Measures of Effect

Ecological effects data are used as measures of direct and indirect effects to biological receptors. Data are obtained from registrant-submitted studies or from literature studies identified by ECOTOX (USEPA 2007c). The ECOTOX database provides more ecological effects data in an attempt to bridge existing data gaps, and is a source for locating single chemical toxicity data and potential chemical mixture toxicity data for aquatic life, terrestrial plants, and

wildlife. ECOTOX was created and is maintained by the USEPA, Office of Research and Development, and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division.

Information on the potential effects of atrazine on non-target animals is also collected from the Ecological Incident Information System (EIIS; USEPA 2007d) and Incident Data System (IDS). The EIIS and IDS are databases containing adverse effects (typically mortality) reports on non-target organisms where such effects have been associated with the use of pesticides.

Incidents reported in the aggregate incident reports and the Avian Incident Monitoring System (AIMS) will also be searched. AIMS is a database administered by the American Bird Conservancy (it was partially funded by the EPA). It contains publicly available data on reported avian incidents involving pesticides http://www.abcbirds.org.

Where available, sub-lethal effects observed in both registrant-submitted and open literature studies are evaluated qualitatively. Such effects may include behavioral changes such as lethargy and changes in coloration. Quantitative assessments of risks, though, are limited to those endpoints that can be directly linked to the EPA's assessment endpoints of impaired survival, growth, and reproduction.

6.6. Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effect characterizations to determine the potential ecological risk from the use of atrazine and the likelihood of direct and indirect effects to non-target organisms in aquatic and terrestrial habitats. The exposure and effects data are integrated in order to evaluate potential adverse ecological effects on non-target species. For the assessment of atrazine risks, the risk quotient (RQ) method is the first approach used to compare estimated exposure data to the measured single-species toxicity values. Acute and chronic EECs are divided by acute and chronic single-species toxicity values. The resulting RQs are then compared to the EPA's Levels of Concern (LOC) (USEPA 2004). In addition, the Agency assesses atrazine risk to aquatic plant communities with an Agency developed method for determining the aquatic plant community LOC (described in **Section 12.2.1**). Lastly, this assessment approaches the evaluation of the environmental risks from atrazine use by considering multiple lines of evidence. The exposure estimates and environmentally measured values from monitoring data as well as the breadth of available ecotoxicity literature are used to indicate when atrazine's use, as directed on the labels, has the potential to cause adverse direct or indirect effects to non-target terrestrial and aquatic organisms and communities. In addition, incident data from EIIS, aggregate incident reports, and AIMS are considered as part of the risk characterization.

6.7. Additional considerations for the analysis of exposure and effects data

Due both to the large body of toxicity data available and the feedback from multiple SAPs, special techniques were used for considering risks to both the aquatic plant community and aquatic-phase amphibians. In addition, higher Tier modeling was incorporated in the analysis of risks to birds. These methodologies are described below.

6.7.1. Additional Considerations for Aquatic Plant Communities

The EPA's process to determine the level of concern (LOC) specifically for atrazine in aquatic ecosystems to protect aquatic organisms and the methodology used to identify watersheds that exceed this LOC are described below. A different assessment methodology is used to address risk to aquatic plants because, although aquatic plants are generally more sensitive than fish and aquatic invertebrates, the risk assessment endpoint is community structure/function rather than growth, reproduction, and survival of an individual species. The LOC methodology uses single-species plant toxicity data and microcosm/mesocosm (cosm) studies to determine what atrazine exposure patterns and concentrations can cause adverse effects on aquatic plant communities. Before these cosm effects can be applied, there is a need to develop a quantitative measure of the relative severity of different exposure time series to compare effects among different experimental ecosystem exposure and to extrapolate these to the field.

The aquatic plant community level of concern, described as the Concentration Equivalent LOC (CELOC), is derived to ensure that the atrazine concentrations in watersheds do not cause detrimental changes in aquatic plant community structure and productivity. While the CELOC is based on effects to aquatic plant communities, by ensuring protection of primary producers, it is intended to also provide protection for the entire aquatic ecosystem, including fish, invertebrates, and amphibians.

6.7.1.1. *Biological Relevance: The Importance of Biodiversity and Plant Communities*

"Biological diversity can be defined as the variety of life and its processes. This definition encompasses genetic, species, assemblage, ecosystem and landscape levels of biological organization and it has structural, compositional and functional components" (Hughes & Noss 1992). A recently published review of North American phytoplankton species richness (Stomp *et al.* 2011), based on the total number of species collected during surveys from 1973-1975 for the EPA National Eutrophication Survey, shows that phytoplankton diversity is greatest (**Figure 9**) throughout the southeastern and isolated areas of the Midwest. This survey, while pointing out that there is higher phytoplankton diversity in the regions with atrazine use, does not answer critical questions regarding community structure, function and food web stability, nor does it address if the sampled lakes were previously exposed to atrazine or if the species present are known to be tolerant to atrazine.

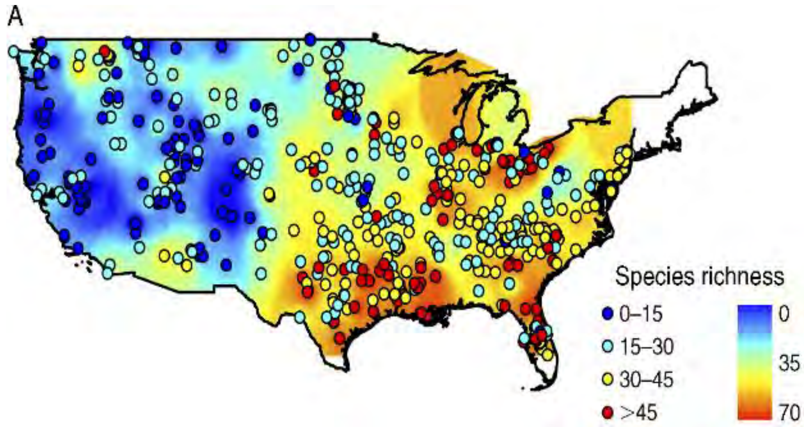


Figure 9. Geographical distribution of phytoplankton species richness across the continental United States (Stomp et al. 2011, reproduced with permission).

The complexity of species coexistence in phytoplankton communities is thought to be directly related to primary productivity (Leibold 1996), light availability (Huisman *et al.* 2004; Steinman 1992; Hill *et al.* 1995), and nutrient supply ratios (*e.g.*, Nitrogen:Phosphorus ratios, Tilman 1982). Atrazine has the potential to affect all three of these factors and thus have a negative impact on the primary producers, their associated food webs, and overall ecosystem function and integrity. Negative impacts leading to instability or harm to the aquatic plant communities would impact aquatic and terrestrial species, which are supported by the aquatic plant communities for their growth, survival, and reproduction in a complex network of interactions.

<u>Decreased diversity may lead to increased nutrient and toxicant outflow to larger streams and lakes.</u>

Cardinale (2011) reported that in stream systems niche partitioning among species of algae can increase the uptake and storage of nitrate. His research also showed that more than 80% of increased cell densities in cultures were driven by niche complementarity in microcosms. Cardinale's research provides "direct evidence that communities with more species take greater advantage of the niche opportunities in an environment and this allows diverse systems to capture a greater proportion of biologically available resources". Cardinale also showed that when niche partitioning was removed or reduced to minimal levels, the periphyton communities collapsed to single species dominance. Cardinale attributes the niche partitioning in streams to specific algal characteristics that make them "best adapted" to specific habitats within the stream. "These adaptations were expressed only when environmental conditions were dynamic in space and or time and when heterogeneity provided ecological opportunities for species to coexist." Some of the adaptations included sheer resistance for high flowing water, large filamentous algal dominance in slow moving waters, and increasing growth rate with habitat disturbance.

This concept was also tested by Villenueve *et al.* (2011) who concluded that increased turbulence led to more diversity in periphyton communities. Villenueve *et al.* also found that higher diversity periphyton communities were more sensitive to the tested pesticides (diuron and azoxystrobin) than less diverse communities. This is likely due to the interconnectivity of diversity and niche partitioning causing a more dramatic loss of species richness in higher diversity systems. The second factor to consider regarding low diversity systems is that they may be comprised of highly tolerant species that are less likely to be affected by the pesticide exposure, while a high diversity system would contain a much greater proportion of sensitive species. In low diversity systems made up of sensitive species, the effect could be great as well. These response phenomena have a potential to greatly impact food web stability.

Food web stability is directly linked to diversity, number of trophic levels, and both top-down and bottom-up pressures.

The aquatic food web is centered around and dependent upon aquatic plant communities (including all autotrophic organisms). These communities are the primary producers and provide sugar energy, lipids, as well as macro- and micronutrients to the herbivore taxa (*e.g*., insects, snails, fish, tadpoles, and waterfowl). In highly diverse and productive aquatic plant communities, high quality food is usually abundant, whereas in productive low diversity systems, there may be limited high quality food resources available to herbivores.

The population sizes of the taxa comprising the primary producer community are greatly dependent on abiotic conditions (bottom-up pressure; *e.g*., light and nutrients) and the size and condition of the herbivore and predator communities (top-down pressure; *e.g*., snail populations). Steinman (1992) found that limitation of periphyton photosynthesis could be mitigated by increasing the levels of light. The effect of light limitation on productivity is well documented. For example, seasonal decreases in available light have been shown to lead to reduced productivity (Triska *et al.* 1983; Hill and Harvey 1990; Hill *et al.* 2001). The algae in the Hill *et al.* (1995) study were reported to adapt to the low light condition over time, but productivity was 4 times greater in high light conditions. The control of autotrophic communities by grazing pressure has also been a focus of research, and several studies show that the top-down pressures are most apparent in short food webs (*i.e.*, producers and a single consumer; *e.g.,* Steinman *et al.*, 1987; McQueen *et al.*, 1989; Steinman, 1992; Kurle and Cardinale, 2011). Steinman (1992) found that herbivore control was so complete that autotroph biomass could not respond to increases in the levels of light and that when grazing pressure was released, the controlling factors shifted back to abiotic factors (*i.e*., seasonality and light).

Hill *et al.* (2001) found that nutrient concentrations (nitrate and phosphate) increased in streams after overstory leaf emergence, which they attributed to a “cascade of shade effects” through the reduction of primary producer communities, resulting in additional abiotic components available to the other portions of the ecosystem. Because herbivore growth increased almost linearly with increased light, reflecting food supply limitation at low light, the cascade of shade effects ultimately led to decreased herbivore densities. The effects of low-

light on the primary productivity of the system can be synergistic with the effects of herbivore grazing pressure. Higher grazing pressure also reduces algal communities and diversity and is more pronounced in low light conditions (*e.g*., Steinman, 1992; Hill *et al.*, 1995), especially after shifts from higher light to lower light (*i.e*., herbivore populations would be higher due to increased food resources in the high light condition, and would demand the same energy input from the lower productivity of the low light condition).

Other impacts on the food web come from another type of top-down pressure, the predator-herbivore interaction. Kurle and Cardinale (2011) report that higher diversity and production-to-biomass ratios in the autotrophic communities reduce the strength of trophic cascades. Therefore, in systems with high algal diversity, herbivores have a greater ability to evade or defend against predators, so that herbivore pressure on the primary producers is more even over time. However, low diversity systems have a propensity to have increased top-down pressure and would be more erratic in behavior and more prone to collapse when stressed (Steinman, 1992; Kurle and Cardinale, 2011).

In addition to food, shelter, and reproduction, there are documented symbiotic relationships between algae and invertebrate and vertebrate species (*e.g*., Douglas, 2010; Oliver and Moon, 2010; and Kerney, 2011). These symbiotic relationships present additional uncertainty regarding the impact of atrazine on these relationships.

Importance of the biological integrity of headwater streams, lakes, wetlands and estuaries:

Meyer *et al.* (2007) summarize the importance of small streams and springs to the entire river system and discuss the ways they enhance the biological diversity of the entire river system. Headwater streams play a critical role in the export of food (e.g., drifting insects; benthic organisms, and emerging insects), they provide a filtration process which increases dissolved oxygen through photosynthetic output, reduces particulate matter (macrophytes), and provides critical nutrient transformations which increase downstream water quality. In addition to these exports, the larger river, lake, and reservoir organisms also depend on the headwaters for refuge (e.g., high flow events, thermal events, predation and competition) and rich feeding sites for spawning and nursery habitat (Meyer *et al*., 2007). While the study by Meyer *et al.* (2007) was focused on the headwater stream, these same exports and downstream dependencies are common to lakes, wetlands and estuaries.

The focus of the assessment endpoints presented in **Section 10.4** is designed to ensure that the atrazine concentrations in watersheds do not cause significant changes to the freshwater aquatic plant community (used as a surrogate for estuarine/marine plant communities) structure and productivity and thus put at risk the food chain and entire ecosystem health.

6.7.2. Additional Considerations for Aquatic Phase Amphibians – Weight of Evidence Analysis

As discussed in **Section 11.2.3**, there is a large body of toxicity data available in the open literature on the effects of atrazine to aquatic phase amphibians. This subject has been the topic of multiple SAP meetings (USEPA, 2003d; 2007a; 2012c). The 2012 SAP pertained directly to the Problem Formulation for the ecological effects from the use of atrazine. A summary of the findings from the 2012 SAP and EPA's summary review of that meeting is located in **Appendix A (Addendum to Problem Formulation).** Some of the general recommendations of the 2012 SAP regarding amphibian toxicity data included:

- Application of a weight of evidence approach to address the body of amphibian toxicity literature, including studies that were previously categorized as qualitative or invalid according to EPA review,
- Inclusion of amphibian toxicity data on other amphibian species outside of *Xenopus laevis* (African Clawed Frog); specifically including data on three native species (e.g., ranid (*e.g., Lithobates* (previously *Rana*) *pipiens*, a hylid (e.g. *Hyla versicolor*) and bufonid (*e.g.*, *Anaryxus* [previously *Bufo*] *americanus*)
- Address concerns about endocrine disruption potential, reproductive effects and immune system effects of atrazine in amphibians and other species

The following describes the methodology used to incorporate these recommendations for aquatic phase amphibians, primarily through the use of a qualitative weight of evidence analysis.

6.7.2.1. *Studies incorporated into analysis*

The data set used for the weight of evidence analysis for effects of atrazine to amphibians included endpoints from studies previously discussed in the 2012 SAP and classified as qualitative or quantitative, additional studies from the ECOTOX database identified between 2011 and 2014, relevant studies identified in the Endocrine Disruptor Screening Program (EDSP) literature reviews through December 2014, and those identified by the 2012 SAP panel. Approximately 55 studies were included in this review. Detailed discussion of these studies is contained in **Section 11.2.3.** Open literature study reviews are contained in **Appendix B**.

6.7.2.2. *Weight of Evidence Methodology*

As discussed in the Addendum to the Problem Formulation (**Appendix A**), many methods are available for conducting a weight of evidence analysis. Several have previously been applied to amphibian and terrestrial toxicity data for atrazine and are discussed in **Section 11.2.3.** For this weight of evidence analysis, a qualitative approach was followed. This methodology is based

largely on an approach currently being developed by EPA for Endangered Species Assessments (ESA) in conjunction with National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS).

The weight of evidence approach consists of the application of the following general steps (explained in further detail below):

- Establishment of a Risk Hypothesis
- Establishment of "Lines of Evidence"
- Evaluation of each line of evidence considering the following criteria
    - Exposure
        - Relevance
        - Robustness
    - Effects
        - Biological Relevance
        - Species Surrogacy
        - Robustness
- Use of the criteria to assign weight (or confidence) in data for each line of evidence
- Comparison of relevant exposure concentration data with effects data to establish overlap (or risk) and assign weight to that risk
- Integrate results from each line of evidence to prove or disprove the risk hypothesis

6.7.2.3. ***Aquatic Phase Amphibian Risk Hypothesis***

Based on the overall risk hypothesis for the atrazine risk assessment, the following hypothesis is applicable to the weight of evidence analysis for amphibians.

"Based on the application methods, mode of action, fate and transport, and the sensitivity of amphibian species, atrazine has the potential to reduce survival, reproduction, and/or growth in amphibians when used in accordance with the current labels."

6.7.2.4. ***Lines of Evidence***

"Lines-of-evidence" refers to the categories of data used to prove or disprove the risk hypothesis. These categories are determined based on available assessment endpoints. In the effects analysis of the amphibian data (**Section 11.2.3**), endpoint classifications were previously created for data analysis. Based on these effects categories, the lines of evidence for direct effects were assigned as follows:

1. **Mortality** (survival) from direct exposure to atrazine according to the registered labels
2. Change in metamorphosis/time to stage (**development**) from the use of atrazine according to registered labels
3. Change in **growth** [mass, snout vent length (SVL)] from the use of atrazine according to registered labels
4. Reduced or repaired **reproduction** (sexual development, sex ratios) from the use of atrazine according to registered labels.

6.7.2.4.a. ***Evaluation criteria for each line of evidence: Exposure and Effects***

<u>Evaluation of exposure data</u>

Exposure data are assessed largely through evaluation of fate parameters and monitoring data, answering the question, "how reliable are our exposure estimates?" Exposure data were evaluated using two general criteria of "relevance" and "robustness".

1. Relevance of predicted EECs for aquatic amphibian habitats:
    - Models that predict concentrations in habitats relevant and suitable for aquatic amphibians strengthens confidence in the EECs (when the exposure estimates based on modeled results and/or targeted monitoring are representative of amphibian habitats).
    - Availability of targeted monitoring data from aquatic amphibian habitats further strengthens the confidence in exposure predictions and relevance.
2. Robustness of EECs derived from environmental fate models:
    - Reliable values used as inputs for environmental fate models. Availability of a robust data set for input parameters strengthens the confidence in EECs.
    - Exposure results similar across lines of information (*e.g.*, SWCC modeling results consistent with available monitoring data and other model predictions) strengthens the confidence in EECs.

<u>Evaluation of effects data</u>

In the same way we evaluate the exposure data, the effects data are evaluated to answer the question, "how reliable is our toxicity data?" Criteria used to evaluate this question include biological relevance, species surrogacy and robustness, as defined below.

1. Biological Relevance:

    - Established relationship between the measure of effect and the assessment endpoint. If there is a logical, well-established link, more confidence is given to this information.
    - More confidence is given to lines of evidence and endpoints that are clearly related to fitness of the organism.

2. Relevance of Surrogates:

    - The relevance of the species used to assess the endpoint, including number of species for which data are available. A larger number of species with similar life history and physiology as the species of concern are given higher weight or confidence.

3. Robustness – consistency within the line of evidence for the taxa grouping:

    - Multiple, independent studies with consistent results increases confidence in our knowledge (*i.e.*, the strength of our evidence) of whether or not the pesticide will cause the effect under the anticipated exposure conditions.
    - Few studies with lower quality data and/or inconsistencies among the results decreases our confidence in the data.

Based on consideration of these criteria for the exposure and effects data, the weight (or confidence) in the line of evidence is assigned a rank of high, medium or low.

6.7.2.5. *Overlap of relevant exposure concentration data with effects data (risk)*

Risk is established by comparing the overlap of exposure ranges resulting in effects for each line of evidence with the exposure modeling estimate ranges and observations from surface water monitoring data. Consideration is also given to the degree of overlap between exposure and effects data. Based on this analysis, risk is assigned a rank of high, medium or low.

6.7.2.6. *Integration of lines of evidence and risk hypothesis analysis*

Based on the weighting of the data and risk for each line, the risk hypothesis is reanalyzed. A table is created to summarize the criteria evaluated for each line of evidence and the overall risk and weighting for each line. Using all the lines of evidence, they are collectively evaluated for the combined confidence and risk associated with the multiple lines of evidence and make a determination if the risk hypothesis is true or false. This is the methodology applied to determine if there is the concern for risk to aquatic-phase amphibians.

6.7.3. Additional Considerations for Risk to Birds: Tier II Terrestrial Model Refinements

In order to provide further refinement from the Tier I terrestrial modeling conducted with T-REX for birds, Tier II modeling was conducted with both the Terrestrial Investigation Model (TIM beta, version 3.0, March 25, 2015) and the Markov Chain Nest Productivity model (Basic MCnest, Version 01.06.2014).

TIM is a refined risk assessment tool that incorporates multimedia exposure/effects to derive quantitative estimates of the probability (or likelihood) and magnitude of mortality to birds exposed to the applications of the simulated pesticide. Avian mortality levels are predicted based on acute pesticide exposure to generic or specific species over a user-defined exposure window. Unlike T-REX, TIM incorporates multiple exposure routes including dietary, dermal, drinking water and inhalation pathways. TIM allows for identification of groups of species that may be at risk (such as small to medium sized insectivores and omnivores) or specific species may be simulated as a refinement in the assessment. More information on TIM can be found at http://www.epa.gov/oppefed1/models/terrestrial/index.htm.

MCnest is a refined model for estimating adverse reproductive effects in birds exposed to applications of pesticides during their normal breeding season. MCnest considers reproductive timing, multiple endpoints from standard avian reproduction studies and the impact (or lack of impact) of exposure timing on specific portions of avian reproductive cycles. The MCnest model library allows for simulation of decreases in the fecundity of 56 species that are known to visit agricultural areas. Exposure values used in MCnest are based on those generated by T-REX for specified application rates and dates. More information on the MCnest model can be found at http://www.epa.gov/med/Prods_Pubs/mcnest.htm .

In addition to individual analyses conducted with these models, OPP/EFED is currently working with ORD to integrate the TIM and MCnest models (TIM-MCnest Beta version) so that exposure estimates generated by TIM (for individual birds and their offspring) may be used for determining the potential decrease in fecundity associated with a pesticide exposure. Analyses with the integrated model were also conducted for several species that are known to visit corn fields in areas where atrazine use is most common. As this model is still in development, all results generated using the TIM-MCnest combined model should be interpreted as preliminary.

7. ENVIRONMENTAL FATE AND TRANSPORT

7.1. Physical and Chemical Properties of Atrazine

Atrazine (1-chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine) physical and chemical properties are shown in **Table 10.** Atrazine has a high solubility, low octanol-water partitioning coefficient, low vapor pressure, and low Henry's Law Constant. These data suggest that atrazine has a low potential for volatilization and bioaccumulation.

Table 10. Physical and Chemical Properties of Atrazine

Physical/Chemical Property	Value
CAS Reg. Number	1912-24
Chemical Formula	$C_8H_{14}ClN_5$
Physical State	Powder
Color	White
Melting Point	175-177 ^{0}C
Molecular Weight	215.69 g/mole
Water Solubility@20°C	33 mg/L
Vapor Pressure@ 20°C	$3.0x10^{-7}$ Torr
Henrys Constant (calculated)	$2.6x10^{-9}$atm-m^3 $mole^{-1}$
K_{ow}	501.18

7.2. Environmental Fate Summary

Atrazine is mobile and persistent in the environment. The main routes of dissipation are microbial degradation under aerobic conditions, runoff, and leaching. Because of its persistence and mobility, atrazine will move into surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water.

7.2.1. Hydrolysis

Atrazine did not hydrolyze in short-term (30 day) abiotic hydrolysis studies in sterile pH 5, 7, and 9 buffer solutions (MRID 40431319). However, open-literature studies show variable hydrolysis half-lives for atrazine in different matrices including soils, clay suspensions, organic matter, and ground water (**Table 11**). Abiotic atrazine hydrolysis can be catalyzed by acid sites on organic compounds (e.g., humic and fulvic acid, organic acids, phenols) and mineral surfaces in soil (Laird and Koskinen, 2008; Cessna, A., 2008). Additionally, atrazine hydrolysis can occur through microbial-mediated processes (Mandelbaum, et al. 2008). The hydrolysis of atrazine leads to formation of 2-hydroxyatrazine.

Table 11. Open-literature data on Hydrolysis Half-lives in Different Environmental Media

Hydrolysis Half-Life (days)	pH	Temp (^{0}C)	Conditions	Medium	Reference
20	2	25	Non-sterile	Buffer solution	Armstrong et al., 1967
20	12	25	Non-sterile	Buffer solution	
200	4	25	Non-sterile	Buffer solution	
200	11	25	Non-sterile	Buffer solution	
>1000	6	25	Non-sterile	Buffer solution	
>1000	10	25	Non-sterile	Buffer solution	

Hydrolysis Half-Life (days)	pH	Temp (^0C)	Conditions	Medium	Reference
209	3.9	25	Non-sterile	Buffer solution	
22	3.9	25	Sterile	Soil and Water	Armstrong et al., 1968
84	5	20	Non-sterile	Buffer solution	Burkhard and Guth, 1981
42	5	30	Non-sterile	Buffer solution	
35	2.9	25	Non-sterile	Buffer solution w/ fulvic acid	Khan, 1978
742	7	25	Non-sterile	Buffer solution w/fulvic acid	
1565	7.7	4	Non-sterile	Deionized Water-65 ppm DOC	Widmer et al., 1993
2022	7.7	30	Non-sterile	Deionized Water-65 ppm DOC	
1565	7.8	4	Non-sterile	Well Water-6 ppm DOC	
1311	7.8	30	Non-sterile	Well Water-6 ppm DOC	
2.48[1]	2	25	Non-sterile	Redistilled water	Gamble, et al. 1983
1732.87[1]	5	25	Non-sterile	Redistilled water	
173286.80[1]	7	25	Non-sterile	Redistilled water	
283	6.66	20	Non-sterile	Ground Water 0.05 ppm DOC	Navarro et al., 2004

1-Estimated from equation: t1/2=0.01356*(0.0245+10-pH)/10-pH years

7.2.2. Photodegradation

Atrazine is persistent ($t_{1/2}$= 168 days) to direct aquatic photodegradation in pH 7 buffer solution under natural sunlight (MRID 42089904; 45545301). However, indirect aquatic photolysis is a degradation pathway of atrazine (Cessna, 2008). Photodegradation products of atrazine include 2-chloro-4-isoprolylamino-6-amino-s-triazine(DEA),chlordiamino-s-triazine (DACT), and 2-chloro-6-ethylamino-4-amino-s-triazine (DIA), 2-hydroxy-4-isopropylamino-6-amino-s-triazine (HA), 2-hydroxy-6-ethylamino-4-amino-s-triazine (DIHA), and 2-hydroxy-4-isopropylamino-6-amino-s-triazine (DHEA). Degradation product structures are presented in **Figure 10**. Similarly, atrazine is moderately persistent ($t_{1/2=}$ 45 days) to photodegradation on soil under natural light (MRID 42089905). Soil photodegradation products of atrazine include DEA, DACT, and DIA.

7.2.3. Soil and Aquatic Metabolism

Atrazine is persistent [($t_{1/2}$= 146 days (linear 1st order); $t_{1/2}$=139 days (non-linear 1st order)] in aerobic mineral soils (MRID 40629303, 40431321, 42089906). Open literature data also indicate that atrazine is moderately persistent to persistent in mineral soils with half-lives ranging from 13 to 1800 days (**Table 12**). The average half-life from open literature data (130 days) is comparable to the half-life observed in the registrant submitted studies (MRID 40629303, 40431321, 42089906). Aerobic soil metabolism degradation products include DEA, DACT, DIA, HA, DIHA, and DHEA.

Table 12: Open-literature data on Soil Metabolism Half-lives in Soils Under Controlled Conditions

Half-life (days)	Soil Texture	OM (%)	pH	Temp (°C)	Comments	Reference
115	sandy loam	4	4.9	22	App Rate 5-48 mg/kg	Armstrong et al., 1967
220	silt loam	13	6.9	22		
1000-1800	Clay	2	7.3	22		
41	Loam	2.5	8	25	17% soil water	Walker and Zimdahl,1981
28	silt loam	1.1	7.3	25		
47	sandy loam	2.6	6.4	25		
181	Loam	2.5	8	5		
133	silt loam	1.1	7.3	5		
179	sandy loam	2.6	6.4	5		
103	Loam	2.5	8	5	5.1% soil water	
55	Silt loam	1.1	7.3	5		
94	Loam	2.6	6.4	5		
16	Loam	0.55	5.4	12-36	Sediment	Jones et al., 1982
13	sandy loam	0.85	4.4	12-36		
110	sandy loam	0.91	5.5	12-36		
36	silty clay loam	0.91	6.4	12-36		
38	silty clay	3.8	5.2	30		Dao et al., 1979
37	Silty clay	2.9	5.8	30		
64	Fine silt loam	2.9	6.3	30		
37	silt loam	1.6	5.1-5.8	22		Hance, 1979
37	silt loam	1.6	6.3-7.0	22		
28	silt loam	1.6	7.7-7.9	22		
27	silt loam	1.6	7.8-8.2	22		
29	silt loam	4.0	4.6-5.2	22		
32	silt loam	4.0	5.3-6.1	22		
36	silt loam	4.0	6.3-7.2	22		
40	Silt loam	4.0	6.8-8.0	22		
71	sandy loam	2.5	7.3	22		Moyer et al., 1972

Atrazine is moderately persistent to persistent ($t_{1/2}$=38 and 155 days) in aerobic river and pond aquatic environments (MRID 46338702). Atrazine is also moderately persistent to persistent in anaerobic aquatic ($t_{1/2}$ =49 to 608 days) and anaerobic soil ($t_{1/2}$= 159 days) environments (MRID 40431323, 40431321, 40629303, 40431321, 42089906). Anaerobic degradation products of atrazine include DEA, DACT, DIA, HA, DIHA and DHEA.

7.2.4. Sorption on Soil

Atrazine has low soil sorption coefficients (K_f= 0.203-2.71; 1/n=0.89-0.94; average Koc= 75) (MRID 41257901), which indicates a Food and Agriculture Organization of the United Nations (FAO) mobility classification of mobile in soil. Open literature data also indicate that atrazine has low sorption affinity to soil (**Table 13)**. In a literature review by Laird and Koskinen, 2008, they found that atrazine sorption can be dependent on several variables including organic matter, clay mineralogy, dissolved organic carbon, atrazine concentration, aging in soil, soil moisture, and temperature.

Table 13. Open-literature data on Soil:Water and Organic Carbon:Water Partitioning Coefficients for Atrazine in Soils

Kd	Koc	Soil Texture	OM (%)	References
0.70	5.3	silt loam	13	Armstrong et al., 1967
0.40	40	loamy sand	4	
0.17	8.5	Clay	2	
1.3	52	sandy loam	2.5	Moyer et al., 1972
6.03	155.8	silty clay loam	3.9	Davidson et al., 1980
0.89	98.9	sandy clay loam	0.90	
0.62	124.0	sandy clay loan	0.50	
0.62	110.7	Sand	0.56	
1.0		Clay		Talbert and Fletchall, 1965
21.5		Peat		
91.8		peat moss		
4.32		silty clay loam	4.2	
1.00	23	Silty clay loam	4.4	Lavy, 1968
0.47	16	sandy loam	2.9	
0.26	15	sandy loam	1.7	
2-11.6	43-252	silty clay loam	4.6	Weidner, 1974
1.4-8.7	48-300	sandy loam	2.9	
0-1.8	0-2571	Gravelly sand	0.07	
2.88	51.4	silt loam	5.6	Wagenet et al., 1987
1.98	55	silt loam	3.6	

7.2.5. Laboratory Volatility

Atrazine, applied at an application rate of 1.5 kg a.i./A as 500 SC formulation on a German sand soil, exhibited low volatility (organic volatiles accounted for 4.2% of applied radioactivity) under a constant air-flow (276 mL/minute) at 20^{o}C during a 24 hour period (MRID 46338701). Additionally, supplemental laboratory volatility studies with high air flow (2040 ml/minute) showed low volatility (organic volatiles accounted for 4.9% of applied radioactivity) of atrazine.

Atrazine, however, has been detected in air, rain, snow, and fog samples (Majewski and Capel, 1995). Observed concentrations of atrazine range from 0.003 to 40 µg/L in rain, 0.000008 to 0.020 µg/L in air, 0.270 to 0.820 µg/L in fog, and 0.02 to 0.03 µg/L in snow. Although the laboratory volatility studies do not show extensive volatilization of atrazine, the atrazine detections in air, rain, snow, and fog samples are probably associated with extensive usage and the large use area of atrazine (Majewski and Capel, 1995).

7.2.6. Field Dissipation Studies

Field dissipation studies show atrazine dissipation is dependent on microbial-mediated degradation, runoff, and leaching. The half-life of atrazine in six field studies in CA, GA, and MN ranged 5.23 to 405 days in fallow and corn planted soil (MRIDs 40431338, 42165506, 42089909, 40431339, 421655508, 42089911, 42165505, 42089908, 40431337, 42089912, and 421655507). Microbial degradation is an important route of dissipation in the cited field studies. Although atrazine leaching or runoff is not clearly shown in the field studies, atrazine dissipation is dependent on runoff (Acc. Nos. 00023543, 00027118, 00027124, 00027123, and 00027119) and leaching (Spalding *et al*. 1980; Junk *et al.* 1980; Spalding *et al.* 1979). Degradation products in the studies include HA, DEA, and DIA. Concentrations of atrazine and its degradation products DEA, HA, and DIA were detected with soil depth in long-term field dissipation studies.

In forestry field studies in Oregon, atrazine was detected on leaf surfaces, leaf litter, and soil. The half-life of atrazine was 87 days for exposed soil, 13 days on foliage and 66 days in leaf litter (MRIDs 40431340 and 42041450).

7.2.7. Bioaccumulation in Fish

Total [^{14}C] atrazine residues accumulated in bluegill sunfish with maximum bioconcentration factors of 7.7x, 12x, and 15x in edible tissues (body, muscle, skin, skeleton), nonedible tissues (fins, head, internal organs), and whole fish, respectively, during 28 days of exposure to uniformly ring-labeled [^{14}C]atrazine (radiochemical purity >99%, specific activity 25.6 µCi/mg) at 0.10 ppm in a flow-through system (MRID 40431344). One degradate, G-28279, comprised 5-11% of the total residues in the 21-and 28-day fish ex-tracts. Three minor G-30033, G-28273, and G-34048 were isolated at <5% of the total residues. After 21 days of depuration, [14C] residues were 0.21 ppm in edible tissues, 0.38 ppm in nonedible tissues, and 0.28 ppm in whole fish; depuration rates were 74, 76, and 78%, respectively.

7.2.8. Degradation Products

Degradation products of atrazine are shown in **Table 14**. There are two major types of degradation products for atrazine. The first type of degradation products (i.e., DIA, DEA, DACT/DDA) are formed through dealkylation of the amino groups. The second type of degradation products (i.e., OIET, OIAT, and OEAT) are formed through substitution of a chlorine

by a hydroxy group via hydrolysis. These degradation products can be formed through abiotic and microbial-mediated processes. Two of these degradation products, DIA and DACT, are also degradation products of simazine. In addition, DACT is also a degradation product of cyanazine. Structures of the degradation products are shown in **Figure 10.** Structures of Atrazine and Its Degradation Products**.**

Table 14. Chemical Names for Atrazine Degradation Products

Common Name	Chemical Name	Chemical Formula	CAS Reg No.	Synonyms
Deisopropylatrazine	2-chloro-6-ethylamino-4-amino-s-triazine	$C_5H_8ClN_5$	1007-28-9	CEAT/DIA/G-28279
Deethylatrazine	2-chloro-4-isopropylamino-6-amino-s-triazine	$C_6H_{10}ClN_5$	6190-65-4	CIAT/DEA/G-30033
Hydroxyatrazine	2-hydroxy-4-isopropylamino-6-ethylamino-s-triazine	$C_8H_{15}N_5O$	2163-68-0	OIET/HA/G-34048
Diadealkylatrazine	chlordiamino-s-triazine	$C_3H_4ClN_5$	3397-62-4	CAAT/DACT/DDA/ GS-28273
Deisopropylhydroxyatrazine	2-hydroxy-6-ethylamino-4-amino-s-triazine	$C_5H_9N_5O$	7313-54-4	OIAT/DIHA/GS-17792
Deethylhydroxyatrazine	2-hydroxy-4-isopropylamino-6-amino-s-triazine	$C_6H_{11}N_5O$	--------------	OEAT/DHEA/GS-17794

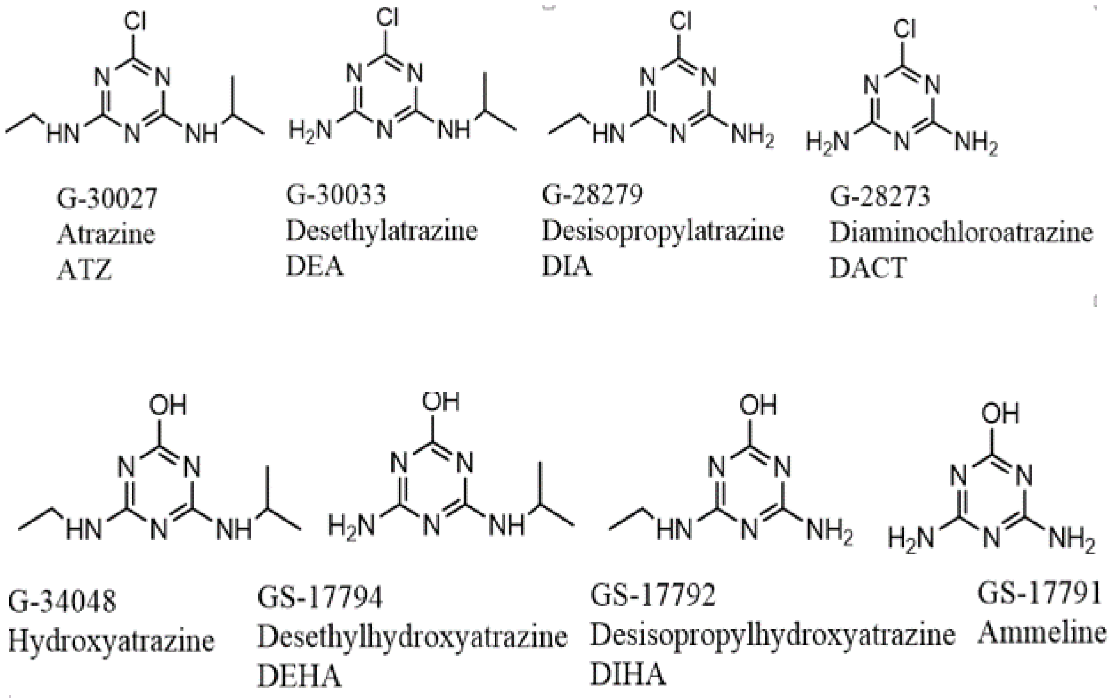


Figure 10. Structures of Atrazine and Its Degradation Products

Deethylatrazine (DEA; G-30033) and deisopropylatrazine (DIA; G-28279) are detected in all laboratory and field studies (**Table 15**). Hydroxyatrazine (HA; G-34048) is detected in all studies except for the photodegradation on soil study; and chlordiamino-s-triazine (DACT; G-28273) is detected in all studies except for the aquatic metabolism studies. Deethylhydroxyatrazine (DEHA; GS-17794) and deisopropylhydroxyatrazine (DIHA; GS-17792) are also detected in the photodegradation in water, aerobic soil metabolism, and anaerobic soil metabolism studies. For studies limited to several months, the relative concentrations of the degradation products in soil were generally HA~DEA>DIA>DACT~DHEA.

Table 15. Identification of Atrazine Degradation Products in Environmental Fate Studies

Study	Degradation Products	Maximum Percentage of Applied Atrazine	References
Hydrolysis	None	None	MRID 40431319
Photodegradation in Water	DACT	15	MRID 42089904 MRID 45545301
	DEA	16	
	DIA	5	
	DIHA	0.22	
	HA	1.19	
	DHEA	0.27	
Photodegradation on Soil	DACT	18.3	MRID 42089905
	DEA	14.5	
	DIA	7.9	
Aerobic Soil Metabolism	DACT	0.317	MRID 40629303 MRID 42089906 MRID 40431321
	DEA	4.18	
	DIA	1.61	
	DIHA	0.410	
	HA	4.20	
	DHEA	0.774	
Anaerobic Soil Metabolism	DACT	0.3	MRID 40629303 MRID 42089906
	DEA	2.1	
	DIA	0.74	
	DIHA	0.22	
	HA	1.22	
	DHEA	0.44	
Anaerobic Aquatic Metabolism	DEA	4.7	MRID 40431323 MRID 46338702
	DIA	1.4	
	HA	12.4	
Aerobic Aquatic Metabolism	DEA	2.9	MRID 46338702
	DIA	0.4	
	HA	14.8	

The mobility of atrazine degradation products can range from low to high mobility in soil. The chloro-triazine degradation products (DACT, DIA, and DEA) exhibit higher mobility than the hydroxyl-triazine degradation products (OIET) because they have lower organic carbon:water and soil:water partition coefficients (**Table 16**).

Table 16. Soil Sorption Coefficients for Atrazine Degradation Products

Degradation Product	K_f	1/n	Average K_{oc}	References
DACT G-28273	0.16-1.56	0.858-1.09	55	MRID 41257904
DIA G-28279	0.16-2.7	0.874-1.025	51	MRID 41257905
DEA G-30033	0.06-1.02	0.715-1.109	29	MRID 41257906
OIET G-34048	1.98-389.6	0.8930-1.075	4331	MRID 41257902

7.3. Aquatic Exposure Assessment

The aquatic exposure assessment is designed to consider standard ecological modeling (*i.e.*, Surface Water Concentration Calculator [SWCC]), surface water monitoring data, as well as geospatial modeling using the USGS Watershed Regressions for Pesticides (WARP). Although each of the exposure assessment methods have limitations in estimating environmental concentrations (EECs) of atrazine, the combination of the modeling approaches and monitoring data, taken together, provide a comprehensive depiction of atrazine occurrence in surface water at various spatial scales.

The standard ecological modeling is a national screening level exposure assessment. The EECs are intended to represent exposure that recurs with a frequency of once every ten years at a site that is more vulnerable to pesticide movement in surface water than 90% of the sites that can be used to grow the treated crop. The model scenarios which represent the 90th percentile sites are selected by best professional judgment and may represent sites more or less vulnerable than the target vulnerability. These estimated exposure concentrations are expected to represent first-order streams and small static water bodies adjacent to atrazine use areas.

The surface water monitoring data available for atrazine is often considered the most robust set of pesticide monitoring data available in the United States. Therefore, the evaluation of the atrazine monitoring data is an important component of the ecological exposure assessment. Evaluation of the monitoring data requires an understanding of the objective of the monitoring program for site selection and sampling strategy. It is important that monitoring sites are located in watersheds with atrazine use. Additionally, it is important to understand the impact of sample frequency and timing for capturing peak atrazine concentrations. The peak atrazine concentration is important in quantifying average concentrations from monitoring data. Because low sample frequencies (*i.e.*, samples collected greater than 14 days apart) are a common attribute in pesticide monitoring data, there is a high probability that peak atrazine

concentrations are not captured. This situation leads to monitoring data underestimating true peak and average atrazine concentrations. In order to address the uncertainty in quantifying atrazine occurrence data due to sample frequency, sampling bias factors (BFs; see **Section 7.4.1**) have been developed using the 2009-2014 Atrazine Ecological Exposure Monitoring Program (AEEMP), Atrazine Monitoring Program (AMP), and National Center for Water Quality Research (NCWQR) (see **Section 7.4.3**). These monitoring programs were selected for determination of BFs because they have high sampling frequencies from daily to 7 day sampling intervals and the sites are associated with atrazine use areas. Additionally, the monitoring programs represent a variety of hydrologic conditions from small-flowing streams, large rivers, and drinking water reservoirs. The BFs correct atrazine occurrence data to account for the impact of sampling frequency on capturing peak or high-end atrazine concentrations. Bias factor adjusted monitoring data is expected to allow for identification of sites where the ecological levels of concern (LOCs) may be exceeded. The available monitoring data for atrazine is evaluated for the ecological exposure assessment as reported monitoring data as well as bias factor adjusted monitoring data.

The USGS WARP model is a set of regression models that allows prediction of atrazine concentrations in flowing water bodies. Because the WARP model input parameters are derived from GIS data layers, the model provides a scale-dependent, modeling approach for estimating atrazine concentrations in flowing water bodies with no prior monitoring (see **Section 7.3.2**). This modeling approach will provide predictions of the occurrence patterns of atrazine across the United States, as well as an understanding on the geographic extent of the atrazine occurrences that may exceed the ecological LOCs. The WARP modeling provides an estimate of atrazine ecological exposure at sites with no monitoring data.

7.3.1. National Scale - Tier II Exposure Assessment using Surface Water Concentration Calculator

The surface water modeling was conducted using the Surface Water Concentration Calculator (version 1.106) (SWCC) for the standard pond. The surface water modeling was conducted for atrazine uses on corn, sorghum, sugarcane, nut crops, fallow, turf, CRP, roadsides, macadamia nuts, guava, conifers (**Table 1** and **Table 2**).

Standard crops scenarios or appropriate custom crop scenarios from cumulative drinking water assessments or endangered species assessments are used in this assessment. Several use patterns such as Conservation Reserve Program (CRP), roadsides, macadamia nuts, and guava do not have standard or customized scenarios. Surrogate model scenarios, therefore, are used to represent these specialized crop use patterns. The use of surrogate scenarios is expected to introduce uncertainties for estimation of EECs due to differences in agronomic conditions, plant types, and soil conditions for surrogate scenarios when compared to the standard crop scenarios. For example, the use of corn scenarios as surrogate scenarios for roadside atrazine use is expected to exaggerate surface water atrazine concentrations due to differences in runoff from a field with constant plant cover such as roadsides versus a cultivated field

condition for corn. **Table 17** shows the selection criteria used for adoption of certain surrogate model scenarios for some labeled sanctioned use patterns.

Table 17. Criteria for Surrogate Model Scenarios in SWCC Modeling

Crop	Scenario	Selection Criteria for Surrogate Scenario
CRP	TX Meadows-BBS	Standard scenarios represent native grasses commonly used for CRP
	TX Rangeland-BBS	
	CA Rangeland-RLF	
Roadsides	KS Corn	Roadside uses of atrazine is allowed in CO, KS, MT, ND, SD, WY, and OK. These scenarios represent soil and climate conditions for label permitted use on roadsides. These scenarios are expected to provide a conservative estimate of atrazine runoff because they are representative of areas with cultivated row crops rather than areas with perennial plant cover.
	NE Corn	
	ND Wheat	
Macadamia Nuts	CA avocado	Although Hawaii has the highest macadamia nut production in the United States, California also has production areas for macadamia nuts. The CA avocado scenario is selected to be representative of a California use site for a nut crop. The use of atrazine on macadamia in Hawaii was not modeled because there are no Hawaii crop scenarios.
Guava	FL avocado	Guava is grown in Florida and California in the United States. These scenarios are selected to represent geographic regions where guava can be grown.
	CA citrus	
Conifers	GA pecans	Because conifers plantations can exist throughout the United States, the selected scenarios represent different geographic regions for tree crops.
	MI cherries	
	OR christmas trees	

The modeling accounts for a 66 feet buffer for spray drift from surface water. This buffer accounts for the label requirement "Cannot be applied by air or ground within 66 feet of the points where field surface water runoff enters perennial or intermittent streams and rivers or within 200 feet around natural or impounded lakes or reservoirs". **Table 18** shows the estimated AgDrift spray drift fractions (Version 2.1.1) for the 66 and 200 feet spray buffers. Application efficiencies used in the model are 0.95 for aerial spray and 0.99 for ground spray.

Table 18. AgDrift Spray Drift Fractions for Required Spray Drift Buffers on Atrazine Labels

Buffer Size (feet)	Application Method	Droplet Size Spectrum	Drift Fraction[3]
66[1]	Ground	Very fine to fine	0.017
	Aerial	Fine to Medium	0.064
200[2]	Ground	Very fine to fine	0.008
	Aerial	Fine to Medium	0.031

1-Drift buffer for perennial or intermittent streams and rivers
2-Drift buffer for natural or impounded lakes or reservoirs
3-Drift fractions were calculated using default droplet size spectrums and application conditions for Tier 1 AgDrift (Version 2.1.1) spray drift assessment (White, et. al., 2013).

The SWCC modeling considers the atrazine application conditions and timing as prescribed on the atrazine Section 3 and 24C labels (**Table 19 and Table 20**) (Atwood *et al*. 2015). Maximum application rates, maximum number of applications, and minimum application intervals are used in the modeling. Application timing is selected, when possible, around plant emergence dates for the crop. For crop or use scenarios with no clear relationship to plant emergence dates, application dates are selected to approximate probable application timing. The selected application dates were reviewed and recommended by the Biological and Economic Analysis Division (Atwood *et al*. 2015). Use patterns and crops requiring specific application dates are the applications to fallow wheat, turf, CRP, roadsides, macadamia nuts, guava, and conifers. The model simulations are representative of aerial application in all cases except when ground application is the only label application method. Fallow uses were modeled as a single application or in a rotation system with corn and sorghum.

Table 19. Application Rates, Number, Intervals and Method for Section 3 Atrazine Labels Used in SWCC Modeling.

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date (month/day)[3]	Application Method	Spray Drift Fraction
Corn (Split App)	KS Corn	2	2/0.5	-14E, +14E	Aerial	0.064[1]
	MS Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	OH Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	PA Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	IL Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	IN Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	MN Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	NC Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	NE Corn	2	2/0.5	-14E, +14E	Aerial	0.064
	CA Corn-OP	2	2/0.5	-14E, +14E	Aerial	0.064
	TX Corn-OP	2	2/0.5	-14E, +14E	Aerial	0.064
	FL-Sweet Corn-OP	2	2/0.5	-14E, +14E	Aerial	0.064
	NCcornOP	2	2/0.5	-14E, +14E	Aerial	0.064
	ORSWcornOP	2	2/0.5	-14E, +14E	Aerial	0.064
	STXcornNMC	2	2/0.5	-14E, +14E	Aerial	0.064
	IA corn	2	2/0.5	-14E, +14E	Aerial	0.064
	NEcorn	2	2/0.5	-14E, +14E	Aerial	0.064
	KS Corn	2	2/0.5	-14E, +14E	Aerial	0.064[1]
	MS Corn	2	2/0.5	-14E, +14E	Ground	0.017
	OH Corn	2	2/0.5	-14E, +14E	Ground	0.017
	PA Corn	2	2/0.5	-14E, +14E	Ground	0.017
	IL Corn	2	2/0.5	-14E, +14E	Ground	0.017
	IN Corn	2	2/0.5	-14E, +14E	Ground	0.017
	MN Corn	2	2/0.5	-14E, +14E	Ground	0.017
	NC Corn	2	2/0.5	-14E, +14E	Ground	0.017
	NE Corn	2	2/0.5	-14E, +14E	Ground	0.017

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date (month/day)[3]	Application Method	Spray Drift Fraction
	CA Corn-OP	2	2/0.5	-14E, +14E	Ground	0.017
	TX Corn-OP	2	2/0.5	-14E, +14E	Ground	0.017
	FL-Sweet Corn-OP	2	2/0.5	-14E, +14E	Ground	0.017
	NCcornOP	2	2/0.5	-14E, +14E	Ground	0.017
	ORSWcornOP	2	2/0.5	-14E, +14E	Ground	0.017
	STXcornNMC	2	2/0.5	-14E, +14E	Ground	0.017
	IA corn	2	2/0.5	-14E, +14E	Ground	0.017
	NEcorn	2	2/0.5	-14E, +14E	Ground	0.017
Corn Fallow + Split App	KS Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	MS Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	OH Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	PA Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	IL Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	IN Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	MN Corn	3	1/0.5/1	-14E, +14E,+169E	Ground	0.017
	NC Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	NE Corn	3	1/0.5/1	-14E, +14E,+169E	Ground	0.017
	CA Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	TX Corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	NCcornOP	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	ORSWcornOP	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	STXcornNMC	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	IA corn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
	NEcorn	3	1/0.5/1	-14E, +14E, +169E	Ground	0.017
Corn Fallow	KS Corn	1	1	+169E	Ground	0.017
	MS Corn	1	1	+169E	Ground	0.017
	OH Corn	1	1	+169E	Ground	0.017
	PA Corn	1	1	+169E	Ground	0.017
	IL Corn	1	1	+169E	Ground	0.017
	IN Corn	1	1	+169E	Ground	0.017
	MN Corn	1	1	+169E	Ground	0.017
	NC Corn	1	1	+169E	Ground	0.017
	NE Corn	1	1	+169E	Ground	0.017
	CA Corn	1	1	+169E	Ground	0.017
	TX Corn	1	1	+169E	Ground	0.017
	NCcornOP	1	1	+169E	Ground	0.017
	ORSWcornOP	1	1	+169E	Ground	0.017
	STXcornNMC	1	1	+169E	Ground	0.017
	IA corn	1	1	+169E	Ground	0.017
	NEcorn	1	1	+169E	Ground	0.017
Sorghum (Split App)	KS Sorghum	2	2/0.5	-14E, +14E	Aerial	0.064
	TX Sorghum-OP	2	2/0.5	-14E, +14E	Ground	0.017
	KS Sorghum	3	1/0.5/1	-14E, +14E,+169E	Aerial	0.064
	KS Sorghum	3	1/0.5/1	-14E, +14E,+169E	Ground	0.017
	TX Sorghum-OP	3	1/0.5/1	-14E, +14E,+169E	Aerial	0.064
	TX Sorghum-OP	3	1/0.5/1	-14E, +14E,+169E	Ground	0.017
Sorghum Fallow	KS Sorghum	1	1	+169E	Ground	0.017

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date (month/day)[3]	Application Method	Spray Drift Fraction
	TX Sorghum-OP	1	1	+169E	Ground	0.017
Sugarcane	LA Sugarcane	4	4/2/2/2	3/1, 3/15, 3/29, 4/13	Aerial	0.064
	LA Sugarcane	4	4/2/2/2	3/1, 3/15, 3/29, 4/13	Ground	0.017
	FL Sugarcane	4	4/2/2/2	3/1, 3/15, 3/29, 4/13	Aerial	0.064
	FL Sugarcane	4	4/2/2/2	3/1, 3/15, 3/29, 4/13	Ground	0.017
Turf	FL Turf-St Augustine	2	4/2	2/1, 2/15	Ground	0.017
	FL Turf-Berm-Spring	2	1/1	2/1,2/15	Ground	0.017
	FL Turf-Fall	2	1/1	11/1, 12/1	Ground	0.017
Wheat+Split App	ND Wheat	3	1/0.5/1	3/2, 3/30,8/15	Ground	0.017
	TX Wheat-OP	3	1/0.5/1	5/1,5/30,10/15	Ground	0.017
Wheat Fallow	ND Wheat	1	1	8/15	Ground	0.017
	TX Wheat-OP	1	1	10/15	Ground	0.017
CRP	Meadows-BBS	1	2	4/1	Aerial[2]	0.064
	Meadows-BBS	1	2	4/1	Ground	0.017
	Rangeland-BBS	1	2	4/1	Aerial[2]	0.064
	Rangeland-BBS	1	2	4/1	Ground	0.017
	CA Rangeland-RLF	1	2	4/1	Aerial[2]	0.064
	CA Rangeland-RLF	1	2	4/1	Ground	0.017
Roadsides	KS Corn	1	1	3/1	Ground	0.017
	NE Corn	1	1	3/1	Ground	0.017
	ND Wheat	1	1	3/1	Ground	0.017
Macadamia Nuts	CA avocado	2	4	6/1, 6/15	Ground	0.017
Guava	FL avocado	2	4	1/15, 5/15	Ground	0.017
	CA citrus	2	4	3/15, 7/15	Ground	0.017
Conifers	GA pecans	1	4	3/1	Aerial	0.064
	GA pecans	1	4	3/1	Ground	0.017
	MI cherries	1	4	4/1	Aerial	0.064
	MI cherries	1	4	4/1	Ground	0.017
	OR christmas trees	1	4	4/1	Aerial	0.064
	OR christmas trees	1	4	4/1	Ground	0.017

1- Spray drift fraction considering a 66 feet buffer using default droplet size spectrum.
2- Label requires aerial application at maximum height of 10 feet with low drift buffers; 400 feet upwind buffer from sensitive plants
3- The minimum labeled retreatment interval for corn is 14-days, the modeling approach used here assumed a 28-day retreatment interval to bracket the planting date for corn.

Table 20. Application Rates, Number, Intervals and Method for Section 24C Atrazine Labels Used in SWCC Modeling

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing (month/day)	Application Method	Spray Drift Fraction
Fallow	KS Corn	1	2.0	+169E	Ground	0.017
	KS Sorghum	1	1.25	+169E	Ground	0.017
	TX Sorghum-OP	1	1.25	+169E	Aerial	0.064[1]
	TX Sorghum-OP	1	1.25	+169E	Ground	0.017
	TX wheat-OP	1	0.5	6/15	Aerial	0.064
	TX wheat-OP	1	0.5	6/15	Ground	0.017
	ND wheat	1	0.5	6/15	Aerial	0.064
	ND wheat	1	0.5	6/15	Ground	0.017
	ND Wheat	1	0.4	9/15	Ground	0.017
CRP	Meadows-BBS	1	2	-14E	Aerial[2]	0.064
	Meadows-BBS	1	2	-14E	Ground	0.017
	Rangeland-BBS	1	2	-14E	Aerial[2]	0.064
	Rangeland-BBS	1	2	-14E	Ground	0.017
	CA Rangeland-RLF	1	2	-14E	Aerial[2]	0.064
	CA Rangeland-RLF	1	2	-14E	Ground	0.017
Roadsides	KS corn	1	2	3/1	Ground	0.017

1-Spray drift fraction considering a 66 feet buffer using default droplet size spectrum.
2-Label requires aerial application at maximum height of 10 feet with low drift buffers; 400 feet upwind buffer from sensitive plants

Additional refinements were conducted with the corn scenarios because the majority of the pounds of atrazine applied nationally is to corn and would represent the largest spatial extent of use.

Because atrazine is co-formulated in different corn herbicide products, the application rates of atrazine are lower in co-formulated herbicide products with atrazine when compared to herbicide products with atrazine as the sole herbicide. In order to assess the atrazine exposure from co-formulated herbicide products with atrazine, additional modeling was conducted to represent the atrazine rates of 0.25 and 0.5 lb a.i./A (**Table 21**). These rates are also bounding the reported typical use rates discussed in **Section 5.5.2.**

Table 21. Application Rates, Number, Intervals and Methods for Single Atrazine Application Rates of 0.25 and 0.5 lb/A to Represent Herbicides Co-formulated with Atrazine

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date(month/day)	Application Method	Spray Drift Fraction
Corn	KS Corn	1	0.5	-14E	Aerial	0.064[1]
	MS Corn	1	0.5	-14E	Aerial	0.064
	OH Corn	1	0.5	-14E	Aerial	0.064
	PA Corn	1	0.5	-14E	Aerial	0.064
	IL Corn	1	0.5	-14E	Aerial	0.064
	IN Corn	1	0.5	-14E	Aerial	0.064
	MN Corn	1	0.5	-14E	Aerial	0.064
	NC Corn	1	0.5	-14E	Aerial	0.064
	NE Corn	1	0.5	-14E	Aerial	0.064
	CA Corn-OP	1	0.5	-14E	Aerial	0.064
	TX Corn-OP	1	0.5	-14E	Aerial	0.064
	FL-Sweet Corn-OP	1	0.5	-14E	Aerial	0.064
	NCcornOP	1	0.5	-14E	Aerial	0.064
	ORSWcornOP	1	0.5	-14E	Aerial	0.064
	STXcornNMC	1	0.5	-14E	Aerial	0.064
	IA corn	1	0.5	-14E	Aerial	0.064
	NEcorn	1	0.5	-14E	Aerial	0.064
	KS Corn	1	0.5	-14E	Aerial	0.064[1]
	MS Corn	1	0.5	-14E	Ground	0.017
	OH Corn	1	0.5	-14E	Ground	0.017
	PA Corn	1	0.5	-14E	Ground	0.017
	IL Corn	1	0.5	-14E	Ground	0.017
	IN Corn	1	0.5	-14E	Ground	0.017
	MN Corn	1	0.5	-14E	Ground	0.017
	NC Corn	1	0.5	-14E	Ground	0.017
	NE Corn	1	0.5	-14E	Ground	0.017
	CA Corn-OP	1	0.5	-14E	Ground	0.017
	TX Corn-OP	1	0.5	-14E	Ground	0.017
	FL-Sweet Corn-OP	1	0.5	-14E	Ground	0.017
	NCcornOP	1	0.5	-14E	Ground	0.017
	ORSWcornOP	1	0.5	-14E	Ground	0.017
	STXcornNMC	1	0.5	-14E	Ground	0.017
	IA corn	1	0.5	-14E	Ground	0.017
	NEcorn	1	0.5	-14E	Ground	0.017
	MS Corn	1	0.25	-14E	Ground	0.017
	OH Corn	1	0.25	-14E	Ground	0.017
	PA Corn	1	0.25	-14E	Ground	0.017
	IL Corn	1	0.25	-14E	Ground	0.017
	IN Corn	1	0.25	-14E	Ground	0.017
	MN Corn	1	0.25	-14E	Ground	0.017
	NC Corn	1	0.25	-14E	Ground	0.017
	NE Corn	1	0.25	-14E	Ground	0.017
	CA Corn-OP	1	0.25	-14E	Ground	0.017
	TX Corn-OP	1	0.25	-14E	Ground	0.017

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date(month/day)	Application Method	Spray Drift Fraction
	FL-Sweet Corn-OP	1	0.25	-14E	Ground	0.017
	NCcornOP	1	0.25	-14E	Ground	0.017
	ORSWcornOP	1	0.25	-14E	Ground	0.017
	STXcornNMC	1	0.25	-14E	Ground	0.017
	IA corn	1	0.25	-14E	Ground	0.017
	NEcorn	1	0.25	-14E	Ground	0.017

Additionally, the atrazine Section 3 labels recommend that atrazine rates be reduced to 1.6 lb/A on highly erodible soils (**Table 22**). This label restriction is meant to limit atrazine runoff from the application site.

Table 22. Application Number, Intervals and Methods for an Atrazine Application Rate of 1.6 lb a.i/A for Highly Erodible Soils.

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date(month/day)	Application Method	Spray Drift Fraction
Corn	KS Corn	1	1.6	-14E	Aerial	0.064[1]
	MS Corn	1	1.6	-14E	Aerial	0.064
	OH Corn	1	1.6	-14E	Aerial	0.064
	PA Corn	1	1.6	-14E	Aerial	0.064
	IL Corn	1	1.6	-14E	Aerial	0.064
	IN Corn	1	1.6	-14E	Aerial	0.064
	MN Corn	1	1.6	-14E	Aerial	0.064
	NC Corn	1	1.6	-14E	Aerial	0.064
	NE Corn	1	1.6	-14E	Aerial	0.064
	CA Corn-OP	1	1.6	-14E	Aerial	0.064
	TX Corn-OP	1	1.6	-14E	Aerial	0.064
	FL-Sweet Corn-OP	1	1.6	-14E	Aerial	0.064
	NCcornOP	1	1.6	-14E	Aerial	0.064
	ORSWcornOP	1	1.6	-14E	Aerial	0.064
	STXcornNMC	1	1.6	-14E	Aerial	0.064
	IA corn	1	1.6	-14E	Aerial	0.064
	NEcorn	1	1.6	-14E	Aerial	0.064
	KS Corn	1	1.6	-14E	Aerial	0.064[1]
	MS Corn	1	1.6	-14E	Ground	0.017
	OH Corn	1	1.6	-14E	Ground	0.017
	PA Corn	1	1.6	-14E	Ground	0.017
	IL Corn	1	1.6	-14E	Ground	0.017
	IN Corn	1	1.6	-14E	Ground	0.017
	MN Corn	1	1.6	-14E	Ground	0.017
	NC Corn	1	1.6	-14E	Ground	0.017
	NE Corn	1	1.6	-14E	Ground	0.017
	CA Corn-OP	1	1.6	-14E	Ground	0.017
	TX Corn-OP	1	1.6	-14E	Ground	0.017
	FL-Sweet Corn-OP	1	1.6	-14E	Ground	0.017

Crop	Scenario	Apps	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date(month/day)	Application Method	Spray Drift Fraction
	NCcornOP	1	1.6	-14E	Ground	0.017
	ORSWcornOP	1	1.6	-14E	Ground	0.017
	STXcornNMC	1	1.6	-14E	Ground	0.017
	IA corn	1	1.6	-14E	Ground	0.017
	NEcorn	1	1.6	-14E	Ground	0.017

Another factor considered in the modeling is the impact of soil incorporation on atrazine runoff (**Table 23**). Soil incorporation was simulated at 2, 4, and 6 cm incorporation depths with an atrazine application rate of 0.5 lbs a.i/A. These model scenarios are expected to provide a lower bound on the potential ecological exposure from atrazine use on corn because of the reduced application rate in conjunction with soil incorporation.

Table 23. Soil Incorporation Modeling for Atrazine Application Rates of 0.5 lb a.i./A on Corn

Crop	Scenario	Apps	Application Depth (cm)	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date (month/day)	Application Method	Spray Drift Fraction
Corn	KS Corn	1	2	0.5	-14E	Ground	0.017
	MS Corn	1	2	0.5	-14E	Ground	0.017
	OH Corn	1	2	0.5	-14E	Ground	0.017
	PA Corn	1	2	0.5	-14E	Ground	0.017
	IL Corn	1	2	0.5	-14E	Ground	0.017
	IN Corn	1	2	0.5	-14E	Ground	0.017
	MN Corn	1	2	0.5	-14E	Ground	0.017
	NC Corn	1	2	0.5	-14E	Ground	0.017
	NE Corn	1	2	0.5	-14E	Ground	0.017
	CA Corn-OP	1	2	0.5	-14E	Ground	0.017
	TX Corn-OP	1	2	0.5	-14E	Ground	0.017
	FL-Sweet Corn-OP	1	2	0.5	-14E	Ground	0.017
	NCcornOP	1	2	0.5	-14E	Ground	0.017
	ORSWcornOP	1	2	0.5	-14E	Ground	0.017
	STXcornNMC	1	2	0.5	-14E	Ground	0.017
	IA corn	1	2	0.5	-14E	Ground	0.017
	NEcorn	1	2	0.5	-14E	Ground	0.017
	KS Corn	1	4	0.5	-14E	Ground	0.017
	MS Corn	1	4	0.5	-14E	Ground	0.017
	OH Corn	1	4	0.5	-14E	Ground	0.017
	PA Corn	1	4	0.5	-14E	Ground	0.017
	IL Corn	1	4	0.5	-14E	Ground	0.017
	IN Corn	1	4	0.5	-14E	Ground	0.017
	MN Corn	1	4	0.5	-14E	Ground	0.017
	NC Corn	1	4	0.5	-14E	Ground	0.017
	NE Corn	1	4	0.5	-14E	Ground	0.017
	CA Corn-OP	1	4	0.5	-14E	Ground	0.017
	TX Corn-OP	1	4	0.5	-14E	Ground	0.017
	FL-Sweet Corn-OP	1	4	0.5	-14E	Ground	0.017

Crop	Scenario	Apps	Application Depth (cm)	Application Rate (lbs/A) per App	Application Timing Emergence Date or Specific Date (month/day)	Application Method	Spray Drift Fraction
	NCcornOP	1	4	0.5	-14E	Ground	0.017
	ORSWcornOP	1	4	0.5	-14E	Ground	0.017
	STXcornNMC	1	4	0.5	-14E	Ground	0.017
	IA corn	1	4	0.5	-14E	Ground	0.017
	NEcorn	1	4	0.5	-14E	Ground	0.017
	KS Corn	1	6	0.5	-14E	Ground	0.017
	MS Corn	1	6	0.5	-14E	Ground	0.017
	OH Corn	1	6	0.5	-14E	Ground	0.017
	PA Corn	1	6	0.5	-14E	Ground	0.017
	IL Corn	1	6	0.5	-14E	Ground	0.017
	IN Corn	1	6	0.5	-14E	Ground	0.017
	MN Corn	1	6	0.5	-14E	Ground	0.017
	NC Corn	1	6	0.5	-14E	Ground	0.017
	NE Corn	1	6	0.5	-14E	Ground	0.017
	CA Corn-OP	1	6	0.5	-14E	Ground	0.017
	TX Corn-OP	1	6	0.5	-14E	Ground	0.017
	FL-Sweet Corn-OP	1	6	0.5	-14E	Ground	0.017
	NCcornOP	1	6	0.5	-14E	Ground	0.017
	ORSWcornOP	1	6	0.5	-14E	Ground	0.017
	STXcornNMC	1	6	0.5	-14E	Ground	0.017
	IA corn	1	6	0.5	-14E	Ground	0.017
	NEcorn	1	6	0.5	-14E	Ground	0.017

Model input parameters for atrazine are shown in **Table 24**. There are sufficient environmental fate data to support surface water modeling using the SWCC (**Appendix N**). Input parameter selection is based on the EFED Input Parameter Guidance (Brady, 2009). The 90th percentile confidence bound on the mean half-life is used for aerobic aquatic metabolism and anaerobic aquatic metabolism half-lives because there is more than 1 half-life value. However, the single aerobic soil metabolism half-life for the non-linear first-order half-life was multiplied by 3 as per input parameter guidance. The estimated 90th percentile confidence bound on the mean half-life for aerobic soil metabolism (417 days) is bracketed by the range of atrazine half-lives in the open literature (Table 12). Additionally, the predicted EECs from SWCC do not substantially change when aerobic soil metabolism half-lives are greater than 100 days such as atrazine. Therefore, the use of input parameter guidance correction for a single half-life will not alter the SWCC predictions. The mean organic carbon:water partitioning coefficient is used because the coefficient of variation for Koc is less than the Kd. These data show that atrazine is persistent and mobile in terrestrial and aquatic environments and, therefore, runoff and leaching are important routes of dissipation. Volatility is not expected to be an important route of dissipation because of a low vapor pressure and Henry's Constant.

Table 24. SWCC Modeling Inputs for Atrazine

PARAMETER	ESTIMATED VALUE (EV)	EFED Modeling VALUE	SOURCE
Aerobic Soil Metabolism Half-life (days)	139	417 (3*EV)	MRID 40629303[2] MRID 40431321 MRID 42089906
Organic Carbon Partition Coefficient (Kf_{oc}) (mL/ g_{oc})	36.94, 38.50, 70.36,155.34	75 (mean)	MRID 41257901
Aerobic Aquatic Half-Life (days)	155 and 39	277(90%CB)[1] Average= 96.5 SD=82 $t_{90,n-1}$= 3.078 n=2	MRID 46338702
Anaerobic Aquatic half-life (days)	101, 49, 608	588(90%CB)[1] Average= 252.6 SD=82 $t_{90,n-1}$= 1.866 n=3	MRID 46338702 MRID 40431323
Aqueous Photolysis half-life (days)	168	168	MRID 42089904 MRID 45545301
Hydrolysis half-life (days)	Stable	Stable	MRID 40431319
Molecular Weight (g/mole)	215.7	215.7	Atrazine RED
Water Solubility @ 25°C (mg/L)	33	33	Atrazine RED
Vapor Pressure (torr)	3.000E-7	3.000E-7	Atrazine RED

1-Calculated 90th confidence bound on the mean half-life value; t_{input} = average $t_{1/2}$ + [$t_{90,n-1}$ *SD/SQRT(n)];
2-Three studies were submitted for a single an aerobic soil metabolism study. These studies provided information on the degradation rate (MRID 40629303 and 40431321) as well as identification of degradation products (MRID 42089906).

The Tier II exposure assessment for Section 3 label uses predict atrazine concentrations ranging from 5.17 to 331 µg/L (median= 48.6 µg/L) for daily peaks, 4.99 to 321 µg/L (median= 47.1 µg/L) for 21-day averages, and 4.7 to 307 µg/L (median= 46.2 µg/L) for 60-day averages (**Table 25**). Among the Section 3 label uses for atrazine, the LA sugarcane scenario has the highest EECs which can be attributed to the high label application rate of atrazine (10 lb a.i./year) on sugarcane.

Table 25. Estimated Environmental Concentrations from SWCC Modeling for Section 3 Uses of Atrazine.

Crop	Scenario	Apps Method	Application Rate (lbs/A) per App	1 in 10 year		
				Peak	21 day average	60 day average
Corn (Split App)	ILCornSTD	Aerial	2/0.5	79.7	78.5	77.2
	MScornSTD	Aerial	2/0.5	105	103	98.4
	NCcornESTD	Aerial	2/0.5	35.3	34.4	33.7
	OHCornSTD	Aerial	2/0.5	56.5	55.1	54.1
	PAcornSTD	Aerial	2/0.5	55	54.1	53.7
	CAcornOP	Aerial	2/0.5	35.9	35.1	34.7
	FLsweetcornOP	Aerial	2/0.5	202	196	190
	NCcornWOP	Aerial	2/0.5	57.9	56.4	54.1
	NDcornOP	Aerial	2/0.5	58.9	58.1	57.5
	ORswcornOP	Aerial	2/0.5	47	46.3	45
	TXcornOP	Aerial	2/0.5	42.9	41.3	39.3
	STXcornNMC	Aerial	2/0.5	79.1	76.8	73.4
	IAcornstd	Aerial	2/0.5	52.9	51.4	49.9
	INCornStd	Aerial	2/0.5	78.5	77.3	74.7
	KSCornStd	Aerial	2/0.5	108	106	102
	MNCornStd	Aerial	2/0.5	73.6	72.5	71.2
	NECornStd	Aerial	2/0.5	107	104	101
	KSCornStd	Ground	2/0.5	100	98.1	94.2
	ILCornSTD	Ground	2/0.5	69.2	68	66.8
	MScornSTD	Ground	2/0.5	99.9	97.5	92.8
	NCcornESTD	Ground	2/0.5	25.2	24.8	23.8
	OHCornSTD	Ground	2/0.5	45.8	44.8	43.6
	PAcornSTD	Ground	2/0.5	43.9	43.2	42.4
	CAcornOP	Ground	2/0.5	25.7	25.1	24.3
	FLsweetcornOP	Ground	2/0.5	204	196	190
	NCcornWOP	Ground	2/0.5	47	45.8	43.7
	NDcornOP	Ground	2/0.5	44.6	44.1	43.4
	ORswcornOP	Ground	2/0.5	34.7	34	33.9
	TXcornOP	Ground	2/0.5	35.2	33.9	31.5
	STXcornNMC	Ground	2/0.5	74.6	71.8	68.3
	IAcornstd	Ground	2/0.5	41.8	40.5	38.6
	INCornStd	Ground	2/0.5	69	67.9	65
	MNCornStd	Ground	2/0.5	60.1	59.2	58.2
	NECornStd	Ground	2/0.5	98.1	95.5	91.9
Corn Fallow + Split App	ILCornSTD	Aerial	1/0.5/1	61.5	60.6	59.8
	MScornSTD	Aerial	1/0.5/1	80.3	78.5	74.7
	NCcornESTD	Aerial	1/0.5/1	62.8	61.5	60.6
	OHCornSTD	Aerial	1/0.5/1	46.2	45.3	43.2
	PAcornSTD	Aerial	1/0.5/1	48	47.2	46.1
	CAcornOP	Aerial	1/0.5/1	28.9	28.3	27.7
	FLsweetcornOP	Aerial	1/0.5/1	117	118	111
	NCcornWOP	Aerial	1/0.5/1	58.6	57.3	55.3
	NDcornOP	Aerial	1/0.5/1	50.5	49.7	48.9
	ORswcornOP	Aerial	1/0.5/1	64.4	64.8	65.6

Crop	Scenario	Apps Method	Application Rate (lbs/A) per App	1 in 10 year		
				Peak	21 day average	60 day average
	TXcornOP	Aerial	1/0.5/1	48.1	46.8	45.1
	STXcornNMC	Aerial	1/0.5/1	52.8	50.2	46.2
	IAcornstd	Aerial	1/0.5/1	37.1	36.2	34.9
	INCornStd	Aerial	1/0.5/1	66.3	65	63.6
	KSCornStd	Aerial	1/0.5/1	94	92.2	88.3
	MNCornStd	Aerial	1/0.5/1	62	61.3	59.9
	NECornStd	Aerial	1/0.5/1	86.5	84.8	82.2
	KSCornStd	Ground	1/0.5/1	88.9	87.1	83.4
	ILCornSTD	Ground	1/0.5/1	54.9	54.2	53.3
	MScornSTD	Ground	1/0.5/1	76.2	74.6	70.7
	NCcornESTD	Ground	1/0.5/1	57.6	56.4	55
	OHCornSTD	Ground	1/0.5/1	39	38.2	37.2
	PAcornSTD	Ground	1/0.5/1	43.4	42.6	41.5
	CAcornOP	Ground	1/0.5/1	24.1	23.6	22.9
	FLsweetcornOP	Ground	1/0.5/1	117	117	111
	NCcornWOP	Ground	1/0.5/1	53.9	52.7	50.8
	NDcornOP	Ground	1/0.5/1	44	43.5	42.9
	ORswcornOP	Ground	1/0.5/1	58.8	59.1	59.8
	TXcornOP	Ground	1/0.5/1	44.2	42	40.4
	STXcornNMC	Ground	1/0.5/1	50.5	47.9	44.1
	IAcornstd	Ground	1/0.5/1	30.3	29.6	28.3
	INCornStd	Ground	1/0.5/1	61.8	60.5	59.1
	KSCornStd	Ground	1/0.5/1	88.9	87.1	83.4
	MNCornStd	Ground	1/0.5/1	54.7	55	52.2
	NECornStd	Ground	1/0.5/1	81.6	79.8	76.8
Corn Fallow	ILCornSTD	Ground	1	28.1	27.7	27.3
	MScornSTD	Ground	1	46.8	45	45
	NCcornESTD	Ground	1	39	38.6	39.4
	OHCornSTD	Ground	1	19.3	18.9	18.7
	PAcornSTD	Ground	1	32.9	32.6	32.1
	CAcornOP	Ground	1	13.6	13.8	13.7
	FLsweetcornOP	Ground	1	47.5	45.3	41.6
	NCcornWOP	Ground	1	38.4	38.4	38.8
	NDcornOP	Ground	1	17.1	16.7	16.4
	ORswcornOP	Ground	1	48.3	48.3	48.9
	TXcornOP	Ground	1	34.4	32.8	32.7
	STXcornNMC	Ground	1	21.8	22.2	23.3
	IAcornstd	Ground	1	14.4	14.2	13.1
	INCornStd	Ground	1	33.6	33.7	34.1
	KSCornStd	Ground	1	39.9	39.2	37.7
	MNCornStd	Ground	1	27.1	26.9	26.6
	NECornStd	Ground	1	48.3	46.9	42.7
	ILCornSTD	Ground	1	28.1	27.7	27.3
	MScornSTD	Ground	1	46.8	45	45
	NCcornESTD	Ground	1	39	38.6	39.4
Sorghum (split trt)	TXsorghumOP	Aerial	1/0.5/1	64.2	61.8	61
	KSsorghumSTD	Aerial	1/0.5/1	54.1	52.9	52.1
	KSsorghumSTD	Ground	1/0.5/1	48.8	47.7	46.5
	TXsorghumOP	Ground	1/0.5/1	60.5	58.2	57.7

Crop	Scenario	Apps Method	Application Rate (lbs/A) per App	1 in 10 year		
				Peak	21 day average	60 day average
	TXsorghumOP	Aerial	2/0.5	76.5	73.2	71.3
	KSsorghumSTD	Aerial	2/0.5	64.7	63.2	61.8
Sorghum (fallow)	TXsorghumOP	Ground	1	35.3	34.2	32.6
	KSsorghumSTD	Ground	1	35.1	35.5	33.1
Sugarcane	FLsugarcaneSTD	Aerial	4/2/2/2	331	321	307
	LAsugarcaneSTD	Aerial	4/2/2/2	282	273	261
	FLsugarcaneSTD	Ground	4/2/2/2	316	307	293
	LAsugarcaneSTD	Ground	4/2/2/2	258	251	241
Wheat+Split App	ND Wheat	Ground	1/0.5/1	60.8	59.4	58.5
	TX Wheat-OP	Ground	1/0.5/1	64.1	62.1	58.7
Wheat Fallow	ND Wheat	Ground	1	45	43.2	41
	TX Wheat-OP	Ground	1	30.7	30.8	31.2
Turf	Turf-Bermuda Spring Trt	Ground	1/1	5.17	4.99	4.7
	Turf-St Aug Fall Trt	Ground	4/2	9.76	9.51	8.78
	Turf-St Aug Spring Trt	Ground	4/2	14.4	14	13.2
CRP	RangeBSS	Aerial	2	43.3	41.7	38.7
	MeadowBSS	Aerial	2	34.8	33.6	32
	CArangelandhayRLF_V2	Aerial	2	25.1	24.4	23.4
	RangeBSS	Ground	2	37.1	35.6	33.1
	MeadowBSS	Ground	2	28.3	27.3	25.7
	CArangelandhayRLF_V2	Ground	2	17.2	16.5	15.7
Roadsides	KS Corn	Ground	1	43.9	43.2	41.9
	NE Corn	Ground	1	42.7	42	40.8
	ND Wheat	Ground	1	24.8	24.6	24
Macadamia Nuts	CA avocado	Ground	2/2	72	71	69.1
Guava	FL avocado	Ground	4/4	155	149	149
	CA citrus	Ground	4/4	14.2	13.6	12.2
Conifers	GAPecansSTD	Aerial	4	113	110	104
	MICherriesSTD	Aerial	4	76.4	75	73.1
	ORXmasTreeSTD	Aerial	4	36.8	36.1	35
	GAPecansSTD	Ground	4	101	98.2	93
	MICherriesSTD	Ground	4	51	50.1	48.9
	ORXmasTreeSTD	Ground	4	12.3	12.1	11.7
	GAPecansSTD	Aerial	4	113	110	104
	MICherriesSTD	Aerial	4	76.4	75	73.1
	ORXmasTreeSTD	Aerial	4	36.8	36.1	35

The Tier II exposure assessment for Section 24C label uses predict atrazine concentrations ranging from 15.7 to 87.8 µg/L (median= 37.9 µg/L) for the daily peak, 15.3 to 86.4 µg/L (median= 37.8 µg/L) for the 21-day average, and 15.3 to 83.8 µg/L (median= 36.9 µg/L) for the 60-day average (**Table 26**). Among the Section 24C label uses for atrazine, the KS corn fallow scenario has the highest EECs.

Table 26. Estimated Environmental Concentrations from SWCC Modeling for Section 24C Uses of Atrazine.

Crop	Scenario	Application Method	Application Rate (lb a.i/A)	1 in 10 year		
				Peak	21 day average	60 day average
Fallow	KSCorn	Aerial	2	86.7	85.2	82.3
	KSCorn	Ground	2	79.7	78.3	75.3
	KSsorghumSTD	Aerial	1.25	37.9	37.8	37.1
	TXsorghumOP	Aerial	1.25	45.9	44.3	39.9
	KSsorghumSTD	Ground	1.25	33.5	33.3	32.8
	TXsorghumOP	Ground	1.25	42.7	41.2	36.9
	TXwheatOP	Aerial	0.5	27.9	26.5	25.4
	NDwheatSTD	Aerial	0.5	15.7	15.3	15.3
	TXwheatOP	Ground	0.5	22.2	21.4	19.8
	NDwheatSTD	Ground	0.5	16.8	16.3	15.3
	KSCorn	Aerial	2	86.7	85.2	82.3
	KSCorn	Ground	2	79.7	78.3	75.3
	KSsorghumSTD	Aerial	1.25	37.9	37.8	37.1
	TXsorghumOP	Aerial	1.25	45.9	44.3	39.9
CRP	MeadowBSS	Ground	2	26.8	25.9	24.5
	RangeBSS	Ground	2	36.4	35.3	33.3
	CArangelandhayRLF_V2	Ground	2	27.5	27.2	26.4
	MeadowBSS	Aerial	2	31.3	30.3	28.6
	RangeBSS	Aerial	2	40.6	39.3	37.1
	CArangelandhayRLF_V2	Aerial	2	35.8	35.3	34.3
Roadsides	Kscorn	Ground	2	87.8	86.4	83.8

Reduced application rates of atrazine at 0.25 and 0.5 lb a.i./A on corn, as expected, are proportionally reduced when compared to EECs for maximum annual application rates of 2.5 lb a.i./A (**Table 27 and Table 28**). A similar situation occurs for the reduced applications rate of atrazine on highly erodible soils (1.6 lb a.i./A); EECs are proportionally reduced when compared to the maximum label annual application rate of 2.5 lb a.i./A (**Table 29**). Soil incorporation is expected to reduce atrazine runoff because atrazine is below the runoff extraction zone in the surface soil. The SWCC modeling indicate that EECs for atrazine applications with soil incorporation at 2 cm are slightly higher than ground applications of atrazine without any soil incorporation (**Table 30**). This observation is related to the assumed pesticide extraction zone for ground and soil incorporation in the SWCC. The pesticide extraction zone for ground applications are assumed to result in a linear decrease in pesticide concentration from the soil

surface to a 4 cm depth. In contrast, the pesticide concentration for soil incorporation is assumed to be uniformly mixed to the soil incorporation depth. The ground applications without soil incorporation, therefore, has a higher proportion of applied atrazine in the pesticide runoff extraction zone in soil. This artifact of the SWCC needs to be considered when evaluating possible mitigation measures for reducing runoff concentrations for atrazine.

Table 27. Estimated Environmental Concentrations from SWCC Modeling for a Single Application Rate of 0.5 lb a.i./A.

Crop	Scenario	Application Method	Application Rate (lbs a.i/A)	1 in 10 year		
				Peak	21 day average	60 day average
Corn	ILCornSTD	Aerial	0.5	18.4	18.1	17.6
	MScornSTD	Aerial	0.5	24.9	24.3	23
	NCcornESTD	Aerial	0.5	7.75	7.55	7.21
	OHCornSTD	Aerial	0.5	13.1	12.8	12.2
	PAcornSTD	Aerial	0.5	12.8	12.6	12.2
	CAcornOP	Aerial	0.5	8.47	8.29	7.95
	FLsweetcornOP	Aerial	0.5	47.7	45.4	42
	NCcornWOP	Aerial	0.5	12.2	11.9	11.5
	NDcornOP	Aerial	0.5	12.6	12.5	12.2
	ORswcornOP	Aerial	0.5	11.1	10.8	10.3
	TXcornOP	Aerial	0.5	9.48	9.16	8.64
	STXcornNMC	Aerial	0.5	15.6	15.1	14.1
	IAcornstd	Aerial	0.5	12.4	12	11.2
	INCornStd	Aerial	0.5	18.9	18.6	17.7
	KSCornStd	Aerial	0.5	24.4	24	23
	MNCornStd	Aerial	0.5	16.7	16.4	15.9
	NECornStd	Aerial	0.5	24.1	23.5	22.2
	ILCornSTD	Ground	0.5	16.3	15.9	15.6
	MScornSTD	Ground	0.5	23.7	23.2	21.9
	NCcornESTD	Ground	0.5	5.52	5.38	5.26
	OHCornSTD	Ground	0.5	10.9	10.7	10.2
	PAcornSTD	Ground	0.5	10.4	10.3	9.98
	CAcornOP	Ground	0.5	6.21	6.06	5.8
	FLsweetcornOP	Ground	0.5	47.8	45.5	42.2
	NCcornWOP	Ground	0.5	9.93	9.73	9.37
	NDcornOP	Ground	0.5	9.63	9.53	9.32
	ORswcornOP	Ground	0.5	8.41	8.2	8.09
	TXcornOP	Ground	0.5	7.83	7.55	7.11
	STXcornNMC	Ground	0.5	14.6	14.1	13.1
	IAcornstd	Ground	0.5	9.98	9.64	9
	INCornStd	Ground	0.5	16.9	16.5	15.7
	KSCornStd	Ground	0.5	22.7	22.3	21.4
	MNCornStd	Ground	0.5	14	13.7	13.2
	NECornStd	Ground	0.5	22.2	21.7	20.5

Table 28. Estimated Environmental Concentrations from SWCC Modeling for a Single Application Rate of 0.25 lb a.i./A

Crop	Scenario	Application Method	Application Rate (lbs a.i/A)	1 in 10 year		
				Peak	21 day average	60 day average
Corn	ILCornSTD	Ground	0.25	8.13	7.97	7.78
	MScornSTD	Ground	0.25	11.9	11.6	11
	NCcornESTD	Ground	0.25	2.76	2.69	2.63
	OHCornSTD	Ground	0.25	5.45	5.33	5.08
	PAcornSTD	Ground	0.25	5.21	5.14	4.99
	CAcornOP	Ground	0.25	3.11	3.03	2.9
	FLsweetcornOP	Ground	0.25	23.9	22.8	21.1
	NCcornWOP	Ground	0.25	4.96	4.87	4.69
	NDcornOP	Ground	0.25	4.81	4.76	4.66
	ORswcornOP	Ground	0.25	4.2	4.1	4.04
	TXcornOP	Ground	0.25	3.91	3.77	3.55
	STXcornNMC	Ground	0.25	7.28	7.03	6.57
	IAcornstd	Ground	0.25	4.99	4.82	4.5
	INCornStd	Ground	0.25	8.44	8.26	7.86
	KSCornStd	Ground	0.25	11.4	11.2	10.7
	MNCornStd	Ground	0.25	6.98	6.84	6.62
	NECornStd	Ground	0.25	11.1	10.8	10.2

Table 29. Estimated Environmental Concentrations from SWCC Modeling for the Atrazine Application Rate for Erodible Soils.

Crop	Scenario	Application Method	Application Rate (lb a.i./A)	1 in 10 year		
				Peak	21 day average	60 day average
Corn	ILCornSTD	Aerial	1.6	58.9	58	56.5
	MScornSTD	Aerial	1.6	79.6	77.8	73.7
	NCcornESTD	Aerial	1.6	24.8	24.2	23.1
	OHCornSTD	Aerial	1.6	42	41.1	39.2
	PAcornSTD	Aerial	1.6	40.9	40.3	39
	CAcornOP	Aerial	1.6	27.1	26.5	25.4
	FLsweetcornOP	Aerial	1.6	153	145	134
	NCcornWOP	Aerial	1.6	39	38.2	36.8
	NDcornOP	Aerial	1.6	40.5	40	39
	ORswcornOP	Aerial	1.6	35.4	34.5	32.9
	TXcornOP	Aerial	1.6	30.3	29.3	27.7
	STXcornNMC	Aerial	1.6	50	48.3	45.1
	IAcornstd	Aerial	1.6	39.6	38.3	35.8
	INCornStd	Aerial	1.6	60.5	59.4	56.6
	KSCornStd	Aerial	1.6	78.2	76.7	73.6
	MNCornStd	Aerial	1.6	53.5	52.4	50.7
	NECornStd	Aerial	1.6	77.2	75.1	71.1
	ILCornSTD	Ground	1.6	52	51	49.8
	MScornSTD	Ground	1.6	75.9	74.1	70.2

Crop	Scenario	Application Method	Application Rate (lb a.i./A)	1 in 10 year		
				Peak	21 day average	60 day average
	NCcornESTD	Ground	1.6	17.7	17.2	16.8
	OHCornSTD	Ground	1.6	34.9	34.1	32.5
	PAcornSTD	Ground	1.6	33.3	32.9	31.9
	CAcornOP	Ground	1.6	19.9	19.4	18.6
	FLsweetcornOP	Ground	1.6	153	146	135
	NCcornWOP	Ground	1.6	31.8	31.1	30
	NDcornOP	Ground	1.6	30.8	30.5	29.8
	ORswcornOP	Ground	1.6	26.9	26.3	25.9
	TXcornOP	Ground	1.6	25	24.2	22.7
	STXcornNMC	Ground	1.6	46.6	45	42
	IAcornstd	Ground	1.6	31.9	30.8	28.8
	INCornStd	Ground	1.6	54	52.8	50.3
	KSCornStd	Ground	1.6	72.7	71.4	68.5
	MNCornStd	Ground	1.6	44.7	43.8	42.4
	NECornStd	Ground	1.6	71.2	69.3	65.6

Table 30. Estimated Environmental Concentrations from SWCC Modeling for a 0.5 lb a.i./A Application Rate with Soil Incorporation at 2, 4, and 6 cm.

Crop	Scenario	Soil Incorporation Depth (cm)	Application Method	Application Rate (lbs/A)	1 in 10 year		
					Peak	21 day average	60 day average
Corn	ILCornSTD	2	Ground	0.5	18.5	18.2	17.7
	MScornSTD	2	Ground	0.5	27.1	26.4	25
	NCcornESTD	2	Ground	0.5	6.14	5.99	5.94
	OHCornSTD	2	Ground	0.5	12.3	12.1	11.5
	PAcornSTD	2	Ground	0.5	11.8	11.7	11.3
	CAcornOP	2	Ground	0.5	6.98	6.81	6.52
	FLsweetcornOP	2	Ground	0.5	54.7	52.1	48.2
	NCcornWOP	2	Ground	0.5	11.1	10.9	10.5
	NDcornOP	2	Ground	0.5	10.9	10.8	10.5
	ORswcornOP	2	Ground	0.5	9.47	9.24	9.13
	TXcornOP	2	Ground	0.5	8.84	8.53	8.03
	STXcornNMC	2	Ground	0.5	16.7	16.1	15
	IAcornstd	2	Ground	0.5	11.3	10.9	10.1
	INCornStd	2	Ground	0.5	19.2	18.8	17.9
	KSCornStd	2	Ground	0.5	26	25.5	24.4
	MNCornStd	2	Ground	0.5	15.8	15.5	15
	NECornStd	2	Ground	0.5	25.4	24.7	23.4
	ILCornSTD	4	Ground	0.5	9.76	9.59	9.35
	MScornSTD	4	Ground	0.5	13.9	13.6	12.9
	NCcornESTD	4	Ground	0.5	3.51	3.42	3.26
	OHCornSTD	4	Ground	0.5	6.64	6.49	6.19
	PAcornSTD	4	Ground	0.5	6.4	6.31	6.12
	CAcornOP	4	Ground	0.5	3.93	3.84	3.68
	FLsweetcornOP	4	Ground	0.5	27.7	26.4	24.4
	NCcornWOP	4	Ground	0.5	6.05	5.93	5.71

Crop	Scenario	Soil Incorporation Depth (cm)	Application Method	Application Rate (lbs/A)	1 in 10 year		
					Peak	21 day average	60 day average
	NDcornOP	4	Ground	0.5	6.04	5.98	5.84
	ORswcornOP	4	Ground	0.5	5.25	5.13	4.91
	TXcornOP	4	Ground	0.5	4.77	4.61	4.34
	STXcornNMC	4	Ground	0.5	8.63	8.33	7.78
	IAcornstd	4	Ground	0.5	6.13	5.92	5.52
	INCornStd	4	Ground	0.5	10.1	9.89	9.42
	KSCornStd	4	Ground	0.5	13.5	13.2	12.7
	MNCornStd	4	Ground	0.5	8.49	8.33	8.06
	NECornStd	4	Ground	0.5	13.2	12.8	12.1
	ILCornSTD	6	Ground	0.5	6.84	6.73	6.56
	MScornSTD	6	Ground	0.5	9.53	9.31	8.81
	NCcornESTD	6	Ground	0.5	2.63	2.56	2.45
	OHCornSTD	6	Ground	0.5	4.74	4.64	4.42
	PAcornSTD	6	Ground	0.5	4.59	4.52	4.39
	CAcornOP	6	Ground	0.5	2.92	2.86	2.74
	FLsweetcornOP	6	Ground	0.5	18.7	17.8	16.4
	NCcornWOP	6	Ground	0.5	4.35	4.26	4.1
	NDcornOP	6	Ground	0.5	4.43	4.38	4.28
	ORswcornOP	6	Ground	0.5	3.86	3.76	3.6
	TXcornOP	6	Ground	0.5	3.42	3.3	3.11
	STXcornNMC	6	Ground	0.5	5.95	5.74	5.36
	IAcornstd	6	Ground	0.5	4.42	4.27	3.99
	INCornStd	6	Ground	0.5	7.03	6.91	6.58
	KSCornStd	6	Ground	0.5	9.28	9.11	8.74
	MNCornStd	6	Ground	0.5	6.05	5.94	5.75
	NECornStd	6	Ground	0.5	9.12	8.88	8.4

7.3.2. Spatially Explicit - Tier III Aquatic Exposure Assessment using USGS Watershed Regressions for Pesticides (WARP)

With the passage of the Food Quality Protection Act (FQPA) in 1996, the USGS initiated development of regression models based on monitoring data to estimate distributions of pesticides at the drinking water locations (Larson and Gilliom, 2001). The regression modeling is based on the premise that pesticide concentrations found in drinking water are not randomly determined, but are in large part determined by the amount, method, and location of pesticide application, as well as by the physical characteristics of the watersheds in which the community water systems (CWS) are located and other environmental factors (such as rainfall) which cause the pesticide to move from the location where it was applied. These regression models are known as USGS Watershed Regression for Pesticides (WARP). The regression models were originally developed for corn herbicides such atrazine, simazine, metolachlor, etc. (Larson and Gilliom, 2001). In 2004, the USGS developed a national atrazine WARP model for estimating concentrations in streams (Larson, et al., 2004). Explanatory variables in the atrazine WARP

model are pesticide use intensity, rainfall and runoff factor (R factor) from the Universal Soil Loss Equation (USLE), K factor from the USLE, watershed area, and Dunne overland flow. In 2011, the USGS developed a regional atrazine WARP model for the Corn Belt. The explanatory variables in the WARP Corn Belt model are the percentage of agricultural land with a soil restrictive layer within 25 cm of the surface, total precipitation from May to June, percentage of streamflow from Hortonian overland flow, watershed area, percentage of the watershed with artificial drainage, and atrazine use intensity. The most important explanatory variable in the WARP models is the atrazine use intensity. For more information on the WARP model, the reader should refer to http://pubs.usgs.gov/of/2011/1141.

The EPA previously evaluated the USGS WARP models for predicting the organophosphate concentrations in drinking water (USEPA, 2000b). More recently, OPP used the atrazine WARP model as a watershed vulnerability tool to predict atrazine concentrations in small streams in the Corn Belt. WARP model predictions were used to rank watershed vulnerability among HUC12 watersheds in the Corn Belt for exceeding aquatic plant community CELOC for atrazine. These data were used to select a representative distribution of vulnerable monitoring sites for the atrazine ecological monitoring program (AEEMP) (USEPA 2007 and 2009). The AEEMP was a part of the data requirement imposed as a condition of reregistration for atrazine (http://www.epa.gov/pesticides/reregistration/atrazine/). Two objectives of the AEEMP were to (1) estimate the extent of watersheds in corn and sorghum areas with water bodies that exceed the atrazine CELOC for aquatic community effects, and (2) use watershed attributes to identify other watersheds where these higher atrazine exposure areas are likely to occur (USEPA 2003c). The 2009 FIFRA SAP encouraged the development of a “Corn Belt Watershed Regression for Pesticide (WARP) Model” and recommended considering additional data related to application (planting dates, timing of atrazine application), weather (rainfall intensity and duration), soils and hydrology (runoff propensity index, composite curve numbers, watershed geometry), and management (riparian buffers/setback areas, tillage, conservation practices, etc.).

This WARP modeling section provides an overview of OPP assessment of variables impacting the watershed vulnerability for atrazine runoff, WARP modeling methods, and a characterization of the WARP output.

7.3.2.1. ***Methods and Input Data for WARP***

The WARP model is a multiple regression statistical model that utilizes five input variables to predict pesticide concentrations: pesticide use rate (USEINTL), total May/June precipitation (PMAYJUN), percent Dunne overland flow (PERDUN), rainfall and runoff factor used in the Universal Soil Loss Equation (RFACTOR)), and the presence of a soil restrictive layer (SRL25) (Stone, et al. 2013). The equations from the WARP model are as follows:

4 day average concentration

$$Y=-3.34+1.19(USEINTL)^{1/4}+0.0131(SRL25)+0.0020(PMAYJUN)+0.5489*\log10(RFACTOR)-0.1088(PERDUN)$$

21-day average concentration

$$Y=-3.38+1.15(USEINTL)^{1/4}+0.0129(SRL25)+0.0021(PMAYJUN)+0.5499*\log10(RFACTOR)-0.1154(PERDUN)$$

60-day average concentration

$$Y=-3.44+1.11(USEINTL)^{1/4}+0.0130(SRL25)+0.0021(PMAYJUN)+0.5382*\log10(RFACTOR)-0.1215(PERDUN)$$

While the original model implementation summarized these input variables by a 1 km^2 grid, EPA has generated model inputs summarized at the level of a 12-digit subwatershed (HUC-12) in the USGS Watershed Boundary Dataset (WBD) with routines developed using the Python scripting language. The WARP model output provides an estimate of atrazine concentration in headwater HUC12s. It does not consider upstream contributions in flow-through HUC12s. Therefore, the WARP predictions of atrazine concentrations in flow-through HUC12s could underestimate the stream concentrations in flow-through HUC12s.

An array-based zonal histogram technique was developed by EFED in order to rapidly summarize all input datasets into more than 80,000 subwatersheds. Zonal boundaries (in this case, HUC-12 subwatersheds and counties) and input data layers are converted into overlapping 30 meter raster grids. Array math is used to summarize the overlap between zone and value grids into tabular histograms of the contents of each zone.

Zonal rasters were generated by converting vector GIS shapefiles of national WBD HUC-12 boundaries and county boundaries into 30 meter raster grids.

Raw input data and data layer development for GIS coverages are described below.

7.3.2.1.a. ***Potential Agricultural Application Area***

Spatially characterizing agricultural pesticide use within watersheds requires several primary datasets. These datasets and how they are manipulated were originally described by Nakagaki and Wolock (2005). These data include; tabular use data attributing a mass of active ingredient (AI) by county, land cover data, and watershed boundaries. By first choosing land cover classes

as a surrogate to represent the application area of an AI, a county's mass of AI can then be divided by the county's application area to calculate the county's application use intensity. The county's application rate is multiplied by the area of each pixel within the application area to attribute a pesticide use raster. The use raster can then be summarized by watershed boundary.

An important characterization in this process is choosing the appropriate land cover classes to represent application area. Nakagaki 2005 used the 1992 National Land Cover Dataset (NLCD). NLCD 92 contained several agricultural thematic classes, of which Nakagaki 2005 chose "row crops" (82), "small grains" (83), and "fallow" (84). Subsequent updates to the USGS WARP model's characterization of application area used updates to the NLCD, and its classes for "cultivated crops" (82) and "pasture/hay" (81) (**Figure 11**).

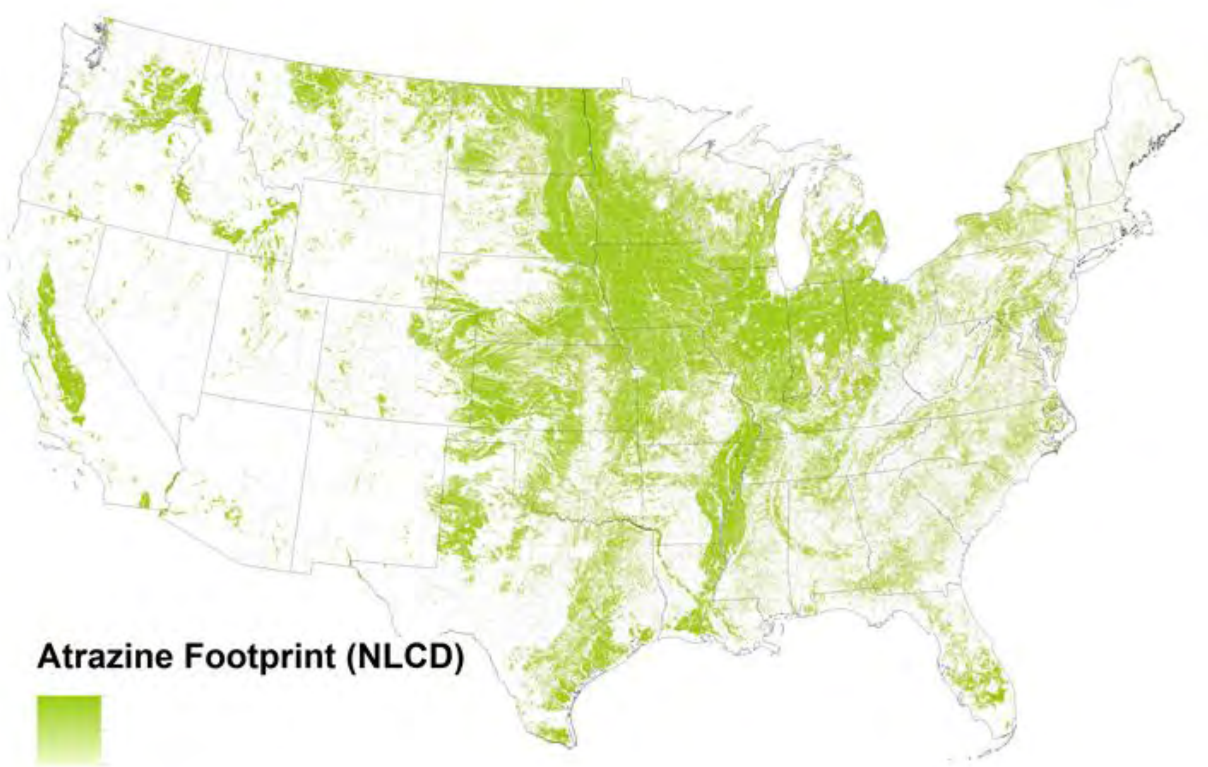


Figure 11. National Land Cover Dataset (NLCD) estimated agricultural layer for potential atrazine use sites for WARP.

EPA has adapted the Nakagaki 2005 method for characterizing application area by using the USDA Cropland Data Layer (CDL). The CDL is the best available land cover data to spatially characterize agricultural crops nationally. As with any land cover data, there will be errors

present. The accuracy of the CDL is well documented on a state by state basis. Essentially, major commodity crops have a more robust training and validation dataset than minor crops, and their accuracy values correspond accordingly. Several methods have been employed to minimize data errors within the CDL (**Appendix C**). EPA has also adapted the Nakagaki 2005 method by keeping the land cover data in its native 30 meter resolution throughout its processing.

EPA assessed the atrazine master label and cross-walked the use labels into the CDL general categories (**Appendix C**). Non-agricultural uses such as rangeland, conservation reserve program lands (CRP), Christmas tree plantations, conifer forests and turf were not reported in the tabular use data; therefore, EPA restricted the agricultural mask by including only those crop lands with the crops that were included in the use table (Thelin & Stone 2013). The general categories that atrazine use corresponded to include: “Corn”, “Vegetables and Ground Fruit”, “Other Grains”, “Wheat”, “Soybeans” (Kansas only), and “Pasture” (Tenessee only). EPA has selected these CDL categories and spatial limitations to represent the application area of atrazine (**Figure 12**). This application area raster is then used with county usage data for calculating application rate, followed by generating county based use rasters.

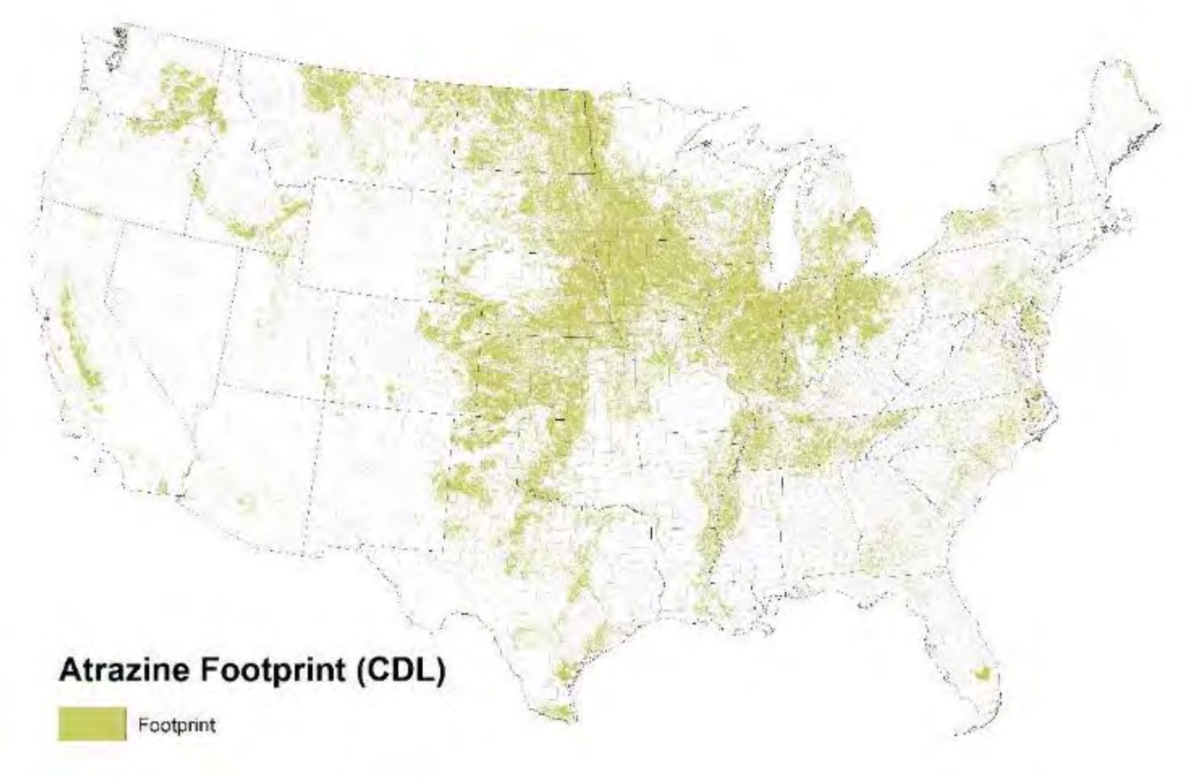


Figure 12. Cropland Data Layer (CDL) estimated agricultural layer for potential atrazine use sites for WARP.

7.3.2.1.b. ***Distribution of tabular use data***

Tabular pesticide use data containing the estimated mass of pesticide applied by county for each year and compound were acquired from the USGS[1]. These data were developed by USGS by combining proprietary surveys of agricultural pesticide use at the Department of Agriculture Crop Reporting District (CRD) scale, which include multiple counties, with the county level estimates of harvested acres collected by the U.S. Department of Agriculture National Agricultural Statistics Service (NASS) (Thelin & Stone 2013). The resulting estimated pesticide use rate (EPest-low) provides the estimated mass of pesticide used in the counties where use was reported in the CRD. The USGS methodology has introduced biases in the usage data, due to the use of harvested acres versus planted acres, the reliance on non-statistically valid sample sizes and the extent of extrapolation. Even so the biases are relatively minor for atrazine use on corn in the central Corn Belt for the following reasons:

- Sub-state proprietary surveys for atrazine usage for this crop are heavily sampled at the crop reporting district level, are conducted annually and at similar geospatial densities, thus have similar geospatial resolution and similar confidence in the use estimate across the primary growing regions of the crops, and
- The amount of estimation is relatively minor for corn.

The data reliability for other crops (e.g., sorghum, sugarcane, etc.) with atrazine usage is much less.

Two atrazine use geospatial footprints were developed by generating a binary footprint raster from the NLCD and CDL layers discussed above (**Figure 11** and **Figure 12**) and the EPest-low use estimates. Each use footprint was resampled to 30 meter resolution and overlaid on the county zonal raster, which provided a total use area for each county (**Figure 13,** Left Map). Pesticide mass for each county was divided by this use area to calculate a use density in kg/m^2. Estimated spatial distribution of pesticide use was developed by assigning each pixel in the use footprint a value equal to the area of the pixel in square meters multiplied by the county use density. These use pixels were then summed by HUC-12 subwatershed with the HUC-12 zonal raster, and normalized by the area of the HUC-12 in km^2 to provide a use rate for each HUC-12 in kg/km^2 (**Figure 13**, right map).

1 Stone, W.W., 2013, Estimated annual agricultural pesticide use for counties of the conterminous United States, 1992–2009: U.S. Geological Survey. http://pubs.usgs.gov/ds/752

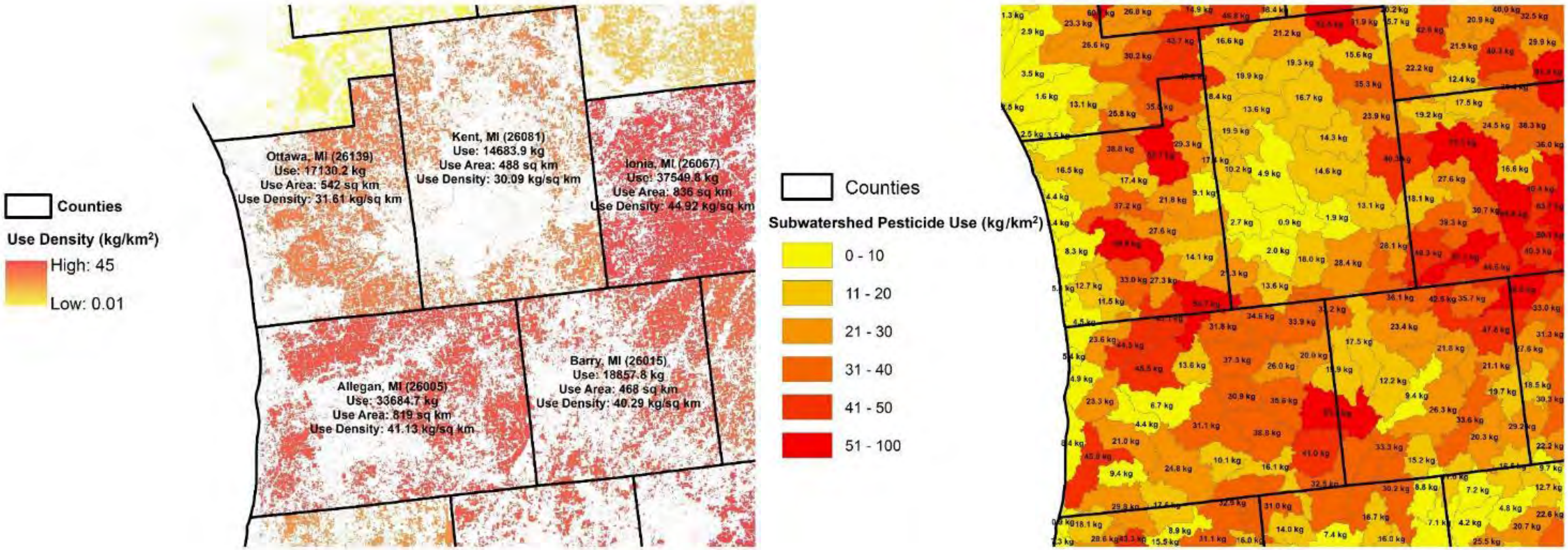


Figure 13. Example of HUC-12 watershed resolution of the atrazine inputs for WARP modeling. Estimated annual agricultural pesticide use for counties (Stone 2013) was used to estimate the total applied kg/km^2 for only those lands where the crop was expected to have been grown (in green on map to left). The map to the right illustrates how the county level use data is assumed to be distributed at the sub-county level by assuming it was applied only to those crops where atrazine is registered and for only those crops that the original survey data collected use information.

Climate data

A climate zone raster and tabular monthly precipitation measurements were acquired from NOAA[2]. The climate zone raster was resampled to 30 meters, and reclassified based on the tabular May and June precipitation measurements. Spatial averages were then calculated using the HUC-12 zonal raster.

All other data

Data for RFACTOR[3], SRL25[4], and PERDUN[5] were all distributed in raster format, and the only processing required for these layers was resampling to 30 meter resolution and the calculation of spatial averages with the HUC-12 zonal raster.

Prior to executing the WARP model, the input parameters from the more than 80,000 HUCs were filtered to limit WARP predictions to HUCs with input parameters within the range of the training data set for the WARP model. The range in explanatory variables to develop the WARP model are shown in **Table 31** (Stone, et al. 2013).

Table 31. Range of Explanatory Variables Used to Develop WARP

Explanatory Variable	Units	Range
USEINTL	Kg/Km^2	0-57.93
RFACTOR	Unitless	7.46-624.12
SR125	%	0-79.42
PERDUN	%	0-7.72
PMAYJUN	mm	0.52-481.08

Input data were written to a series of 10 comma-separated text files because a single file was found to be too computationally taxing. The WARP model distributed by USGS was modified slightly in order to automatically run through each of the 10 input files and generate an equal number of output files.

2 http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/offline/ftppage.html
3 Daly, C. and G.H. Taylor, 2002. United States Mean Annual R-Factor, 1971-2000.
PRISM Climate Group, Oregon State University, Corvallis Oregon.
ftp://ftp.nacse.org/pub/prism/maps/Precipitation/rfactor/U.S./us_rfactor_meta.html

4 http://water.usgs.gov/GIS/metadata/usgswrd/XML/ssurgo_srlag.xml
5 Wolock, D.M., 2003a. Saturation Overland Flow Estimated by TOPMODEL for the Conterminous United States. U.S. Geological Survey Open-File Report 03-264.

WARP outputs are programmatically concatenated and converted into a .dbf database file which can be easily read and manipulated in the ArcGIS software package for mapping and spatial analysis.

7.3.2.2. ***WARP Results***

Descriptive statistics for WARP modeling average EECs from 2006 to 2009 for state HUC12s are summarized in **Table 32**. The summary data represent descriptive statistics of EECs in HUC12s that including those that cross state boundaries. The WARP modeling was conducted using the Crop Data Layer (CDL) and the National Landcover Data (NLCD) to determine the use intensity of atrazine. A HUC12 was excluded from the description of WARP results if input parameters were beyond the limits of the validated WARP model (see discussion in **Section 7.3.2.1**). A distinction was made to identify the HUC12s that were excluded due to the predicted use rate exceeding the model limits as they would likely result in higher concentrations than the watersheds within the constraints of the model validation. This modeling approach was taken to address uncertainties associated with distribution of the crop areas among HUC-12s. The WARP results presented here are averages of the 4 years (2006-2009) of model run output for each HUC12, which differed year to year with the reported use data and weather. For the purposes of this exposure assessment using the WARP model, the predicted 4-day average concentration in lieu of the peak estimate is used to represent exposure endpoint for acute effects to aquatic animals and plants. This approach may not accurately capture the worst case scenario for peak values, and thus may not be conservative for acute toxicity comparisons. A complete compilation of the WARP modeling results and input files are available in **Appendix D**.

Concentrations estimated using the CDL or NLCD agricultural footprints result in the same estimated average concentrations for each state (**Table 32**); however, the number of watersheds exceeding a given threshold, probabilities for exceeding thresholds, and concentration estimates differ slightly at the HUC12 scale when comparing the model results (for comparison see **Section 17.1**).

The concentrations presented in **Table 32** represent the average of the maximum or mean concentrations estimated from individual modeled years 2006, 2007, 2008, and 2009. As expected, the highest EECs are associated with states with high corn and/or sorghum production and atrazine use (**Table 32**). The states include AR, IA, IL, IN, KS, KY, LA, MI, MO, MS, NE, OH and TX. Some states have locally high estimates and relatively low EECs for the remainder of the state. These anomalies may be partially explained by a high use of atrazine for a localized crop such as sugarcane production in Florida.

Table 32. Average CDL WARP Modeling EECs from 2006-2009.

State	Number of Included HUC12s	Number of Excluded HUC12s	Number of Excluded HUC12s Exceeding Maximum Use Rate	4-day Average		21-Day Average		60-Day Average	
				Mean	Maximum	Mean	Maximum	Mean	Maximum
				µg/L					
AL	1402	87	4	0.27	14.55	0.19	9.20	0.13	5.48
AR	1507	47	3	0.58	68.04	0.41	44.68	0.26	27.48
AZ	2585	703	0	0.01	0.57	0.01	0.44	0.00	0.31
CA	2486	1984	0	0.01	0.52	0.01	0.42	0.01	0.32
CO	3022	140	0	0.30	18.10	0.23	12.92	0.16	8.89
CT	182	0	0	0.11	1.65	0.09	1.16	0.06	0.73
DC	6	0	0	0.09	0.18	0.07	0.14	0.05	0.10
DE	87	14	11	1.00	3.93	0.70	2.72	0.44	1.69
FL	885	463	6	0.10	19.00	0.07	12.94	0.05	7.80
GA	1741	122	0	0.10	1.72	0.08	1.20	0.05	0.77
IA	1637	77	28	6.34	60.40	4.47	41.73	2.86	26.85
ID	2196	376	0	0.00	0.11	0.00	0.09	0.00	0.07
IL	1557	318	312	7.45	85.28	5.16	56.35	3.24	35.51
IN	1323	256	253	4.34	34.19	3.00	22.55	1.88	13.83
KS	2043	14	9	3.80	63.10	2.75	43.71	1.82	28.50
KY	1213	76	64	1.08	43.87	0.76	28.88	0.49	17.91
LA	845	425	28	1.64	63.25	1.11	39.63	0.69	23.88
MA	241	7	7	0.08	2.01	0.07	1.45	0.05	0.93
MD	383	18	12	0.88	12.36	0.63	8.41	0.40	5.24
ME	1028	20	1	0.02	1.66	0.02	1.13	0.01	0.70
MI	1792	46	10	0.62	34.36	0.45	23.63	0.30	15.42
MN	2424	57	0	0.46	11.40	0.34	8.26	0.23	5.65
MO	1921	82	54	4.57	84.78	3.23	56.17	2.10	35.26
MS	1177	178	31	0.67	23.39	0.46	15.22	0.29	9.44
MT	4013	212	0	0.02	0.38	0.02	0.31	0.01	0.24
NC	1665	105	3	0.44	9.02	0.32	6.14	0.21	3.89
ND	1890	24	0	0.12	4.15	0.09	3.06	0.07	2.14
NE	2005	90	70	3.18	97.89	2.21	65.90	1.41	42.18
NH	332	2	0	0.04	0.26	0.04	0.20	0.03	0.14
NJ	273	3	0	0.19	2.93	0.14	2.12	0.10	1.39
NM	3086	96	0	0.06	11.26	0.05	8.07	0.04	5.47
NV	1713	850	0	0.00	0.03	0.00	0.02	0.00	0.02
NY	1609	53	43	0.30	7.54	0.22	5.01	0.15	3.17
OH	1480	70	35	3.90	55.46	2.72	36.99	1.75	23.54
OK	2026	49	6	0.32	16.31	0.25	11.85	0.18	8.19
OR	2518	612	0	0.01	0.43	0.01	0.32	0.01	0.23
PA	1468	6	2	0.56	12.36	0.41	8.41	0.27	5.24
RI	55	0	0	0.08	1.59	0.07	1.11	0.04	0.69
SC	969	6	3	0.33	5.97	0.24	4.02	0.16	2.45
SD	2152	268	0	0.34	6.52	0.27	4.91	0.19	3.50

State	Number of Included HUC12s	Number of Excluded HUC12s	Number of Excluded HUC12s Exceeding Maximum Use Rate	4-day Average		21-Day Average		60-Day Average	
				Mean	Maximum	Mean	Maximum	Mean	Maximum
				µg/L					
TN	1107	21	15	0.53	13.24	0.38	8.59	0.24	5.21
TX	5513	809	26	0.76	50.85	0.57	35.25	0.40	23.00
UT	1901	673	0	0.01	0.36	0.01	0.28	0.01	0.21
VA	1219	33	17	0.31	8.78	0.23	5.78	0.15	3.46
VT	258	6	0	0.18	7.54	0.14	5.01	0.10	3.17
WA	1560	435	3	0.01	1.12	0.01	0.72	0.01	0.43
WI	1778	28	1	0.59	7.96	0.44	5.63	0.30	3.60
WV	748	2	2	0.10	5.78	0.08	3.94	0.06	2.45
WY	2112	289	0	0.01	0.63	0.01	0.48	0.01	0.34

A geographic depiction of the summarized 4-year CDL results for the maximum 4-day average, maximum 21-day average, and maximum 60-day average atrazine EECs are shown in **Figure 14**, **Figure 15**, and **Figure 16**. These figures clearly illustrate that the midwestern Corn Belt is the focal point for high EECs for atrazine, and identify other regions of the country that have elevated concentrations. These modeling predictions are directly correlated to the high atrazine use in these regions of country.

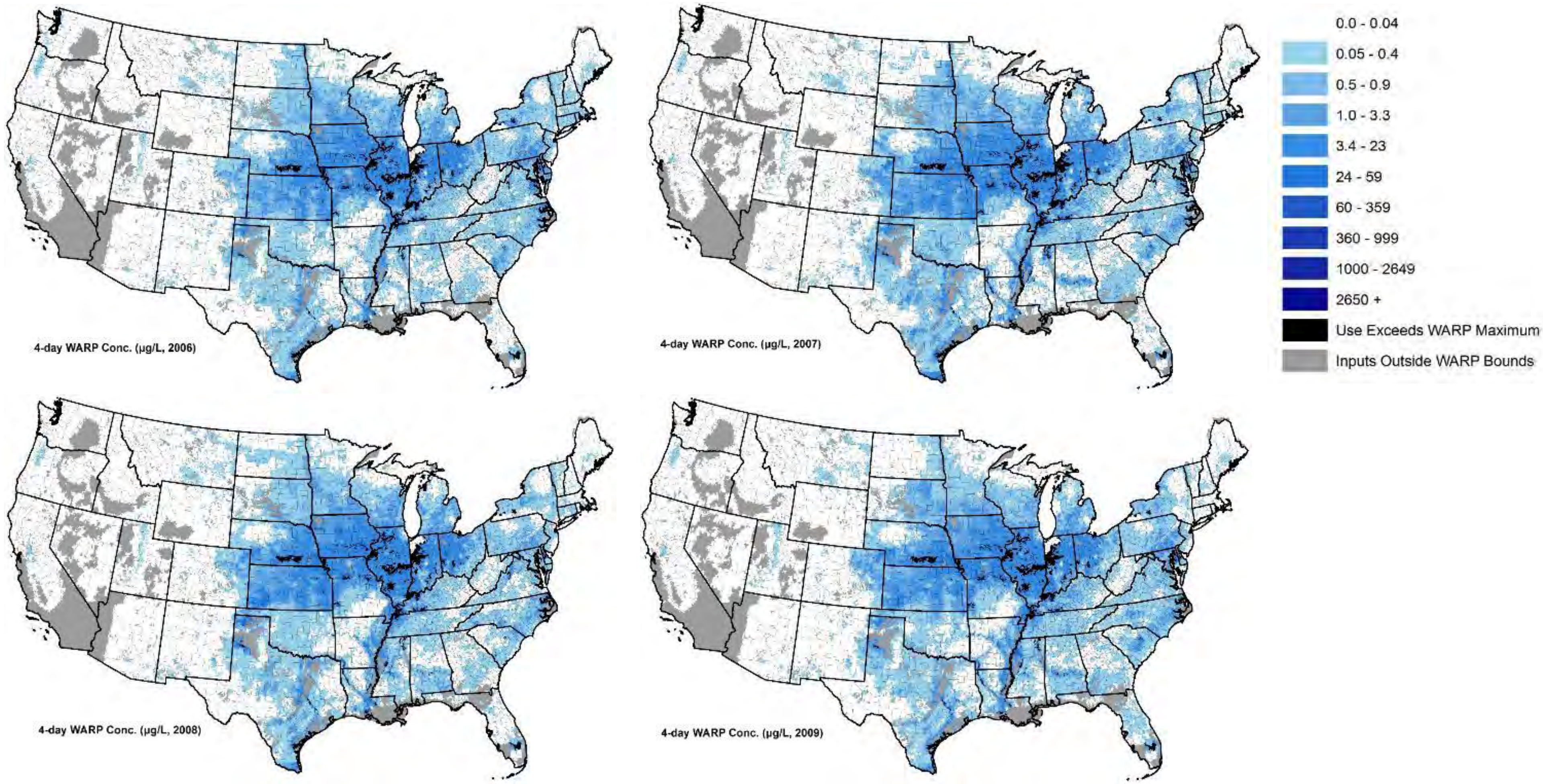


Figure 14. Results from 2006 – 2009 WARP modeling were summarized within HUC12s by averaging the predicted maximum average 4-day atrazine concentration for each HUC12.

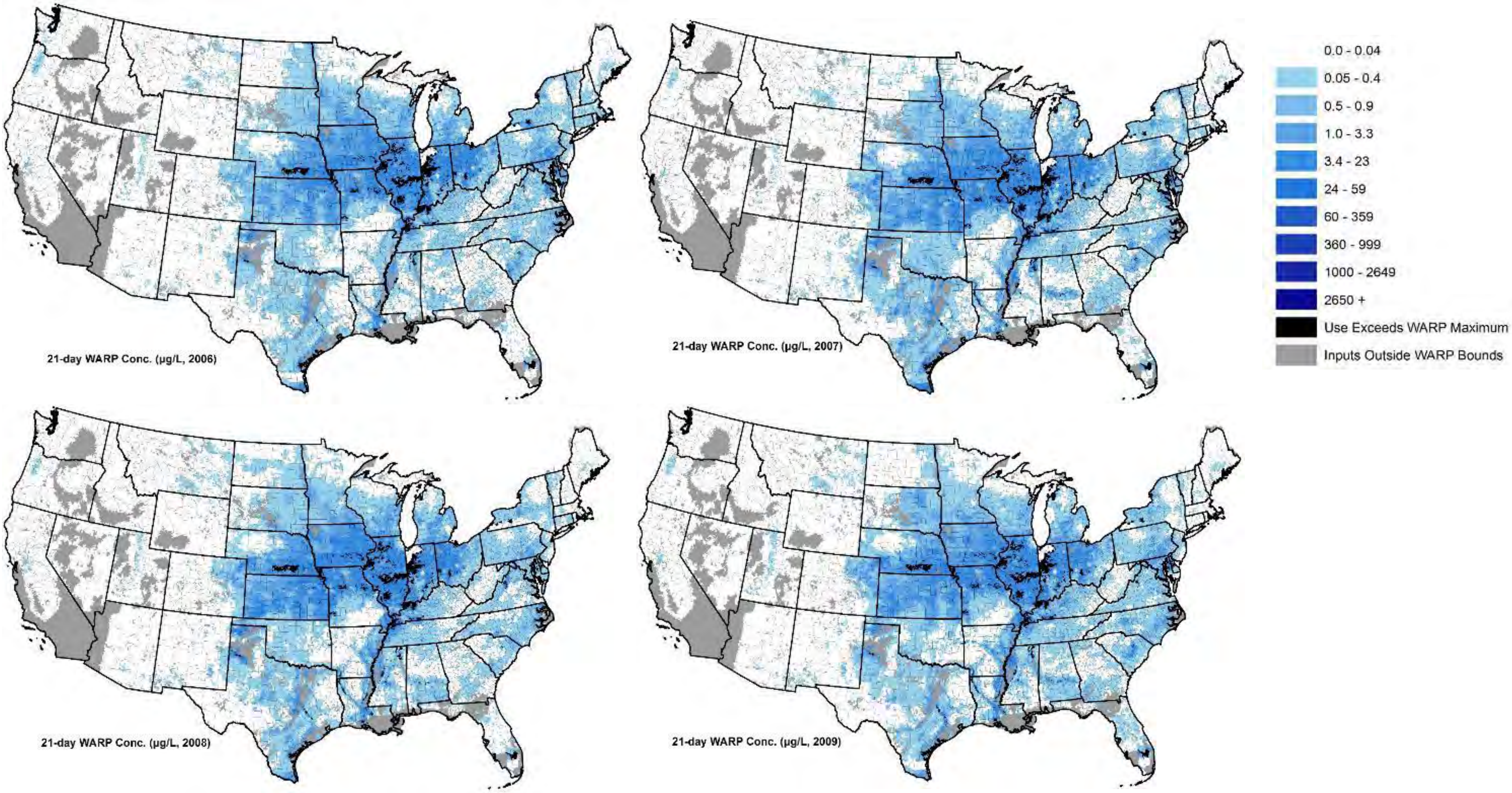


Figure 15. Results from 2006 – 2009 WARP modeling were summarized within HUC12s by averaging the predicted maximum average 21-day atrazine concentration for each HUC12.

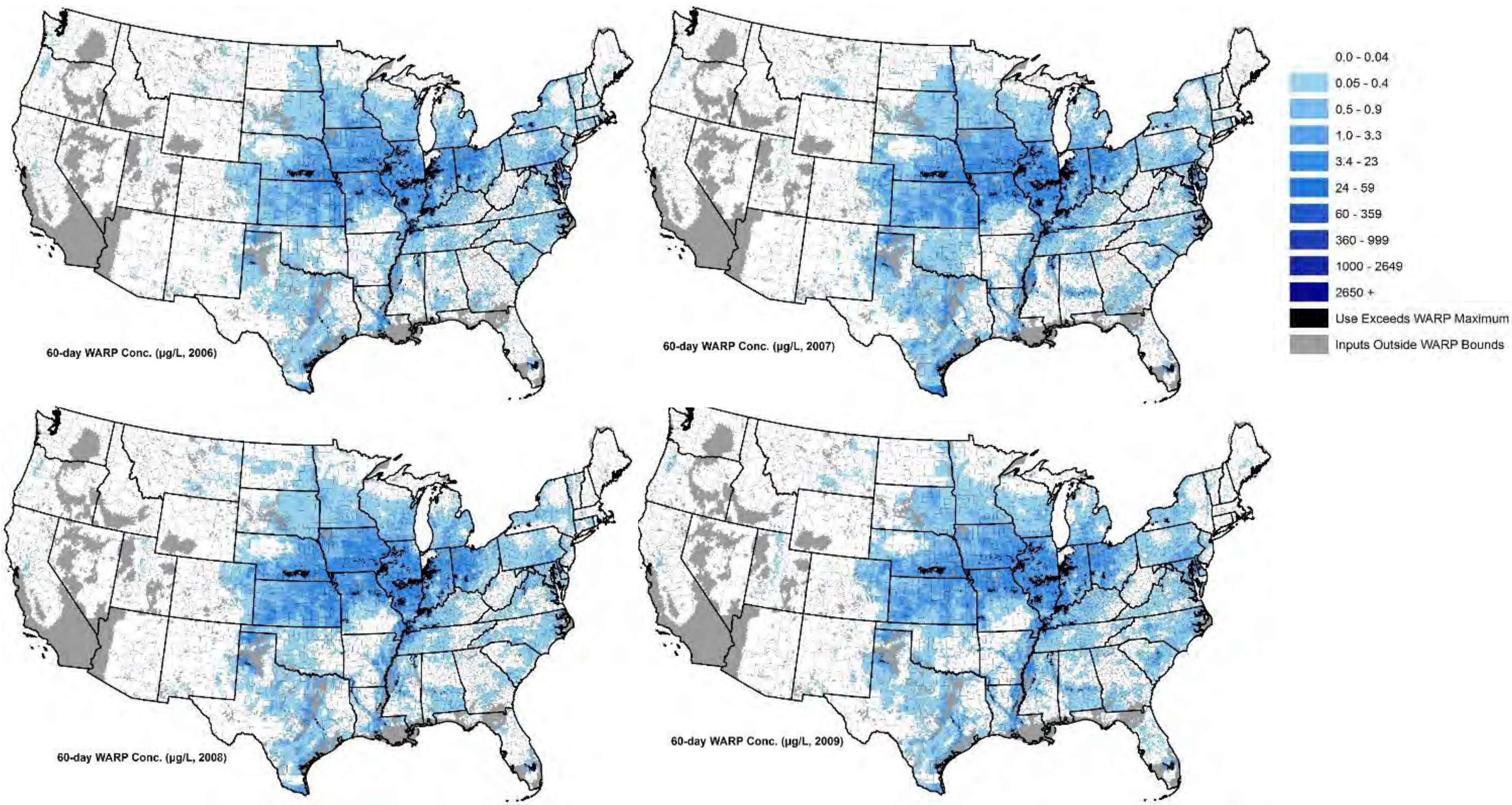


Figure 16. Results from 2006 – 2009 WARP modeling were summarized within HUC12s by averaging the predicted maximum average 60-day atrazine concentration for each HUC12.

7.4. Water Monitoring Data

7.4.1. Accounting for Uncertainty in Quantifying Atrazine Concentrations from Monitoring Data to Assess Potential Effects to Aquatic Animals and Aquatic Plant Communities

The vast majority of pesticide monitoring data in the United States have limited sampling frequencies due to the cost associated with sampling and analysis. Additionally, pesticide use, as well as hydrologic patterns, is spatially and temporally variable. The net effect is a complex set of variables controlling pesticide occurrence in surface water. Because there is uncertainty in determining the exact pesticide occurrence pattern in any specific watershed, there is an inherent bias to underestimate actual pesticide concentrations because of the inability to capture peak or upper-bound concentrations through monitoring.

The surface water monitoring data available for atrazine is often considered the most robust set of pesticide monitoring data available in the United States, and there have been several FIFRA SAP meetings discussing the uncertainty in deriving human health and ecological exposure atrazine concentrations from the monitoring data (USEPA 2010, USEPA 2011 and USEPA 2012). These SAPs have vetted different statistical approaches to account for uncertainty due to low sampling frequency, including the use of bias factors and kriging/ sequential stochastic simulation. The SAP recommended that OPP consider using sampling bias factors (BF), as well as SEAWAVEQ (a regression model developed by USGS), for a quantitative estimate of uncertainty in the atrazine monitoring data. This section provides an analysis of sampling bias factors derived from the Atrazine Ecological Exposure Monitoring Program (AEEMP), Atrazine Monitoring Program (AMP), and National Center for Water Quality Research (NCWQR) monitoring programs.

The 2012 FIFRA Scientific Advisory Panel recommended that development and implementation of sampling bias factors should consider the following issues:

- Bias factors should consider different watershed characteristics
- Development of bias factors should be representative of watersheds with atrazine use.
- Bias factors should be based on an adequate number of site-years
- Bias factors should represent different sampling intervals
- Bias factors should be developed to account for different sampling strategies (stratified, stratified random, systematic, random)
- Bias factors should be developed on robust monitoring data
- Bias factors should be developed for different hydrological conditions
- Bias factors should provide a specific exposure endpoint with known statistical confidence in magnitude and frequency

The BF serves as a protective multiplier of the actual concentration from monitoring data to account for uncertainty associated with sampling frequency. The general bias factor equation is as follows:

$$\hat{Y}=X*\text{Bias Factor}$$

Where:

$\hat{Y}$ = Estimated atrazine concentration
X= Atrazine concentration obtained from monitoring data
Bias Factor=True atrazine conc./Estimated 5th percentile atrazine concentration estimated from 10,000 simulated chemographs

The statistical implication of the bias factor is that 95% of the time the bias factor adjusted atrazine concentration will be equal to or greater than the true value in the monitoring data.

7.4.1.1. *Bias factor development*

The development of bias factors is based on selected monitoring data from the AEEMP, AMP, and NCWQR monitoring programs. These monitoring data were selected because they have high sampling frequency, are representative of different watershed properties, and have a high number of site-years to provide a reliable representation of variability for climate, agronomic practices, and atrazine use rates (**Table 33**).

Table 33. Criteria for Selection of Monitoring Data Used for Bias Factor Development

Monitoring Program	Factors Considered in Selection Monitoring Data for BF Development					
	Shortest Sampling Interval	Seasonal Sampling	Number of Years	Site Years	Watershed Size	Surface Water Classification
AEEMP	Daily	April-September	6	135	Small	Streams
AMP	7 days	January-December	12	320	Medium to Large	Rivers, Reservoirs, Lakes
NCWQR	Daily	January-December	22	130	Large	Rivers

Using these criteria, monitoring data selected for bias factor development consider the 2009-2014 AEEMP monitoring data because there are adequate site-years (135) in ten states and the sample frequency is daily during the high runoff period (April-September). The AMP data is selected to account for different hydrologic conditions such as rivers or static water bodies.

The AMP data used for bias factor estimation is representative of twelve states. An uncertainty in the AMP monitoring data is that the sampling is conducted using a fixed 7 day sampling interval and, therefore, data in-filling is required to develop daily chemographs. Furthermore, the data infilling method does not take into account that concentration between measurement dates may be greater than what was measured on either bracketing date. This means that bias factors developed with 7-day sampling intervals are still likely to underestimate daily concentrations. The NCWQR data are representative of large rivers in Ohio. The NCWQR monitoring data has high sampling frequency (daily) for multiple years. The data used to develop bias factors are shown in **Appendix E**. Descriptive statistics of the monitoring data used to develop the bias factor regression equations are shown in **Table 34** and **Table 35** and **Table 36**.

Table 34. Descriptive Statistics of AMP Data Used for Bias Factor Development

Waterbody Type	Statistic	Atrazine Concentration (µg/L)							
		Daily	4 day[a]	7 day	14 day	21 day	28 day	60 day	90 day
Static	Min	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00
	Q25	0.96	0.95	0.93	0.90	0.87	0.82	0.70	0.61
	Q50	2.16	2.16	2.11	1.95	1.82	1.75	1.52	1.37
	Q75	4.62	4.57	4.48	3.81	3.44	3.12	2.71	2.39
	Max	44.92	44.92	44.92	39.46	35.15	30.88	17.59	13.30
	Average	4.09	4.05	4.01	3.45	3.06	2.82	2.16	1.80
	Count	386.00	386.00	386.00	386.00	386.00	386.00	386.00	386.00
Flowing	Min	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00
	Q25	2.19	2.19	2.19	1.84	1.61	1.46	1.12	0.95
	Q50	4.76	4.71	4.60	3.63	3.10	2.77	2.06	1.75
	Q75	10.99	10.99	10.77	8.05	6.41	5.86	4.02	3.10
	Max	57.98	57.98	57.98	35.65	25.76	23.07	18.23	17.42
	Average	7.72	7.65	7.53	5.71	4.70	4.20	2.87	2.23
	Count	322.00	322.00	322.00	322.00	322.00	322.00	322.00	322.00

[a] **Maximum average concentration over specific interval of time (4, 7, 14, 21, 28, 60, 90 days)**

Table 35. Descriptive Statistics of AEEMP Data Used for Bias Factor Development

Waterbody Type	Statistic	Atrazine Concentration (µg/L)							
		Daily	4 day[a]	7 day	14 day	21 day	28 day	60 day	90 day
Flowing	Min	0.08	0.0725	0.07	0.069286	0.067619	0.065714	0	0
	Q25	18.06	11.85	8.86	6.55	5.49	5.00	3.31	2.26
	Q50	38.25	23.72	18.64	13.53	10.63	9.01	5.90	4.12
	Q75	64.64	41.04	33.05	22.69	18.69	15.19	9.64	6.98
	Max	344.26	336.58	312.86	270.13	233.58	189.14	90.83	61.01
	Average	51.47	34.68	27.96	20.25	16.14	13.43	8.01	5.67
	Count	128.00	128.00	128.00	128.00	128.00	128.00	128.00	128.00

[a] **Maximum average concentration over specific interval of time (4, 7, 14, 21, 28, 60, 90 days)**

Table 36. Descriptive Statistics of NCWQR Data Used for Bias Factor Development

Waterbody Type	Statistic	Atrazine Concentration (µg/L)							
		Daily	4 day[a]	7 day	14 day	21 day	28 day	60 day	90 day
Flowing	Min	0.407	0.407	0.407	0.2895	0.240333	0.22275	0.146183	0.112711
	Q25	4.365	4.211438	3.876714	3.615	3.300274	2.975518	2.093825	1.469175
	Q50	13.734	10.90475	10.07679	8.836179	7.710119	6.652357	4.914033	3.698139
	Q75	22.355	18.58438	16.99464	13.59773	12.1325	10.82275	7.055433	5.381542
	Max	54.382	52.29075	37.635	29.35579	22.28205	19.57739	12.78117	9.156211
	Average	16.00414	13.62493	11.9005	9.29725	7.976412	7.195239	4.75412	3.553715
	Count	64	64	64	64	64	64	64	64

[a] **Maximum average concentration over specific interval of time (4, 7, 14, 21, 28, 60, 90 days)**

7.4.1.2. *Derivation of Bias Factors*

Bias factors (BFs) for stratified random sampling are derived using a Monte Carlo sub-sampling process as presented to the 2011 FIFRA SAP (FIFRA SAP, 2011). A similar approach is used by Syngenta to develop bias factors from AEEMP and NCWQR data in Mosquin *et al*. 2011. Although the FIFRA SAP and public comments recommend development of bias factors for other sampling strategies, the methods for development have not been fully developed to provide reasonable confidence in the BF estimation process. Therefore, this assessment employs only the stratified random sampling strategy as presented to the 2012 SAP.

For stratified random sampling, each constructed chemograph was randomly subsampled 10,000 times using subsampling intervals of 4 days, 7 days, 14 days, and 28 days. The sampling simulation was conducted using the Crystal Ball software programs (Crystal Ball® 2000 and Crystal Ball Predictor™, 1999) starting with a random seed. For each sampling realization, a

random value from the custom distribution of values within the designated time interval was selected to represent a value at each sampling interval within the chemograph. These selected concentrations were then used to construct simulated daily chemographs of atrazine concentrations using a linear interpolation. From a distribution of the 10,000 simulated chemographs, the 5th percentile maximum daily, 4 day average, 7 day average, 14 day average, 21 day average, 28 day average, 60 day average, and 90 day average atrazine concentrations were selected to derive the bias factors. Selection of the 5th percentile exposure atrazine concentration would provide development of conservative bias factors. The bias factor was calculated by dividing the true maximum value from the original chemograph by the 5th percentile maximum exposure atrazine concentration from the Monte Carlo simulation.
Bias factors were derived from selected monitoring data for AMP static waterbodies. Descriptive statistics for bias factors used in the development of regression models are shown in **Table 37** and **Table 38**. The data used to develop the linear regression equations for estimation of bias factors are shown **Appendix E**.

Table 37. Descriptive Statistics of BF in AMP Static Waterbodies

Sampling Interval	Statistic	BF for Static Waterbodies			BF for Flowing Waterbodies		
		Daily	21 day	60 day	Daily	21 day	60 day
7 day	Min	0.83	0.83	0.83	1.00	0.71	0.75
	Q25	1.00	1.02	1.01	1.00	1.04	1.03
	Q50	1.00	1.04	1.04	1.00	1.09	1.08
	Q75	1.05	1.11	1.08	1.25	1.24	1.22
	Max	2.65	2.15	1.64	9.37	3.76	2.78
	Average	1.07	1.08	1.06	1.35	1.23	1.17
	Count	386.00	386.00	381.00	322.00	322.00	319.00
14 day	Min	0.83	0.83	0.83	1.00	0.47	0.54
	Q25	1.05	1.06	1.05	1.20	1.22	1.21
	Q50	1.20	1.15	1.12	1.74	1.51	1.48
	Q75	1.51	1.33	1.24	3.13	2.17	1.89
	Max	6.62	4.01	2.47	16.29	7.08	5.18
	Average	1.46	1.27	1.20	2.68	1.92	1.67
	Count	386.00	386.00	381.00	322.00	322.00	319.00
21 day	Min	0.83	0.83	0.83	1.00	0.56	0.74
	Q25	1.17	1.12	1.11	1.64	1.40	1.34
	Q50	1.39	1.26	1.21	2.84	2.14	1.87
	Q75	1.77	1.51	1.39	5.29	3.30	2.62
	Max	28.86	17.58	7.29	29.73	21.97	12.88
	Average	1.89	1.54	1.36	4.29	2.79	2.17
	Count	386.00	386.00	381.00	322.00	322.00	319.00

Sampling Interval	Statistic	BF for Static Waterbodies			BF for Flowing Waterbodies		
		Daily	21 day	60 day	Daily	21 day	60 day
28 day	Min	0.83	0.74	0.83	1.00	0.30	0.34
	Q25	1.22	1.15	1.14	1.93	1.68	1.48
	Q50	1.50	1.33	1.26	3.73	2.57	2.15
	Q75	2.00	1.66	1.48	7.31	4.60	3.34
	Max	29.34	18.18	9.23	115.67	45.51	17.25
	Average	2.20	1.78	1.51	5.92	3.67	2.66
	Count	386.00	386.00	381.00	322.00	322.00	319.00

Table 38. Descriptive Statistics of BF in the AEEMP and NCWQR

Sampling Interval	Statistic	BF for AEEMP			BF for NCWQR		
		Daily	21 day	60 day	Daily	21 day	60 day
4	Min	1.00	1.00	0.97	0.99	1.00	1.06
	Q25	1.78	1.31	1.25	1.00	1.13	1.11
	Q50	2.62	1.45	1.38	1.26	1.21	1.14
	Q75	3.55	1.77	1.52	1.50	1.30	1.24
	Max	14.50	3.43	2.76	16.28	2.72	2.85
	Average	3.05	1.61	1.45	1.58	1.26	1.21
	Count	128.00	128.00	127.00	64.00	64.00	64.00
7	Min	1.14	1.06	0.97	0.99	1.00	0.97
	Q25	2.93	1.54	1.50	1.00	1.09	1.11
	Q50	4.34	1.89	1.71	1.53	1.26	1.22
	Q75	6.39	2.55	2.04	2.08	1.54	1.41
	Max	43.73	9.71	6.91	17.25	3.80	3.75
	Average	5.80	2.24	1.89	2.00	1.39	1.32
	Count	128.00	128.00	127.00	64.00	64.00	64.00
14	Min	1.17	1.10	1.21	1.09	1.09	1.17
	Q25	5.16	2.13	1.97	1.77	1.47	1.36
	Q50	9.28	3.14	2.64	2.60	1.82	1.62
	Q75	14.95	4.70	3.69	4.42	2.38	2.03
	Max	109.80	23.17	11.71	39.35	5.38	5.49
	Average	13.31	4.00	2.99	4.00	2.15	1.88
	Count	128.00	128.00	127.00	64.00	64.00	64.00
21	Min	1.18	1.10	1.21	1.09	1.32	1.19
	Q25	9.45	3.46	2.78	2.62	1.71	1.55
	Q50	15.72	5.37	3.88	3.93	2.61	2.01
	Q75	25.19	8.10	5.37	7.23	3.85	3.03
	Max	142.29	31.31	17.95	94.26	10.65	11.26
	Average	21.92	6.68	4.48	6.79	3.14	2.56
	Count	128.00	128.00	127.00	64.00	64.00	64.00
28	Min	1.17	1.09	1.37	1.46	1.23	0.98
	Q25	13.00	4.58	3.30	3.02	2.00	1.82
	Q50	22.38	6.63	4.92	5.22	3.40	2.60
	Q75	37.55	11.74	7.14	10.59	6.10	4.02
	Max	277.00	60.56	27.90	135.11	21.93	16.46
	Average	31.32	9.06	5.64	10.23	4.64	3.64
	Count	128.00	128.00	127.00	64.00	64.00	64.00

7.4.1.3. *Estimation of Bias Factors for Other Monitoring Data*

As presented in the 2012 FIFRA SAP, the estimate of bias factors for various monitoring data requires understanding the sampling strategy, sampling frequency, watershed characteristics, hydrology, and atrazine use. These factors were highlighted in both FIFRA SAP comments and public comments on the atrazine problem formulation for the development and use of bias factors in quantifying the uncertainty in atrazine occurrence data. The objective of the BF estimation process is to provide a linear regression equation to estimate bias factors for different atrazine monitoring data with specific attributes.

The selection of the appropriate linear regression equation for BF estimation will be determined according to the characteristics of hydrology, watershed area, and location (**Table 39**). For this assessment, four sets of regression equations are being developed to account for unique watershed characteristics for monitoring sites in the AEEMP, AMP, and NCWQR monitoring programs.

Table 39. Factors Considered for Selection of Bias Factor Regression Equations

Monitoring Regression	Stream Order	Waterbody Type (Flowing/Static)	Watershed Area (Km^2)	States
AEEMP	≤ 3rd	Flowing	23-253	IA, IL, IN, KS, KY, LA, MN, MO, NE, OH, TN, TX
AMP1	3rd to 7th	Flowing	0.82-2,955,814	IA, IL, IN, KS, KY, LA, MO, OH, TX
AMP2	NA	Static	1-1,242,000	IA, IL, IN, KS, KY, LA, MN, MO, NE, OH, TN, TX
NCWQR		Flowing	1,777-16,395	OH

Least squares linear regression equations were determined using the EXCEL 2013. The regressions were conducted using sample interval as the independent variable and log10 transformed bias factor as the dependent variable. The log transformation of bias factor reduces any trend in the regression equation residuals. Regression equations were developed for the daily peak, 21 day average, and 60 day average exposure period (**Table 40**).

Table 40. Linear Regression Equations for BF Estimation from a Stratified Random Sampling Design

Monitoring Program	Regression Models				
	Exposure Estimate	Regression Equation[2]	R^2	F-test Probability Regression	Limitations[1]
AEEMP (Flowing)	Peak	0.354485 +0.03741X	0.47	<0.05	See table footnote
	21-day	0.112909+0.027481X	0.51	<0.05	
	60-day	0.093328+0.022318X	0.54	<0.05	
AMP1 (Flowing)	Peak	-0.0478+0.023998X	0.28	<0.05	≥ 7 day sampling interval ; See table footnote
	21-day	-0.03154+0.017807X	0.28	<0.05	
	60-day	-0.0196+0.014011X	0.29	<0.05	
AMP2 (Static)	Peak	-0.0345+0.015095X	0.18	<0.05	≥ 7 day sampling interval; See table footnote
	21-day	-0.01638+0.007425X	0.15	<0.05	
	60-day	-0.01084+0.005603X	0.17	<0.05	
NCWQR (Flowing)	Peak	0.039677+0.02764X	0.40	<0.05	See table footnote
	21-day	0.004501+0.01996X	0.46	<0.05	
	60-day	0.006318+0.01642X	0.50	<0.05	

1-**Regression models should be selected according the factors in Table 41. State location, watershed size, hydrology should correspond within the range of the data used to develop the regression model.**
2-Regression equations represent slopes of the relationship of log BF *vs* sampling interval (days); the X is the independent variable (sampling interval in days) in the regression equation where log BF= slope*sampling interval+intercept.

Selection of the proper regression model should be based on the watershed factors listed in **Table 39**. Although comprehensive ancillary data may not be available for all monitoring data, key factors should include the waterbody type (static vs flowing), state location, and the watershed size. Other important factors such as average flow and the atrazine use in the watershed should also be considered. The key factors should be within the range of the data used to develop a specific regression equation. Additionally, the BF equations should not be calculated for monitoring data with greater than a 28 day-sample interval. The predicted log BF from the regression equations requires antilog transformation ($10^{\wedge(logBF)}$) to estimate the BF. The statistical interpretation of the predicted BF is that 95% of time the median BF will provide an estimated concentration equal to or higher than the true concentration. Because the monitoring data used to generate the regression equations are derived from monitoring programs with different numbers of years, interpretation of return frequency cannot be consistently calculated among the monitoring programs. Additionally, the data used in the development of bias factors is associated with multiple sites which further complicates interpretation of the return frequency.

The coefficient of determination for the regression equations varied among the monitoring programs. Sampling frequency only accounted for 47 to 54% of BF variation for the AEEMP, 28 to 29% BF variation for AMP (flowing), 15 to 18% of BF variation in the AMP (static), and 40% to 50% BF variation for NCWCR. Although the regression equations are statistically significant (P<0.05), the coefficient of determination statistic implies that variables other than sampling frequency are important in estimation of BF. Further analysis is needed to assess the impact of other variables in altering the bias factors.

7.4.1.4. *Uncertainties, Assumptions, and Limitations*

Some uncertainties, limitations, and assumption in the development and application of the bias factor in this analysis are:

- The extent of data infilling for the development of an annual chemograph is expected to impact the reliability of the bias factor estimation. In this analysis, the AMP and NCWQR monitoring data required data infilling to provide daily chemographs. The data infilling process is expected to dampen the variability in the daily pesticide concentrations and, therefore, it should reduce the variability in bias factors.
- The development of linear regression models for estimation of BF requires an assumption of no dependence of BF among sampling intervals. This independence assumption may not be valid because each site-year BF for the peak, 21-day average, and 60 day average are determined from a distribution of 10,000 Monte Carlo simulated time series from a common time series of monitoring data. Although the Monte Carlo simulation of sampling is expected to remove some of the dependence of the BF among sampling intervals, the interaction of autocorrelation and sample interval are expected to control the dependence of BF among sampling windows. A time series with low autocorrelation of daily samples is expected to exhibit less dependence of the BF among sampling intervals. In contrast, a time series with high autocorrelation is expected to exhibit more dependence of BF among a shorter sampling intervals. Semi-variogram analysis of atrazine monitoring data indicate high autocorrelation at time lags of 4 to 28 days (FIFRA SAP 2011 and 2010).

7.4.2. Surface Water Monitoring

The surface water monitoring data available for atrazine is often considered the most robust set of pesticide monitoring data available in the United States. Monitoring data for atrazine occurrence in surface water were obtained from USGS National Water Information System (NWIS), EPA Storage and Retrieval Warehouse (STORET), and USGS National Water Quality Assessment (NAWQA). Additionally, monitoring data were obtained from California Department of Pesticide Regulation (CalDPR), Syngenta's Atrazine Monitoring Program (AMP), Syngenta's Atrazine Ecological Exposure Monitoring Program (AEEMP), Oregon ELEM

(ORELEM), Oregon LASAR (OR LASAR), Kansas Department of Health and Environment (KDHE), Montana Department of Agriculture (MTDA), Minnesota Department of Agriculture (MNDA), Iowa Department Natural Resources (IA DNR), Nebraska Department of Agriculture (NDA), Washington Department of Agriculture (WDA), USDA Pesticide Data Program (PDP) and USGS-EPA reservoir monitoring program (USGS-EPA RES). Additionally, atrazine surface water monitoring data prior to 2003 has been previously analyzed in the USEPA IRED (2003b). There are 43,000 site-years of atrazine surface water monitoring data considered in this monitoring data analysis (**Appendix O**). A site-year represent an exposure concentration for a given sampling site in a particular year. There can be multiple site-years at a single site because the site was sampled over numerous years.

Characteristics of monitoring programs for atrazine from 1975 to 2014 are shown in **Table 41**. The monitoring programs, as expected, vary regarding their objective and monitoring strategy. Several of the programs such as the USGS National Water Quality Assessment, California Surface Water Monitoring Program (CSW), Iowa Ambient Monitoring Program, USGS-EPA Pilot Monitoring Program, Heidelberg University National Center of Water Quality (NCWQR) were developed to assess general pesticide occurrence in ambient surface water. In contrast, other monitoring programs such as the Nebraska State Surface Water Monitoring Program, Kansas State Surface Water Monitoring, Wisconsin State Surface Water Monitoring Program, Minnesota State Monitoring Program, Montana State Monitoring Program, and Syngenta's Atrazine Ecological Monitoring Program (AEEMP) monitoring programs were targeted to atrazine use areas.

Table 41. Characteristics of Representative Monitoring Programs for Atrazine and Its Degradation Products in Surface Water

Study	Number of States and Territories	Number of Sampling Stations	Years	Targeted Monitoring	Reported LOD (µg/L)
California Department of Pesticide Regulation	1	558	1991-2012	No	0.001- 4.76
Iowa Department of Natural Resources	1	175	2003-2006	No	0.05
Nebraska Department of Agriculture	1	232	2001-2006	Yes	≤ 0.3
Minnesota Department of Agriculture	1	9	1993-2007	Yes	0.05
Montana Department of Agriculture	1	25	2006-2008	Yes	0.0022
Kansas Streams/	1	393	1977-2008	Yes	<6.3

Study	Number of States and Territories	Number of Sampling Stations	Years	Targeted Monitoring	Reported LOD (µg/L)
Kansas Department of Health and Environment					
Kansas Lakes	1	284	1975-2008	Yes	<6.3
Wisconsin	1	21	2009-2011	Yes	0[1]
USGS-EPA Reservoir	12	20	1999-2000	No	<0.009
NCWQR	1	6	1983-2008	No	0[1]
AEEMP	12	74	2004-2014	Yes	<0.05
AMP and SMP	13	181[2]	2003-2013	Yes	0.05
PDP	26	61	2004-2009	No	0.0066
STORET	33	5372	1977-2015	No	0.00024-1010
NWIS	52	5530	1989-2015	No	0.001-2
NAWQA	49	2,300	1991-2014	No	0.001-0.16
Washington Department of Agriculture	1	25	2003-2013	Unknown	0.013-0.027
Oregon LASAR	1	251	1990-2012	Unknown	0.0005-0.044
Oregon Elem	1	233	2012-2015	Unknown	0.0036-0.159
Louisiana Department of Agriculture and Forestry	1	39	2010-2014	Unknown	not reported

1-LOD was reported as zero in data.
2- This is the number of Community Water Systems monitored. Each CWS may have one or more source-water sampling locations across site-years.

7.4.3. Monitoring Data Analysis

The monitoring data for atrazine is analyzed by site-year. This strategy was employed because pesticide occurrence is dependent on spatially-dependent site conditions including pesticide use, agronomic practices, soil properties, meteorology, *etc*., as well as temporally-dependent conditions, including pesticide application timing and rainfall occurrence.

The monitoring data are analyzed using a custom macro in an Excel spreadsheet. Each site-year of monitoring data with 4 or more samples in a year were analyzed by generating a stair-step chemograph from the first sampling date to last sampling date. The concentrations for non-detections in the chemograph were expressed as 1/2 the minimum reporting concentration

(*i.e.*, LOD or LOQ). Chemographs were not generated for monitoring data with less than 4 samples in the year. This restriction was used because it is the minimum sampling frequency for assessing atrazine rolling average concentrations for human health Maximum Contaminant Levels. Atrazine chemographs are generated by stair-step imputation between measured values. The stair-step chemograph, therefore, provides a daily chemograph from the first sampling date to the last sampling date in the year. From this chemograph, maximum daily concentration, maximum 4-day average concentration, maximum 21-day average concentrations, maximum 60-day average concentrations, and maximum 90-day average concentrations were derived. Additionally, the EXCEL macro provides a count on the number of samples, number of non-detects, number of samples per quarter, and the average and median sampling intervals. For site years with less than 4 samples per year, the maximum atrazine concentration is reported.

The atrazine monitoring data illustrates that the detection frequencies of atrazine concentrations in ambient water samples range from 7% to 100% (**Table 42**). For the purpose of the analysis, ambient surface water is defined as surface water from flowing water (rivers, streams, and springs), reservoirs, ponds, lakes, wetlands, canals, ditches, estuaries, and oceans, as well as raw surface source water from community water systems (CWS). The maximum daily concentration reported in STORET is 20,000 µg/L. This concentration was confirmed by the Louisiana Department of Environmental Quality (LDEQ). This sample was taken in 2012 from Kings Ditch, which is located in an extensive sugarcane growing area west of Baton Rouge and east of the Atchafalaya River basin. Additionally, there were other sites in this area with atrazine concentrations of 505 to 17,000 µg/L in 2012. Reported non-STORET maximum daily concentrations range from 0.25 µg/L to 683.4 µg/L, the latter of which is associated with a monitoring site in Nebraska (Site ID SLB2TLSNDY60). A quality assurance check was conducted on reported atrazine concentrations above 500 µg/L. These high concentrations were found in the STORET database from a few reporting units such as The KAW Nation, The SAC and FOX Nations, MN state monitoring program, and the LA Department of Environmental Quality. These concentrations, in most cases, are reported in ng/L rather than µg/L (Email Communication from Francine Hackett for KAW Nation on 6/19/2015; and, Lisa Montgomery for SAC and FOX Nation of Missouri in Kansas and Nebraska on 6/18/2015). The highest concentration in the non-STORET (683.4 µg/L) is associated with an atrazine spill or illegal disposal (Williams, Ronald W., 2012). There was no attempt to QA all the monitoring data in this analysis. Nor was there an effort to define the circumstances for reported atrazine concentrations in the monitoring data.

Table 42. **Descriptive Statistics of Atrazine Concentrations In Ambient Surface Water Monitoring Programs**

Monitoring Program	Number of samples	Number of non-detects	Detection Frequency Across All Site-Years	Maximum Daily Peak	Maximum 21 Day Average	Maximum 60 Day Average
				µg/L		
California Department of Pesticide Regulation	8,128	7,495	8%	5.3	5.3	3.725
Iowa Department of Natural Resources	2,327	141	94%	16.3	16.3	15
Nebraska Department of Agriculture	12,701	2,832	78%	683.4	683.4	683.4
Minnesota Department of Agriculture	1,865	294	84%	32	8	5.38
Montana Department of Agriculture	55	51	7%	0.002	insufficient monitoring data available to calculate	Insufficient monitoring data available to calculate
Kansas/Kansas Department of Health and Environment	17,205	3,584	79%	105	105	61.5
Wisconsin	1,485	100	93%	21.2	21.2	19.6
NCWQR	4,768	568	88%	54.38	22.28	12.78
USGS-EPA Reservoir	396	15	96%	11.6	8.25	6.06
AEEMP	20,265	0	100%	237.5	103.10	102.35
AMP and SMP	39,092	1,895	95%	227	227	227
PDP	2,374	407	83%	11.77	11.77	4.64
STORET	73,301	33,720	54%	20000	3,020	1,673.10
NWIS	47,847	11,386	76%	252	191	191
NAWQA	32,039	5,693	82%	201	191	191
Washington Department of Agriculture	3,631	3,183	14%	0.25	0.16	0.16
Oregon LASAR	5,010	655	13%	1.59	1.19	1.19
Oregon Elem	2,036	1,583	22%	3.87	1.78	1.78
Louisiana Department of Agriculture and Forestry	252	0	100%	165	0.62	0.62

The peak atrazine concentration in ambient surface water ranges from 0.0035 to 344.26 µg/L (**Table 43**). These concentrations represent all monitoring site-years with a detection of atrazine.

Higher confirmed atrazine concentrations were identified in STORET (*e.g.*, 500 - 20,000 µg/L), and were all associated with 2012 submitted data from the Louisiana Department of Environmental Quality (LDEQ; Personal Communication from Al Hindrichs to James Hetrick on 7/2/15). These concentrations are substantially higher than the 344.26 µg/L, the highest daily peak concentration from the AEEMP monitoring program. Additionally, the 20,000 µg/L peak concentration is approaching the water solubility of atrazine at 33,000 µg/L. These concentrations, therefore, are suspect as being a reliable concentrations for assessing risk from normal agricultural uses of atrazine.

A distributional analysis among the states shows that the median of daily peak concentrations ranges from 0.00035 to 2.775 µg/L. These data illustrate that high daily peaks are not typical for all site-years. This observation is consistent with the WARP modeling as well as the targeted watershed monitoring data that watersheds vary according to their vulnerability for atrazine runoff. This is dependent on the use intensity, soil type, application timing, and rainfall amounts.

Table 43. Distribution of peak concentrations reported in monitoring data.

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years
AK	0.0005	0.0005	0.0005	0.0035	0.0035	0.0288	0.0369	25
AL	0.0005	0.003	0.018	0.059	0.533	4.5	201	384
AR	0	0.0005	0.0023	0.0084	0.063	0.866	21.7	737
AS	0.004	0.004	0.004	0.004	0.004	0.004	0.004	4
AZ	0.0005	0.0005	0.0035	0.005	0.006	0.05	0.712	167
CA	0	0.0005	0.0035	0.023	0.05	0.25	5.3	2537
CO	0.0005	0.0005	0.005	0.017	0.063	0.396	6.82	405
CT	0.0005	0.0005	0.00715	0.012	0.0185	0.07027	4.6	123
DC	0.0005	0.0037	0.011	0.031	0.039	0.1018	0.145	17
DE	0.005	0.0072	0.025	0.025	0.0475	0.665	30	43
FL	0.0003	0.00445	0.023	0.11	0.59625	3.4	40.5	1576
GA	0.0005	0.0005	0.0035	0.015	0.06	0.2766	1.15	808
HI	0.0005	0.0005	0.0035	0.0042	0.025	0.049	2.05	61
IA	0	0.05	0.22	0.61	1.8	9.2	344.26	3945
ID	0	0.0005	0.003	0.006	0.009	0.039	0.5	297
IL	0	0.03	0.52	2.25	5.88	27.7	228.18	949
IN	0	0	0.6925	2.775	9.3	27.018	237.5	958

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years
KS	0	0	0.15	0.6	1.8	8.147	105	13144
KY	0	0.0036	0.16	0.488	2.18	14.2	26.4	317
LA	0	0.0162	0.201	0.803	1.8	13.744	193.65	809
MA	0.0005	0.0005	0.0035	0.006	0.015	0.02	0.027	147
MD	0.0005	0.000875	0.025	0.0852	0.3265	4.3	25	296
ME	0.0005	0.0005	0.0005	0.0012	0.0035	0.0035	0.0035	9
MI	0.002	0.00635	0.024	0.06335	0.17975	1.738	11.9	108
MN	0.0005	0.019	0.025	0.09	0.37	2.75	310	1751
MO	0	0	0.00435	0.6	2.68	25.451	285.86	1915
MS	0	0	0.025	1.17	3.81	11.54	252	219
MT	0.0005	0.0011	0.0011	0.0035	0.0095	0.159	0.6	146
NC	0.0005	0.0005	0.006	0.023	0.09	0.74	4.9	721
ND	0	0	0	0.0141	0.05	0.516	4.5	357
NE	0	0.025	0.2	1	4.8825	38.0105	224	2304
NH	0.0005	0.0005	0.0005	0.003	0.004875	0.008	0.037	42
NJ	0.0005	0.002	0.004	0.01	0.031	0.489	13.2	889
NM	0.0005	0.0005	0.0035	0.02	0.059	0.26	6.605	414
NV	0.0005	0.0005	0.0035	0.006	0.009	0.0248	0.18	175
NY	0.0005	0.0005	0.0045	0.011	0.05275	0.55825	20.7	910
OH	0.0068	0.17805	1.1225	4.77	14.82	38.68335	227	548
OK	0	0.01149	0.194	0.5	3.84	50	187	115
OR	0	0.002	0.0085	0.027	0.08	0.2	4.53	1213
PA	0.0005	0.0035	0.0467	0.132	0.2715	1.6	12	303
RI	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1
SC	0.0005	0.0045	0.02	0.023	0.16	0.58	1.15	141
SD	0	0	0.0195	0.06	0.25	1.55	29.6	193
TN	0.0005	0.0055	0.023	0.0885	0.5775	2.505	36.4	156
TX	0.0005	0.0005	0.051	0.53	1.71	7.892	133.89	385
UT	0	0.0005	0.005	0.01635	0.25	0.5	11	398
VA	0.0005	0.0005	0.006	0.0306	0.0934	1.6215	28.5	308
VT	0.0005	0.0005	0.004	0.013	0.029	0.148	0.28	17
WA	0.0005	0.0005	0.004	0.01305	0.034	0.086085	1.4	784
WI	0	0.004	0.032	0.122	0.496	6.4	97	457
WV	0.0005	0.0005	0.003125	0.009	0.04025	0.212	1	50
WY	0	0.0005	0.0035	0.0035	0.008	0.0307	0.14	163

The maximum 21-day and 60 day average atrazine concentration in ambient surface water range from 0.01 to 233.57 µg/L and 0.02 to 191 µg/L, respectively (**Table 44** and **Table** 45). These concentrations represent monitoring site-years with 4 or more samples per year. A distributional analysis among the states shows that the median of the 21-day average and 60-day average concentrations range from 0.01 to 50.0 µg/L and 0.01 to 48 µg/L, respectively. These data illustrate that typical 21-day and 60 day exposure to atrazine in some states can have evaluated atrazine concentration.

Table 44. Distribution of 21-day concentrations reported in monitoring data with 4 or more samples per year.

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years ≥ 4 samples
AK	0.0005	0.0005	0.0005	0.002964	0.005495	0.005653	5.69E-03	4
AL	0.004033	0.02324	0.086	0.36	1.44	14.6	1.35E+02	177
AR	0.0005	0.0035	0.005321	0.0635	0.69975	5.91	2.17E+01	96
AS	NA	NA	NA	NA	NA	NA	NA	0
AZ	0.0005	0.003	0.0035	0.0045	0.006175	0.033754	3.08E-01	64
CA	0	0.0005	0.005	0.0179	0.25	0.25	5.30E+00	1015
CO	0.0005	0.0035	0.008875	0.022857	0.0915	0.2963	6.82E+00	140
CT	0.005	0.007333	0.009193	0.013	0.018004	0.07027	4.60E+00	63
DC	0.039	0.0438	0.063	0.087	0.116	0.1392	1.45E-01	3
DE	0.06	0.860571	4.062857	8.065714	12.06857	15.27086	1.61E+01	2
FL	0.0021	0.00845	0.055464	0.235	1	4.3105	1.80E+01	830
GA	0.0005	0.005	0.024	0.0688	0.160476	0.414952	1.15E+00	265
HI	0.0005	0.0005	0.00275	0.00525	0.014053	0.036203	3.69E-02	8
IA	0.05	0.15	0.44	1	2.6	9.668667	2.34E+02	1787
ID	0.0005	0.0005	0.006985	0.00805	0.010217	0.029227	4.00E-02	72
IL	0	0.139167	0.949405	2.666667	6.023333	16.03631	1.08E+02	696
IN	0	0.14705	1.543929	3.841429	7.734762	19.03429	1.11E+02	612
KS	0	0.052317	0.919167	2.3	5.405	16.26617	1.05E+02	1168
KY	0.023	0.0241	0.2845	0.53	1.814167	7.1235	1.78E+01	192
LA	0.003071	0.1116	0.76881	1.438095	2.251905	18.31914	6.74E+01	385
MA	0.0035	0.0035	0.00682	0.011	0.015	0.02	2.00E-02	53
MD	0.009	0.05475	0.13025	0.398476	1.38	8	9.73E+00	58
ME	0.00348	0.003482	0.00349	0.0035	0.0035	0.0035	3.50E-03	3
MI	0.0446	0.0458	0.0777	0.169	0.319	6.653333	7.08E+00	37
MN	0.015	0.025	0.094429	0.280714	0.848893	2.612286	1.11E+01	640
MO	0	0	0.2	1.597143	4.565	20	1.56E+02	1057
MS	0.068462	0.235	0.981	2.565	4.922905	10.89	1.76E+02	98
MT	0.0005	0.00182	0.005	0.00821	0.025	0.256987	6.00E-01	57

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years ≥ 4 samples
NC	0.0035	0.008225	0.0343	0.099367	0.417	1.328333	3.38E+00	156
ND	0	0	0.007238	0.041	0.125	0.543	4.50E+00	58
NE	0.00356	0.05	0.24	1.37	6	30.56821	1.91E+02	1716
NH	NA	NA	NA	NA	NA	NA	NA	0
NJ	0.02281	0.03005	0.059	0.102	0.344	5.534667	1.00E+01	102
NM	0.0005	0.0005	0.0005	0.0005	0.004	0.0074	1.70E-02	17
NV	0.0005	0.003	0.004	0.006	0.00895	0.018214	6.90E-02	106
NY	0.0005	0.0056	0.015	0.056	0.250524	1.569838	2.07E+01	185
OH	0.03	0.286278	1.258667	3.908571	9.176667	20.3561	1.10E+02	397
OK	0.224143	0.3166	0.956	50	50	50	1.87E+02	25
OR	0	0.002175	0.025455	0.0406	0.1	0.2094	4.53E+00	753
PA	0.0121	0.022539	0.137711	0.246071	0.6465	1.488929	3.23E+00	66
RI	NA	NA	NA	NA	NA	NA	NA	0
SC	0.004	0.005769	0.0294	0.106	0.292857	0.612	1.15E+00	65
SD	0.05	0.05	0.07	0.09	0.12	2.104	2.53E+00	29
TN	0.005254	0.023	0.040275	0.35	0.8	3.104167	3.64E+01	86
TX	0.00291	0.00672	0.27	0.918286	2.067714	7.132381	5.60E+01	233
UT	0.0005	0.003475	0.006675	0.014681	0.042524	0.5	5.00E-01	80
VA	0.004	0.0083	0.042	0.136	0.368133	3.6	2.50E+01	101
VT	0.029	0.029	0.029	0.029	0.029	0.029	2.90E-02	2
WA	0.0005	0.003017	0.006121	0.029	0.035	0.100933	1.02E+00	403
WI	0	0.038686	0.12	0.32	1.24	7.258	3.40E+01	169
WV	0.0035	0.0035	0.019575	0.0408	0.1055	0.604333	7.90E-01	7
WY	0.0035	0.0035	0.0035	0.009	0.025	0.076	1.40E-01	17

Table 45. Distribution of 60-day concentrations reported in monitoring data with 4 or more samples per year.

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years ≥ 4 samples
AK	0.0005	0.0005	0.0005	0.002169	0.003883	0.003991	4.02E-03	4
AL	0.00299	0.022829	0.0765	0.286183	0.942533	10.233	5.43E+01	177
AR	0.0005	0.002095	0.004172	0.0635	0.662033	3.015208	1.36E+01	96
AS	NA	NA	NA	NA	NA	NA	NA	0
AZ	0.0005	0.001901	0.0035	0.004019	0.005295	0.023265	1.95E-01	64
CA	0	0.0005	0.004	0.015	0.25	0.25	3.73E+00	1015

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years ≥ 4 samples
CO	0.0005	0.0035	0.007954	0.018893	0.0821	0.246208	3.89E+00	140
CT	0.005	0.00577	0.008314	0.011283	0.017075	0.061867	4.60E+00	63
DC	0.039	0.0438	0.063	0.087	0.098233	0.10722	1.09E-01	3
DE	0.06	0.482	2.17	4.28	6.39	8.078	8.50E+00	2
FL	0.0021	0.005725	0.05	0.22	0.915083	3.855	1.80E+01	830
GA	0.0005	0.004038	0.023	0.058417	0.12975	0.35873	1.11E+00	265
HI	0.0005	0.0005	0.002645	0.00518	0.013408	0.033524	3.41E-02	8
IA	0.045417	0.116767	0.348741	0.7804	1.8	6.088133	9.66E+01	1787
ID	0.0005	0.0005	0.005936	0.007725	0.008794	0.020267	4.00E-02	72
IL	0	0.122458	0.789331	2.03	4.327875	9.922619	1.08E+02	696
IN	0	0.119684	1.090567	2.648487	4.941417	14.225	8.90E+01	612
KS	0	0.048638	0.774708	1.81	3.706667	10.94	6.15E+01	1168
KY	0.023	0.0241	0.24375	0.47095	1.525	5.095268	1.43E+01	192
LA	0.002217	0.100864	0.643833	1.084033	1.72	11.13474	4.07E+01	385
MA	0.0035	0.0035	0.005304	0.008	0.014333	0.02	2.00E-02	53
MD	0.009	0.044536	0.107725	0.291375	1.340658	4.721833	6.20E+00	58
ME	0.003402	0.003412	0.003451	0.0035	0.0035	0.0035	3.50E-03	3
MI	0.0364	0.04492	0.063415	0.09939	0.188442	4.204187	5.34E+00	37
MN	0.015	0.025	0.083708	0.21737	0.508367	1.567984	5.37E+00	640
MO	0	0	0.122333	1.4	3.635517	13.16372	1.56E+02	1057
MS	0.068462	0.219612	0.832	1.671042	3.061317	6.8294	1.51E+02	98
MT	0.0005	0.00146	0.004825	0.007453	0.019432	0.2388	6.00E-01	57
NC	0.0035	0.008013	0.029953	0.083562	0.23109	0.717617	2.94E+00	156
ND	0	0	0.007	0.031833	0.125	0.286337	3.60E+00	58
NE	0.003527	0.039375	0.166667	0.975	4.019469	17.68158	1.91E+02	1716
NH	NA	NA	NA	NA	NA	NA	NA	0
NJ	0.01994	0.024501	0.040925	0.085163	0.225928	2.658513	4.45E+00	102
NM	0.0005	0.0005	0.0005	0.0005	0.004	0.0074	1.70E-02	17
NV	0.0005	0.001793	0.003869	0.005056	0.008	0.015539	4.00E-02	106
NY	0.0005	0.004938	0.011687	0.047011	0.170217	0.965467	8.67E+00	185
OH	0.03	0.197559	0.913261	2.785333	5.629333	13.984	4.31E+01	397
OK	0.21793	0.314667	0.956	48.235	50	50	9.71E+01	25
OR	0	0.002172	0.025172	0.033821	0.099275	0.17856	3.12E+00	753
PA	0.0121	0.016728	0.107843	0.189825	0.434	1.050333	1.63E+00	66
RI	NA	NA	NA	NA	NA	NA	NA	0
SC	0.003945	0.005136	0.023	0.076117	0.239533	0.58	1.15E+00	65
SD	0.05	0.05	0.06	0.08	0.12	1.916067	2.38E+00	29

State	0%	5%	25%	50%	75%	95%	100%	No. of Site-years ≥ 4 samples
TN	0.00344	0.019661	0.033068	0.239088	0.6775	3.08625	2.34E+01	86
TX	0.001475	0.005787	0.201003	0.78	1.46925	5.0985	2.07E+01	233
UT	0.0005	0.003475	0.006338	0.013	0.029084	0.5	5.00E-01	80
VA	0.004	0.0083	0.0306	0.136	0.302992	2.078786	1.26E+01	101
VT	0.029	0.029	0.029	0.029	0.029	0.029	2.90E-02	2
WA	0.0005	0.002494	0.005336	0.026	0.0341	0.080877	7.59E-01	403
WI	0	0.03684	0.109	0.236667	0.917745	4.37625	3.40E+01	169
WV	0.0035	0.0035	0.019575	0.039933	0.105	0.314002	3.76E-01	7
WY	0.003	0.0034	0.0035	0.009	0.025	0.0685	1.03E-01	17

The atrazine monitoring data are important to identify areas with potential ecological impacts from atrazine use. Atrazine detections, as expected, are most prominent in areas with high atrazine use such as the Corn Belt of the United States. As illustrated in **Table 43, Table 44,** and **Table** 45, atrazine detections are higher in monitoring programs in the Midwest compared to monitoring data from California, Oregon, and Washington. Additionally, the highest atrazine concentrations are found in the high atrazine use areas. The spatial distribution of atrazine occurrence in ambient surface waters are shown in **Figure 17**, **Figure 18**, and **Figure 19**. This spatial distribution of atrazine occurrence is not unexpected because it overlays with atrazine use areas of the United States as shown in **Figure 12**.

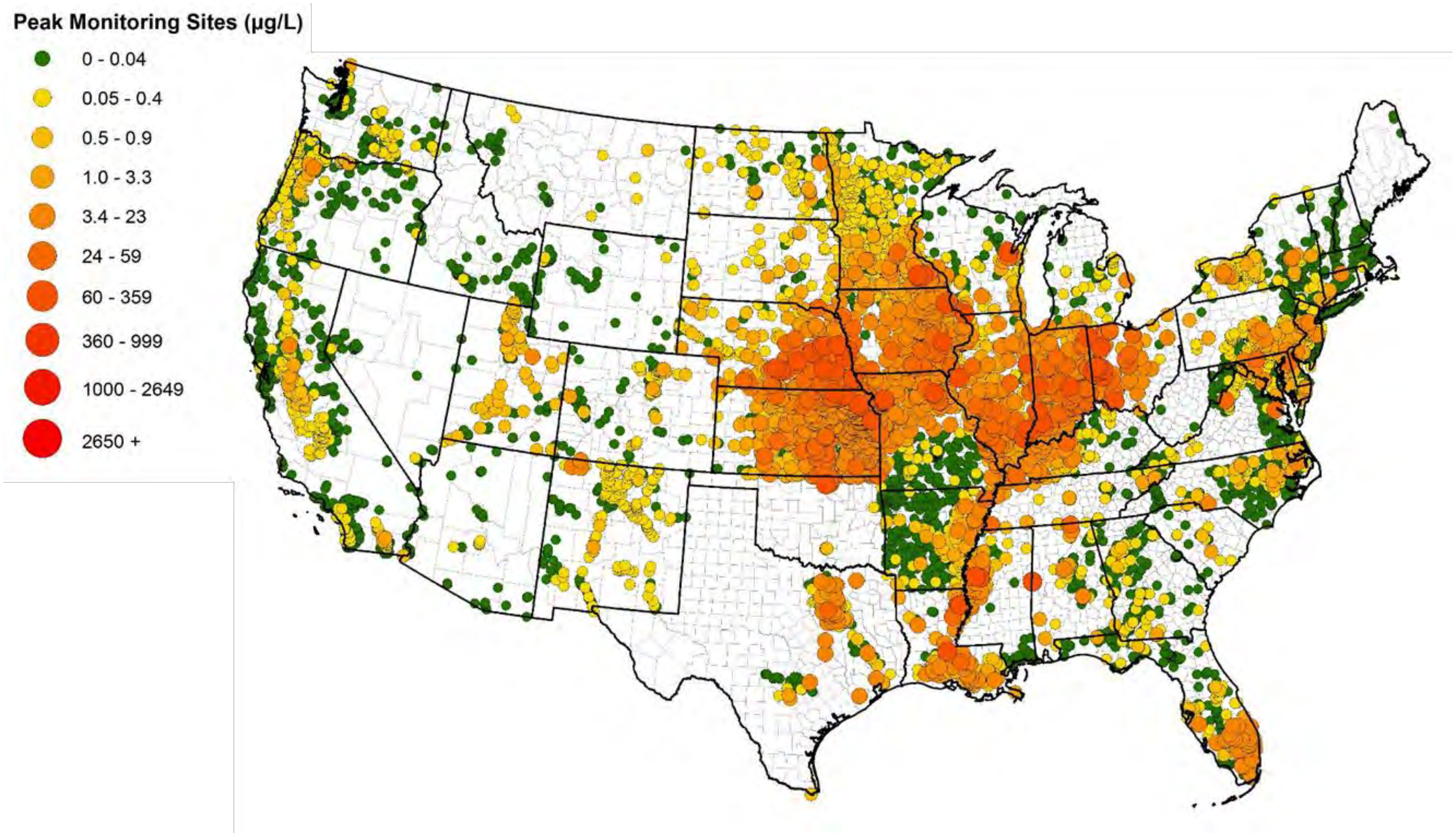


Figure 17. Distribution of the peak concentrations of atrazine for georeferenced monitoring sites.

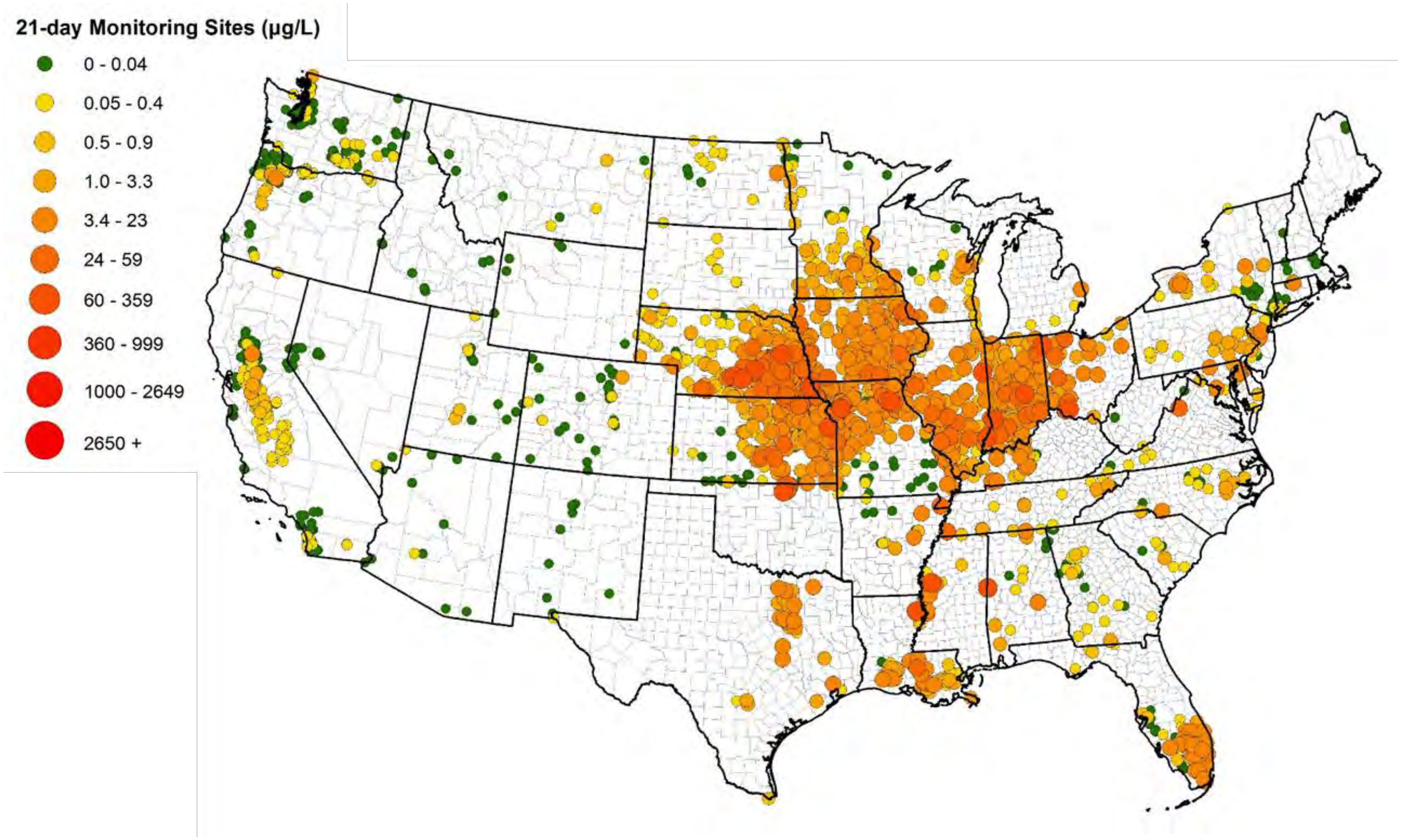


Figure 18. Distribution of the maximum average 21-day concentrations of atrazine for georeferenced monitoring sites that had 4 samples or more.

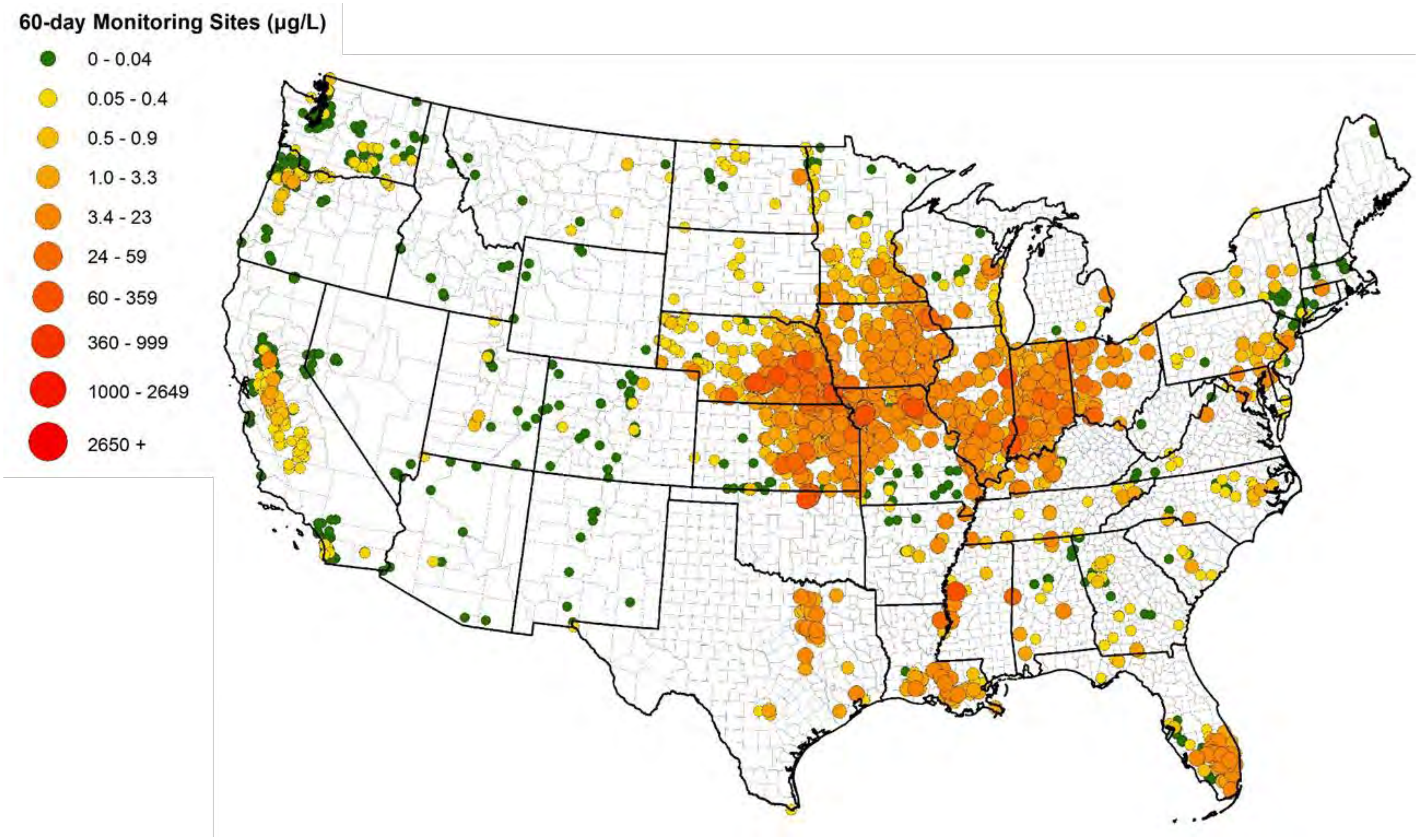


Figure 19. Distribution of the maximum average 60-day concentrations of atrazine for georeferenced monitoring sites that had 4 samples or more.

Another aspect of the monitoring data analysis is accounting for uncertainty in quantifying atrazine concentrations because of low sampling frequency. Bias factors were determined for monitoring data using regression equations. Please refer to the bias factor section (**section 7.4.1**) of this assessment for more information. Because some monitoring data could be used in two different BF regression equations (AEEMP and AMP1), bias factors were estimated using both equations for some sites. The average sampling interval in each site-year in the monitoring data was used in the appropriate regression equation to determine a BF for peak, 21-day average, and 60 day average atrazine concentrations. The BF was then multiplied by each observed exposure endpoint in a site-year. Application of bias factors increased atrazine concentrations from 2 to 5X regardless of the exposure duration endpoint (**Table 46**).

Table 46. Impact of Bias Factor Adjustment on Selected Percentiles Atrazine Concentrations for Maximum Daily, 21-day Average, and 60-day Average.

Exposure Endpoint	Percentile	Non BF Adjustment	BF Adjustment
Daily	99.9	344.3	1826.7
	95	62.2	173.2
	90	41	92.4
	75	16.4	34.7
	50	4.7	10.6
21-Day Average	99.9	233.6	556.4
	95	26.5	50.2
	90	17.7	30.2
	75	8.5	13.9
	50	2.7	4.5
60- Day Average	99.9	155.5	374.8
	95	16.8	28.2
	90	11	16.7
	75	5.2	7.5
	50	1.9	2.7

8. STRESSORS OF CONCERN

The focus of this assessment is on parent atrazine because it is expected to be protective for non-target organisms that may be exposed to the parent and any of its degradates (USEPA, 2009b). Because of atrazine's structural similarity to simazine, propazine and 3 other chlorotriazine degradates, atrazine is considered to be of equal potency to simazine and propazine and the chlorinated degradates with respect to their toxicity to terrestrial animals and plants. Therefore this assessment considered data from these chlorinated triazines to characterize the potential ecological risks to animal and plant taxa.

In its ecological risk assessments, the EPA does not routinely include a quantitative evaluation of mixtures of active ingredients, either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank. In the case of the product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. Available toxicity data for environmental mixtures of atrazine with other pesticides are presented as part of the ecological risk assessment. It is expected that the toxic effect of atrazine, in combination with other pesticides used in the environment, is likely to be a function of many factors, including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (*e.g.*, organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data and methodologies. However, a qualitative discussion of implications of the available pesticide mixture effects data on the confidence of risk assessment conclusions are addressed as part of the uncertainty analysis.

9. EVALUATION OF ATRAZINE TOXICITY TO SPECIFIC TAXA

The risk assessment for atrazine relies on a surrogate species approach. Toxicological data generated from surrogate test species, which are intended to be representative of broad taxonomic groups, are used to extrapolate the potential effects on a variety of species included under these taxonomic groupings.

Acute and chronic toxicity data from single-species studies submitted by pesticide registrants along with the available open literature were used to evaluate the potential direct and indirect effects of atrazine to aquatic and terrestrial species, including sublethal effects that can be directly linked to survival, growth, or fecundity. These data include toxicity on the technical grade active ingredient, degradates, and when available, formulated products.

The open literature studies are identified through EPA's ECOTOXicology (ECOTOX 2007c) database, which employs a literature search engine for locating chemical toxicity data for aquatic life, terrestrial plants, and wildlife. The evaluation of both open literature as well as the registrant submitted data may provide insight into the direct and indirect effects of atrazine on biotic communities from loss of species that are sensitive to the chemical and from changes in structure and functional characteristics of the affected communities. Several ECOTOX runs have been conducted over the years prior to this risk assessment (2003, 2004, 2006, 2007, 2008, 2011, and 2014).

The assessment endpoints for pesticide risk assessments are growth, reproduction, and survival of species. For this assessment, evaluated taxa include aquatic-phase amphibians, freshwater

and saltwater fish, freshwater and saltwater invertebrates, aquatic plants, birds (surrogate for terrestrial-phase amphibians), mammals, terrestrial invertebrates, and terrestrial plants. Acute (short-term exposure) and chronic (long-term exposure) toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on atrazine and its degradates.

A summary of the data to be used for quantitative and qualitative risk assessment for non-target species and communities exposed to atrazine in aquatic and terrestrial habitats is provided in this section. See **Appendix F** for a complete list of submitted "Acceptable" and "Supplemental" studies.

10. TOXICITY TO PLANTS

10.1. Toxicity to Terrestrial Plants

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature are reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in OCSPP test guidelines. Sub-lethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages.

Based on the results of the submitted terrestrial plant toxicity tests, it appears that the seedling emergence stage of plant development is more sensitive to atrazine than the vegetative vigor stage of development. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine.

For Tier II seedling emergence, the most sensitive dicot is carrot and the most sensitive monocot is oat. IC_{25} values, on an equivalent application rate basis, for oats and carrots, which are based on a reduction in dry weight, are 0.003 and 0.004 lb a.i./A, respectively; NOAEC values for both species are 0.0025 lb a.i./A. **Table 47** summarizes the most sensitive Tier II terrestrial plant seedling emergence toxicity data.

Table 47. Nontarget Terrestrial Plant Seedling Emergence Toxicity (Tier II). All definitive endpoints are used quantitatively, bold endpoints identify the most sensitive monocot and dicot species.

Surrogate Species	% a.i	IC_{25} / NOAEC (lbs a.i/A)	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	> 4.0 / > 4.0	No effect	420414-03 Chetram 1989	Acceptable
Monocot - Oat (*Avena sativa*)	97.7	**0.004 / 0.0025**	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Onion (*Allium cepa*)	97.7	0.009 / 0.005	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Monocot - Ryegrass (*Lolium perenne*)	97.7	0.007 / 0.005	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Carrot (*Daucus carota*)	97.7	**0.003 / 0.0025**	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Soybean (*Glycine max*)	97.7	0.19 / 0.025	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.005 / 0.0025	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.01	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Tomato (*Solanum lycopersicum*)	97.7	0.034 / 0.01	Reduction in dry weight	420414-03 Chetram 1989	Acceptable
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.013 / 0.005	Reduction in dry weight	420414-03 Chetram 1989	Acceptable

For Tier II vegetative vigor studies, the most sensitive dicot is cucumber, and the most sensitive monocot is onion. In general, dicots appear to be more sensitive than monocots via foliar routes of exposure with all tested monocot species showing a significant reduction in dry weight and plant height at IC_{25} values ranging from 0.008 to 1.7 lb a.i./A. In contrast, two of the four tested monocots showed no effects from atrazine (corn and ryegrass), while IC_{25} values for onion and oats were 0.61 and 2.4 lb a.i./A, respectively. **Table 48** summarizes the most sensitive terrestrial plant vegetative vigor toxicity data used to derive risk quotients in this assessment.

Table 48. Nontarget Terrestrial Plant Vegetative Vigor Toxicity (Tier II). All definitive endpoints are used quantitatively, bold endpoints identify the most sensitive monocot and dicot species

Surrogate Species	% a.i	IC25 / NOAEC (lbs a.i/A)	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	> 4.0 / > 4.0	No effect	420414-02 Chetram 1989	Acceptable
Monocot - Oat (*Avena sativa*)	97.7	2.4 / 2.0	Reduction in dry weight	420414-02 Chetram 1989	Acceptable
Monocot - Onion (*Allium cepa*)	97.7	**0.61 / 0.5**	Reduction in dry weight	420414-02 Chetram 1989	Acceptable
Monocot - Ryegrass (*Lolium perenne*)	97.7	> 4.0 / 4.0	No effect	420414-02 Chetram 1989	Acceptable
Dicot - Carrot (*Daucus carota*)	97.7	1.7/ 2.0	Reduction in plant height	420414-02 Chetram 1989	Acceptable
Dicot - Soybean (*Glycine max*)	97.7	0.026 / 0.02	Reduction in dry weight	420414-02 Chetram 1989	Acceptable
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.33 / 0.25	Reduction in dry weight	420414-02 Chetram 1989	Acceptable
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.005	Reduction in dry weight	420414-02 Chetram 1989	Acceptable
Dicot - Tomato (*Solanum lycopersicum*)	97.7	0.72 / 0.5	Reduction in plant height	420414-02 Chetram 1989	Acceptable
Dicot - Cucumber (*Cucumis sativus*)	97.7	**0.008 / 0.005**	Reduction in dry weight	420414-02 Chetram 1989	Acceptable

In the open literature there are a few additional studies which report growth endpoints in terms of the IC_{25} following exposure at the vegetative vigor stage (Dalton 2007; White and Boutin 2007; Boutin et al. 2010). The definitive vegetative vigor IC_{25} endpoints were used to establish a species sensitivity distribution (SSD; **Figure 20**) by combining the IC_{25} endpoints reported in **Table 48** with the available open literature endpoints. The 5th percentile hazard concentration of the SSD (HC_{05}) for vegetative vigor is 0.016 lb a.i./A (M. Etterson SSD-tool, USEPA/ORD 2015).

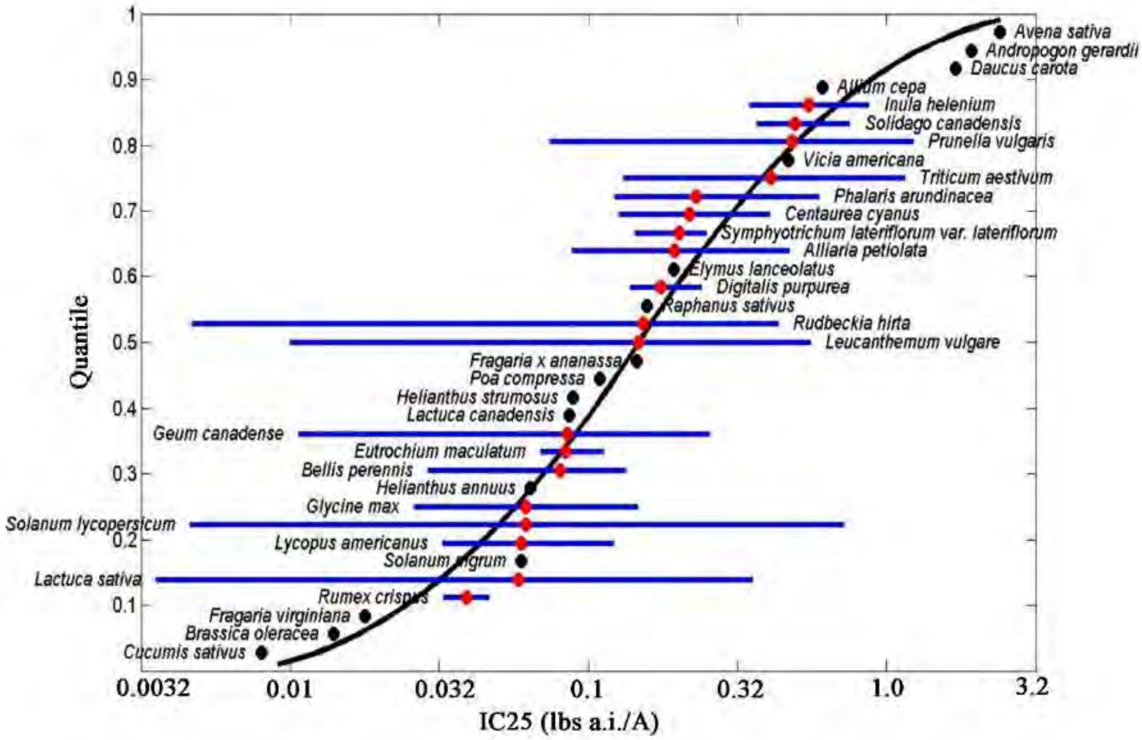


Figure 20. Species sensitivity distribution of IC_{25} vegetative vigor stage endpoints. Selected model was triangular, fit using maximum likelihood estimation, selected based on the lowest AIC and the highest p-value for model fit. Horizontal blue lines indicate the range of toxicity values. Red points are geometric means for taxa with multiple estimates. Black points are single estimates.

The data in **Table 47** were the only seedling emergence IC_{25} data in the available literature, so the definitive IC_{25} data from this study were the only endpoints used to establish the SSD for seedling emergence (**Figure 21**). The resulting HC_5 of the seedling emergence SSD is 0.0022 lb a.i./A. These species sensitivity distributions support the conclusion that plants exposed at the seedling emergence growth stage are more sensitive than when exposed at the vegetative vigor growth stage, and there is roughly an order of magnitude frame shift between the two distributions (**Figure 22**).

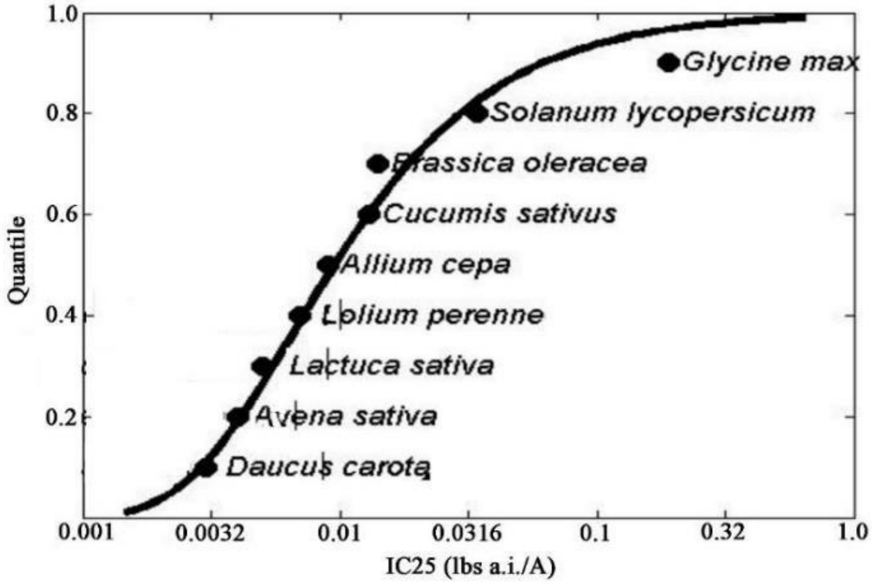


Figure 21. Species sensitivity distribution of IC_{25} seedling emergence stage endpoints. Selected model was gumbel fit using moment estimation, selected based on the lowest AIC and highest p-value for model fit. Black points are single estimates.

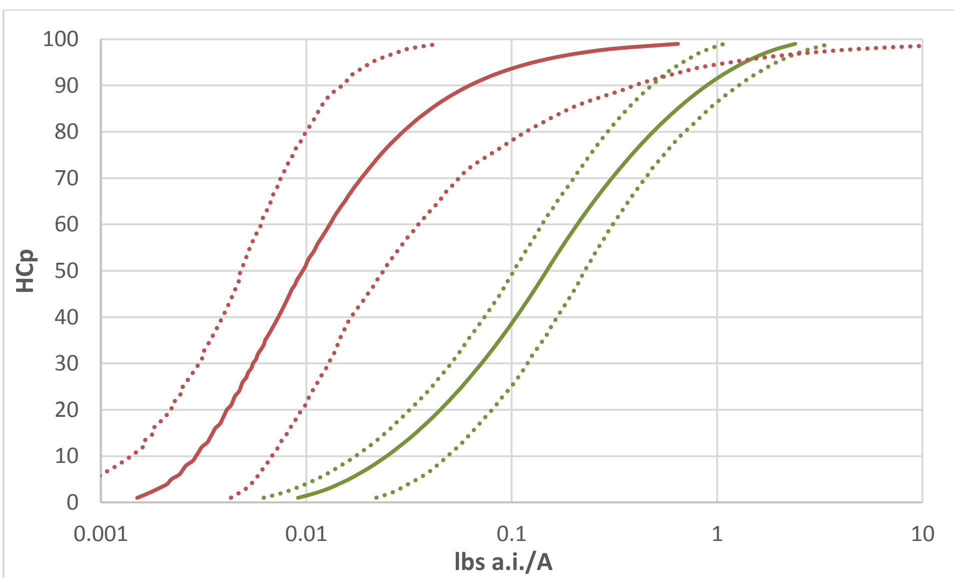


Figure 22. Comparison of the species sensitivity distributions of IC_{25} values for seedling emergence stage endpoints (solid red line) versus vegetative vigor stage endpoints (solid green line). Dotted lines represent the 95% confidence interval for each distribution.

In addition, a report on the toxicity of atrazine to woody plants (Wall *et al.*, 2006; MRID 46870401) was reviewed. A total of 35 species were tested at application rates ranging from 1.5 to 4.0 lb a.i./A. Twenty-eight species exposed to atrazine as mature plants exhibited either no or negligible phytotoxicity. Seven of 35 species exhibited >10% phytotoxicity. However, further examination of the data indicates that atrazine application was clearly associated with severe phytotoxicity in one species (Shrubby Althea, *Hybiscus sp.*). These data suggest that, although sensitive woody plants exist, atrazine exposure to most established or mature woody plant species at application rates of 1.5 to 4.0 lb a.i./A is not expected to cause significant adverse effects. This study does not specifically address the seedling emergence of these woody species, which based upon the submitted guideline studies, and the species sensitivity distributions (**Figure 22**) is a more sensitive lifestage to atrazine exposure. A summary of the available woody plant data is provided in **Appendix B**.

10.2. Toxicity to Aquatic Non-Vascular Plants

The following two toxicity sections (**10.2** and **10.310.3**) are organized based on the taxonomic groups shown in **Figure 23** and are representative of closely related taxa. These sections are followed by **Section 10.4**, which describes the toxicity information available from microcosm and mesocosm studies, including the breadth of diversity in the studies. **Sections 10.2** and **10.3** represent the toxicity to individual species, whereas **Section 10.4** represents the toxicity of atrazine to the aquatic plant communities found in North America. Although the toxicity information is presented in separate sections (single species tests vs. cosm studies), the data represent the effects of atrazine on aquatic autotrophic species and communities of aquatic plants, and are considered of equal importance in the risk characterization.

The category of "Aquatic Non-Vascular Plants" is representative of a broad diversity of unicellular and multicellular organisms. These include Eubacteria (*e.g*., blue-green algae), Archaeoplastida (*e.g*., red algae, glaucophytes, green algae, and aquatic bryophytes), Chromalveolates (*e.g*., aveolates, cryptomonads, dinoflagellates, diatoms, water molds, and brown algae), Excavates (*e.g*., euglena), and the Unikonts (*e.g*., fungi, and collared-flagellates) except the "Animals" lineage.

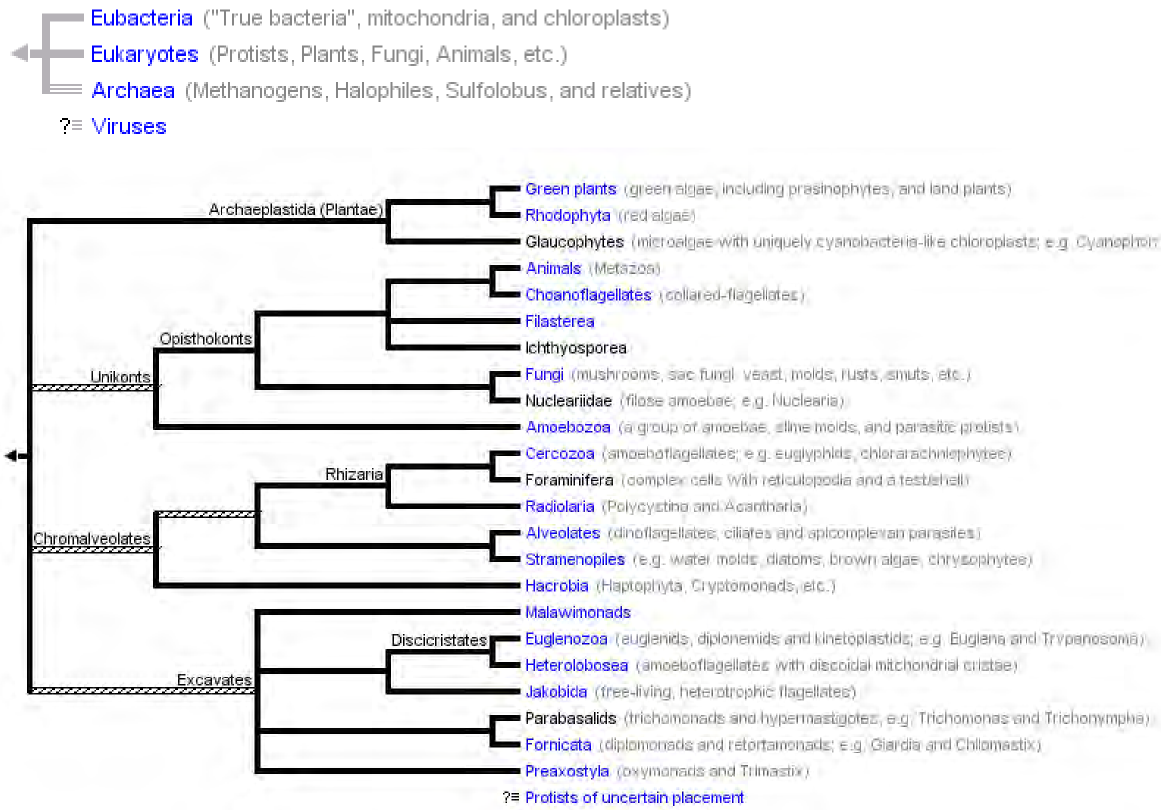


Figure 23. The taxonomy followed in this risk assessment is based on the information available at the Tree of Life Web Project (http://tolweb.org/tree/) and is consistent with current understandings of the relationships between these taxa.

Single-species aquatic plant toxicity studies are used as the foundation for evaluating whether atrazine may affect primary production and diversity in aquatic ecosystems (see **Section 12.2** for further explanation). Numerous aquatic non-vascular plant toxicity studies have been submitted to EPA and/or published in the open literature (**Appendix B**; USEPA 2007c). A summary of the most sensitive endpoints for freshwater non-vascular plants is provided below; **Appendix B** includes a more comprehensive list of the available data. The most sensitive single species data for aquatic non-vascular plants from either supplemental or acceptable studies (**Table 49**) were used for risk characterization and risk quotient calculations.

Table 49. Summary of the most sensitive aquatic non-vascular plant toxicity endpoints available from the registrant submitted studies and the open literature.								
Taxonomic Group		**Number of Families Tested**	**Number of Genera Tested**	**Number of Species Tested**	**Minimum ED/IC/EC_{50} Endpoint[1]**	**FW/SW and Duration[2]**	**Species and Effect Used for Reported Endpoint**	**Citation (MRID)**
EUBACTERIA:	CYANOBACTERIA: (Blue-Green Algae)	5	14	29	EC_{50} <1 µg/L	FW 7 days	*Oscillatoria lutea* 93% reduction of chlorophyll production	Torres and O'Flaherty 1976 (000235-44)
EUKARYOTES:								
ARCHAEOPLASTIDA	**GREEN PLANTS:**							
	EMBRYOPHYTA: (Non-Vascular Land Plants)	1	1	1	EC_{50} < 2 µg/L	FW 24 hrs	*Fontinalis hypnoides* 90% reduction in photosynthesis	Hoffman and Winkler 1990
	EMBRYOPHYTA: (Vascular Land Plants)	21	30	42	EC_{50} = 4.6 µg/L	FW 14 days	*Elodea canadensis* 50% reduction in root dry-weight	McGregor et al. 2008
	CHLOROPHYTA and STREPTOPHYTA[3]: (Green Algae)	16	26	34	EC_{50} < 1 µg/L	FW 7 days	*Stigeoclonium tenue* 67% reduction in chlorophyll production	Torres and O'Flaherty 1976 (000235-44)
	PRASINOPHYTA: (Prasinophytes)	2	3	4	EC_{50} = 14.2 µg/L LOAEC = 1.1 µg/L	SW 4 hours	*Nephroselmis pyriformis* 50% photoinhibition	Magnussun et al. 2010

	RHODOPHYTA: (Red Algae)	2	2	2	EC_{50} = 79 µg/L	SW 72 hrs	*Porphyridium cruentum* 50% reduction in oxygen production	Mayer 1986 (402284-01)
CHROMALVEOLATES	**HACROBIA:**							
	HAPTOPHYTA: (Coccolithophorads)	2	2	2	EC_{50} = 30 µg/L	SW 72 hrs	*Isochrysis galbana* 50% growth inhibition	Debelius et al. 2008
	CRYPTOPHYCOPHYTA: (Cryptomonads)	2	3	5	EC_{50} = 22.17 µg/L NOAEC < 12.5 µg/L	SW 96 hrs.	*Storeatula major* 50% reduction in abundance	DeLorenzo et al. 2004
	STRAMENOPILES:							
	BACILLARIOPHYTA: (DIATOMS)	17	22	46	EC_{50} = 19.4 µg/L	SW 48 hrs.	*Bellerochea polymorpha* 50% reduction in population growth	Walsh et al. 1988
	PHAEOPHYTA: (Brown Algae)	1	1	2	EC_{50} = ~90 µg/L LOAEC = 10 µg/L NOAEC < 1 µg/L	SW > 18 days	*Laminaria hyperborea* growth reduction	Hopkin and Kain 1978
	CHRYSOPHYTA: (Golden Algae)	3	3	4	EC_{50} = 77 µg/L	SW 1.5 hr	*Monochrysis lutheri* 50% reduction in oxygen evolution	Hollister and Walsh 1973
	OCHROPHYTA: (Yellow-Green Algae)	3	3	4	EC_{50} = 185 µg/L	SW 72 hrs	*Nannochloropsis gaditana* 50% total fluorescence inhibition	Debelius et al. 2008

	AVEOLATES:							
	PYRROPHYCOPHYTA (Dinoflagellates):	4	5	5	EC_{50} = 17.19 µg/L NOAEC < 12.5 µg/L	SW 96 hrs.	*Amphidinium operculatum* 50% reduction in total biovolume	DeLorenzo et al. 2004
	CILIOPHORA: (Ciliates)	2	2	2	ED_{50} = 5.83 µg/L	FW 24 hrs	*Tetrahymena pyriformis* 50% reduction in survival	Toth & Tomasovicova 1979
EXCAVATES	**EUGLENOZOA:** (Euglenoids)	1	1	1	EC_{50} = 496 µg/L	FW 7 days	*Euglena gracilis* 50% inhibition of photosynthesis	Thuillier-Bruston et al. 1996

[1]These endpoints were collected over different exposure periods.
[2]FW= fresh water, SW = salt water
[3]The Embryophytes are treated separately here.

Eubacteria: Toxicity data from studies on Cyanobacteria (Cyanophyceae) span three orders and include six species: the Oscillatoriales (*Oscillatoria lutea*), the Nostocales (*Anabaena cylindrica; A. inaequalis; A. variabilis; A. flos-aquae*), and the Chroococcales (*Microcystis aeruginosa*). The lower 95% confidence interval on the overall EC_{50} data in the ECOTOX database is 13.6 µg/L. The most sensitive endpoint from these open literature data reports a 93% reduction in chlorophyll production at <1 µg/L in *O. lutea* in a 7-day study (**Table 49**). In another study (Stratton 1984) using *A. inaequalis*, the most sensitive endpoint was reduced biomass (measured as cell count) followed by reduced growth rate and lastly by reduced photosynthesis. This pattern of reduced biomass as the most sensitive measured endpoint was reflected in several other studies on cyanobacteria (**Appendix B).**

Archaeoplasida (Embryophyta): Under the broad category "Non-Vascular Aquatic Plants" the Bryophyta (mosses, liverworts and hornworts) are the only group that is represented (**Table 49**). All other Embryophyta taxa are represented in either aquatic or terrestrial vascular plant sections of this risk assessment. The available toxicity data for bryophyta does not report an EC_{50}; however, an EC_{90} of 2 µg/L is reported for the species *Fontinalis hypnoides* based on reduced photosynthesis (Hoffmann and Winkler 1990). This study also reports morphological effects to the structural composition of chloroplasts and leaf blade cellular structure at 2 and 10 µg/L, respectively.

Archaeoplasida (Chlorophyta and Streptophyta): This group of non-vascular plants is represented by 118 different studies in the toxicity literature, including 16 different families and 34 species of both marine and freshwater environments (**Table 49**). The lower 95% confidence interval on the overall EC_{50} data in the ECOTOX database is 20.0 µg/L. The most sensitive endpoint for the freshwater toxicity tests is based on a 67% reduction in chlorophyll production in *Stigeoclonium tenue* at <1 µg/L (Torres and O'Flaherty 1976). The authors also tested *Chlorella vulgaris* and report a 50% reduction in chlorophyll production at 1 µg/L. In another study by Kish (2004), the author reports a NOAEC of 0.012 µg/L for *Pithophora oedogonia* based on total chlorophyll. In the saline aquatic systems, this group of Archaeoplasida is less sensitive than their counterparts in freshwater.

Archaeoplasida (Prasinophyta): This group of non-vascular plants is represented by 5 different studies in the toxicity literature, including 2 different families and 4 species (**Table 49**). The most sensitive endpoint for the freshwater toxicity is an EC_{50} of 34.3 µg/L based on reduced photosynthesis (Podola and Melkonian 2005). The most sensitive endpoint for saltwater taxa is an IC_{50} of 14.2 µg/L, based on 50% photoinhibition (Magnussun *et al*. 2010).

Archaeoplasida (Rhodophyta): The Rhodophyta (red algae) are represented in the toxicity literature by the *Porphyridium cruentum* (Bangiophyceae) (**Table 49**), which is the species from which the Japanese seaweed Nori is produced (Mayer 1986). This study reported a reduction in O_2 production, which reflects the decline in photosynthetic activity, at an EC_{50} of 79 µg/L. The data suggest that the red algae may be less sensitive to atrazine than the other Arcaeoplastida groups.

Chromalveolates (Hacrobia): These taxa are represented in the toxicological literature by 4 different families and 7 species (**Table 49**). The most sensitive reported endpoints come from the DeLorenzo *et al*. (2004) study that reported an EC_{50} of 22.17 µg/L based on reduced abundance but also report effects at the lowest concentration tested (12.5 µg/L). Similarly, Debelius *et al*. (2008) reported a 50 % growth inhibition at 30 µg/L.

Chromalveolates (Stramenopiles): The Stramenopiles are a highly diverse lineage of aquatic organisms that include diatoms, brown algae, golden-algae and yellow-green algae. They are represented by studies including 24 different families and 56 species of both marine and freshwater environments (**Table 49**). The available data suggests that these taxa have relatively similar toxicity to atrazine exposure. The most sensitive freshwater taxon, *Phaeodactylum tricornutum*, was reported to have a 50% inhibition of photosynthesis at 33.6 µg/L and effects at the lowest concentration tested, 4.5 µg/L (Magnussun *et al*. 2010). The most sensitive estuarine/marine taxon tested is a diatom with an EC_{50} of 19.4 µg/L based on population growth reduction (Walsh *et al*. 1988). In a study of atrazine toxicity to brown algae by Hopkin and Kain (1978), reproductive and sporophyte growth effects were reported at all concentrations tested (NOAEC < 1 µg/L).

Chromalveolates (Aveolates): This diverse lineage of aquatic microorganisms is represented in the toxicological literature by 4 different families and 5 species (Table 4.2). The most sensitive reported EC_{50} is 17.19 µg/L (NOAEC < 12.5 µg/L) based on reduction of total biovolume (DeLorenzo *et al*. 2004).

Chromalveolates (Ciliophora): Ciliates are represented in the toxicological literature by 5 studies on two species from different families (**Table 49**). The most sensitive reported endpoints come from the Toth and Tomasovicova (1979) study that reported ~ 50 % reduction in survival at 5.83 µg/L.

Excavates (Euglenozoa): The euglenoids are represented in the toxicological literature by only one study on *Euglena gracilis* (**Table 49**; Thuillier-Bruston *et al.* 1996). The authors report a 50% inhibition of photosynthesis at 496 µg/L.

Unikonts (Amebozoa): The Unikonts are a lineage that includes fungi, amoebae, collared-flagellates and animals (**Table 49**). There are a great number of studies on animals, which are discussed in **Section 11** of this assessment; however, only one aquatic single species test is available from the remainder of the Unikonts. This study on an amoeba reported an LD_{50} greater than 100 µg/L (Prescott and Olson 1977).

10.3. Toxicity to Aquatic Vascular Plants

Archaeoplasida (Embryophyta): Single-species aquatic plant toxicity studies are used as one of the measures of effect to evaluate whether atrazine may affect primary production and diversity in aquatic ecosystems. Numerous aquatic vascular plant toxicity studies have been

submitted to EPA and/or published in the open literature. **Appendix B** includes a more comprehensive list of the available data.

Freshwater vascular plants are as sensitive to atrazine as freshwater non-vascular plants, with the most sensitive vascular plant EC_{50} value of 4.6 µg/L, based on root dry-weight reduction (biomass reduction) in *Elodea* (McGregor et al. 2008) (**Table 49**). The available estuarine/marine toxicity data for aquatic vascular plants show less sensitivity than from fresh water studies, with 50% mortality of *Vallisneria Americana* at 12 µg/L from a 47-day study (Correll & Wu 1982).

The most sensitive single species data for aquatic vascular plants from either supplemental or acceptable studies (**Table 49**) are used for risk characterization and risk quotient calculations.

10.4. Toxicity to Aquatic Plant Communities

In addition to reviewing the toxicity data for individual species, the toxicity of atrazine to aquatic plant communities was evaluated. Concentrations of atrazine that affect plant productivity and community structure typically occur at levels lower than those that directly affect fish and aquatic invertebrates. This focus is designed to ensure that the atrazine concentrations in watersheds do not cause significant changes in aquatic plant community structure and productivity and thus put at risk the food chain and entire ecosystem integrity.

In this approach single-species plant toxicity data and cosm studies (**Appendix B; Appendix G, and Section 12.2.3**) are used to determine what atrazine exposure patterns and concentrations are likely to result in adverse effects to aquatic plant communities. From these data, a level of concern (LOC) is developed, which together with monitoring data is used to identify watersheds where atrazine levels are above that level of concern. While the LOC is based on effects to aquatic plant communities by ensuring protection of primary producers, it is intended to provide protection for the entire aquatic ecosystem including fish, invertebrates, and amphibians.

Potential effects of atrazine on plant communities were evaluated using available cosm studies (**Appendix G and Section 12.2.3**). Cosm studies conducted with atrazine provide measurements of primary productivity that incorporate the aggregate responses of multiple species in aquatic plant communities. Because plant species vary widely in their sensitivity to atrazine, the overall response of the plant community may be different from the responses of the individual species measured in laboratory toxicity tests. Cosm studies allow observation of population and community recovery from atrazine effects and of indirect effects on higher trophic levels. In addition, cosm studies, especially those conducted in outdoor systems, incorporate partitioning, degradation, and dissipation, factors that are not usually accounted for in laboratory toxicity studies, but that may influence the magnitude of ecological effects.

10.4.1. COSM Study Screening Criteria

The process for reviewing cosm studies (**Appendix G**) started with the establishment of criteria for selection. First, all studies were prescreened. The screen required that: (1) treatments were exposed to only atrazine, and not mixtures or multi-active ingredients, (2) exposure concentrations were reported, (3) measured effects were specific to aquatic plant communities (defined as two or more species), and (4) the study was written in English. If any of these four criteria were not met, the study was no longer considered for use.

Studies that met the basic elements of the prescreen criteria were further screened using additional quality criteria (**Appendix G**). Criteria included basic elements such as use of controls and use of at least two replicates per treatment group. The accepted studies were then used as the basis for deriving the initial atrazine Concentration Equivalent Level of Concern (CELOC; See **Section 12.2** for complete details on the CELOC methodology). The acceptance criteria presented in **Appendix G** are intended to identify studies with confounding study design and performance elements to allow greater confidence in the study results. The criteria were derived using peer reviewed sources from U.S. EPA, SETAC (Society of Environmental Toxicology and Chemistry), and OECD (Organization for Economic Co-operation and Development) (Giddings *et al*. 1999; OECD, 2004; U.S. EPA, 2004).

10.4.2. COSM Study Evaluation and History

A total of 35 cosm studies were originally included in the 2003 IRED (USEPA 2003c), and an additional 38 cosm studies were identified in the May 2009 SAP for a total of 73 studies. After the prescreening and acceptance criteria were applied to the 73 studies, 46 studies were considered acceptable for inclusion in the development of the LOC for aquatic plant communities. Citations of all 73 cosm studies considered can be found in **Appendix G**. Since the 2012 SAP, an additional three studies were added to the list (**Section 12.2.3**).

A total of 97 endpoints were used in the analysis to develop the LOC for atrazine. These endpoints came from the 49 studies that passed the prescreening and acceptance criteria. Effects observed in the cosm studies included changes in aquatic plant biomass, chlorophyll *a* concentration, photosynthesis rate (^{14}C uptake, oxygen production), and shifts in aquatic plant community structure (*e.g.*, species composition and diversity) relative to a control. The durations of these studies ranged from a few weeks to several years at constant or variable and declining exposure concentrations ranging from 0.1 µg/L to 10,000 µg/L.

The 2012 SAP Panel recommended changes to the cosm dataset, which would reduce the number of cosm endpoints to be included in the CELOC calculation. These recommendations included restricting the candidate cosm study endpoints to those within the typical concentration and duration window for atrazine. Based on the Atrazine Ecological Exposure Monitoring Program (AEEMP), EPA determined that a 240-day exposure/testing window would adequately represent the typical seasonal exposures of atrazine in the midwestern corn

producing regions. The time restriction impacts endpoints 1, 2, 4, 5, 41, and 42 (**Appendix G**). These endpoints all originate from a series of multi-year experiments conducted at the University of Kansas from 1979-1991 (summarized in deNoyelles *et al.* 1982 and 1989). The effects noted in these studies were initially reported within the first few days to weeks following atrazine introduction into the mesocosms. However, as these effects were occurring throughout the study, they were considered as relevant to the expected durations in the environment, so these endpoints were not removed from the current cosm endpoint database.

The Panel's recommendation to limit the endpoints to more environmentally-relevant atrazine exposures, as identified from monitoring data, reduced the available cosm endpoint database. The peak non-spill related concentration of atrazine in the natural environment is 375 µg/L. EPA has decided to use 500 µg/L to bound the upper concentration for inclusion in the analyses. This resulted in the removal of 11 endpoints (**Table 50**) from the cosm database.

Table 50. Endpoints Removed from Available Cosm Endpoint Database Due to Restriction of Initial Endpoint Concentrations to Those Below 500 ppb.

Endpoint Number	Reference(s)	Initial Test Concentration (µg/L)
14	Stay *et al*., 1985	820
15	Stay *et al.*, 1985	3980
19	Brockway *et al.*, 1984	5000
27	Johnson, 1986	1000
29	Kosinski, 1984; Kosinski and Merkle, 1984	1000
30	Kosinski, 1984; Kosinski and Merkle, 1984	10000
33	Moorhead and Kosinski, 1986	1000
37	Stay *et al.*, 1989	1000
38	Stay *et al.*, 1989	5000
45	Moorhead and Kosinski, 1986	10000
97	Diana *et al*., 2000	2036

Most of the studies focused on atrazine effects on phytoplankton, periphyton, and macrophytes; however, some also included measurements on fish and/or invertebrates. Although most studies did not provide the identity of the phytoplankton, periphyton or zooplankton, those that did report it showed that a great diversity of taxa were tested (**Table 51**). The numbers provided in **Table 51** only reflect a subset of the microorganism diversity tested. Estimates from some studies suggest that there were 150-200 microorganism species present in a single mesocosm sourced from lake water (*e.g.,* Pratt *et al.* 1988). It is assumed that these studies represent natural communities and the breadth of diversity found in North American freshwater environments. A summary of all cosm endpoints used in the analysis is presented in **Appendix G**.

Table 51. The taxonomic distribution of reported species in COSM studies. See **Figure 23** and discussion in **Section 10.2** for representatives of these taxonomic groups and relationships between them. These numbers represent only approximations of those taxa that were identified to genera and/or species. **Appendix B** contains details on which COSM studies contained these taxa.

Taxonomic Group		Genera	Species
EUBACTERIA:	CYANOBACTERIA: (Blue-Green Algae)	14	27
EUKARYOTES			
ARCHAEOPLASTIDA	**GREEN PLANTS:**		
	EMBRYOPHYTA: (Non-Vascular Land Plants)	-	-
	EMBRYOPHYTA: (Vascular Land Plants)	11	20
	CHLOROPHYTA and STREPTOPHYTA: (Green Algae)	43	86
	PRASINOPHYTA: (Prasinophytes)	1	1
CHROMALVEOLATES	**HACROBIA:**		
	HAPTOPHYTA: (Coccolithophorads)	2	4
	CRYPTOPHYTA: (Cryptomonads)	4	13
	STRAMENOPILES:		
	BACILLARIOPHYTA: (DIATOMS)	24	67
	CHRYSOPHYTA: (Golden Algae)	7	12
	XANTHOPHYTA: (Yellow-Green Algae)	2	2
	AVEOLATES:		
	PYRROPHYCOPHYTA (Dinoflagellates):	4	4
EXCAVATES	**EUGLENOZOA:** (Euglenoids)	1	1
UNIKONTS	**FUNGI:**	2	2
	CHOANOFLAGELLIDA:	3	3
	ANIMALS:		
	VERTEBRATES:	9	15
	INVERTEBRATES:	137	196

10.4.3. COSM Endpoint Scoring Criteria

Effects in the cosm studies were scored using a binary effect/no effect score. In previous analyses, the cosm studies were assigned Brock scores, which is a 5-point effects scoring system. A Brock score of 1 was assigned to studies that did not produce an effect and a Brock score of 5 was assigned to studies that produced clear effects without recovery for 56 days or more. Studies with Brock scores of 1 (no effect) or 2 (slight or transient effect) were

distinguished from studies assigned 3 (clear effect with recovery) or higher for the LOC analysis. Functionally, the binary effects scoring is identical to the manner in which Brock scores were used (Brock scores of 1 and 2 were considered no effects and Brock scores of 3 or higher were considered to be effects). However, in response to recommendations by the 2009 SAP (USEPA 2009a), all Brock scores were re-evaluated to ensure that each endpoint was categorized into the appropriate "effect" or "no effect" group. A binary effect/no effect system was considered to be more clear and transparent, which is the reason for adopting it for this analysis.

The EPA established criteria for scoring an endpoint in a cosm as an effect or no effect classification (described below) followed the same basic principles discussed in Brock *et al.* 2000 and de Jong *et al.* 2008. Each endpoint was evaluated by a panel of EPA scientists, and discussed and justified in a Data Evaluation Record (DER) for each study, which is available in the docket for Atrazine http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2003-0367). The EPA scientists determined that an effect had occurred at a specific test concentration based on a statistically significant difference from the control or based on the magnitude and duration of the effect in the absence of a statistical analysis. The EPA scientific committee reviewing the cosm studies had further discussions about endpoints that were challenging to classify to determine the final endpoint classification through best professional judgment and scientific consensus.

In the absence of statistical analysis, EPA used the following criteria to judge whether or not an effect was treatment-related:

a. Professional judgment based decisions took into consideration the replication of treatment concentrations within the study, the type of endpoint, the variability in the response within and across test concentrations, the magnitude of the effect, and lastly, recovery. Generally, slight differences from the control were not considered effects in the absence of statistical analysis. However, in some cases, an endpoint may have been classified as an "Effect" when the magnitude could be considered as slight, but the difference from the control was statistically significant and persisted throughout the study. An effect was considered transient when recovery occurred quickly. However, it was not always possible to determine whether or not an effect was transient due to the study design and measurement schedule. Slight or transient effects were classified as a "No effect" for that test concentration. These effects would be considered as category 1 or 2 under the Brock *et al.* (2000) and de Jong *et al.* (2008) methods.

b. A pronounced effect did not require statistical significance for most endpoints (*e.g.,* species composition, or chlorophyll A). In some cases a pronounced effect was reported; however, recovery of the measurement had occurred by the next measurement. Most pronounced effects reported did not recover by the end of the cosm experiment and were classified as an "Effect".

c. In the available cosm study dataset, recovery was only reported in a few of the studies. Graphics and data presented in each of the studies were used to qualitatively review if

recovery had occurred; however, this was difficult to interpret in most studies. Recovery from the effects of atrazine and the development of resistance to the effects of atrazine in some vascular and non-vascular aquatic plant species have been reported in both single species studies and cosm experiments. However, reports of recovery were often based on differing interpretations. Additional uncertainty for recovery is that a single endpoint measurement (*e.g.*, chlorophyll A) may show recovery, but other significant changes, such as community composition shifts, may have occurred in the study and were not documented or recovery was not observed.

Recovery from the effects of atrazine and the development of resistance to the effects of atrazine in some vascular and non-vascular aquatic plant species have been reported in both single species studies and cosm experiments and may add uncertainty to these findings. For the purposes of this assessment, recovery is defined as a return to pre-exposure levels for the *affected individual, population or community*, not for a replacement population or community of more tolerant species.

11. TOXICITY TO ANIMALS

Animal toxicity data for terrestrial and aquatic species from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under specific conditions and with species defined in OCSPP toxicity test guidelines. A summary of specific assessment endpoints to be used quantitatively in the assessment are listed in **Table 52**. These studies and additional toxicity endpoints, including degradate toxicity data, are discussed in more detail under the specific taxon below.

Table 52. Summary of Endpoints for Animals Considered in this Assessment for Estimating Quantitative Risks to Non-target Taxa

TAXA	MEASURE OF EFFECT			
Survival, growth and/ or reproduction of:	**Species**	**Toxicity**	**Endpoint**	**MRID/ECOTOX number**
Aquatic Species				
Freshwater Fish	***Acute***			
	Oncorhynchus mykiss Rainbow trout	LC_{50} = 5,300 ug a.i./L	Mortality	MRID 00024716
	Chronic			
	Oryzias latipes Japanese Medaka	NOAEC = 5 ug a.i./L LOAEC = 50 ug a.i./L	Reduced cumulative egg production	Papoulias *et al.* 2014[1]
Freshwater Invertebrates	***Acute***			
	Chironomus tentans Midge	EC_{50} = 720 ug a.i./L	Mortality	MRID 00024377
	Chronic			
	Gammarus fasciatus Scud	NOAEC = 60 ug a.i./L LOAEC = 140 ug a.i./L	Growth of second generation	MRID 00024377
	Acute			

Estuarine/Marine Fish	*Cyprinodon variegates* Sheepshead minnow	LC_{50} = 2,000 ug a.i./L	Mortality	MRID 452083-03 & 452277-11
	Chronic			
	Oryzias latipes Japanese Medaka	NOAEC = 5 ug a.i./L LOAEC = 50 ug a.i./L	Reduced cumulative egg production	Papoulias *et al.* 2014[1]
Estuarine/Marine Invertebrates	***Acute***			
	Neomysis integer Opposum shrimp	LC_{50} = 48 ug a.i./L	Mortality	E103334
	Chronic			
	Neomysis integer Opposum shrimp	Estimated NOAEC = 3.8 ug a.i./L	Mortality[2]	Based on ACR analysis[2]
Terrestrial Species				
Birds	***Acute***			
	Colinus virginianus Northern bobwhite quail	LD_{50} = 783 mg a.i./kg-bw	Mortality	MRID 00024721
	Sub-acute			
	Anas platyrhynchos Mallard Duck	LC_{50} >5000 mg a.i./kg-diet	Mortality	MRID 00022923
	Chronic			
	Anas platyrhynchos Mallard Duck	NOAEC < 75 mg a.i./kg-diet LOAEC = 75 mg a.i./kg-diet	Hatchling weight	MRID 42547101
Mammals	***Acute***			
	Rattus norvegicus Norway Rat	LD_{50} = 1,869 mg a.i./kg-bw	Mortality	MRID 00024706
	Chronic			
	Rattus norvegicus Norway Rat	NOAEL = 50 mg a.i./kg-diet /3.7 mg a.i./kg-bw (females)	Based on decreased body weights, decreased body weight gains and food consumption	MRID 40431306
Terrestrial Invertebrates	***Acute***			
	Apis mellifera Honey Bee	LD_{50} > 97 µg/bee (contact)	Mortality	MRID 00036935

[1] Not captured in ECOTOX 2014 refresh, retrieved through open literature; based on general conservation of other endpoints for fish and invertebrate between fresh and estuarine/marine environments and the lack of a similar study for estuarine/marine fish, this endpoint was applied for chronic assessment for fish in both freshwater and marine and estuarine environments.

[2] An estimated acute to chronic ratio of 12.5 was derived for mysid shrimp based on an acute LC50 of 1000 µg/L (MRID 45202920) and a chronic NOAEC of 80 µg/L (MRID 45202920) and applied to the most sensitive acute endpoint of 48 ug a.i./L for opposum shrimp (*Neomysis Integer*) (48/12.5 = 3.8 ug a.i./L).

11.1. Toxicity to Terrestrial Animals

11.1.1. Toxicity to Birds, Reptiles and Terrestrial Phase Amphibians

Effects data for acute and chronic bird, terrestrial-phase amphibian, and reptile data, including data published in the open literature, are summarized in the following sections. A summary of the most sensitive endpoints for birds is presented in **Table 53**. Also included in **Table 53** are relevant endpoints on degradate and formulation toxicity to birds. Additional studies and details on the studies summarized below are included in **Appendix B.** EPA uses birds as a surrogate for terrestrial-phase amphibians and reptiles when sufficient toxicity data for each specific taxonomic group are not available.

Table 53. Summary of the most sensitive endpoints for bird acute, subacute and chronic toxicity data for atrazine and degradation products

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
ACUTE ORAL					
Northern Bobwhite quail (*Colinus virginianus*)	LD_{50} = **783** mg a.i./kg-bw	Atrazine TGAI (unknown %)	00024721 (Fink, 1976)	Acceptable	Conducted with 14 day old chicks and study only conducted for 8 days; Considered acceptable as no deaths occurred after the fourth day
Mallard Duck *(Anas platyrhynchos)*	LD_{50} >2,000 mg/kg-bw (1,520 mg a.i./kg-bw)	Atrazine 80 WP 76 %	001600-00 Hudson, Tucker & Haegle 1984	Supplemental	Formulation; supplemental as only 3 birds used; 6-months old; 14-day test
Northern bobwhite quail *(Colinus virginianus)*	LD_{50} >2,000 mg a.i./kg-bw	<u>**Degradate:**</u> Deisopropylatrazine (DIA) 96%	465000-07 Stafford, 2005a	Acceptable	18-week old chicks; 14-day test
Northern bobwhite quail *(Colinus virginianus)*	LD_{50} >2,000 mg a.i./kg-bw	<u>**Degradate:**</u> Hydroxyatrazine (HA) 97.1%	465000-08 Stafford, 2005b	Acceptable	18-week old chicks; 14-day test

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
Northern bobwhite quail *(Colinus virginianus)*	LD_{50} = 768 mg a.i./kg-bw	**Degradate:** Deethylatrazine (DEA) 96%	465000-09 Stafford, 2005c	Acceptable	16-week old chicks; 14-day test
SUB-ACUTE DIETARY					
Mallard duck (*Anas platyrhynchos*)	**LC_{50} >5,000** mg a.i./kg-diet	Atrazine TGAI (99%)	00022923 (Hill *et al.* 1975)	Supplemental	Conducted with 10 day old ducklings; 30% mortality at 5,000 mg a.i./kg-diet; supplemental due to no raw control data
Northern bobwhite *(Colinus virginianus)*	LC_{50} >5,000 mg a.i./kg-diet	Atrazine TGAI (99%)	00022923 (Hill *et al.* 1975)	Supplemental	Conducted with 9-days old chicks; supplemental due to no raw control data
Northern bobwhite *(Colinus virginianus)*	LC_{50} = 5,760 mg a.i./kg-diet	Atrazine 80W 76 %	000592-14 Beliles & Scott 1965	Supplemental	Formulation; Supplemental due to use of 6 week old birds
Mallard duck (*Anas platyrhynchos*)	LC_{50} = 19,560 mg a.i./kg-diet	Atrazine 80W 76 %	000592-14 Beliles & Scott 1965	Acceptable	Formulation
CHRONIC					
Mallard duck (*Anas platyrhynchos*)	NOAEC **<75** mg a.i./kg-diet LOAEC = 75 mg a.i./kg-diet	Atrazine TGAI (97.1%)	42547101	Acceptable	Based on reduced hatchling weight at 75 mg a.i./kg – diet; effects seen on egg production and food consumption at 225 mg a.i./kg-diet
Northern Bobwhite quail (*Colinus virginianus*)	NOAEC = 225 mg a.i./kg-diet LOAEC = 675 mg a.i./kg-diet	Atrazine TGAI (97.1%)	42547102	Acceptable	Based on egg production and embryo viability

Bold = Values used quantitatively in risk assessment

11.1.1.1. ***Birds: Acute Exposure (Mortality) Studies***

The available data in birds suggest that atrazine is slightly toxic to avian species on an acute oral exposure basis. For parent atrazine, the lowest reported acute oral LD_{50} is 783 mg/kg-bw (bobwhite quail, *Colinus virginianus*) (MRID 00024721). The previous Data Evaluation Record (DER), which reported the study authors' LD_{50} result, was recalculated using the current EFED methodology. In addition, this study was conducted using 14-day old birds as opposed to typically adult birds. For an atrazine formulation in which the resulting LD_{50} values were >2,000 mg/kg-bw (1,520 mg a.i./kg), signs of poisoning in mallards (*Anas platyrhynchos*) first appeared 1 hour after treatment and persisted up to 11 days, and in ring-necked pheasants, (*Phasianus colchicus*), remission of signs of intoxication occurred by 5 days after treatment (U.S. EPA, 2003a; MRID 001600-00). Signs of poisoning included weakness, hyper-excitability, ataxia, and tremors; weight loss also occurred in mallards.

An acute oral toxicity study with passerines is not available for atrazine.

Because all subacute avian LC_{50} values are greater than 5,000 mg/kg-diet, atrazine is categorized as practically non-toxic to avian species on a subacute dietary basis. In the subacute dietary study in mallard ducks (*A. platyrhynchos*), 30% mortality was observed at the highest test concentration of 5,000 mg/kg-diet (MRID 00022923); one mortality was observed in the Japanese quail (*Coturnix japonica*) study at 5,000 mg/kg-diet. The time to death was Day 3 for the one Japanese quail (*C. japonica*) and Day 5 for three mallard ducks (U.S. EPA, 2003a; MRID 00022923 and 0002292; J. Spann at Patuxent Wildlife Center, 1999, personal communication). Four species of birds were tested in the Hill *et al.*, (1975) (MRID 00022923) study; however, control performance for the tests was not reported. In addition, the treated feed was not analyzed for stability.

11.1.1.2. ***Birds: Chronic Exposure (Growth, Reproduction) Studies***

Reproduction studies in birds have reported effects at atrazine concentrations of 75 mg a.i./kg-diet and higher. Both northern bobwhite quail (*C. virginianus*) and mallard duck (*A. platyrhynchos*) reproduction studies were conducted using atrazine. Stability or homogeneity in the test feed was not analyzed for either study and therefore, there is uncertainty in the dietary exposure concentration. In the northern bobwhite study, the following endpoints were affected at 675 mg a.i./kg-diet: egg production and embryo viability, and a reduction in weight gain in the males (MRID 42547102). The number of cracked eggs in the control was about three times the accepted threshold noted in the OCSPP 850.2300 guideline. The NOAEC in the bobwhite study was 225 mg a.i./kg-diet. In the mallard study, decreased hatchling weight was significant at all concentrations tested, with decreases ranging from 5.3 to 12.3% at 75 to 675 mg a.i./kg-diet, respectively. At a concentration of ≥225 mg a.i./kg-diet, there were effects on egg production and mean food consumption while live embryos and hatchlings per eggs set and male weight gain were affected at 675 mg a.i./kg-diet. (MRID 42527101). The previous DER reported the NOAEC in this study as 225 mg/kg-diet. These endpoints have been revised based

on the effects noted herein at both 225 and 75 mg/kg-diet. For the purposes of this risk assessment, 75 mg a.i./kg-diet serves as the toxicological endpoint for evaluating chronic effects in birds.

11.1.1.3. ***Birds: Sublethal Effects***

Japanese quail (*C. japonica*) were exposed to atrazine [35% (w/w)] at concentrations of 10, 25, 50, 100, 250 and 500 mg/kg-bw in a 45 day oral dosing study (Hussain *et al*., 2011; E153875). Body weights (absolute) were reduced at atrazine concentrations of 25 mg/kg-bw at 45 days. Feed consumption and leukocyte counts were reduced at concentrations of 50 mg/kg-bw and above. Testes were reported to be grossly smaller in size in all treatment groups at 45 days; however, there was no significant difference in testes weights relative to controls at this sampling point. Other reported changes included hematological changes, behavioral changes and histopathological changes at higher test doses. The name and type of formulation used in the study were not reported. It was also not apparent if the dosages were adjusted for the % formulation of atrazine and a vehicle control was not used.

11.1.1.4. ***Birds: Degradate Toxicity***

Available toxicity data for atrazine degradates in the northern bobwhite are summarized in **Table 53**. Based on the available acute oral studies, the northern bobwhite was more sensitive to the parent compound and therefore was the preferred test species for degradate toxicity testing. For degradates DIA and HA, reported LC_{50} values indicated these compounds have lower toxicity than the parent compound. However, LC_{50} values for DEA indicated a very similar but slightly higher toxicity than the parent compound. As discussed in **Section 7.2.6,** DEA was detected in all laboratory and field studies and had the highest relative concentration of all degradation products in soil. No information is available on the toxicity of DEHA, DIHA or DACT in birds. DACT has been shown to be of equivalent toxicity compared with atrazine in mammals **(Section 11.1.3**).

11.1.1.5. ***Birds: Additional open literature identified since the 2012 Problem Formulation***

The ECOTOX database was reviewed for any additional studies not previously captured regarding the toxicity of atrazine in birds since the 2012 Problem Formulation. No additional studies were identified with more sensitive apical endpoints than those previously discussed. All studies are summarized in **Appendix B**.

11.1.2. Toxicity to Reptiles

Limited data are available for reptiles as discussed below, and there was limited available data for terrestrial-phase amphibians.

Atrazine was tested on eggs of the red-eared slider turtle (*Trachemys scripta elegans*) and the American alligator (*Alligator mississippiensis*) to determine if atrazine produced endocrine effects on the sex of the young (Gross, 2001). The turtle and alligator eggs were placed in nests constructed of sphagnum moss treated with 0, 10, 50 100 and 500 µg a.i./L for 10 days shortly after being laid. No adverse effects were found. Analysis of the embryonic fluids indicated that no atrazine was present in the eggs at the detection limit (0.5 µg/L) (MRID 455453-03 and 455453-02).

Two additional open literature studies in which snapping turtle (*Chelydra serpentine*) and alligator eggs (*Alligator mississippiensis*) were exposed to atrazine either via direct application or incubation in soil treated with atrazine were available (De Solla *et al*., 2006 and Crain et al., 1999). In the snapping turtle study, concentrations tested were 1.32 and 13.2 lb a.i./A TGAI (corresponding to 0.64 and 8.1 ppm in soil). Some males with testicular oocytes and females were produced in the atrazine-treated groups (3.3 – 3.7%), but not in the control group; however, no statistical differences were found among the treatment and control groups. For the alligator study, tested concentrations ranged from 0.14 to 14 ppm topical application of TGAI to eggs. No differences in gonadal and reproductive tract histology or hepatic aromatase activity were observed in any of the atrazine-treated or control alligators. These studies are described further in **Appendix B.**

11.1.2.1. ***Reptiles: Additional open literature identified since the 2012 Problem Formulation***

The ECOTOX database was reviewed for any additional studies not previously captured regarding the toxicity of atrazine in reptiles and terrestrial-phase amphibians since the 2012 Problem Formulation.

One study was identified (E165290; Walters, 2014) in which the effects of atrazine on the scalation of neonate Marcy's checkered garter snakes, *Thamnophis marcianus,* was examined. Snakes were exposed to atrazine through the injection of mice fed to the snakes at corresponding concentrations of 10, 100 and 1000 µg a.i./kg-bw snake. Snakes were fed the atrazine injected mice once weekly for 18 months then hibernated for 7 weeks to stimulate reproduction. At birth, each neonate from an exposed mother had the number of left and right postocular, left and right upper labial, left and right lower labial, and split ventral scales counted. A significant increase in the number of head scales in both the 100 and 1000 ug/kg groups were noted as compared to controls. Although the study results indicated a statistically significant developmental alteration with maternal atrazine exposure, the author discussed the

theory that higher head scale counts could actually provide greater flexibility and ability to consume larger prey items, making it difficult to relate the observed effect to impaired fitness and survival of the individual.

Neuman-Lee et al. (2014) investigated the effects of atrazine ingestion on wild-caught northern watersnakes (*Nerodia sipedon*) and their offspring using multiple endpoints. Pregnant females were administered atrazine through dietary exposure at 2, 20, or 200 ug a.i./kg-diet. The diet consisted of live minnows (*Notropis sp.*) that received intramuscular injections of 0.1 mL of atrazine solution per gram of fish. The proportions of live born offspring were decreased in all atrazine treatment groups in a non-dose-dependent manner compared to controls. Atrazine treatment was also associated with effects on scale row symmetry at the mid-body also in a non-dose-dependent manner, with more asymmetries occurring in offspring born to mothers in the medium-dose ($p = 0.002$).

11.1.3. Toxicity to Mammals

A summary of the most sensitive endpoints for mammals is presented in Table 54.

Table 54. Summary of the most sensitive endpoints for mammalian acute and chronic toxicity data for atrazine and degradation products.

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
ACUTE ORAL					
Norway Rat (*Rattus Norvegicus*)	LD_{50} = 1,869 mg/kg-bw	Atrazine	00024706	Acceptable	Only overall male (M) & female (F) LD50 reported (not reported for M & F individually)
Norway Rat (*Rattus Norvegicus*)	LD_{50} = 1,240 mg/kg-bw	**Degradate:** Deisopropylatrazine (DIA) (*G-28279*) 96%	43013201	Acceptable	Overall M & F reported to be consistent with parent reporting; LD_{50} for M = 2290 mg a.i./kg-bw; F = 810 mg a.i./kg-bw
Norway Rat (*Rattus Norvegicus*)	LD_{50} = 1,110 mg/kg-bw	**Degradate:** Deethylatrazine (DEA) (*G-30033*) 96%	43013202	Acceptable	Overall M & F reported to be consistent with parent reporting; LD_{50} for M = 1890 mg a.i./kg-bw; F = 668 mg a.i./kg-bw
CHRONIC					
Norway Rat (*Rattus Norvegicus*)	NOAEL = 50 mg/kg-diet (3.7 mg/kg-bw)	Atrazine TGAI (97.1%)	40431306	Acceptable	2-generation reduction study in rat; Based on decreased body weights,

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
	LOAEL = 500 mg/kg-diet (39 mg/kg-bw)				body weight gains, and food consumption.
Norway Rat (*Rattus Norvegicus*)	NOAEL = 3.3 mg/kg-bw LOAEL = 34.5 mg/kg-bw	Atrazine TGAI (97.1%)	44723701	Acceptable	90 day oral toxicity in rodents (870.3100) Based on decreased body weights
Norway Rat (*Rattus Norvegicus*)	NOAEL = 2.5 mg/kg-bw LOAEL = 25 mg/kg-bw	**Degradate:** DACT (GS-28273) TGAI (97.1%)	41392402	Acceptable	Prenatal developmental toxicity in rodents (870.3700a) Based on decreased body weight gain during initial dosing period
Norway Rat (*Rattus Norvegicus*)	NOAEL = 3.2 mg/kg-bw LOAEL = 34.9 mg/kg-bw	**Degradate:** DIA (*G-28279*) TGAI (97.1%)	43013205	Acceptable	90 day oral toxicity in rodents (870.3100) Based on decreased body weights and body weight gains
Norway Rat (*Rattus Norvegicus*)	NOAEL = 3.2 mg/kg-bw LOAEL = 35.1 mg/kg-bw	**Degradate:** DEA (*G-30033*) TGAI (97.1%)	43013206	Acceptable	90 day oral toxicity in rodents (870.3100) Based on decreased body weights and food efficiency
Norway Rat (*Rattus Norvegicus*)	NOAEL = 1.0 mg/kg-bw LOAEL = 7.8 mg/kg-bw	**Degradate:** Hydroxytriazine (GS-17794) TGAI (97.1%)	43532001	Acceptable	Combined chronic toxicity/oncogenicity- rats (870.4100a) Based on gross and histopathological changes in the kidneys.

11.1.3.1. *Mammals: Acute Exposure (Mortality) Studies*

The acute oral LD_{50} value for parent atrazine in the rat (*Rattus norvegicus*) is 1,869 mg/kg-bw (MRID 00024706). Acute oral data for degradates DEA and DIA indicate similar acute toxicity as the parent compound for males and females combined; however, females appear more sensitive to both degradates. No data is available on acute toxicity of degradates DACT and HA.

11.1.3.2. *Mammals: Reproduction Toxicity Studies*

The mammalian LOAEL in reproduction toxicity studies was 500 mg a.i./kg-diet based on significant reductions in adult rat body weight and adult food consumption (NOAEL 50 mg a.i./kg-diet) (U.S. EPA, 2003a; MRID 40431303). In the 2-generation reproduction study (MRID 40431303), technical grade atrazine was administered to rats (*Rattus norvegicus*) 30/sex/dose) in the diet at concentrations of 0, 10, 50, and 500 mg a.i./kg-diet. Parental body weights, body weight gain, and food consumption were statistically significantly reduced at the 500 mg a.i./kg-diet dose in both sexes and both generations throughout the study. Compared to controls,

body weights for F_0 males and females at 70 days into the study were decreased by 12% and 15%, respectively, while F_1 body weight for the same time period was decreased by 15% and 13% for males and females, respectively. The only other parental effect, which may have been treatment related was a slight, but statistically significant increase in relative testes weight, occurring in both generations of the high dose. There did not appear to be any reproductive effects from compound exposure. Measured reproductive parameters from both generations did not appear to be altered in a dose-related manner. The LOAEL was 500 mg/kg-diet (39 mg/kg/day in males, 43 mg/kg/day in females) based on decreased body weights, body weight gains, and food consumption. The NOAEL was 50 mg/kg-diet (3.8 mg/kg/day in males, and 3.7 mg/kg/day in females).

Typically a 2-generation reproduction study is used to evaluate chronic toxicity to wild mammals. The study conducted using the rat (*Rattus norvegicus*) (MRID 40431303) described above has been used in previous evaluations; however, additional reproduction/developmental toxicity data are available for atrazine and it's degradates (U.S. EPA, 2011a). Table 54 above lists the most sensitive mammalian data for these compounds. Additional information and studies are listed in **Appendix B**. Between atrazine and the degradate data, there are 16 studies which report NOAECs in the range of 2.5 to 3.7 mg/kg-bw based primarily on decreased body weight or body weight gain (LOAECs range from 9.9 to 39 mg/kg-bw). As noted in Table 54, one study for hydroxytriazine reported a NOAEC of 1.0 mg/kg-bw (LOAEC = 7.8 mg/kg-bw) for gross and histopathological changes in the kidneys. Although not a specific apical endpoint, animals in the next higher concentration died from kidney failure and kidney changes noted in the lower concentrations tested could be indicators of early development of this disease. Based on the available studies, kidney disease appears to be a more sensitive endpoint for hydroxytriazine compared to weight gain.

11.1.3.3. *Mammals: Additional open literature identified since 2012 SAP*

A large body of literature is available on the sublethal effects of atrazine on mammalian species. Relevant apical endpoints from studies in the open literature are identified and discussed in **Appendix B**. No apical endpoints were identified from studies in the ECOTOX acceptable database that were more sensitive than the endpoints identified above; however, a large body of data is reported on a variety of effects to mammalian species in ECOTOX for atrazine. In order to illustrate the range of reported mammalian effects in the ECOTOX database, effects endpoints reported at concentrations less than 500 mg a.i./kg-bw are displayed graphically below. **Figure 24** illustrates the data available for dose based (mg a.i./kg-bw) endpoints for some of the organism level effects (mortality, growth, reproduction, behavior and physiology) as entered in the acceptable ECOTOX database. These studies were available in the ECOTOX database and were not fully reviewed by OPP, but were considered "acceptable" studies from the ECOTOX database based on EPA OPP criteria. Other data exists for multiple endpoints recorded in other units (ppm, mg/organism, etc.) and for other sublethal categories (biochemical, cellular, etc.) that were not displayed but are captured in the ECOTOX table in **Appendix B.**

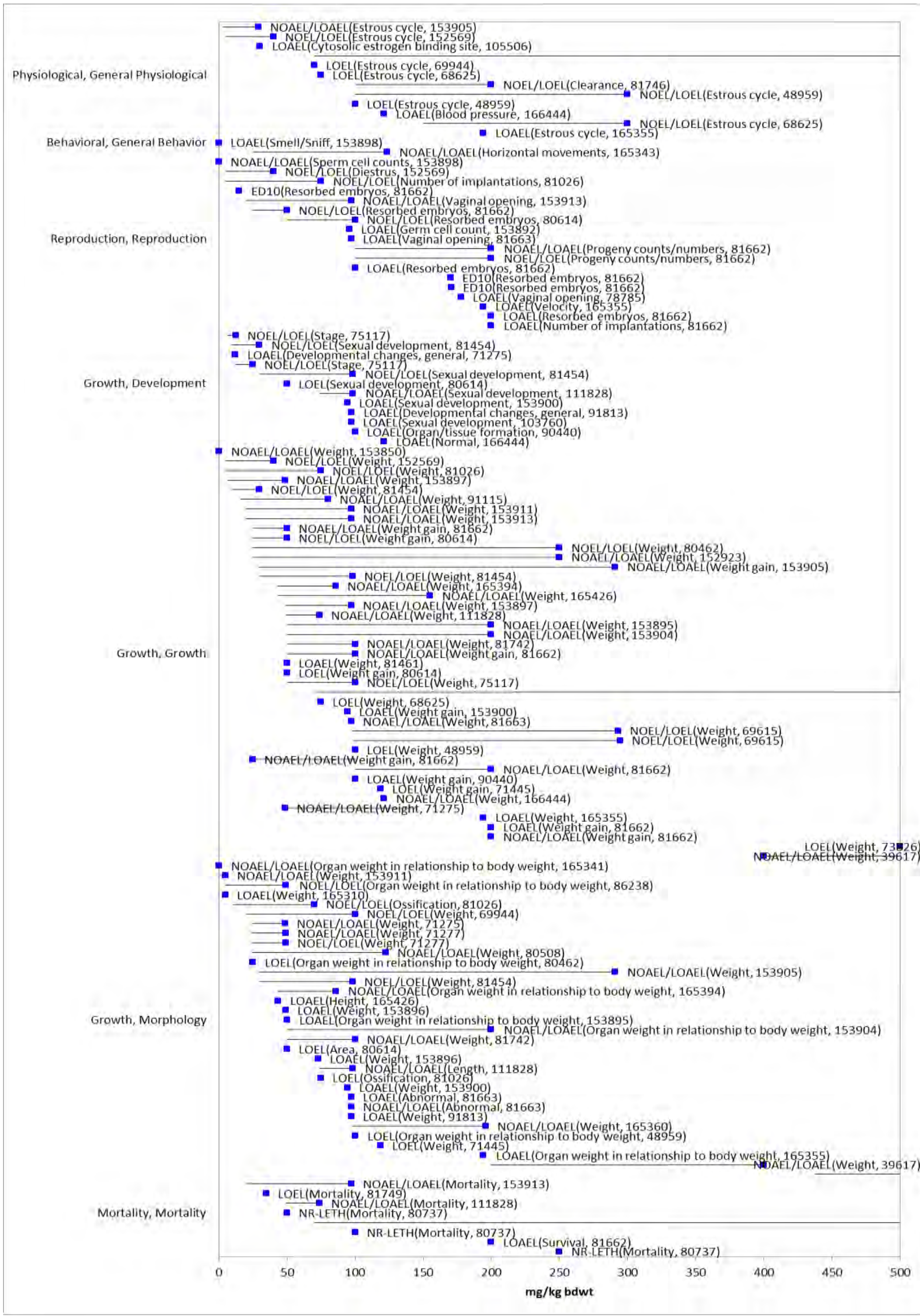


Figure 24. Subset of mammalian effects endpoints from ECOTOX database [denoted as (Effect, ECOTOX Ref id#].

11.1.4. Toxicity to Terrestrial Invertebrates

A summary of the available terrestrial insect data is presented in **Table 55** below. Additional details are included in **Appendix B**.

Table 55. Summary of Available Terrestrial Invertebrate Toxicity Studies

Species	Toxicity Summary	Comment	Citation
Beetles	NOAECs ranged from 0.8 lbs a.i./Acre to 8 lbs a.i./Acre	Soil sprayed with atrazine at levels that ranged from 0.8 to 8 lbs a.i./Acre did not result in statistically significant ($p<0.05$) reductions in survival. LOAEC: Not achieved	Kegel, 1989 ECOTOX No. 64007 Brust, 1990 ECOTOX No. 70406 Samsoe-Petersen, 1995 ECOTOX No. 63490
Earthworms	28-day LC_{50}: 381 mg/kg soil 14-Day LC_{50}: 273- 926 mg/kg soil	Spiked soil studies; endpoints included mortality and body mass	Mosleh et al., 2003 ECOTOX No. 77549 Haque and Ebing, 1983 ECOTOX No. 40493
Micro arthropods	NOAEC: 0.9 – 1.8 lbs a.i./Acre LOAEC: 5.4 lbs a.i./Acre	The LOAEC was based on reduced abundance from a field study (Fretello et al., 1985); it could not be determined if reduced abundance was caused by migration (repellency), by toxic effects, or both.	Cortet et al., 2002 ECOTOX No. 75784 Fratello et. al., 1985 ECOTOX No. 59428
Springtails	30-Day LD_{50}: 17 ppm to 20 ppm (approximately 7 lbs a.i./Acre)[a] LOAEC: 2.5 - 20 ppm soil (approx. 1 – 7 lbs a.i./Acre)[a]	Exposure occurred via treated soil; mortality rate at 2.5 ppm and 20 ppm soil was 18% and 51%, respectively, compared with 0% in controls.	Mola et al., 1987. ECOTOX No. 71417
Fruit flies *Drosophila*	NOAEC: 15 ug/fly	No increased mortality occurred in groups exposed to atrazine alone relative to controls.	Lichtenstein et al., 1973 Ecotox No. 2939
Honey bees	LD_{50}: >97 ug/bee	5% mortality occurred at the highest dose tested (97 ug/bee)	MRID 00036935
Earthworm Wire worm Springtail	LOAEC: 8 lb/acre NOAEC: Not achieved	Field study examining the impacts of several herbicides on soil invertebrate populations. The endpoint measured was abundance of several species. Study authors suggested that reduced abundance was likely caused by repellency and not direct toxicity.	Fox, 1964 ECOTOX No. 36668

[a] Application rate was estimated from soil concentration by assuming a soil density of 1.3 grams/cm^3 and a soil depth of 3 cm.

Atrazine is practically non-toxic to adult honey bees (*Apis mellifera L.*); the reported LD_{50} value is >97 µg/bee with 5% mortality reported at the highest dose tested (MRID 00036935). Atrazine also did not cause adverse effects in fruit flies (*Drosophila melanogaster*), houseflies (*Musca domestica*), and mosquito larvae (*Aedes aegypti*) exposed to 15 µg/fly (Lichtenstein *et al*., 1973). LC_{50} values in earthworms ranged from 273 to 926 ppm soil (Mosleh *et a*l., 2003; Haque and Ebing, 1983). Atrazine did not produce statistically significant (p>0.05) adverse effects in studies on several beetle species at any level tested, which ranged from application rates of approximately 1 lb a.i./Acre to 8 lbs a.i./Acre (Kegel, 1989; Brust, 1990; Samsoe-Petersen, 1995).

The most sensitive terrestrial invertebrate species tested was the springtail (*Onychiurus apuanicus* and *O. armatus*). Exposure to *O. apuanicus* at 2.5 ppm resulted in 18% mortality, and exposure to *O. armatus* at 20 ppm resulted in 51% mortality (Mola *et al*., 1987); lower levels were not tested. These soil concentrations are associated with an application rate of approximately 1 lb a.i./Acre and 7 lbs a.i./Acre, respectively, assuming a soil density of 1.3 grams/cm^3 and a soil depth of 3 cm. Additional details for these studies may be found in **Appendix B.**

The Agency has recently issued interim guidance for assessing the potential risks of pesticides to bees and the data needed to support such assessments (USEPA et al., 2014). The guidance document indicates that if exposure of bees to a pesticide is expected, a Tier I risk assessment is conducted. Using the new pollinator guidance to estimate terrestrial invertebrate risk, an RQ value for acute contact toxicity in the honey bee was calculated as 0.11; less than the LOC of 0.4 for acute exposure. However, risk to pollinators (e.g., honey bees) is an uncertainty due to the lack of data (i.e. oral or larval honey bee exposure with simazine) available in order to complete the Tier 1 risk assessment. If risk concerns are identified in the screening-level assessment, the assessment may be refined using data that further define exposure or through additional toxicity data from Tier II semi-field or Tier III full-field studies conducted with whole colonies.

11.2. Toxicity to Aquatic Animals

A brief summary of submitted and open literature data considered relevant to the ecological risk assessment for aquatic species is presented below. Additional information is provided in **Appendix B.**

11.2.1. Toxicity to Fish

A summary of acute and chronic fish data, including data from the open literature, is provided in the following sections (**Table 56**). Additional information is included in **Appendix B.** From the review of available parent and degradate toxicity information for aquatic animals, the parent atrazine was found to be generally of equal or greater toxicity than the tested degradates.

Therefore, the most sensitive endpoints and the following discussion focus largely on the parent compound.

Table 56. Summary of the most sensitive endpoints for fish acute and chronic toxicity data for atrazine and degradation products

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
ACUTE					
Freshwater Fish					
Rainbow Trout *(Oncorhynchus mykiss)*	LC_{50} = 5,300 ug a.i./L	Atrazine 98.8 %	000247-16 Beliles & Scott 1965	Acceptable	Water quality other than temp not reported
Bluegill sunfish (Lepomis macrochirus)	LC_{50} > 8,000 ug a.i./L 6,700 ug a.i./L (7-day test) (not specified)	Atrazine 94 %	000243-77 Macek et al. 1976	Supplemental	6.5-gram fish & no raw data
Estuarine/Marine Fish					
Sheepshead minnow (*Cyprinodon variegates*)	LC_{50} = 2,000 ug a.i./L	Atrazine 97.1%	MRID 452083-03 & 452277-11	Supplemental	No raw data on mortalities Based on 25% salinity (toxicity increased with increasing salinity)
CHRONIC					
Freshwater and Estuarine/Marine Fish					
Japanese Medaka (*Oryzias latipes*)	NOAEC = 5 ug a.i./L LOAEC = 50 ug a.i./L	Atrazine 98%	Papoulias *et al.* 2014	Supplemental	Based on reduced cumulative egg production

11.2.1.1. ***Acute Exposure (Mortality) Studies***

Atrazine toxicity has been evaluated in numerous fish species, and the results of these studies demonstrate a wide range of sensitivity. LC_{50} values range from 2,000 to 60,000 µg/L (2 mg/L to 60 mg/L) (See **Appendix B** for additional details on these studies)). Therefore, atrazine is classified as moderately to slightly toxic to fish on an acute basis. Several of the higher concentrations noted in these studies exceed the solubility limit (*e.g*. 60 mg/L is 2x the solubility).

11.2.1.1.a. ***Parent Atrazine: Freshwater Fish***

Acute toxicity data for freshwater fish are available for at least 8 different species. The most sensitive freshwater fish acute study is the rainbow trout with an 96-hour LC_{50} of 5,300 µg a.i./L, which appears to be based on nominal concentrations (MRID 43344901). In this study, the fish exhibited a dose-response change in coloration (darkening) for 48 hours after test initiation (data not reported). Other than temperature, water quality parameters such as dissolved oxygen were not reported in this static study; the dilution water was aerated prior to dosing and was renewed every 24 hours.

11.2.1.1.b. ***Parent Atrazine: Estuarine/marine Fish***

Atrazine toxicity data have been submitted for two estuarine/marine fish species: sheepshead minnow and spot (*Leiostomus xanthurus*). A sheepshead study (MRID 45208303; 45227711; LC_{50} = 2,000 µg a.i./L) and the spot study (MRID 45202920; LC_{50} = 8,500 µg a.i./L) only reported the LC_{50} value with no summary mortality data reported. In addition, in the sheepshead study the fish were fed at 48-hours which the reviewer indicated that the fish were *ca.* 48 hours old at test initiation and withholding food for 96 hours was not appropriate. Another sheepshead minnow acute study reported an 96-hour LC_{50} of 13,400 µg a.i./L, based on measured concentrations (MRID 00024716). At concentrations of 4,600 µg a.i./L and greater, fish in this study exhibited sublethal effects such as loss of equilibrium, surfacing and extended abdomen.

11.2.1.1.c. ***Atrazine Formulations***

Toxicity studies using atrazine formulations are available for freshwater fish. The acute LC_{50} values range from 12,600 to 42,000 µg a.i./L and are classified as slightly toxic. As in the TGAI acute studies, several of the higher concentrations noted in these studies exceeded the solubility limit. Based on comparison of acute toxicity data for technical grade atrazine and formulated products of atrazine, it appears that freshwater fish are more sensitive to the TGAI. Acute studies with atrazine formulations for estuarine/marine fish were not available.

11.2.1.2. ***Chronic Exposure (Growth/Reproduction) Studies***

Chronic freshwater fish toxicity studies are used to assess potential effects to fish and aquatic phase amphibians via potential effects primarily to growth and reproduction. Freshwater fish early life-stage and life-cycle studies, as well as early-life stage studies for estuarine/marine fish for atrazine are available and summarized in **Appendix B.** Some of these studies, in addition to open literature studies, are discussed below.

11.2.1.2.a. ***Freshwater Fish***

Several early life-stage (ELS) and life-cycle studies were available for freshwater fish using parent atrazine as well as ELS studies with atrazine formulations. For two of the ELS studies with rainbow trout (*Oncorhynchus mykiss*) and channel catfish (*Ictalurus punctatus*) the studies examined early life-stage and the study durations were too short to capture chronic exposure, with test durations of 27-d (4-d post hatch) and 8-d (4-d post hatch), respectively (MRID 45202902). However, reduced hatch survival was reported at the lowest test concentrations in both species (6% reduction at 19 µg/L in rainbow trout and 16% reduction at 28 µg/L in channel catfish) as compared to controls. Teratogenicity at hatch occurred in both species starting at approximately 50 µg/L that increased in a dose dependent manner. In addition, LC_{50}s were reported at 220 and 870 µg/L for hatch in channel catfish and rainbow trout respectively.

Another ELS study was conducted with rainbow trout (86-d duration) with a reported NOAEC and LOAEC of 410 and 1,100 µg/L, respectively, based on delayed hatching and reduced weight (MRID 45208304). However, this study was conducted with the solvent dimethylsufoxide (DMSO) which can promote movement of chemicals across membranes. It also appears that only one replicate tank was used per concentration and if more were used, then variability within a treatment group was not reported. In another submitted ELS study, zebrafish (*Brachydanio rerio)* were exposed for 35 days, and the reported NOAEC and LOAEC were 300 and 1,300 µg/L, respectively (MRID 45202908); raw data were not available.

In addition to the ELS studies, there were several life-cycle fish studies conducted with atrazine. A 44-week study using brook trout (*Salvelinus fontinalis*) resulted in the most sensitive NOAEC, 65 µg a.i./L based on growth (MRID 00024377). Several concerns with this study have been identified: 1) it appears the study did not use a solvent control although DMSO was used in the atrazine concentrations; therefore, potential solvent effects could not be evaluated; 2) the use of DMSO is discouraged as it can promote movement across membranes; 3) following distribution to the test chambers, the fish were treated with malachite green and formalin (25 µg/L of formalin containing 3.7 g/L malachite green) to prevent further disease (disease was observed prior to distribution to the tanks when the fish were treated at that time); and 4) according to the authors, variability in the reproduction endpoint was highly variable which precluded the ability to ascribe statistical significance to treatment groups that appeared to have reduced values. This variability may have been potentially enhanced by the use of only two replicates during the reproduction phase. The other chronic studies reported in MRID 00024377, bluegill sunfish (*Lepomis macrochirus*) and fathead minnow (*Pimephales promelas*), also appeared to use DMSO without a solvent control. In the bluegill study, the percent survival in the F1 generation was 22% after 30 days, and according to the authors the spawning was too sporadic to be conclusive. Control survival in the fathead minnow (*Pimephales promelas*) after 30 days was 47-60%. Another chronic fathead minnow life-cycle study, MRID 42547103, resulted in a non-definitive NOAEC (<150 µg/L) as growth in the F1 generation was significantly lower in all treatment groups compared to the negative control.

Short-term reproduction studies for freshwater fish were also available in which reproduction in adult fish was monitored for several weeks. These studies were conducted using mature actively-spawning fish to evaluate reproduction and did not capture exposure to embryo or larval stages. Adult fathead minnows (*Pimephales promelas*) were exposed to atrazine (5 and 50 µg/L) or 21-day with estradiol as a positive control (Brignole *et al.* 2004). While not statistically significant, the study authors reported a dose-dependent trend for percent embryos fertilized, male gonad-somatic index (GSI) and testicular maturity.

A 30-d short-term reproduction study with fathead minnow reported effects of atrazine on reproduction (total number of eggs, and number of spawns) as well as alterations in ovarian maturation compared to the control (Tillitt *et al*., 2010). These adverse effects were reported at a concentration of ≥0.5 µg/L; however, an apparent threshold response was observed as similar results were obtained at 0.5 and 5.0 µg/L. Limitations identified in this study included the lack of a negative control treatment group, the presence of histological abnormalities in the adult fish in the solvent control treatment group, variability in the measured test concentrations for the atrazine treatment groups, the use of replacement fish and uncertainty in the atrazine exposure for these fish and the acetone solvent concentration in the solvent control group was twice the highest rate recommended in the OCSPP 850 guidelines.

An additional 30-d short-term reproduction study was conducted exposing Japanese medaka (*Oryzias latipes*) to atrazine concentrations of 0.5, 5 and 50 µg/L (Papoulias *et al*., 2014). Total cumulative egg production was lower (36-42%) in all atrazine-exposed groups compared to the controls. According to the authors, the LOAEC in this study was reported at 0.5 µg/L for cumulative egg production. This study underwent extensive review by EPA and raw data were reanalyzed using statistical methodology consistent with EDSP Tier II Test guidelines 890.2200 (medaka extended one-generation reproduction test (MEOGRT), USEPA 2015). The complete analysis is detailed in EPA's Data Evaluation Record (DER) (**Appendix B**) for this study. Based on EPA's analysis, a statistically significant LOAEC for cumulative egg production was determined to be 50 µg/L and the corresponding NOAEC of 5 µg/L. This represents the lowest reproductive endpoint for freshwater fish.

In late 2015, the agency received another short-term reproduction study on the Japanese medaka (MRID 49694001). This study followed the OCSPP 890.1350 guideline but intended to repeat the Papoulias *et al.* (2014) study by testing concentrations of 0.5, 5.0, and 50 ug a.i./L. Fecundity in the negative control was 40.9 eggs/female/day/replicate, with eggs produced daily; and with fertilization success in controls at 91.6%. Atrazine did not significantly alter fertility or fecundity at any treatment level, however there were reductions of 6.5, 1.6, and 4.2 % fecundity in the 0.5, 5.0, and 50 ug a.i./L treatment levels. Plasma vitellogenin was significantly increased (p = 0.0090) in male fish at the mean-measured 0.0054 mg a.i./L treatment level; no differences were detected for females. No remarkable effects on gonadal histopathology were observed in male fish at any treatment level. A small number of fish showed an increase in atretic oocytes, however, the overall score for oocyte atresia did not show a concentration related increase. Atrazine exposure was associated with a slight (3.44%)

increase in female body length ($p = 0.0151$) in the 50 ug a.i./L treatment level. No other effects on secondary sex characteristics and clinical signs (*i.e.*, behavioral and other sublethal effects) were observed.

11.2.1.2.b. ***Estuarine/marine fish***

Two chronic toxicity tests with sheepshead minnow were available. The study with the most sensitive NOAEC was a 28 days post hatch early life-cycle study with a NOAEC value of 1,100 µg a.i./L based on growth; this study was classified as acceptable (MRID 46648203 and 46952604).

11.2.1.3. ***Sublethal Effects and Additional Open Literature Information***

In addition to registrant-submitted studies, data from the open literature that reported sublethal effect levels to freshwater fish were also evaluated. A number of open literature studies were reviewed as part of the 2003 IRED. The results of these studies, which showed sublethal effects to olfaction, behavior, kidney histology, and tissue growth at atrazine concentrations ranging from 0.1 to 3,000 µg/L (**Appendix B**). In addition, the risk assessment for the California red-legged frog (CRLF) (U.S. EPA, 2009b) also identified open literature studies reporting sublethal effects. Another open literature search was completed (via ECOTOX and including studies up until June 2014) and additional studies reporting sublethal effects were reviewed for this assessment. A summary of some of the reviewed studies are provided below.

Reported sublethal effects included a change in plasma vitellogenin in male and female rainbow trout and plasma testosterone in males at atrazine concentrations of ca. 50 µg/L (MRID 45622304). Effects on fish behavior, including preference for the dark part of the aquarium (MRID 45204910), grouping behavior (MRID 45202914), as well as alterations in trout kidney histology (MRID 45202907) have been reported at atrazine concentrations of 5 µg/L. In salmon (*Salmo salar*), smolt gill physiology, represented by changes in Na-K-ATPase activity, was altered at 2 µg/L (Waring and Moore, 2004) with similar effects observed at 0.5 µg/L (Moore *et al*., 2007). Survival was evaluated after transfer to full salinity sea water (33 %) in Waring and Moore (2004). Atrazine exposure for 5 to 7 days in freshwater followed by transfer to full salinity sea water resulted in higher mortality at atrazine concentrations of 14 µg/L (14 % mortality) and higher mortality in one study at 1 µg/L (15 % mortality) and higher mortality in a separate experiment presented in the publication (no controls died; statistical significance was not indicated). The salinity used by Waring and Moore (2004) simulated full strength seawater (33 %).

Tierney *et al*. (2007) studied the effect of 30-minute exposure to atrazine on behavioral and neurophysiological responses of juvenile rainbow trout to an amino acid odorant (L-histidine at 10^{-7} M, which had been shown to elicit an avoidance response in salmonids). Although the study authors concluded that L-histidine preference behavior was altered by atrazine at exposures $\geq$ 1 µg/L, no significant decreases in preference behavior were observed at 1 µg/L,

nor was a dose response relationship observed. Hyperactivity (measured as the number of times fish crossed the center line of the tank) was observed in trout exposed to 1 and 10 µg/L atrazine. In the study measuring neurophysiological responses following atrazine exposure, electro-olfactogram (EOG) response was significantly reduced (EOG measured changes in nasal epithelial voltage due to response of olfactory sensory neurons).

Nieves-Puigdoller *et al.* (2007) studied the effects of atrazine exposure to Atlantic Salmon smolts through freshwater exposure to atrazine for 21 days at 10 and 100 µg/L and subsequent saltwater challenge. During the freshwater exposure period, 9% of the fish exposed to atrazine at 100 µg/L died (compared to 0% mortality in control and 10 µg/L groups). Fish in this treatment group also exhibited significantly reduced feeding after 10 days of exposure (with zero food consumption reported when measured on day 15), decreased growth rate in freshwater and decreased growth after the first month in saltwater. A compensatory growth period occurred in the second and third month in saltwater. Freshwater smolts in the 100 µg/L group also had decreased plasma Cl^-, Mg^{2+}, Na^+ and Ca^{2+} ions and increased cortisol. No effect on plasma levels of GH, IGF-I, T4 or T3 was found in FW smolts in this group. Following the SW challenge, fish previously exposed to 100 µg/L atrazine had significant increases in hematocrit, plasma cortisol, Cl^-, Mg^{2+}, Na^+, Ca^{2+} and a decrease in T4 and T3. There was an increase in the HSI in females in the 100 µg/L group and a decrease in the male GSI in this group after 21 days atrazine exposure. The study authors also reported decreased activity and response to external stimuli in the 100 µg/L treatment group.

In Weber *et al.* (2013), zebrafish embyros were examined after exposure to atrazine (technical grade) at 0.3, 3 or 30 ppb from 1-72 hours post fertilization. Eye diameter, head length, and total larval length were measured for 20 larvae from each treatment group. A significant difference in head length (5-8% increase in larval head length) at all exposure concentrations (0.3, 3, and 30 ug/L) was noted. No other developmental abnormalities were reported. Transcriptomic and protein alterations were also assessed. Results showed alterations in gene expression at all atrazine treatment groups compared to control (21, 62, and 64 genes in the 0.3, 3, and 30 ppb, respectively). The altered genes were associated with neuroendocrine and reproductive system development, function, and disease; cell cycle control; and carcinogenesis. Two of these genes (CYP17A1 and SAMHD1) were found to be altered at all three exposure concentrations.

In another published study by Plhalova *et al.* (2012), the potential for subchronic atrazine exposure to affect zebrafish (*Dania rerio*) growth and development was examined. Juvenile (30-day-old) zebrafish were exposed to atrazine at 0.3, 3.0, 30.0, or 90.0 µg/L. Mortalities were reported to be ≤5% in the control and treatment groups over the course of the study. No changes in behavior were noted except for the 90.0 µg/L treatment group, in which decreased food intake was observed compared to controls; the fish reportedly only swam in the middle of the tank and showed no interest in food. At study termination, body weights and growth rates were significantly decreased ($p<0.05$) in fish in the 90.0 µg/L atrazine concentration group. Histopathological examinations revealed pathological lesions in the 90.0 µg/L atrazine concentration group, including moderate dystrophic lesions of the hepatocytes, hydropic to

vacuolar degeneration of the hepatocytes, the dilatation of the capillaries, and hyperaemia, compared to the negative control.

Shenoy *et al*. (2012) exposed adult male guppies (*Poecilia reticulata*) to atrazine at 1 and 15 ug/L in water for 16 weeks to test effects on mating behavior and courtship signals. There was an observed reduction in courtship displays in both treatment groups in a non-dose dependent manner, but statistics were only displayed for pooled treatment groups compared to controls. No significant treatment related effects were found in orange coloration (mating signal), copulatory attempts or male-male aggression, although orange coloration was decreased by 1% in the high treament group but was not statistically signficant when compared to controls.

Shenoy *et al.* (2014) evaluated the effects of prenatal exposure to atrazine on mating behaviors in male guppies (*Poecilia reticulata*). Female guppies were exposed to atrazine throughout the gestation period until a brood was produced, from 6 to 88 days, and offspring were raised without further treatment. The study author concluded that overall, maternal exposure to low doses of atrazine (1 and 13.5 µg/L) reduced a male offspring's likelihood of performing mating behaviors and the frequency of the behaviors performed. Atrazine exposure also made males less aggressive towards rivals in the presence of a female and females showed a preference for untreated males over atrazine-treated males. The observed reductions in mating behaviors were more significant in the 1 µg/L atrazine group compared to the 13.5 µg/L atrazine group.

Additional studies were available in the ECOTOX database that were not fully reviewed by OPP, but were considered "acceptable" studies from the ECOTOX database based on EPA OPP criteria. Many of these studies are related to sublethal effects not used for assessment endpoints, but still can provide qualitative information on the range of available effects data. These data points are displayed in **Figure 25** and **Figure 26** (split across two figures due to the large number of endpoints). Additional information on a number of these studies, predominantly those studies that were reviewed for more sensitive endpoints, is contained in **Appendix B.**

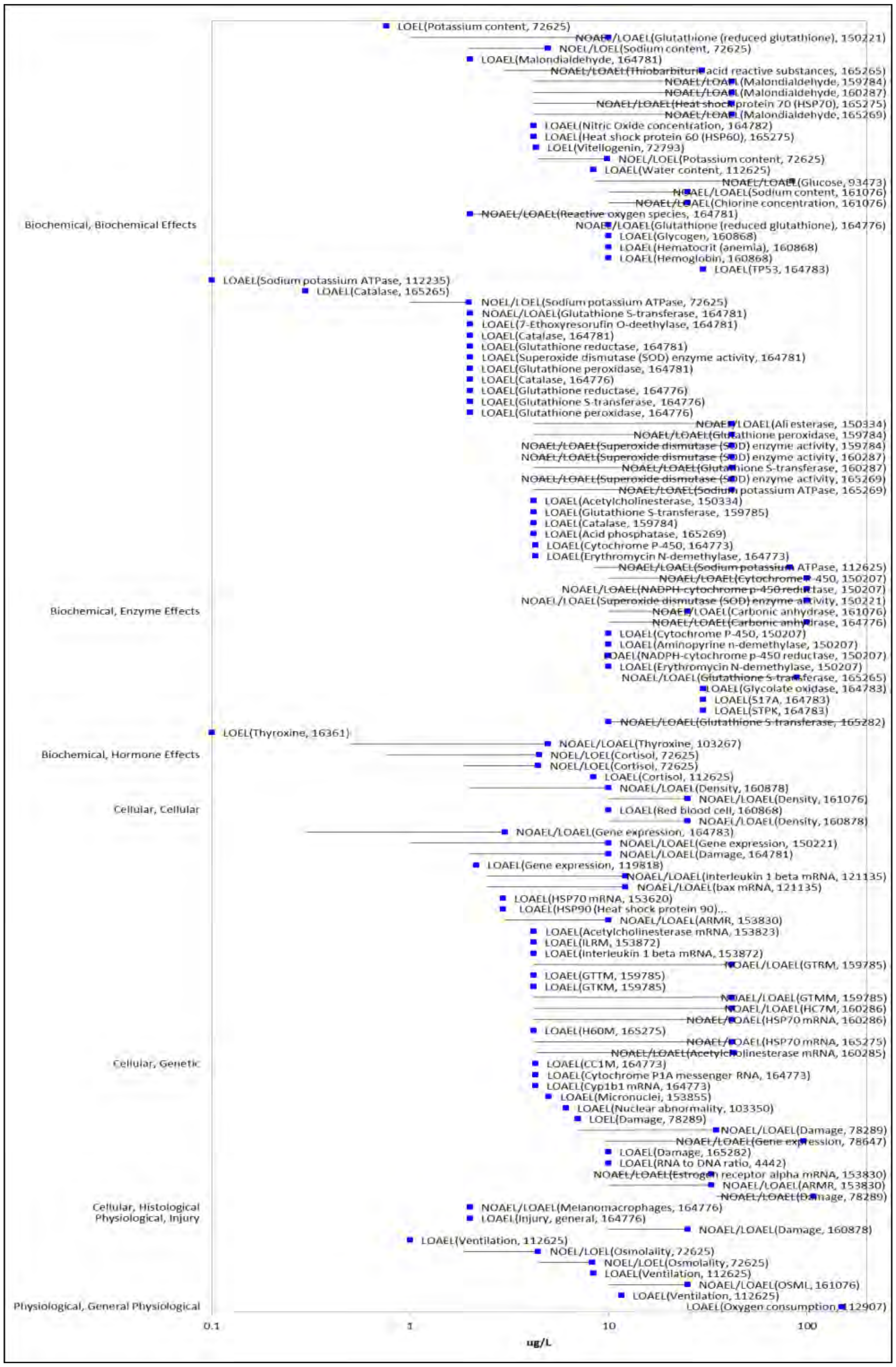


Figure 25. Reported sublethal biochemical, cellular and physiological fish effects endpoints < 200 µg/L from ECOTOX database; denoted in parentheses as (Effect, ECOTOX Reference number). Chronic effect endpoint used for risk quotient derivation is denoted in red.

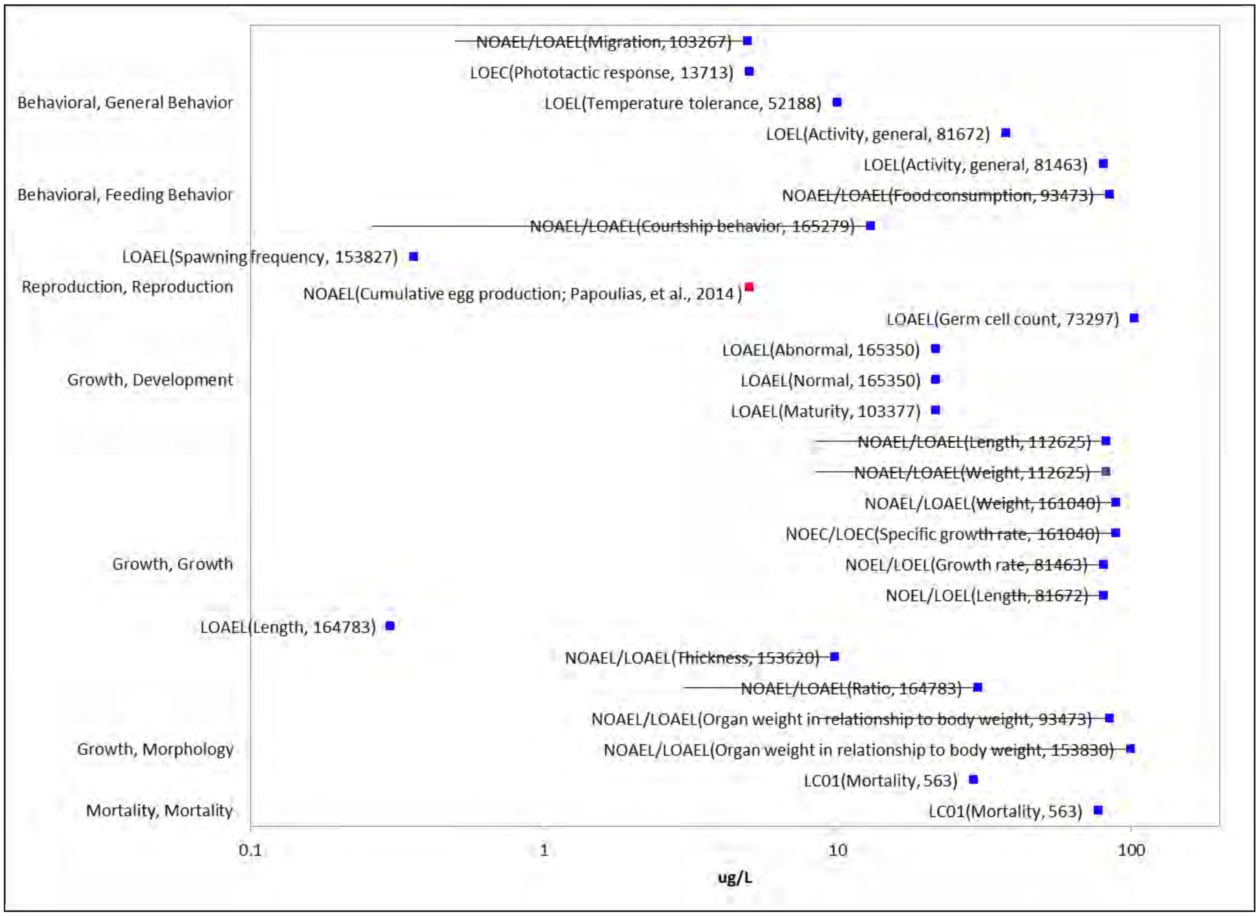


Figure 26. Reported behavioral, reproduction, growth and mortality fish effects endpoints < 200 µg/L from ECOTOX database; denoted in parentheses as (Effect, ECOTOX Reference number). Chronic effect endpoint used for risk quotient derivation is denoted in red.

11.2.1.1. Selected quantitative endpoint for chronic effects in fish

Based on the study by Papoulias *et al.* (2014), previously discussed and as re-analyzed by EPA, the chronic endpoint for fish has been established at 5 µg/L based on the NOAEC for fecundity. In order to provide additional characterization regarding published chronic effects to fish across concentrations surrounding the NOAEC, a summary of the reported chronic effects at concentrations less than 50 µg/L was provided (**Figure 27).** Although more sensitive apical endpoints are reported in the available literature, EPA believes that the Papoulias *et al.* study is suitable for use quantitatively in RQ calculations and assessing chronic risk to fish quantitatively. The other endpoints that are presented in **Figure 27** are considered in risk characterization (**Sections 15.1.1** and **15.2).**

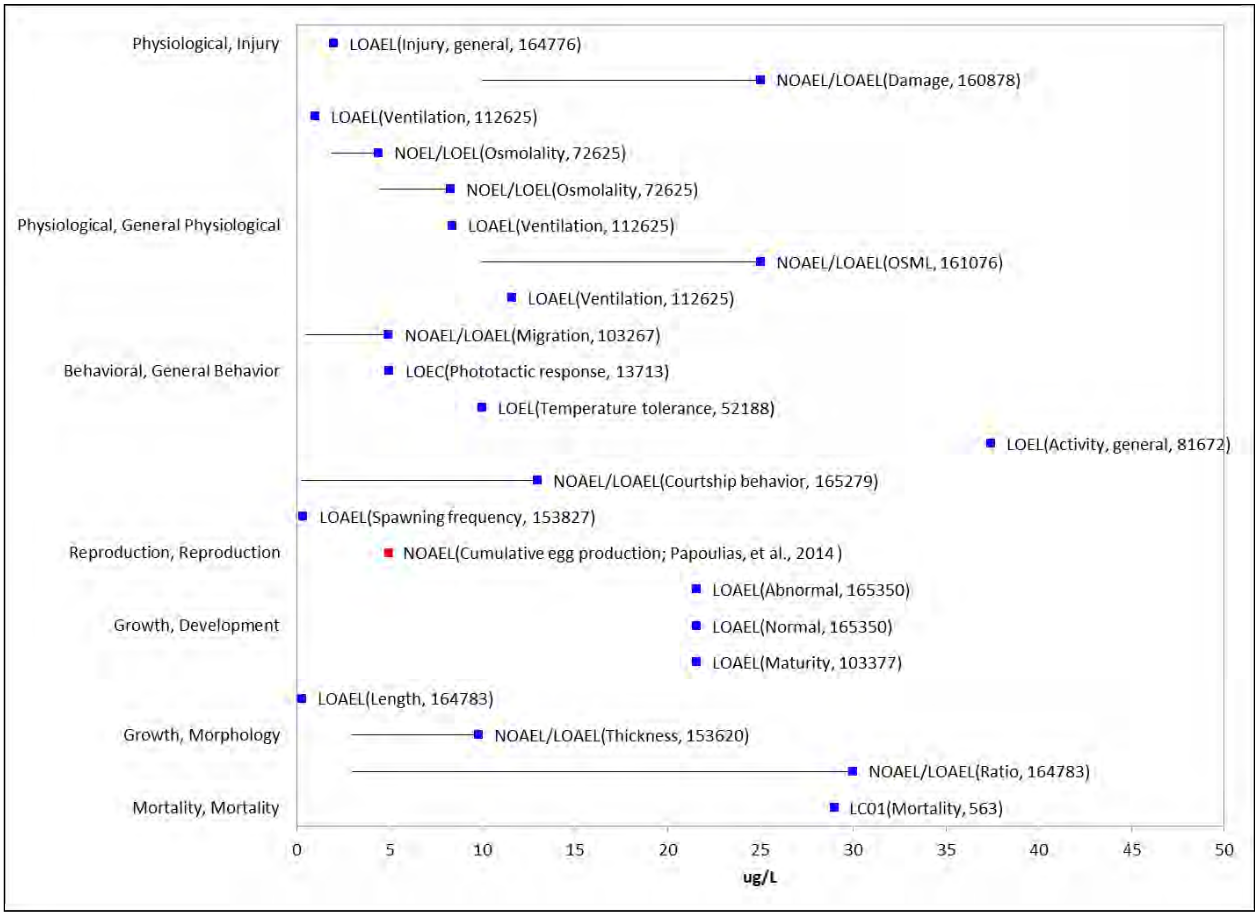


Figure 27. Reported physiological, behavioral, reproduction, growth and mortality fish effects endpoints < 50 µg/L from ECOTOX database; denoted in parentheses as (Effect, ECOTOX Reference number). Chronic effect endpoint used for risk quotient derivation is denoted in red.

11.2.2. Toxicity to Aquatic Invertebrates

A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in the following sections (Table 57).

Table 57. Summary of the most sensitive endpoints for invertebrates acute and chronic toxicity data for atrazine and degradation products.

TAXON	ENDPOINT	TEST SUBSTANCE	MRID	STUDY CLASS-IFICATION	COMMENTS
ACUTE					
Freshwater Invertebrates					
Midge (*Chironomus tentans*)	96-hour LC_{50} = 720 µg a.i./L	Atrazine 94 %	00024377	Supplemental	No 48-hour LC50 or raw data reported
Estuarine/Marine Invertebrates					
Opposum shrimp (*Neomysis integer*)	LC_{50} = 48 µg/L	Atrazine 98-99%	E103334 Noppe *et al.*, 2007	Quantitative	No raw data reported
Copepod (*Acartia tonsa*)	LC_{50} = 88.9 µg/L	Atrazine 70%	452029-18 Thursby *et al.*, 1990	Supplemental	12% control mortality
CHRONIC					
Freshwater Invertebrates					
Scud (*Gammarus fasciatus*)	NOAEC = 60 µg a.i./L LOAEC = 140 µg a.i./L	Atrazine 94%	00024377	Supplemental	Based on reduced development of F1 to seventh instar. Supplemental due to use of DMSO with no solvent control, increased mortality in control group
Estuarine/Marine Invertebrates					
Mysid shrimp (*Americamysis bahia*)	NOAEC = 80 µg a.i./L LOAEC = 190 µg a.i./L	Atrazine 97.4%	45202920	Supplemental	Based on 37 % reduction in adult survival. Supplemental due to no raw data for statistical analysis
Chronic Endpoints for most sensitive estuarine/marine species on acute basis using Acute to Chronic Ratio (ACR)[1]					
Opposum shrimp (*Neomysis integer*)	Predicted NOAEC = 3.8 µg a.i./L	N/A	N/A	N/A	Based on acute toxicity value of 48 µg/L ÷ ACR of 12.5
Copepod (*Acartia tonsa*)	Predicted NOAEC = 7.0 µg a.i./L	N/A	N/A	N/A	Based on acute toxicity value of 88.9 µg/L ÷ ACR of 12.5

[1] An estimated acute to chronic ratio of 12.5 was derived for mysid shrimp based on an acute LC50 of 1000 µg/L (MRID 45202920) and a chronic NOAEC of 80 µg/L (MRID 45202920). This was applied to the two most sensitive estuarine/marine species on an acute basis to further characterize chronic risks to aquatic species. Further discussed in **Section 11.2.2.2.b**

11.2.2.1. ***Acute Studies***

Atrazine toxicity has been evaluated in numerous aquatic invertebrate species, and the results of these studies demonstrate a wide range of sensitivity. Definitive EC/LC_{50} values range from 48 to 30,000 µg/L (0.048 mg/L to 30 mg/L), with several other studies reporting non-definitive EC/LC_{50} values >4,900 to >100,000 µg/L (see **Appendix B** for additional details on these studies). Therefore, atrazine is classified as highly to slightly toxic to aquatic invertebrates on an acute basis. As noted in the acute fish studies, several of the higher concentrations noted in these studies exceeded the solubility limit of atrazine.

11.2.2.1.a. ***Parent Atrazine: Freshwater Invertebrates***

There are many acute toxicity studies using atrazine for freshwater invertebrate species with a range of toxicity values. The acute LC/EC_{50} values range from 720 to greater than 30,000 µg a.i./L. For the available studies, while acute LC/EC_{50} values are reported, summary data for the controls and individual treatment groups are not reported. Therefore, verification of the reported LC/EC_{50} values could not be determined. Also, for some studies, details on the test design and/or environmental conditions were not well documented. The most sensitive value is for the midge, *Chironomus tentans*, with a 48-hour LC_{50} value of 720 µg a.i./L (MRID 00024377).

A sediment toxicity test with whole sediment was available for *Chironomus tentans* (MRID 45904002). The study was a 10-day static-renewal study using spiked sediment. The NOAEC and LOAEC, based on dry weight, was 24 and 60 mg a.i./kg based on mean measured sediment concentrations, respectively, and 4.0 and 21.5 mg a.i./L based on mean measured pore-water concentrations.

11.2.2.1.b. ***Parent Atrazine: Estuarine/marine Invertebrates***

As with the freshwater invertebrates, there are many acute toxicity tests available for estuarine/marine invertebrates, and like the freshwater invertebrate studies, the studies primarily only report LC/EC_{50} values with no documentation of test concentration toxicity data. The reported range of acute LC/EC_{50} values for estuarine-marine organisms range from 48 to 13,300 µg/L, with several non-definitive endpoints. The most sensitive organism tested was the juvenile estuarine/marine shrimp, *Neomysis integer* (LC_{50} of 48 µg/L; Noppe et al. 2007; E103334); only the LC_{50} value was reported, no raw data was provided and control mortality was unknown.

A 10-d sediment toxicity test with the clam, *Mercenaria mercenaria*, was available in the open literature (Lawton *et al*. 2006; E89627). This study reported no effects on survival, mass and size at atrazine concentrations of ≤20,000 µg/kg, the highest concentration tested.

11.2.2.1.c. ***Formulations: Freshwater Invertebrates***

Two 48-hour acute toxicity studies with *Daphnia* for atrazine formulations (80WP and 40.8 4L) are available with acute LC_{50} values ranging from 36,500 to 49,000 µg/L and >31,000 µg a.i./L

(MRID 42041401; 45227712). These studies were conducted above the limit of solubility for atrazine (33 mg/L). Another study reported a 96-hour LC_{50} of 16,000 µg a.i./L for *Hyalella azteca* (Wan *et al.,* 2006). An acute study with glochidia and juvenile stage freshwater mussels, *Lampsilis siliquoidea*, was conducted using Aatrex 4L (40.8% a.i.) (Bringolf *et al.,* 2007; E99469). The reported 96-hour LC_{50} value for both stages was >30,000 µg/L (12,200 µg a.i./L).

11.2.2.1.d. *Formulations: Estuarine-marine Invertebrates*

There were several acute toxicity studies conducted with atrazine formulations for estuarine/marine invertebrates including eastern oyster (*Crassostrea virginica*), Pacific oyster (Crassostrea gigas), fiddler crab (*Uca pugilator*), and European brown shrimp (*Crangon crangon*) and cockle (*Cardium edule*). Several studies resulted in non-definitive values, LC_{50} >100 to >100,000 µg a.i./L (MRID 00024720; 45227728), while others resulted in definitive LC_{50} values, 10,000 to 239,000 µg a.i./L (MRID 45227728; 00024395), of which some are above the solubility of atrazine.

11.2.2.2. *Chronic Exposure Studies*

11.2.2.2.a. *Freshwater Invertebrates*

There are several chronic toxicity tests for freshwater invertebrates. The most sensitive chronic endpoint for freshwater invertebrates was based on a 30-day flow-through study on the scud, *Gammarus fasciatus*, with a NOAEC of 60 µg/L, based on growth of the second generation (MRID 00024377). As with the chronic freshwater fish, this study appeared to be conducted using the solvent DMSO with no concurrently tested solvent control. In addition, the control survival after 30 days was 64-74%, and only one of the two replicates in the control reproduced. Results were available for freshwater invertebrate species (*D. magna, C. tentans*) from the same document, MRID 00024377; however, they all also appeared to use DMSO with no concurrent solvent control. The reported NOAEC and LOAEC for *D. magna* and *C. tentans* was 140 and 250 µg a.i./L (based on reproduction and survival) and 120 and 230 µg a.i./L (based on reduced pupating and emergence), respectively. In the *Daphnia magna* test, control performance was an issue with only 61% survival after 15 days for the parental generation. Several other chronic toxicity studies were also available with NOAECs ranging from 200 to 5,000 µg a.i./L, but toxicity data and/or methods were not reported; therefore the results could not be verified.

11.2.2.2.b. *Estuarine-marine Invertebrates*

In order to estimate chronic estuarine invertebrate risks, data are usually required from the most sensitive species based on an acute basis. This represents an uncertainty in the chronic toxicity data as chronic toxicity data suitable for risk quotient derivation are not available on the most acutely sensitive marine invertebrate, the opposum shrimp (*Neomysis integer*). As shown in Table 57, an estimated acute to chronic ratio of 12.5 was derived for mysid shrimp based on an acute LC50 of 1000 µg/L (MRID 45202920) and a chronic NOAEC of 80 µg/L (MRID

45202920). Applying this ACR to the acute LC50 in opossum shrimp of 48 µg/L results in an estimated chronic NOAEC of 3.8 µg/L.

For further characterization, the ACR was also used to calculate a chronic toxicity value for copepods as they represented another species with sensitive acute toxicity endpoints in several studies (MRID 45202918, 45202920, 45202803, E19281, E80951) with the lowest reported acute LC50 of 88.9 µg/L (MRID 45202918). Based on the ACR, the estimated NOAEC for copepods (*Acartia tonsa*) was 7 µg/L. Additional chronic endpoints were reported in the literature for copepods ranging from <2.5 to 25 µg/L and are discussed in **Appendix B**. Although only considered qualitatively based on reviews, these studies support the calculated chronic NOAEC for copepods of 7 µg/L.

The most sensitive chronic bioassay in estuarine-marine species was a 28-day study in mysid shrimp (*Americamysis bahia*) that reported a NOAEC of 80 µg/L based on a reduction in survival (MRID 45202920). However, toxicity data were not available for endpoint verification. Thus, endpoint values are presented in a table with only the mean value and no standard error or deviations. In addition, while the report stated that the assay was conducted according to Nimmo *et al*. (1977), no explicate test duration was reported. Another mysid shrimp life-cycle study was available (MRID 46648202) with a reported NOAEC of 260 µg a.i./L, based on growth.

Additional studies reporting acute and chronic endpoints for freshwater and estuarine-marine invertebrates were captured in ECOTOX and are discussed in **Appendix B.** These were studies available in the ECOTOX database that were not fully reviewed by OPP, but were considered "acceptable" studies based on EPA OPP criteria. These data points are displayed in **Figure 28**. Additional information on a number of these studies, predominantly those studies that were reviewed for more sensitive endpoints but considered qualitative, is contained in **Appendix B.**

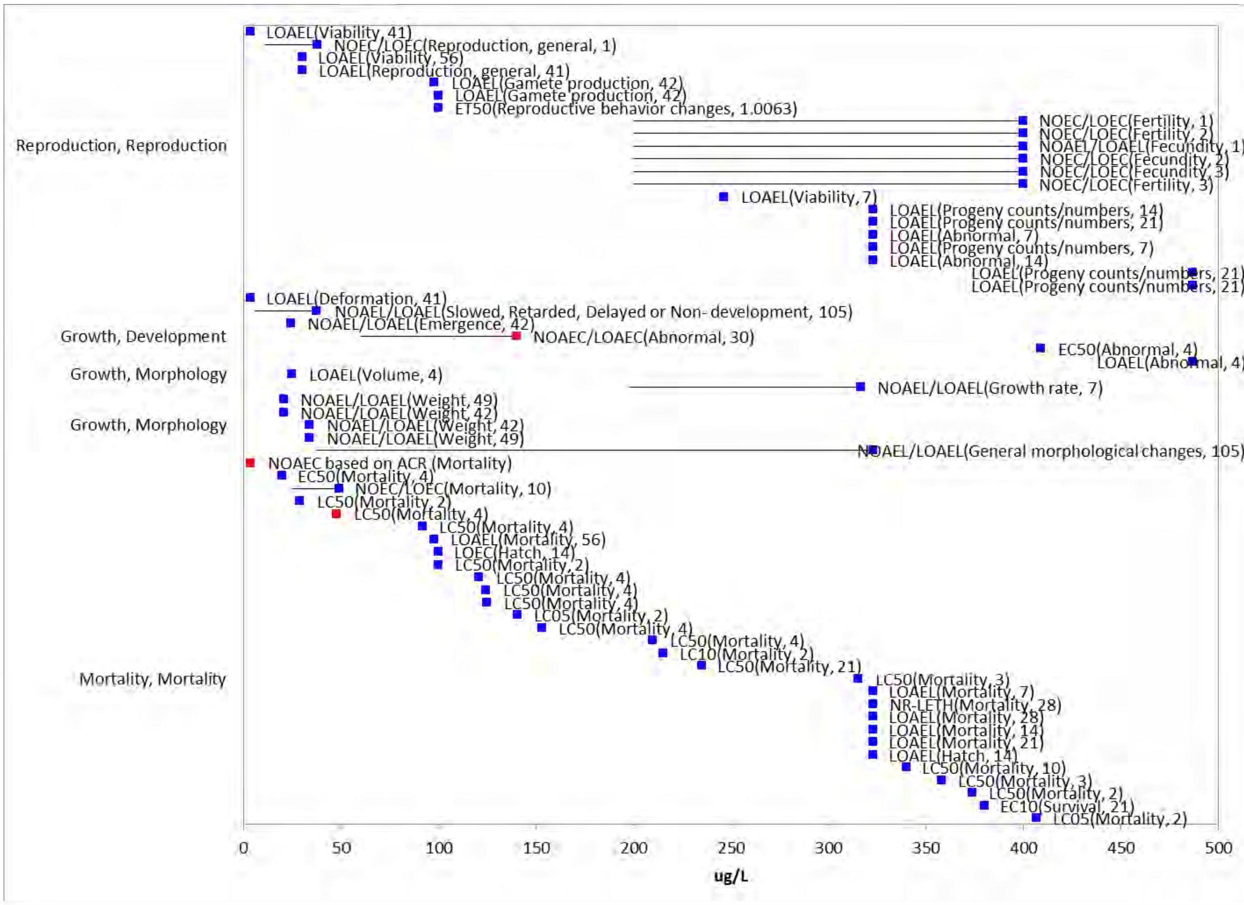


Figure 28. Reported freshwater and saltwater invertebrate effects endpoints < 500 µg/L from ECOTOX database; note variation in study durations as denoted in parentheses (Effect, Study duration in days). Effect endpoints used for risk quotient derivation are denoted in red. [Acute freshwater endpoint not depicted as >500 µg/L (720 µg/L)].

11.2.3. Toxicity to Amphibians (aquatic-phase and terrestrial)

To evaluate the potential for atrazine to affect amphibians in the environment, the Agency evaluated the available amphibian toxicity dataset, which is discussed below. The amphibian data has been given notable consideration in the past through various analyses and FIFRA SAPs. A brief history of these SAPs is provided below prior to a discussion of the effects data.

11.2.3.1. *History of Previous Amphibian SAPs*

A large number of studies are available examining the potential effects of atrazine on amphibians. Previously, reviews of studies specific to the potential effects of atrazine on amphibian gonadal development were written in support of consultations with the SAP. Detailed transcripts and recommendations from those SAPs can be found at http://www.epa.gov/pesticides/reregistration/atrazine/ (USEPA, 2003d; 2007a; 2012c).

In the 2003 SAP on potential developmental effects of atrazine on amphibians, the Agency determined that existing data were sufficient to warrant further examination of atrazine effects on development (U.S. EPA, 2003d). The SAP concurred with a tiered testing approach proposed by EPA using the African clawed frog (*Xenopus laevis*) and indicated that *X. laevis* was a suitable surrogate test species for amphibians. In 2004, EPA issued a data call-in (DCI) to registrants for the study outlined in the first tier and at a 2007 SAP on the potential for atrazine to affect amphibian gonadal development, the results of the DCI study and evaluation of open literature data to date were presented (U.S. EPA, 2007a). The EPA concluded that, based on available data at that time, atrazine did not appear to produce consistent effects on amphibian development and that based on the tiered testing approach reviewed by the 2003 SAP, no further testing was needed. However, EPA indicated in 2007 that it would continue to monitor information as it becomes available. The SAP agreed that the study conducted in response to the DCI (which was comprised of two studies conducted in parallel) showed no effect to *X. laevis* on development from exposure to atrazine concentrations ranging from 0.01-100 µg/L. However, the 2007 SAP Panel expressed concerns about the use of *X. laevis* to represent all native species and the sensitivity of the strain of *X. laevis* used in the study.

In 2012, EPA presented the findings of an updated review of the open literature using critical test design elements, which are evaluation criteria based largely on OPP's open literature guidelines. A total of 64 studies were reviewed and classified as invalid, qualitative (high, medium or low) or quantitative based on this criteria. The majority (54 out of 64) of the available laboratory studies had a classification of qualitative with a lower level of confidence (n= 30) or invalid (n= 24). Several potential confounding test design elements were commonly observed in the available data including: a lack of reporting/measuring atrazine in control or treatments, use of field collected organisms, water quality concerns or a lack of summary data/test design. Only the DCI study (Kloas *et al*. 2009) was considered acceptable for quantitative use with a reported NOAEC of 100 µg/L for survival, metamorphosis, growth, behavioral effects, and sexual development, at the highest concentration tested. This analysis is described in detail in the 2012 Problem Formulation for Atrazine (USEPA 2012b).

The 2012 SAP panel provided feedback as discussed in the transmittal of the meeting minutes (http://www.regulations.gov/#!docketDetail;rpp=25;po=0;D=EPA-HQ-OPP-2011-0898). Although the Panel agreed that the test design elements were valid criteria for establishing a "cause and effect" relationship, the Panel raised concerns with the analysis methodology. In the Panel's opinion, there was an exclusion of too many studies based on what they considered a strict application of the test design elements. The panel questioned the use of *X. laevis*, specifically from the same clutches of eggs from the same strain, as a suitable surrogate for all amphibian species. This was a similar concern raised by the 2007 panel. The Panel recommended testing with native species using multiple laboratories across the country. In addition, they recommended using a weight of evidence approach to analyze test results including the studies labeled qualitative and potentially some studies labeled invalid. Specific concern was expressed regarding the endocrine disruption potential, reproductive effects and

immune system effects of atrazine in amphibians. In addition, the Panel recommended that the Agency review several additional studies that were not included in the 2012 review.

The approach to the amphibian data for the risk assessment presented herein attempts to address several of the concerns raised by previous SAPs. A weight of evidence analysis was conducted for the amphibian risk characterization as described in **Section 15.1.3**. For this analysis, all studies classified as quantitative and qualitative (high, medium and low) were included. The 2012 detailed study analyses were utilized in that the uncertainties or deficiencies identified in these studies were incorporated into the assessment of the overall confidence in data quality for each line of evidence (as described in **Section 15.1.3**). The inclusion of these studies allowed for the incorporation of toxicity data on multiple native amphibian species data as recommended by the 2012 SAP. A discussion of the available toxicity data for amphibians up to the 2012 SAP is included in **Sections 11.2.3.2 and 11.2.3.3**. **Section 11.2.3.4** contains summaries of new studies identified for review since the 2012 SAP, including amphibian studies specifically identified by the SAP. Detailed study reviews and a summary table of all endpoints is provided in **Appendix B.** Study reviews conducted since 2012 incorporated recommendations from the SAP on the application of evaluation criteria.

11.2.3.2. ***Acute Exposure Studies***

Available acute data for amphibians indicate that they are relatively insensitive to technical grade atrazine with acute LC_{50} values generally > 10,000 µg/L for juveniles and embryos (e.g., Birge *et al*. 1980; Howe *et al*. 1998; Kloas *et al.* 2009, Morgan *et al*. 1996; Wan *et al*. 2006). Teratogenic effects were also evaluated for amphibian embryos with EC_{50} values ≥2,100 µg/L (Fort *et al*., 2004). The lowest acute value was reported by Birge *et al*. (1980) in which the reported 4 days post hatch LC_{50} for *R. catesbeiana* was 410 µg/L; this value represents both lethality as well as observed abnormalities expected to result in mortality under natural conditions. With the exception of Kloas et al. 2009, statistical analyses for survival for the other studies were not provided. Rather, an overall mortality/survival was generally reported as survival was generally high.

11.2.3.3. ***Chronic Exposure Studies***

A number of chronic exposure effects have been reported in the literature. For the following discussion, chronic effects are categorized into studies reporting effects on survival, development (metamorphosis), growth, sexual development, biochemical and molecular function, immune system/infection and behavioral modification.

11.2.3.3.a. ***Survival***

A wide range of sub-chronic or chronic survival results are available. No effects on survival have been reported at atrazine concentrations of up to and around 200 µg/L and above (400 µg/L) for several studies and species: *X. laevis* (Allran and Karasov, 2000 and Hayes *et al*., 2002); *Hyla versicolor* (LaFiandra *et al*., 2008); and *A. barbouri* (Rohr *et al*., 2003). Long term carry-over effects on survival for *A. barbouri* were reported in one study at 4 µg/L, the lowest concentration tested (Rohr *et al*., (2006). In addition, chronic (32 days) atrazine exposure to four species of tadpole frogs including spring peepers (*Pseudacris crucifer*), American toads (*Bufo americanus*), green frogs (*Rana clamitans*), and wood frogs (*Rana sylvatica*) was studied at early (Gosner stages 25-27) and late (stages 29-36) developmental stages (Storrs and Kiesecker, 2004). For spring peepers, American toads and green frogs, survival was significantly reduced at the lowest concentration tested, 2.84 µg/L; however, survival was not always significant at higher concentrations (25 and 64 µg/L). In this study, atrazine was tested as a formulation (85.5% atrazine) and there is uncertainty in if, and how, the inert ingredients may have influenced the toxicity.

11.2.3.3.b. ***Development (metamorphosis)***

Effects on metamorphosis were reported in 29 laboratory studies at concentrations ranging from 3 to 400 µg/L. Seven studies reported effects at 100 µg/L or less: Koprivnikar, 2010; Coady *et al.,* 2004; Rohr *et al.,* 2004; Larson *et al.,* 1998; Olivier and Moon, 2010; Brodeur *et al*., 2009 and Freeman and Rayburn, 2005. Of the seven studies reporting effects on metamorphosis at 100 µg/L or less, two were conducted with ranids (*Rana pipiens* and *R. clamitans*) and three were conducted with salamanders (*Ambystoma tigrinum, A. barbouri, and A. maculatum*); the other two were conducted with the frogs *Rhinella arenarum* and *X. laevis*. Effects included: 1) reduced developmental stage at test termination at 3 µg/L, only concentration available for analysis (Koprivnikar, 2010); 2) longer time to metamorphosis (Coady *et al.,* 2004) at 11 but not 28 µg/L; 3) decrease in time (day) of metamorphosis (presented as year standardized means) at 40 µg/L but not at 4 µg/L (Rohr *et al.,* 2004); 4) delayed metamorphosis at 81.8 µg/L (Larson *et al.,* 1998); 5) decrease in time to metamorphic stage at 100 µg/L (Brodeur *et al.,* 2009; Freeman and Rayburn, 2005); and 6) stage before death or hatch at 100 µg/L (Olivier and Moon, 2010).

In three studies, there was no effect on growth or time to metamorphosis at 25 µg/L and 100 µg/L, and no effect on rate of development or growth at 30 µg/L, the highest concentrations tested (Choung *et al.,* 2011; Kloas *et al.,* 2009; Spolyarich *et al.,* 2010). Two of those studies were tested using Australian species of frogs, *Litoria raniformis* (Choung *et al.,* 2011) and *Limnodynates tasmaniensis* (Spolyarich *et al.* 2010) with the other species being *Xenopus laevis* (Kloas *et al.,* 2009). The relative sensitivity of the Australian species is not known, as a positive control, such as 17-β estradiol, was not conducted with either study. Another study report

effects on metamorphosis with *X. laevis* with a decrease in metamorphic stage after a certain study duration (3-5 weeks) at 100 µg/L, the lowest concentration tested (Freeman and Rayburn, 2005); no significant effect on mass was reported in the study. However, as time to metamorphosis was not determined in this study, the overall effect on metamorphosis is uncertain. In addition, since the study was terminated prior to metamorphosis, with presumably organisms at different developmental stages, it is unknown how each stage was accounted for when comparing tadpole mass between groups.

An effect on flow cytometric analysis (nuclei-whole body homogenized) meant to illustrate development stage was reported at exposure concentrations of 800 µg/L; however, this effect was not observed in all trials conducted at 800 µg/L (Freeman and Rayburn, 2005).

11.2.3.3.c. ***Growth***

Growth endpoints (*e.g*., mass and snout-vent-length (SVL)) were examined in 27 of the available laboratory studies. Many of the studies reported effects at or below 400 µg/L and examined both metamorphosis and growth. Both of these endpoints are frequently linked together (U.S. EPA, 2007a; Rohr and McCoy, 2010) as growth is reported in the context of metamorphosis. For the laboratory studies, adverse effects on growth were reported from 0.19 µg/L to 800 µg/L (one study at 800 µg/L) with three laboratory studies reporting effects at less than 100 µg/L. In Hayes, *et al*. (2006b) an effect on *R. pipiens* growth (decreased mass and SVL), but not metamorphosis, was reported at 0.19 µg/L; however, Koprivnkiar (2010) reported both an effect on *R. pipiens* growth and metamorphosis at 3 µg/L (*ca*. 100% mortality reported at 300 µg/L). Reported decrease in mass for *X. laevis* at 20 µg/L (lowest concentration tested) was lower than the reported effect on metamorphosis (increase in time to metamorphosis) (LOEC >320 µg/L) for the same study (Sullivan and Spence, 2003). Studies also reported no effects on growth or metamorphosis at atrazine concentrations of 30 µg/L or less: 1.25 µg a.i./L for B*. americanus*, *H. versicolor*, and *P. triseriata* (Williams and Semlitsch, 2010). Several studies have reported no effects for growth around 20-30 µg/L, although they may have reported effects at higher concentrations, for example: Choung *et al*. (2011) reported a NOEC for growth and metamorphosis at 25 µg/L in *Litoria raniformis*; Zaya *et al*. (2011) reported a NOAEC for *X. laevis* growth at 25 µg/L with LOEC at 200 µg/L.

11.2.3.3.d. ***Sexual Development***

Many studies have been conducted that evaluate different aspects of sexual development (*e.g.*, sex ratio, gonad development, other organs involved in reproduction) in amphibians. Effects on sexual development (*i.e*., change in sex ratio, increase in gonadal malformations (ovotestes), changes in laryngeal muscles) were reported at atrazine concentrations of 50 µg/L or lower. Seven out of eleven of these studies report effects on sex ratio and gonadal malformations at concentrations of 15 µg/L atrazine or lower.

Effects on sex ratio were reported for atrazine concentrations ranging from 0.92 to 124 µg/L. However, observed effects on sex ratio need to be considered with respect to when the effect

was measured in the life cycle of the organism. Many of the studies were conducted to metamorphosis; however, there is some evidence that somatic development (metamorphosis) and gonadal maturation do not necessarily coincide, *i.e*., gonadal maturation occurs later in the life cycle (Storrs and Semlitsch, 2008).

Effects on gonadal development and morphological changes were examined in several studies. Effects such as observation of ovotestes, changes in testicular morphology, effects on gonadal somatic index compared to the controls and changes in other organs used for reproduction or mating (*e.g*., larynx) were reported at atrazine concentrations ranging from 0.1 to 25 µg/L atrazine (Hayes *et al*. 2002, 2003, 2006a, 2010a; Tavera-Mendoza *et al*. 2002a and 2002b, Goleman *et al*. 2003; and Hecker *et al.,* 2005b).

In contrast, no effect on sexual development was also reported at concentrations greater than the adverse effect concentrations described above (Spolyarich *et al*., 2010; Kloas *et al*., 2009a; LaFiandra *et al*., 2008). Sex ratio and gonadal development were reported to not be affected at 30 and 100 µg/L for *L. tasmaniensis* (Spolyarich *et al.,* 2010) and *X. laevis* (Kloas *et al.,* 2009); However, as previously discussed, observed effects on sex ratio need to be considered with respect to when the effect was measured in the life cycle of the organism as rate of gonadal development may not in sync with somatic development rate (metamorphosis).

11.2.3.3.e. ***Biochemical and Molecular Endpoints***

Studies evaluating biochemical and/or molecular endpoints reported effects primarily at concentrations ≤ 500 µg/L. Many of the studies examined a diverse array of endocrine-related endpoints (*e.g*., aromatase, estradiol, and testosterone). Studies reported changes in a variety of biochemical endpoints (*e.g*., testosterone, estradiol, corticosteroid and thyroxine) at concentrations less than 100 µg/L (Coady *et al.,* 2005; Hayes *et al*., 2010a, Hayes *et al*., 2002; and Larson *et al*., 1998). No effect on biochemical endpoints at concentrations of 25 µg/L and above were also reported (Kloas *et al*., 2009a; Oka *et al*., 2008; Hecker *et al*., 2005).

11.2.3.3.f. ***Immune System and Infection***

Several papers evaluated the potential effects of atrazine on the immune system and susceptibility to infection; several different immune response endpoints were examined in addition to susceptibility to infection. The majority of the studies evaluating the immune system report effects on ranids at or below 200 µg/L. Several studies reported effects at 30 µg/L or less: Brodkin *et al,* 2007 (decrease in number of phagocytic cells (at 0.01 µg/L) and a decrease in white blood cells and mean percentage of peritoneal phagocytic cells at 21 µg/L in adult *R. pipiens* frogs); Houck and Sessions (2006) (reduction in the number of plaques representing antibody-secreting cells at 1 µg/L for adult *R. pipiens*); Forson and Stofer (2006) (decreased leukocyte levels (16 and 160 µg/L) and increased infections of *Ambystoma tigrinum* virus (ATV) at 16 µg/L in tiger salamanders, *Ambystoma tigrinum* with a NOAEC of 1.6 µg/L reported); and Koprivnikar *et al.,* 2007 (increase in intensity of infection in *R. clamitans* tadpoles at 30 µg/L). An increase in activated caspase3 immunopositive cells was reported at 400 µg/L,

NOAEC of 200 µg/L in *X. laevis* (Zaya *et al*., 2011a). No effects on viral load was reported at 200 µg/L in *A. tigrinum* (Kerby *et al*., 2009);

11.2.3.3.g. ***Behavioral Modification***

There were some studies that evaluated behavioral aspects (*e.g*., feeding, locomotion, avoidance) of amphibians when exposed to atrazine concentrations of ≤400 µg/L. Suppressed mating behavior was reported at an atrazine concentration of 2.5 µg/L in *X. laevis* (Hayes *et. al*. 2010). In Goleman *et al*. (2003) abnormal swimming was observed in *X. laevis* tadpoles at 19.5 µg/L atrazine with a reported NOAEC of 10.3 µg/L. Increased activity with decreased water conserving behavior (*i.e*., huddled, against side of dish, inactivity) was observed at 40 µg/L, but not at 4 µg/L, in adult *A. barbouri* salamanders (Rohr and Palmer, 2005). In Rohr et al. 2003 and 2004, adverse behavior modification (increased activity after tapping on glass tank, and reduced shelter use) was reported at 400 µg/L, but not at 40 µg/L, for *A. barbouri*. No effect on fear cues were reported for B. americanus at 196 µg/L (Rohr *et al*., 2009). For *Bufo americanus,* behavior (expressed as fear cues and overall activity) was not modified at 196 µg/L (Rohr *et al.,* 2009) and the toads did not have a preference for soil treated with atrazine or not at atrazine soil concentrations of 1430 µg/kg (Storrs Mendez *et al.,* 2009).

11.2.3.3.h. ***Cosm Studies***

A summary of the cosm studies and the identified uncertainties associated with each study are presented in **Appendix G.** Metamorphosis was frequently examined in the cosm studies. One cosm study reported reduced number of animals reaching metamorphosis at 0.1 µg/L; however, growth and age at metamorphosis were not affected (Langlois *et al.* 2010). No effect on metamorphosis was also reported for other cosm studies at concentrations from 6.4 to 197 µg/L (Relyea *et al.,* 2009; Rohr and Crumrine, 2005; and Du Preez *et al.,* 2008). In the cosm studies, growth effects were observed around 200 µg/L for *R. sphenocephala* and *B. americanus* (Boone and James, 2003; Diana *et al.,* 2000) except for Relyea (2009) who reported increased body weight for gray tree frogs (*H. versicolor*) treated with 6.4 µg/L, although time to metamorphosis was not affected.

For behavioral modifications, the cosm study by Rohr and Crumrine (2005) reported a decrease in the percentage of *R. sylvatic* tadpole hiding and an increase in tadpole activity compared to the control at 50 µg/L. In another cosm study, Rohr *et al.* (2008) reported a decrease in melanomacrophages in *R. pipiens* and eosinophils with an increase in trematode cysts in *R. palustris* at an atrazine concentration of 117 µg/L. Survival was reported as significantly lower for *R. pipiens* but not for *R. palustris,* compared to control. A cosm study by Langlois *et al.* (2010) reported a change in brain and tail biochemistry (changes in estrogen receptor-α and tail dio3 enzyme (involved in thyroid conversion)) in *R. pipiens* at an atrazine concentration of 1.8 µg/L. In the cosm study by Langlois *et al.* (2010) a significant change in sex ratio was observed at 1.8 µg/L for *R. pipiens.*

11.2.3.4. ***Additional study reviews since 2012 SAP***

Amphibian studies recommended for review by the 2012 SAP

As part of the 2012 SAP, several studies were identified by the panel for review. Amphibian studies identified therein are discussed below.

Bishop *et al.* (2010) examined the effects of pesticides and water chemistry in the hatching success of several amphibian species in British Columbia Canada using predator-proof cages containing Stage 4 eggs placed in nonagricultural reference sites and in conventionally sprayed and organic orchards. Pesticides were detected at low concentrations (ng/L) in ponds near sprayed orchards. There was significant variation in chloride, sulfate, conductivity, nitrate and phosphorus among sites. Results indicated lower mean hatching success in all species in the conventionally sprayed orchards as compared to both organic and non-agricultural sites. In 2005, atrazine was found to account for 79% of the variation using a stepwise regression analysis. In 2006, atrazine, total nitrate and chlorpyrifos accounted for 80% of the variability. Some of the limitations of this study include the limited analysis of pesticides (two samples per year), small sample size, limited replication and the number of variables present.

The effects of atrazine and the chytrid fungus *Batrachochytrium dendrobatidi* (Bd) were investigated in Paetow *et al.* (2012). Post-metamorphic northern leopard frogs (*Lithobates pipiens*) were exposed to atrazine at 2.1 µg/L (actual levels 1.70 to 4.28 µg/L) alone for 21 days then followed by *Bd* and observed for 94 days. Significant effects on mass gain were seen in the atrazine treated group over the course of the experiment (Days 1-94) with 11% and 8% decrease in mass gain as compared to control means in atrazine alone and atrazine + *Bd* groups collectively. No significant effects were seen on survival, biomarkers of animal health or immune function. There was no evidence of active *Bd* infection in the frogs at the end of the exposure period, which the author attributed to a potentially resistant strain of frogs and significantly increased skin shedding in exposed frogs which may have helped resist or clear infection.

Additional amphibian open literature study reviews since 2012 SAP

Additional amphibian studies were identified both through the ECOTOX database and through the weight of evidence analysis conducted for atrazine for the EDSP program. These studies are briefly summarized below.

Brodeur *et al.* (2011) examined the effects of atrazine (0, 0.1, 1, 10 and 100 µg/L) on the timing of metamorphosis and body size at metamorphosis in the common South American toad *Rhinella arenarum*. Tadpoles exposed to atrazine at 1000 µg/L took significantly ($p<0.05$) more time than controls to reach stage 39 (increased T39), whereas exposure to 1, 10 and 100 µg/L significantly reduced T39 compared to the controls. The same results were observed with time to reach stage 42. The accelerated time to development to stage 39 and 42 both displayed a non-linear dose response, as the greatest acceleration in development time was seen in the 10

μg/L group whereas similar responses were seen in the 1 and 100 μg/L group. No significant difference from controls was seen in the 0.1 μg/L exposure groups and this was the reported NOAEC in this study. Response to the positive control exposed to 100 μg/L of 17β-estradiol was similar to that observed in the 1 and 100 μg/L treatment groups.

Davis et al (2012) examined the impact of atrazine presence on crawfish predation and the effect of vegetation on tadpole survival through microcosm studies. Results indicated atrazine did not influence the effect of either parameter on tadpole survival.

Dornelles and Oliveria (2014) examined the effects of atrazine at 5, 10 and 20 μg/L on bullfrog tadpoles *(Lithobates catesbeianus*) on biochemical parameters, lipid peroxidation and survival. Biochemical parameters analyzed included glycogen, total lipids, triglycerides, cholesterol and total proteins in liver, gill and muscle. Atrazine exposure induced significant changes in all biochemical parameters analyzed and increased lipid peroxidation levels, with significant impacts to glycogen stores in all compartments. No significant changes in growth or survival in treatment groups as compared to controls were noted at the end of 14 days.

McMahon *et al.* (2013) studied the effects of atrazine and chlorothalonil on the survival of *Bd* both in culture and on *Osteopilus septentrionalis* (Cuban treefrog) tadpoles. At all concentrations tested (0.011 μg/L – 212 μg/L) atrazine reduced *Bd* growth in culture and reduced *Bd* growth on tadpoles as compared to controls. Overall tadpole survival was impacted by *Bd* but not atrazine exposure. The atrazine treated tadpoles had significant decreases in the time to death as compared to controls and mass of tadpoles as compared to the chlorothalonil group; however, this was provided in discussion only and treatment levels at which this occurred were not described.

Paetow *et al*. (2013) investigated the effects of atrazine on larval American bullfrogs (*Lithobates catesbeianus*) experimentally exposed to Bd. After the start of the experiment, the sample population was found to be infected with *gyrodactylus jennyae* leading to mild to severe skin erosions in the experimental population. Increased mortality was observed between control groups and *Bd* and *Bd*+ atrazine groups, but no difference was found between *Bd* and *Bd* + atrazine groups. The relationship between the co-infections and the severity of skin lesions was correlated with their influence on survival.

Rohr and Palmer (2013) examined the effects of temperature (22ºC or 27 ºC), moisture (wet or dry) and atrazine exposure (0, 4, 40 and 400 μg/L) on the survival, growth, behavior and foraging of streamside salamanders (*Ambystoma barbouri*). Changes in temperature and moisture alone caused significant loss of mass and mortality with atrazine exposure having an additive effect by decreasing water conserving behavior, foraging efficiency, mass and time to death. Compared to controls, at the end of the experiment there was a significant negative effect on the percent of mass change at all atrazine concentrations tested as well as a negative association between atrazine concentration and time of survival. Temperature had the greatest impact on individual fitness, with higher temperatures having a higher impact on survival than moisture.

Rohr *et al.* (2013) examined the effects of 6 day atrazine exposure at 65.9 µg/L to Cuban tree frog tadpoles (*Osteopilus septentrionalis*) on the response to *Bd* exposure both immediately after atrazine exposure as tadpoles and 46 days later (post-metamorphosis). Tadpoles were exposed to atrazine during the first week (window 1; Gosner stage 26-28) and the second week (window 2; Gosner stage 35-37) of development. A significant difference was found in tadpoles exposed during window 2 but not window 1 in SVL and time to metamorphosis; those tadpoles exposed during window 2 were smaller and morphed earlier than window 1. Mortality was significantly higher in atrazine exposed groups when exposed to *Bd* both immediately and 46 days later (post metamorphosis) as compared to solvent controls exposed to *Bd*.

Ghodageri *et al.* (2013) examined the effects of atrazine on the rate of germinal vesicle breakdown (GVBD) in fully grown pre-ovulatory oocytes of the Indian skipper frog (*Euphlyctis cyanophlyctis*), using an *in vitro* culture system. Atrazine was found to have a stimulatory effect, causing an increased rate of GVBD with exposure to 1 µg/mL eliciting 59±1% GVBD at 24 hours (not statistically significant), whereas those exposed to 5, 10, 15, and 20 µg/mL exhibited 72-77% GVBD at 24 hours which was significantly greater than the control (29 ±1% GVBD). Positive control (progesterone, 1 µM) elicited 84 ±2% GVBD at 24 hours.

Sifkarovski *et al.* (2014) exposed *Xenopus laevis* Stage 50 tadpoles and adults to atrazine at 0, 0.1, 1 and 10 µg/L for 1 week followed by Frog Virus 3 (FV3) infection via water bath and intraperitoneal (i.p.) injection and monitored for survival and changes in immuno-relevant genes (TNF-a, Type I IFN, Mx1, IL-1b, IFN-c, IL-10, CSF-1). Survival was significantly reduced at 10 µg/L atrazine exposure in the water bath group and at 1 µg/L in the i.p. exposure group. In addition, TNF-a and Type I IFN were significantly and markedly reduced (greater than ~8 fold decrease) at all test concentrations in atrazine exposed tadpoles 6 days post FV3 infection as compared to infected controls. Mortality was not impacted in atrazine exposed adult frogs and gene expression changes were only slight.

11.2.3.5. ***Other Evaluations – Published Literature Reviews***

The EPA is aware of previous attempts to investigate a relationship between atrazine exposure and adverse effects on amphibians as well as other taxa (Rohr and McCoy, 2010; Hayes *et al.*, 2011; Solomon *et al*., 2008; Mann *et al*., 2009; Vandenberg *et al.,* 2012; Bernanke and Köhler, 2008; Hayes *et al*., 2010; van der Kraak *et al.*, 2014). For an open literature paper to be considered for potential inclusion in a risk assessment, the paper is the primary source of the data (USEPA, 2011). Therefore, while the references in the literature review paper may be extracted for screening for further potential review, the literature review papers themselves are typically not considered for further review.

In the paper by Rohr and McCoy (2010), the authors conducted a qualitative meta-analysis on atrazine effects to freshwater fish and amphibians. The authors included specific criteria for inclusion/exclusion of data in their evaluation, including factors such as control contamination

and lack of statistical analyses as exclusion criteria. Their analysis included studies that showed trends and studies in which compounds other than atrazine were present (*e.g*., mixtures and agricultural sites). Evaluation of potential effects in this paper was done by tallying the number of studies that reported an effect and those that did not. This process gave equal weight to each represented study regardless of potential confounding factors beyond those that were considered in their analysis. The authors stated that for survival endpoints, their general conclusions from the studies are consistent with other reviews (Giddings *et al.*. 2005; Huber 1993 and Solomon *et al.* 1996, 2008) in that there is no consistent published evidence that atrazine (at environmentally relevant concentrations) is directly toxic to fish or amphibians with some important exceptions (*e.g*., Alvarex and Fuiman 2005; Rohr *et al.*. 2006b, 2008c, Storrs and Kiesecker 2004). The study authors conclude that while there is much left to learn about atrazine effects, they identified several consistent effects of atrazine that must be considered when conducting a cost-benefit analysis.

In another review by Van Der Kraak et al. (2014), sponsored and submitted to EPA by Syngenta, the authors developed a quantitative weight of evidence approach to evaluate the published literature on atrazine effects to fish, amphibians and reptiles. This methodology included a detailed review of the literature, similar to that of previous reviews (*e.g.*, USEPA 2012) however differed in that it applied a numerical score to weigh the study strength and relevance to apical endpoints. The authors concluded that atrazine, at concentrations similar to typical environmental exposures, may affect the expression of genes and proteins, the concentration of hormones, and biological processes. The authors concluded that while these effects were noted, they did not translate into adverse outcomes in terms of the typical apical endpoints.

The review by Hayes *et al.* (2011) evaluated atrazine effects on demasculinization and feminization of male gonads across vertebrate classes including amphibians. This review examines the effects of atrazine on sexual development for different vertebrate classes applying the nine "Hill criteria." The authors identify studies in which they believe support each of the nine criteria. The study authors state that the situation of atrazine as an endocrine disruptor which demasculinizes and feminizes male vertebrates meets all nine of the "Hill criteria".

In the review by Solomon *et al*. (2008), the authors evaluated laboratory and field studies and assessed causality using procedures derived from Koch's postulates and the Bradford-Hill guidelines. The authors state that they identified strengths and uncertainties, and some studies were omitted from their summary tables due to concerns about data quality. The authors report that on a weight of evidence analysis, the theory that atrazine at environmentally-relevant concentrations affect reproduction and/or reproductive development in fish, amphibians and reptiles is not supported by vast majority of observations. They further state that this conclusion holds for other theories (*e.g.*, effects on biochemical endpoints, immune function, or parasitism).

An examination of amphibians and agricultural chemicals was presented by Mann *et al*. (2009). Effects on amphibians, in addition to potential mechanisms of toxicity, from chemicals such as

atrazine among others were discussed. Similar to the other reviews, the study authors identified studies that reported effects as well as reported no effects for various endpoints such as sexual development, metamorphosis, growth and immune response. The study authors argue that more emphasis needs to be placed on examining pesticide mixtures.

A review by Vandenberg *et al.* (2012) on low-dose effects and nonmonotonic dose response included a discussion on atrazine exposure and sexual development. The study authors cite studies in which effects on sexual development were reported as well as studies that reported no effects. For amphibians, based on a weight-of-evidence (reported as taking together the results from the studies that reported effects along with one negative study), the study authors conclude that low-dose atrazine adversely affects sexual differentiation.

A paper (Bernanke and Köhler 2008) on the impact to wildlife vertebrates from environmental chemicals included a discussion about atrazine. As before, the study authors discuss the impact of pesticides and cite studies which report effects to amphibians from atrazine exposure for several different endpoints such as survival, metamorphosis, behavior modifications, and sexual development.

A paper on potential causes for amphibian declines (Hayes *et al*. 2010) cites studies that report effects from atrazine exposure on sexual development and behaviors, metamorphosis, uptake of atrazine and immune/infection response.

11.2.3.6. ***Evaluation of Amphibian Studies and Adverse Outcome Pathways***

The available amphibian data suggest that the range of effects reported for amphibians exposed to atrazine vary considerably between species and testing conditions. Predominantly chronic effects have been reported on metamorphosis, growth and sexual development as well as changes in biochemical parameters, immunologic indicators and behavior. Some of these endpoints are linked, such as size in regards to time to metamorphosis, and therefore significant differences for one endpoint may often be correlated to another effect endpoint. Many uncertainties and concerns have been identified in study protocols and results of the available amphibian data. Therefore, it is difficult to make definitive conclusions about the impact of atrazine at a given concentration but multiple studies have reported effects to various endpoints at environmentally-relevant concentrations.

11.3. Endocrine Disruptor Screening Program

As required by FIFRA and FFDCA, EPA reviews numerous studies to assess potential adverse outcomes from exposure to chemicals. Collectively, these studies include acute, subchronic and chronic toxicity, including assessments of carcinogenicity, neurotoxicity, developmental, reproductive, and general or systemic toxicity. These studies include endpoints which may be susceptible to endocrine influence, including effects on endocrine target organ histopathology,

organ weights, estrus cyclicity, sexual maturation, fertility, pregnancy rates, reproductive loss, and sex ratios in offspring. For ecological hazard assessments, EPA evaluates acute tests and chronic studies that assess growth, developmental and reproductive effects in different taxonomic groups. As part of this risk assessment, EPA reviewed these data and selected the most sensitive endpoints for relevant risk assessment scenarios from the existing hazard database. However, as required by FFDCA section 408(p), atrazine is subject to the endocrine screening part of the Endocrine Disruptor Screening Program (EDSP).

EPA has developed the EDSP to determine whether certain substances (including pesticide active and other ingredients) may have an effect in humans or wildlife similar to an effect produced by a "naturally occurring estrogen, or other such endocrine effects as the Administrator may designate." The EDSP employs a two-tiered approach to making the statutorily required determinations. Tier 1 consists of a battery of 11 screening assays to identify the potential of a chemical substance to interact with the estrogen, androgen, or thyroid (E, A, or T) hormonal systems. Chemicals that go through Tier 1 screening and are found to have the potential to interact with E, A, or T hormonal systems will proceed to the next stage of the EDSP where EPA will determine which, if any, of the Tier 2 tests are necessary based on the available data. Tier 2 testing is designed to identify any adverse endocrine-related effects caused by the substance, and establish a dose-response relationship between the dose and the E, A, or T effect.

Under FFDCA section 408(p), the Agency must screen all pesticide chemicals. Between October 2009 and February 2010, EPA issued test orders/data call-ins for the first group of 67 chemicals, which contains 58 pesticide active ingredients and 9 inert ingredients. A second list of chemicals identified for EDSP screening was published on June 14, 2013[6] and includes some pesticides scheduled for registration review and chemicals found in water. Neither of these lists should be construed as a list of known or likely endocrine disruptors. Atrazine is on List 1 for which EPA has received all of the required Tier 1 assay data. The Agency has reviewed all of the assay data received for the appropriate List 1 chemicals and the conclusions of those reviews are available in the chemical-specific public dockets (see EPA-HQ-OPP-2013-0367 for atrazine). For further information on the status of the EDSP, the policies and procedures, the lists of chemicals, future lists, the test guidelines and Tier 1 screening battery, please visit our website[2].

On June 29, 2015, EPA released the findings of the atrazine EDSP weight-of-evidence analysis (WoE) (http://www2.epa.gov/sites/production/files/2015-06/documents/atrazine-080803_2015-06-29_txr0057155.pdf). EPA concluded that based on the weight-of-evidence analysis, atrazine has the potential to interact with the estrogen and androgen pathways in mammals and other wildlife, and that there was not convincing evidence of potential

[6] See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0477-0074 for the final second list of chemicals.

[2] Available: http://www.epa.gov/endo/

interaction with the thyroid pathway. Overall, the potential for interaction with the estrogen and androgen pathway is supported by the SAP conclusion that the chlorotriazines (including atrazine and its DEA, DIA and DACT degradates) function through a neuroendocrine MOA that suppresses the hypothalamic release of Gonadotrophin-releasing hormone (GnRH) and therefore Luteinizing Hormone (LH), which may result in downstream effects on estrogen and androgen signaling pathways.

With regards to regulatory endpoints for the ecological risk assessment, at the time of finalizing the WoE, the risk assessment endpoint for chronic risk to aquatic vertebrates was based on observations of reduced fecundity in medaka (*Oryzias latipes*) exposed at 0.5 µg/L and above (Papoulias 2014). As discussed in **Section 11.2.1**, EPA has further reviewed this study, revised its interpretation of the study results, and established the NOAEC at 5.0 µg/L with a corresponding LOAEC of 50 µg/L based on reduced fecundity. For mammals, the current endpoint used in the ecological risk assessment is a NOAEC of 3.7 mg/kg/day based on reduced weight gain and food consumption (MRID 40431306). For non-mammalian terrestrial vertebrates, the current chronic risk assessment endpoint is based on reduced mallard duck hatchling weight at 75 mg/kg-diet and above, with reproductive effects (*e.g.*, reduced number of hatchlings) observed only at higher treatment levels (MRID 42547101). At this time, EPA considers that the available ecotoxicological dataset is sufficient for adequately evaluating potential risk to non-target taxa from exposure to atrazine.

12. METHODOLOGY FOR DETERMINING THE LEVELS OF CONCERN FOR ATRAZINE.

12.1. The Risk Quotient Method and Levels of Concern for Terrestrial Plants and Terrestrial and Aquatic Animals.

The Risk Quotient Method is used to integrate the results of exposure and ecotoxicity data. For this method, Risk Quotients (RQs) are calculated by dividing exposure estimates by the acute and chronic ecotoxicity values (i.e., RQ = EXPOSURE/TOXICITY). These RQs are then compared to OPP's levels of concern (LOCs). These LOCs are criteria used by OPP to indicate potential risk to non-target organisms and the need to consider regulatory action. EFED has defined LOCs for acute risk, acute restricted use classification, acute and chronic risk to endangered species. Risk presumptions, along with the corresponding RQs and LOCs are summarized in Table 58**.**

Table 58. Risk Presumptions and LOCs

Risk Presumption		RQ	LOC
Birds[1]			
	Acute Risk	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.5
	Acute Restricted Use	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day (or LD_{50} < 50 mg/kg)	0.2
	Acute Endangered Species	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.1
	Chronic Risk	EEC/NOEC	1
Wild Mammals[1]			
	Acute Risk	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.5
	Acute Restricted Use	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day (or LD_{50} < 50 mg/kg)	0.2
	Acute Endangered Species	EEC/LC_{50} or LD_{50}/sqft or LD_{50}/day	0.1
	Chronic Risk	EEC/NOEC	1
Aquatic Animals[2]			
	Acute Risk	EEC/LC_{50} or EC_{50}	0.5
	Acute Restricted Use	EEC/LC_{50} or EC_{50}	0.1
	Acute Endangered Species	EEC/LC_{50} or EC_{50}	0.05
	Chronic Risk	EEC/NOEC	1
Terrestrial and Semi-Aquatic Plants			
	Acute Risk	EEC/EC_{25} or IC_{25}	1
	Acute Endangered Species	EEC/EC_{05} or IC_{05} or NOEC	1

[1] LD50/sqft = (mg/sqft) / (LD_{50} * wt. of animal)
LD_{50}/day = (mg of toxicant consumed/day) / (LD_{50} * wt. of animal)
[2] EEC = (ppm or ppb) in water

12.2. The Method for Determining the Level of Concern for Aquatic Plant Communities

12.2.1. The Aquatic Plant Community LOC Methodology.

The focus of this methodology is to determine a level of concern at which atrazine concentrations would negatively affect the primary productivity and composition of aquatic plant communities. LOC calculations are typically based on laboratory toxicity studies of individual species and calculated based on the RQs (See Section 12.1). With atrazine, the concern is the effect of atrazine on the individual species as well as effects to the whole community.

Atrazine has been the subject of various microcosm and mesocosm (cosm) studies in which such effects have been documented (**Appendix B**). These studies serve as the foundation for identifying atrazine exposures that are detrimental to aquatic plant communities. However, the concentration and length of exposure varied markedly among these cosm studies. The lengths of the studies varied from one week to one year, and the concentrations remained constant or steadily declined over the exposure period. These studies demonstrate that there is a need to relate the concentration and length of exposure across all cosm studies and the effects they have on the cosm.

The issue of comparing effects across different exposure time-series becomes even more important when trying to relate observed effects in cosms to expected effects in natural systems. Atrazine enters lakes, streams, and rivers primarily as a result of rainfall-driven runoff. This results in highly variable and episodic exposures that can be linked to rainfall distribution, atrazine application patterns, and geology (*e.g.* topography, and soil properties). **Figure 29** provides examples of atrazine chemographs (graphs showing exposure levels over time, note different y-axis scales) measured in streams in the Midwestern U.S. (raw data available to the public at: EPA-HQ-OPP-2003-0367-0178, EPA-HQ-OPP-2003-0367-0205, and EPA-HQ-OPP-2003-0367-0206). These highly variable exposures are markedly different from the exposures typical of laboratory toxicity tests and cosm studies, which have a defined duration (typically between 6 and 60 days) and relatively constant or steadily declining concentrations. They also differ from the exposures expected in lakes and reservoirs, which tend to be steadier over time. There is thus a need for a method to quantify the relative toxic severity of different exposure time series in order to relate effects between different cosm exposures and to extrapolate effects from cosm exposures to field exposures.

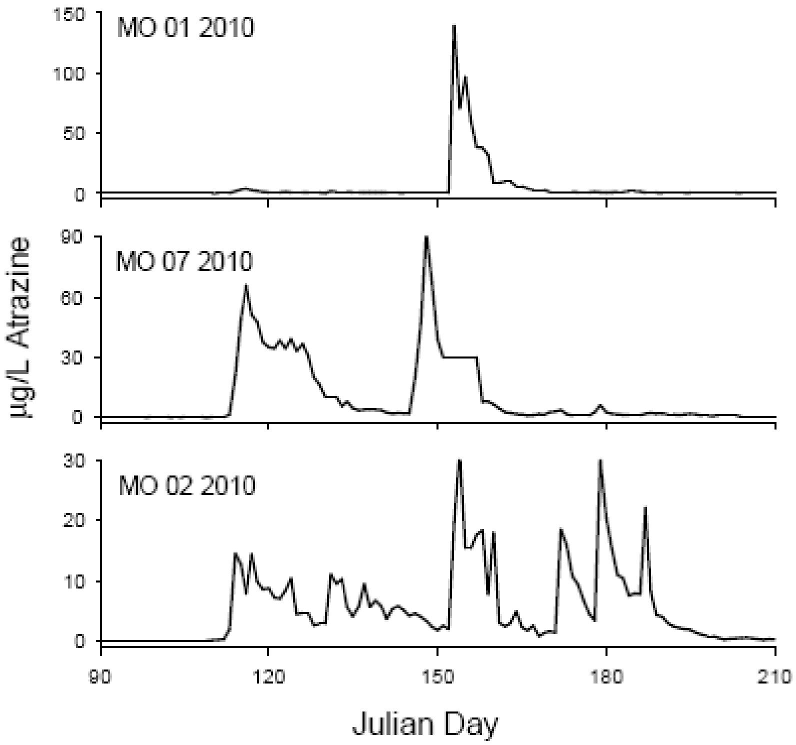


Figure 29. Examples of atrazine exposure time-series for natural freshwater systems.

The primary goal is to be able to extrapolate the toxicity of different atrazine concentrations and length of exposure times from cosm studies to the concentrations and length of exposure occurring in the natural environment. EPA developed the Plant Assemblage Toxicity Index (PATI), which uses single-species aquatic plant toxicity data to build an index against which the cosm and environmental monitoring chemographs could be related. Additional tools such as species sensitivity distributions or the calculation of the 5th percentile hazard criterion (USEPA 2012b), given similar results as the methodology using PATI but do not account for the durations of exposure needed to assess risk to aquatic plant communities.

The LOC methodology is a four stage that uses single-species plant toxicity data and cosm studies to discern what atrazine exposure patterns and concentrations can cause adverse effects on aquatic plant communities. With this methodology, an LOC is developed which, together with monitoring data, can be used to identify watersheds where atrazine levels may result in adverse effects to the aquatic plant community structure and function.

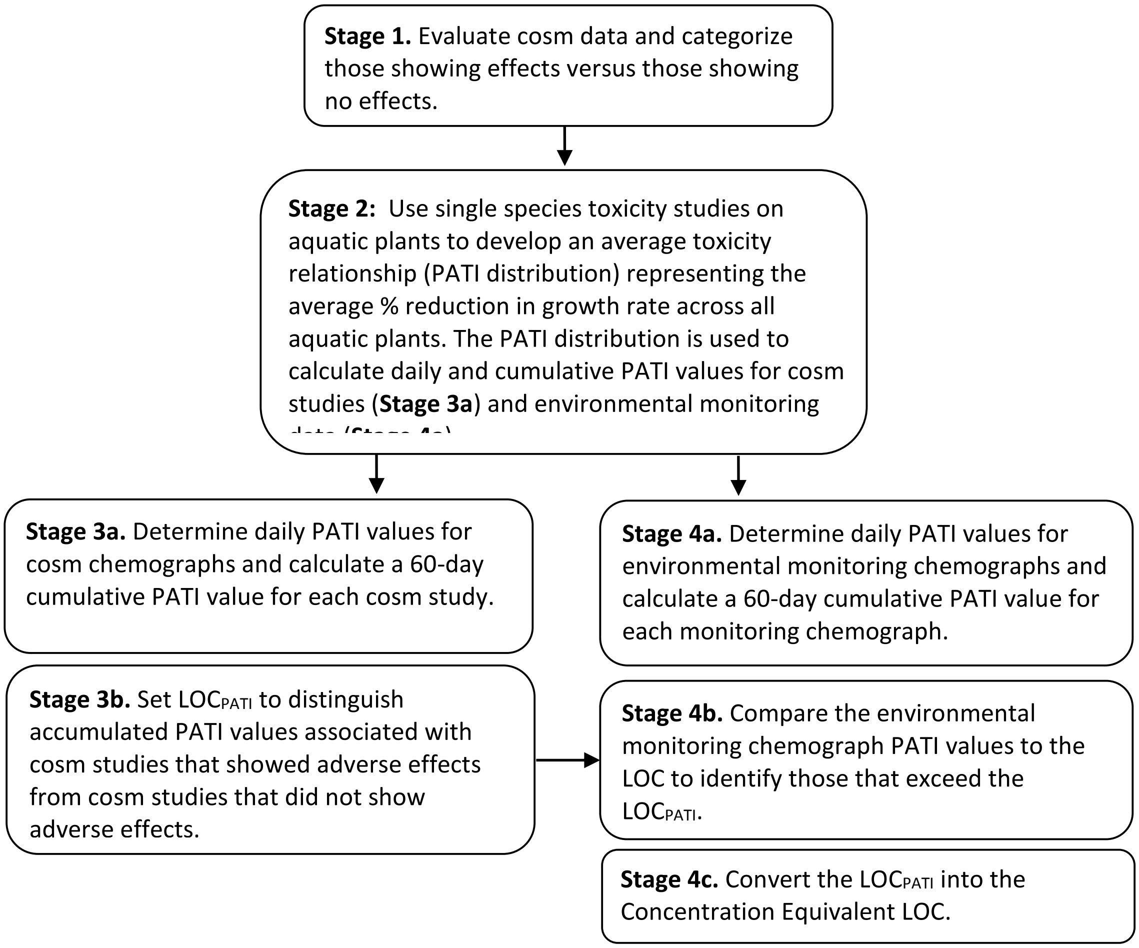


Figure 30. The four-stage process to set an LOC for atrazine.

Stage 1: Summarize Toxic Effect to Communities Based on Microcosm and Mesocosm Studies.

For atrazine, an extensive set of cosm studies have documented effects of atrazine on plant community structure and productivity (**Appendix B).** These cosm studies are the foundation of the methodology and are the primary determining factor for the establishment of the Concentration Equivalent Level of Concern (CELOC). In all, EPA is using 86 atrazine exposure values from 47 published articles on effects of atrazine on cosm systems (**Figure 31**). These 47 studies were selected from the larger pool of candidate studies because they met the established pre-screening and data quality criteria (**Section 10.4**). The EPA reviewed each of the cosm studies that met the quality criteria in order to determine if atrazine-related effects were observed and at what atrazine concentration. Examples of atrazine-related effects observed in the cosm studies included reductions in aquatic plant biomass, concentration of chlorophyll *A*,

rate of photosynthesis (^{14}C uptake and oxygen production), and shifts in aquatic plant community structure (*e.g.*, species composition and diversity) relative to a control.

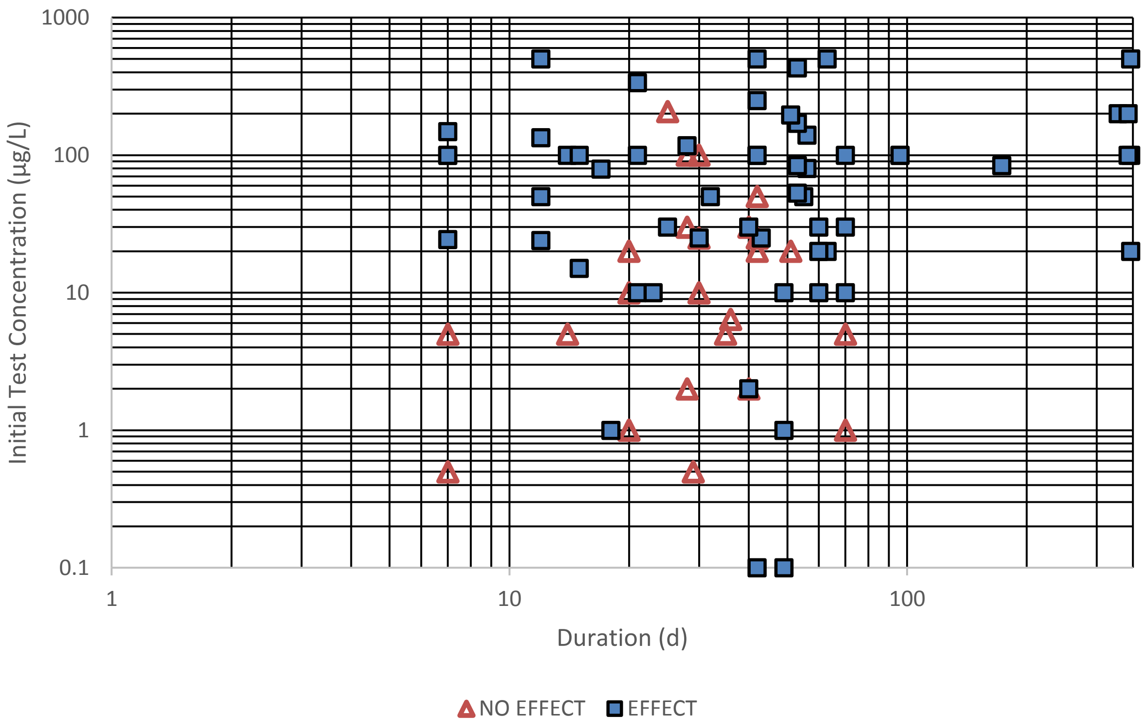


Figure 31. Distribution of Effect and No-Effect endpoints as related to initial study concentration and reported duration.

Stage 2**: **Summarize Toxic Effect Across An Aquatic Plant Assemblage Based on Single Species Toxicity Tests.

As noted above, a primary requirement for this methodology is to estimate the relative effects of different exposure time series on aquatic plant communities, in order to relate effects in different cosm exposures to each other and to extrapolate these effects to exposures in natural systems. PATI estimates such relative effects based on an aggregate of the toxicity relationships determined for individual aquatic plant species. This assemblage of test species is used as a surrogate for aquatic plant communities (only with regard to the relative effects of different exposure time series). PATI is described and evaluated at length in **Appendix I** and is only summarized here (additional options and updates to PATI are provided in **Appendix J**).

PATI represents an expansion of the Species Sensitivity Distribution (SSD) concept commonly used in aquatic risk assessments. SSDs summarize available toxicity tests as a statistical distribution of toxicity endpoints (*e.g.*, EC_{50}s – median effect concentrations) across different taxa (**Figure 32)**. PATI expands on this concept by considering the entire toxicity relationship for plant taxa rather than the single level of effect embodied in EC_{50}s and by determining the

average effect across all taxa rather than focusing on a single taxon at a specific percentile in the SSD. For example, in the middle panel of **Figure 32** curve #1 shows that as atrazine concentration increases, the percent of growth rate reduction also increases. With higher concentrations there is a reduction in the growth of the taxon (*i.e.*, there is a toxic response). This curve represents the toxicity relationship for a single plant taxon. PATI assembles the toxicity relationships from many different taxa of plants and calculates the average toxicity relationship. This represents the average reduction in growth rate across all taxa and concentrations and is called the **PATI distribution** (**Figure 32**, lower panel). PATI thus provides a more complete description of the reduction in productivity of an assemblage of plants and of the driving force for atrazine effects on aquatic plant communities.

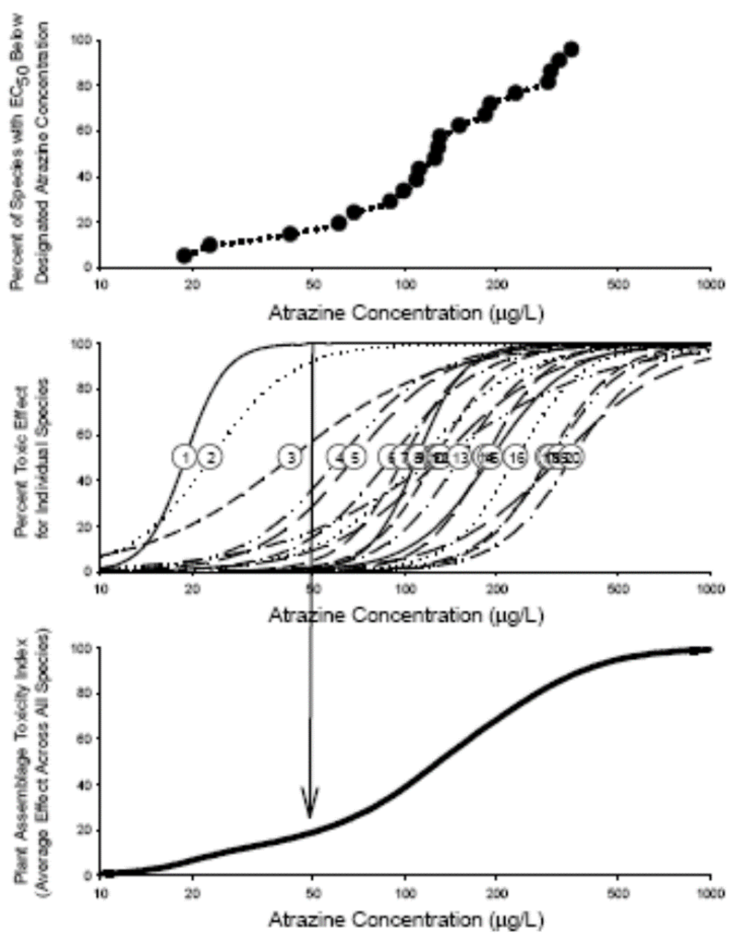


Figure 32. Comparison of toxicity relationships for 20 plant genera (middle panel), the SSD of EC_{50}s for these genera (top panel), and the plant assemblage toxicity index (bottom panel, PATI = the average of the curves in the middle panel) (from Erickson 2012).

Stage 3: Calculate a Level of Concern for Aquatic Plant Communities Based on the PATI Relationship and the COSM Studies.

In the LOC methodology, the PATI distribution is used to specify the average reduction in plant growth rate for each day (daily PATI value) in both the cosm studies and the chemographs available from environmental monitoring data. Because of the potential rapid recovery of growth rates after atrazine exposures (*e.g*., Abou-Waly *et al.*, 1991, Desjardin *et al.* 2003), daily PATI values need not consider residual toxicity from exposures on previous days, but rather only the toxicity for the current day's exposure.

The cumulative effects of an exposure through time (*i.e.,* the total toxic severity of an exposure time series) will take into account the total effect on the community. The EPA addresses this total effect by summing the daily PATI values to produce a "**cumulative PATI value.**" Such a summation cannot be indefinite, but rather is limited to an "**assessment period,**" and this limit must reflect judgments about cumulative effects and the duration of the available cosm data.

Because atrazine exposure outside the assessment period is considered inconsequential by PATI, the assessment period needs to be long enough to encompass (a) exposures of significance to establishing LOC_{PATI} from the cosms (**Figure 31**) and (b) effects expected from seasonal field exposures. However, it should not be any longer than necessary, in order to avoid uncertain inferences regarding (a) cumulative effects of low concentrations and (b) widely separated exposures that are independent regarding ecological effects.

The 60-day assessment period was chosen because it would include all or almost all periods of significant exposure in the AEEMP monitoring data, and would also encompasses the duration of all but a few of the cosm studies. A few additional considerations regarding this period relative to the treatments in the cosm studies should be noted (**Appendices A and G**):

- It is slightly shorter than the longest cosm study treatment with no effect. If the assessment period is significantly shorter than treatments with no effect, this will under-represent how substantial exposures could be without causing effects and thus be too restrictive.
- For those treatments with effects, a shorter period will also be too restrictive by assuming that less exposure is needed to elicit effects than actually is involved (*e.g*., an effect observed over a 60-day exposure would be assumed to require less exposure than actually was required). This consideration does not pertain to the few cosms with extremely long durations, because they simply verify significant effects for high PATI values. For the LOC, the important treatments with effects are those whose exposures near to those without effects.
- That 60-day exposure is longer than many cosm treatments with effects is not an issue, provided the effects from these shorter exposures will still be considered unacceptable from the perspective of this longer assessment period. For example, if a 30-day

exposure showing effects had been monitored for another 30 days without exposure, the effects during the first 30 days would be considered unacceptable despite any recovery that occurred during the second 30 days.

One drawback to assessment periods longer than 63 days is that there are limited data from cosm studies that extend beyond this duration. The Agency determined the 60-day assessment period was most representative of the available data because most cosm studies were in the 7-63 day duration range, and the LOC values derived for the 60-day assessment period should be protective of the shorter time periods**.**

To establish an LOC for aquatic plant communities based on PATI, the first task is to calculate a cumulative PATI value for each cosm study. Daily PATI values for a cosm exposure are first calculated by applying the PATI relationship (e.g., **Figure 32**) to each day's concentration. The cumulative PATI value for the cosm exposure is then based on the 60-day period that has the greatest cumulative PATI value. For example if a cosm study has an atrazine concentration of 50 µg/L and that concentration is held constant, based on the PATI relationship (Figure 33) the daily PATI value is 19%, and the 60 day cumulative PATI is 1140%-days. After this cumulative value has been calculated for all of the cosm studies the values are then combined with the effects/no effects classifications determined in Stage 1.

The relationship of the cosm studies cumulative PATI values to their effects/no effects classification(s) (see **Figure 31**) is used to specify the LOC_{PATI} (the LOC in cumulative PATI values). Figure 33 provides a binary plot of cosm treatment effects/no effects determinations versus their calculated 60-d cumulative PATI values. The LOC_{PATI} is set as the cumulative PATI value that corresponds to a 50 percent probability of an effect based on a logistic binary regression conducted to determine the probability relationship **(Appendix I).** In other words, at a PATI score of 100, there is a 50:50 chance of having adverse effects. EPA decided upon a 50 percent cutoff due to a variety of factors including variability in sensitivities of the cosm studies, magnitude and duration of effects observed in the cosm studies, statistical uncertainty in the calculation of the LOC_{PATI} and ecological relevance of observed effects in the cosm studies. This LOC_{PATI} is expressed in PATI values and needs to be converted to a concentration-based LOC to be more easily compared against monitoring data. This conversion is discussed in Stage 4 below.

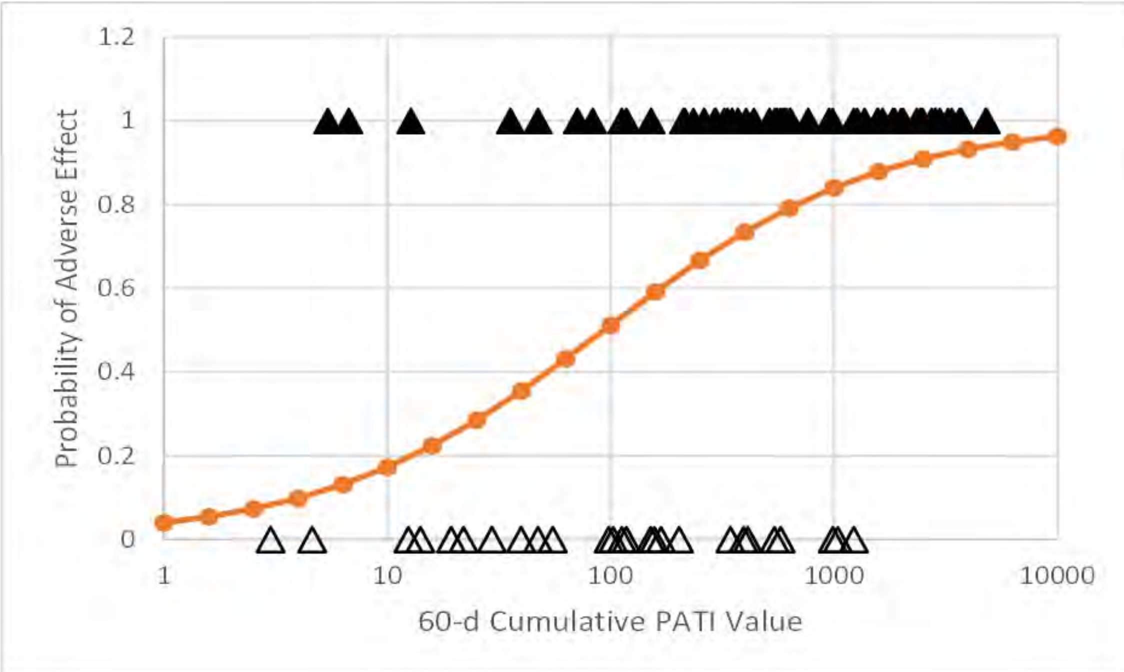


Figure 33. Cosm studies plotted as effect (closed triangle)/no-effect (open triangles) versus PATI fitted to a logistic relationship for the probability of an effect versus PATI, this probability being 50% when PATI equals 93.1.

Stage 4: Determine if Watersheds Exceed the Concentration Equivalent Level of Concern Based on the PATI Distribution and the Environmental Monitoring Data.

The first task is to calculate a cumulative PATI value for each environmental monitoring site. A daily PATI value is calculated for each day of the study, by taking the concentration for each day and finding the corresponding PATI value from the PATI relationship (see **Figure 32** for an example). After each day has been calculated the 60-day period that has the greatest cumulative PATI value is recorded. For example if an environmental monitoring site had an atrazine chemograph as shown in the top panel of **Figure 34**, based on the PATI relationship (**Figure 32**) the daily PATI value would be variable depending on the daily concentration, and the maximum 60-day cumulative PATI would be 150. The monitoring sites with cumulative PATI values greater than the LOC_{PATI} would be predicted to cause adverse effects to the ecological communities in those lakes, streams or rivers.

To assess whether the LOC_{PATI} is exceeded in natural systems, the next step is to quantify the difference between each of the environmental monitoring sites and the LOC_{PATI}. The cumulative PATI value from each monitoring site chemograph (*e.g*. 150) is divided by the LOC_{PATI}. This number is called the Effects Exceedance Factor (EEF), and is similar to risk quotient methods in most EPA risk assessments as it identifies high- or low-risk situations (for examples visit: EPA Risk Characterization).

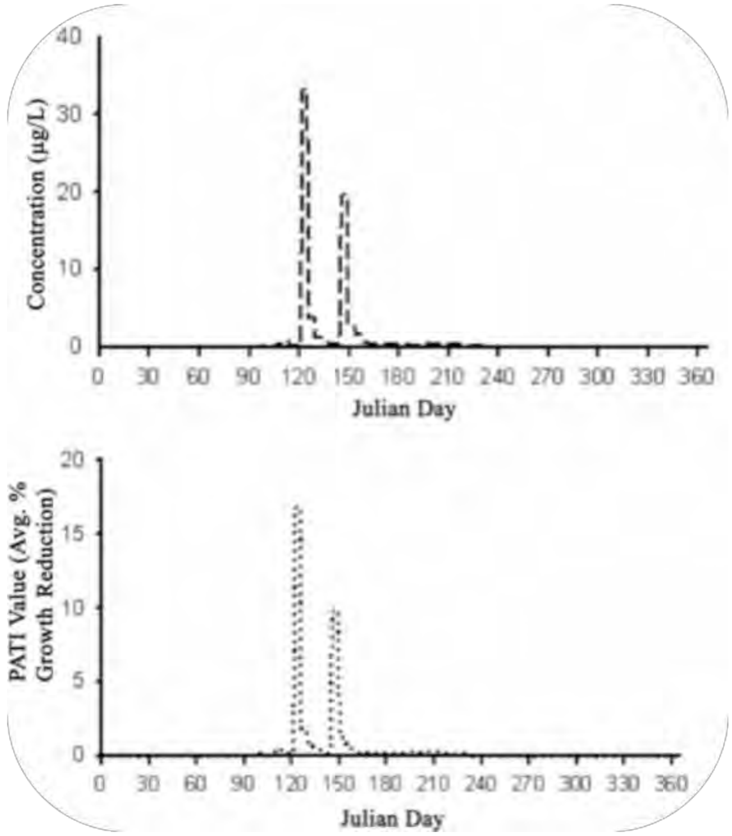


Figure 34. Typical atrazine exposure chemograph from monitoring data (top panel). The calculated daily PATI values and cumulative PATI value for a 60-day window for the example chemograph in the top panel.

Finally, the LOC_{PATI} is converted into a concentration-based LOC called the Concentration Equivalent Level of Concern (CELOC). The CELOC is determined as the concentration at which the monitoring site cumulative PATI value is equal to the LOC_{PATI}, or in other words, the EEF equals 1. This conversion to a concentration allows for rapid comparison of monitoring data to the CELOC in terms of the 60-day maximum average concentration, and avoids the need for running new environmental monitoring chemographs through the model to compare to the LOC_{PATI}. In calculating this CELOC, EPA used Syngenta's monitoring data (AEEMP 2004-2014; http://www.epa.gov/opp00001/reregistration/atrazine/atrazine_update.htm). Additional calculations were carried out to determine the variability in CELOC values based on different analytical/statistical methods (these analyses are discussed further in **Sections 12.2.4 and 12.2.5).** A discussion of how the CELOC will be implemented is presented in **Section 15.1.5.**

12.2.2. History of the Aquatic Plant Community LOC Methodology and the Effects on the LOC from Implementation of Suggestions by Scientific Advisory Panels.

12.2.2.1. *A Synopsis of the Changes Incorporated into the Current Aquatic Plant Community LOC Methodology 2007-2009.*

The EPA made the following revisions to the LOC approach based on recommendations made by the SAPs in 2007, 2009:

- Modifications to Comprehensive Aquatic System Model (CASM) after the 2007 review,
- Critical evaluation of CASM and consideration of alternatives to CASM,
- Re-evaluation the suitability of the original cosm endpoints based on peer-reviewed acceptance criteria (66 of the original 77 endpoints remained),
- Re-classification of the endpoints from the 1-5 Brock score scale to an effect/no effect determination (5 of the original endpoints were re-classified from a Brock score of 2 [treated as “no effect” in the analysis] to ”effect”,
- Addition of one endpoint from one of the original cosm studies that was not previously included,
- Incorporation of 20 additional cosm endpoints from new studies recommended by the SAP,
- Change in the LOC method from balancing the absolute numbers of Type I/II errors to a logistic regression approach
- Replacement of the assumed constant nominal atrazine concentration over the duration of the cosm study with time-variable atrazine concentrations

12.2.2.2. *Modifications Based on the Suggestions from the 2009 SAP (Presented to the SAP in 2012).*

12.2.2.2.a. *New COSM Studies and Old COSM Reclassifications*

The original cosm data set was comprised of 35 studies and 77 endpoints for the CASM development. The Agency evaluated 38 additional studies recommended by the 2009 SAP, and re-evaluated the 35 studies using a rigorous set of acceptance criteria (**Appendix G**). The new cosm study dataset now includes 46 studies and 87 endpoints (plotted in **Figure 33**). In this current cosm data set, the cosm effects were changed from the 5-tier Brock score to an effect-no effect classification. Of the original cosm studies, 5 endpoints that were previously classified as the equivalent of “no effect” (Brock Score of 2) were reclassified as “effect” under the revised analysis (Endpoints 51, 52, 58, 59, and 60).

- Endpoint #51 (Brockway *et al.*, 1984): the effects were based on a 25% reduction in phytoplankton oxygen production occurring the first day of a twelve-day study at 50 µg/L. Recovery was not observed during the study period.

- Endpoint #52 (deNoyelles *et al.*, 1982, 1989): the effects were based on a 50% decline in ^{14}C-uptake and 50% decline in phytoplankton biomass. All effects were statistically

significant. Recovery of both ^{14}C-uptake and biomass was not specified at this level, but assumed to be ≥3 weeks, given the lower magnitude of effect and recovery at the higher concentrations.

- Endpoint #58 (Lampert *et al.*, 1989): the effects were based on a 50% decrease in chlorophyll-a and oxygen saturation for the phytoplankton community at 1 µg/L in the 18-day study. Reductions in oxygen may have been related to daphnid mortality; however, chlorophyll-a reductions were considered to be treatment related. Recovery was not observed.

- Endpoint #59 (Pratt *et al.*, 1988): the effects were based on 35% decrease in dissolved oxygen, slight reductions in magnesium and calcium levels for this 21-day study at 32 µg/L. All effects were statistically significant. Recovery was not reported in the study.

- Endpoint #60 (Pratt *et al.*, 1988): the effects were based on a 35% decrease in dissolved oxygen, a 60% reduction in chlorophyll-a, and slight reductions in magnesium and calcium levels for this 21-day study at 110 µg/L. All effects, except chlorophyll-a reduction, were statistically significant. Recovery was not reported in the study.

12.2.2.2.b. ***Changes to the calculation of the LOC_{PATI}***

The second suggestion from the 2009 SAP was to modify the way that cosm endpoints were used to estimate the LOC_{PATI}. Instead of determining the LOC_{PATI} as the PATI value at which a balance of absolute numbers of effect endpoints fall below and no effect endpoints fall above the value, which is problematic where the numbers of effect and no effect endpoints are unbalanced, the Agency now uses a probability of adverse effects (**Appendix J**). The relationship of the probability of effect in the cosms to the PATI value determined for each cosm exposure is determined using binary logistic regression. The LOC_{PATI} is the point at which there is a 50% probability of an effect.

12.2.2.2.c. ***Final calculation of the Concentration-Equivalent LOC***

The Agency uses the AEEMP monitoring sites (EPA-HQ-OPP-2003-0367-0206) and the LOC_{PATI} to derive a single concentration-duration endpoint, the CELOC. The CELOC can be derived using a variety of methods and assessment periods.

In investigatory studies of the effect of assessment period on the CELOC, the LOC_{PATI} was calculated for 7, 14, 30, 60 and 90-day assessment periods **(Table 59)** using the 2011 Cumulative PATI model and the full cosm dataset (**Appendix J**). The CELOC was calculated by conducting two linear regressions of the EEFs for each duration versus the maximum running average for each duration, one using all the data and one using only those points with

0.5<EEF<2.0. The CELOC was estimated as the concentration on the regression line corresponding to EEF=1.0 (**Table 59**). At shorter assessment periods, 7 to 60 days, the linear regression was a poor fit of the data (*i.e.*, missing the center of the distribution at EEF=1). The linear regression on only the 0.5<EEF<2.0 portion of the data set, resulted in a good fit of the data and was used to establish the CELOC.

Table 59. Effect of averaging period and method of derivation on the percent of AEEMP site/years exceeding the CELOC (2012 Cosm.

Averaging Period	**7-Day**	**14-Day**	**30-Day**	**60-Day**	**90-Day**
Cumulative PATI Value (%-days)	65.5	107.4	132.7	140.0	141.8
CELOC (µg/L) Linear Regression (Entire Data Set)	19.0	15.6	8.6	4.2	2.8
CELOC (µg/L) Linear Regression (0.5-2.0 EEF Range)	18.0	14.9	8.3	4.2	2.7

12.2.2.3. ***Modifications Based on the Suggestions from the 2012 SAP.***

12.2.2.3.a. ***Realistic Exposure Conditions and Cosm Study Duration to Best Represent Atrazine Exposure Conditions in the Field.***

The Panel recommended changes to the available cosm dataset, reducing the number of cosm endpoints to be included in the CELOC calculation. These recommendations included restricting the candidate cosm study endpoints to those within the typical concentration and duration window for atrazine.

Based on the Atrazine Ecological Exposure Monitoring Program (AEEMP), EPA determined that a 240-day survey window would adequately represent the typical seasonal exposures of atrazine in the midwestern corn producing regions. Therefore this time frame will be used to limit the endpoints and chemographs from the cosm studies. The time restriction impacts endpoints 1, 2, 4, 5, 41, and 42 (**Appendix G**). These endpoints all originate from a series of multi-year experiments conducted at the University of Kansas from 1979-1991 (summarized in deNoyelles *et al.* 1982 and 1989). The effects noted in these studies were initially reported within the first few days to weeks following atrazine introduction into the mesocosms. However, as these effects were occurring throughout the study, these endpoints were not removed from the cosm endpoint database.

The Panel's recommendation to limit the endpoints to more realistic atrazine exposures, as identified from monitoring data, reduced the available cosm endpoint database. The peak non-spill related concentration of atrazine in the natural environment is 237.5 µg/L (excluding the value of 683.4 µg/L, which is thought to be a result of a chemical spill; see Table 11 in problem formulation). EPA has decided to use 500 µg/L (approximately 2X the measured peak value) to

bound the upper concentration for inclusion in the analyses. This results in the removal of 11 endpoints (**Table 50**, **page 143**). These implemented changes had negligible effect on the CELOC, changing the level from 4.23 µg/L to 4.38 µg/L.

12.2.2.3.b. *Additional Cosm Study Reviews*

The Panel had concerns with the effects/no effects determinations for several cosm endpoints and proposed that several studies be removed from the endpoint dataset (**Table 60**). These studies and endpoints were reevaluated. EPA's justification and supporting evidence for currently including these endpoints and classifying the endpoints from these studies as effects are available in the data evaluation records (DER) for these studies (http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2003-0367) and is briefly described below.

Table 60. Studies to be Re-reviewed Prior to the Risk Assessment.

Endpoint Numbers	Reference(s)	Initial Test Concentrations (µg/L)
58, 58b	Lampert *et al*. (1989)	0.1, 1
1, 2, 3, 4, 5, 41, 42, 52	deNoyelles *et al*. (1982), Carney and deNoyelles (1986), Dewey *et al*. 1986), Kettle *et al*. (1987), deNoyelles *et al*. (1989)	20, 100, 200, 500
22, 23, 24, 25	Detenbeck *et al*. (1996)	15, 25, 50, 79
28, 44	Kosinski (1984)	10, 100
83, 84	Sequin *et al*. (2001a)	2, 30
85, 86	Sequin *et al.* (2001b)	2, 30
87	Sequin *et al.* (2002)	30

Lampert et al. 1989 (Endpoints 58 & 58b):

EPA has identified that significant effects to the community occurred after 7 days of exposure to atrazine at both 0.1 and 1 µg/L.

The effects noted in the study for the 1 µg/L test concentration included:

- percent oxygen saturation declines ~100 % on day 7 to ~30-40% on days 15 and 20.
- 50% decline in chlorophyll a between day 7 and day 20
- particulate organic carbon increased between day 7 and day 20.
- zooplankton density (daphnia, cyclops, bosimia, nauplii) all reduced in 1 µg/L test after 7 days.

The effects noted in the study for the 0.1 µg/L test concentration included:

- % oxygen saturation declines by >50% between day 7 and day 20 in warm water experiments

- % oxygen saturation declines by >50% between day 10 and day 20 in cold water experiments
- photosynthetic rate much lower than controls in the warm and cold water experiments after day 1 until the period of time between day 15 and day 25 where recovery was noted.
- daphnid die off occurred between day 10 and day 20.

The foremost concern with this study is the use of ethanol as a solvent. The data described by Lampert *et al.* (1989) were generated from a graduate research project (Fleckner 1981). The authors describe using a concentrated stock of atrazine dissolved in 5 ml of ETOH and then diluted to 100 ml with deionized water. They report that they pipetted volumes to be added to each 1700 L cosm. EPA has calculated the total estimated oxygen demand for ethanol degradation based on a worst case assumption by assuming that the entire volume of stock concentrate was added to an individual cosm (*i.e.*, 5 ml of ETOH into one 1700 L cosm). The theoretical oxygen demand for this condition, in the absence of organic matter, is calculated to be 8000 mg of oxygen for the complete degradation of the 5 ml of ETOH. The reported temperature and percent oxygen saturation allows for the determination that there would be ~ 16,150 mg of oxygen in the solution of the cosm. So, roughly half of the oxygen would be used for ETOH degradation.

The Fleckner study clearly states that the cosms were dosed with a small pipetted volume of the stock solution, thus there would have been far less ETOH added to each cosm. The exact dosing volume and the concentration of the stock solution were not reported. The dissipation of ETOH in the cosms would have occurred much more quickly than the time frame of effects reported in the study. The half-life of ETOH in standing water is between 0.25 and 1 day through biodegradation and there is a high likelihood that ETOH would have vaporized from the solution, thus when the samples were taken from the cosms for chemical and biological testing, some of the ETOH would be lost with the 300 L head space air exchange.

deNoyelles et al. 1982, Carney and deNoyelles 1986, Dewey et al. 1986, Kettle et al. 1987, deNoyelles et al. 1989 (Endpoints 1, 2, 3, 4, 5, 41, 42, 52):

The endpoints identified from the various reported results from these studies were re-reviewed as recommended by the 2012 SAP. The main focus of the review was to identify first the endpoints where there was agreement between EPA's endpoint classifications and the 2012 SAP and Giddings 2012 classifications. The review identified agreement for all endpoints that were 100 µg/L or higher (endpoints 1, 3, 4, 5, 41, and 42). Therefore there was disagreement on endpoints 2 and 52, each of which was reported from an independent mesocosm study testing the effects of 20 µg/L for 365 and 63 days, respectively. Reported effects for endpoint 2 included only the first year of the 805-day study where no recovery was reported, and there were biologically significant decreases in floating and submerged plant cover (40% decline in *Typha*; 50% decline in SAV; 50% decline in *Najas*). Reported effects for endpoint 52 were a 50% decline in ^{14}C-uptake and the biomass of phytoplankton, with recovery to control levels taking longer than 3 weeks.

Detenbeck et al. 1996 (Endpoints 22, 23, 24, 25):

This study was designed as an artificial flow-through system through a swamp, with test concentrations of 15, 25, 50 and 79 µg/L staged in increasing concentrations across two artificial wetlands. The endpoints identified by EPA were those related to periphyton plates that were added at the start of each study stage. The 15 µg/L test started May 1st and continued to June 1st, reporting a 23% decrease in dissolved oxygen (DO) and significant reduction in gross productivity. The second stage increased atrazine concentration to 25 µg/L from June 2nd through July 15th, and reported endpoints included statistically significant decreases in respiration and net primary productivity. The third stage (endpoint 24) tested 50 µg/L from July 16th through August 17th, and reported statistically significant reduction in net primary production. The final stage of the study tested 79 µg/L from August 18th through September 8th and resulted in statistically significant declines in net primary productivity.

Kosinski, 1984; Kosinski and Merkle, 1984 (Endpoints 28, 44)

These studies reported the results from a 21-day study testing 10, 100, 1000 and 10000 µg/L of atrazine in recirculating artificial streams. The highest two test concentrations are excluded from the current EPA Cosm Effects Database (**Appendix B**) because they are above the expected environmental concentrations (maximum 500 µg/L). The results from the 10 µg/L test concentrations indicated a statistically significant 40% decrease in primary productivity and a slight decrease in biovolume. The 100 µg/L test concentration reported a statistically significant decrease (30%) in primary productivity and no change in biovolume.

Seguin et al. 2001a (Endpoints 83, 84):

EPA reported these endpoints as no-effects for the database presented to the 2012 SAP. The results indicate that there were 14% and 61% increases in periphyton chlorophyll a concentration at 2 and 30 µg/L respectively. While these are stimulatory effects, they are indications of changes occurring on a dose response manner, and are not uncommon periphyton responses at lower atrazine concentrations. As atrazine exposure begins, effects to phytoplankton communities may lead to increased light penetration to the periphyton on the bottom of the mesocosms. The authors do not report on the effects to phytoplankton in this study and thus this connection is unclear. EPA maintains the endpoint classifications, that there were no negative effects to the periphyton community reported in this study report.

Seguin et al. 2001b (Endpoints 85, 86):

This study describes multiple experiments ranging from single species tests to outdoor microcosms and mesocosms. Endpoints 86 and 87 were identified as significant effects in the mesocosm tests resulting from exposures at 2 and 30 µg/L respectively. The effects noted in the 2 µg/L test concentration included significant shift in the phytoplankton community composition based on statistically significant decrease in the density chlorophyceaean

phytoplankton and statistically significant increase in the density of chrysophycean phytoplankton populations. At the 30 µg/L test concentration, the effects seen at the 2 µg/L test concentration were more pronounced and additionally included statistically significant increases in bacillariophycean phytoplankton densities.

Seguin et al. 2002 (Endpoint 87):

The SAP briefly commented on this study and endpoint, not directly disagreeing with the effects classification, but mentioned that the study did not report recovery. Further stating that the "preponderance of evidence in the literature indicates that recovery would be expected". EPA classified this endpoint as an effect because of the significant decreases in chlorophyll-a (22%), dry weight (30%), and dissolved oxygen (20%), as well as significant changes in community structure and the Bray-Curtis similarity index. Changes in biomass (chlorophyll-a and dry weight) were evident at day 9, changes in community structure began at day 11, changes in Bray-Curtis began day 9, and changes in DO about day 3. Although dissolved oxygen showed an apparent recovery about day 12, it diverged from the control again starting about day 17 through the end of the experiment. There were no other recoveries reported in these endpoints.

12.2.3. New Cosm Studies Added Since the 2012 SAP

Data evaluation records for the following newly added studies can be found in **Appendix B.**

Pannard et al. 2009 (Endpoints 102, 103, 104):

In this 7-week study, indoor microcosms comprised of natural phytoplankton communities collected from a freshwater wetland in France were exposed to 0.1, 1.0, and 10 µg/L atrazine. Significant declines in phytoplankton density (27-79%) were reported for multiple genera across all test concentrations. At and above 1.0 µg/L this surmounted into a significant shift in the community compositions as compared to the controls. An increase in the Simpsons index as well as a shift in the composition in a dose response manner indicates that the concentrations tested affected the community composition leading to more variable communities than the controls and that the dominance in the community had shifted from few taxa being dominant to more even spread of dominance across species. Statistics for diversity and composition were provided only for the end of the study (60 days), thus reflect any recovery that may have occurred during the continuous exposure.

King et al., 2014 (Endpoints 105, 106, 107)

This registrant submitted study was conducted at Baylor University in 2014. The study was designed to represent a stream environment and included three main sections (riffle, glide, and pool). The source of the inoculant colonization and water was the local wetland which was described in the paper as "pristine". Atrazine was added to the flow through design as three 4-day long pulse events with a 7-day period between pulses, and a 28 day recovery period after

the final pulse. Test concentrations for each pulse event were 50, 100, and 150 µg/L, which translated to the targeted 60-day averages of 10, 20, and 30 µg/L. The study also included the continuous addition of nutrients, NO_3-N (1 mg/L) and PO_4-P (0.15 mg/L) to "stimulate autotrophic production and estimate daily nutrient uptake". The constant addition of high levels of nutrients in this study compromised the utility of many endpoints due to the rampant growth of filamentous algae. Eventually the filamentous algae sloughed off of the riffle portion (upper most portion) of the mesocosms, resulted in a scrubbing of the tiles as it went past, then accumulated in the ungrazed glide and pool portions of the study. This severely impacted many of the macrophyte and phytoplankton endpoints that would have been collected later in the study because the controls were negatively impacted by the metaphyton while atrazine treatments controlled the rampant growth of the metaphyton. These effects began around day 22 of the study in the controls, which is 5 days short of the last day of exposure. Therefore, endpoints were selected from among those portions of the cosms in which control performance would not be severely impacted by the accumulation of the mesophyton, in addition metaphyton biomass was also used as an endpoint. The study results indicated that there was significantly less metaphyton biomass (80%) compared to the controls on day 27 for all test concentrations and on day 60 the treatments continued to be behind controls (50% less). In addition, the end of study periphyton biomass in the riffle portion of the cosms responded in in a dose response manner with reductions of 36%, 42, and 64 % as compared to the controls. EPA has classified these endpoints as effects.

Baxter et al. 2011 (Endpoints 108, 109, 110, 111):

This study was conducted over 73 d at the University of Guelph Turfgrass Institute Microcosm Facility (Guelph, ON, Canada). Each 12,000-L microcosm were filled with spring water from adjacent irrigation pond and circulated at 12,000 L/d for seven weeks. Atrazine was added in a random design with nominal concentrations of 0, 1, 10, 30, and 100 µg/L with 3 replicates per treatment level. Results were reported as comparisons at the end of the 70 day exposure period. At the 1 µg/L test concentration, there were not statistical or biologically significant differences in macrophyte biomass as compared to the controls, however there may have been effects from the exposure but these had recovered to control levels by day 70. Effects on macrophyte biomass were noted for all other test concentrations, with 48, 14, and 86 % reductions in the 10, 30 and 100 µg/L tests as compared to the controls. Therefore, endpoint 108 was classified as no-effect, and all other endpoints were classified as effects.

12.2.4. Analyses of Driving Factors Affecting the CELOC

This section evaluates the relative impacts of recommendations made by the 2007, 2009 and 2012 Scientific Advisory Panels (USEPA 2007b, USEPA 2009a, USEPA 2012) on the CELOC **(Table 61).** Based on the 2003 method, for the 60-day duration, the preliminary trigger was 17.5 µg/L. The direct comparison between the preliminary trigger and CELOC endpoints derived from PATI is problematic because a different set of cosm data, LOC approach, expanded set of field chemographs, and atrazine concentration profile, have been used. In addition, the CASM model used in that preliminary derivation has changed since 2003 based on SAP recommendations.

TABLE 61. COMPARISON OF EFFECT OF LOC METHODS, COSM EXPOSURE CHARACTERIZATION, AND COSM DATASETS ON RESULTING 60-DAY PATI MODEL-DERIVED LOCS AND CONCENTRATION-EQUIVALENT LOCS					
LOC Method	**Cosm Data**	**Cosm Exposure**	**Changes**	**LOC_{PATI}**	**CELOC (µg/L)**
Old	Original 77	Constant Nominal	2003 Preliminary	NA	17.5[a]
LOC BASED ON 2007 SAP RECOMMENDATIONS					
Old	Original 77	Constant Nominal	Estimated change in LOC switching from preliminary version of CASM to updated version of CASM	NA	11.7[b, c]
Old	Original 77	Time-Variable	Changed representation of cosm atrazine concentrations from assumed nominal to actual concentrations over time	NA	7.2[b, c]
Old	Original 77	Constant Nominal	Switched from CASM to PATI to derive the LOC after 2007 SAP recommendations for modifying CASM, additional sensitivity analyses	4.97	9.6
Old	Original 77	Time-Variable	Changed representation of cosm atrazine concentrations from assumed nominal to actual concentrations over time	4.24	8.1
LOC BASED ON 2009 SAP RECOMMENDATIONS AND UPDATED COSM DATABASE					
New	Original 77	Time-Variable	Changed LOC from balancing absolute numbers of Type I/II errors to logistic regression	4.15	7.9
New	Original screened re-evaluated	Time-Variable	Screened 77 original studies with new acceptance criteria: - Dropped 7 effects endpoints (6, 11, 12, 16, 20, 21, 43) - Dropped 4 no effects (55, 56, 57, 74) Re-evaluated the 66 remaining original cosm endpoints that passed the new acceptance criteria (broken down in steps)	-	-
			(a) Changed endpoint durations to match observed effect	4.55	8.7
			(b) Changed 5 studies from no effect (original Brock score of 2) to effect (51, 52, 58, 59, 60)	3.01	5.5
			(c) Added a second endpoint from the Lambert study (58b)	2.89	5.3
New	New Revised Cosm Set	Time-Variable	Added 20 endpoints from new cosm studies	2.33	4.2
LOC BASED ON MODIFICATIONS TO THE MODEL AND UPDATED COSM DATABASE					
New	Modified New Rev. Set	Time-Variable	Changed 5 of original cosm endpoints from effect back to original no effect determination (see discussion below)	235.0	7.4

New	New Revised Cosm Set	Time-Variable	Changed from an average PATI value to Cumulative PATI. (Final dataset presented to 2012 SAP)	140.0	4.2
LOC BASED 2012 SAP RECOMMENDATIONS AND UPDATED COSM DATABASE					
New	New Revised Cosm Set	Time-Variable	Removed 11 endpoints from the cosm database (greater than 500 µg/L) Added 9 new endpoints (see above)	85.2[d]	3.4[d]

[a] The 2003 concentration is not a CELOC, but a trigger concentration.
[b] For calculation of the CELOC when implementing the CASM model in the process, both the concentration and EEF were Log_{10} transformed. All subsequent regressions were conducted using linear regression of untransformed data.
[c] CASM was implemented with a logistic toxicity relationship for the initial single species toxicity data to be consistent with the current version of PATI. The version of CASM presented to the 2007 SAP used a sigmoidal-threshold toxicity relationship.
[d] Median estimated LOC_{PATI} and CELOC, See **section 12.2.5** for more details.

12.2.4.1. ***Effect of 2007 CASM Changes***

One consequence of the 2007 SAP was the recognition by all parties that the initial CASM model was unrealistic and needed modification. Changes were made that provided a more realistic depiction of a midwestern stream and this version was used for evaluations leading up to the 2009 SAP. To establish the impact of these changes on the difference between the CELOC and the preliminary screening value, the modified version of CASM used for the 2009 SAP was applied with the same cosm data and LOC method as the 2003 evaluations. These CASM-based LOCs were then applied to the same AEEMP data used for current CELOC derivations, in order to derive what the EEFs and CELOC would be for the modified version of CASM. This resulted in a CELOC of 11.7 µg/L, compared to the screening value of 17.5 µg/L. In other words, correcting only the deficiencies of the 2003/2007 CASM version and applying it to a more extensive and realistic set of field data than used in 2003 caused the CELOC to be 29% lower than the 2003 trigger.

12.2.4.2. ***Change from assumed constant nominal to time-variable atrazine concentrations over the duration of the cosm study***

The original analysis of cosm studies (for the 2003 preliminary trigger concentrations and the 2007 SAP) assumed atrazine concentrations remained constant throughout the duration of the study. However, for a majority of the cosm data, atrazine concentrations declined throughout the study period. As part of the revisions leading up to the 2009 SAP, chemographs were developed for each cosm treatment (these chemographs were also reviewed by Syngenta's consultants). Using the modified CASM with these new time-variable chemographs, while still implementing the 2003 CELOC methodology, results in a CELOC of 7.2 µg/L (**Table 61**). A significant drop is to be expected because constant concentrations indicate a higher concentration was needed to cause effects in the cosms than was actually present. Again, by addressing only the changes recommended by the 2003 SAP, there is more than a two-fold

difference between the preliminary trigger and the CELOC. This is before considering the switch to PATI, the change in the CELOC method, and changes in cosm data. The 2003 and 2007 SAP evaluations presented in **Table 61** were intended to be preliminary illustrations of methodology rather than providing assessment concentrations and were recognized at the time to require additional changes, so that this difference between the trigger and the CELOC is to be expected.

12.2.4.3. ***Switch from CASM to PATI***

Based on the recommendations from the 2007 SAP, as an alternative to CASM, EPA developed PATI. PATI was developed after the change to the time-variable chemographs, however to compare to the earlier CELOCs, PATI was modified to use the constant concentration chemographs used in earlier versions of CASM. The resulting CELOC for comparison to the constant nominal concentration for CASM, explained in the earlier step, is 9.6 µg/L for PATI. This reflects the change from CASM to PATI. The resulting CELOC for the time variable concentrations is 8.1 µg/L, the same as the time variable CASM based value.

12.2.4.4. ***Change the LOC determination approach from balancing Type I/II errors to logistic regression.***

The old LOC approach balanced the absolute number of effect endpoints that fell below the LOC with the number of no-effect endpoints above the LOC. However, because there are fewer no-effect endpoints in the cosm dataset, this allows for a higher percentage of no-effect endpoints above the LOC than effect endpoints below the LOC. The 2009 SAP expressed concern about the approach and recommended exploring alternative approaches.

The new LOC approach is based on the relative probability of an adverse effect, linking the PATI index value with the 50^{th} percent probability of an adverse effect. The change from the old (original) LOC approach to the logistic regression approach using the original cosm dataset (77 cosm endpoints) resulted in the CELOC dropping from 8.1 to 7.9 µg/L.

12.2.4.5. ***Re-evaluation of the original 77 cosm endpoints***

The 2009 SAP made several recommendations regarding the original set of cosm studies EPA used for the LOC determination, ranging from the Brock scoring effects determination to the suitability of some studies for use (based on a review Syngenta submitted to the docket for the 2009 SAP). The re-evaluation included several steps, which have been broken out as separate increments in **Table 61:**

(a) The studies were screened against acceptance criteria based on number of controls, exposure, experimental design, statistical methods, and data interpretation (**Appendix G**). The re-evaluation resulted in 11 of the original 77 endpoints being dropped, which included 7 effects endpoints and 4 no effects endpoints. During the re-evaluation

process, some endpoint durations from the original evaluation were revised to match the effects endpoints. Twenty-five durations were adjusted, with 15 effects durations increased and 10 effects durations decreased. This resulted in a net increase in the CELOC to 8.7 µg/L

(b) The next sequential change was a change in the effects endpoint classification from the 1-5 Brock score to a binary effect (1) / no effect (0) score. This resulted in a change from no effect (Brock score 2) to effect for 5 of the original cosm endpoints (**Appendix G**): #51 (Brockway *et al.*, 1984), #52 (deNoyelles *et al.*, 1982, 1989), #58 (Lampert *et al*., 1989), #59 and #60 (Pratt *et al*., 1988). The effective classification of the other endpoints remained unchanged. This resulted in the greatest change in the CELOC from 8.7 µg/L to 5.5 µg/L

(d) The re-review also resulted in adding an effects endpoint from the Lampert et al. (1989) study, identified at #58b, which showed an effect at a concentration of 0.1 µg/L, and resulted in a slight reduction in the CELOC from 5.5 to 5.3 µg/L (**Appendix G**).

Next to the revision in the CASM model recommended by the 2003 SAP, the re-evaluation of the cosm endpoints and, in particular, the re-classification of 5 of the studies from an original no-effect to effect (**Appendix G**), resulted in the greatest reduction in the CELOC.

12.2.4.6. ***Incorporated additional endpoints from new cosm studies recommended by the 2009 SAP.***

The 2009 SAP provided EPA with a list of additional cosm studies that were not included in the original set of cosm studies. The Agency's review of these studies, using the study acceptance criteria, added 15 new studies with a total of 20 new endpoints (13 effect endpoints, 7 no effect endpoints; **Appendix G**). The addition of the new cosm endpoints to the existing revised endpoints resulted in a change in the CELOC from 5.3 to 4.2 µg/L.

12.2.4.7. ***Changed from an average PATI value to Cumulative PATI.***

The initial development of PATI as presented at the 2009 SAP used the average PATI value over the assessment period. The change to cumulative PATI better reflects the intent to describe cumulative effects. Because the effects index is intended to describe total toxic impact, the approach to address time is simply to sum the daily PATI values to provide a cumulative PATI. The summation units of this cumulative PATI are analogous to the ppb-days or, more familiarly, with degree-days used to describe the total heating or cooling impact of seasonal weather. A fundamental aspect of such a summation is that a certain reduction in growth over 1 d is treated as being of equal importance as half that reduction persisting for 2 d, a quarter of that reduction persisting for 4 d, etc. This summation cannot be continued indefinitely, but rather is

limited here to a 60-day period. The change from an average PATI to the cumulative PATI does not change the EEFs or CELOC, because they are mathematically equivalent.

12.2.4.8. *Cosm Endpoint Database Changes*

All of the substantial changes to the resulting CELOC are derived from changes made to the cosm endpoint database. Through the years EPA has re-reviewed the available cosm data, added or excluded studies based on the selection criteria, and changed the classification of endpoints (effects/no-effects). These refinements to the cosm endpoint database have been made in response to the suggestions and recommendations made by the multiple SAPs. Comparisons are often made between differing approaches of deriving a CELOC or similar level of concern for atrazine, but when using one endpoint database to compare all of these differing methods, the methods ultimately come up with very similar results (*e.g.* 2007-2009 CASM vs. PATI resulted in 7.4 versus 8.1 based on the common endpoint database at the time). Large differences in the CELOCs that have been presented at public meetings (e.g., Giddings 2012) are based primarily on differing interpretations of effects or no-effects at each endpoint and how endpoints are derived from each study. EPA considers a test concentration in a study as providing one endpoint and uses this holistic approach to the effects on a community as the primary comparable endpoint to the protection of aquatic plant communities. Other interpretations of the endpoints have resulted in splitting periphyton, phytoplankton and macrophytes into separate endpoints for the database. These splitting events disassociate the connectivity of the community and impart bias on the database of effect/no-effects endpoints by effectively erasing the effect from the binary logistic regression step that establishes the 50^{th} percentile of effects/no-effects data. Therefore, EPA has maintained its approach of a single endpoint per test concentration in each experiment.

As an example of the sensitivity due to the cosm classifications, EPA presented the CELOC as a range in concentrations to the 2012 SAP due to the uncertainty involved in the classification of a few COSM endpoints. The reclassification of 5 of the cosm endpoints from “no effect” to “effect” resulted in an approximate 40% reduction in the revised baseline 60-day CELOC. If the classification of 5 of those endpoints that were previously considered to be “no effect” were changed back to “no effect”, the CELOC would be 7.4 µg/L. Based on the results of these analyses in 2012 EPA determined the CELOC range to be between 4-7 µg/L.

The current EPA cosm endpoint database results in a CELOC of 3.4 µg/L. This means that those fresh water and estuarine/marine monitoring sites with a **60-day running average at or above 3.4 µg/L** have atrazine concentrations that are above the CELOC, and that ecologically significant changes in aquatic plant community structure, function, and/or productivity would be expected.

12.2.5. Uncertainty in the Calculation of the LOC_{PATI} and CELOC

There are several calculations in the derivation of the CELOC that incorporate uncertainty into the final estimate. These sources include the building of the PATI distribution, the estimation of the 50th percentile of the effects/no effects distribution (LOC_{PATI}), and the final conversion to the CELOC. To explore the potential population of CELOC estimates based on the uncertainty in the PATI distribution, and in the estimation of LOC_{PATI}, the agency revised the software presented to the 2012 SAP. The new programs generate such alternative distributional parameter sets and use them to compute alternative cumulative PATI values for exposures of interest, alternative LOCs for the cumulative PATI values, and alternative risk ratios (EEFs) for field chemographs.

The Agency approached the error analysis by stepping through the error to describe how each piece of the model approach is contributing to the potential population of potential CELOCs. In this uncertainty analysis, multiple CELOC estimates are made which account for the different sources of uncertainty described above. The pool of these CELOC estimates for each iteration of the analysis can be considered as a population of potential true estimates of the CELOC and thus have a distribution that can described with minimum, median and maximum concentrations.

The first modification to the models presented to the 2012 SAP was to the method of obtaining the PATI distribution. PATI is calculated using distributions of $logEC_{50}$ and the logSteepness based on available plant toxicity tests. The best overall estimates of these distributions are 2.12 and 0.37 for the mean and standard deviation of $logEC_{50}$ and -0.05 and 0.18 for the mean and standard deviation of logSteep (Erickson 2012). Uncertainties in these parameter values can be used to calculate alternative sets of parameters that define the uncertainty of the PATI distribution and thus can be used to describe the uncertainty of PATI-based assessments. The program reads in exposure chemographs and effect data for a user-specified set of cosm endpoints and generates a user-specified number of different PATI distribution (NSET). Each NSET PATI distribution is based on an alternative set of input parameters sampled from the toxicity data described in Erickson 2012. The user also has the opportunity to define the number of points from the distributions that are sampled for PATI function calculations (NSAMP). NSAMP should be at least 10,000 and can be as high as 100,000. Even these large samples leave some computational uncertainty in the results. This computational uncertainty can be examined by specifying the program to ignore the uncertainties both of the toxicity data and of the LOC_{PATI} estimation (*e.g.*, **Table 62: Run 1**) and comparing it to the results when accounting for the uncertainty in the PATI distribution (**Table 62: Run 2**). This is completed by entering the exposure data for a user-specified set of field chemographs and the alternative NSET PATI functions and LOC_{PATIs}. For each NSET, the maximum 60-d running average concentration and the 60-d cumulative PATI value are calculated for each field chemograph. Finally, the EEF for each chemograph is calculated by comparing the cumulative PATI value for that field chemograph to the selected LOC_{PATI} for that same NSET. Finally a CELOC is calculated for each NSET $PATI_{LOC}$ result using linear regression. The analysis identified that the contribution of error from the individual toxicity data (Run 1) results in a narrowly distributed

population of CELOCs for Run 1, and suggest that the error contribution from the individual toxicity data is small. The error contribution of the PATI distribution (Run 2) is slightly larger but remains narrow, having an inter-quartile range from 2.1 to 4.1 µg/L.

To address the next source of error, estimation of LOC_{PATI}, for each NSET, the 60-d cumulative PATI value for each cosm endpoint is calculated, and the best estimate of and standard error for the $PATI_{LOC}$ (50th percentile of the effects/no-effects distribution, **Figure 18**) are calculated. Once those estimates are defined, the LOC_{PATI} for that NSET is randomly selected from the uncertainty distribution (*i.e.*, selects from the potential values within the standard error of the best estimate) of the LOC_{PATI}. Therefore the resulting population of NSET LOC_{PATIs} reflects the error of the estimation of the LOC_{PATI}. In **Table 62, Run 3** results describe this error as being comparable to the error introduced by the estimation of the PATI distribution (Run 2) with a same median estimate (2.9 µg/L) and a similar interquartile range (2.0 to 4.2 µg/L).

The last iteration of the uncertainty analysis took into account the combined error of the CELOC methodology and reflects the total error of the estimations given the input data and mathematical calculations (*i.e*., combining error from Runs 1, 2, and 3). The resulting population of CELOCs from cumulative evaluation are lognormally distributed with a median value of 3.4 µg/L, a lower quartile of 2.4 µg/L, an upper quartile of 4.7 µg/L, and a range from 0.4 to 16.1 µg/L. This population of potential CELOCs provides a range in which EPA is confident that the true CELOC is distributed. **EPA has selected the median estimate value as the best estimate of these results and will use a 60-day maximum running average of 3.4 µg/L as the regulatory threshold for assessing risk to aquatic plant communities.**

Table 62. Description of the population of CELOC results (µg/L) from each uncertainty analysis conducted. The bolded median for Run 4 represents the best estimate of the CELOC given the cumulative uncertainty in the CELOC derivation methodology.

	Run 1 – Mathematical Error	Run 2 – Mathematical and Individual Toxicity Error	Run 3 – Mathematical and LOC_{PATI} Estimation Error	Run 4- Cumulative Mathematical, Individual Toxicity and LOC_{PATI} Error
Median	3.3	2.9	2.9	**3.4**
5th Percentile	3.3	1.2	1.2	1.4
25th Percentile	3.3	2.1	2.0	2.4
75th Percentile	3.4	4.1	4.2	4.7
95th Percentile	3.4	6.9	7.9	7.9
Range	3.0 – 3.6	0.4 – 14.0	0.4 - 16.0	0.4 – 16.1

Another source of uncertainty that was not included in the analyses described above is the contribution of potential error in the cosm endpoint database. Different interpretations of effects occurring in the cosms can greatly change the CELOC (*e.g.*, Giddings 2012), scoring methodology, and study inclusion or exclusion can greatly impact the resulting CELOC. As described in **Sections 10.4** and **12.2**, EPA applied criteria for endpoint inclusion and classification which differs from the Syngenta process (Giddings 2012), and thus the two

databases result in different CELOC estimates. Using the EPA's current CELOC methodology with the Syngenta scoring method and accounting for uncertainty in the model (*i.e.*, Run 4) the CELOC based on the database and classifications by Giddings (2012) the CELOC would be 20.8 µg/L with a range of 13.5 to 40.5 µg/L. This illustrates how influential changes in the endpoint inclusion, interpretation and splitting of functional groups can be on the end results. See section 12.2.4 for a discussion regarding splitting endpoints, and EPA's justification for effects calls on endpoints that the 2012 SAP identified as needing re-review.

13. INCIDENT DATA

Three incident databases are available: 1) the Ecological Incident Information System v. 2.1.1 (EIIS), maintained by EFED; 2) the Avian Incident Monitoring System (AIMS), maintained by the American Bird Conservancy; and, 3) the Incident Data System (IDS) maintained by OPP. These databases were searched on 5/6/2014.

The results of the EIIS database review for terrestrial, plant, and aquatic incidents are discussed below. A more complete list of the incidents including associated uncertainties is included as **Appendix K**. Each incident is assigned a level of certainty from 0 (unrelated) to 4 (highly probable) that atrazine was a causal factor in the incident. As of the writing of this assessment, 667 incidents are in EIIS for atrazine spanning the years 1970 to 2015; however, 607 of the incidents were assigned a certainty index of 2 or higher (possible, N=481; probable, N=122; or highly probable, N=4). The remaining 60 incidents were assigned a certainty index of unlikely or unrelated. Most (609/667, 91%) of the incidents involved damage to terrestrial plants, and most of the terrestrial plant incidences involved damage to crops treated directly with atrazine or that were damaged from atrazine application to crops that were planted on the agricultural field in a previous crop rotation. Concerning other taxa, 48 incidents involved aquatic animals and 18 involved terrestrial animals. These incidents are summarized in **Appendix K**. There were 23 incidents associated with aquatic or terrestrial animal kills assigned a certainty index of 2 or higher. These incidents were further evaluated and were grouped into three categories:

1. Incidents in which atrazine concentrations were confirmed to be sufficient to either cause or contribute to the incident, including directly via toxic effects to aquatic organisms or indirectly via effects to aquatic plants, resulting in depleted oxygen levels;

2. Incidents in which insufficient information is available to conclude whether atrazine may have been a contributing factor – these may include incidents where there was a correlation between atrazine use and a fish kill, but the presence of atrazine in the affected water body was not confirmed; and

3. Incidents in which causes other than atrazine exposure are more plausible (*e.g.*, presence of substance other than atrazine confirmed at toxic levels).

The presence of atrazine at levels thought to be sufficient to cause either direct or indirect effects was confirmed in 3 aquatic incidents evaluated. Atrazine use was also correlated with 14 incidents where its presence in the affected water was not confirmed, but the timing of atrazine application was correlated with the incident. Therefore, a definitive causal relationship between atrazine use and the incident could not be established; however, atrazine may or may not have contributed to or caused the associated incident. The remaining incidents were likely caused by some factor other than atrazine. Other causes primarily included the presence of other pesticides at levels known to be toxic to affected animals. Further information on the atrazine incidents and a summary of uncertainties associated with all reported incidents are provided in **Appendix K**.

In addition to the incident reports available in EIIS, there have also been a total of 340 aggregate incidents reported to the Agency (dates ranging from 1/1/1995-12/31/2014). Of these 340, 323 involved plants as the affected species and 21 involved wildlife while 286 are associated with active registrations (54 involved products no longer registered or no registration number was reported) (see **Appendix K** and **Table 63)**

Since 1998, incidents that are allowed to be reported aggregately by registrants [under FIFRA 6(a)(2)] include those that are associated with an alleged effect to plants, wildlife (birds, mammals, or fish) and other non-target organisms. Typically, the only information available for aggregate incidents is the date (*i.e.*, the quarter) that the incident(s) occurred, the number of aggregate incidents that occurred in the quarter, and the PC code of the pesticide and the registration number of the product involved in the incident. Because of the limited amount of data available on aggregate incidents it is not possible to assign certainty indices or legality of use classifications to the specific incidents. Therefore, the incidents associated with currently registered products are assumed to be from registered uses unless additional information becomes available to support a change in that assumption.

Table 63. Aggregate Incidents for Atrazine Involving Currently Registered Products.

PRODUCT REGISTRATION NUMBER	PRODUCT NAME	NUMBER OF AGGREGATE INCIDENTS	FORMULATION
000100-00497	AATREX 4L HERBICIDE	1	Emulsifiable Concentrate
000100-00817	BICEP II MAGNUM	16	Soluble Concentrate
000100-00827	BICEP LITE II MAGNUM	4	Soluble Concentrate
000100-01152	LUMAX	17	Emulsifiable Concentrate
000100-01201	LEXAR	12	Emulsifiable Concentrate
000100-01414	LEXAR EZ	2	Emulsifiable Concentrate
000100-01442	LUMAX EZ	2	Pressurized Liquid

PRODUCT REGISTRATION NUMBER	PRODUCT NAME	NUMBER OF AGGREGATE INCIDENTS	FORMULATION
000352-00585	DUPONT BASIS GOLD HERBICIDE	2	Water Dispersible Granule
000352-00624	DUPONT CINCH ATZ HERBICIDE	2	Emulsifiable Concentrate
000352-00723	DUPONT BREAKFREE ATZ LITE HERBICIDE	1	Emulsifiable Concentrate
000352-00724	DUPONT BREAKFREE ATZ HERBICIDE	1	Emulsifiable Concentrate
000524-00329	LARIAT HERBICIDE	1	Flowable Concentrate
000538-00018	BONUS S	77	Granular
000538-00018-062355	WEED & FEED FOR ST. AUGUSTINE	14	Granular
000538-00229	SUPER BONUS S	16	Granular
000538-00234	LAWN CARE SYSTEM-SOUTH	1	Granular
000538-00234-000239	WEED-B-GON SPOT WEED KILLER FOR ST.AUGUSTINE LAWNS	12	Granular
000538-00301	BONUS S MAX	18	Ready-to-Use Solution
000538-00307	BONUS S MAX	5	Granular
000538-00315	SNAP PAC SOUTHERN WEED & FEED	2	Granular
007969-00136	MARKSMAN	12	Water Dispersible Granule
007969-00192	GUARDSMAN MAX HERBICIDE	8	Emulsifiable Concentrate
007969-00200	GUARDSMAN MAX LITE	3	Emulsifiable Concentrate
008660-00012	STA-GREEN CRABGRASS PREVENTER WITH FERTILIZER	15	Granular
009688-00227-008845	VIGORO ULTRA TURF SOUTHERN WEED & FEED	4	Granular
009688-00263	CHEMSICO HERBICIDE CONCENTRATE 48A	5	Soluble Concentrate
010404-00039	ST. AUGUSTINE GRASS/17-3-11 WEED & FEED (LESCO)	1	Granular
062719-00368	KEYSTONE* HERBICIDE	8	Emulsifiable Concentrate
062719-00371	FULTIME SELECTIVE HERBICIDE	5	Emulsifiable Concentrate
062719-00479	KEYSTONE LA HERBICIDE	4	Emulsifiable Concentrate
073327-00003	VIGORO ULTRA TURF SOUTHERN WEED & FEED	13	Granular

The AIMS database included 3 reports of bird incidents involving atrazine, 2 with a probable rating and 1 with an unlikely rating. However, all of these incidents were captured in the EIIS database so no new incidents were reported through AIMS.

The lack of documented incidents in any of these databases does not necessarily mean that such incidents did not occur. Mortality incidents must be seen, reported, investigated, and submitted to the Agency in order to be recorded in the incident databases. In addition, incident reports for non-target organisms typically provide information only on mortality events and plant damage. Sublethal effects in organisms such as abnormal behavior, reduced growth and/or impaired reproduction are rarely reported, except for phytotoxic effects in terrestrial plants. Given the primary concern of chronic risks to terrestrial and aquatic animals from atrazine, these effects would be difficult to capture through typical incident data reporting.

14. TERRESTRIAL RISK CHARACTERIZATION AND CONCLUSIONS

14.1. Terrestrial Animals Exposure and Risk Quotients (RQ) Values

14.1.1. Terrestrial Exposure to Animals

Terrestrial wildlife exposure estimates are typically calculated for birds and mammals by emphasizing the dietary exposure route of uptake of pesticide active ingredients. These exposures are considered to be surrogates for exposures to terrestrial-phase amphibians and reptiles. For exposures to terrestrial organisms, such as birds and mammals, pesticide residues on food items are estimated based on the assumption that organisms are exposed to pesticide residues as a function of the pesticide use pattern. For atrazine, application methods for the registered uses include ground and aerial applications.

T-REX (v. 1.5.2) is used to calculate dietary and dose-based EECs of atrazine residues on food items for mammals and birds generated by spray applications for the labeled uses. Input values for deriving EECs using T-REX are located in **Table 64**. All use scenarios are not necessarily included; only those uses that would generate variable EECs based on differences in maximum application rates and number of applications were modeled. Upper-bound Kenaga nomogram values are used to derive EECs for atrazine exposures to terrestrial mammals and birds (**Table 65, Table 66** and **Table 67**), based on a 1-year time period. Consideration is given to different types of feeding strategies for mammals, including herbivores, insectivores and granivores. Dose-based exposures are estimated for three weight classes of birds (20 g, 100 g, and 1000 g) and three weight classes of mammals (15 g, 35 g, and 1000 g).

Table 64. Input Parameters for Deriving Terrestrial EECs for Atrazine (T-REX v. 1.5.2).

Crop	Max App Rate (lbs/A)	Max Apps	Min App Interval (days)	Max Annual Rate (lbs/A)	Foliar Dissipation Half-life (days)	Label Numbers
Section 3 and 24c labeled rates						
Corn/Sorghum[1] (2/0.5)	2/0.5	2	14	2.5	35	100-497 35915-4 66222-36 100-585 35915-3
Sugarcane[2]	4/2/2/2	4	14	10		
Turf- Bermudagrass	1	2	30	2		
Turf- St Augustinegrass[3]	4/2	2	14	6		
Fallow- Prior to planting corn and sorghum	2.25	1	NA	2.25		
Roadside	1	1	NA	1.0		
CRP	2.0	1	NA	2.0		
Macadamia Nuts	4	2	14	8		
Guava	4	2	120	8		
Conifers	4	1	NA	4		
Reduced Rates[4]						
Corn/Sorghum (0.5)	0.5	1	NA	0.5	35	NA
Corn/Sorghum (0.25)	0.25	1	NA	0.25		

[1] Corn/Sorghum (2/0.5) – 1 application at 2 lb a.i./A then 1 application at 0.5 lb a.i./A with 14 day interval
[2] Sugarcane – 1 application at 4 lb a.i./A followed by 3 applications at 2 lb a.i./A with 14 day interval
[3] Turf – St. Augustine grass - 1 application at 4 lb a.i./A then 1 application at 2 lb a.i./A with 14 day interval
[4] Reduced application rates were modeled to simulate the range of reported application rates as specified in **Section 7.3.** For RQ calculations, if LOCs were not exceeded at the 0.5 rate, the 0.25 rate RQs were not reported as risks would be lower.

When foliar dissipation data are absent, EFED uses a default 35-day foliar dissipation half-life, based on the work of Willis and McDowell (1987), in its T-REX analysis. Magnitude of residue studies (OCSPP Guideline 860.1500) were submitted to the Agency and reviewed in order to estimate a dissipation rate for crops treated with atrazine for both the IRED (USEPA 2003) and the CRLF assessment (USEPA 2009). Based on the highest value measured for foliar dissipation half-life from the application of atrazine to turf in the Southeastern United States, a foliar half-life of 17 days was used. These foliar dissipation half-lives are most representative of atrazine used as a post-emergent herbicide applied directly to foliage of target plants. Atrazine is, however, used predominantly during crop pre-planting and pre-emergence and under these circumstances is applied directly to soil rather than to foliage. In addition, as discussed in **Section 10.1,** there are degradates of atrazine believed to be more toxic or equally toxic to birds and mammals based on the current available data. Due to these concerns and the known

formation of degradates in the terrestrial environment, the default foliar dissipation half-life of 35 days was maintained for the T-REX analysis. For characterization purposes, the half-life of 17 days was applied to the T-Rex analysis to determine a relative range of RQs and days exceeding the RQ.

Screening level EECs (upper bound Kenaga) for the T-REX analysis are contained in **Table 65, Table 66** and **Table 67.** Differences in exposures between ground and aerial applications cannot be assessed with the current T-REX model; therefore exposure and risk estimates from the T-REX model are considered relevant to both application scenarios.

Table 65. Dose-based EECs (mg/kg bw) as Food Residues for Birds, Reptiles, and Terrestrial-Phase Amphibians from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga).

Primary Feeding Strategy →	**Herbivores and Omnivores**												**Insectivores**			**Granivores**		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**			**Seeds, grains, *etc.***		
Corn/Sorghum (2/0.5)	551	252	310	34	314	144	177	20	141	64	79	9	215	123	55	8	4	2
Sugarcane	1751	802	985	109	998	458	562	62	447	205	251	28	686	391	175	24	14	6
Turf-Bermudagrass	424	194	239	27	424	194	239	27	424	194	239	27	166	95	42	6	3	2
Turf-St Augustinegrass	1375	630	774	86	784	359	441	49	351	161	198	22	539	307	138	19	11	5
Fallow- Prior to planting corn and sorghum	615	282	346	38	351	161	197	22	157	72	88	10	241	137	61	9	5	2
Roadside	273	125	154	17	156	71	88	10	70	32	39	4	107	61	27	4	2	1
CRP	547	251	308	34	312	143	175	19	140	64	79	9	214	122	55	8	4	2
Macadamia Nuts	1922	881	1081	120	1096	502	616	68	491	225	276	31	753	429	192	27	15	7
Guava	1195	548	672	75	681	312	383	43	305	140	172	19	468	267	119	17	9	4
Conifers	1093	501	615	68	623	286	351	39	279	128	157	17	428	244	109	15	9	4
Corn/Sorghum (0.5)	137	63	77	9	78	36	44	5	35	16	20	2	54	31	14	2	1	0
Corn/Sorghum (0.25)	68	31	38	4	39	18	22	2	17	8	10	1	27	15	7	1	1	0

Table 66. Dose-based EECs (mg/kg bw) as Food Residues for Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga).

Primary Feeding Strategy →	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Corn/Sorghum (2/0.5)	461	211	259	29	319	146	179	20	74	34	42	5	181	125	29	6	4	1
Sugarcane	1466	672	824	92	1013	464	570	63	235	108	132	15	574	397	92	20	14	3
Turf- Bermudagrass	355	163	200	22	245	112	138	15	57	26	32	4	139	96	22	5	3	1
Turf- St Augustinegrass	1151	528	648	72	796	365	448	50	184	85	104	12	451	312	72	16	11	3
Fallow- Prior to planting corn and sorghum	515	236	290	32	356	163	200	22	83	38	46	5	202	139	32	7	5	1
Roadside	229	105	129	14	158	72	89	10	37	17	21	2	90	62	14	3	2	1
CRP	458	210	257	29	316	145	178	20	73	34	41	5	179	124	29	6	4	1
Macadamia Nuts	1609	737	905	101	1112	510	625	69	258	118	145	16	630	436	101	22	15	4
Guava	1000	458	563	63	691	317	389	43	160	73	90	10	392	271	63	14	10	2
Conifers	915	20	515	57	633	290	356	40	147	67	83	9	358	248	57	13	9	2
Corn/Sorghum (0.5)	114	52	64	7	79	36	44	5	18	8	10	1	45	31	7	2	1	0
Corn/Sorghum (0.25)	57	26	32	4	40	18	22	2	9	4	5	1	22	15	4	1	1	0

Table 67. Dietary-based EECs (mg/kg diet) as Food Residues for Birds, Reptiles, Terrestrial-phase Amphibians, and Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga).

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Corn/Sorghum (2/0.5)	484	222	272	30	189
Sugarcane	1537	705	865	96	602
Turf- Bermudagrass	372	171	210	23	146
Turf- St Augustine grass	1208	553	679	75	473
Fallow- Prior to planting corn and sorghum	540	248	304	34	212
Roadside	240	110	135	15	94
CRP	480	220	270	30	188
Macadamia Nuts	1688	773	949	105	661
Guava	1049	481	590	66	411
Conifers	960	440	540	60	376
Corn/Sorghum (0.5)	120	55	68	8	47
Corn/Sorghum (0.25)	60	28	34	4	24

14.1.2. Risk Quotient (RQ) Values for Terrestrial Animal Species

This assessment of the labeled uses of atrazine relies on the deterministic RQ method to provide a metric of potential risks. The RQ provides a comparison of exposure estimates to toxicity endpoints (*i.e.*, the estimated exposure concentrations are divided by acute and chronic toxicity values, respectively). The resulting unitless RQ values are compared to the Agency's LOCs, as shown in Table 58**.** The LOCs are used by the Agency to indicate when the use of a pesticide, as directed by the label, has the potential to cause adverse effects to non-target organisms. For endangered species, LOC exceedances require an additional in-depth listed species evaluation of the potential co-occurrence of listed species and areas in which use crops are grown to characterize risks. In this assessment, RQs that exceed the non-listed species LOC also exceed the listed species LOC.

Because the sub-acute dietary based toxicity endpoints are non-definitive for birds (LC_{50} > 5,000 mg/kg diet), RQ values are not calculated for acute risk to birds through dietary exposure. If an LC_{50} value = 5000 mg/kg-diet is assumed for T-REX calculations, the maximum RQ value = 0.34

(macadamia nuts scenarios, 4 lb a.i./A, 2 applications; birds consuming short grass), which exceeds the LOC for listed birds. However, the lowest dose-based short grass RQ (large birds) is still greater than this RQ for the same application rate. Therefore, conclusions for acute risk based on the dose-based RQ are considered to be protective of acute dietary risks for birds.

Table 68 through **Table 72** contain RQ values for upper Kenaga EECs, whereas **Table 73** through **Table 77** contain RQs for mean Kenaga EECs. EECs for upper bound Kenaga values are listed in **Table 65** through **Table 67** above and mean Kenaga EECs are found in **Appendix L**. At the maximum single application rate for each of the modeled Section 3 and Section 24c labeled uses, RQs for listed and non-listed terrestrial animals are above the LOCs for multiple uses. In addition, the model was run assuming potential reduced single application rates of 0.5 and 0.25 lbs a.i./A. These resulting RQs are also above the levels of concern for certain sizes and dietary items, particularly for chronic risks.

More detailed discussion of these results is contained in the individual sections below on birds and mammals. For characterization purposes, RQs were calculated with a reduced foliar half-life of 17 days. Reducing the foliar half-life to 17 days had little impact on the number of RQs exceeding the LOC (results not shown).

Table 68. Acute Dose-based RQ values for Birds, Reptiles, and Terrestrial-Phase Amphibians from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods,	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods,	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods,	Arthropods			Seeds, grains, *etc.*		
Corn/Sorghum (2/0.5)	**0.98**	0.45	**0.55**	0.06	0.44	0.20	0.25	0.03	0.14	0.06	0.08	0.01	0.38	0.17	0.05	0.01	0.01	0.00
Sugarcane	**3.10**	**1.42**	**1.75**	0.19	**1.39**	**0.64**	**0.78**	0.09	0.44	0.20	0.25	0.03	**1.22**	**0.54**	0.17	0.04	0.02	0.01
Turf- Bermudagrass	**0.75**	0.34	0.42	0.05	**0.59**	0.27	0.33	0.04	0.42	0.19	0.24	0.03	0.29	0.13	0.04	0.01	0.00	0.00
Turf- St Augustinegrass	**2.44**	**1.12**	**1.37**	0.15	**1.09**	0.50	**0.61**	0.07	0.35	0.16	0.20	0.02	**0.96**	0.43	0.14	0.03	0.02	0.00
Fallow- Prior to planting corn and sorghum	**1.09**	0.50	**0.61**	0.07	0.49	0.22	0.27	0.03	0.15	0.07	0.09	0.01	0.43	0.19	0.06	0.02	0.01	0.00
Roadside	0.48	0.22	0.27	0.03	0.22	0.10	0.12	0.01	0.07	0.03	0.04	<0.01	0.19	0.09	0.03	0.01	0.00	0.00
CRP	**0.97**	0.44	**0.55**	0.06	0.43	0.20	0.24	0.03	0.14	0.06	0.08	0.01	0.38	0.17	0.05	0.01	0.01	0.00
Macadamia Nuts	**3.41**	**1.56**	**1.92**	0.21	**1.53**	**0.70**	**0.86**	0.10	0.48	0.22	0.27	0.03	**1.33**	**0.60**	0.19	0.05	0.02	0.01
Guava	**2.12**	**0.97**	**1.19**	0.13	**0.95**	0.43	**0.53**	0.06	0.30	0.14	0.17	0.02	**0.83**	0.37	0.12	0.03	0.01	0.00
Conifers	**1.94**	**0.89**	**1.09**	0.12	**0.87**	0.40	0.49	0.05	0.28	0.13	0.15	0.02	**0.76**	0.34	0.11	0.03	0.01	0.00
Corn/Sorghum (0.5)	0.24	0.11	0.14	0.02	0.11	0.05	0.06	0.01	0.03	0.02	0.02	0.00	0.09	0.04	0.01	0.00	0.00	0.00
Corn/Sorghum (0.25)	0.12	0.06	0.07	0.01	0.05	0.02	0.03	0.00	0.02	0.01	0.01	0.00	0.05	0.02	0.01	0.00	0.00	0.00

Table 69. Acute Dose-based RQ values for Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	**Herbivores and Omnivores**												**Insectivores**			**Granivores**		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**			**Seeds, grains, *etc.***		
Corn/Sorghum (2/0.5)	0.11	0.05	0.06	0.01	0.10	0.04	0.05	0.01	0.05	0.02	0.03	0.003	0.04	0.04	0.02	0.002	0.001	0.001
Sugarcane	0.36	0.16	0.20	0.02	0.30	0.14	0.17	0.02	0.16	0.07	0.09	0.01	0.14	0.12	0.06	0.005	0.004	0.002
Turf-Bermudagrass	0.09	0.04	0.05	0.01	0.07	0.03	0.04	0.005	0.04	0.02	0.02	0.002	0.03	0.03	0.02	0.001	0.001	0.001
Turf-St Augustinegrass	0.28	0.13	0.16	0.02	0.24	0.11	0.13	0.01	0.13	0.06	0.07	0.01	0.11	0.09	0.05	0.004	0.003	0.002
Fallow- Prior to planting corn and sorghum	0.13	0.06	0.07	0.01	0.11	0.05	0.06	0.01	0.06	0.03	0.03	0.004	0.05	0.04	0.02	0.002	0.001	0.001
Roadside	0.06	0.03	0.03	0.003	0.05	0.02	0.03	0.003	0.03	0.01	0.01	0.002	0.02	0.02	0.01	0.001	0.001	0.000
CRP	0.11	0.05	0.06	0.01	0.10	0.04	0.05	0.01	0.05	0.02	0.03	0.003	0.04	0.04	0.02	0.002	0.001	0.001
Macadamia Nuts	0.39	0.18	0.22	0.02	0.33	0.15	0.19	0.02	0.18	0.08	0.10	0.01	0.15	0.13	0.07	0.01	0.005	0.002
Guava	0.24	0.11	0.14	0.02	0.21	0.10	0.12	0.01	0.11	0.05	0.06	0.01	0.10	0.08	0.04	0.003	0.003	0.002
Conifers	0.22	0.10	0.13	0.01	0.19	0.09	0.11	0.01	0.10	0.05	0.06	0.01	0.09	0.07	0.04	0.003	0.003	0.001
Corn/Sorghum (0.5)	0.03	0.01	0.02	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.001	0.01	0.01	0.00	0.000	0.000	0.000

Table 70. Chronic Dose-based RQ values for Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, upper bound Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	**Herbivores and Omnivores**												**Insectivores**			**Granivores**		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**			**Seeds, grains, *etc.***		
Corn/Sorghum (2/0.5)	**56.7**	**26.0**	**31.9**	**3.5**	**48.4**	**22.2**	**27.3**	**3.0**	**26.0**	**11.9**	**14.6**	**1.6**	**22.2**	**19.0**	**10.2**	0.8	0.7	0.4
Sugarcane	**180.2**	**82.6**	**101.4**	**11.3**	**154.0**	**70.6**	**86.6**	**9.6**	**82.5**	**37.8**	**46.4**	**5.2**	**70.6**	**60.3**	**32.3**	**2.5**	**2.1**	**1.1**
Turf-Bermudagrass	**43.7**	**20.0**	**24.6**	**2.7**	**37.3**	**17.1**	**21.0**	**2.3**	**20.0**	**9.2**	**11.2**	**1.2**	**17.1**	**14.6**	**7.8**	0.6	0.5	0.3
Turf-St Augustinegrass	**141.6**	**64.9**	**79.6**	**8.8**	**120.9**	**55.4**	**68.0**	**7.6**	**64.8**	**29.7**	**36.5**	**4.1**	**55.5**	**47.4**	**25.4**	**2.0**	**1.7**	0.9
Fallow- Prior to planting corn and sorghum	**63.3**	**29.0**	**35.6**	**4.0**	**54.1**	**24.8**	**30.4**	**3.4**	**29.0**	**13.3**	**16.3**	**1.8**	**24.8**	**21.2**	**11.4**	0.9	0.8	0.4
Roadside	**28.1**	**12.9**	**15.8**	**1.8**	**24.0**	**11.0**	**13.5**	**1.5**	**12.9**	**5.9**	**7.2**	0.8	**11.0**	**9.4**	**5.0**	0.4	0.3	0.2
CRP	**56.3**	**25.8**	**31.7**	**3.5**	**48.1**	**22.0**	**27.0**	**3.0**	**25.8**	**11.8**	**14.5**	**1.6**	**22.0**	**18.8**	**10.1**	0.8	0.7	0.4
Macadamia Nuts	**197.9**	**90.7**	**111.3**	**12.4**	**169.0**	**77.5**	**95.1**	**10.6**	**90.6**	**41.5**	**51.0**	**5.7**	**77.5**	**66.2**	**35.5**	**2.7**	**2.3**	**1.3**
Guava	**123.0**	**56.4**	**69.2**	**7.7**	**105.1**	**48.2**	**59.1**	**6.6**	**56.3**	**25.8**	**31.7**	**3.5**	**48.2**	**41.2**	**22.1**	**1.7**	**1.5**	0.8
Conifers	**112.6**	**51.6**	**63.3**	**7.0**	**96.1**	**44.1**	**54.1**	**6.0**	**51.5**	**23.6**	**29.0**	**3.2**	**44.1**	**37.7**	**20.2**	**1.6**	**1.3**	0.7
Corn/Sorghum (0.5)	**14.1**	**6.4**	**7.9**	0.9	**12.0**	**5.5**	**6.8**	0.8	**6.4**	**3.0**	**3.6**	0.4	**5.5**	**4.7**	**2.5**	0.2	0.2	0.1
Corn/Sorghum (0.25)	**7.0**	**3.2**	**4.0**	0.4	**6.0**	**2.8**	**3.4**	0.4	**3.2**	**1.5**	**1.8**	0.2	**2.8**	**2.4**	**1.3**	0.1	0.1	0.0

Table 71. Chronic Dietary-Based RQs for Birds, Reptiles, and Terrestrial-phase Amphibians of Different Feeding Classes (T-REX v. 1.5)[1]. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Corn/Sorghum (2/0.5)	**6.5**	**3.0**	**3.6**	0.4	**2.5**
Sugarcane	**20.5**	**9.4**	**11.5**	**1.3**	**8.0**
Turf- Bermudagrass	**5.0**	**2.3**	**2.8**	0.3	**1.9**
Turf- St Augustinegrass	**16.1**	**7.4**	**9.1**	**1.0**	**6.3**
Fallow- Prior to planting corn and sorghum	**7.2**	**3.3**	**4.1**	0.5	**2.8**
Roadside	**3.2**	**1.5**	**1.8**	0.2	**1.3**
CRP	**6.4**	**2.9**	**3.6**	0.4	**2.5**
Macadamia Nuts	**22.5**	**10.3**	**12.7**	**1.4**	**8.8**
Guava	**14.0**	**6.4**	**7.9**	0.9	**5.5**
Conifers	**12.8**	**5.9**	**7.2**	0.8	**5.0**
Corn/Sorghum (0.5)	**1.6**	0.7	0.9	0.1	0.6
Corn/Sorghum (0.25)	0.8	0.4	0.5	0.1	0.1

Table 72. Chronic Dietary-Based RQs for Mammals of Different Feeding Classes (T-REX v. 1.5, upper kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**
Corn/Sorghum (2/0.5)	**9.7**	**4.4**	**5.4**	0.6	**3.8**
Sugarcane	**30.7**	**14.1**	**17.3**	**1.9**	**12.0**
Turf- Bermudagrass	**7.4**	**3.4**	**4.2**	0.5	**2.9**
Turf- St Augustinegrass	**24.2**	**11.1**	**13.6**	**1.5**	**9.5**
Fallow- Prior to planting corn and sorghum	**10.8**	**5.0**	**6.1**	0.7	**4.2**
Roadside	**4.8**	**2.2**	**2.7**	0.3	**1.9**
CRP	**9.6**	**4.4**	**5.4**	0.6	**3.8**
Macadamia Nuts	**33.8**	**15.5**	**19.0**	**2.1**	**13.2**
Guava	**21.0**	**9.6**	**11.8**	**1.3**	**8.2**
Conifers	**19.2**	**8.8**	**10.8**	**1.2**	**7.5**
Corn/Sorghum (0.5)	**2.4**	**1.1**	**1.4**	0.2	0.9
Corn/Sorghum (0.25)	**1.2**	0.6	0.7	0.1	0.5

Table 73. Acute Dose-based RQ values for Birds, Reptiles, and Terrestrial-Phase Amphibians from Labeled Uses of Atrazine (T-REX v. 1.5.2, mean Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	**Herbivores and Omnivores**												**Insectivores**			**Granivores**		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**			**Seeds, grains, *etc.***		
Corn/Sorghum (2/0.5)	0.35	0.15	0.18	0.03	0.15	0.07	0.08	0.01	0.05	0.02	0.03	0.00	0.26	0.12	0.04	0.01	0.00	0.00
Sugarcane	**1.10**	0.47	**0.58**	0.09	0.49	0.21	0.26	0.04	0.16	0.07	0.08	0.01	**0.84**	0.38	0.12	0.02	0.01	0.00
Turf- Bermudagrass	0.17	0.07	0.09	0.01	0.08	0.03	0.04	0.01	0.02	0.01	0.01	0.00	0.13	0.06	0.02	0.00	0.00	0.00
Turf- St Augustinegrass	**0.86**	0.37	0.46	0.07	0.39	0.16	0.20	0.03	0.12	0.05	0.06	0.01	**0.66**	0.30	0.09	0.02	0.01	0.00
Fallow- Prior to planting corn and sorghum	0.39	0.16	0.20	0.03	0.17	0.07	0.09	0.01	0.05	0.02	0.03	0.00	0.30	0.13	0.04	0.01	0.00	0.00
Roadside	0.17	0.07	0.09	0.01	0.08	0.03	0.04	0.01	0.02	0.01	0.01	0.002	0.13	0.06	0.02	0.00	0.00	0.00
CRP	0.34	0.15	0.18	0.03	0.15	0.07	0.08	0.01	0.05	0.02	0.03	0.00	0.26	0.12	0.04	0.01	0.00	0.00
Macadamia Nuts	**1.21**	**0.51**	**0.64**	0.10	**0.54**	0.23	0.29	0.04	0.17	0.07	0.09	0.01	**0.92**	0.41	0.13	0.02	0.01	0.00
Guava	**0.75**	0.32	0.40	0.06	0.34	0.14	0.18	0.03	0.11	0.05	0.06	0.01	**0.57**	0.26	0.08	0.01	0.01	0.00
Conifers	**0.69**	0.29	0.36	0.06	0.31	0.13	0.16	0.03	0.10	0.04	0.05	0.01	**0.52**	0.24	0.07	0.01	0.01	0.00
Corn/Sorghum (0.5)	0.09	0.04	0.05	0.01	0.04	0.02	0.02	0.00	0.01	0.01	0.01	0.00	0.07	0.03	0.01	0.00	0.00	0.00

Table 74. Acute Dose-based RQ values for Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, mean Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	**Herbivores and Omnivores**												**Insectivores**			**Granivores**		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	**Short Grass**	**Tall Grass**	**Broad-leaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Short Grass**	**Tall Grass**	**Broadleaf Plants**	**Fruits, pods, seeds, *etc.***	**Arthropods**			**Seeds, grains, *etc.***		
Corn/Sorghum (2/0.5)	0.04	0.02	0.02	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.01	0.001	0.03	0.03	0.01	0.001	0.001	0.000
Sugarcane	0.13	0.05	0.07	0.01	0.11	0.05	0.06	0.01	0.06	0.02	0.03	0.00	0.12	0.08	0.08	0.003	0.002	0.002
Turf- Bermudagrass	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.001	0.01	0.00	0.00	0.001	0.02	0.01	0.01	0.000	0.000	0.000
Turf- St Augustinegrass	0.10	0.04	0.05	0.01	0.08	0.04	0.04	0.01	0.05	0.02	0.02	0.00	0.08	0.06	0.03	0.002	0.002	0.001
Fallow- Prior to planting corn and sorghum	0.04	0.02	0.02	0.00	0.04	0.02	0.02	0.00	0.02	0.01	0.01	0.002	0.03	0.03	0.02	0.001	0.001	0.000
Roadside	0.02	0.01	0.01	0.002	0.02	0.01	0.01	0.001	0.01	0.00	0.00	0.001	0.02	0.01	0.01	0.000	0.000	0.000
CRP	0.04	0.02	0.02	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.01	0.001	0.03	0.03	0.01	0.001	0.001	0.000
Macadamia Nuts	0.14	0.06	0.07	0.01	0.12	0.05	0.06	0.01	0.06	0.03	0.03	0.01	0.11	0.09	0.05	0.00	0.002	0.001
Guava	0.09	0.04	0.05	0.01	0.07	0.03	0.04	0.01	0.04	0.02	0.02	0.00	0.07	0.06	0.03	0.002	0.001	0.001
Conifers	0.08	0.03	0.04	0.01	0.07	0.03	0.04	0.01	0.04	0.02	0.02	0.00	0.06	0.05	0.03	0.001	0.001	0.001
Corn/Sorghum (0.5)	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.01	0.01	0.00	0.000	0.000	0.000

Table 75. Chronic Dose-based RQ values for Mammals from Labeled Uses of Atrazine (T-REX v. 1.5.2, mean Kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size →	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Corn/Sorghum (2/0.5)	**20.1**	**8.5**	**10.6**	**1.7**	**17.2**	**7.3**	**9.1**	**1.4**	**9.2**	**3.9**	**4.9**	0.8	**15.4**	**13.1**	**7.0**	0.4	0.3	0.2
Sugarcane	**63.8**	**27.0**	**33.8**	**5.3**	**54.5**	**23.1**	**28.9**	**4.5**	**29.2**	**12.4**	**15.5**	**2.4**	**58.3**	**41.1**	**42.5**	**1.4**	1.0	**1.0**
Turf- Bermudagrass	**10.0**	**4.2**	**5.3**	0.8	**8.5**	**3.6**	**4.5**	0.7	**4.6**	**1.9**	**2.4**	0.4	**9.1**	**6.4**	**6.6**	0.2	0.2	0.2
Turf- St Augustinegrass	**50.1**	**21.2**	**26.5**	**4.1**	**42.8**	**18.1**	**22.7**	**3.5**	**23.0**	**9.7**	**12.2**	**1.9**	**38.3**	**32.8**	**17.6**	0.9	0.8	0.4
Fallow- Prior to planting corn and sorghum	**22.4**	**9.5**	**11.9**	**1.8**	**19.2**	**8.1**	**10.1**	**1.6**	**10.3**	**4.3**	**5.4**	0.8	**17.1**	**14.6**	**7.9**	0.4	0.4	0.2
Roadside	**10.0**	**4.2**	**5.3**	0.8	**8.5**	**3.6**	**4.5**	0.7	**4.6**	**1.9**	**2.4**	0.4	**7.6**	**6.5**	**3.5**	0.2	0.2	0.1
CRP	**19.9**	**8.4**	**10.6**	**1.6**	**17.0**	**7.2**	**9.0**	**1.4**	**9.1**	**3.9**	**4.8**	0.8	**15.2**	**13.0**	**7.0**	0.4	0.3	0.2
Macadamia Nuts	**70.1**	**29.7**	**37.1**	**5.8**	**59.9**	**25.4**	**31.7**	**4.9**	**32.1**	**13.6**	**17.0**	**2.6**	**53.6**	**45.8**	**24.5**	**1.3**	**1.1**	0.6
Guava	**43.6**	**18.5**	**23.1**	**3.6**	**37.2**	**15.8**	**19.7**	**3.1**	**19.9**	**8.4**	**10.6**	**1.6**	**33.3**	**28.5**	**15.3**	0.8	0.7	0.4
Conifers	**39.9**	**16.9**	**21.1**	**3.3**	**34.1**	**14.4**	**18.0**	**2.8**	**18.3**	**7.7**	**9.7**	**1.5**	**30.5**	**26.0**	**14.0**	0.7	0.6	0.3
Corn/Sorghum (0.5)	**5.0**	**2.1**	**2.6**	0.4	**4.3**	**1.8**	**2.3**	0.4	**2.3**	1.0	**1.2**	0.2	**3.8**	**3.3**	**1.7**	0.1	0.1	0.0
Corn/Sorghum (0.25)	**2.5**	**1.1**	**1.3**	0.2	**2.1**	0.9	**1.1**	0.2	**1.1**	0.5	0.6	0.1	**1.9**	**1.6**	0.9	0.0	0.0	0.0

Table 76. Chronic Dietary-Based RQs for Birds, Reptiles, and Terrestrial-phase Amphibians of Different Feeding Classes (T-REX v. 1.5.2, mean kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Corn/Sorghum (2/0.5)	**2.3**	**1.0**	**1.2**	0.2	**1.7**
Sugarcane	**7.3**	**3.1**	**3.8**	0.6	**5.6**
Turf- Bermudagrass	**1.1**	0.5	0.6	0.1	0.9
Turf- St Augustinegrass	**5.7**	**2.4**	**3.0**	0.5	**4.4**
Fallow- Prior to planting corn and sorghum	**2.6**	**1.1**	**1.4**	0.2	**2.0**
Roadside	**1.1**	0.5	0.6	0.1	0.9
CRP	**2.3**	1.0	**1.2**	0.2	**1.7**
Macadamia Nuts	**8.0**	**3.4**	**4.2**	0.7	**6.1**
Guava	**5.0**	**2.1**	**2.6**	0.4	**3.8**
Conifers	**4.5**	**1.9**	**2.4**	0.4	**3.5**
Corn/Sorghum (0.5)	0.6	0.2	0.3	0.0	0.4

Table 77. Chronic Dietary-Based RQs for Mammals of Different Feeding Classes (T-REX v. 1.5.2, mean kenaga). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Corn/Sorghum (2/0.5)	**3.4**	**1.5**	**1.8**	0.3	**2.6**
Sugarcane	**10.9**	**4.6**	**5.8**	0.9	**8.3**
Turf- Bermudagrass	**1.7**	0.7	0.9	0.1	**1.3**
Turf- St Augustinegrass	**8.6**	**3.6**	**4.5**	0.7	**6.5**
Fallow- Prior to planting corn and sorghum	**3.8**	**1.6**	**2.0**	0.3	**2.9**
Roadside	**1.7**	0.7	0.9	0.1	**1.3**
CRP	**3.4**	**1.4**	**1.8**	0.3	**2.6**

Primary Feeding Strategy →	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items → / Use(s) ↓	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Macadamia Nuts	**12.0**	**5.1**	**6.3**	**1.0**	**9.1**
Guava	**7.4**	**3.1**	**3.9**	0.6	**5.7**
Conifers	**6.8**	**2.9**	**3.6**	0.6	**5.2**
Corn/Sorghum (0.5)	0.9	0.4	0.5	0.1	0.7

14.1.3. Risks to Birds

Based on upper and mean Kenaga values from T-REX (**Table 65, Table 66 and Table 67**; **Appendix L**), LOCs are exceeded for multiple labeled uses for atrazine in birds for both acute and chronic exposures. Maximum RQs occur for the small bird with short grass as the primary food item and the sugarcane and macadamia nut use scenarios. For corn uses (upper Kenaga values), RQs range from 0.01 – 3.41 for acute risks and 0.2- 22.5 for chronic risks across the range of application rates, sizes and dietary items of birds (**Table 68, Table 69, Table** 70**, Table 71 and Table 72**). Summary tables below (**Table 78 and Table 79**) include minimum and maximum ranges for each use as well as the percentage of times LOCs were exceeded for all the modeled sizes of birds and dietary items. Although acute risks are of concern with a maximum value of 3.41 and 72% (13 out of 18) and 44% (8 out of 18) of scenarios exceeding listed and non-listed LOCs respectively, chronic risks are a greater concern in birds. RQ values are as high as 22.5 and exceed LOCs for 80-100% of the scenarios modeled for all uses. Primary concern with chronic risk is consistent with the available atrazine toxicity data in birds as well as other species.

For the modeled reduced rates, risk to birds is reduced but still exceeds the LOC for acute risk to listed species and chronic risk for the 0.5 lb a.i./A rate. At 0.25 lb a.i./A, LOCs are exceeded only for acute risk to listed species.

Table 78. Range of RQs for Birds, Reptiles, and Terrestrial-phase Amphibians of Different Feeding Classes (T-REX v. 1.5.2, upper bound Kenaga)[1].

Use	Dose-based RQ range avian acute risk		Dietary-based RQ range avian chronic risk	
	Min	Max	Min	Max
Corn/Sorghum (2/0.5)	<0.01	**0.98**	0.40	**6.45**
Sugarcane	0.01	**3.10**	**1.28**	**20.50**
Turf- Bermudagrass	<0.01	**0.75**	0.31	**4.97**
Turf- St Augustinegrass	<0.01	**2.44**	**1.01**	**16.10**
Fallow- Prior to planting corn and sorghum	<0.01	**1.09**	0.45	**7.20**
Roadside	<0.01	**0.48**	0.20	**3.20**
CRP	<0.01	**0.97**	0.40	**6.40**
Macadamia Nuts	0.01	**3.41**	**1.41**	**22.50**
Guava	<0.01	**2.12**	0.87	**13.99**
Conifers	<0.01	**1.94**	0.80	**12.80**
Corn/Sorghum (0.5)	<0.01	0.24	0.10	**1.60**
Corn/Sorghum (0.25)	<0.01	0.12	0.05	0.8

Table 79. Percentage of LOC exceedance for Birds, Reptiles, and Terrestrial-phase Amphibians of Different Feeding Classes (T-REX v. 1.5.2, upper bound Kenaga)[1].

Use	Dose-based RQs avian acute risk		Dietary-based RQs avian chronic risk
	% scenarios that exceed LOC listed	% scenarios that exceed LOC non-listed	% scenarios that exceed LOC for listed or non-listed species
Corn/Sorghum (2/0.5)	50%	11%	80%
Sugarcane	72%	44%	100%
Turf- Bermudagrass	61%	11%	80%
Turf- St Augustinegrass	72%	33%	100%
Fallow- Prior to planting corn and sorghum	50%	11%	80%
Roadside	33%	0%	80%
CRP	50%	11%	80%
Macadamia Nuts	72%	44%	100%

Use	Dose-based RQs avian acute risk		Dietary-based RQs avian chronic risk
	% scenarios that exceed LOC listed	% scenarios that exceed LOC non-listed	% scenarios that exceed LOC for listed or non-listed species
Guava	72%	33%	80%
Conifers	72%	28%	80%
Corn/Sorghum (0.5)	22%	0%	20%
Corn/Sorghum (0.25)	6%	0%	0%

14.1.3.1. ***Risks to Birds Off Field***

Spray deposition curves calculated using AgDRIFT (version 2.1.1) (Tier I) were used to estimate the distance from the edge of the field to where effects to non-target organisms are no longer of concern following a single application of 0.5, 2 or 4 lbs a.i./A by aerial or ground applications.

The distance estimated for birds and mammals is based on one application and does not reflect possible cumulative exposure from multiple applications. It is recognized that a species could receive exposure from multiple applications, in which case, this methodology may underestimate risk. The distance estimated for aquatic and terrestrial animals for multiple applications may occur when wind is blowing consistently in one direction for all applications or when wind is blowing in different directions during different applications as long as the organism is downwind in each case and regardless of whether it is mobile or stationary. This may result in an overestimation of exposure for aquatic and terrestrial organisms whose spray drift distances are based on exposure to the maximum number of applications and who are not downwind of every application. Exposure to multiple applications is more likely to occur when agricultural fields/use areas are on multiple sides of an aquatic or terrestrial area of interest and when local wind direction is not variable.

The following figures describe the risk associated with aerial and ground spray applications assuming different droplet sizes and release/boom heights. Drift exposure to birds following an aerial application of 2 lbs a.i./A may result in near field (within 100 feet) chronic risks for all droplet sizes (**Figure 35** and **Figure 36**), with the use of coarser droplet size reducing this distance. For ground applications at 2 lb a.i./A, risk concern to birds is not anticipated based on chronic exposure at significant distances off field. Acute risks to birds are not anticipated at either ground or aerial application at 2 lb a.i./A.

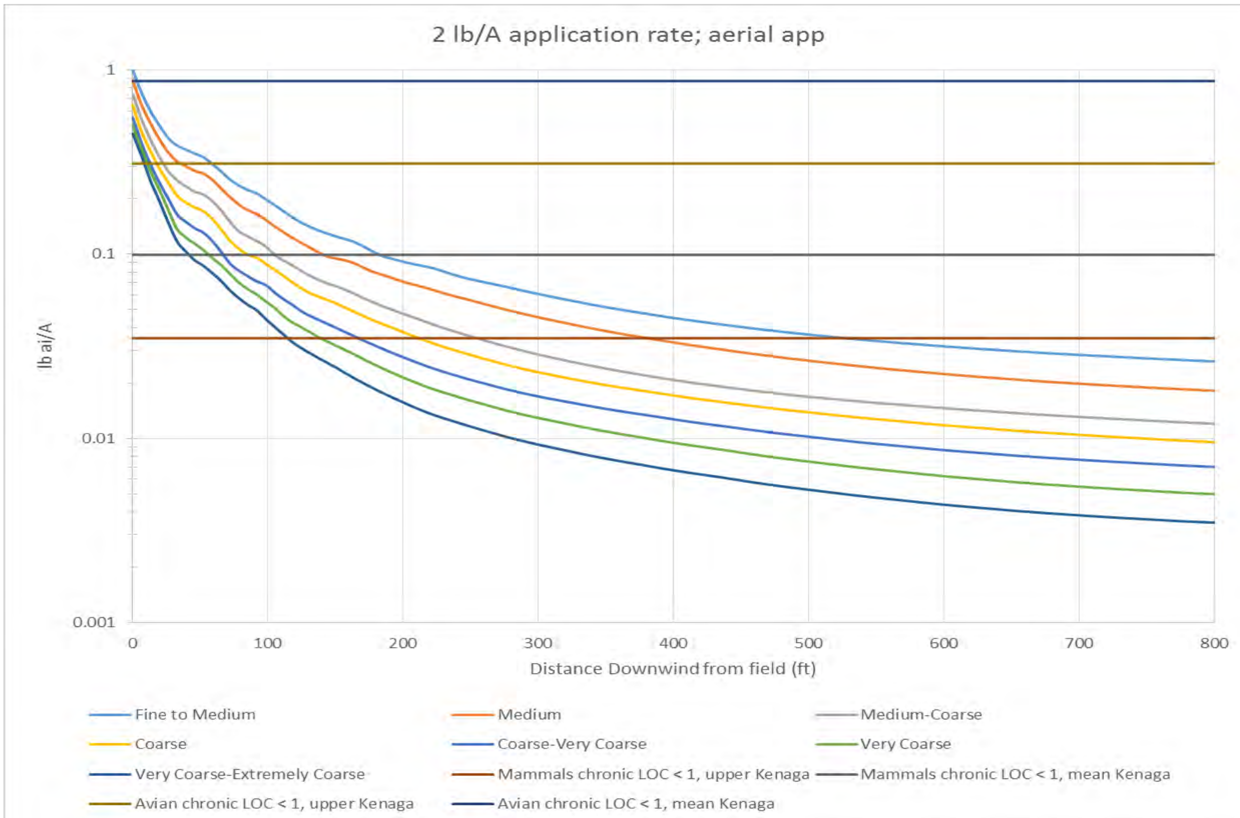


Figure 35. Spray drift deposition curves for various droplet spectra following a single aerial application of 2.0 lbs a.i/A.

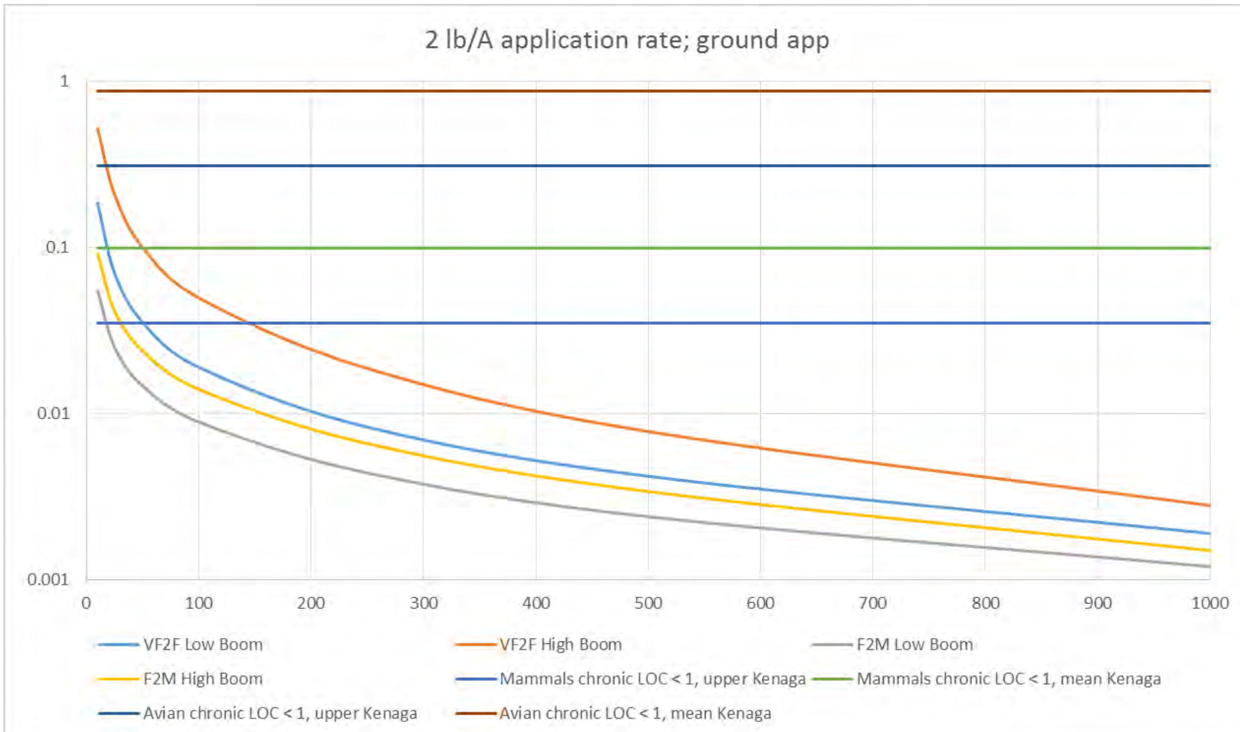


Figure 36. Spray drift deposition curves for various droplet spectra following a single ground application of 2.0 lbs a.i/A

Drift exposure to birds following an aerial application of 4 lbs a.i./A may result in near field acute (within 100 feet) and chronic (slightly over 100 ft) risks for all droplet sizes with coarser droplets reducing this distance (**Figure 37)**. For ground applications at this rate, drift exposure may result in chronic risks at distances up to approximately 50 ft (**Figure 38**).

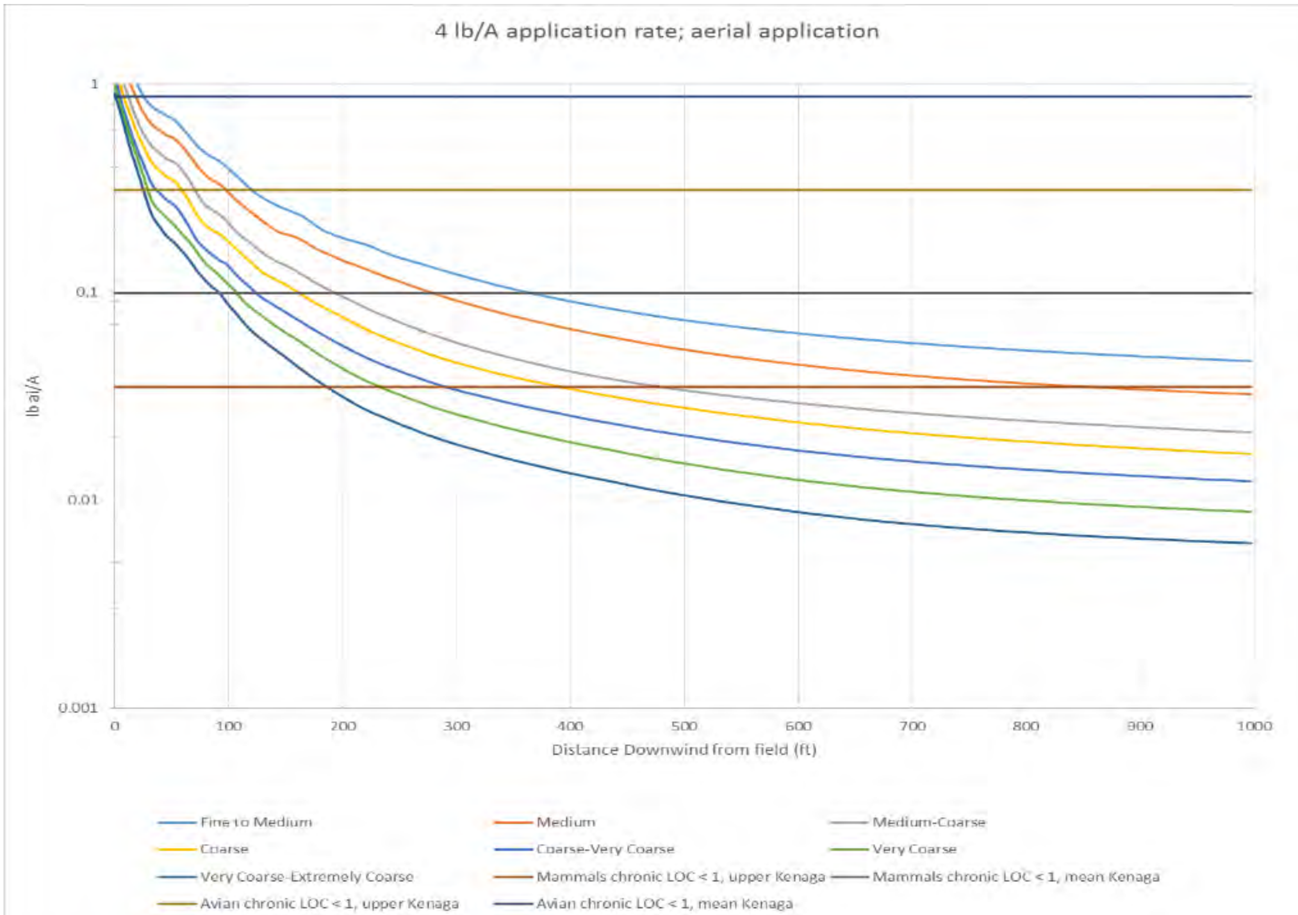


Figure 37. Spray drift deposition curves for various droplet spectra following a single ground application of 4.0 lbs a.i/A.

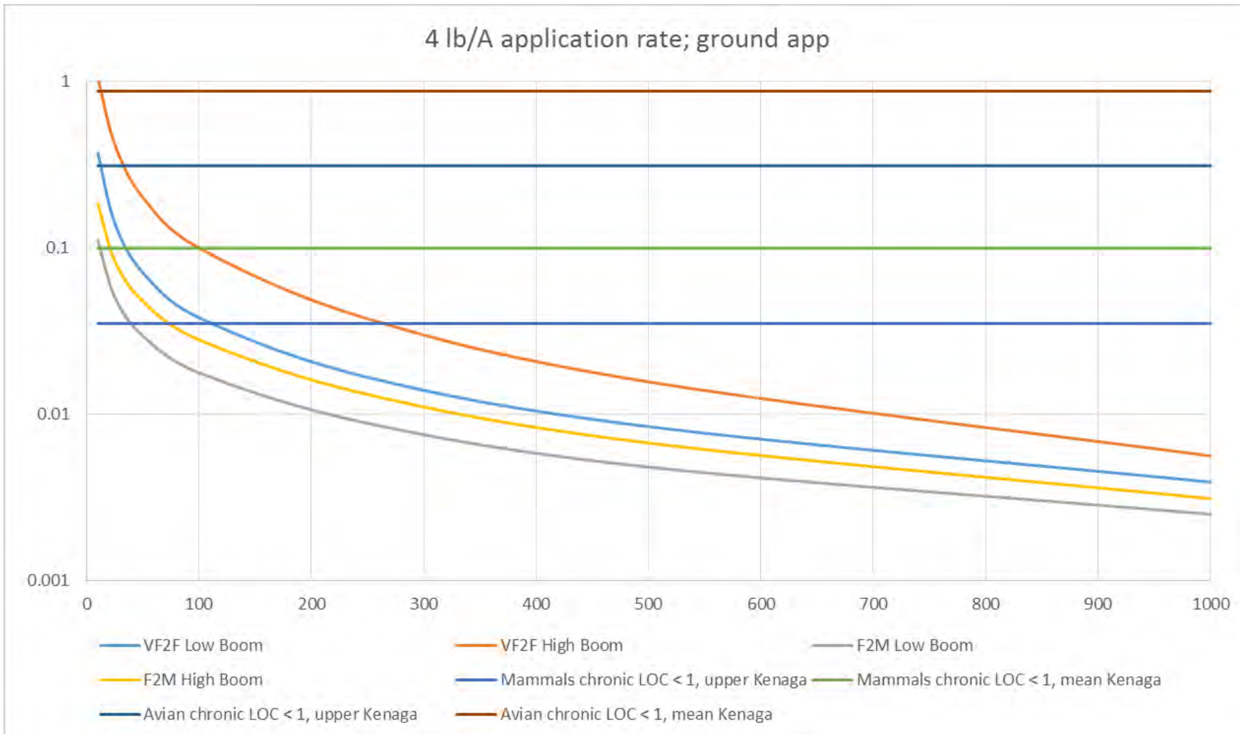


Figure 38. Spray drift deposition curves for various droplet spectra following a single ground application of 4.0 lbs a.i/A.

To explore the effect of rate reduction, spray drift distances were also calculated at 0.5 lb a.i./A for a single application. Off-field risk to birds is a not anticipated at aerial or ground applications of 0.5 lb a.i./A (**Figure 39** and **Figure 40**).

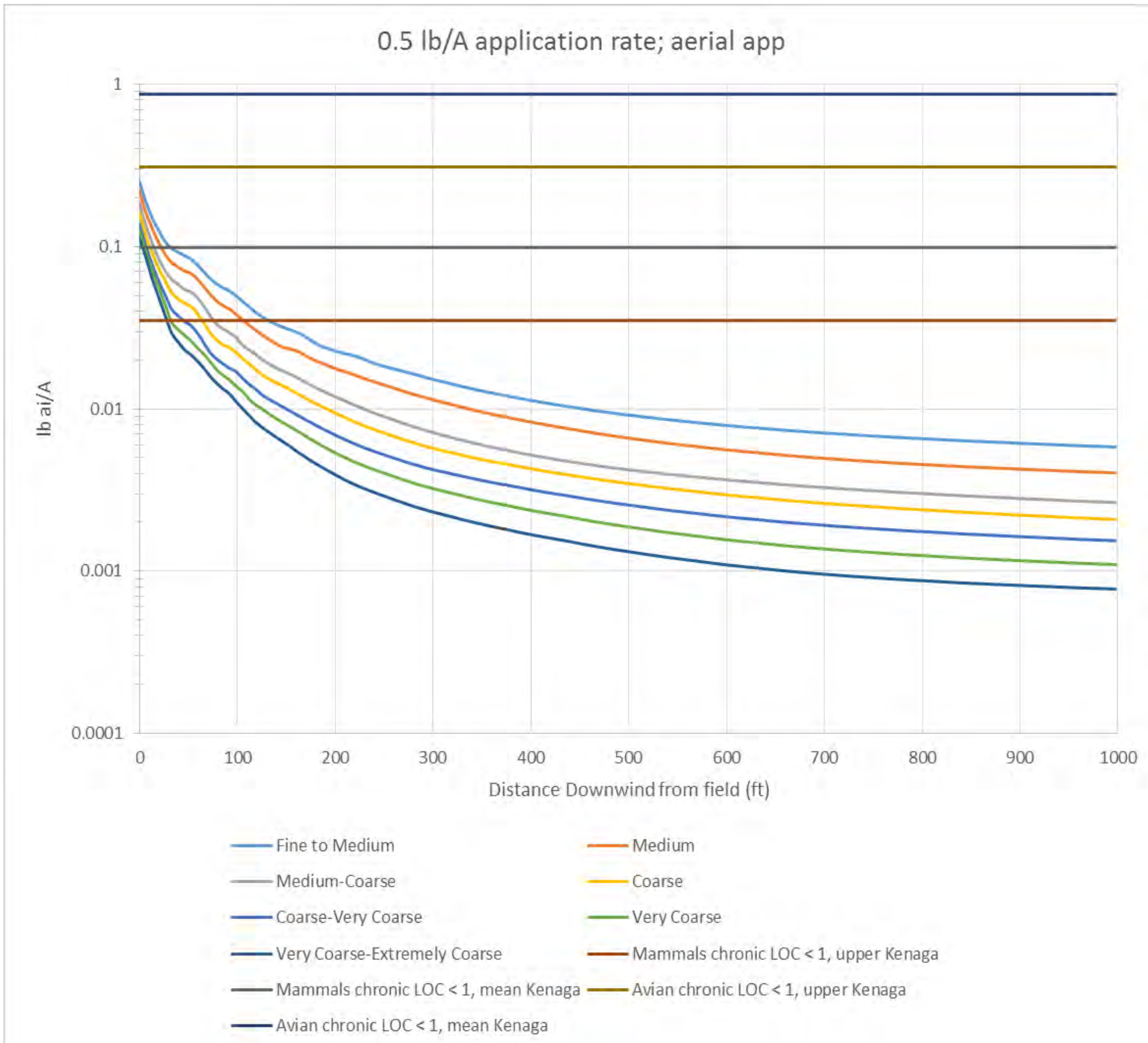


Figure 39. Spray drift deposition curves for various droplet spectra following a single aerial application of 0.5 lbs a.i/A.

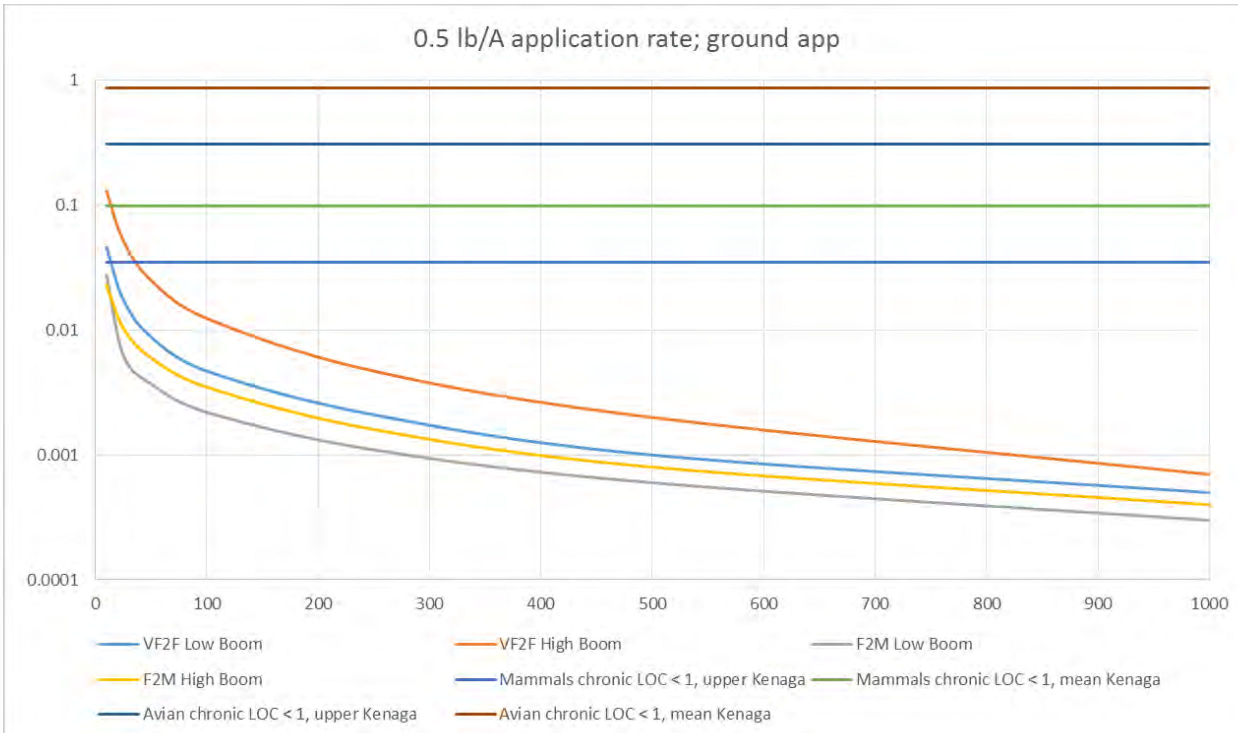


Figure 40. Spray drift deposition curves for various droplet spectra following a single ground application of 0.5 lbs a.i/A.

14.1.3.2. *Further refinement of risks to birds: Use of TIM and MCnest models*

As acute and chronic risks were identified for birds, higher tier modeling was used to further refine this risk through the use of the Terrestrial Investigation Model (TIM; version 3.0 beta), and the Markov Chain Nest Productivity (MCnest) models (see **Section 6.7.3**).

14.1.3.2.a. *TIM Model: Probabilistic Mortality Estimates from Acute Exposure*

Model parameterization

As corn is the predominant agricultural use for atrazine, higher tier modeling was conducted using application rates and dates associated with the use of atrazine on corn. Input parameters are contained in **Table 80**. The most common and potentially sensitive bird groupings were modeled using TIM, including the small and medium insectivores and omnivore groups (Appendix D of TIM manual; https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#terrestrial). Example species associated with these groupings are provided in **Table 81.** According to Atwood et al. (2015), field crops and corn in Kansas are usually planted between Apr 15 and May 15. With a pre-emergent application of atrazine, the mid-point of the range, May 1st represents the most likely application date and

was used for most analyses. Varied application rates as well as sensitivity analyses on a range of parameters and species were conducted and are presented below in **Table 82.**

The guidance provided in Appendix A of the TIM manual was used to select model parameter values, including defaults (https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#terrestrial).

Table 80. TIM input parameters

Parameter Name	Parameter Value	Source/Comments
Scenario Parameters		
Number of days simulated	30	Recommended model default
Number of birds	10,000	Recommended model default
Flock size	25	Recommended model default
Random Seed	0	Recommended model default
Initial app date	1-May	Applicable application date
Method	Ground broadcast	Relevant application method
Droplet Spectrum	Very fine to fine	Relevant droplet spectrum
Crop type	Field	For corn simulation
Fraction edge habitat receiving drift	1	100% edge field receives treatment
Length of in field buffer (m)	0	No in field buffer assumed
Fraction organic carbon	0.017	Based on SWCC scenario for Kansas; representative corn use scenario
Soil bulk density	1.3	Based on SWCC for Kansas
Hour of first app	8:00 AM	Relevant application time
Spray height (m)	0.5	Recommended model default
Spray duration (hr)	0.5	Recommended model default
Crop height (m)	0.1	Pre-emergence
Crop mass	70000	Calculated per manual guidance (crop specific; used assumptions provided in manual for corn crop)
Pesticide Toxicity Parameters		
Avian LD_{50}	783	MRID number 00024721 No other definitive LD50 values available; LD50 of DIA (degradate) = 768

Parameter Name	Parameter Value	Source/Comments
Mean body weight (g)	35	MRID number 00024721
Mineau scaling factor	1.15	No atrazine-specific value is available so default is used.
Scaled LD_{50} (calc)	--	Calculated within model or manually
Slope of avian LD_{50}	2.263	MRID number 00024721
Avian Acute oral Inhalation	0	No value is available for atrazine
Rat Inhalation LD_{50} (mg/kg-bw)	1026	MRID 42089901 See Appendix A of TIM manual; LC50 > 5.82 mg/L, 4 hour exposure
Rat acute oral LD_{50} (mg/kg-bw)	1869	MRID number 00024706
Respiratory physiology adjustment Factor	0	Recommended model default (Only needed for custom species)
Avian Dermal LD_{50} (mg/kg-bw)	0	No value is available for atrazine
Food matrix adjustment factor	1	Recommended model default
Fraction of pesticide retained	0.985	MRIDs 40431422
Ratio of juvenile to adult toxicity	1	Recommended model default
Pesticide Chemical Properties		
Pesticide half-life (puddle) (days)	417	Chemical properties in **Section7.1 Physical and**

Parameter Name	Parameter Value	Source/Comments
Koc	75	**Chemical Properties of Atrazine**
Kow	501	
Henry's Law Constant (atm-m^3 $mole^{-1}$)	2.6 x 10-9	
Solubility in water (mg/L)	33	
Dislodgable foliar residue adjustment factor	0.62	Recommended model defaults
Dermal absorption factor	1	
Diet: Contaminated fraction/half-life (days)		Default value = 35 days (used in T-REX modeling due to degradate toxicity and persistence; used reduced half-life of 17 days in sensitivity analysis)
Insects	1/35	
Seed	1/35	
Fruit	1/35	
Grass	1/35	
Broadleaf	1/35	
Species Properties		
Field resident type	Field	Likely scenario
Species Type	Passerine	Likely scenario
Feeding times	AM	Recommended model defaults
Start min	5	
Start max	6	
End min	7	
End max	12	
Prop min	0.4	Recommended model default; Indicates min and max proportion of daily feeding attributed to morning
Prop max	0.6	
Gorging factor	1	Recommended model default

Table 81. Avian groups analyzed and example species

Avian Group	Example species
Small insectivore	Warbler, flycatcher, chickadee, swallow
Small omnivore	Sparrows, starlings
Medium insectivore	Meadowlark, flicker
Medium omnivore	Blackbird, woodpecker, grackle

Table 82. Input parameter alternative values modeled

Parameter	Values modeled
Input parameters	
Slope of LD_{50}	2.263 (reported value), 4.5, 9
Dermal absorption factor	1, off
Foliar half-life (days)	35, 17
Field resident type	Edge, field
Type of bird	Passerine bird, precocial bird
Initial application dates	May 1, April 15

Model output

Probability distributions of expected mortalities are provided below in **Figure 41**. Several different output graphs are available from the TIM model. The Probability Density Function (PDF) is shown below for 2 current labeled application rates for corn use (2 lb a.i./A followed by 0.5 lb a.i./A with 14 day retreatment interval (hereafter referred to as 2/0.5 lb a.i./A), 1 lb a.i/A) and a possible reduced rate (0.5 lb a.i./A) for the small insectivore group. At 2/0.5 lb a.i/A, the maximum labeled rate for corn, the model predicts there is a 95% chance that between 5 and 14 birds out of the flock of 25 will die, with the greatest likelihood of 9 deaths. When application rates are dropped to 1 lb a.i./A for one application, this prediction drops to between 0 and 9 birds and at 0.5 lb a.i./A this drops to less than approximately 4 birds. The predominant exposure pathways are through dietary and dermal exposure.

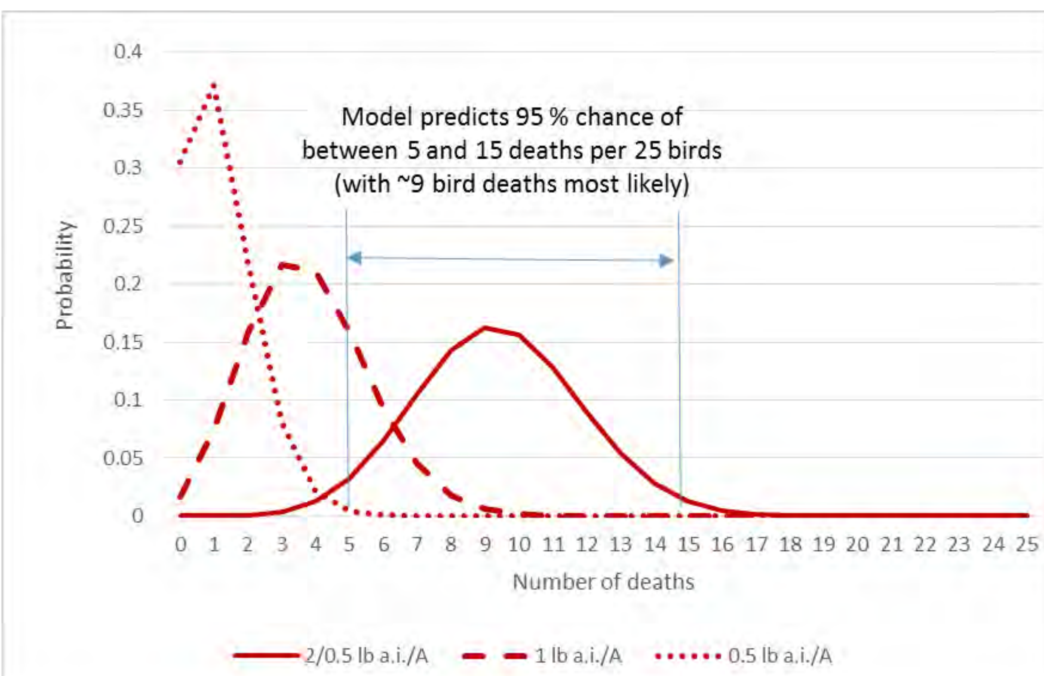


Figure 41. Probability distribution of number of dead birds estimated using TIM.

Additional bird groups and sensitivity analyses

Initial runs indicate that inhalation is not a significant exposure pathway so this route of exposure was turned off for additional sensitivity analyses. Output for additional sensitivity analyses are provided in **Figure 42** and **Figure 43**. At the maximum rate of 2/0.5 lb a.i./A, three additional bird groups were simulated - small omnivores, medium insectivores and medium omnivores. As shown in **Figure 42**, the predicted mortality decreases with increasing size of the bird and diversified diet. For parameter sensitivity analyses, the small insectivore group was chosen as it is one of the more likely classes of birds to be present on or adjacent to corn fields and also represents the most sensitive species in the analysis. The range of probability distributions are displayed in **Figure 43**. The lowest predicted probability distributions are associated with a slope in the avian LD_{50} study of 9, use of an alternate LD_{50} value of 2,000 mg a.i./kg-bw and no dermal exposure. The slope change and no dermal exposure would be considered extreme values on the sensitivity analysis, as the slope reported in the LD_{50} study was 2.263, much lower than 9, and the assumption of zero percent dermal exposure would be unlikely. The non-definitive LD_{50} reported in the mallard duck study at 2,000 mg a.i./kg-bw was modeled to provide additional characterization around the LD_{50} as this tends to be a sensitive input parameter. Use of the lower LD_{50} value of 783 mg a.i./kg-bw in the analysis represents a conservative assumption in the model parameterization; however, this is consistent with the study selection guidelines used for RQ analysis for risks to birds. It is worth noting that the reported LD_{50} value for one degradate (DEA) was reported at 768 mg a.i./kg-bw in a separate study conducted 30 years later in the same species, the bobwhite quail, giving additional confidence to this value for baseline use in the model.

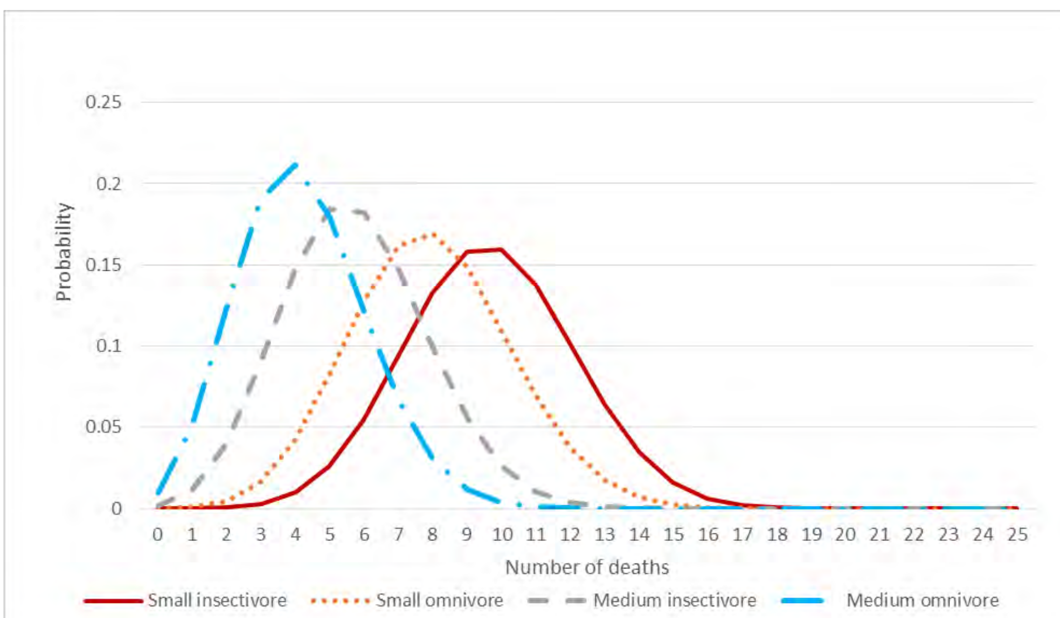


Figure 42. Probability distribution of number of dead birds estimated using TIM for multiple bird groups.

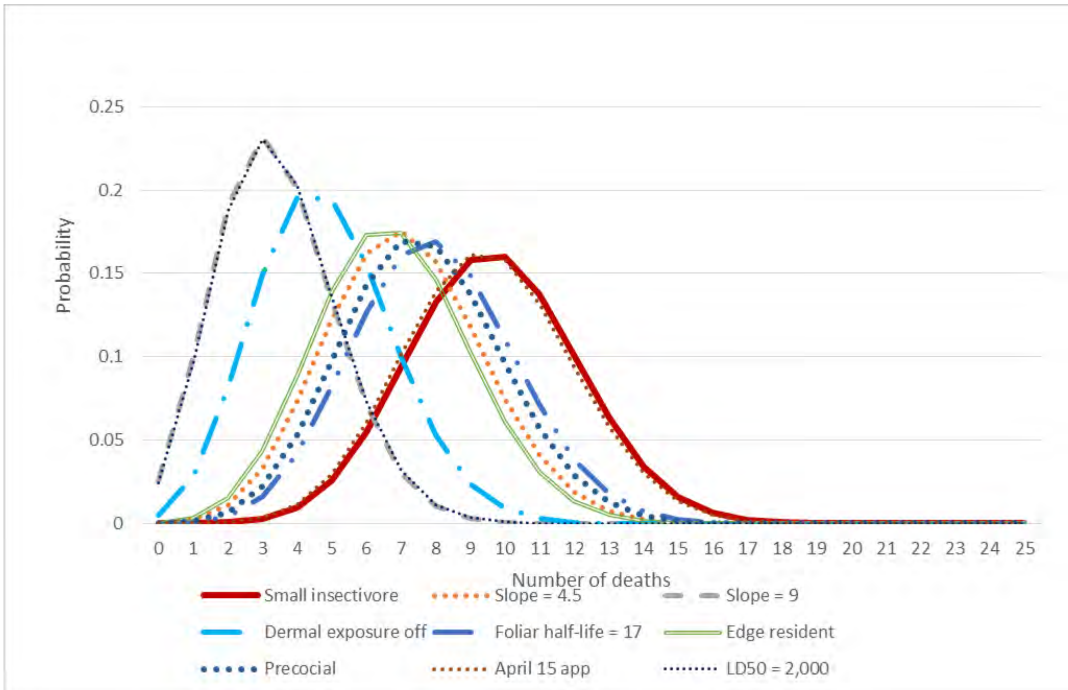


Figure 43. Model parameter sensitivity analyses of probability distributions of number of dead birds estimated using TIM.

14.1.3.2.b. *MCnest Model*

Model parameterization

Similar to the analysis conducted with TIM, MCnest modeling incorporated exposure scenarios typically associated with corn use. Basic MCnest allows for the modeling of 56 individual species and the predicted effects of a specific chemical application rate and date on the reproductive output of that species. Output is displayed as the number of broods expected for a bird species with no pesticide application and with pesticide application. Input parameters used for the MCnest model are listed in **Table 83**.

Table 83. MCnest Input parameters

Parameter Name	Parameter Value	Source/Comments
Half-life (days)	35	Default value (used in T-REX modeling due to degradate toxicity and persistence)
Avian Reproduction Test		
Test species	Mallard Duck	MRID 42547101
Test Concentrations	75, 225 and 675 ppm	
Number of eggs laid, NOAEC	75	
% of viable eggs set, NOAEC	225	

Parameter Name	Parameter Value	Source/Comments
% live 3 week embryos, NOAEC	675	
% hatchlings of live 3-wk embryos, NOAEC	675	
%14-d chicks of hatchlings, NOAEC	675	
Shell thickness, NOAEC	675	
Prelaying female weight, NOAEC	675	
Prelaying male weight, NOAEC	225	
Avian LD50 Test		
LD_{50} (mg/kg – bw)	783	MRID 00024721
Mineau scaling factor	1.15	
Body weight (g)	35	
Avian LC_{50} Test		
LC_{50} (mg/kg-diet)	1000	MRID 00059214 This value based on sublethal affects noted in study, weight loss and marked decrease in food consumption
Fraction of LC_{50}	1	Fraction set to 1 as LC_{50} value based on observed sublethal effect
Mean body weight (g)	57	
Mean food ingestion rate (g/d)	15	
MCnest Toxicity Thresholds (mg/kg/d)		
Alternative behavioral threshold	9999	Default value
1/10 LD_{50}	163.94	These thresholds based on inputs listed above
Adult prelaying body weight	26.96	
Eggs laid per hen	9.46	
Mean eggshell thickness per pen	78.70	
Viable eggs set per pen	26.96	
Hatchlings per viable egg per pen	78.70	
14-d chicks per hatchling per pen	78.70	
Fraction of juvenile 5-d LC_{50}	263.16	

MCnest Output

Figure 44 displays the output for all 56 species modeled using MCnest for the corn scenario at 2/0.5 lb a.i/A with a May 1 application date and a 14 day treatment interval. Based on a lack of overlap between the lower confidence bound on the number of broods expected without pesticide application and the upper confidence bound on the number of broods expected with application, approximately 88% of species modeled could be impacted by atrazine use under this exposure scenario.

Additional analyses were conducted using different application rates and timing. These results were compiled in **Table 84** using the relative % of species impacted as compared to controls. As expected, the number of species impacted decreased with the application rate, but did not vary by a large degree with a shift in the application date over a typical application date range (April 15 to May 15) for corn.

It should be noted that some conservative estimates in the MCnest model include the assumption that all females are exposed to the pesticide, that nest failure is triggered by any exceedance of the applicable endpoint based on NOAEC values and that when nest loss does occur, it is complete (partial nest loss does not occur). These conservative assumptions are generally used based on the lack of data to conduct an adequate dose response curve given the toxicity data available from the reproductive studies. To provide further characterization, model runs were conducted using alternative endpoints with LOAEC values in place of NOAEC values for model inputs and an alternative foliar half-life of 17 days. Reproductive effects were reduced but still anticipated using these less conservative assumptions (output provided in **Appendix M**).

Although the output graphs as displayed suggest an absolute impact on the number of broods produced with atrazine application, the results should be interpreted as indicating a relative shift in the overall reproduction of the group of birds or species modeled. MCnest was a model originally designed to predict reproductive effects on birds based on changes in pesticide application timing during the year and changes in application rates. As presented in **Table 84**, both the effect of changes in application timing and application rate are reflected in the analysis with reductions in application rate having a more substantial impact than changes in the application date within the likely window of application of atrazine to corn.

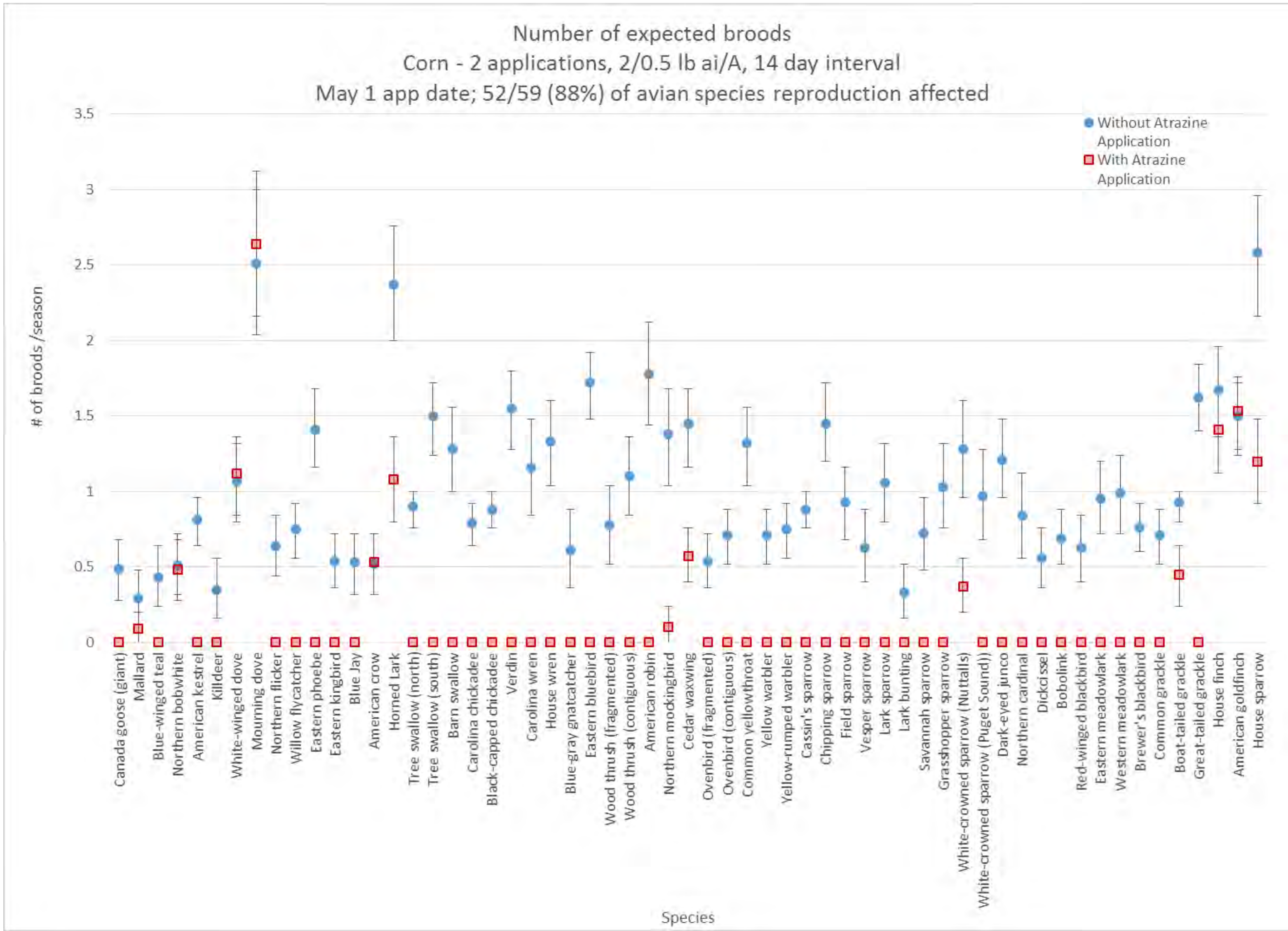


Figure 44. Reproductive impacts (number of broods per season) with and without atrazine application for MCnest bird species

Table 84. MCnest output for reproductive effects at varying corn application rates and dates

Crop, Application Rate (lb a.i/A), Interval (days)	Initial Application Date	% of species reproduction affected
Labeled rates		
Corn, 2.0/0.5, 14	May 1	88% (52/59)
Corn, 2.0/0.5, 14	April 1	88% (52/59)
Corn, 1.0, N/A	April 15	59% (35/59)
Corn, 1.0, N/A	April 29	66% (39/59)
Reduced rate scenarios		
Corn, 0.5, N/A	April 15	41% (24/59)
Corn, 0.25, N/A	April 15	11% (7/59)

14.1.3.2.c. ***TIM- MCnest species specific combined model results***

Using the beta test version of the combined TIM-MCnest model, specific species were analyzed for mortality and reproductive effects due to the application of atrazine at 2/0.5 lb a.i./A on May 1 with a 14 day treatment interval in the Midwest. As this model is still in development, all results generated using the TIM-MCnest combined model should be interpreted as preliminary.

Appendix D of the TIM manual contains species-specific information on the frequency of birds on agricultural fields according to crop and location. Results from two specific studies (Best *et al.*, 1990, MRID 41742701) reported the frequency with which certain species were identified on corn fields in Iowa and Illinois. Using this analysis and the initial MCnest analysis, species were selected with varying degrees of frequency on the field and different magnitude of effects in the initial MCnest analysis. Five species were selected including the mourning dove, eastern kingbird, American robin, common yellowthroat and vesper sparrow. Results for the combined TIM-MCnest analysis are shown in **Table 85** and depicted graphically in **Figure 45** and **Figure 46**. Similar to the results of the separate TIM and MCnest analyses, reproductive output and mortality were impacted in all species modeled to varying degrees. These outputs represent a greater refinement to the model and are indicative of impacts to species that are known to frequently visit the corn fields in the geospatial area of heaviest atrazine use. A limited sensitivity analysis for the TIM-MCnest model is presented in **Appendix M**, including variation of parameters such as foliar half-life, frequency on field and gorging factor**.**

Table 85. TIM-MCnest combined model output for five test species

Species	Size/class	Broods predicted without exposure [mean (range)]	T-REX-MCnest (Basic MCnest) broods predicted [mean (range)]	TIM-MCnest broods predicted [mean (range)]
Mourning Dove	Medium, granivore	2.61 (2.12 – 3.08)	2.65 (2.16 – 3.12)	1.23 (0.84 –1.64)
Eastern Kingbird	Small/med, insectivore	0.55 (0.36 – 0.76)	0	0.05 (0 – 0.16)
American Robin	Medium, insectivore	1.85 (1.52 – 2.2)	0	0.14 (0-0.32)
Common Yellowthroat	Small, insectivore	1.38 (1.08 – 1.64)	0	0.04 (0-0.12)
Vesper Sparrow	Small, omnivore	0.69 (0.44 – 0.96)	0	0

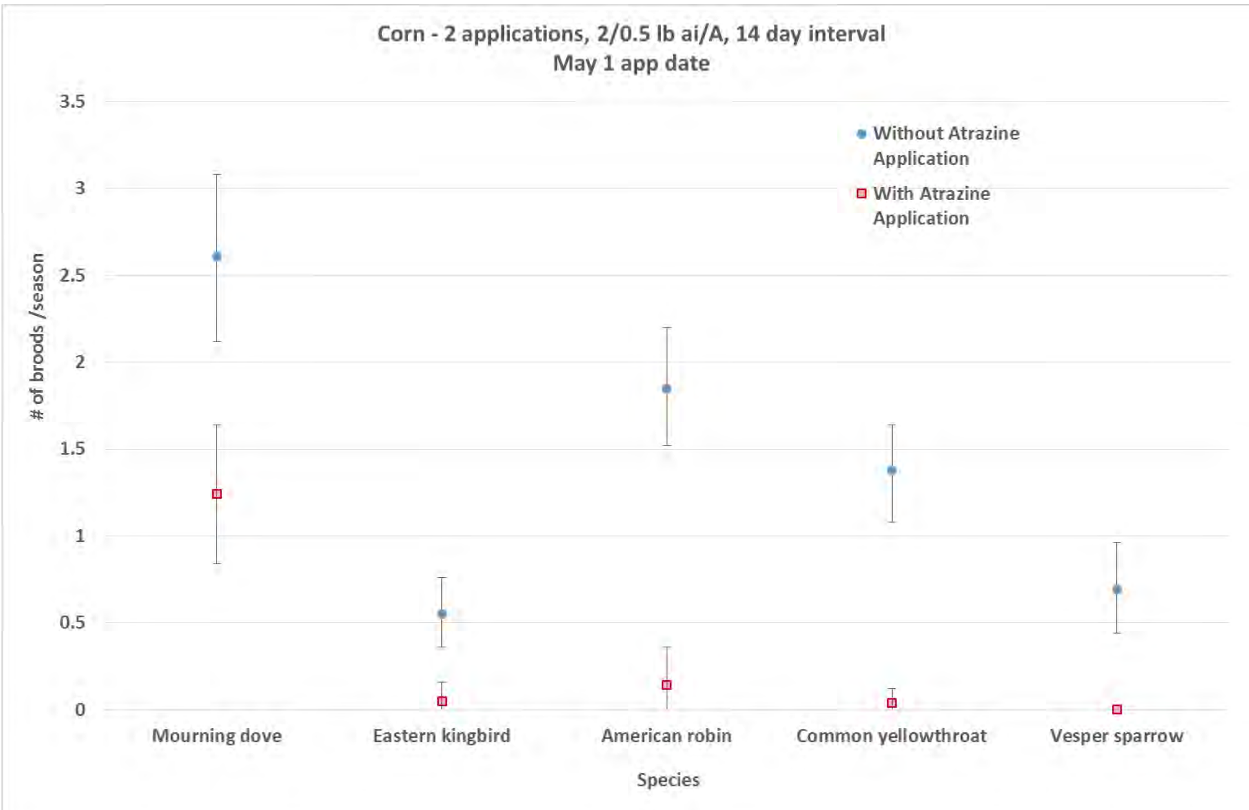


Figure 45. Reproductive impacts (number of broods per season) with and without atrazine application for several bird species known to frequent corn fields in midwestern states (Iowa and Illinois).

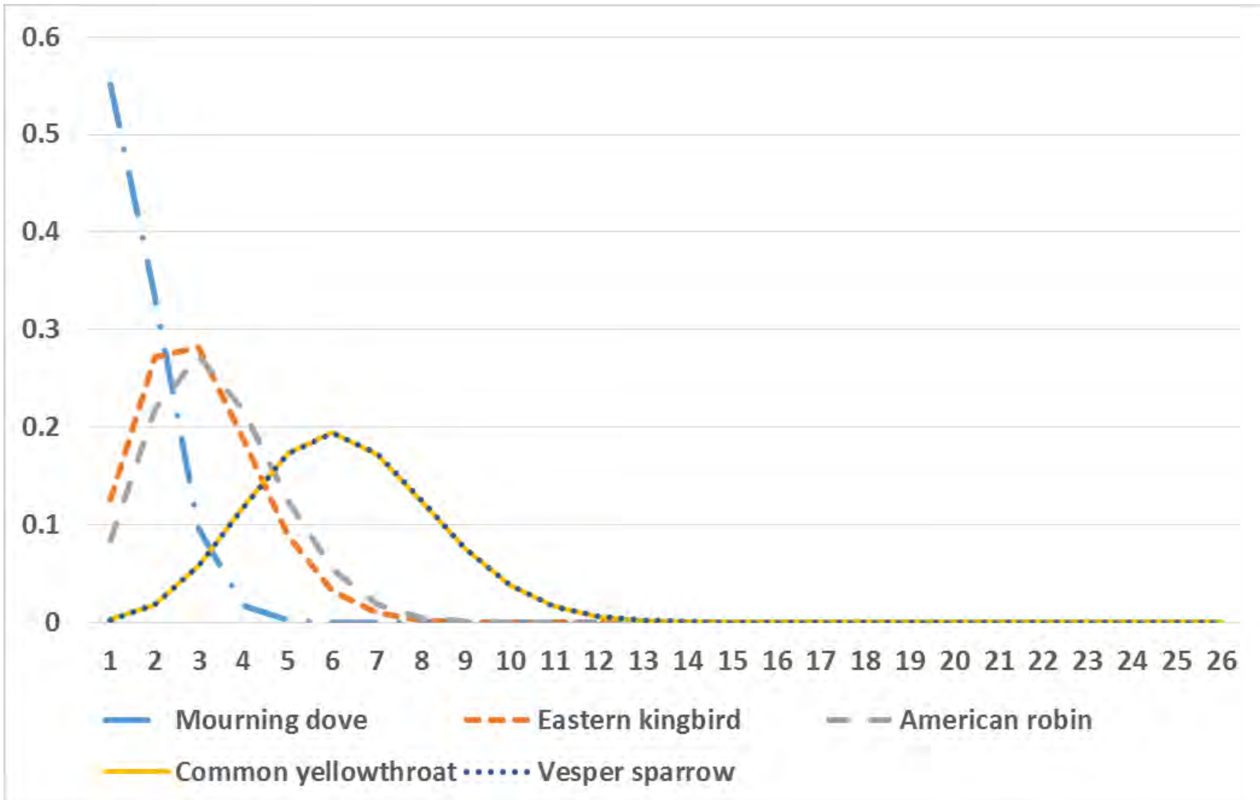


Figure 46. Probability distribution of number of dead birds estimated for several bird species known to frequent corn fields in midwestern states (Iowa and Illinois) with atrazine application at 2/0.5 lb a.i./A with 14 day retreatment interval.

14.1.4. Risks to Mammals

Based on upper and mean Kenaga values from T-Rex **(Table 65 and Table 66)**, chronic LOCs for mammals are exceeded. Acute LOCs are only exceeded for listed species, and only for the highest use rates for mean Kenaga values. The highest maximum RQs occur for the small mammal with short grass as the primary food item and the sugarcane and macadamia nut use scenarios. For corn uses (upper Kenaga values), RQs range from 0.0 – 0.4 for acute risks and 0.1-198 for chronic risks across the range of sizes and dietary items of mammalian species. Summary tables below (Tables 80-81) include minimum and maximum ranges for each use as well as the percentage of times LOCs were exceeded for the modeled sizes of mammals and various dietary items. The most common use (corn) and uses with the highest application rates are highlighted in the tables for emphasis. Chronic risks are of primary concern with RQ values are as high as 198 and LOCs exceeded for 80-100% of the scenarios modeled for all uses. Primary concern with chronic risk is consistent with the available atrazine toxicity data in mammals as well as other species.

For the reduced rates modeled, RQs based on acute risk to mammals are less than the LOC for listed and non-listed species. However, the LOC for chronic risk is still exceeded for single application of both 0.25 and 0.5 lb a.i./A with RQs of 7 and 14 for dose based chronic risks, respectively.

Table 86. Range of RQs for Mammals of Different Feeding Classes (T-REX v. 1.5.2, upper bound Kenaga).

Use	Dose-based RQ range mammalian acute risk		Dose-based RQ range mammalian chronic risk		Dietary-based RQ range mammalian chronic risk	
	Min	Max	Min	Max	Min	Max
Corn/Sorghum (2/0.5)	0.0	0.1	0.4	57	0.6	9.7
Sugarcane	0.0	0.4	1.1	180	1.9	31
Turf- Bermudagrass	0.0	0.1	0.3	44	0.5	7.4
Turf- St Augustinegrass	0.0	0.3	0.9	142	1.5	24
Fallow- Prior to planting corn and sorghum	0.0	0.1	0.4	63	0.7	11
Roadside	0.0	0.1	0.2	28	0.3	4.8
CRP	0.0	0.1	0.4	56	0.6	9.6
Macadamia Nuts	0.0	0.4	1.3	198	2.1	34
Guava	0.0	0.2	0.8	123	1.3	21
Conifers	0.0	0.2	0.7	113	1.2	19
Corn/Sorghum (0.5)	0.0	0.24	0.1	14	0.2	2.4
Corn/Sorghum (0.25)	0.0	0.12	0.0	7	0.1	1.2

Table 87. Percentage of LOC exceedance for Mammals of Different Feeding Classes (T-REX v. 1.5.2, upper bound Kenaga). Major use (corn) and uses with maximum rates highlighted.

Use	Dose-based RQs mammalian acute risk		Dose-based RQs mammalian chronic risk	Dietary-based RQs mammalian chronic risk
	% scenarios that exceed LOC listed	% scenarios that exceed LOC non-listed	% scenarios that exceed LOC for listed or non-listed species	% scenarios that exceed LOC for listed or non-listed species
Corn/Sorghum (2/0.5)	6%	0%	83%	80%
Sugarcane	50%	0%	100%	100%
Turf- Bermudagrass	0%	0%	83%	80%

Use	Dose-based RQs mammalian acute risk		Dose-based RQs mammalian chronic risk	Dietary-based RQs mammalian chronic risk
	% scenarios that exceed LOC listed	% scenarios that exceed LOC non-listed	% scenarios that exceed LOC for listed or non-listed species	% scenarios that exceed LOC for listed or non-listed species
Turf- St Augustinegrass	44%	0%	94%	100%
Fallow- Prior to planting corn and sorghum	11%	0%	83%	80%
Roadside	0%	0%	78%	80%
CRP	6%	0%	83%	80%
Macadamia Nuts	56%	0%	100%	100%
Guava	33%	0%	94%	100%
Conifers	33%	0%	94%	100%
Corn/Sorghum (0.5)	0%	0%	67%	60%
Corn/Sorghum (0.25)	0%	0%	67%	20%

Figure 47 is taken from the T-REX model output and illustrates the number of days for which the screening-level (upper-bound) dietary EECs based on the labeled application rate for corn (2/0.5 lb a.i/A) exceeds the Agency's LOC for chronic risk to mammals. As seen in the figure, for 4 out of 5 of the dietary items considered, this scenario exceeds the Agency's LOC for chronic risk to mammals for 80 to 130 days out of the year. Although not shown graphically, when the same analysis is completed for sugarcane, the highest labeled use rate, the LOC is exceeded for approximately 70 to 215 days out of the year for all dietary items. Using a foliar half-life of 17 days instead of 35 days reduces the number of days exceeding for 4 out of 5 dietary items to 35 to 65 days for corn and 90 to 120 days for sugarcane.

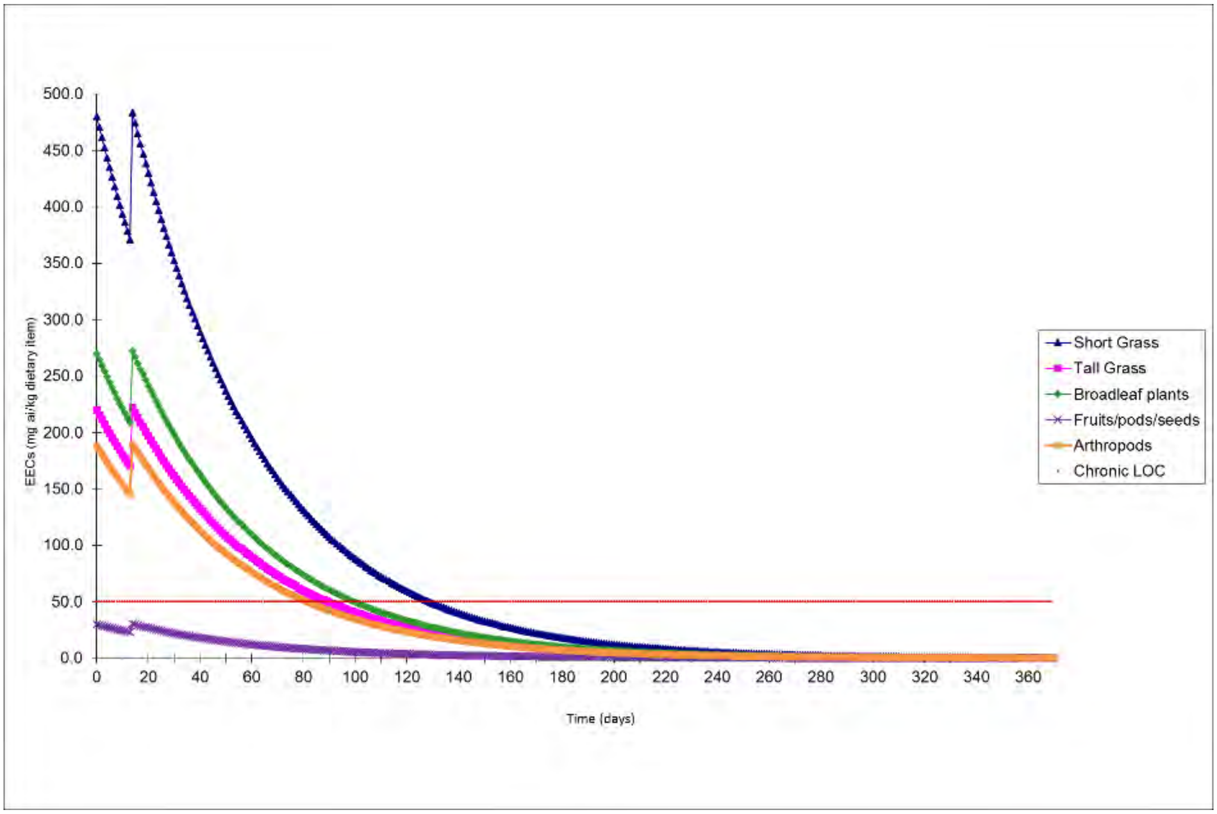


Figure 47. Terrestrial dietary EECs for atrazine applied at 2/0.5 lbs a.i/A with a retreatment interval of 14 days (maximum labeled corn use rate). Day 0 = date of first application.

14.1.4.1. *Risk to Mammals Off-Field*

As discussed in **Section 14.1.3.1** for avian species, spray deposition curves calculated using AgDRIFT (version 2.1.1) (Tier II) were used to estimate the distance from the edge of the field to where effects to non-target organisms are no longer of concern. The corresponding application rates to achieve a distance less than the LOC for birds and mammals are displayed on the curves (**Figure 35 - Figure 40**).

Appreciable drift concerns to mammals are not anticipated for acute risks, but has potential concern for chronic risks for the three application rates modeled (0.5, 2 and 4 lb a.i/A). Distances increase with increasing application rate with 2 lb a.i/A corresponding to risks between 100 and 500 ft off field and 4 lb a.i/A corresponding to potential concerns between 100 and >997 ft off field (**Figure 35 - Figure 38**). Distances to reach an exposure level of no concern are reduced for ground vs. aerial application and with increasing droplet size, as illustrated in the figures. For ground applications at the 2 lb a.i./A application rate, off-field chronic risks to mammals is reduced to approximately 25 ft with the use of fine to medium

droplet size released from a low boom. For the modeled reduced rate, 0.5 lbs a.i./A, drift exposure to mammals following an aerial application may result in chronic risks within 150 ft for all droplet sizes (**Figure 39**), with the use coarser droplet sizes reducing this distance. Ground application at 0.5 lbs a.i/A reduces the potential off-field chronic risks to mammals from spray drift exposure to within 50 feet for fine- very fine droplet spectra and within the field for coarser droplet spectra (**Figure 40**)

14.1.4.2. ***Data Arrays of Mammalian Effects***

As discussed previously in Section **11.1.3.3**, many additional mammalian effects endpoints are reported in the ECOTOX database. The data array below (Figure 48) displays a subset of these effects along with relevant EECs (colored vertical exposure ranges). The figure illustrates the overlap of effects and exposure concentrations considering endpoints from multiple sources of data and the subsequent effect of rate reductions on this overlap.

Endpoints that fall within or to the left of one of the colored exposure ranges indicate an exceedance of the LOC based on that endpoint and the modeled application rate, and in this case are mostly chronic in nature. As discussed in the effects characterization section, the effects data points on this figure capture studies reviewed by OPP and also those only reviewed to meet the standards of an "acceptable" study by EPA ORD ECOTOX guidelines.

The red exposure range represents the range of modeled EECs for small mammals feeding on short grass and tall grass or broadleaf plants (representing higher exposure groups) following the labeled use rate of 2/0.5 lb a.i./A. The figure illustrates that for a majority of the endpoints in the available scientific literature modeled EECs following application to corn would exceed exposure concentrations that resulted in effects to mammals.

Although not displayed on the graph, sugarcane and macadamia nut uses would shift exposure ranges further to the right (EECs range from approximately 600 to 1600 mg/kg bw), therefore exceeding nearly all of the available effects data.

To illustrate the effect of lower application rates, the expected EEC ranges for small mammals feeding on short grass and tall grass or broadleaf plants following reduced application rates of 0.5 and 0.25 lb a.i./A are also displayed in the figure. Although less endpoints are exceeded at the lower rates, exceedance of the most sensitive effects concentrations still occurs at the lowest reduced rate modeled (0.25 lb a.i./A).

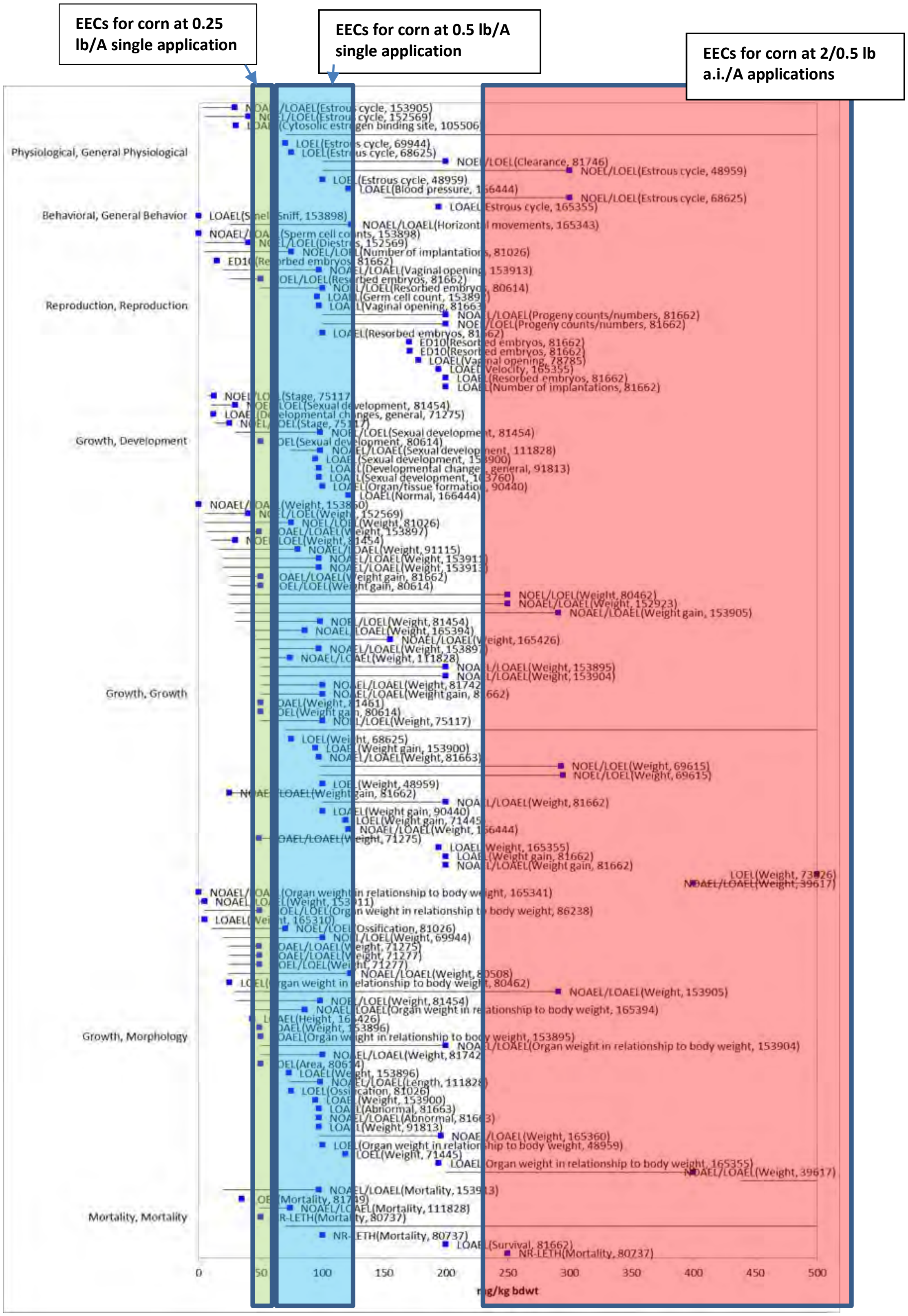


Figure 48. Dose based mammalian effects endpoints from ECOTOX database [denoted as (Effect, ECOTOX Ref id#] and expected exposure concentrations (EECs).

14.1.5. Risk to Reptiles and Terrestrial-phase Amphibians

Toxicity data for birds is used as a surrogate for reptiles and terrestrial-phase amphibians due to the lack of data acceptable for quantitative analysis in these species. Therefore, discussion on EECS, RQs and drift analysis in **Section 14.1.3** above are applicable to risks for reptiles and terrestrial-phase amphibians. Supplemental analysis is provided below using the T-HERPS model.

14.1.5.1. *Use of T-HERPS to refine terrestrial reptile and amphibian risk analysis*

Terrestrial phase amphibians and reptiles are poikilotherms, which means that their body temperature varies with environmental temperature, while birds are homeotherms (temperature is regulated, constant, and largely independent of environmental temperatures). As a consequence, the caloric requirements of terrestrial phase amphibians are markedly lower than birds. Therefore, on a daily dietary intake basis, birds consume more food than terrestrial phase amphibians. This can be seen when comparing the caloric requirements for free living iguanid lizards (used as a surrogate for reptiles and terrestrial phase amphibians) to song birds (U.S. EPA, 1993):

$$\textbf{iguanid FMR (kcal/day)= 0.0535 (bw g)}^{0.799}$$

$$\textbf{passerine FMR (kcal/day) = 2.123 (bw g)}^{0.749}$$

With relatively comparable slopes to the allometric functions, one can see that, given a comparable body weight, the free living metabolic rate (FMR) of birds can be 40 times higher than reptiles and terrestrial phase amphibians, though the requirement differences narrow with high body weights.

Because the existing risk assessment process is driven by chronic risks due to the dietary route of exposure, a finding of safety for birds, with their much higher feeding rates and, therefore, higher potential dietary exposure, is reasoned to be protective of terrestrial phase amphibians. For this not to be the case, terrestrial phase amphibians would have to be 40 times more sensitive than birds for the differences in dietary uptake to be negated. However, existing dietary toxicity studies in amphibians and reptiles are lacking. To quantify the potential differences in food intake between birds and terrestrial phase amphibians and reptiles, food intake equations for the iguanid lizard replaced the food intake equation in T-REX for birds, and additional food items were evaluated. These functions were encompassed in a model called T-HERPS. T-HERPS is available at: http://www.epa.gov/oppefed1/models/terrestrial/index.htm.

Results of this analysis are presented in **Table 88** – **Table 93**. As corn represents the highest yearly use of atrazine, based on usage data (see **Section 5.5**), 2 single application rate scenarios (0.5 lb a.i./A and 2 lb a.i./A) were modeled. Macadamia nuts were also modeled as they produced the highest RQs for birds (2 applications at 4 lb a.i./A with 14 day interval). T-HERPS is not able to model variable application rates so these rates were not included. Results for both reptiles and terrestrial –phase amphibians are presented below.

As expected with this refinement, RQs for reptiles and terrestrial-phase amphibians were lower than those calculated using birds as a surrogate species. For acute risks, RQ values exceeded LOCs primarily for those herpetofauna consuming herbivore mammals at all application rates modeled but included groups with other dietary items for higher rates (insectivore mammals and broadleaf plants/small insects). Consistent with the calculated RQs for birds, the primary risk concerns for herpetofauna were associated with chronic risk. RQs ranged from 1.2 to 22.6, with reptiles and amphibians consuming herbivore mammals exceeding LOCs at even the lowest application rate, but all dietary items exceeding at the highest application rate modeled.

Comparing reptiles to terrestrial-based amphibians, RQ values are very similar for both taxa. In general, reptiles have slightly higher RQs for acute risks but terrestrial-phase amphibians have slightly higher RQs for chronic risks.

Although RQs for reptiles and terrestrial-phase amphibians were lower than those predicted using birds as a surrogate, the lack of consideration of other exposure routes (e.g. dermal) for these species should be considered in interpretation of the results, as they could represent significant exposure routes.

Table 88. Upper Bound Kenaga, Acute Herpetofauna Dose-Based Risk Quotients (Corn; 0.5 lbs a.i./Acre, 1 application). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Size Class (grams)	Adjusted LD50	EECs and RQs based on dietary item									
		Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
Reptiles											
2.0	783.00	3.75	0.00	0.42	0.00	283.17	0.36	17.70	0.02	3.89	0.00
20	783.00	2.22	0.00	0.25	0.00	113.79	0.15	7.11	0.01	2.62	0.00
200	783.00	1.32	0.00	0.15	0.00	45.72	0.06	2.86	0.00	1.76	0.00
Terrestrial-Phase Amphibians											
2.0	783.00	3.7	0.0	0.4	0.0	219.1	0.3	13.7	0.0	2.7	0.0
20	783.00	2.2	0.0	0.2	0.0	80.3	0.1	5.0	0.0	1.6	0.0
200	783.00	1.3	0.0	0.1	0.0	29.4	0.0	1.8	0.0	1.0	0.0

Table 89. Upper Bound Kenaga, Chronic Herpetofauna Dietary-Based Risk Quotients (Corn; 0.5 lbs a.i./Acre, 1 application). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

NOAEC (mg a.i/kg diet)	EECs and RQs based on dietary item									
	Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
	EEC	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**
Reptiles										
75	67.5	0.9	7.5	0.1	92.0	**1.2**	5.8	0.08	2.12	0.03
Terrestrial-Phase Amphibians										
75	67.5	0.9	7.5	0.1	120.4	**1.6**	7.5	0.1	2.4	0.0

Table 90. Upper Bound Kenaga, Acute Herpetofauna Dose-Based Risk Quotients (Corn; 2 lb a.i./A, 1 application). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Size Class (grams)	Adjusted LD50	EECs and RQs based on dietary item									
		Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
Reptiles											
2.0	783.00	14.99	0.02	1.67	0.00	1133	**1.45**	70.8	0.09	15.58	0.02
20	783.00	8.89	0.01	0.99	0.00	455.15	**0.58**	28.5	0.04	10.48	0.01
200	783.00	5.27	0.01	0.59	0.00	182.89	0.23	11.4	0.01	7.05	0.01
Terrestrial-Phase Amphibians											
2.0	783.00	15.0	0.0	1.7	0.0	876.5	**1.1**	54.8	0.1	11.0	0.0
20	783.00	8.9	0.0	1.0	0.0	321.2	0.4	20.1	0.0	6.5	0.0
200	783.00	5.3	0.0	0.6	0.0	117.7	0.2	7.4	0.0	3.9	0.0

Table 91. Upper Bound Kenaga, Chronic Terrestrial Herpetofauna Dietary-Based Risk Quotients (Corn; 2 lbs a.i./Acre, 1 application). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

NOAEC (mg a.i/kg diet)	EECs and RQs based on dietary item									
	Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
	EEC	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**
Reptiles										
75	270.00	**3.60**	30.00	0.40	367.94	**4.91**	23	0.31	8.47	0.11
Terrestrial-Phase Amphibians										
75	270.0	**3.6**	30.0	0.4	481.8	**6.4**	30.1	0.4	9.7	0.1

Table 92. Upper Bound Kenaga, Acute Herpetofauna Dose-Based Risk Quotients (Macadamia Nuts; 4 lbs a.i./Acre, 2 applications, 14 day interval). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

Size Class (grams)	Adjusted LD50	EECs and RQs based on dietary item									
		Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
		EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ	EEC	RQ
Reptiles											
2.0	783.00	52.7	0.1	5.9	0.0	3982	**5.1**	249	0.3	54.8	0.1
20	783.00	31.3	0.0	3.5	0.0	1600	**2.0**	100	0.1	36.8	0.0
200	783.00	18.5	0.0	2.1	0.0	643	0.8	40.2	0.1	24.8	0.0
Terrestrial-Phase Amphibians											
2.0	783.00	52.7	0.1	5.9	0.0	3081	**3.9**	193	0.2	38.5	0.0
20	783.00	31.3	0.0	3.5	0.0	1129	1.4	70.6	0.1	22.8	0.0
200	783.00	18.5	0.0	2.1	0.0	414	0.5	25.9	0.0	13.5	0.0

Table 93. Upper Bound Kenaga, Chronic Terrestrial Herpetofauna Dietary-Based Risk Quotients (Macadamia Nuts; 4 lbs a.i./Acre, 2 applications, 14 day interval). Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances.

NOAEC (mg a.i/kg diet)	EECs and RQs based on dietary item									
	Broadleaf Plants/ Small Insects		Fruits/Pods/ Seeds/ Large Insects		Herbivore Mammals		Insectivore Mammal		Amphibians	
	EEC	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**	**EEC**	**RQ**
Reptiles										
75	949.2	**12.7**	105.5	**1.4**	1294	**17.2**	80.8	**1.1**	29.8	0.4
Terrestrial-Phase Amphibians										
75	949.2	**12.7**	105.5	**1.4**	1694	**22.6**	106	**1.4**	34.3	0.5

14.1.6. Risk to Terrestrial Invertebrates

The acute contact LD_{50} in honey bees was >97 ug/bee (5% mortality occurred at the highest dose level) (MRID 00036935) which is classified as practically non-toxic. A dose of 97 µg/bee corresponds to an atrazine concentration on the bee of approximately 757 mg/kg-bw, assuming an adult honey bee weighs 128 mg (Mayer and Johansen, 1990). The corresponding exposure value to honey bees at an application rate of 4 lbs a.i./A is approximately 60 mg/kg-bw. Exposure assessments for honey bees were also calculated using the new pollinator guidance. Based on Tier I exposure estimates for contact exposure and a maximum single application rate of 4 lb a.i./A, the exposure estimate was 10.8 µg/bee. The RQ based on the Tier I exposure estimate and non-definitive LD_{50} was 0.11. This is below the LOC of 0.4. At a maximum yearly application rate of 10 lb a.i./A as labeled for sugarcane use, the RQ is 0.28 and is still less than the LOC. No additional data were available for honey bee toxicity; therefore RQs based on adult oral exposure or larval exposure were not calculated.

Studies that showed statistically significant ($p<0.05$) effects to terrestrial invertebrates occurred at application rates that were below the highest yearly application rate of 10 lbs a.i./A for sugarcane and typically less than the maximum rate of 2.5 lbs a.i./A for corn and sorghum. The most sensitive terrestrial insect tested was the springtail (*Onychiuridae*). Mortality rates in *Onychiurus armatus* were approximately 50% at 20 mg/kg soil, which is associated with an application rate of 7 lbs a.i./A assuming a soil depth of 3 cm and a soil density of 1.3 g/cm^3. Another species of springtail, *O. armatus,* was associated with 18% mortality at soil levels associated with approximately 1 lb a.i./A (Mola et al., 1987), which is within the range of labeled atrazine application rates. An application rate of 5.4 lbs a.i./A was associated with reduced abundance of microarthropods (Fratello et. al., 1985); however, reduced abundance

could have been caused by indirect effects (migration/repellency). Application rates of 0.9 and 1.8 lbs a.i./A did not affect abundance of microarthropods (Cortet et al., 2002; Fratello et. al., 1985).

Atrazine did not affect survival in a number of beetle species at application rates that ranged from 0.8 to 8 lbs a.i./A (Kegel, 1989; Brust, 1990; Samsoe-Petersen, 1995). No studies in beetles established definitive LOAEC or EC_{50} values. Because the studies in beetles produced free-standing NOAECs, their utility is somewhat limited; however, they do suggest that abundance would not likely be affected at atrazine applications up to 8 lbs a.i./A for ground beetles (Poecilus) and 2 lbs a.i./A for carabid beetles.

In addition, earthworm LC_{50}s were 270 and 380 mg/kg soil (Mosleh et al., 2003; Haque and Ebing, 1983). The highest soil concentrations expected from the maximum labeled single application rate (4 lbs a.i./A) on the treated field would be approximately 11 mg/kg in the top 3 cm of soil (RQ would be approximately 0.04).

14.2. Risks to Terrestrial Plants

14.2.1. Runoff and Spray Drift Exposure to Terrestrial and Semi-Aquatic Plants

Exposure of non-target terrestrial and semi-aquatic (wetland) plant species is estimated using OPP's TerrPlant (v. 1.2.2) model. Loading via spray drift to dry, non-target, adjacent areas is assumed to occur from one acre of treated land to one acre of the non-target area. Runoff is also expected to be a source of pesticide loading to non-target areas. TerrPlant calculates EECs as a function of application rate, solubility, and default assumptions regarding spray drift. The default spray drift assumptions are 1% of the application rate for ground spray applications and 5% for aerial spray applications (USEPA 2006b). The EECs for terrestrial and semi-aquatic plants for a single application of atrazine at the maximum labeled rates for representative uses are presented in **Table 94**.

Table 94. EECs for Terrestrial and Semi-Aquatic Plants Near Atrazine Use Areas (TerrPlant v. 1.2.2)[1].

Crop	Single Max. Application Rate (lbs a.i/A)	EECs (lbs a.i/A)					
		Spray Drift Only		Runoff and Spray Drift (Dry Areas)		Runoff and Spray Drift (Semi-Aquatic Areas)	
		Ground spray	Aerial spray	Ground spray	Aerial spray	Ground spray	Aerial spray
Corn/Sorghum	2	0.02	0.1	0.06	0.14	0.42	0.5
Sugarcane	4	0.04	0.2	0.12	0.28	0.84	1
Turf- Bermudagrass	1	0.01	0.05	0.03	0.07	0.21	0.25

Crop	Single Max. Application Rate (lbs a.i/A)	EECs (lbs a.i/A)					
		Spray Drift Only		Runoff and Spray Drift (Dry Areas)		Runoff and Spray Drift (Semi-Aquatic Areas)	
		Ground spray	Aerial spray	Ground spray	Aerial spray	Ground spray	Aerial spray
Turf- St Augustinegrass	4	0.04	0.2	0.12	0.28	0.84	1
Fallow- Prior to planting corn and sorghum	2.25	0.0225	0.1125	0.0675	0.1575	0.4725	0.5625
Roadside	1	0.01	0.05	0.03	0.07	0.21	0.25
CRP	2	0.02	0.1	0.06	0.14	0.42	0.5
Macadamia Nuts	4	0.04	0.2	0.12	0.28	0.84	1
Guava	4	0.04	0.2	0.12	0.28	0.84	1
Conifers	4	0.04	0.2	0.12	0.28	0.84	1
Corn/Sorghum Reduced Rate	0.5	0.005	0.025	0.015	0.035	0.105	0.125
Corn/Sorghum Reduced Rate	0.25	0.0025	0.0125	0.0075	0.0175	0.0525	0.0625

14.2.2. Risk Quotient (RQ) Values for Terrestrial Plant Species

14.2.2.1. *Spray drift and Runoff*

This assessment of the labeled uses of atrazine relies on the deterministic RQ method to provide a metric of potential risks. The RQ provides a comparison of exposure estimates to toxicity endpoints (*i.e.*, the estimated exposure concentrations are divided by toxicity values). The resulting unitless RQ values are compared to the Agency's LOCs, as shown in **Table 58**. The LOCs are used by the Agency to indicate when the use of a pesticide, as directed by the label, has the potential to cause adverse effects to non-target organisms. For endangered species, LOC exceedances require an additional in-depth listed species evaluation of the potential co-occurrence of listed species and areas in which new use crops are grown to characterize risks. In this assessment, RQs that exceed the non-listed species LOC also exceed the listed species LOC.

At the maximum single application rate for each of the modeled Section 3 and Section 24c labeled uses, RQs for listed and non-listed monocots and dicots are above the LOCs for upland (dry areas) and wetland (semi-aquatic areas) habitats based on spray drift exposure alone as well as through the combination of runoff and spray drift exposure (**Table 95**). In addition the model was run assuming potential reduced single application rates of 0.5 and 0.25 lbs a.i./A. The resulting RQs are above the levels of concern for runoff and spray drift to upland and wetland habitats.

The RQs resulting from ground spray applications result in lower drift concerns than those resulting from aerial applications, however these application methods contribute equally to runoff concerns. Because of the relatively high solubility of atrazine and its persistence in the environment, any species of plant that are downhill of the application area are likely to receive runoff from use sites. EPA assumes that the protection of the aquatic plant communities with the CELOC (**Section 12.2**) would also be protective of wetland plant communities modeled in the TerrPlant semi-aquatic areas.

Table 95. Risk Quotients for Terrestrial and Semi-Aquatic Plants Near Atrazine Use Areas (TerrPlant v. 1.2.2)

Exposure Scenario →	RQs: Non-Listed and (Listed) Species											
	Spray Drift Only				Runoff and Spray Drift (Dry Areas)				Runoff and Spray Drift (Semi-Aquatic Areas)			
	Ground spray		Aerial spray		Ground spray		Aerial spray		Ground spray		Aerial spray	
Plant Group → Use(s) ↓	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot
Corn/Sorghum (2 lbs/A)	5 (8)	7 (8)	25 (40)	33 (40)	15 (24)	20 (24)	35 (56)	47 (56)	105 (168)	140 (168)	125 (200)	167 (200)
Sugarcane	10 (16)	13 (16)	50 (80)	67 (80)	30 (48)	40 (48)	70 (112)	93 (112)	210 (336)	280 (336)	250 (400)	333 (400)
Turf- Bermudagrass	2.5 (4)	3.3 (4)	13 (20)	17 (20)	7.5 (12)	10 (12)	18 (28)	23 (28)	53 (84)	70 (84)	63 (100)	83 (100)
Turf- St Augustinegrass	10 (16)	13 (16)	50 (80)	67 (80)	30 (48)	40 (48)	70 (112)	93 (112)	210 (336)	280 (336)	250 (400)	333 (400)
Fallow- Prior to planting corn and sorghum	6 (9)	8 (9)	28 (45)	38 (45)	17 (27)	23 (27)	39 (63)	53 (63)	118 (189)	158 (189)	141 (225)	188 (225)
Roadside	2.5 (4)	3.3 (4)	13 (20)	17 (20)	7.5 (12)	10 (12)	18 (28)	23 (28)	53 (84)	70 (84)	63 (100)	83 (100)
CRP	5 (8)	7 (8)	25 (40)	33 (40)	15 (24)	20 (24)	35 (56)	47 (56)	105 (168)	140 (168)	125 (200)	167 (200)
Macadamia Nuts	10 (16)	13 (16)	50 (80)	67 (80)	30 (48)	40 (48)	70 (112)	93 (112)	210 (336)	280 (336)	250 (400)	333 (400)
Guava	10 (16)	13 (16)	50 (80)	67 (80)	30 (48)	40 (48)	70 (112)	93 (112)	210 (336)	280 (336)	250 (400)	333 (400)
Conifers	10 (16)	13 (16)	50 (80)	67 (80)	30 (48)	40 (48)	70 (112)	93 (112)	210 (336)	280 (336)	250 (400)	333 (400)
Corn/Sorghum Reduced Rate (0.5 lbs/A)	1 (2)	2 (2)	6 (10)	8 (10)	4 (6)	5 (6)	9 (14)	12 (14)	26 (42)	35 (42)	31 (50)	42 (50)
Corn/Sorghum Reduced Rate (0.25 lbs/A)	0.6 (1)	0.8 (1)	3 (5)	4 (5)	2 (3)	3 (3)	4 (7)	6 (7)	13 (21)	18 (21)	15 (25)	21 (25)

The RQs presented in the table above describe the risk in terms of comparison to the most sensitive monocot and dicot, however for atrazine there are a large number of studies reporting IC_{25s} that are comparable to the guideline Seedling Emergence (850.4100) and Vegetative Vigor (850.4150) studies. These data were used to develop Species Sensitivity Distributions (SSDs, described in **Section 10.1**, **Figure 20** and **Figure 21**). These SSDs provide the HC_p distribution which is the percentile ranking of the distribution such that 5% of the taxa have an IC_{25} estimate lower than the concentration at an HC_{05}. As discussed in **Section 10.1**, the seedling emergence stage is more sensitive than the vegetative vigor stage. The SSDs (**Figure 20** and **Figure 21**) were compared to the EECs from the TerrPlant modeling (**Table 94**). The results indicate similar trends as discussed above with considerable risk from spray drift following aerial application, and runoff combined with spray drift from all application methods. The percent of the SSD exceeded by the TerrPlant EECs is interpreted as the percent of species that will have a 25 percent or greater reduction in growth. As an example, in **Table 96**, a ground application of atrazine on corn results in a 25% or greater reduction in growth for 7% of plant species based on spray drift alone, for 26% of species based on runoff and spray drift to upland dry areas, and for semi-aquatic habitats 76% of species would be expected to be impacted by reductions of 25% or greater on growth.

As discussed with the single species comparisons based on the most sensitive species, risk from exposures off of the field were expected for plants. The diversity of species that are included in the SSDs for both vegetative vigor and seedling emergence data suggests that a broad diversity of plants are sensitive to atrazine exposure. This does not mean that the weeds present on or near the field are equally sensitive, in fact the exposures required to control many weed species are several orders of magnitude less sensitive than the taxa discussed here. The breadth of species and families of plants potentially impacted by atrazine use at under all section 3 and section 24c labels, as well as under the reduced risk evaluations at 0.5 and 0.25 lbs a.i./A, suggest that terrestrial plant communities are likely to be impacted from predicted off-field exposures via runoff and/or spray drift. Seedling emergence endpoints reflect the most sensitive data, but also the most likely stage of plant development during the corn application season. These analyses estimate that for semi-aquatic habitats more than 95% of species could have at least a 25% reduction in emergence (survival) or growth. Even under the reduced application rate scenario 80% of species are estimated to be impacted when exposed as developing seedlings in semi-aquatic habitats (**Table 97**).

Table 96. Estimated percent of terrestrial and semi-aquatic plant species expected to have a 25% or greater reduction in growth based on vegetative vigor stage exposures estimated with the vegetative vigor SSD (Figure 20) and TerrPlant EECs in Table 94.

Crop	Single Max. Application Rate (lbs a.i/A)	Estimated Percent of Vegetative Vigor SSD (Species) that is Exceeded by TerrPlant EECs					
		Spray Drift Only		Runoff and Spray Drift (Dry Areas)		Runoff and Spray Drift (Semi-Aquatic Areas)	
		Ground spray	Aerial spray	Ground spray	Aerial spray	Ground spray	Aerial spray
Corn/Sorghum	2	7	38	26	48	76	80
Sugarcane	4	17	58	43	67	89	91
Turf-Bermudagrass	1	1	22	12	29	60	64
Turf- St Augustinegrass	4	17	58	43	67	89	91
Fallow- Prior to planting corn and sorghum	2.25	8	41	28	51	79	82
Roadside	1	1	22	12	29	60	64
CRP	2	7	38	26	48	76	80
Macadamia Nuts	4	17	58	43	67	89	91
Guava	4	17	58	43	67	89	91
Conifers	4	17	58	43	67	89	91
Corn/Sorghum Reduced Rate	0.5	<1	10	4	15	40	44
Corn/Sorghum Reduced Rate	0.25	<1	2	<1	5	23	27

Table 97. Estimated percent of terrestrial and semi-aquatic plant species expected to have a 25% or greater reduction in growth based on vegetative vigor stage exposures estimated with the seedling emergence SSD (Figure 21) and TerrPlant EECs in Table 94.

Crop	Single Max. Application Rate (lbs a.i/A)	Estimated Percent of Seedling Emergence SSD that is Exceeded by TerrPlant EECs (lbs a.i./A)					
		Spray Drift Only		Runoff and Spray Drift (Dry Areas)		Runoff and Spray Drift (Semi-Aquatic Areas)	
		Ground spray	Aerial spray	Ground spray	Aerial spray	Ground spray	Aerial spray
Corn/Sorghum	2	71	93	89	95	98	98
Sugarcane	4	84	96	94	97	99	99
Turf-Bermudagrass	1	51	87	80	91	96	97

Crop	Single Max. Application Rate (lbs a.i/A)	Estimated Percent of Seedling Emergence SSD that is Exceeded by TerrPlant EECs (lbs a.i./A)					
		Spray Drift Only		Runoff and Spray Drift (Dry Areas)		Runoff and Spray Drift (Semi-Aquatic Areas)	
		Ground spray	Aerial spray	Ground spray	Aerial spray	Ground spray	Aerial spray
Turf- St Augustinegrass	4	84	96	94	97	99	99
Fallow- Prior to planting corn and sorghum	2.25	74	94	90	95	98	98
Roadside	1	51	87	80	91	96	97
CRP	2	71	93	89	95	98	98
Macadamia Nuts	4	84	96	94	97	99	99
Guava	4	84	96	94	97	99	99
Conifers	4	84	96	94	97	99	99
Corn/Sorghum Reduced Rate	0.5	26	76	64	82	93	94
Corn/Sorghum Reduced Rate	0.25	7	58	41	68	88	90

14.2.2.2. *Spray Drift to Off-field Terrestrial Plants*

Because TerrPlant assumes a single fraction of the spray deposition, the model cannot describe the distance to the point when an LOC is not exceeded. Spray deposition curves calculated using AgDRIFT (version 2.1.1) (Tier I) were used to estimate the distance from the edge of the field to where effects to non-target organisms are no longer of concern following a single application of 0.25, 0.5, 2, or 4 lbs a.i./A by aerial or ground applications. The deposition curves were then compared against the most sensitive monocot and dicot IC_{25} values as well as the HC_5, HC_{10}, HC_{50}, HC_{90} and HC_{95} from the SSD.

The distance estimated for plants is based on one application and does not reflect possible cumulative exposure from multiple applications. It is recognized that a species could receive exposure from multiple applications, in which case, this distance may underestimate risk. The distance estimated for aquatic and terrestrial animals for multiple applications may occur when wind is blowing consistently in one direction for all applications or when wind is blowing in different directions during different applications as long as the organism is downwind in each case and regardless of whether it is mobile or stationary. This may result in an overestimation of exposure for aquatic and terrestrial organisms whose spray drift distances are based on exposure to the maximum number of applications and who are not downwind of every application. Exposure to multiple applications is more likely to occur when agricultural

fields/use areas are on multiple sides of an aquatic or terrestrial area of interest and when local wind direction is not variable.

The single maximum label rate for corn is 2 lbs a.i/A, which leads to deposition off the field through drift. The next two figures describe the risk associated with aerial and ground spray applications assuming different droplet sizes and boom heights. Drift to terrestrial plant species following an aerial application of 2 lbs a.i./A results greater than 95% of the seedling emergence SSD exceeded near field (within 100 feet) for all droplet sizes (**Figure 49**)**.** Coarser droplets may keep the risk reduced, however risks extend between beyond 1000 feet for the most sensitive tested monocot and dicot species, as well as for the HC_{10} and HC_5.

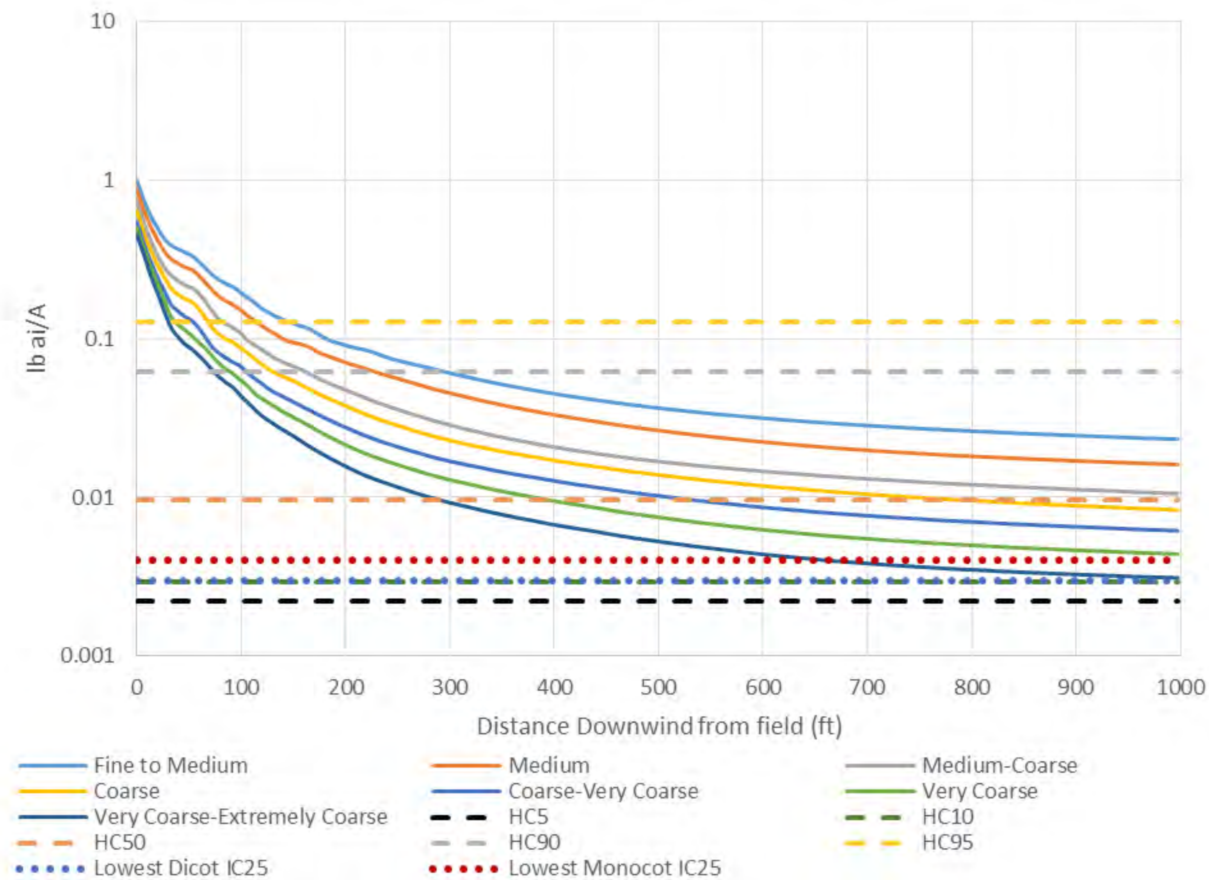


Figure 49. Spray drift deposition curves for various droplet spectra following a single aerial application of 2.0 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Ground application at 2.0 lbs a.i./A results in drift concerns for plant effects that span from 100 to 400 feet for 50% of tested terrestrial plants (**Figure 50**). Risks to more sensitive taxa extend between 300 and 600 feet for the coarsest droplet spectra with a low boom release height. All

other modeled scenarios extend this distance out to beyond 1000 feet for the very-fine to fine droplet spectra and a high-boom release height.

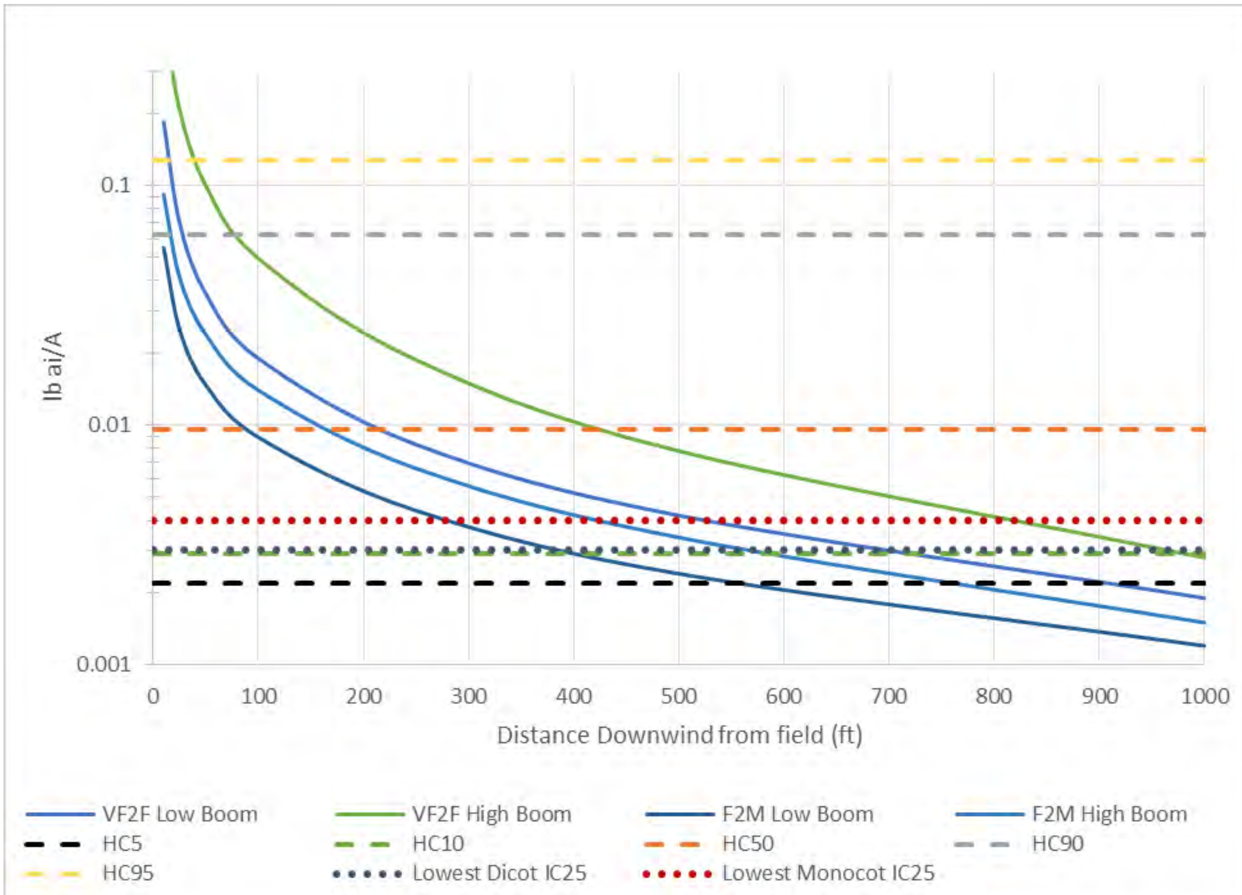


Figure 50. Spray drift deposition curves for various droplet spectra following a single ground application of 2.0 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Risk to terrestrial plants is expected from aerial applications of 4 lbs a.i./A drifting to off field locations (**Figure 51**). Even when applying with a very coarse-extremely coarse droplet spectrum, there are risks to the HC_{50} out to 100 feet, to ~200ft for the HC_{10}, 350 feet for the HC_{05}. With medium-coarse droplet size risk to the HC_{50} goes out to 200 feet, and extends beyond 1000 feet for the $HC_{10,}$ HC_5 and most sensitive taxa.

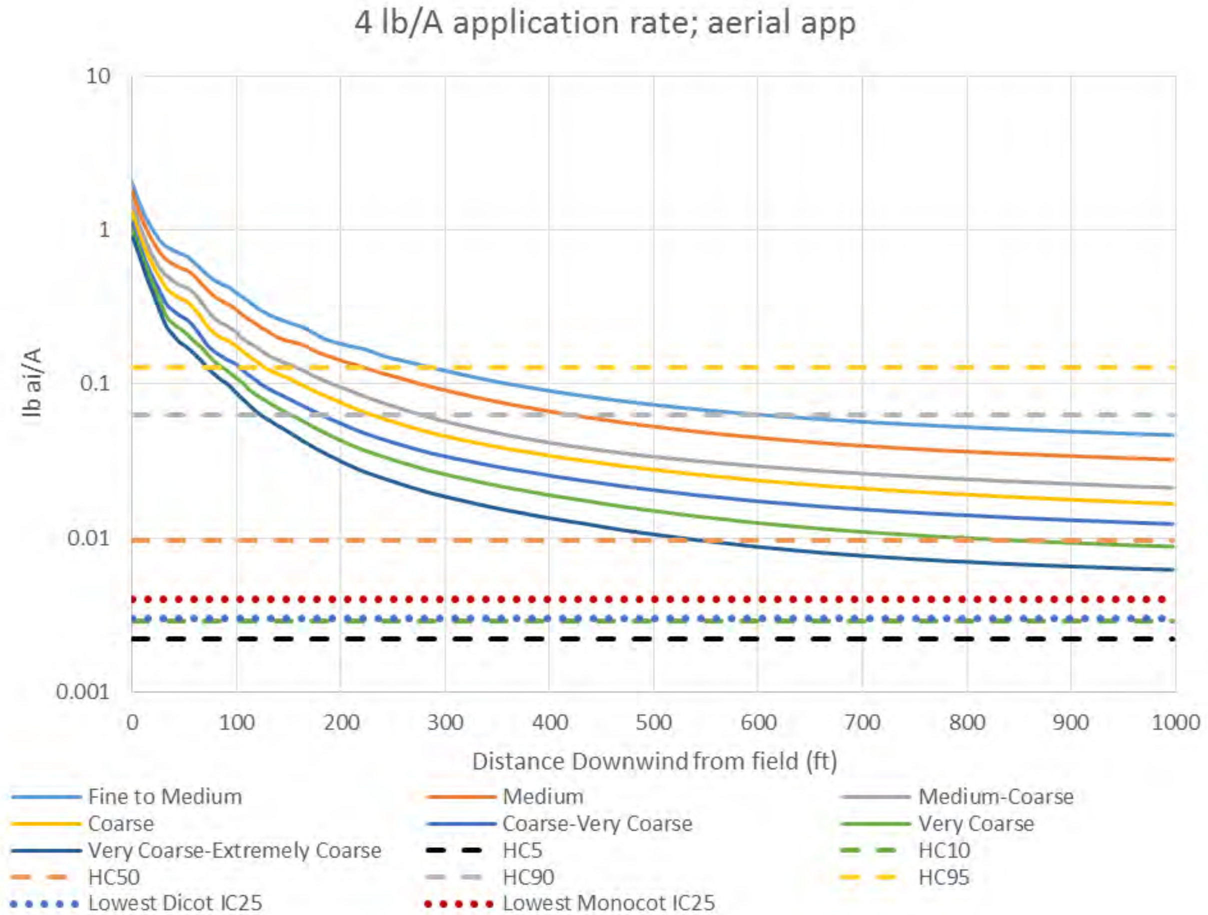


Figure 51. Spray drift deposition curves for various droplet spectra following a single aerial application of 4.0 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Ground application at 4.0 lbs a.i./A reduces the drift somewhat, however concerns for plant effects go out to 600 feet for the most sensitive monocot and extend beyond 1000 feet for all spectra for the $HC_{10,}$ HC_{04} and the most sensitive dicot (Figure 52). The very-fine to fine droplet size when released from a high-boom results in estimated deposition EECs exceeding 95%, 90% and 50% of the seedling emergence SSD at 75, 150 and 700 feet respectively.

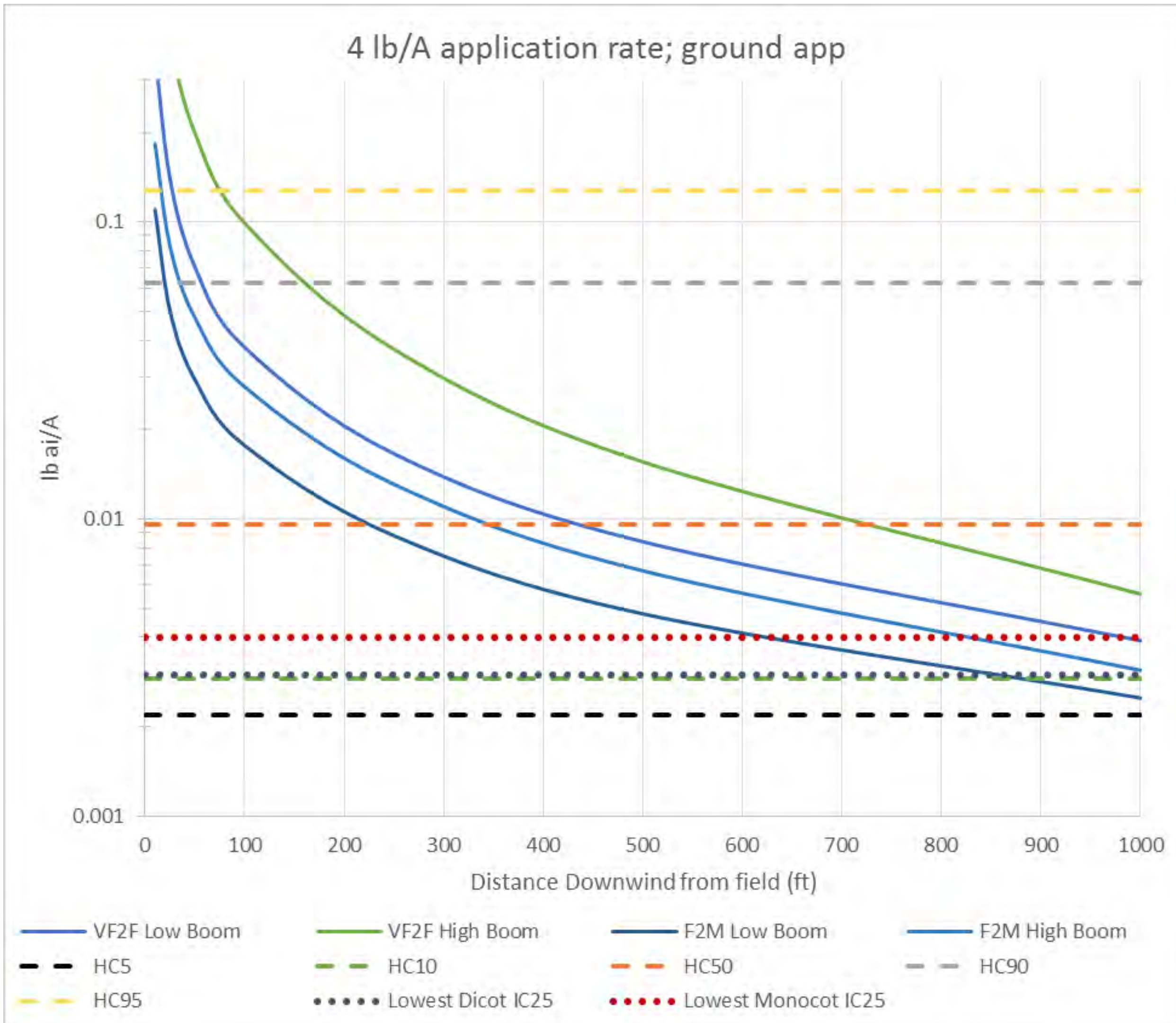


Figure 52. Spray drift deposition curves for various droplet spectra following a single ground application of 4.0 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Drift concerns to terrestrial plant species following an aerial application of 0.5 lbs a.i./A extend to 1000 and beyond 1000 feet for the HC_5, and Most sensitive IC_{25} for dicot species (Figure 53) The drift profile for all of the modeled droplet spectra suggest that there are risks to 50% of species out to 100 feet for the coarsest modeled droplet spectra to between 200 and 250 feet for medium-coarse droplet sizes.

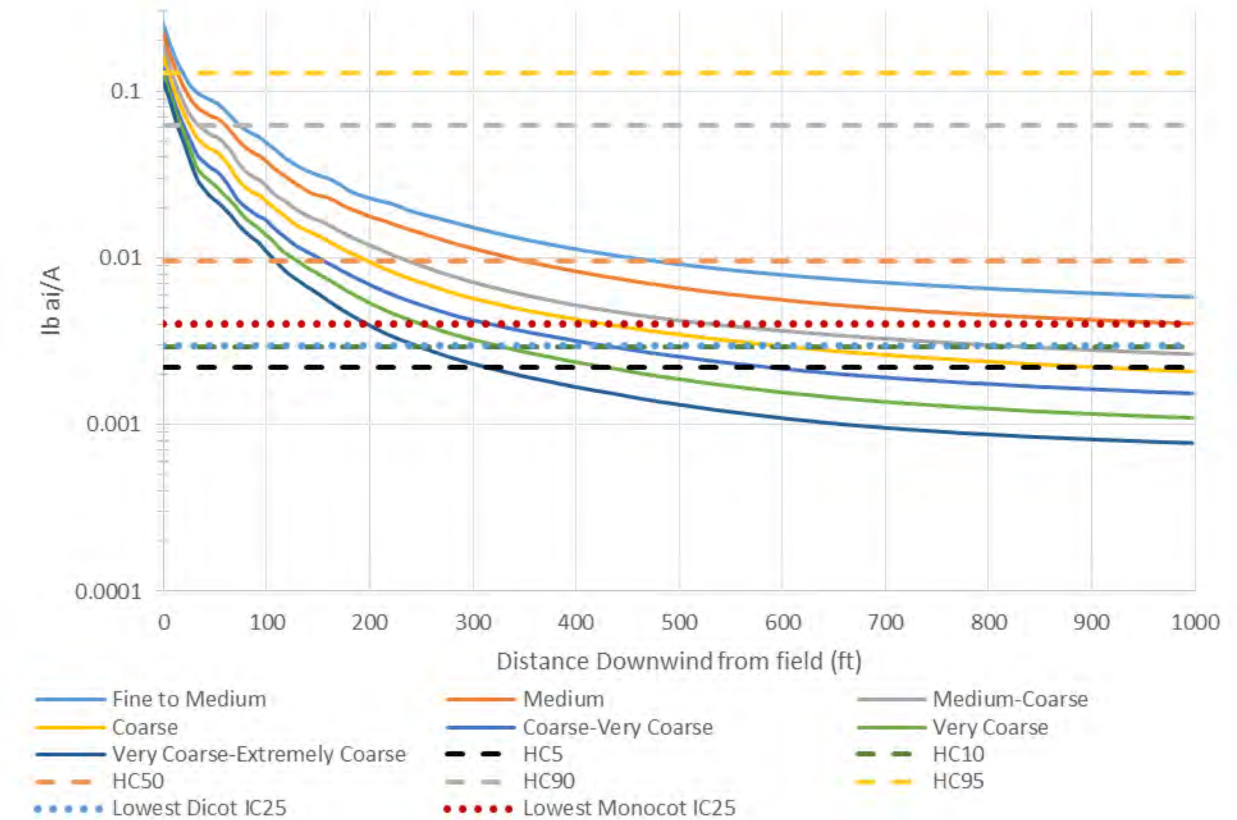


Figure 53. Spray drift deposition curves for various droplet spectra following a single aerial application of 0.5 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Drift concerns can be mitigated to within 200 feet of the edge of the field by requiring ground application of Fine to Medium Droplet sizes with a low boom height (**Figure 54**). Ground spray application using a high boom and very-fine to fine results in deposition estimates of risk concern between 100 and 400 feet for the most sensitive endpoints.

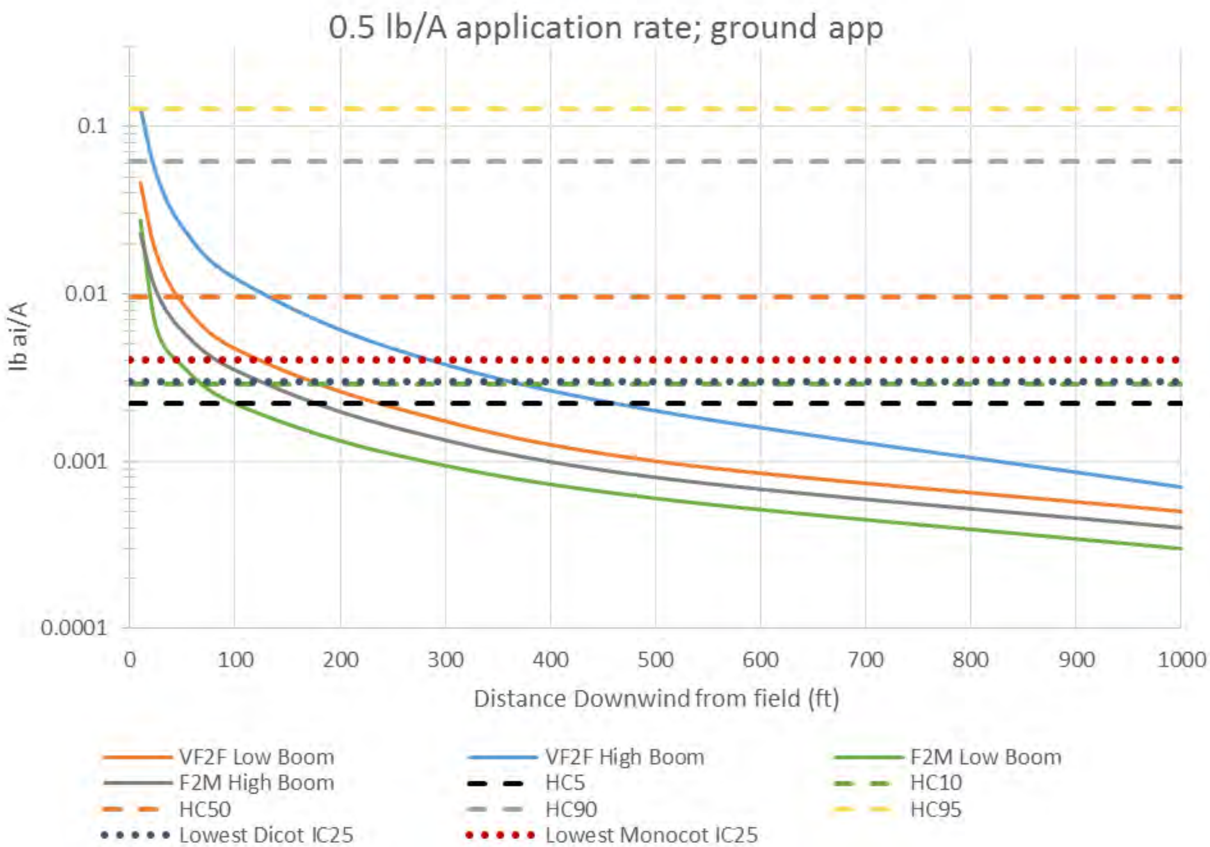


Figure 54. Spray drift deposition curves for various droplet spectra following a single ground application of 0.5 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

Depending on the droplet sizes typical for herbicide applications (medium-coarse and greater) drift concerns to terrestrial plant species following an aerial application of 0.25 lbs a.i./A extend to between 100 and 300 for the most sensitive monocot to between 200 and 500 feet for the HC_5 (**Figure 55**). Ground spray application at this rate is not expected to result in off-site spray drift deposition exceeding levels of concern based on the most sensitive species, or the HC_{10} of the seedling emergence SSD.

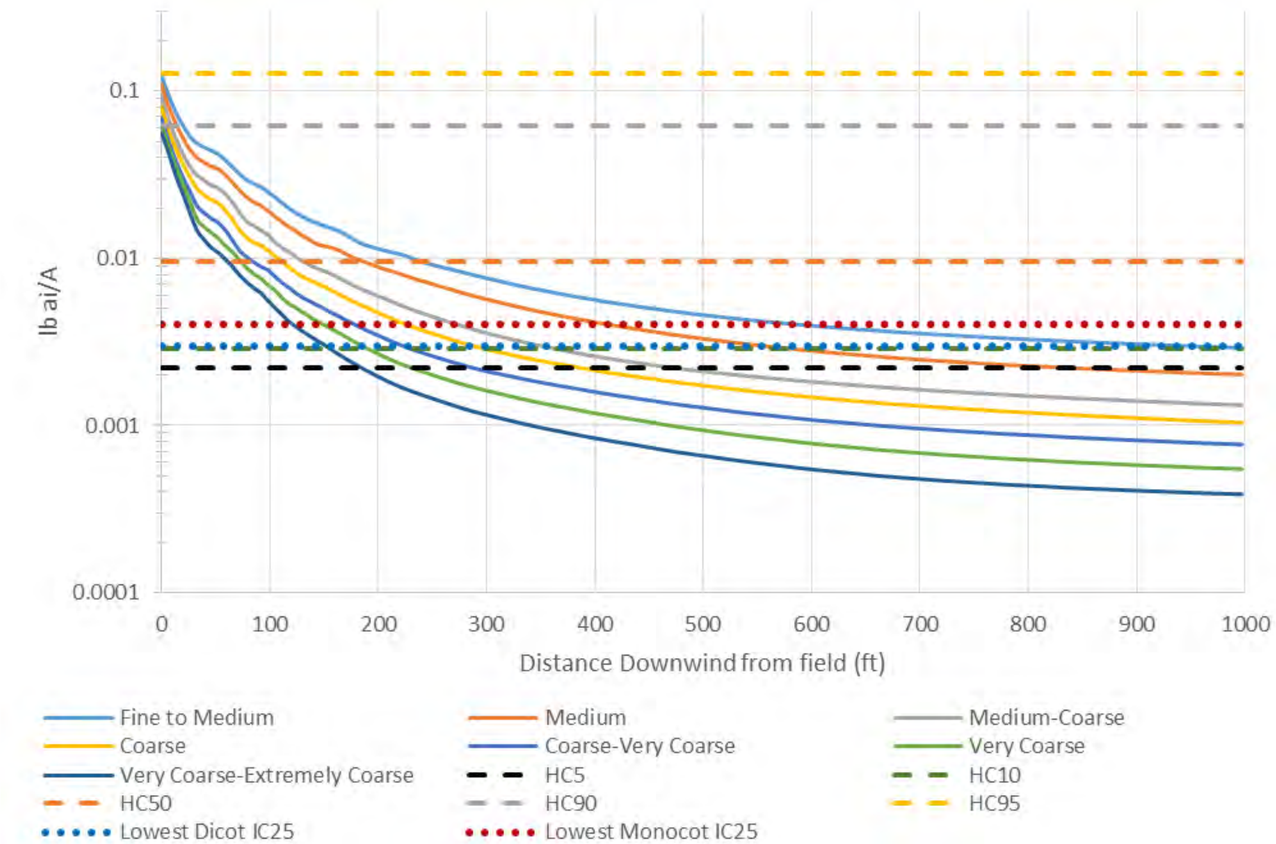


Figure 55. Spray drift deposition curves for various droplet spectra following a single aerial application of 0.25 lbs a.i/A. Horizontal dashed lines represent specific points along the seedling emergence SSD. Horizontal dotted lines represent the most sensitive tested seedling emergence IC_{25s}.

14.3. Terrestrial Plant Communities

Few studies are available that explore the impacts of atrazine treatment on terrestrial plant communities (e.g., Miller and Doxtader 1995). Given the available single species toxicity tests and the expected exposures due to runoff and spray drift, broad impacts to plant populations would be expected. The atrazine exposure impacts would be most significant initially on the seedling emergence phase of the plant life cycle, however non-lethal exposures impacting growth are expected annually and through multiple pulses, which may lead to reduced fecundity and furthermore may lead to impacts on community structure and composition.

15. AQUATIC RISK CHARACTERIZATION AND CONCLUSIONS

Because the risk from runoff from the site of application differs based on the use site (crop, geography, soil, and climate) application timing and method risks to aquatic taxa and communities are discussed below on a crop by crop basis. This discussion relies upon environmental exposure concentrations (EECs) based on the Surface Water Calculator Concentration (SWCC, see **Section 0** for details) using first the current labeled rates and application scenarios for each crop. Additionally a suite of alternative application scenarios (*e.g.,* reduced single/annual application rates and soil incorporation) were evaluated for the corn uses in order to evaluate the potential risks under such changes.

Following the crop by crop discussion of risk to each taxon, a geographic evaluation of the risk is discussed (**Section 17**) based on available monitoring data, bias factor adjusted monitoring data, and results from the WARP model. Further discussions focus on States within which the Agency has greatest confidence in the application of the developed bias factors, and WARP estimations, and where monitoring data indicates significant exceedances of the aquatic LOCs.

As discussed in **Section 7.2** the 1 in 10-year peak EECs from the SWCC are within the ranges of measured monitoring data collected across a wide range of sites. The 21-day and 60-day EECs are generally greater in the model than in the monitoring data which are more frequently representing flowing waters and thus would have higher turnover than those sites modeled in the SWCC. Therefore, comparisons to both the SWCC results and monitoring data reflect the potential atrazine exposure and risk to aquatic organisms and communities. The EECs generated with the WARP model are also consistent with the SWCC and available monitoring data. In **Section 17**, the WARP results are used to assess the probability of exceeding the aquatic LOCs and portrays those risks across geographic regions where the risk is highest.

15.1. Corn Uses: Aquatic Risk Characterization and Conclusions

A summary of the risks for aquatic animals, plants and the aquatic plant community are provided in **Table 98** for Section 3 labels, in **Table 99** for Section 24 labels, and **Table** 100 provides risks based on EECs reflecting potential label refinements such as reduced rates of application or soil incorporation. A discussion of risk from each of these scenarios is provided below the summary tables.

Table 98: Summary of SWCC Estimated Environmental Concentrations (µg/L) for Atrazine from Corn Uses on Section 3 Labels. Maximum, minimum, and median estimates of water concentrations, RQs, and the number of modeling scenarios resulting in level of concern exceedances. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances. There were a total of 17 scenarios run for SWCC corn modeling. *RQs for listed species of aquatic plants were not evaluated because exceedances of the non-listed LOCs indicate that risks to listed species are expected.

Estimated Environmental Concentrations (µg/L) for Atrazine from Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Corn Aerial 2/0.5 lbs. a.i./A 14-day interval	max	202	196	190	0.04	**38.0**	0.10	**38.0**	0.28	3.27	**4.21**	**51.6**	**202.0**	**43.9**	**Exceeded**
	min	35.3	34.4	33.7	0.01	**6.7**	0.02	**6.7**	0.05	0.57	**0.74**	**9.1**	**35.3**	**7.7**	**Exceeded**
	median	58.9	58.1	57.5	0.01	**11.5**	0.03	**11.5**	0.08	0.97	**1.23**	**15.3**	**58.9**	**12.8**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	9/17	17/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	4/17	17/17	17/17	9/17	17/17	17/17	*	*	17/17
Corn Ground 2/0.5 lbs. a.i./A 14-day interval	max	204	196	190	0.04	**38.0**	0.10	**38.0**	0.28	3.27	**4.25**	**51.6**	**204.0**	**44.3**	**Exceeded**
	min	25.2	24.8	23.8	0.00	**4.8**	0.01	**4.8**	0.04	0.41	**0.53**	**6.5**	**25.2**	**5.5**	**Exceeded**
	median	47	45.8	43.7	0.01	**8.7**	0.02	**8.7**	0.07	0.76	**0.98**	**12.1**	**47.0**	**10.2**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	8/17	17/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	4/17	17/17	15/17	8/17	17/17	17/17	*	*	17/17
Corn Fallow Aerial 1/0.5/1 lbs. a.i./A 14-day interval	max	117	118	111	0.02	**22.2**	0.06	**22.2**	0.16	1.97	**2.44**	**31.1**	**117.0**	**25.4**	**Exceeded**
	min	28.9	28.3	27.7	0.01	**5.5**	0.01	**5.5**	0.04	0.47	**0.60**	**7.4**	**28.9**	**6.3**	**Exceeded**
	median	61.5	60.6	59.8	0.01	**12.0**	0.03	**12.0**	0.09	1.01	**1.28**	**15.9**	**61.5**	**13.4**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	10/17	17/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	2/17	17/17	16/17	10/17	17/17	17/17	*	*	17/17

Estimated Environmental Concentrations (µg/L) for Atrazine from Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Corn Fallow Ground 1/0.5/1 lbs. a.i./A 14-day interval	max	117	117	111	0.02	**22.2**	0.06	**22.2**	0.16	1.95	**2.44**	**30.8**	**117.0**	**25.4**	**Exceeded**
	min	24.1	23.6	22.9	0.00	**4.6**	0.01	**4.6**	0.03	0.39	**0.50**	**6.2**	**24.1**	**5.2**	**Exceeded**
	median	54.7	54.2	52.2	0.01	**10.4**	0.03	**10.4**	0.08	0.90	**1.14**	**14.3**	**54.7**	**11.9**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	4/17	7/17	17/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	2/17	17/17	15/17	7/17	17/17	17/17	*	*	17/17
Corn Fallow Ground 1 lb. a.i./A 14-day interval	max	48.3	48.3	48.9	0.01	**9.8**	0.02	**9.8**	0.07	0.81	**1.01**	**12.7**	**48.3**	**10.5**	**Exceeded**
	min	13.6	13.8	13.1	0.00	**2.6**	0.01	**2.6**	0.02	0.23	0.28	**3.6**	**13.6**	**3.0**	**Exceeded**
	median	33.6	32.8	32.7	0.01	**6.5**	0.02	**6.5**	0.05	0.55	**0.70**	**8.6**	**33.6**	**7.3**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	0/17	12/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	0/17	17/17	10/17	0/17	17/17	17/17	*	*	17/17
Corn, Erodible Soils Aerial 1.6 lbs. a.i./A	max	153	145	134	0.03	**26.8**	0.08	**26.8**	0.21	2.42	**3.19**	**38.2**	**153.0**	**33.3**	**Exceeded**
	min	24.8	24.2	23.1	0.00	**4.6**	0.01	**4.6**	0.03	0.40	**0.52**	**6.4**	**24.8**	**5.4**	**Exceeded**
	median	42	41.1	39.2	0.01	**7.8**	0.02	**7.8**	0.06	0.69	**0.88**	**10.8**	**42.0**	**9.1**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	7/17	17/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	1/17	17/17	14/17	7/17	17/17	17/17	*	*	17/17
Corn, Erodible Soils Ground 1.6 lbs. a.i./A	max	153	146	135	0.03	**27.0**	0.08	**27.0**	0.21	**2.43**	**3.19**	**38.4**	**153.0**	**33.3**	**Exceeded**
	min	17.7	17.2	16.8	0.00	**3.4**	0.01	**3.4**	0.02	0.29	0.37	**4.5**	**17.7**	**3.8**	**Exceeded**
	median	34.9	34.1	32.5	0.01	**6.5**	0.02	**6.5**	0.05	0.57	**0.73**	**9.0**	**34.9**	**7.6**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	4/17	15/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	1/17	17/17	10/17	4/17	17/17	17/17	*	*	17/17

Table 99. Summary of SWCC Estimated Environmental Concentrations (µg/L) for Atrazine from Corn Uses on Section 24c Labels. Maximum, minimum, and median estimates of water concentrations, RQs are provided. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances. There were a total of 2 scenarios run for SWCC corn modeling. *RQs for listed species of aquatic plants were not evaluated because exceedances of the non-listed LOCs indicate that risks to listed species are expected.

Estimated Environmental Concentrations (µg/L) for Atrazine from Corn Uses on Section 24c Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Kansas Corn, Fallow Aerial 2 lbs. a.i./A	KSCorn	86.7	85.2	82.3	0.02	**16.5**	0.04	**16.5**	0.12	**1.42**	**1.81**	**22.4**	**86.7**	**18.8**	**Exceeded**
Kansas Corn, Fallow Ground 2 lbs. a.i./A	KSCorn	79.7	78.3	75.3	0.02	**15.1**	0.04	**15.1**	0.11	**1.31**	**1.66**	**20.6**	**79.7**	**17.3**	**Exceeded**

Table 100. Summary of SWCC Estimated Environmental Concentrations (µg/L) for Atrazine from Potential Refinement to Corn Uses on Section 3 Labels. Maximum, minimum, and median estimates of water concentrations, RQs, and the number of modeling scenarios resulting in level of concern exceedances. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances. There were a total of 17 scenarios run for SWCC corn modeling. *RQs for listed species of aquatic plants were not evaluated because exceedances of the non-listed LOCs indicate that risks to listed species are expected.

Estimated Environmental Concentrations (µg/L) for Atrazine from Potential Refinement to Corn Section 3 Labeled Uses					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Corn, Reduced Rate Aerial 0.5 lbs. a.i./A	Max	47.7	45.4	42	0.01	**8.4**	0.02	**8.4**	0.07	0.76	**0.99**	**11.9**	**47.7**	**10.4**	**Exceeded**
	Min	7.75	7.55	7.21	0.00	**1.4**	0.00	**1.4**	0.01	0.13	0.16	**2.0**	**7.8**	**1.7**	**Exceeded**
	Median	13.1	12.8	12.2	0.00	**2.4**	0.01	**2.4**	0.02	0.21	0.27	**3.4**	**13.1**	**2.8**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	0/17	4/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	0/17	17/17	1/17	0/17	17/17	17/17	*	*	17/17
Corn, Reduced Rate Ground 0.5 lbs. a.i./A	Max	47.8	45.5	42.2	0.01	**8.4**	0.02	**8.4**	0.07	0.76	**1.00**	**12.0**	**47.8**	**10.4**	**Exceeded**
	Min	5.52	5.38	5.26	0.00	**1.1**	0.00	**1.1**	0.01	0.09	0.12	**1.4**	**5.5**	**1.2**	**Exceeded**
	Median	10.9	10.7	10.2	0.00	**2.0**	0.01	**2.0**	0.02	0.18	0.23	**2.8**	**10.9**	**2.4**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	0/17	4/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	0/17	17/17	1/17	0/17	17/17	17/17	*	*	17/17
Corn, Reduced Rate Ground 0.25 lbs. a.i./A	max	23.9	22.8	21.1	0.00	**4.2**	0.01	**4.2**	0.03	0.4	**0.50**	**6.0**	**23.9**	**5.2**	**Exceeded**
	min	2.76	2.69	2.63	0.00	0.5	0.00	0.5	0.00	0.0	0.06	0.7	**2.8**	0.6	
	median	5.45	5.33	5.08	0.00	**1.0**	0.00	**1.0**	0.01	0.1	**0.11**	**1.4**	**5.5**	**1.2**	**Exceeded**

Estimated Environmental Concentrations (µg/L) for Atrazine from Potential Refinement to Corn Section 3 Labeled Uses					RQs										
Crop (Application Rate)	**SWCC Scenario**	**Peak**	**21-day**	**60-day**	**Acute FW Fish**	**Chronic FW Fish**	**Acute EM Fish**	**Chronic EM Fish**	**Acute FW Inverts**	**Chronic FW Inverts**	**Acute EM Inverts**	**Chronic EM Inverts**	**Non-Vascular Plants**	**Vascular Plants**	**CELOC**
	Scenarios Exceeding Non-listed LOC				0/17	10/17	0/17	10/17	0/17	0/17	1/17	15/17	17/17	13/17	15/17
	Scenarios Exceeding Listed LOC				0/17	10/17	0/17	10/17	0/17	0/17	17/17	15/17	*	*	15/17
Corn, 2 cm incorporation 0.5 lbs. a.i./A	max	54.7	52.1	48.2	0.01	**9.6**	0.03	**9.6**	0.08	0.87	**1.14**	**13.7**	**54.7**	**11.9**	**Exceeded**
	min	6.14	5.99	5.94	0.00	**1.2**	0.00	**1.2**	0.01	0.10	0.13	**1.6**	**6.1**	**1.3**	**Exceeded**
	median	12.3	12.1	11.5	0.00	**2.3**	0.01	**2.3**	0.02	0.20	0.26	**3.2**	**12.3**	**2.7**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	17/17	0/17	17/17	0/17	0/17	4/17	17/17	17/17	17/17	17/17
	Scenarios Exceeding Listed LOC				0/17	17/17	0/17	17/17	1/17	0/17	17/17	17/17	*	*	17/17
Corn, 4 cm incorporation 0.5 lbs. a.i./A	max	27.7	26.4	24.4	0.01	**4.9**	0.01	**4.9**	0.04	0.44	**0.58**	**6.9**	**27.7**	**6.0**	**Exceeded**
	min	3.51	3.42	3.26	0.00	**0.7**	0.00	**0.7**	0.00	0.06	0.07	0.9	**3.5**	**0.8**	
	median	6.64	6.49	6.19	0.00	**1.2**	0.00	**1.2**	0.01	0.11	0.14	**1.7**	**6.6**	**1.4**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	14/17	0/17	14/17	0/17	0/17	1/17	16/17	17/17	15/17	16/17
	Scenarios Exceeding Listed LOC				0/17	14/17	0/17	14/17	0/17	0/17	17/17	16/17	*	*	16/17
Corn, 6 cm incorporation 0.5 lbs. a.i./A	max	18.7	17.8	16.4	0.00	**3.3**	0.01	**3.3**	0.03	0.30	0.39	**4.7**	**18.7**	**4.1**	**Exceeded**
	min	2.63	2.56	2.45	0.00	0.5	0.00	0.5	0.00	0.04	0.05	**0.7**	**2.6**	**0.6**	
	median	4.74	4.64	4.42	0.00	0.9	0.00	0.9	0.01	0.08	0.10	**1.2**	**4.7**	**1.0**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	8/17	0/17	8/17	0/17	0/17	0/17	14/17	17/17	13/17	14/17
	Scenarios Exceeding Listed LOC				0/17	8/17	0/17	8/17	0/17	0/17	17/17	14/17	*	*	14/17

Estimated Environmental Concentrations (µg/L) for Atrazine from Potential Refinement to Corn Section 3 Labeled Uses					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Corn, 8 cm incorporation 0.5 lbs. a.i./A	max	14.2	13.5	12.5	0.00	**2.5**	0.01	**2.5**	0.02	0.23	0.00	**3.6**	**14.2**	**3.1**	**Exceeded**
	min	2.19	2.14	2.05	0.00	0.4	0.00	0.4	0.00	0.04	0.00	**0.6**	**2.2**	**0.5**	
	median	3.8	3.71	3.54	0.00	**0.7**	0.00	**0.7**	0.01	0.06	0.00	**1.0**	**3.8**	**0.8**	**Exceeded**
	Scenarios Exceeding Non-listed LOC				0/17	6/17	0/17	6/17	0/17	0/17	0/17	10/17	17/17	8/17	11/17
	Scenarios Exceeding Listed LOC				0/17	6/17	0/17	6/17	0/17	0/17	17/17	10/17	*	*	11/17

Corn, 15 cm incorporation 0.5 lbs. a.i./A	max	7.84	7.47	6.91	0.00	**1.4**	0.00	**1.4**	0.01	0.12	**0.16**	**2.0**	**7.8**	**1.7**	**Exceeded**
	min	1.58	1.54	1.48	0.00	0.3	0.00	0.3	0.00	0.03	0.03	**0.4**	**1.6**	**0.3**	
	median	2.5	2.47	2.41	0.00	**0.5**	0.00	**0.5**	0.00	0.04	**0.05**	**0.7**	**2.5**	**0.5**	
	Scenarios Exceeding Non-listed LOC				0/17	1/17	0/17	1/17	0/17	0/17	1/17	4/17	17/17	1/17	4/17
	Scenarios Exceeding Listed LOC				0/17	1/17	0/17	1/17	0/17	0/17	14/17	4/17	*	*	4/17

15.1.1. Risks to Fish

On an acute exposure basis, there are no risk concerns to non-listed or listed freshwater fish (**Table 98 and Table 99**). For estuarine/marine fish, acute exposure following aerial or ground application of 2 lbs a.i./A followed by 0.5 lbs a.i./A results in risk to non-listed species for the Florida sweetcorn scenario (RQ = 0.1). The listed estuarine/marine fish LOC is exceeded several times following aerial or ground multiple applications of 2/0.5 lbs a.i/A, 1/0.5/1 lbs a.i./A or a single application of 1.6 lbs a.i./A.

On a chronic exposure basis, freshwater and estuarine marine species RQs exceed levels of concern for all Section 3 and Section 24c labeled uses and application methods (**Table 98** and **Table 99)**, with RQs ranging from 2.6 to 38. These LOCs are exceeded for 100% of the modeled scenarios. These taxa share the same endpoint; statistically and biologically significant reductions in fecundity based on reductions of cumulative egg production (**Section 11.2.1**).

Figure 56 displays reported effects data from the ECOTOX database as well as the reported range of surface water 60-day average concentrations from monitoring data and the predicted EECs from the SWCC. Chronic effects displayed on the graph include effects on growth and reproduction as well as endpoints in the general categories of behavioral, physiological, cellular and biochemical effects. The figure illustrates the considerable overlap of these effects endpoints with EECs generated from the various SWCC model runs as well as overlap with the measured concentrations in the available monitoring data. This overlap of exposure concentrations and multiple effects endpoints further supports the potential for chronic risks to fish following currently labeled uses of atrazine.

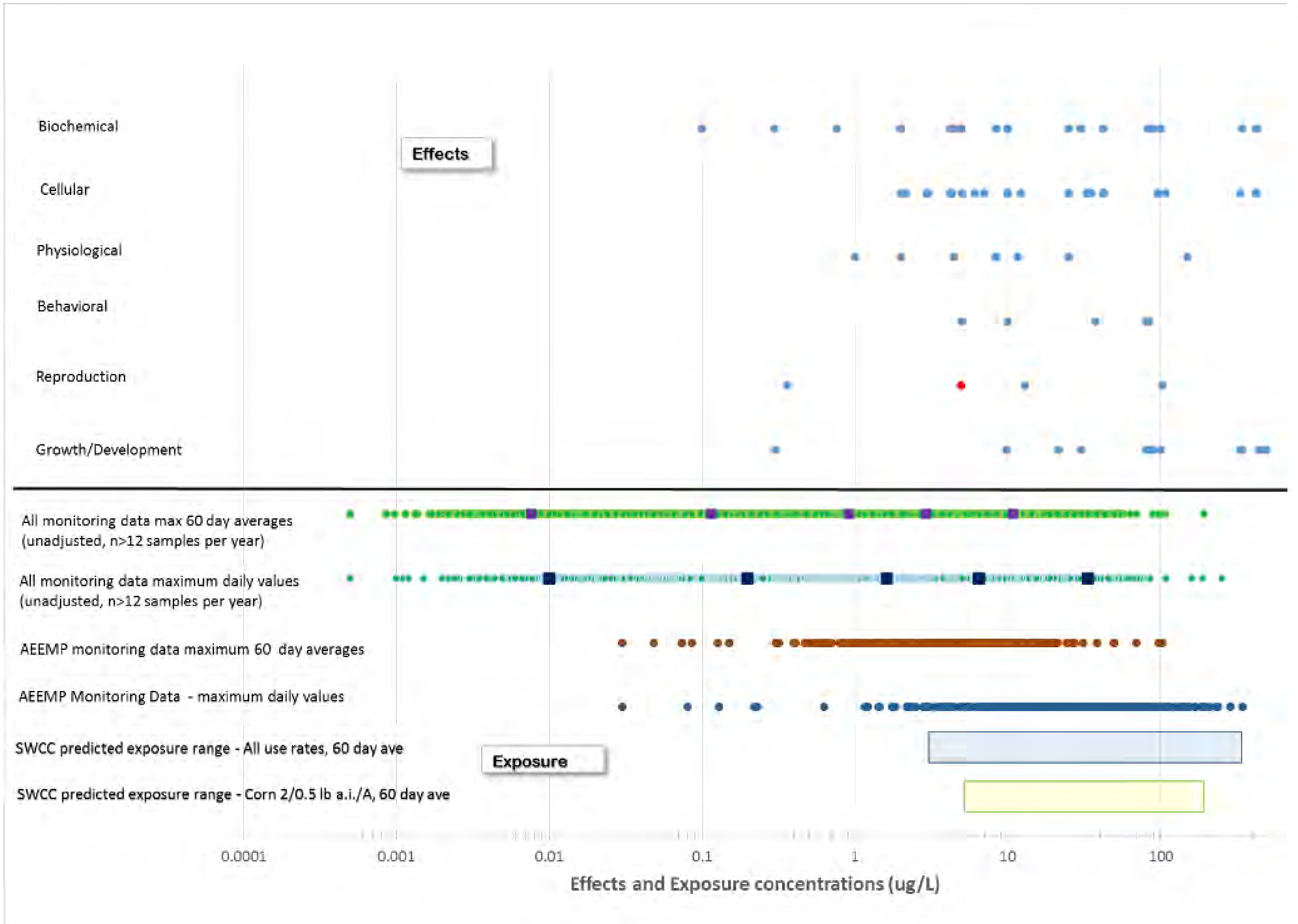


Figure 56. Reported sublethal fish effects endpoints from ECOTOX database and expected exposure concentrations. Chronic effect endpoint used for risk quotient derivation is denoted in red. NOTE logarithmic scale.

The evaluation of alternative application scenarios does not significantly change the risk picture for chronic risk to freshwater and estuarine/marine fish (**Table 100**). While reduction of the application rate to 0.5 lbs a.i./A results in LOC exceedances for chronic exposures to fish (RQs range from 84 to 11), the rate reduction results in a 78% and 70% reduction in RQs compared to the 2/0.5 lbs a.i/A and 1.6 lbs a.i./A scenarios (**Table 98**). Further rate reduction to 0.25 lbs a.i/A reduces the chronic RQs to between 42 and 5.3, however the number of scenarios exceeding LOCs remains at 100%. Additional modeling evaluating soil incorporation provided little reduction in the RQs from the 0.5 lbs a.i./A application rate (**Table 100**). The SWCC accounts for incorporation by assuming a uniform distribution of the chemical across the depth of incorporation, and assumes that only the material in the top 2 cm of the soil profile is available for runoff.

15.1.2. Risks to Aquatic Invertebrates

The SWCC results for Section 3 and Section 24c labeled rates of application result in exceedances of the acute listed freshwater invertebrate LOC for a majority of modeled scenarios (**Table 98** and **Table 99**). Lower application rates result in fewer scenarios exceeding the acute LOC for listed species however a majority of the scenarios modeling currently labeled rates and applications exceed (RQs range from 0.28 to 0.02). The EECs resulting from all modeled rates and application methods, except the ground application 1 lb a.i./A to fallow corn, result in several scenarios for each with chronic freshwater non-listed and listed LOC exceedances (RQs range from 3.3 to 0.5).

Estuarine/marine invertebrates are more sensitive to atrazine exposure than freshwater species on an acute and chronic basis. The SWCC modeling suggests that non-listed and listed species LOCs are exceeded for all Section 3 and Section 24c labeled rates and that most of the scenarios tested for each application rate/method result in acute non-listed and listed species LOC exceedances (RQs range from 4.3 to 0.3). On a chronic exposure basis LOCs are exceeded for 100% of scenarios for each of the modeled application rates (RQs range from 52 to 6) for current labels.

The evaluation of alternative application scenarios significantly changes the risk picture for acute and chronic risk to freshwater invertebrates (**Table 100**). A single application of 0.5 lbs a.i./A to corn results in significantly lower RQs for freshwater invertebrates on an acute and chronic exposure basis. However, even at this reduced rate there remain significant exceedances of the non-listed and listed acute and chronic LOCs for estuarine marine invertebrates. Soil incorporation appears to reduce the risks to estuarine marine invertebrates, however chronic risks to non-listed species are predicted even when applying 0.5 lbs a.i./A and incorporating to 15 cm.

15.1.3. Risk to Aquatic-phase amphibians: Weight of Evidence Analysis

Using the methodology described in **Section 6.7.2**, the following section presents the weight of evidence analysis for aquatic phase amphibians. Data associated with each line of evidence is presented in the individual sections as well as the analysis summary table (**Table 101**). A list of the studies used and review material on these studies is contained in **Appendix B**.

As stated previously, approximately 55 studies were incorporated into the weight of evidence analysis. All studies classified as either quantitative or qualitative were included in the analysis. The study classifications are discussed in **Section 11.2.3**. For the 2012 SAP literature review, when studies were categorized as qualitative, they were also given a high, medium or low rank. New studies reviewed since 2012 were only rated as invalid or qualitative, as all studies ranked as qualitative were considered acceptable for use in risk assessment and were included in this analysis. Cosm studies reviewed in the past were only rated as qualitative without high, medium or low rank.

The methodology used in the weight of evidence analysis did not specifically focus on the individual study analysis and parameters. Instead, the focus was to evaluate the data in totality across all studies and identify the overarching trends and conclusions for each line of evidence. This is in line with the findings of the 2012 SAP, which specifically advised the incorporation of all study findings in the risk assessment and weight of evidence approach. However, as previous reviews had made efforts to subcategorize classifications (qualitatively with a high, medium or low rank), these classifications were taken into consideration in evaluating the robustness of the data for each line of evidence. Some of the general criteria that were used for study classification included measurement of test concentrations in solution, sufficient replication, control contamination, use of a negative and solvent control, proper use of solvents and sufficient data reporting including water quality parameters and statistical analysis methods. More specific information of evaluation criteria and methodology used in the 2012 study classifications are outline in **Appendix A (Problem formulation).**

15.1.3.1. *Exposure Data Evaluation: All lines of evidence*

In order to establish risk estimates, concentrations at which effects are reported are compared to the relevant environmental exposure concentrations. For this analysis, exposure concentrations based on modeling output from the SWCC and those reported in the extensive surface water monitoring program for atrazine were used. A detailed discussion of the fate analysis is contained in **Sections 7.3** and **7.4.**

All modeled use scenarios are representative of agricultural and non-agricultural uses which could be in close proximity to aquatic-phase amphibian habitats. The simulated water bodies represent first-order streams and small static water bodies, which are suitable and typical habitats for amphibian species. Water bodies from which monitoring data were obtained are also suitable habitats for aquatic-phase amphibians, representing both static and flowing water bodies.

Fate data used in conducting surface water monitoring analyses were from submitted registrant studies and were all reviewed and deemed acceptable for use in the risk assessment according to EPA guidelines. Input parameters used for model simulations were reviewed by senior fate scientists within EPA for validity and accuracy in depicting the use scenarios that were modeled.

15.1.3.2. ***Effects Data Evaluation***

15.1.3.2.a. ***Mortality Line of Evidence***

The line of evidence for mortality draws on the available data for reported LD_{50}s, LC_{50}s, NOAECs and LOAECs for mortality and survival for a range of durations, species and life stages. **Figure 57** contains the summary data for mortality to amphibians with endpoint concentrations less than 500 µg/L. Studies in blue denoted with an "NE" signify no effects were seen in the study (*i.e.* an unbounded NOAEC). The red dots indicate results where an effect was reported and are denoted with a line ranging between the LOAEC and NOAEC when both are available. The data consisted of 54 endpoints across 35 studies and 16 species. **Figure 58** depicts ranges of concentrations across available LOAECs for 11 species, which included salamanders, toads and frogs. LOAECs ranged from 2 to 400 µg/L with most of the overlap in reported effects ranges occurring between 20 and 100 µg/L. Other mortality data were available at higher concentrations, but the data displayed herein was limited to those data points less than 500 ug/L in order to remain within environmentally relevant concentrations and because of the large spread in mortality effects concentrations (maximum reported value was 232,000 ug/L). Although LC_{50} values are discussed, the focus of this analysis was on chronic effects (predominantly LOAECs for different mortality endpoints) as this is where survival effects were reported within an environmentally relevant range. For individual species, the largest range within the represented species was for *Ambystoma barbouri*, the streamside salamander, as shown in **Figure 58**. The breakdown of study classifications for mortality effects were: 1 study rated quantitative, 2 studies rated qualitative high, 4 studies rated qualitative medium, 18 studies rated qualitative low and 10 studies rated qualitative. Study classifications were distributed fairly evenly across those studies with no effects reported and those with effects reported (*e.g.,* 8 studies where effects were reported were classified qualitative low and 12 studies where no effects were reported were classified as qualitative low).

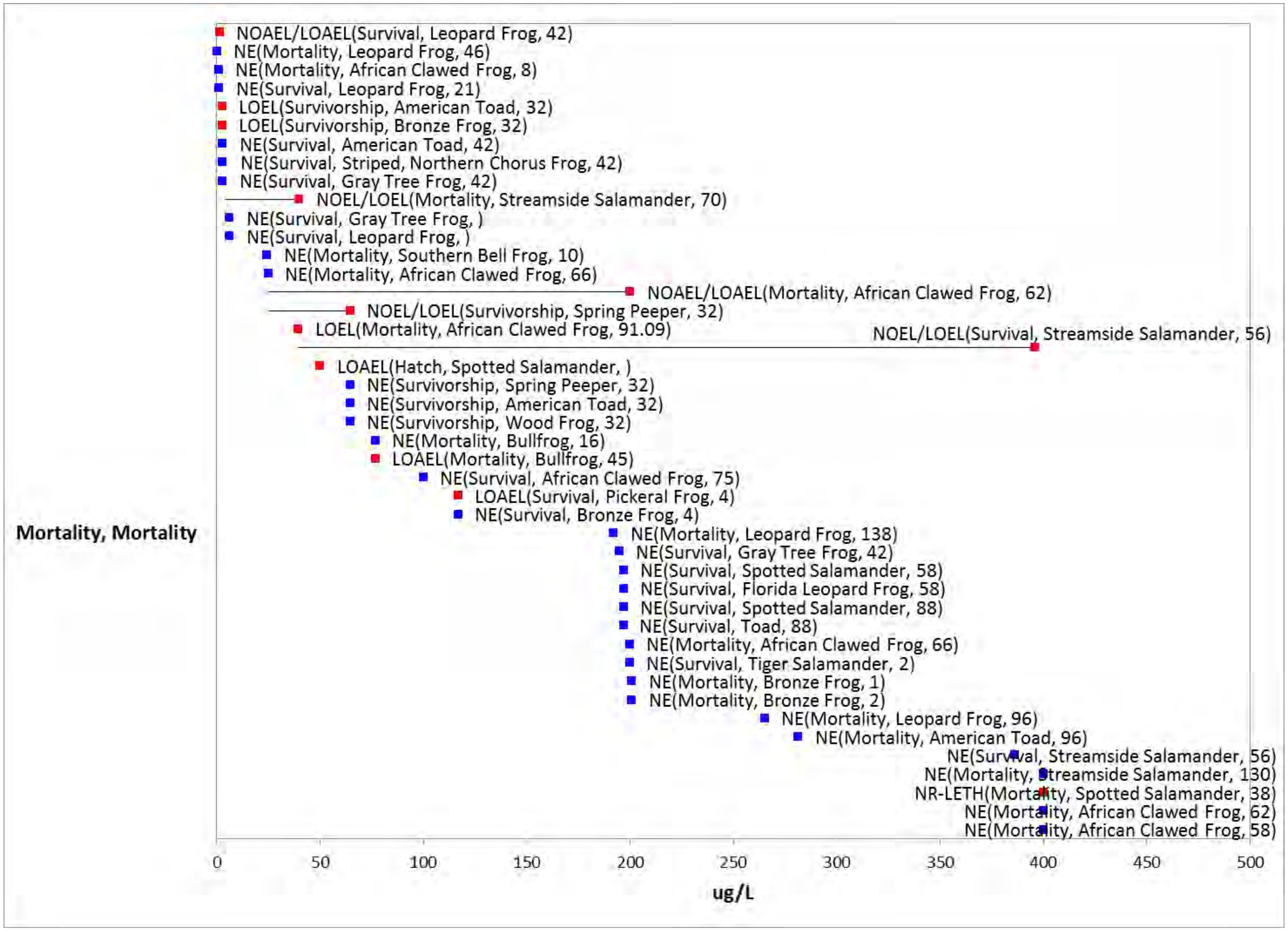


Figure 57. Reported amphibian mortality endpoints < 500 µg/L; [Labels key: Endpoint (Effect, Species, duration in days)]; Red dots denote a measured effect where blue dots represent no effect (NE) seen in study.

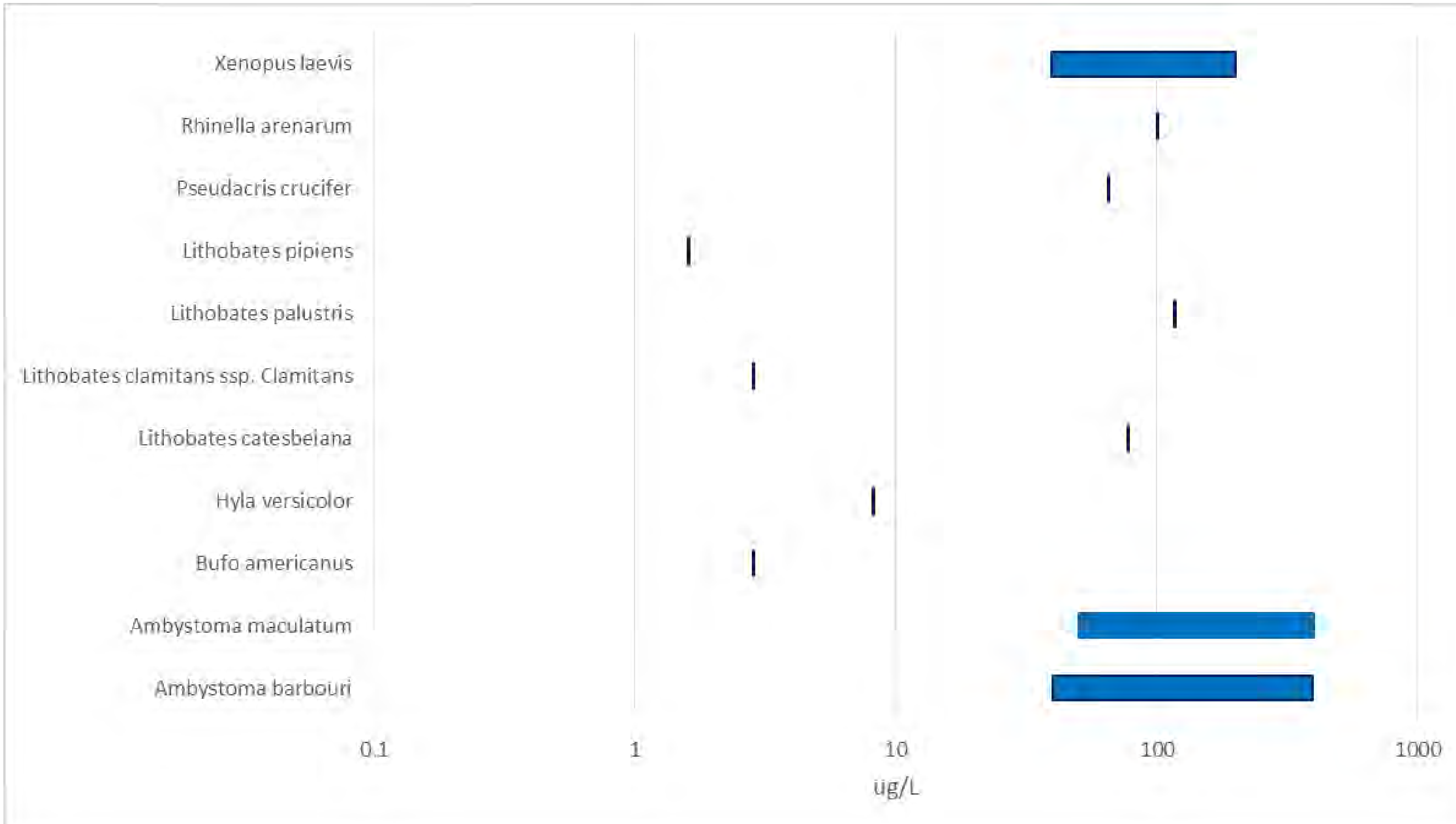


Figure 58. Range of reported mortality effects endpoints by species at concentrations < 500 ug/L (bar represents range of reported concentrations, thin lines indicate only one concentration reported).

15.1.3.2.b. ***Development Line of Evidence***

The line of evidence for developmental effects to amphibians draws largely from endpoints reported for metamorphosis and change in time to reach a stage as compared to controls. Reported effects included 47 endpoints across 23 studies and 14 species for concentrations less than 500 µg/L (**Figure 59**). **Figure 60** depicts ranges of concentrations across available LOAECs for 9 species, which included salamanders, toads and frogs. LOAECs ranged from 0.01 to 10,000 µg/L with most of the overlap in reported effects ranges occurring between 10 and 200 µg/L. The largest reported range within a species was for *Lithobates pipiens.* All studies used in the assessment were reviewed and the breakdown of study classifications were: 1 study rated quantitative, 2 studies rated qualitative high, 2 studies rated qualitative medium, 12 studies rated qualitative low and 6 studies rated qualitative. Study classifications were distributed fairly evenly across those studies with no effects reported and those with effects reported (*e.g.* 8 studies where effects were reported were classified qualitative low and 9 studies where no effects were reported were classified as qualitative low). Measurement endpoint codes reported in ECOTOX and included in the developmental data were metamorphosis; organ/tissue formation; stage; slowed, retarded, delayed or non- development; developmental changes, general; abnormal and deformation.

Figure 59. Reported amphibian developmental endpoints < 500 µg/L [Labels key: Endpoint (Effect, Species, duration in days)] Red dots denote a measured effect where blue dots represent no effect (NE) seen in study.

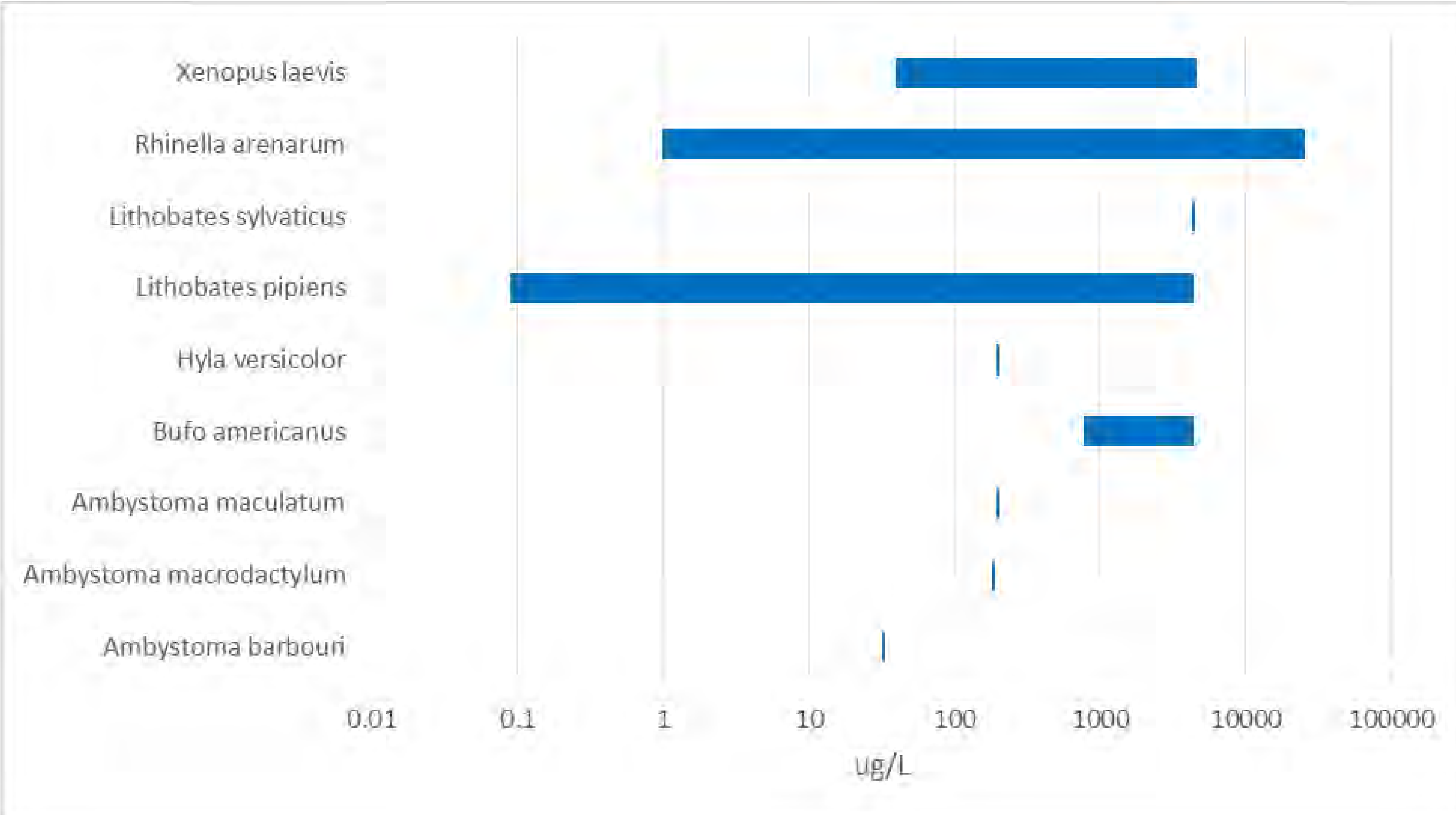


Figure 60. Range of reported LOAECs for developmental endpoints by species (bar represents range of reported concentrations, thin lines indicate only one concentration reported).

15.1.3.2.c. ***Growth Line of Evidence***

The line of evidence for growth effects to amphibians draws largely from endpoints reported for changes in weight, organ weight, length and snout-vent length (SVL). Reported effects included 40 endpoints across 21 studies and 13 species for concentrations less than 500 µg/L (**Figure 61**). **Figure 62** depicts ranges of concentrations across available LOAECs for 8 species, which included salamanders, toads and frogs. LOAECs ranged from 0.1 to 784 µg/L with the largest reported range within a species for *Xenopus laevis.* All studies used in the assessment were reviewed and the breakdown of study classifications were: 1 study rated quantitative, 2 studies rated qualitative high, 1 study rated qualitative medium, 13 studies rated qualitative low and 4 studies rated qualitative. Study classifications were distributed fairly evenly across those studies with no effects reported and those with effects reported (*e.g.* 8 studies where effects were reported were classified qualitative low and 9 studies where no effects were reported were classified as qualitative low).

Figure 61. Reported amphibian growth endpoints at concentrations < 500 µg/L; [Labels key: Endpoint (Effect, Species, duration in days)]; Red dots denote a measured effect where blue dots represent no effect (NE) seen in study.

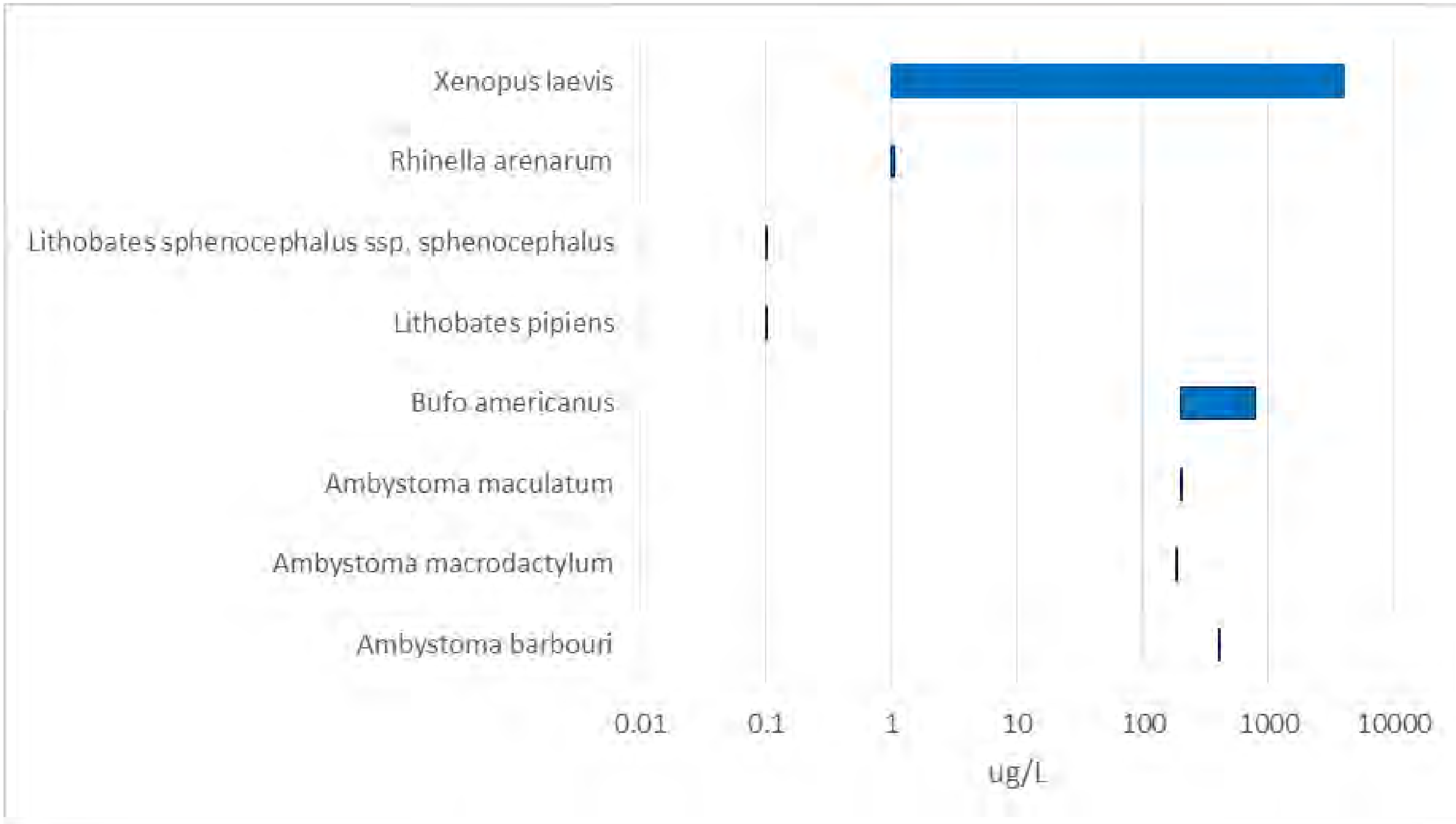


Figure 62. Range of reported LOAECs for growth endpoints by species (bar represents range of reported concentrations, thin lines indicate only one concentration reported).

15.1.3.2.d. ***Reproduction Line of Evidence***

The line of evidence for reproductive effects to amphibians draws largely from endpoints reported for sex ratio changes and specific reproductive developmental changes. Reported effects included 31 endpoints across 14 studies and 6 species (**Figure 63**). **Figure 64** depicts ranges of concentrations across available LOAECs for 4 species, which included toads and frogs. LOAECs ranged from 0.1 to 400 µg/L with the largest reported range within a species for *Xenopus laevis.* All studies used in the assessment were reviewed and the breakdown of study classifications were: 1 study rated quantitative, 1 study rated qualitative high, 10 studies rated qualitative low and 2 studies rated qualitative. Study classifications were distributed fairly evenly across those studies with no effects reported and those with effects reported (*e.g.* 7 studies where effects were reported were classified qualitative low and 7 studies where no effects were reported were classified as qualitative low).

Measurement endpoint codes reported in ECOTOX and included in the reproduction data were laryngeal muscle length, reproductive organ weight in relationship to body weight, resorption, sexual development, fully developed oocytes, gamete production, germ cell count, imposex, intersex conditions, number of ovarian follicles, ovotestes, progeny counts/numbers, sex ratio, sperm cell counts, and spermatogonia.

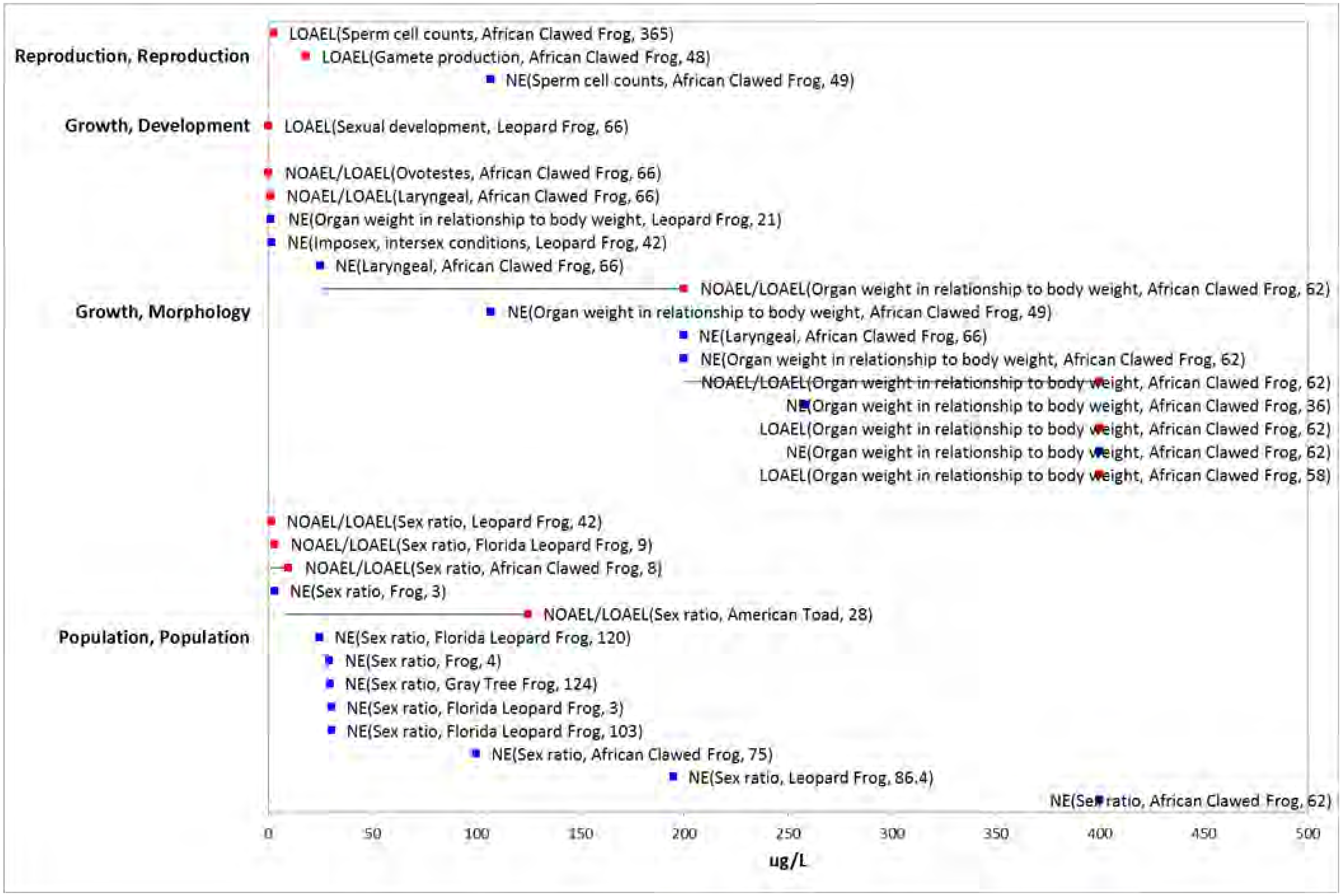


Figure 63. Reported amphibian reproduction/sexual development endpoints <500 ug/L; [Labels key: Endpoint (Effect, Species, duration in days)]; Red dots denote a measured effect where blue dots represent no effect (NE) seen in study.

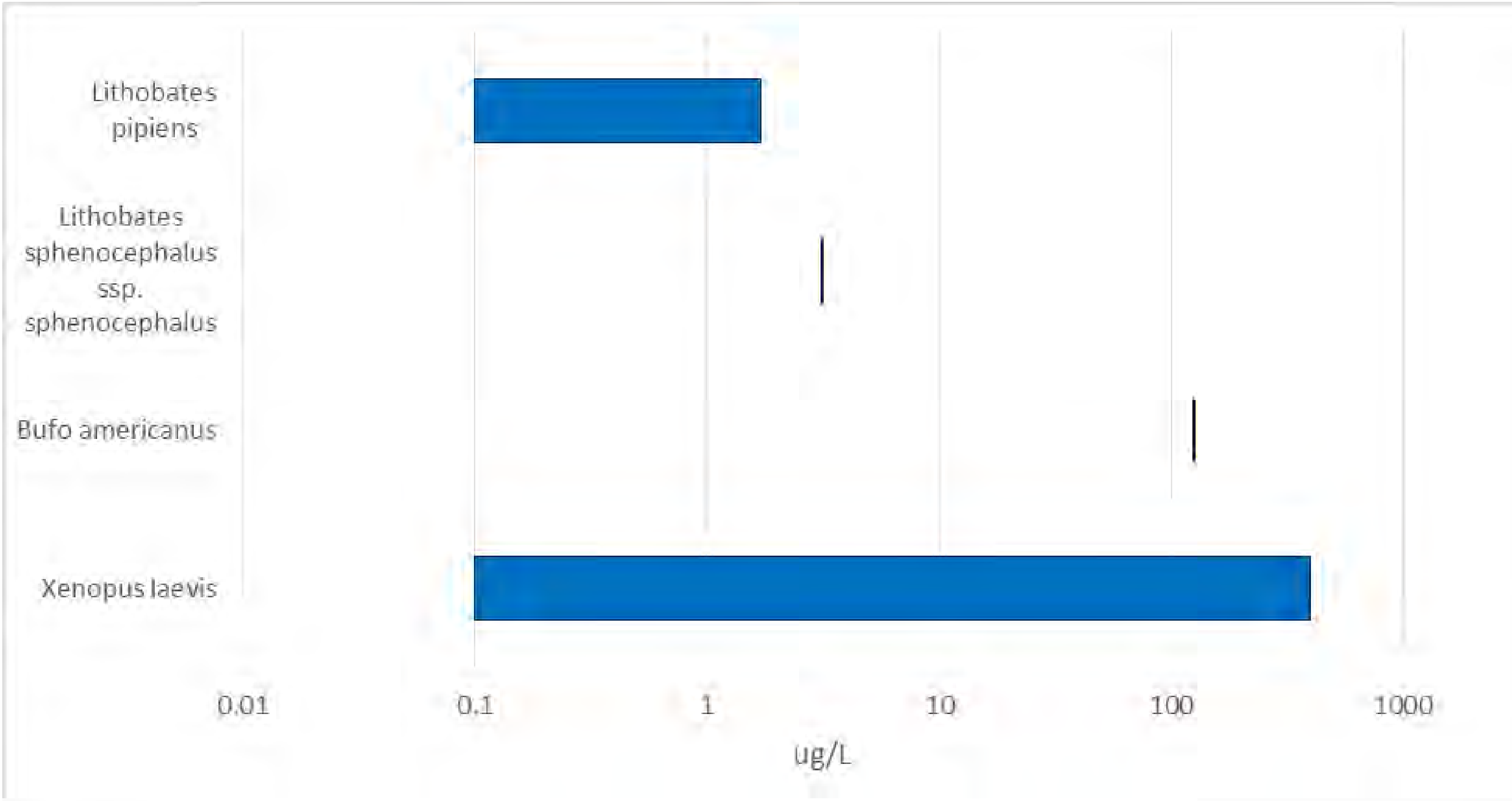


Figure 64. Range of reported reproduction/sexual development LOAECs by species (bar represents range of reported concentrations, thin lines indicate only one concentration reported).

15.1.3.3. ***Overlap of Effects and Exposure Data***

Figure 65 displays the overlap of atrazine concentrations between observed effects endpoints and measured and predicted aexposure concentrations. The Atrazine Ecological Exposure Monitoring Program (AEEMP) was used to represent concentrations in predominantly flowing water bodies in areas where atrazine use on corn has been heavily monitored. Each monitoring data point represents an annual 60-day average and maximum peak daily concentration. As indicated by squares along the distribution of measured concentrations, percentages of the distribution were demarcated as 5, 25, 50, 75 and 95% to illustrate the proportion of measured concentrations that overlap with the effects endpoints. Also provided are the Surface Water Calculator (SWCC) predicted exposure concentrations. These ranges represent the range of predicted 1 in 10 year maximum 60-day average concentration results for all modeled scenarios and use rates (blue bar). In addition, SWCC predicted concentration ranges for all scenarios modeled for corn for 2 applications at rates of 2 and 0.5 lb a.i./A (14 day retreatment interval) are provided (yellow bars) (see **Section 7.3.2** for specific values). Apparent in this figure is the significant overlap of reported chronic effects endpoints from all lines of evidence with both the measured and predicted exposure data from available monitoring data and the SWCC model predictions. These results are further discussed for each line of evidence in **Table 101.**

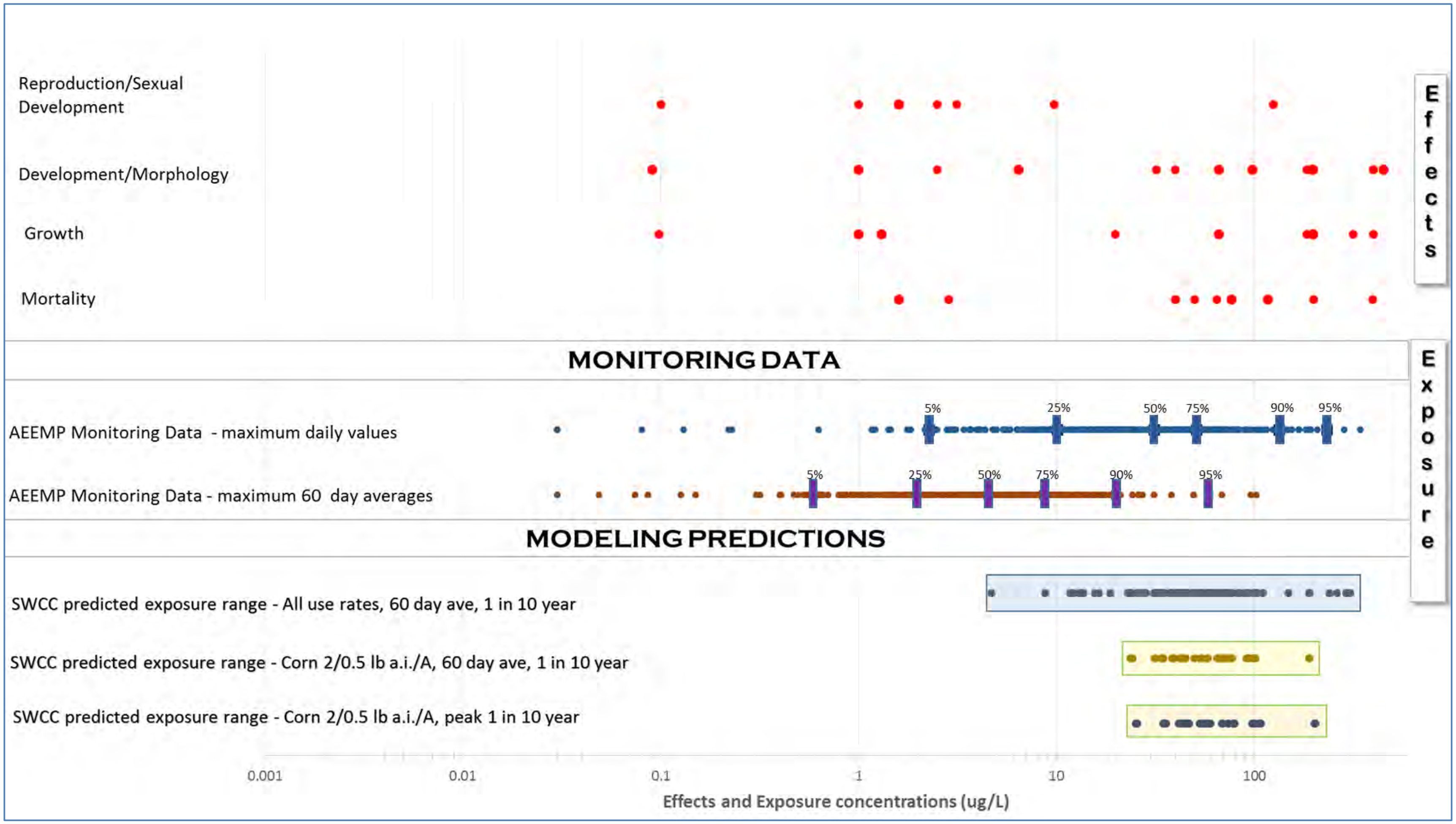


Figure 65. Effects endpoints (LOAECs) for mortality, growth, development and reproduction as compared to measured environmental surface water monitoring data and predicted surface water concentrations using the Surface Water Concentration Calculator (SWCC).

Table 101. Summary of the weighting considerations and weight determinations for exposure, effects and risks for each line of evidence (mortality, growth, development and reproduction).

Line of evidence	Considerations, justifications and weights for exposure and effect data that influence the risk determinations					Risk (extent of overlap of exposure and effects data; see Figure 65 for overlap)	Weight of the Line (confidence in data)
	Exposure		Effects				
	Relevance	Robustness	Relevance (biological)	Surrogacy	Robustness		
Mortality due to atrazine exposure	1. Modeled water bodies are representative of amphibian habitats. 2. Multi-state, multi-year ongoing, monitoring program including targeted monitoring data in areas of likely habitats.	1. Complete fate database available. 2. Agreement between model output results and monitoring data. 3. Additional spatial regression analysis prediction (WARP) available for predicting surface water concentrations.	1. Mortality is directly relevant to species fitness. 2. Most endpoints are direct measurements of mortality (predominantly LD_{50}, LC_{50}, etc.)	1. Large range of amphibian species (22) both native and non-native are representative of taxon as whole, including data for frogs, toads, salamanders. 2. Multiple life phases represented. 3. Effects concentration ranges seen in other surrogate species (fish) are fairly consistent with the range of effects seen in amphibians.	1. LC_{50} values available for 5 species from 4 studies. 2. Almost all LC_{50} values based on formulated product. 3. Large portion of effects and no effects endpoints are rated as qualitative low. 4. Variable range of data across species.	1. LC_{50}s range from 2.32 to 232 mg/L, with many values above typical surface water concentrations seen (less risk). 2. Mortality (LOAECs/NOAECs) still seen in the range of predicted surface water concentrations and monitoring data for 5 species.	Lower confidence due primarily to limitations noted in effects robustness sections.
WEIGHTING	HIGH	HIGH	HIGH	HIGH	LOW	**LOW-MEDIUM**	**MEDIUM-HIGH**

Line of evidence	Considerations, justifications and weights for exposure and effect data that influence the risk determinations					Risk (extent of overlap of exposure and effects data; see Figure 65 for overlap)	Weight of the Line (confidence in data)
	Exposure		Effects				
	Relevance	Robustness	Relevance (biological)	Surrogacy	Robustness		
Altered development due to atrazine exposure	Same for all lines (see mortality)	Same for all lines (see mortality)	1. Developmental changes and delay can be strongly related to fitness of the organism. 2. Most endpoints were "time to metamorphosis" which is direct measure of development. 3. The magnitude of effect as compared to the control was low in several studies.	Same for all lines (see mortality)	1. Included 47 endpoints across 23 studies and 14 species. 2. LOAECs ranged from 0.1 to 10,000 µg/L across species, with most of the overlap in reported effects ranges occurring between 10 and 200 µg/L. 3. Large portion of studies rated as qualitative low (12 of 23). 4. Conflicting results across studies: multiple species having no effects and effects seen at same concentrations for the same endpoint.	Most developmental endpoints overlap with both predicted and measured surface water concentrations.	Lower confidence due to limitations noted in effects relevance and robustness sections.
WEIGHTING	HIGH	HIGH	MEDIUM	HIGH	LOW	**MEDIUM-HIGH**	**MEDIUM**

Line of evidence	Considerations, justifications and weights for exposure and effect data that influence the risk determinations					Risk (extent of overlap of exposure and effects data; see Figure 65 for overlap)	Weight of the Line (confidence in data)
	Exposure		Effects				
	Relevance	Robustness	Relevance (biological)	Surrogacy	Robustness		
Altered growth due to atrazine exposure	Same for all lines (see mortality)	Same for all lines (see mortality)	1. Growth is relevant to species fitness. 2. Most endpoints were weight or length, direct measures of growth and fitness of the organism. 3. The magnitude of effect as compared to the control was low in several studies.	Same for all lines (see mortality)	1. Included 40 endpoints across 21 studies and 13 species. 2. Reported LOAECs ranged from 0.1 to 784 µg/L. 3. Some consistency in LOAECS across species groups, with salamanders appearing less sensitive and frogs more sensitive. 4. Large portion of studies rated as qualitative low (13 of 21).	Most growth endpoints overlap with both predicted and measured surface water concentrations.	Lower confidence due to limitations noted in effects relevance and robustness sections.
WEIGHTING	HIGH	HIGH	MEDIUM	HIGH	LOW	**MEDIUM-HIGH**	**MEDIUM**

Line of evidence	Considerations, justifications and weights for exposure and effect data that influence the risk determinations					Risk (extent of overlap of exposure and effects data; see Figure 65 for overlap)	Weight of the Line (confidence in data)
	Exposure		Effects				
	Relevance	Robustness	Relevance (biological)	Surrogacy	Robustness		
Altered reproduction and sexual development due to atrazine exposure	Same for all lines (see mortality)	Same for all lines (see mortality)	1. Reproduction is highly relevant to species fitness. 2. Several endpoints captured sex ratio shifts, which could be significant at population levels. 3. Some endpoints captured less direct measurements such as gamete production and sperm cell counts, although these are relatable effects.	Same for all lines (see mortality)	1. Included 31 endpoints across 14 studies and 6 species. 2. Results tended to group with sex ratio effects seen at lower concentrations and organ weight changes seen at higher concentrations. 3. Majority of studies rated as qualitative low (10/14). All studies where effects were seen are rated as qualitative low.	Almost all reproduction endpoints overlap with both predicted and measured surface water concentrations.	Lower confidence due to limitations noted in effects relevance and robustness sections.
WEIGHTING	HIGH	HIGH	MEDIUM	HIGH	LOW	**HIGH**	**LOW-MEDIUM**

15.1.3.4. ***Integration of All Lines of Evidence***

As shown in **Table 101** above, lines of evidence were rated generally in the medium to high range for risk and medium range for confidence in the data. To evaluate overall risk to amphibians using the weight of evidence approach, the last two columns of the **Table 101**, "Risk" and "Weight of the Line", are combined graphically as displayed in **Figure 66**. The placement of each line of evidence on this graph integrates where they fall on the spectrum together. The bottom left hand corner represents low weight (low confidence) and low risk (weak overlap of effects and exposure) whereas the upper right hand corner represents high weight (high confidence) and high risk (high overlap of effects and exposure). Based on the weighting discussed in **Table 101**, the lines of evidence vary slightly in their placement (**Figure 66**). There is higher confidence in the mortality line of evidence with the potential for low risk, whereas the reproductive line of evidence indicates high risk, but has lower confidence in the data. Likewise, the growth and developmental lines both have medium-high risk concerns with medium confidence in their data sets.

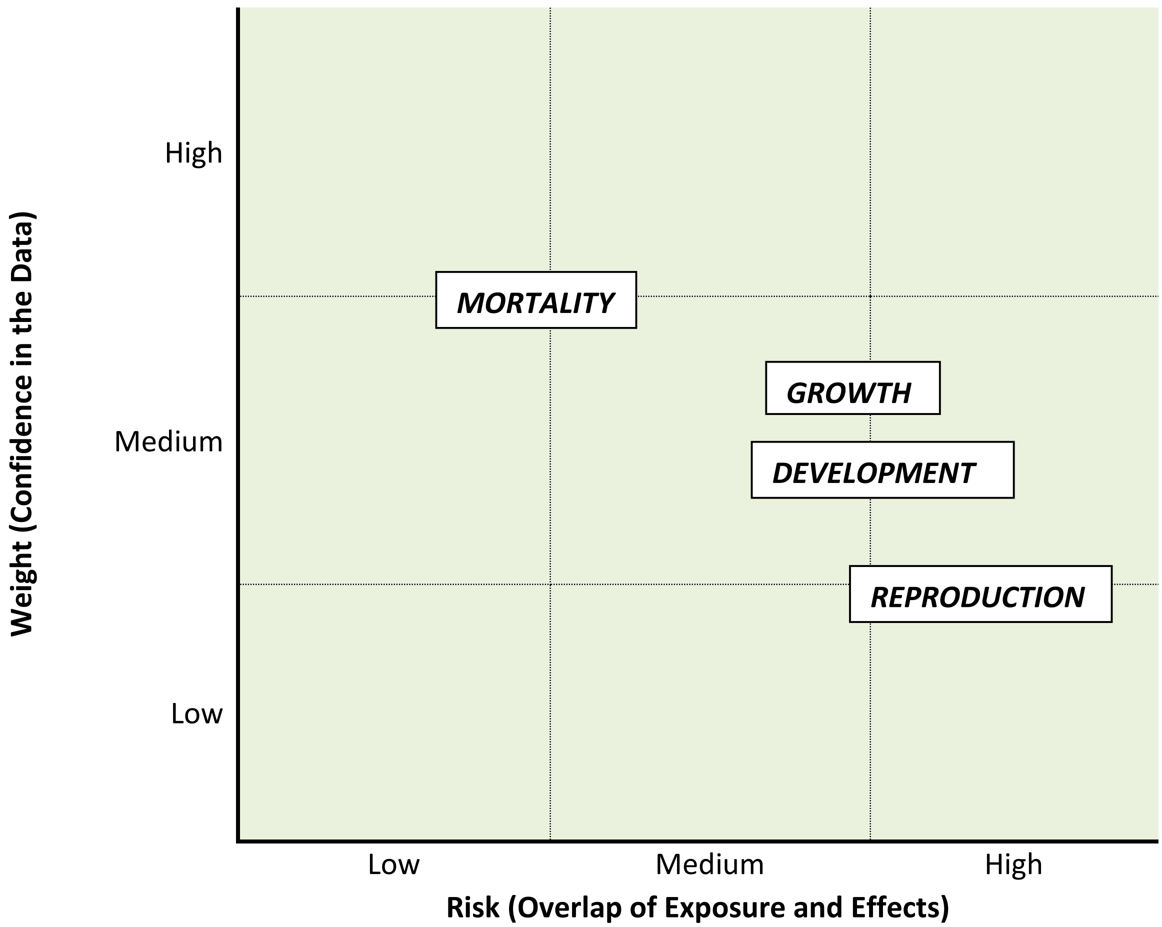


Figure 66. Illustration of the Weight of Evidence conclusions for the available effects and exposure data related to the mortality, growth, development and reproduction lines of evidence.

15.1.3.5. ***Other effects data for consideration in risk to aquatic-phase amphibians***

Although not specifically evaluated through lines of evidence, other reported toxicological endpoints included those involving biochemical and molecular effects, immunological effects and behavioral modifications as well as in vitro effects**.** These types of effects were reported in 7 species and involved an environmentally relevant range of effects concentrations from 2.5 – 400 ug/L. As these endpoints are generally not used for establishing quantitative endpoints in a FIFRA risk assessment, they were not specifically considered as individual lines of evidence. However, the reported effects at these concentrations, including alteration in oocyte

development, reduced survival after pathogen challenge, reduction in immunologic genes/markers, alterations in biochemical profiles and changes in feeding behavior, were considered in the overall assessment of the potential for chronic adverse effects to amphibians.

15.1.3.6. ***Conclusions for amphibian weight of evidence evaluation***

Based on the weight of evidence analysis, there is a potential risk concern to amphibians due to atrazine exposure when used in accordance with the current labels. As discussed above, throughout the analysis, consideration is given to each individual factor that influences the risk and weight decisions. This includes factors such as the environmental exposure concentrations, both predicted and measured, the range of species tested, the quality of the data produced and the relevance of those data points to the fitness of an individual. As previously discussed in several SAPs, in the literature there is a high degree of variability in the concentrations for some reported effects endpoints, both within and across amphibian species. Reasons for these differences may include the impact of variability in environmental conditions or stressors across studies, but the definitive reason for the differences in results remains unknown. Despite these uncertainties associated with the toxicity data, the other factors included in the analysis influence the overall weighting of the evidence. In particular, a large portion of the reported effects for amphibian mortality, development, growth and reproduction are at or below concentrations measured in the environment as well as the estimated environmental concentrations from modeling data (**Figure 65**). The EPA has high confidence in the measured and estimated exposure concentrations (see **Sections 7.3** and **7.4**), and considers this overlap with amphibian reported effects to be considerable. The multiple factors discussed above contributed equally to the determination of potential chronic effects to amphibians when considering the available toxicity data set in conjunction with the current measured and predicted concentrations in surface water.

15.1.3.7. ***Quantifying risks to amphibians***

As previously discussed, there is considerable contradiction in the reported concentrations at which effects and no effects occur in atrazine amphibian toxicity studies. Some of the lowest data points are from studies with quality concerns and have not been replicated since the original study, despite multiple studies involving the same endpoint. Similarly, many studies where no effects were seen at various concentrations were also found to have significant limitations. In this sense, although individual study flaws or deficiencies were not expressly considered in the weight of evidence analysis, lower quality studies could be found throughout all high and low endpoints, for both effects and no effects data. When looking at the studies collectively, the individual study quality concerns were deemed less important, and emphasis was placed on interpreting the range of reported results across all of the studies. The

conclusion, based upon the overall preponderance of evidence, is that there are potential risks to amphibians from chronic exposure to atrazine.

When considering studies in the weight of evidence approach, it is challenging to determine a specific quantitative chronic effects endpoint for aquatic-amphibians. In order to evaluate amphibians in light of the overall findings of this ecological risk assessment, the current CELOC at 3.4 ug/L (the threshold for risks to the aquatic plant community) was used as a representative quantitative threshold for amphibians. Based on the available amphibian toxicity data, the CELOC is protective for a majority of the observed direct effects to amphibians, and this endpoint also provides protection from indirect effects to amphibians through impacts to aquatic plant communities. Described below is further analysis comparing the quantitative endpoint of 3.4 ug/L for the CELOC to the available amphibian direct effects data.

15.1.3.7.a. ***Consideration of the effects and no effects endpoints as compared to the CELOC***

Figure 67 depicts the effects endpoints for the 4 major lines of evidence (apical endpoints), including LOAECs and NOAECs (both bounded and unbounded) from the ECOTOX database. Also displayed on Figure 67 is the CELOC ("LOC", red vertical line) as a reference point for the potential protection threshold for amphibians. Notably, **Figure 67** shows that there are a number of reported effects below the CELOC threshold and far more at concentrations greater than the threshold. To further explore those data with endpoints reported at low concentrations and to compare these to the CELOC, the narrower range of 0.01 to 5 ug/L is displayed in **Figure 68**. The main concern for the distribution of LOAEC and NOAEC endpoints lies in the question, "Is the CELOC at 3.4 ug/L protective given the body of available evidence?" Although, within each line of evidence, there are a few LOAECs less than 3.4 ug/L, there are as many or more data points that demonstrated no effects at or below the CELOC. When narrowing in on the endpoints that were reported at concentrations lower than the CELOC, consideration of individual study quality becomes more significant. This is further discussed below utilizing the analysis presented at the 2012 SAP.

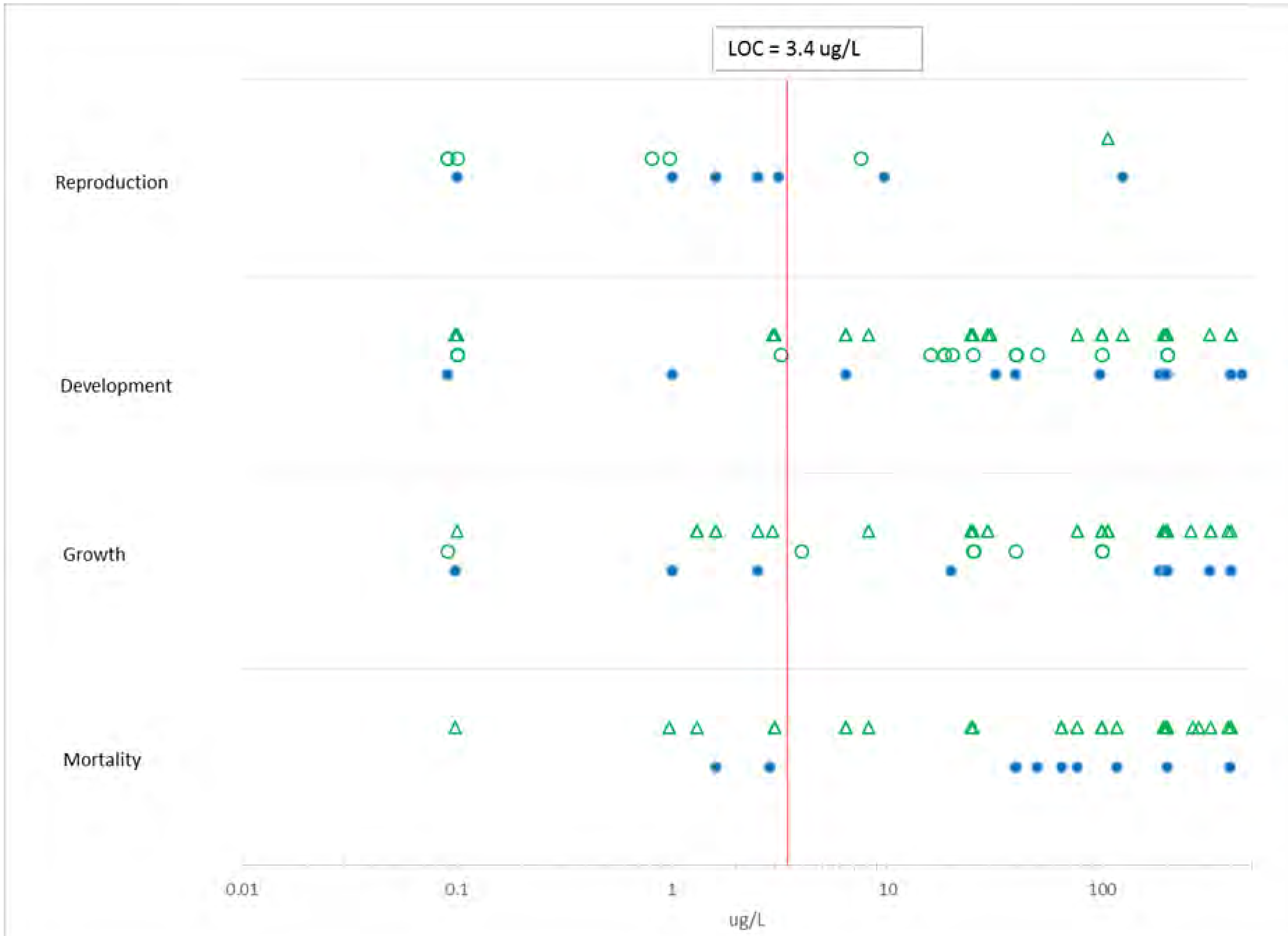


Figure 67. Amphibian effects and no effects endpoints from 0.01 to 500 ug/L (logarithmic scale) [Effects data are LOAECs (filled blue circles), No effects data are NOAECs (bounded NOAECs - open green circles, unbounded NOAECs - open green triangles)].

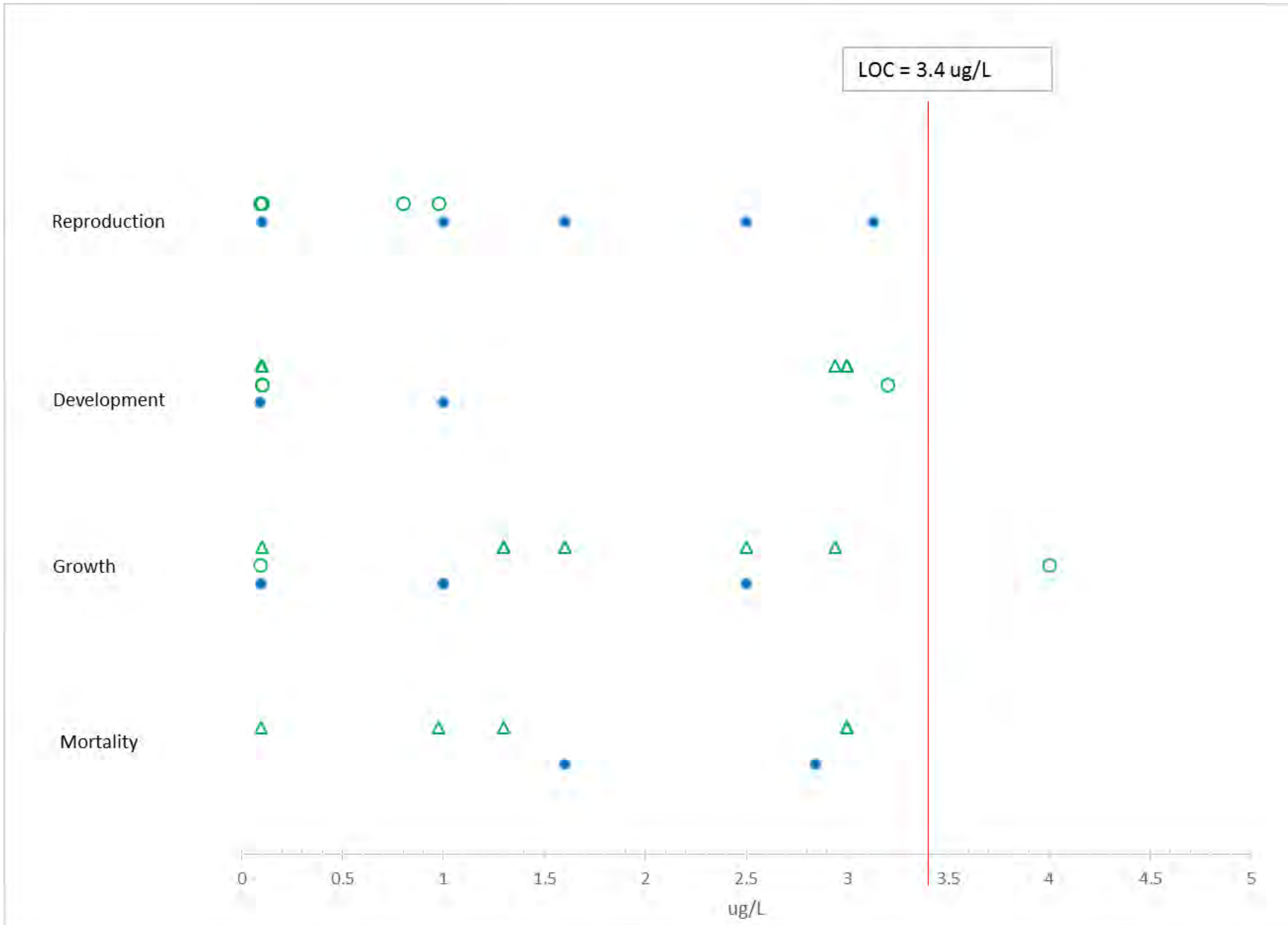


Figure 68. Amphibian effects and no effects endpoints for low level concentrations (0.01 to 5 ug/L) [Effects data are LOAECs (filled blue circles), No effects data are NOAECs (bounded NOAECs - open green circles, unbounded NOAECs - open green triangles)].

For the 2012 SAP (USEPA 2012), several Weibull charts were presented which provided useful summaries of available endpoints for several effects groups, as well as including EPA's study classification of effects endpoints. Presented in **Figure 69** are figures capturing both NOAECs and LOAECs for endpoints associated with metamorphosis/development, growth, and sexual development. When the CELOC is compared to these endpoints, as represented by the red line on the figures, the majority of the data points lie to the right of this level (at higher concentrations). Across the three effects groups presented in the figures, NOAECs tend to cluster in the range of 10 – 20 µg/L. Although this could be an artifact of the concentrations tested and dosing interval, it represents the trends observed across the available literature and suggests the use of the CELOC at 3.4 ug/L would be protective of effects seen in the majority of available studies based on the 2012 analysis. While the plots below do not include all of the studies presented in the WOE analysis (**Sections 15.1.3.2** and **15.1.3.3**), and include "invalid" studies which were excluded from the WOE analysis, the data trends presented in **Figure 69** are consistent with results reported in the current amphibian literature included in the WOE analysis. EPA reviews of studies representing effects at concentrations lower than the CELOC, as shown in **Figure 69**, concluded that these would not be of sufficient quality to be used quantitatively (**Appendix B**). Therefore, when considering the question "is the CELOC at 3.4 ug/L protective given the body of available evidence?", the EPA determined that, based on the preponderance of evidence, the CELOC is protective of amphibians and represents a reasonable quantitative threshold for evaluating risk to amphibians.

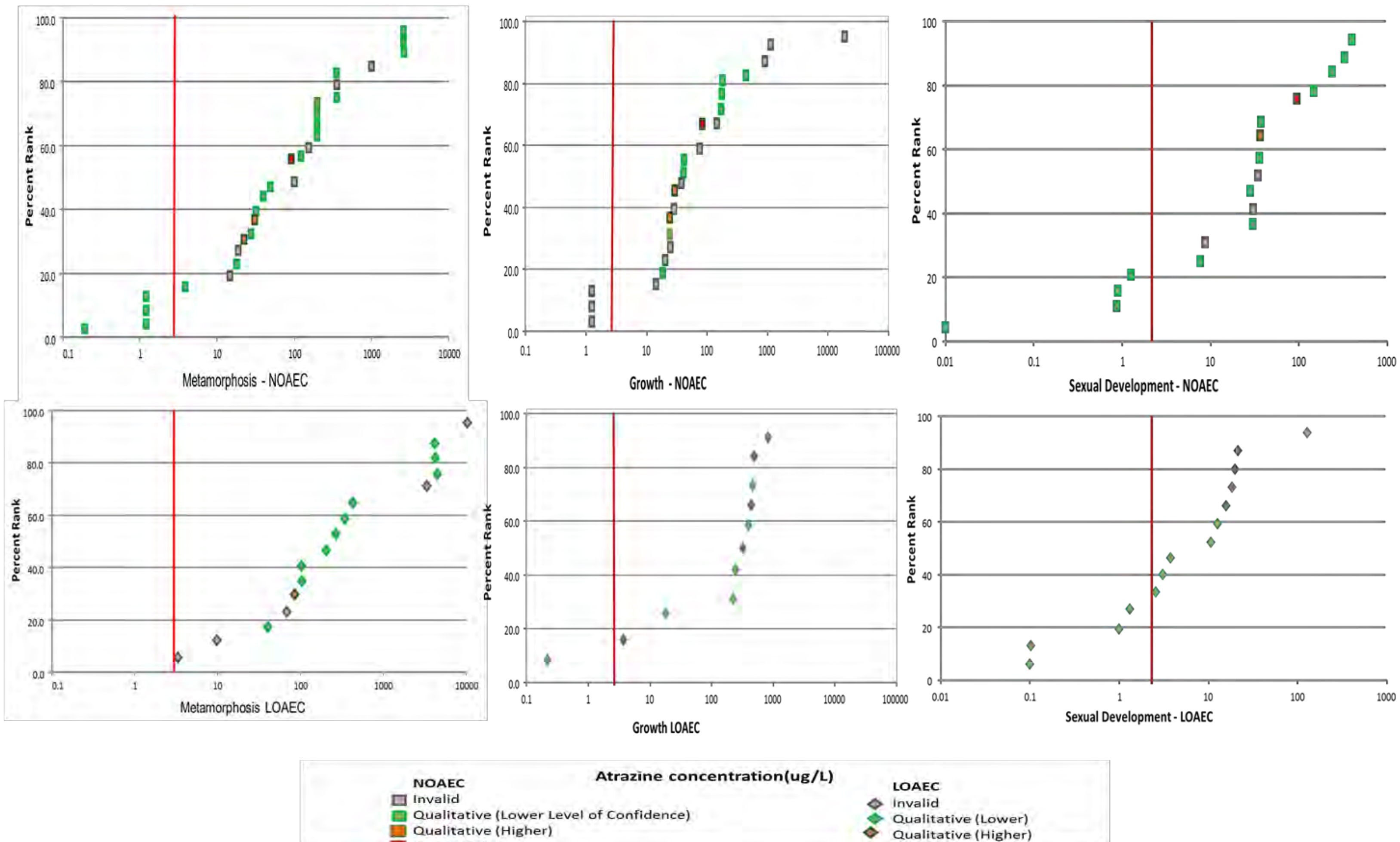


Figure 69. Summary of metamorphosis, growth, sexual development endpoints (NOAECs and LOAECs) from the 2012 SAP white paper (USEPA 2012).

15.1.4. Risk to Non-Vascular Aquatic Plants (Corn Uses)

The predicted EECs using SWCC indicate when based against the most sensitive taxon the non-listed non-vascular plant LOCs are exceeded for all Section 3 and Section 24c uses on corn for 100% of modeled scenarios (RQs range from 204 to 14, **Table 98** and **Table 99**). The exploration of risk resulting from reduced rates (0.5 or 0.25 lbs a.i/A) and soil incorporation does not lead to a single scenario with RQs below the level of concern.

As discussed in **Sections 10.2, 10.3,** and **10.4,** not all species of aquatic plants are equally sensitive to atrazine. The most sensitive endpoints for the major lineages were used to explore the potential risk to these lineages following the aforementioned applications of Section 3 corn uses. **Table 102** illustrates that risk to nearly all of major lineages of photoautotrophs is anticipated for all labeled rates and applications.

Table 102. Estimated Risk to Aquatic Plants for Atrazine from Corn Uses on Section 3 Labels

Crop (Application Rate)		Cyano-bacteria	Non-Vasc. Embryo-phytes	Vasc. Embryo-phytes	Chloro-phyta and Strepto-phyta	Prasino-phyta	Rhodo-phora	Hapoto-phyta	Chrypto-phyco-phyta	Bacillario-phyta	Phaeo-phyta	Chryso-phyta	Ocro-phyta	Pyrro-phyco-phyta	Euglen-ophyta
Corn Aerial 2/0.5 lbs. a.i./A 14-day interval	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**7/17**	**17/17**	**17/17**	**17/17**	**4/17**	**8/17**	**1/17**	**17/17**	0/17
	RQ Range	**202 - 35**	**101 - 18**	**44 - 8**	**202 - 35**	**14 - 2**	**3 - <1**	**7 - 1**	**9 -2**	**10 - 2**	**2 - <1**	**3 - <1**	**1 - <1**	**12 -2**	<1
Corn Ground 2/0.5 lbs. a.i./A 14-day interval	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**5/17**	**15/17**	**17/17**	**17/17**	**4/17**	**5/17**	**1/17**	**17/17**	0/17
	RQ Range	**204 - 25**	**102 - 13**	**44 - 5**	**204 - 25**	**14 - 2**	**3 - <1**	**7 - 1**	**9 -1**	**11 - 1**	**2 - <1**	**3 - <1**	**1 - <1**	**12 -1**	<1
Corn Fallow Aerial 1/0.5/1 lbs. a.i./A 14-day interval	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**4/17**	**17/17**	**17/17**	**17/17**	**3/17**	**4/17**	1/17	**17/17**	0/17
	RQ Range	**117 - 29**	**59 - 14**	**25 - 6**	**117 - 29**	**8 - 2**	**1 - <1**	**4 - 1**	**5 - 1**	**6 - 1**	**1 -<1**	**2 - <1**	1 - <1	**7 - 1**	<1
Corn Fallow Ground 1/0.5/1 lbs. a.i./A 14-day interval	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**4/17**	**16/17**	**17/17**	**17/17**	**2/17**	**4/17**	0/17	**17/17**	0/17
	RQ Range	**117 - 24**	**59 - 12**	**25 - 5**	**117 - 24**	**8 - 2**	**1 - <1**	**4 - 1**	**5 - 1**	**6 - 1**	**1 -<1**	**2 - <1**	<1	**7 - 1**	<1
Corn Fallow Ground 1 lb. a.i./A 14-day interval	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	0/17	**10/17**	**13/17**	**14/17**	0/17	0/17	0/17	**15/17**	0/17
	RQ Range	**48 - 14**	**24 - 7**	**11 - 3**	**48 - 14**	**3 - 1**	<1	**2 - <1**	**2 - 1**	**2 - 1**	<1	<1	<1	**3 - 1**	<1
Corn, Erodible Soils Aerial 1.6 lbs. a.i./A	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**4/17**	**15/17**	**17/17**	**17/17**	**1/17**	**4/17**	0/17	**17/17**	0/17
	RQ Range	**153 - 25**	**77 -12**	**33 - 5**	**153 - 25**	**11 - 2**	**2 - <1**	**5 - 1**	**7 - 1**	**8 - 1**	**2 - <1**	**2 - <1**	<1	**9 - 1**	<1
Corn, Erodible Soils Ground 1.6 lbs. a.i./A	Number of Scenarios	**17/17**	**17/17**	**17/17**	**17/17**	**17/17**	**2/17**	**13/17**	**15/17**	**16/17**	**1/17**	**3/17**	0/17	**17/17**	0/17
	RQ Range	**153 - 18**	**77 -9**	**33 - 4**	**153 - 18**	**11 - 1**	**2 - <1**	**5 - 1**	**7 - 1**	**8 - 1**	**2 - <1**	**2 - <1**	<1	**9 - 1**	<1

15.1.5. Risks to Aquatic Plant Communities (Corn Uses)

The CELOC is exceeded for all currently labeled Section 3 and Section 24c uses (**Table 98** and **Table 99**) and for 100% of all SWCC scenarios modeled for these uses The evaluation of rate reductions to 0.5 lbs a.i./A result in reduced RQs, however there remains risk to the aquatic plant community (**Table** 100), with all scenarios still exceeding the CELOC. EECs following a reduced application rate, 0.5 lbs a.i./A, and soil incorporation at the time of application at depths greater than 6 cm, the 60-day average concentrations begin to fall below the CELOC for some scenarios, with only 11 and 4 of the 17 modeled scenarios exceeding for 8 and 15 cm depths respectively.

The estimated concentrations based on the currently labeled corn uses, indicate that significant effects to non-vascular and vascular plant species are expected in vulnerable waters (**Section 15.1.3, Table 102**). The CELOC encompasses effects on species, populations, community composition, as well as effects on critical functions that the aquatic plants serve in the ecosystem, such as food and habitat for protection and reproduction. Exceedances of the CELOC are interpreted as there being a likelihood of 50% or greater that an effect on the aquatic plant community will occur. Alternatively, as a comparison, cosm endpoints can be looked at individually against the concentrations while considering their duration. As **Figure 70** illustrates, the majority of the effects endpoints reported from available cosm data used to determine the CELOC fall below the maximum and median EECs (peak, 21-day and 60-day values plotted) for corn uses following applications of 2 and 0.5 lbs/A. The minimum modeled EEC from this ground application rate is also higher than 17 effects endpoints in the database.

Following the consideration of a reduction in application rates, a single application of 0.5 or 0.25 lbs a.i./A results in maximum, median, and minimum EECs exceeding the concentrations showed effects to several of the tested communities (**Figure 71** and **Figure 72**). Exposures following a 0.25 lb a.i./A ground application resulted in RQs below the CELOC for two SWCC scenarios (NCcornESTD and CAcornOP) the other 15 scenarios result in RQs greater than the CELOC. It is also important to note that the figures show how these EECs are not only above the CELOC but are also above those concentrations in the many of the cosm experiments which resulted in an effect to the communities tested.

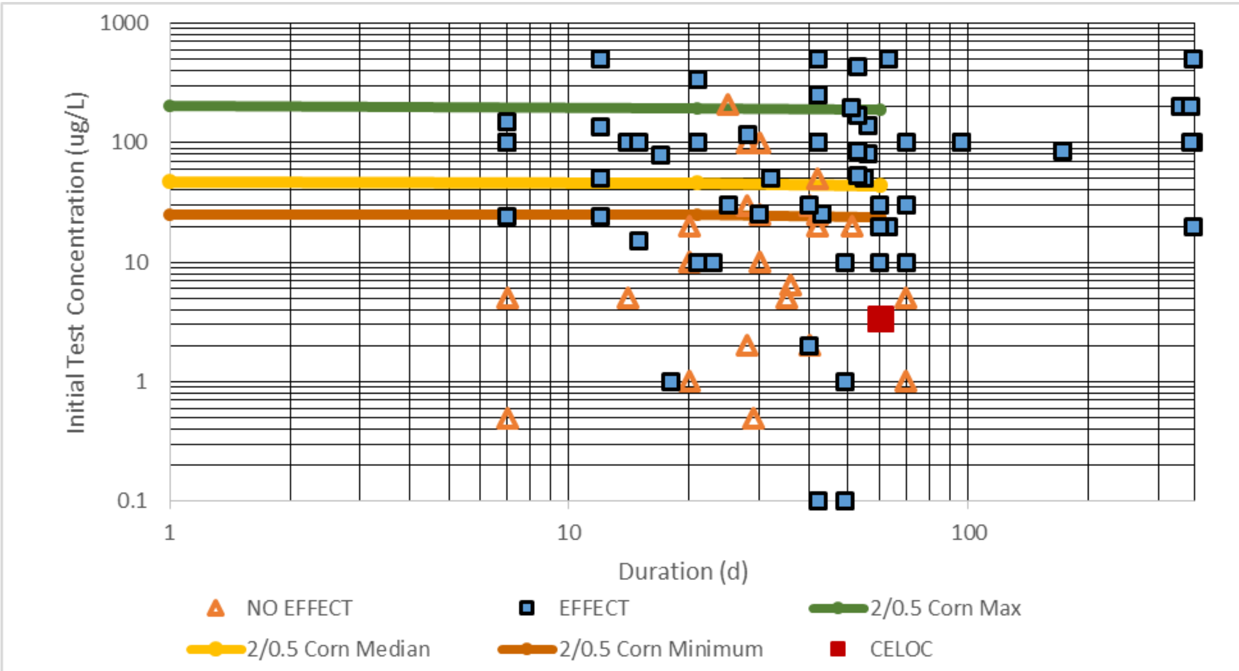


Figure 70. Comparison of Cosm Effects/No Effects Endpoints with Minimum, Median and Maximum SWCC EECs following ground applications of 2.0 and 0.5 lbs a.i./A with a 14-day reapplication interval (peak, 21-day and 60-day values are plotted; values provided in Table 98).

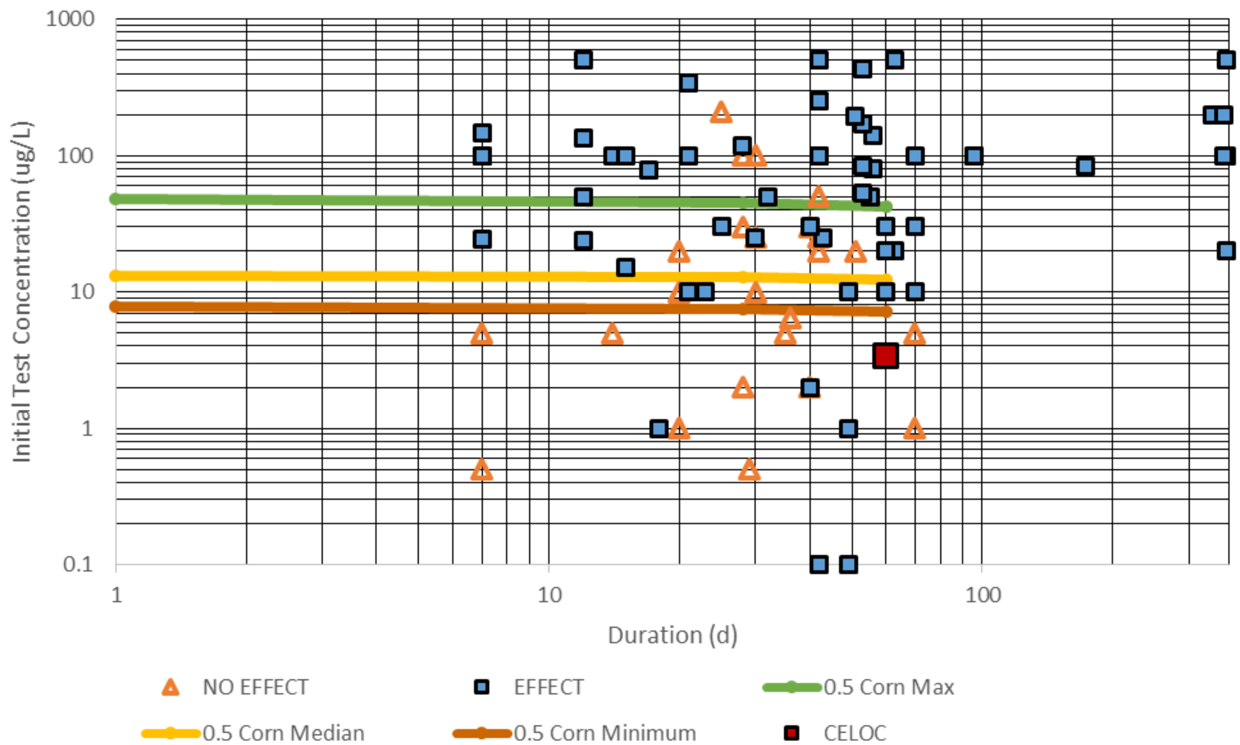


Figure 71. Comparison of Cosm Effects/No Effects Endpoints with Minimum, Median and Maximum SWCC EECs following a single ground application of 0.5 lbs a.i./A (peak, 21-day and 60-day values are plotted; values provided in Table 100).

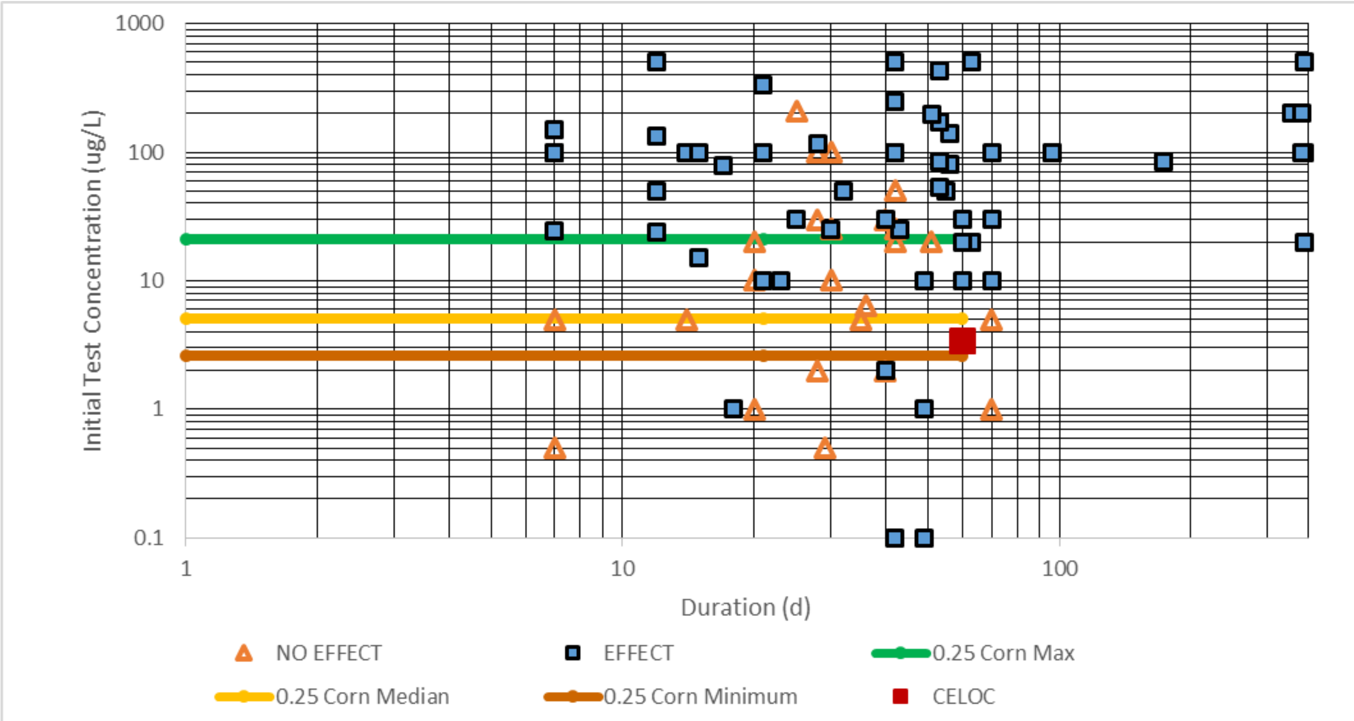


Figure 72. Comparison of Cosm Effects/No Effects Endpoints with Minimum, Median and Maximum SWCC EECs following a single ground application of 0.25 lbs a.i./A (peak, 21-day and 60-day values are plotted; values provided in Table 100).

The modeled SWCC EECs represent aquatic and semi-aquatic areas such as, but not limited to, wetlands, marshes, ponds, lakes, reservoirs, streams and small rivers. These habitats are comprised of many aquatic organisms that rely upon the aquatic plant community for food and habitat. In streams it is well documented from monitoring data, such as AEEMP and Heidelberg, that there is a stochastic nature of the exposures in streams (*i.e.,* multiple pulse events of variable durations, **Figure 29***,* both seasonally as well as annually).

The CELOC, which was established with consideration of plant population and community recovery, was intended to be protective of longer duration events that postpone critical plant population and community development timing. Because the phytoplankton community represents the primary producers (food items) for the aquatic ecosystem, reduced and delayed growth would have negative effects on the organisms that rely upon phytoplankton for food and could cause effects throughout the trophic system. Reduction and/or delays in the growth of macrophytes and metaphyton (algae mats) growth, would result in a delay in the habitat structural maturation for use by amphibian, fish and invertebrate taxa. The taxa that may be most affected by these delays or reductions would likely be those taxa that rely upon the macrophytes and metaphyton for reproduction and protection of young during primary atrazine runoff periods midwestern corn uses in the months of April, May, and June. This

timing is likely to include a wide diversity of taxa from these animal lineages that depend on the structural components of the aquatic plant community. Other consequences of the atrazine exposures have been shown to manifest in the form of more complex ecosystem responses (*e.g.*, Rohr *et al.* 2009, Boone *et al.* 2012). These cosm studies have indicated that atrazine can increase light penetration to the below water surfaces by reducing phytoplankton populations. Covering these surfaces are periphyton communities, dominated by diatoms. These periphyton communities have been shown to benefit from the increased light penetration to the surfaces following low dose exposure to atrazine. The increased periphyton growth has been connected in cosm experiments to increased populations invertebrates (snails) which forage on the periphyton. These authors stress that the increased population of snails may lead to increased disease (trematode infection) in aquatic amphibians, as the snail is the infection transmission vector.

Streams, rivers, reservoirs and other similar water bodies, have an annual cycle of community structure that can be influenced by many different environmental factors in addition to the components of the community at various times of the year (Baker and Baker 1981, Cardinale 2011, Dalton *et al.* 2015, Andrus *et al.* 2013, Hall *et al*. 2014, Andrus *et al*. 2015). Impacts of atrazine and recovery from exposure on relatively fast growing populations of unicellular photoautotrophs are very different from their slower growing relatives in the non-vascular and vascular embryophytes. Reductions in growth on a macrophyte may take a great while longer to recover to control conditions than the recovery times that are published for unicellular phytoplankton and periphyton (*e.g.,* Prosser *et al.* 2013, Brain *et al.* 2012). The repeated annual atrazine non-lethal exposures to macrophytes and other embryophytes, would manifest themselves over greater time periods and would be difficult to attribute to an individual year of atrazine exposure and would be equally difficult to attribute to atrazine exposure as the sole cause of the declining population. However, evidence from the available individual species toxicity tests and the cosm studies suggests that significant impacts to macrophytes would be expected and these effects would carry over to the next growing season and would likely negatively impact asexual and sexual reproduction.

15.2. Non-Corn Uses; Risk to Aquatic Organisms and Aquatic Plant Communities for Non-Corn Uses

Aquatic EECs estimated using the SWCC and related aquatic taxa RQs for all non-corn uses are presented in **Table 103** and **Table 104.** The maximum single application rates modeled for each of these uses range from 1 to 4 lb a.i./A, with sugarcane having the maximum yearly rate of 10 lb a.i/A applied as 4/2/2/2 lb a.i./A with a 14 day treatment interval. The risk concerns discussed in section 15.1 are relevant to all uses and exposures in tables **Table 103** and **Table 104,** therefore risks related to each of these uses are only discussed briefly below.

Table 103. Summary of SWCC Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 3 Labels. Maximum, minimum, and median estimates of water concentrations, RQs, and the number of modeling scenarios resulting in level of concern exceedances. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances. *RQs for listed species of aquatic plants were not evaluated because exceedances of the non-listed LOCs indicate that risks to listed species are expected.

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Sorghum (Fallow) Ground 1 lb a.i./A	TXsorghumOP	35.3	34.2	32.6	0.01	**6.5**	0.02	**6.5**	0.05	0.6	**0.74**	**9.0**	**35.3**	**7.7**	**Exceeded**
	KSsorghumSTD	35.1	35.5	33.1	0.01	**6.6**	0.02	**6.6**	0.05	0.6	**0.73**	**9.3**	**35.1**	**7.6**	**Exceeded**
Sorghum (Fallow) Aerial 1/0.5/1 lbs. a.i./A 14-day interval	TXsorghumOP	64.2	61.8	61	0.01	**12.2**	0.03	**12.2**	0.09	**1.0**	**1.34**	**16.3**	**64.2**	**14.0**	**Exceeded**
	KSsorghumSTD	54.1	52.9	52.1	0.01	**10.4**	0.03	**10.4**	0.08	0.9	**1.13**	**13.9**	**54.1**	**11.8**	**Exceeded**
Sorghum (Fallow) Ground 1/0.5/1 lbs. a.i./A 14-day interval	KSsorghumSTD	48.8	47.7	46.5	0.01	**9.3**	0.02	**9.3**	0.07	0.8	**1.02**	**12.6**	**48.8**	**10.6**	**Exceeded**
	TXsorghumOP	60.5	58.2	57.7	0.01	**11.5**	0.03	**11.5**	0.08	**1.0**	**1.26**	**15.3**	**60.5**	**13.2**	**Exceeded**
Sorghum (Fallow) Aerial 2/0.5 lbs. a.i./A 14-day interval	TXsorghumOP	76.5	73.2	71.3	0.01	**14.3**	0.04	**14.3**	**0.11**	**1.2**	**1.59**	**19.3**	**76.5**	**16.6**	**Exceeded**
	KSsorghumSTD	64.7	63.2	61.8	0.01	**12.4**	0.03	**12.4**	0.09	**1.1**	**1.35**	**16.6**	**64.7**	**14.1**	**Exceeded**

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Sugarcane Aerial 4/2/2/2 lbs a.i./A 14-day interval	FLsugarcaneSTD	331	321	307	0.06	**61.4**	**0.17**	**61.4**	**0.46**	**5.4**	**6.90**	**84.5**	**331.0**	**72.0**	**Exceeded**
	LAsugarcaneSTD	282	273	261	0.05	**52.2**	**0.14**	**52.2**	**0.39**	**4.6**	**5.88**	**71.8**	**282.0**	**61.3**	**Exceeded**
Sugarcane Ground 4/2/2/2 lbs a.i./A 14-day interval	FLsugarcaneSTD	316	307	293	0.06	**58.6**	**0.16**	**58.6**	**0.44**	**5.1**	**6.58**	**80.8**	**316.0**	**68.7**	**Exceeded**
	LAsugarcaneSTD	258	251	241	0.05	**48.2**	**0.13**	**48.2**	**0.36**	**4.2**	**5.38**	**66.1**	**258.0**	**56.1**	**Exceeded**
Wheat Ground 1/0.5/1 lbs a.i./A 14-day interval	NDWheat Split Treat	60.8	59.4	58.5	0.01	**11.7**	0.03	**11.7**	0.08	**1.0**	**1.27**	15.6	**60.8**	**13.2**	**Exceeded**
	TXWheat Split Treat	64.1	62.1	58.7	0.01	**11.7**	0.03	**11.7**	0.09	**1.0**	**1.34**	16.3	**64.1**	**13.9**	**Exceeded**
Wheat (Fallow) Ground 1 lb a.i./A 14-day interval	TXWheat Fallow	45	43.2	41	0.01	**8.2**	0.02	**8.2**	0.06	0.7	**0.94**	11.4	**45.0**	**9.8**	**Exceeded**
	NDWheat Fallow	30.7	30.8	31.2	0.01	**6.2**	0.02	**6.2**	0.04	0.5	**0.64**	8.1	**30.7**	**6.7**	**Exceeded**
Macadamia Nuts Ground 2/2 lbs. a.i./A 14-day interval	CA avocado	72	71	69.1	0.01	**13.8**	0.04	**13.8**	**0.10**	**1.2**	**1.50**	18.7	**72.0**	**15.7**	**Exceeded**
Guava Ground 4/4 lbs a.i./A 14-day interval	FL avocado	155	149	149	0.03	**29.8**	0.08	**29.8**	0.22	**2.5**	**3.23**	**39.2**	**155.0**	**33.7**	**Exceeded**
	CA citrus	14.2	13.6	12.2	0.00	**2.4**	0.01	**2.4**	0.02	0.2	0.30	3.6	**14.2**	**3.1**	**Exceeded**

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Turf (Spring) Ground 1/1 lbs a.i./A 14-day interval	Turf-Bermuda Spring	5.17	4.99	4.7	0.00	**0.9**	0.00	**0.9**	0.01	0.1	0.11	**1.3**	**5.2**	**1.1**	**Exceeded**
Turf (Fall) Ground 4/2 lbs a.i./A 14-day interval	Turf-St Aug Fall	9.76	9.51	8.78	0.00	**1.8**	0.00	**1.8**	0.01	0.2	0.20	**2.5**	**9.8**	**2.1**	**Exceeded**
Turf (Spring) Ground 4/2 lbs a.i./A 14-day interval	Turf-St Aug Spring	14.4	14	13.2	0.00	**2.6**	0.01	**2.6**	0.02	0.2	0.30	**3.7**	**14.4**	**3.1**	**Exceeded**
CRP Aerial 2 lbs a.i./A	RangeBSS	43.3	41.7	38.7	0.01	**7.7**	0.02	**7.7**	0.06	0.7	**0.90**	**11.0**	**43.3**	**9.4**	**Exceeded**
	MeadowBSS	34.8	33.6	32	0.01	**6.4**	0.02	**6.4**	0.05	0.6	**0.73**	**8.8**	**34.8**	**7.6**	**Exceeded**
	CArangelandhay RLF_V2	25.1	24.4	23.4	0.00	**4.7**	0.01	**4.7**	0.03	0.4	**0.52**	**6.4**	**25.1**	**5.5**	**Exceeded**
CRP Ground 2 lbs a.i./A	RangeBSS	37.1	35.6	33.1	0.01	**6.6**	0.02	**6.6**	0.05	0.6	**0.77**	**9.4**	**37.1**	**8.1**	**Exceeded**
	MeadowBSS	28.3	27.3	25.7	0.01	**5.1**	0.01	**5.1**	0.04	0.5	**0.59**	**7.2**	**28.3**	**6.2**	**Exceeded**
	CArangelandhay RLF_V2	17.2	16.5	15.7	0.00	**3.1**	0.01	**3.1**	0.02	0.3	0.36	**4.3**	**17.2**	**3.7**	**Exceeded**
Roadsides Ground 1 lb a.i./A	KS Corn	43.9	43.2	41.9	0.01	**8.4**	0.02	**8.4**	0.06	0.7	**0.91**	**11.4**	**43.9**	**9.5**	**Exceeded**
	NE Corn	42.7	42	40.8	0.01	**8.2**	0.02	**8.2**	0.06	0.7	**0.89**	**11.1**	**42.7**	**9.3**	**Exceeded**
	ND Wheat	24.8	24.6	24	0.00	**4.8**	0.01	**4.8**	0.03	0.4	**0.52**	**6.5**	**24.8**	**5.4**	**Exceeded**

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 3 Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Conifers Aerial 4 lbs a.i./A	GAPecansSTD	113	110	104	0.02	**20.8**	0.06	**20.8**	0.16	**1.8**	**2.35**	**28.9**	**113.0**	**24.6**	**Exceeded**
	MICherriesSTD	76.4	75	73.1	0.01	**14.6**	0.04	**14.6**	0.11	**1.3**	**1.59**	**19.7**	**76.4**	**16.6**	**Exceeded**
	ORXmasTreeSTD	36.8	36.1	35	0.01	**7.0**	0.02	**7.0**	0.05	0.6	**0.77**	**9.5**	**36.8**	**8.0**	**Exceeded**
Conifers Ground 4 lbs a.i./A	GAPecansSTD	101	98.2	93	0.02	**18.6**	0.05	**18.6**	0.14	**1.6**	**2.10**	**25.8**	**101.0**	**22.0**	**Exceeded**
	MICherriesSTD	51	50.1	48.9	0.01	**9.8**	0.03	**9.8**	0.07	0.8	**1.06**	**13.2**	**51.0**	**11.1**	**Exceeded**
	ORXmasTreeSTD	12.3	12.1	11.7	0.00	**2.3**	0.01	**2.3**	0.02	0.2	0.26	**3.2**	**12.3**	**2.7**	**Exceeded**

Table 104. Summary of SWCC Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 24c Labels. Maximum, minimum, and median estimates of water concentrations, RQs, and the number of modeling scenarios resulting in level of concern exceedances. Shaded cells identify LOC exceedances for listed species and bolded values indicate non-listed LOC exceedances. *RQs for listed species of aquatic plants were not evaluated because exceedances of the non-listed LOCs indicate that risks to listed species are expected.

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 24 c Labels					RQs										
Crop (Application Rate)	SWCC Scenario	Peak	21-day	60-day	Acute FW Fish	Chronic FW Fish	Acute EM Fish	Chronic EM Fish	Acute FW Inverts	Chronic FW Inverts	Acute EM Inverts	Chronic EM Inverts	Non-Vascular Plants	Vascular Plants	CELOC
Sorghum (Fallow) Aerial 1.25 lbs a.i./A	KSsorghumSTD	37.9	37.8	37.1	0.01	**7.4**	0.02	**7.4**	0.05	0.6	**0.79**	**9.9**	**37.9**	**8.2**	**Exceeded**
	TXsorghumOP	45.9	44.3	39.9	0.01	**8.0**	0.02	**8.0**	0.06	0.7	**0.96**	**11.7**	**45.9**	**10.0**	**Exceeded**
Sorghum (Fallow) Ground 1.25 lbs a.i./A	KSsorghumSTD	33.5	33.3	32.8	0.01	**6.6**	0.02	**6.6**	0.05	0.6	**0.70**	**8.8**	**33.5**	**7.3**	**Exceeded**
	TXsorghumOP	42.7	41.2	36.9	0.01	**7.4**	0.02	**7.4**	0.06	0.7	**0.89**	**10.8**	**42.7**	**9.3**	**Exceeded**

Estimated Environmental Concentrations (µg/L) for Atrazine from Non-Corn Uses on Section 24 c Labels					RQs										
Crop (Application Rate)	**SWCC Scenario**	**Peak**	**21-day**	**60-day**	**Acute FW Fish**	**Chronic FW Fish**	**Acute EM Fish**	**Chronic EM Fish**	**Acute FW Inverts**	**Chronic FW Inverts**	**Acute EM Inverts**	**Chronic EM Inverts**	**Non-Vascular Plants**	**Vascular Plants**	**CELOC**
Wheat (Fall Fallow) Aerial 0.5 lbs a.i./A	TXwheatOP	27.9	26.5	25.4	0.01	**5.1**	0.01	**5.1**	0.04	0.4	**0.58**	**7.0**	**27.9**	**6.1**	**Exceeded**
	NDwheatSTD	15.7	15.3	15.3	0.00	**3.1**	0.01	**3.1**	0.02	0.3	0.33	**4.0**	**15.7**	**3.4**	**Exceeded**
Wheat (Spring Fallow) Ground 0.5 lbs a.i./A	TXwheatOP	22.2	21.4	19.8	0.00	**4.0**	0.01	**4.0**	0.03	0.4	0.46	**5.6**	**22.2**	**4.8**	**Exceeded**
	NDwheatSTD	16.8	16.3	15.3	0.00	**3.1**	0.01	**3.1**	0.02	0.3	0.35	**4.3**	**16.8**	**3.7**	**Exceeded**
Roadsides Ground 2 lbs a.i./A	Kscorn	87.8	86.4	83.8	0.02	**16.8**	0.04	**16.8**	0.12	**1.4**	**1.83**	**22.7**	**87.8**	**19.1**	**Exceeded**
CRP Ground 2 lbs. a.i./A	MeadowBSS	26.8	25.9	24.5	0.01	**4.9**	0.01	**4.9**	0.04	0.4	**0.56**	**6.8**	**26.8**	**5.8**	**Exceeded**
	RangeBSS	36.4	35.3	33.3	0.01	**6.7**	0.02	**6.7**	0.05	0.6	**0.76**	**9.3**	**36.4**	**7.9**	**Exceeded**
	CArangelandhayRLF_V2	27.5	27.2	26.4	0.01	**5.3**	0.01	**5.3**	0.04	0.5	**0.57**	**7.2**	**27.5**	**6.0**	**Exceeded**
CRP Aerial 2 lbs. a.i./A	MeadowBSS	31.3	30.3	28.6	0.01	**5.7**	0.02	**5.7**	0.04	0.5	**0.65**	**8.0**	**31.3**	**6.8**	**Exceeded**
	RangeBSS	40.6	39.3	37.1	0.01	**7.4**	0.02	**7.4**	0.06	0.7	**0.85**	**10.3**	**40.6**	**8.8**	**Exceeded**
	CArangelandhayRLF_V2	35.8	35.3	34.3	0.01	**6.9**	0.02	**6.9**	0.05	0.6	**0.75**	**9.3**	**35.8**	**7.8**	**Exceeded**

15.2.1. Sorghum Uses

Current Section 3 and Section 24c labels with sorghum uses allow for single maximum application rates from 1 to 2 lbs a.i./A, and there is a maximum allowable annual rate of 2.5 lbs a.i./A. These uses result in risk concerns from acute exposure to listed freshwater invertebrates (RQs from 0.05 to 0.11), listed and non-listed estuarine/marine invertebrates (RQs 0.73 to 1.6) and aquatic plants (RQs from 7.3 to 76.5), as well as chronic risks to freshwater and estuarine/marine fish (RQs from 6.5 to 14.3), listed and non-listed freshwater invertebrates (RQs from 0.6 to 1.2), listed and non-listed estuarine/marine invertebrates (RQs 9.0 to 19.3) amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses). These risks are similar to those following corn applications and are discussed further in section 15.1.

15.2.2. Sugarcane Uses

Current Section 3 labels with sugarcane uses allow for single maximum application rates of 4 lbs a.i./A, and there is a maximum allowable annual rate of 10 lbs a.i./A. These uses result in risk concerns from acute exposure to listed freshwater and estuarine/marine fish (RQs from 0.06 to 0.17), listed and non-listed freshwater and estuarine/marine invertebrates (RQs 0.36 to 6.9) and all aquatic plants (RQs from 56 to 331). Chronic risk concerns include all of these taxa as well, with freshwater and estuarine/marine fish (RQs 48.2 to 61.8), freshwater and estuarine/marine invertebrates (RQs 4.2 to 84.5), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses). These risks are substantially greater than those following corn applications (discussed in section 15.1.) due to the increased single and maximum annual application rates.

The geographic isolation of sugarcane production in the conterminous U.S. reduces the breadth of potential habitats impacted by atrazine runoff from Sugarcane uses, however these agricultural lands are in close proximity to wetlands, and freshwater and estuarine marine habitats in southern Texas, Louisiana, and southern Florida.

15.2.3. Wheat Uses

Current Section 3 labels with wheat uses allow for single maximum application rates up to 1 lb a.i./A, and there is a maximum allowable annual rate of 2.5 lbs a.i./A. These uses result in risk concerns from acute exposure to listed freshwater invertebrates (RQs from 0.04 to 0.09), listed and non-listed estuarine/marine invertebrates (RQs from 0.64 to 1.34) and aquatic plants (RQs from 6.7 to 64). Chronic risks following all uses are expected for freshwater and estuarine/marine fish (RQs from 6.2 to 11.7), freshwater and estuarine/marine invertebrates (RQs 0.5 to 64.1), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses).

Current Section 24c labels with wheat uses allow for single maximum application rates up to 0.5 lbs a.i./A, and there is a maximum allowable annual rate of 0.5 lbs a.i./A. These uses result in risk concerns from acute exposure to listed and non-listed estuarine/marine invertebrates (RQs from 0.33 to 0.58) and aquatic plants (RQs from 3.7 to 28). Following these applications, chronic risks to listed and non-listed freshwater and estuarine/marine fish (RQs from 3.1 to 5.1), freshwater and estuarine/marine invertebrates (RQs 4.0 to 7.0), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC exceeded) are expected.

These risks from applications to wheat are similar to those following corn applications and are discussed further in section 15.1.

15.2.4. Roadside Uses

Roadside uses under section 3 and section 24c labels allow for single applications up to 1 and 2 lbs a.i./A, respectively, and only a single application per year. The section 3 labeled rates result in risk concerns to fish (RQs from 4.8 to 8.4), freshwater and estuarine/marine invertebrates (RQs 0.4 to 11.4), amphibians (See WOE discussion, **Section 15.1.3**), and aquatic plants and communities from chronic exposures, as well as risk to aquatic invertebrates (Freshwater RQs from 0.03-0.06, Estuarine/Marine RQs from 0.52 to 0.91) from acute exposures.

Section 24c application rates result in LOC exceedances for all taxa on an acute (except fish) and chronic exposure basis. Risk Quotients for chronic exposures are 16.8 for fish, and 1.4 to 22.7 for aquatic invertebrates, and exceed the CELOC. Amphibians are also anticipated to be at risk from these uses, see WOE for discussion. Following acute exposures the RQs are 0.12 to 1.8 for aquatic invertebrates, and 19 to 88 for aquatic plants.

These risks are similar to those following corn applications and are discussed further in section 15.1.

15.2.5. Macadamia Nut Uses

Current Section 3 labels with macadamia nut uses allow for single maximum application rate of 2 lbs a.i./A, and there is a maximum allowable annual rate of 4 lbs a.i./A. These uses result in risk concerns from acute exposure to listed and non-listed freshwater and estuarine marine invertebrates (RQs from 0.1 to 1.5), and aquatic plants (RQs from 16 to 72). Chronic risk concerns include these taxa as well, with freshwater and estuarine/marine fish (RQ of 13.8), freshwater and estuarine/marine invertebrates (RQs 18.7), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses). These risks are substantially greater than those following corn applications (discussed in section 15.1.) due to the increased single and maximum annual application rates.

15.2.6. Guava Uses

Current Section 3 labels with guava uses allow for single maximum application rate of 4 lbs a.i./A, and there is a maximum allowable annual rate of 8 lbs a.i./A. These uses result in risk concerns from acute exposure to listed and non-listed estuarine/marine fish (RQ of 0.08), listed and non-listed invertebrates (RQs from 0.2 to 2.5), and aquatic plants (RQs from 3.1 to 155). Chronic risk concerns include all of these taxa as well, with freshwater and estuarine/marine fish (RQs from 2.4 to 29.8), freshwater and estuarine/marine invertebrates (RQs 0.2 to 39.2), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses). These risks are greater than those following corn applications (discussed in section 15.1.) due to the increased single and maximum annual application rates.

15.2.7. Turf Uses

Current Section 3 labels with turf uses allow for single maximum application rate of 1 to 4 lbs a.i./A, and there is a maximum allowable annual rate of 6 lbs a.i./A. These uses result in risk concerns from acute exposure to listed and non-listed freshwater and estuarine marine invertebrates (RQs from 0.1 to 0.3), and aquatic plants (RQs from 1.1 to 14). Chronic risk concerns to freshwater and estuarine/marine fish (RQs from 9.4 to 26), freshwater and estuarine/marine invertebrates (RQs 0.1 to 3.7), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses). These risks from applications to turf are similar to those following corn applications and are discussed further in section 15.1.

15.2.8. Conservation Reserve Program (CRP) Uses

Current Section 3 and Section 24c labels with CRP uses allow for single maximum application rates of 2 lbs a.i./A, and there is a maximum allowable annual rate of 2 lbs a.i./A. These uses result in risk concerns from acute exposure to freshwater invertebrates (RQs from 0.02 to 0.06), estuarine/marine invertebrates (RQs from 0.36 to 0.9) and aquatic plants (RQs from 3.7 to 43). Chronic risks to freshwater and estuarine/marine fish (RQs from 3.1 to 7.7), freshwater and estuarine/marine invertebrates (RQs 0.3 to 11.0), amphibians (see WOE discussion in corn **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses) are also expected from these uses. These risks are similar to those following corn applications and are discussed further in section 15.1.

15.2.9. Conifer Uses

Current Section 3 labels with conifer uses allow for single maximum application rate of 4 lbs a.i./A, and there is a maximum allowable annual rate of 4 lbs a.i./A. These uses result in risk concerns from acute exposure to listed estuarine/marine fish (RQs from 0.01 to 0.06), listed

and non-listed freshwater and estuarine marine invertebrates (RQs from 0.2 to 2.35), and aquatic plants (RQs from 2.7 to 113). There are also risk concerns to freshwater and estuarine/marine fish (RQs from 2.3 to 20.8), freshwater and estuarine/marine invertebrates (RQs 0.2 to 28.9), amphibians (see WOE discussion in corn, **Section 15.1.3**), aquatic plants and aquatic plant communities (CELOC Exceeded for all uses) based on chronic exposures. These risks from applications to conifers are similar to those following corn applications and are discussed further in section 15.1.

16. DESCRIPTION OF UNCERTAINTIES, LIMITATIONS AND ASSUMPTIONS

16.1. Exposure uncertainties

Uncertainties in the aquatic exposure assessment are associated with the application rates of co-formulated atrazine products, environmental fate properties of atrazine, quality assurance of the monitoring data, and interpolation of monitoring data for calculation of average concentrations for the exposure assessment.

The SWCC modeling was conducted using a single atrazine soil metabolism half-life (139 days) multiplied by 3 as per model input parameter guidance (Brady, 2009). This multiplier was used to approximate the upper 90th confidence bound on the mean half-life. Although the multiplier increased the aerobic soil metabolism half-life from 139 days to 417 days, this modification in half-life has minimal impact on the predicted EECs from SWCC. The adjusted atrazine half-life in soil, however, is within the range of half-lives for atrazine from the open-literature data (13-1800 days).

16.2. Monitoring data

The atrazine monitoring data were derived from available databases including NWIS, STORET, state, registrant, etc. For the most part, the atrazine concentrations reported in the monitoring programs were taken at face value. However, a quality assurance check was conducted on reported atrazine concentrations above 500 µg/L. These high concentrations were found in the STORET database from a few reporting units such as The KAW Nation, The SAC and FOX Nations, MN state monitoring program. These concentrations, in most cases, are reported in ng/L rather than µg/L (Email Communication from Francine Hackett for KAW Nation on 6/19/2015; and, Lisa Montgomery for SAC and FOX Nation of Missouri in Kansas and Nebraska on 6/18/2015). Therefore, the actual concentration is 1000th of the reported concentration; for example, the 3,020 ng/L is actually 3.020 µg/L. The highest confirmed concentrations reported in STORET (500 to 20,000 µg/L) are associated with LA Department of Environmental Quality monitoring study. These data represent surface water samples around an intensive sugarcane production area in 2012. The highest concentration reported in the non-STORET databases (683.4 µg/L) is associated with an atrazine spill (Williams, Ronald W., 2012). This QA process

indicates the STORET monitoring data contain reporting errors. The extent of these errors is difficult to quantify. Additionally, atrazine occurrence at some sampling sites may be caused by unique circumstances that are not identified in the reported monitoring data.

Average concentrations from monitoring data were calculated using a stair step interpolation between measured values. The stair step interpolation was used to avoid assuming linear interpolation between measured values. To address the uncertainty with interpolation of monitoring data, sampling site-years with 12 or more samples per year were used for estimating the 21-day and 60 day average atrazine concentrations. Twelve samples would represent in the worst case, a single sample each month for a year. Because calculation of average concentrations require at least two measured values, the selection of 12 or more samples are expected to provide a reasonable number of measured concentrations for calculation of average concentrations.

16.3. Impact of atrazine on chemical mixtures in the environment

As outlined in **Section 5.1,** atrazine is co-formulated with 22 different active ingredients in 52 formulated products, indicating that it is co-applied with other active ingredients when used in standard formulations. In addition to these multi a.i. products, it is well documented that tank mixtures and environmental mixtures occur, resulting in the presence of chemical mixtures in both terrestrial and aquatic environments. USGS summarized the composition of pesticide mixtures observed in surface water samples collected throughout the US during the 1990s. The analysis determined that herbicides were the most commonly detected pesticides within agricultural areas, with atrazine and its degradates being the most frequently detected (found in 2/3 of all samples taken from streams with agricultural landcovers representing their watersheds). More than 50% of the stream samples had ≥5 different active ingredients. Atrazine and metolachlor were the most commonly detected mixture in agricultural watersheds, followed by atrazine/prometon/metolachlor (USGS, 1999). A review of NAWQA data collected between 1992 and 2001 showed that atrazine, metolachlor, and cyanazine were the most frequently detected herbicides in agricultural watersheds (USGS, 2006). Mixture composition varied over time, with different compositions of chemicals and relative amounts measured. **Table 105** includes the most frequently detected mixtures of pesticide active ingredients in streams with agricultural watersheds.

Table 105. The most common unique mixtures of pesticides and degradates found in stream waters with agricultural watersheds. (USGS, 2006).

Number of chemicals in mixture	Chemicals present	Frequency of detection in agricultural streams (percentage of time)
2	Atrazine Metolachlor	77
	Atrazine Deethylatrazine	77
	Atrazine Simazine	64
	Atrazine Prometon	50
	Prometon Simazine	41
	Deethylatrazine Metolachlor	69
	Deethylatrazine Simazine	57
3	Atrazine Deethylatrazine Prometon	48
	Atrazine Prometon Simazine	41
	Atrazine Diazinon Simazine	16
	Atrazine Diazinon Prometon	10
	Diazinon Prometon Simazine	9
	Atrazine Deethylatrazine Metolachlor	69
	Atrazine Deethylatrazine Simazine	57
	Atrazine Metolachlor Simazine	57
4	Atrazine Deethylatrazine Metolachlor Simazine	52
	Atrazine Deethylatrazine Metolachlor Prometon	45
	Alachlor Atrazine Deethylatrazine Metolachlor	42
	Atrazine Deethylatrazine Prometon Simazine	39
	Atrazine Metolachlor Prometon Simazine	38
	Atrazine Diazinon Prometon Simazine	9
5	Atrazine Deethylatrazine Metolachlor Prometon Simazine	37
	Alachlor Atrazine Deethylatrazine Metolachlor Prometon	33
	Alachlor Atrazine Deethylatrazine Metolachlor Simazine	33
	Atrazine Cyanazine Deethylatrazine Metolachlor Simazine	33
	Alachlor Atrazine Deethylatrazine Prometon Simazine	26
	Atrazine Deethylatrazine Metolachlor Simazine Tebuthiuron	19
	Atrazine Deethylatrazine Prometon Simazine Tebuthiuron	16
	Atrazine Diazinon Metolachlor Prometon Simazine	8
	Atrazine Deethylatrazine Diazinon Prometon Simazine	8
	Atrazine Carbaryl Diazinon Prometon Simazine	2

The presence of chemical mixtures in terrestrial and aquatic environments is a concern due to the potential for one chemical to increase the toxicity of another chemical. Atrazine has been reported to synergistically increase the toxicity of organophosphates in aquatic invertebrates (Anderson and Lydy, 2002; Perez et al., 2013) and terrestrial invertebrates (Chen et al., 2015). There are also examples of atrazine having an antagonistic effect on toxicity or a relationship that can change from being antagonistic at low doses to becoming synergistic at higher doses (Yang et al., 2015). Due to this complexity, it is difficult to quantitatively predict the impact of all chemical combinations that can exist in the environment, and this remains an uncertainty in the assessment. However, due to the widespread detection of atrazine in the aquatic environment, the potential for atrazine to increase the toxicity of other chemicals must be considered in the overall risk picture.

16.4. Drinking water risks to birds and mammals

Based on the analysis conducted using the SIP model (**Section 6.5**) in the Problem Formulation, drinking water exposure was identified as a potential risk for mammals and birds due to chronic but not acute exposure. SIP is a screening model based on conservative assumptions using the solubility limit of atrazine. For birds, drinking water exposure was one of the pathways incorporated into the refined analysis using TIM and the TIM/MCnest (beta) model. Based on the TIM output, drinking water exposure was not identified as the predominant pathway of concern (relative to diet and dermal exposure) although this is based on acute toxicity in TIM whereas SIP identified risks based on chronic toxicity. Although EPA is currently working on refined methodologies to incorporate drinking water as an exposure route to terrestrial organisms such as birds and mammals, these tools are still in development and are not available at this time. Given the frequent detection of atrazine in the aquatic environment, not accounting for risks from drinking water could underestimate the chronic risks to mammals and birds and remains as an area of uncertainty in this risk assessment.

16.5. Effects uncertainties – general

The toxicity assessment for terrestrial and aquatic plants and animals is limited by the number of species tested in the available toxicity studies. Use of toxicity data on representative species does not provide information on the potential variability in susceptibility to acute and chronic exposures.

Although the risk assessment relies on a selected toxicity endpoint from the most sensitive species tested, it does not necessarily mean that the selected toxicity endpoints reflect sensitivity of the most sensitive species existing in a given environment. The relative position of the most sensitive species tested in the distribution of all possible species is a function of the overall variability among species to a particular chemical. The relationship between the sensitivity of the most sensitive tested species versus wild species (including listed species) is

unknown and a source of significant uncertainty. In addition, in the case of listed species, there is uncertainty regarding the relationship of the listed species' sensitivity and the most sensitive species tested.

16.6. New Scientific Studies, Reviews and Monitoring Data.

Studies on atrazine are published in the open literature every year. This assessment attempted to include all of the available monitoring data and relevant primary scientific literature identified through EPA's ECOTOX program up to June 2014. This assessment also includes all registrant-submitted studies received through December 2015. Due to timing constraints, some of the registrant-submitted studies that arrived late in 2015 are addressed in **Appendix H** and not in the main document, however, it is important to note that none of these studies were found to change risk conclusions described in the assessment.

EPA continues to monitor the scientific literature and will include additional studies, as appropriate, in any future updates to this risk assessment.

16.7. Atrazine degradates

As demonstrated in **Table 105** the degradates of atrazine are one of the most frequently detected chemicals in aquatic monitoring data along with the parent compound. Atrazine degradates are also expected to form in the terrestrial environment. There are data available on degradates from both the exposure and effects database, but data deficiencies do remain (*e.g.*, no information on chronic effects from degradates in birds and limited information in fish). Therefore, uncertainty remains in assessing the risks from degradates in the terrestrial and aquatic environment.

16.8. Pollinators

Although atrazine is classified as practically non-toxic to bees based on the acute contact study with a reported LD_{50} value >97 µg a.i./bee (5% mortality reported at the highest dose tested), this is the only available registrant study regarding toxicity to pollinators. Exposure assessments for honey bees were calculated using the new pollinator guidance. Based on Tier I exposure estimates for contact exposure and a maximum single application rate of 4 lb a.i./A, the exposure estimate was 10.8 µg/bee. The RQ based on the Tier I exposure estimate and non-definitive LD_{50} was 0.11. This is below the LOC of 0.4. At a maximum yearly application rate of 10 lb a.i./A as labeled for sugarcane use, the RQ is 0.28 and is still less than the LOC. No additional data were available for honey bee toxicity; therefore RQs based on adult oral exposure or larval exposure were not calculated.

The Agency has recently issued interim guidance for assessing the potential risks of pesticides to bees and the data needed to support such assessments (USEPA et al., 2014). The guidance

document indicates that if exposure of bees to a pesticide is expected, a Tier I risk assessment is conducted. Using the new pollinator guidance to estimate terrestrial invertebrate risk, an RQ value for acute contact toxicity in the honey bee was calculated as 0.11; less than the LOC of 0.4 for acute exposure. However, risk to pollinators (e.g., honey bees) is an uncertainty due to the lack of data (i.e. oral or larval honey bee exposure with atrazine) available in order to complete the Tier 1 risk assessment. If risk concerns are identified in the screening-level assessment, the assessment may be refined using data that further define exposure or through additional toxicity data from Tier II semi-field or Tier III full-field studies conducted with whole colonies.

16.9. Endangered Species

Consistent with EPA's responsibility under the Endangered Species Act (ESA), the Agency will evaluate risks to federally listed threatened and endangered (listed) species from registered uses of pesticides in accordance with the Joint Interim Approaches developed to implement the recommendations of the April 2013 National Academy of Sciences (NAS) report, *Assessing Risks to Endangered and Threatened Species from Pesticides*. The NAS report outlines recommendations on specific scientific and technical issues related to the development of pesticide risk assessments that EPA and the Services must conduct in connection with their obligations under the ESA and FIFRA. EPA will address concerns specific to atrazine in connection with the development of its final registration review decision for atrazine.

In November 2013, EPA, the U.S. Fish and Wildlife Service, National Marine Fisheries (the Services), and USDA released a white paper containing a summary of their joint Interim Approaches for assessing risks to listed species from pesticides. These Interim Approaches were developed jointly by the agencies in response to the NAS recommendations, and reflect a common approach to risk assessment shared by the agencies as a way of addressing scientific differences between the EPA and the Services. Details of the joint Interim Approaches are contained in the November 1, 2013 white paper, *Interim Approaches for National-Level Pesticide Endangered Species Act Assessments Based on the Recommendations of the National Academy of Sciences April 2013 Report.*

Given that the agencies are continuing to develop and work toward implementation of the Interim Approaches to assess the potential risks of pesticides to listed species and their designated critical habitat, this ecological problem formulation supporting the Preliminary Work Plan for atrazine does not describe the specific ESA analysis, including effects determinations for specific listed species or designated critical habitat, to be conducted during registration review. While the agencies continue to develop a common method for ESA analysis, the planned risk assessment for the registration review of atrazine will describe the level of ESA analysis completed for this particular registration review case. This assessment will allow EPA to focus its future evaluations on the types of species where the potential for effects exists, once the scientific methods being developed by the agencies have been fully vetted. Once the agencies have fully developed and implemented the scientific methods necessary to

complete risk assessments for listed species and their designated critical habitats, these methods will be applied to subsequent analyses of atrazine as part of completing this registration review. EPA will complete its effects determination and initiate consultation for atrazine by 2020.

17. SCOPE OF NATIONAL AQUATIC SPECIES AND PLANT COMMUNITIES POTENTIALLY IMPACTED BY ATRAZINE EXPOSURE.

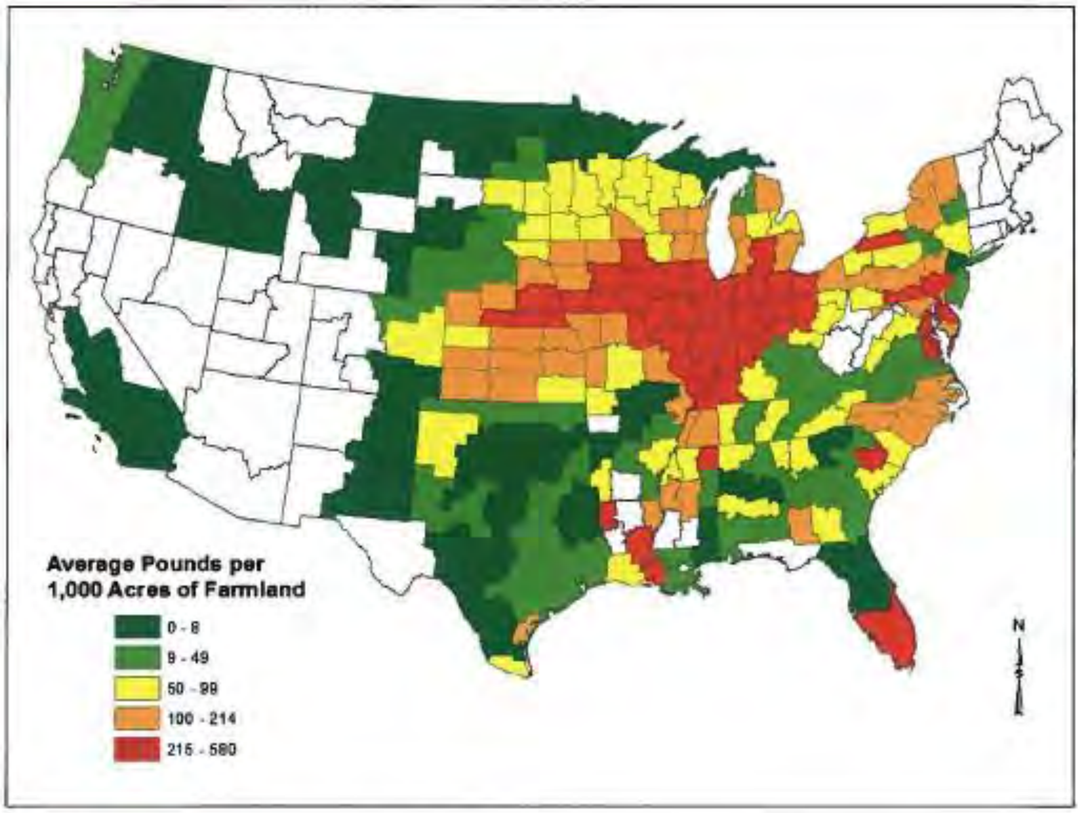
The extent of the atrazine levels exceeding the terrestrial and aquatic levels of concern and the Aquatic Plant Community CELOC is reviewed in this section. The available monitoring data from Federal, State, Local and Registrant sources, as well as from results of the WARP model, are used to identify where detections have exceeded and not exceeded the aquatic LOCs. The monitoring data is useful for watersheds that have characteristics outside of the ranges used in the development of the WARP model, and WARP is useful for identifying watersheds with potential risk to aquatic taxa and communities following atrazine use.

Following a brief discussion of the geographic extent of national risk concerns, the available monitoring data and WARP results relevant to each state are discussed. In this review of the monitoring data, the data were parsed into two categories, "Prior to 2006" and "2006-2014". These categories were selected to account for potential differences in exposure from lowering the maximum label rates, which began in 2006. For every monitoring station considered in this portion of the assessment, the peak, 21-day average, and 60-day average atrazine concentrations within each calendar year were calculated to determine whether levels of concern were exceeded in any of the years in which monitoring data were collected for that station (site-year). An additional consideration in the state by state summary below, is the consideration of the data which had less than 12 samples for a given year. These data did not have 21-day or 60-day average concentrations calculated, however were included in separate column for purposes of comparing appropriate acute endpoints to the reported peak concentrations.

17.1. National Risk Picture

17.1.1. National Distribution of Risk to Terrestrial Species

The potential footprint of atrazine risk to terrestrial animals and plants is associated with those lands and adjacent habitats where atrazine is applied or is transported to through spray drift and/or runoff. It is assumed that for agricultural uses the landscape for potential chronic risk to mammals and birds, and risk to terrestrial plants and communities looks much like the agricultural map of reported atrazine use (**Figure 73**). However, for non-agricultural uses and those uses not included in the atrazine use survey data (see **Section 5** for details), such as range grasses, conservation reserve program, turf grasses, fallow land, roadsides, Christmas tree plantations and conifer forests, the potential risk landscape would extend into the white areas on the map in **Figure 73**.



Sources:
Proprietary Data. 2006-2010
USDA, 2006-2010. NASS Crop Reporting Districts.
USDA, 2007. Census of Agriculture.

Figure 73. Atrazine Usage by Crop Reporting District (2006-2010).

17.1.2. National Distribution of Risk to Aquatic Species and Communities

17.1.2.1. *Interpretation of Maps*

As discussed in **Section 7.3.2** the mean and maximum atrazine concentrations calculated using these NLCD or CDL agricultural layers are exactly the same on a state by state basis. However, the number of watersheds that exceed a given LOC may differ, and typically is lower for the CDL results. For the discussions that follow, both the NLCD and CDL results are summarized in terms of the frequency of each aquatic LOC that is exceeded, however mapping is only provided for the CDL results.

The maps illustrating WARP results in the following sections show the probability of a HUC12 exceeding a particular level of concern. These mapped probabilities are the average

probabilities predicted from model runs for 2006, 2007, 2008, and 2009 based on the atrazine use and weather data for that year. As discussed in section **7.3.2,** there are five variables that WARP uses in the analysis, one of which is the atrazine use rate. In these maps, those HUC12s that have use rates for any of the modeled years above those parameterized in the WARP model (57 kg/km^2) are identified with a grey hatch pattern, and are not used in the comparison to aquatic levels of concern. Nevertheless, these watersheds are most often identified in the highest reported use regions, and are therefore considered watersheds of concern. Also presented on the maps are the applicable water monitoring data (see **section 7.4** for more details on these data). Comparisons to the acute levels of concern included all available georeferenced monitoring data. Comparisons to the chronic levels of concern and for the CELOC included only those georeferenced monitoring sites that collected 12 or more samples.

Figure 74 is an example from the state level scale of mapping. Georeferencenced monitoring sites with 12 or more samples per year are identified as green when the reported concentration is below the CELOC or level of concern. The background colors are representing the probability of exceeding a given threshold, in this case the CELOC. Black areas are those HUC12s with one or more years that have atrazine use rates above 57 kg/km^2, and those HUC12s colored grey have one or more of the other WARP input parameters that are outside of the model limits. Interpretation of the results for this example is that there are identifiable regions from WARP results and monitoring data that have exceeded the CELOC or have an increased probability to do so. The monitoring data that exceed the CELOC are located in regions that either identified as having high probabilities of exceeding the CELOC or had watershed properties that were outside of the WARP model parameter allowances. Also notable in this example are the watersheds that are identified with higher probabilities of exceedance that are not associated with georeferenced monitoring data.

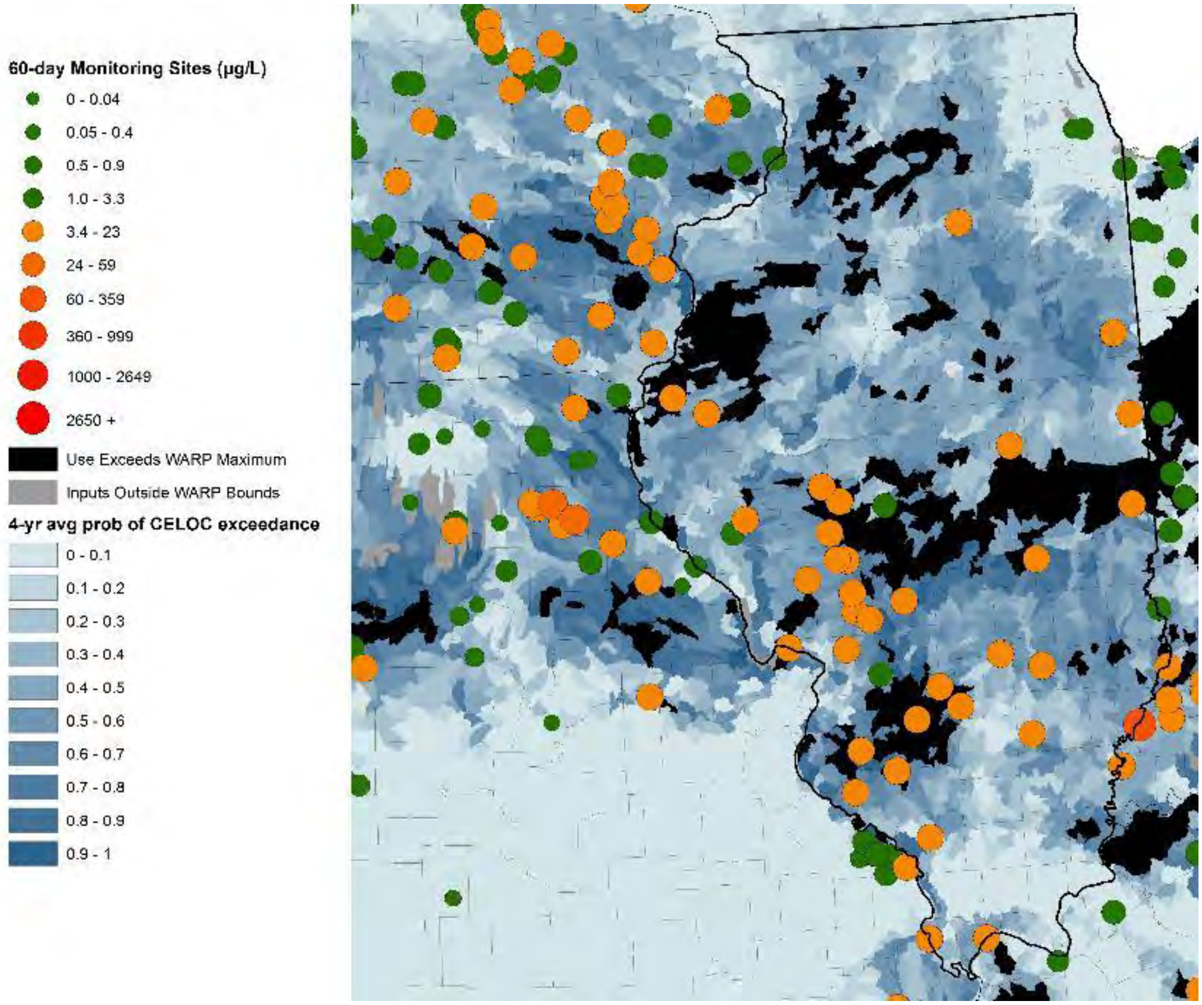


Figure 74. Example State Scale Map showing WARP probabilities of exceeding the CELOC and the distribution to georeferenced monitoring data which exceed this threshold.

17.1.2.2. ***Nationwide Geographic Distribution of the observed and predicted probability of Exceeding Chronic Levels of Concern for Freshwater Fish***

As discussed in the risk characterization and conclusions section (**Section 15.1.1**) the primary risk concern for freshwater and estuarine marine fish are from chronic exposures based on reproductive effects at 0.5 µg/L. The probability of a HUC12 having concentrations in flowing water systems that exceed this 60-day concentration is shown in **Figure 75**. This distribution of exceedance probability is corroborated by the available georeferenced monitoring data that had 12-samples or more in a given year (**Figure 76**). These data suggest that if atrazine is used according to current application rates, the chronic fish level of concern has a high probability of being exceeded across the agricultural use area (**Figure 73**) and that exceedances have been detected in monitoring data across this landscape.

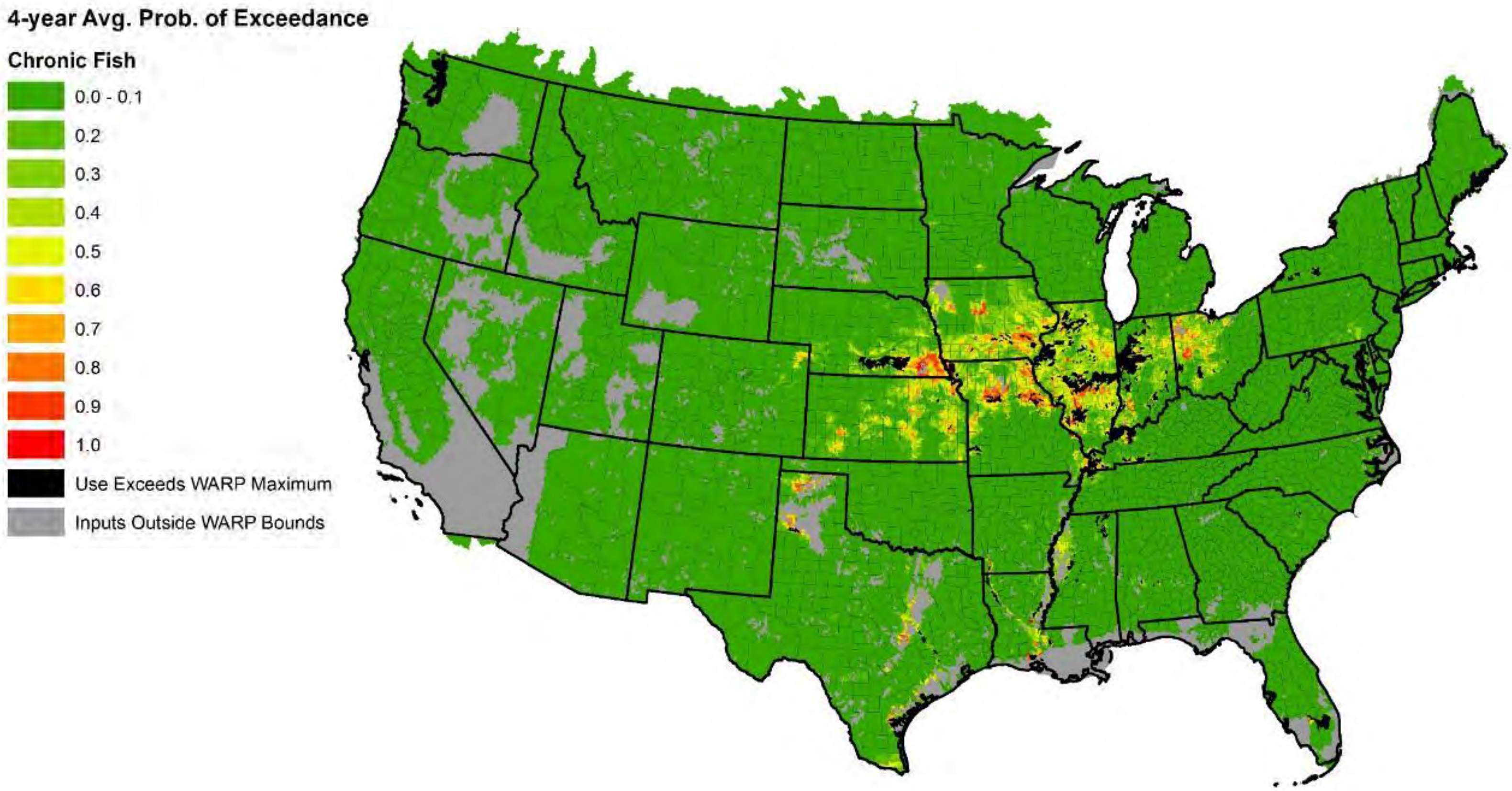


Figure 75. 4-year average probability of exceeding the chronic fish level of concern.

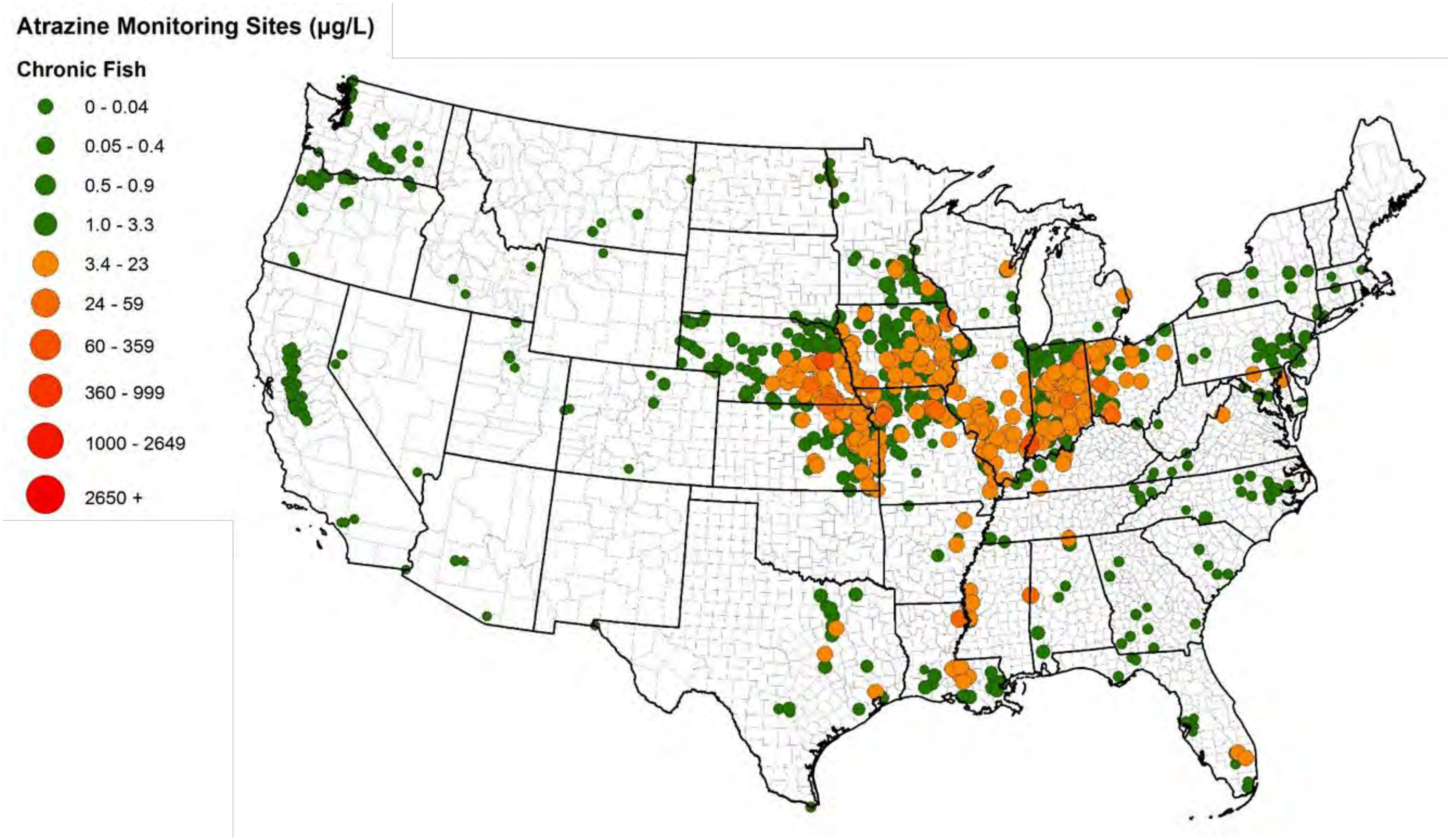


Figure 76. Distribution of georeferenced monitoring sites with 12 or more samples/year and with maximum average 60-day concentrations exceeding (orange to red) the chronic fish level of concern.

17.1.2.3. ***Nationwide Geographic Distribution of the observed and predicted probability of Exceeding Levels of Concern for Freshwater Invertebrates***

The probability of exceeding the acute and chronic levels of concern for freshwater invertebrates are presented in **Figure 77** and **Figure 79.** Based on the WARP analysis, there is a low probability of exceeding the acute invertebrate level of concern, however there are several regions that have high probabilities of exceeding the chronic level of concern (**Figure 79**).The monitoring data are also showing low frequency of monitoring sites exceeding these levels of concern (**Figure 78** and **Figure 80**).

Figure 77. 4-year average probability of exceeding the acute freshwater invertebrate level of concern.

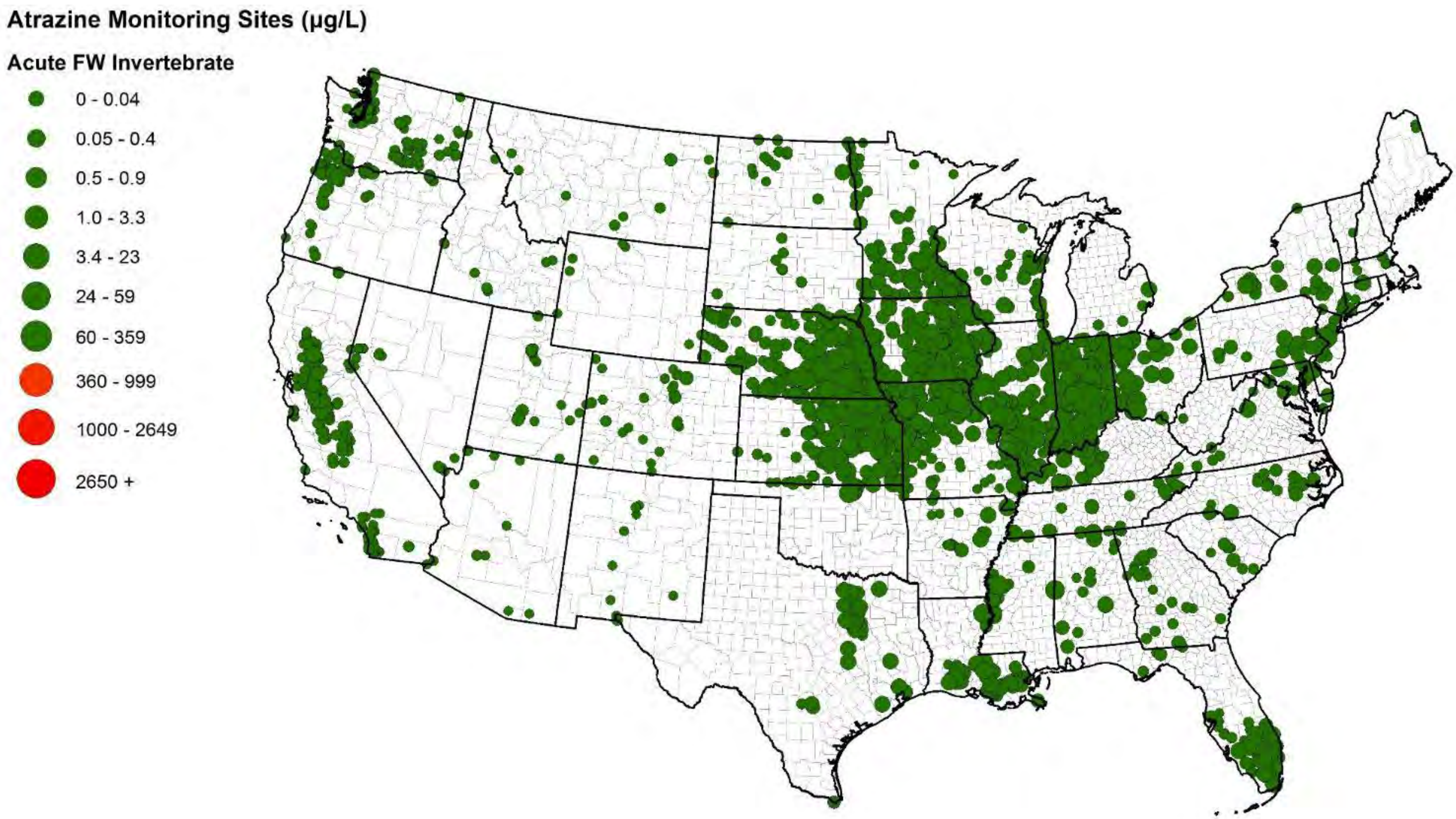


Figure 78. Distribution of monitoring sites with 12 or more samples and peak concentrations exceeding the acute freshwater invertebrate level of concern.

Figure 79. 4-year average probability of exceeding the chronic freshwater invertebrate level of concern

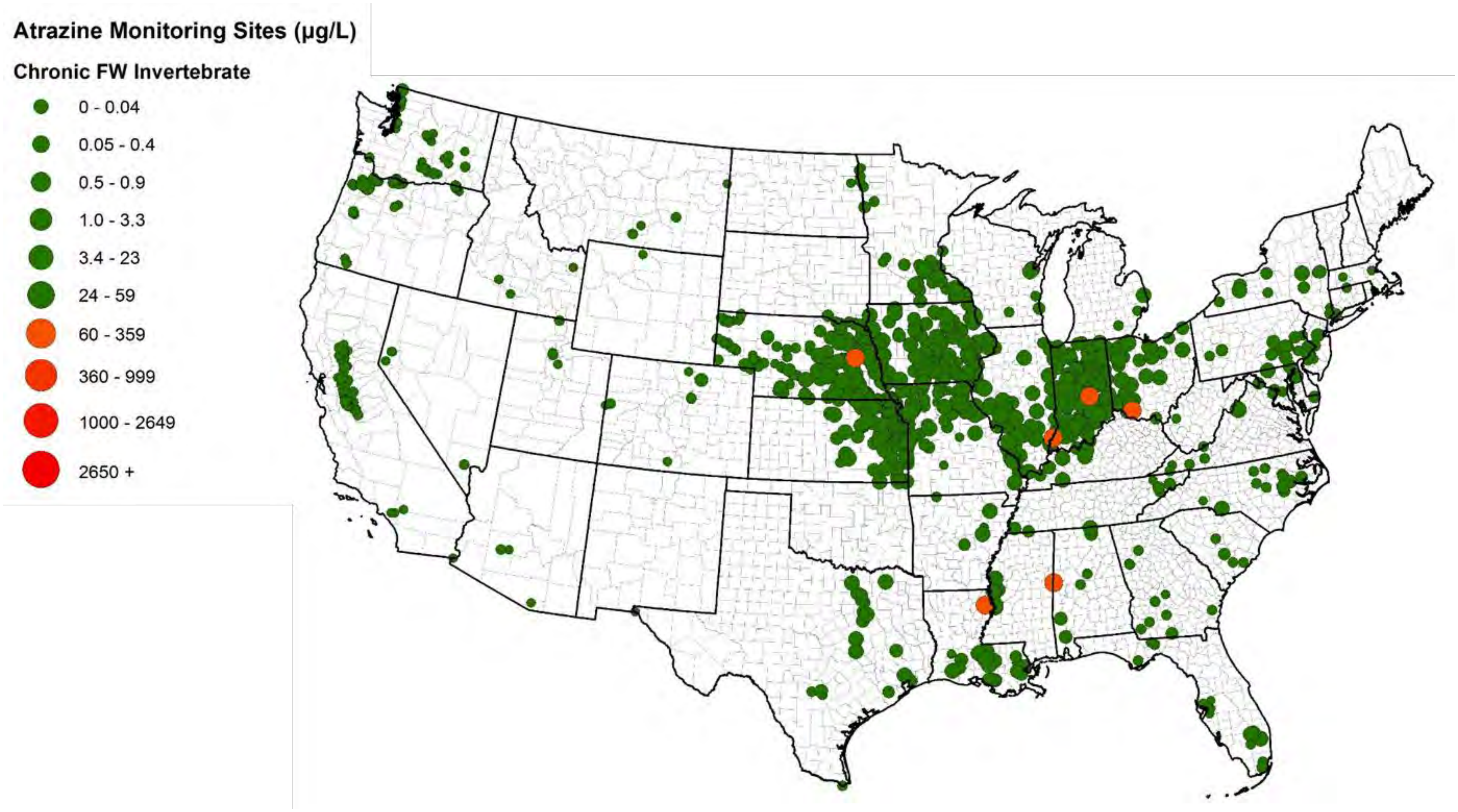


Figure 80. Geographic distribution of monitoring sites with 21-day maximum average concentrations exceeding the chronic freshwater invertebrate level of concern.

17.1.2.4. ***Nationwide Geographic Distribution of the observed and predicted probability of Exceeding Levels of Concern for Plants***

The probability of exceeding the levels of concern for aquatic non-vascular and vascular plants is high for nearly all of the agricultural use area **Figure 81** and **Figure 83**). These predictions are supported by the available monitoring data (**Figure 82** and **Figure 84**). These data suggest that if atrazine is used according to current application rates, there is a high probability of exceeding these levels of concern across the agricultural use area (**Figure 73**) and that exceedances have been detected in monitoring data across this landscape.

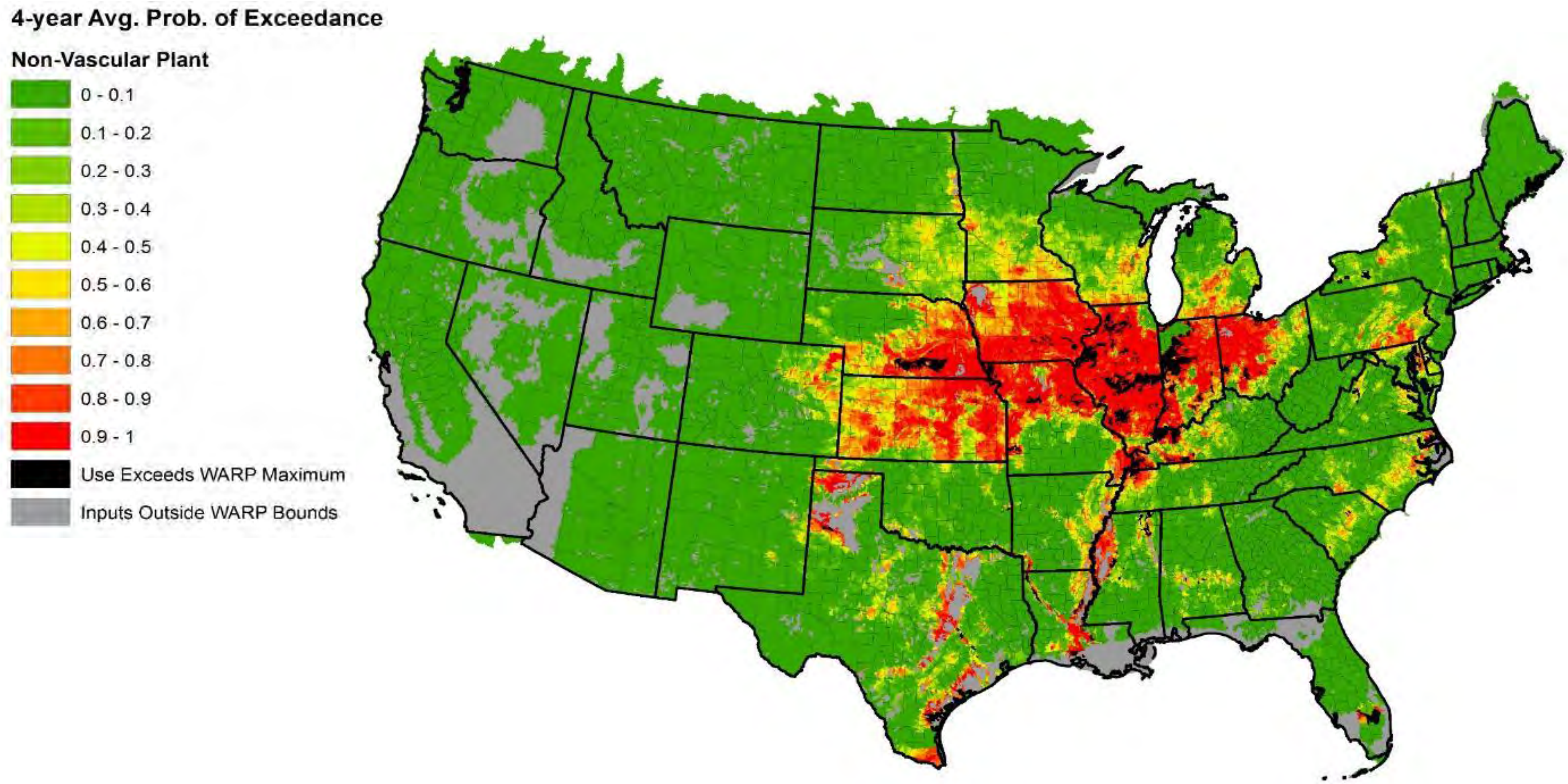


Figure 81, 4-year average probability of exceeding the aquatic non-vascular plant level of concern

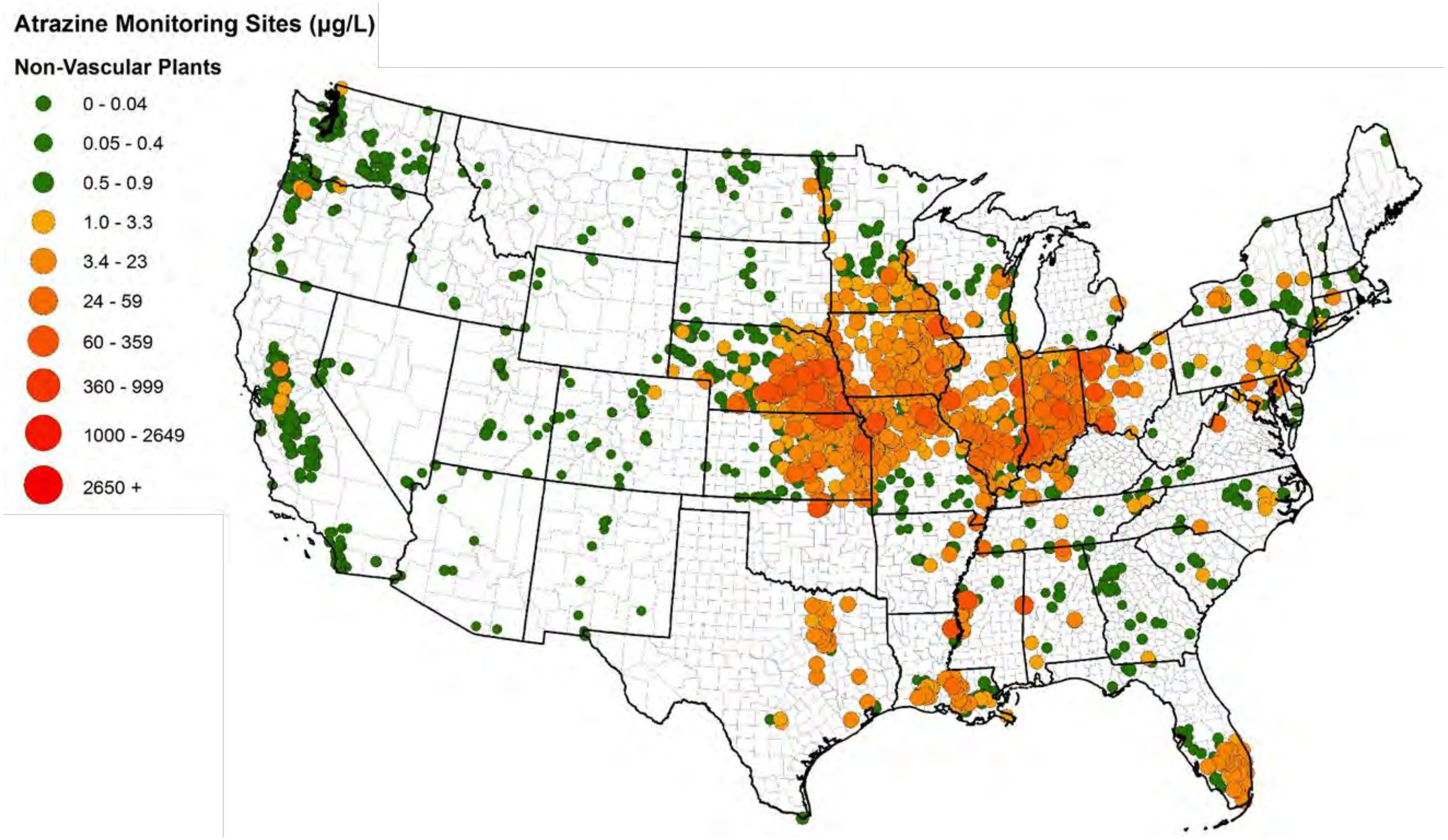


Figure 82. Geographic distribution of monitoring sites with peak concentrations exceeding the non-vascular aquatic plant level of concern.

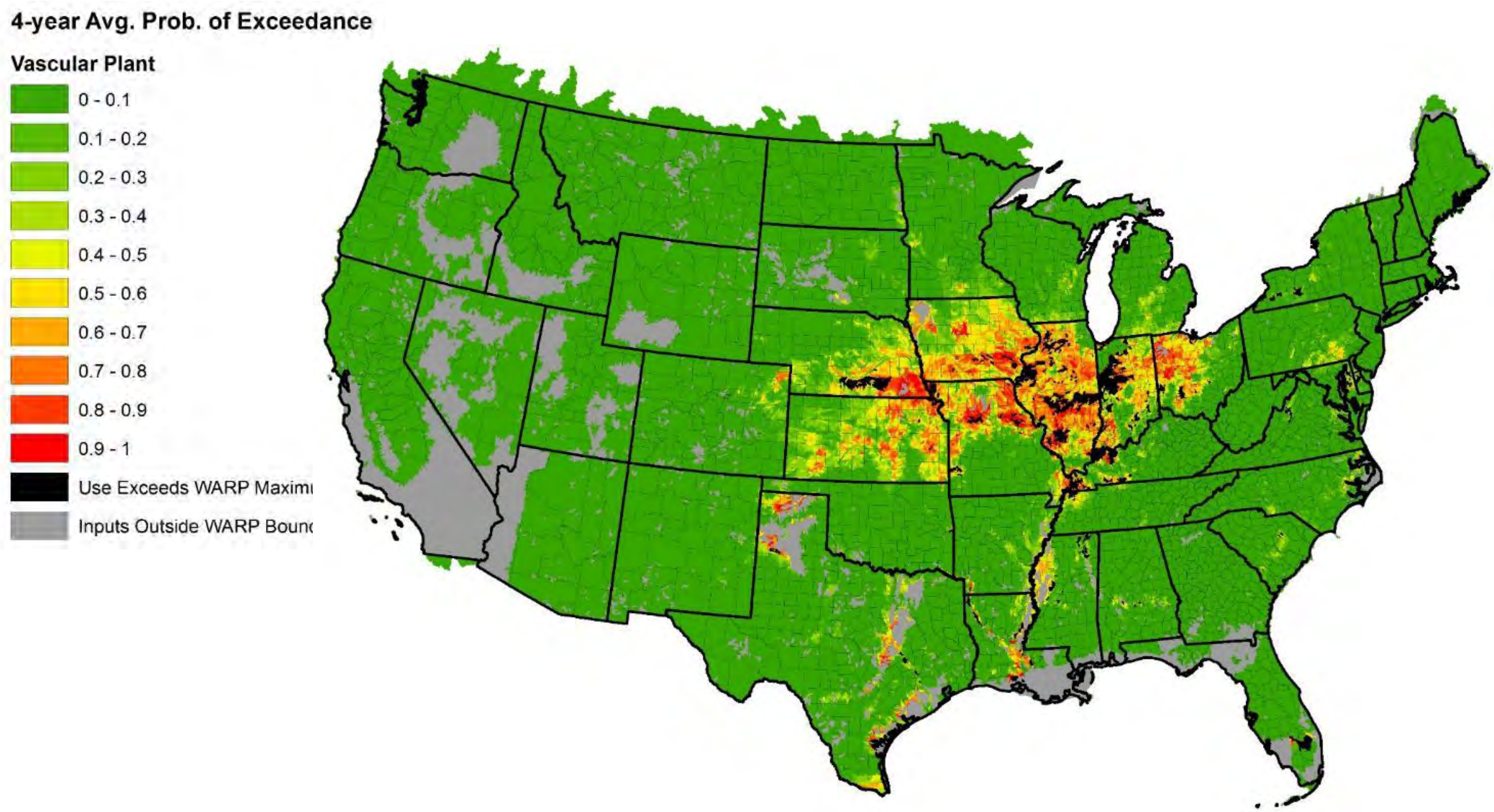


Figure 83. 4-year average probability of exceeding the aquatic vascular plant level of concern

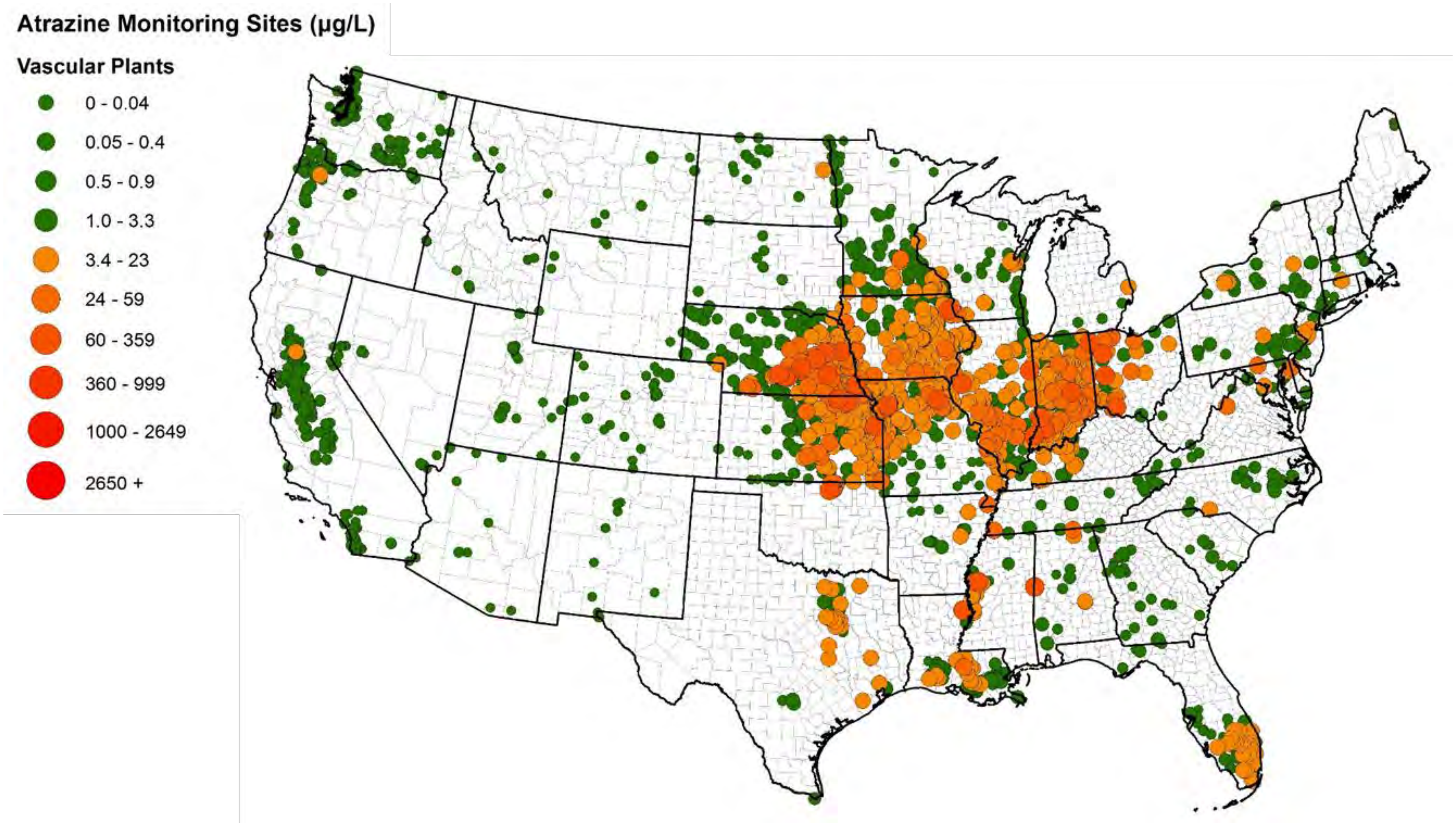


Figure 84. Geographic distribution of monitoring sites with peak concentrations exceeding the vascular aquatic plant level of concern.

17.1.2.5. ***Nationwide Geographic Distribution of the observed and predicted probability of Exceeding the CELOC***

The CELOC is the level of concern for aquatic plant communities above which there is a 50% or greater chance of having an effect aquatic plant communities. The biological complexity of a community and its connection to other organisms makes exceedances of the CELOC particularly alarming. The highest probabilities of exceeding the CELOC are primarily centered in the midwestern corn belt (**Figure 85**) however high exceedance probabilities are predicted across much of the atrazine use area. Measured 60-day average concentrations from monitoring data support this conclusion, and substantiate the risks to these communities over a broad landscape (**Figure 86**).

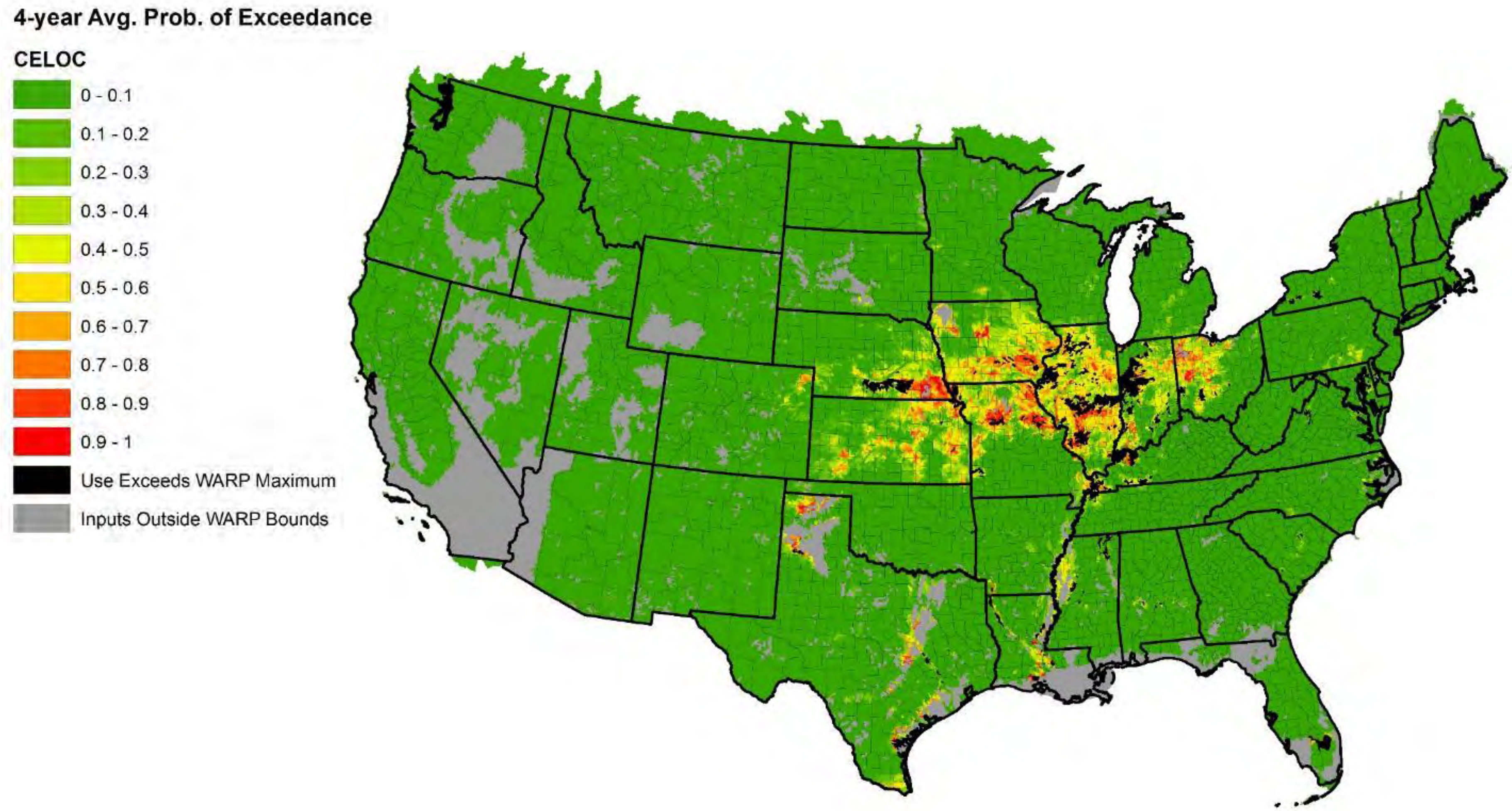


Figure 85. 4-year average probability of exceeding the aquatic plant community level of concern (CELOC)

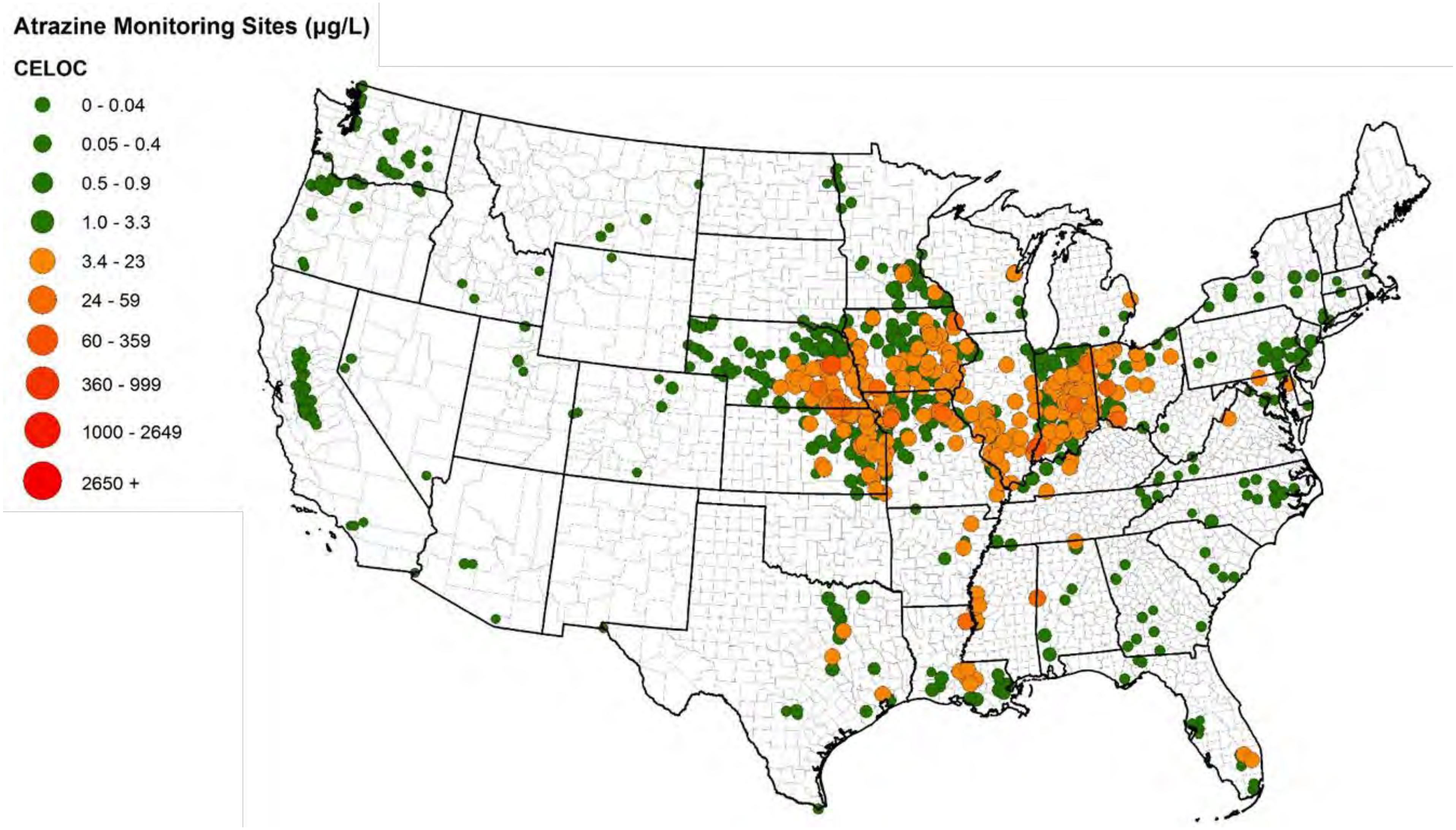


Figure 86. Geographic distribution of monitoring sites with 60-day concentrations exceeding the CELOC

17.2. State By State Summary of Monitoring Data and WARP Results

This section provides a summary of the monitoring data concentrations, WARP model results, and aquatic taxa LOCs and CELOC exceedances for each state (listed alphabetically).

Monitoring Data

Tables are provided that summarize the entirety of the monitoring data for each state. **Appendix O** contains all of the monitoring data presented in this section and includes additional information such as the monitoring site and source of data. The available monitoring data have been segregated into two general time periods, “Prior to 2006” and “2006-2014”, selected based on label modification that reduced application rates for corn in 2006. In addition, monitoring data with less than 12 samples within a year are were used for calculating the 21-day or 60-day concentration, however these data are provided separately for illustrating peak concentrations and relevant acute LOC exceedances as there is less confidence in the 21 and 60 day estimates than in the data with greater than 12 samples.

A summary of the AEEMP and the other available monitoring data are provided in **Figure 87** and **Figure 88**. The AEEMP data represent some of the most robust water monitoring data that have been collected for atrazine. The data suggest that there are frequent exceedances of the CELOC across the geographic region of the midwestern states corn and sorghum production, see **Section 7.4** for more discussion of this monitoring program. Summarizing the monitoring data by state and in contrast to the CELOC enables a quick evaluation within each state as well as a different perspective of the national risks that were described in **Section 17.1.2**. For further details within each state please refer to the data provided in the tables provided later in this section.

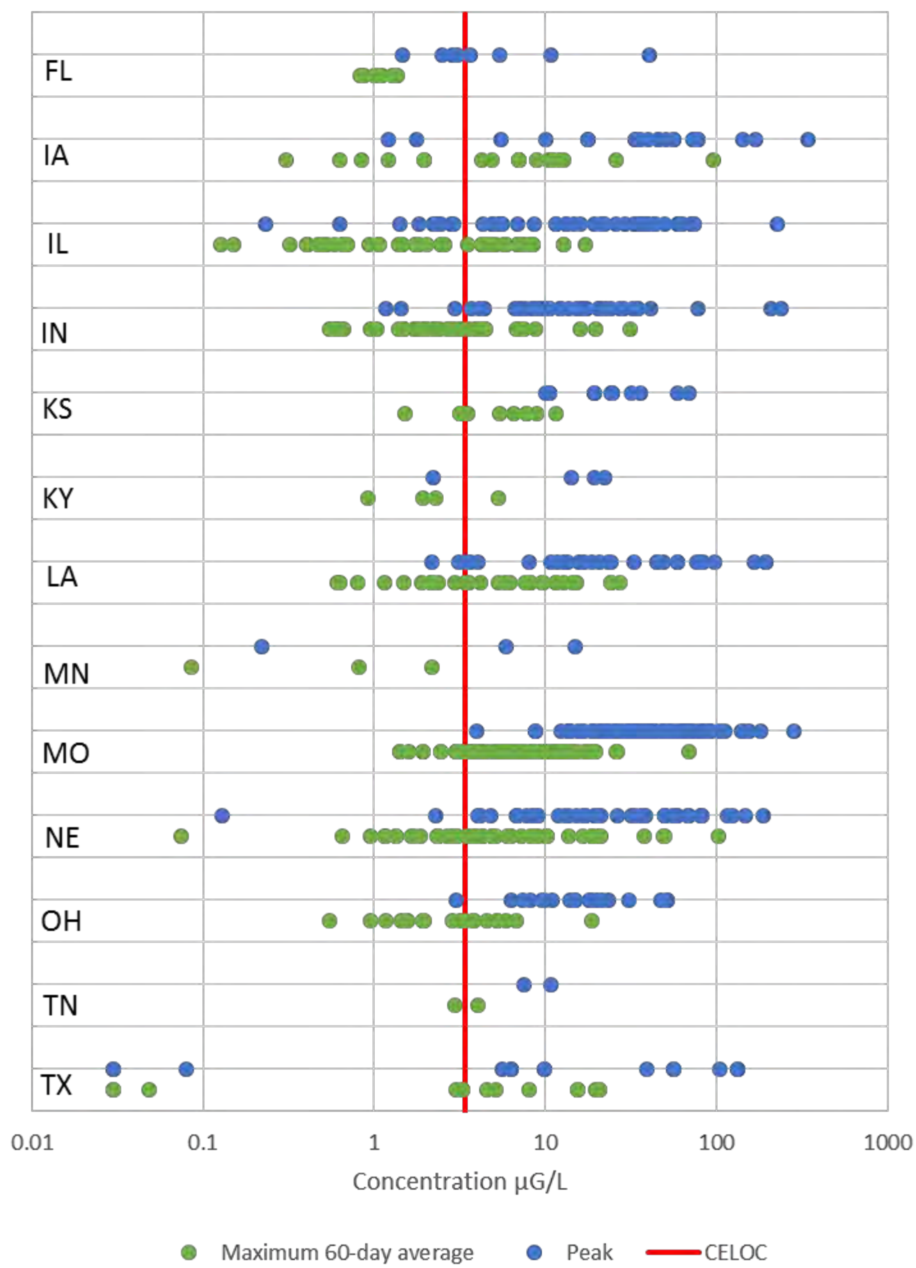


Figure 87. Summary of the maximum 60-day average and peak atrazine concentration reported in the AEEMP data. The CELOC is provided as a reference for the maximum 60-day average concentrations that exceed the threshold.

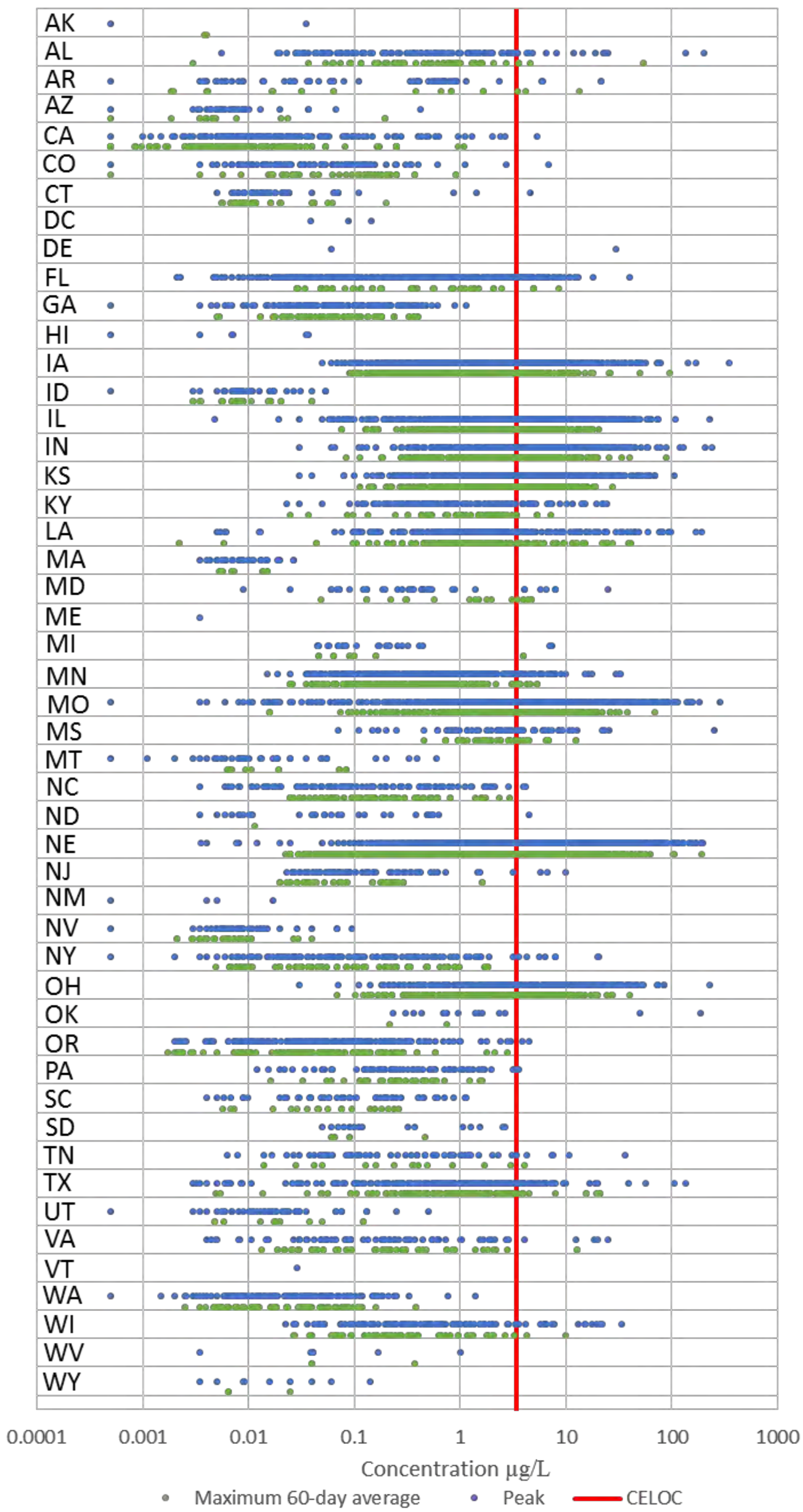


Figure 88. Summary of the maximum 60-day average and peak atrazine concentrations reported in the available monitoring data. Maximum peak concentrations rely upon the entirety of the available monitoring data, whereas the maximum 60-day averages were included from only those site-year data with 12 or more samples per year. The CELOC is provided as a reference to illustrate states with 60-day average concentrations that exceed the threshold

WARP Results

A table summarizing the WARP predicted concentrations and number of HUC12 watersheds with LOC exceedances for each individual year and the 4-year average is provided for each state (except Hawaii and Alaska). The number of watersheds included for each year differed year to year for some states because some watersheds did not meet the validation criteria of the WARP model. Watersheds that were excluded because the estimated atrazine use-rate was too high are considered exceeding levels of concern for aquatic taxa and exceeding the CELOC. The number of watersheds excluded and those that had high use rates are provided and illustrated on the maps.

Mapping

Maps are provided for states that were identified as having watersheds with significant probabilities of exceeding the CELOC based on the WARP analyses. As discussed earlier in **Section 17**, many monitoring stations did not include latitude and longitude coordinate data, so these maps only reflect the sites where this information was provided. Additionally, the watersheds identified with the WARP analysis only reflect the model estimates from reported agricultural use, and do not provide a good estimate the distribution of risk for use outside of the surveyed regions, or for non-agricultural use such as on turf, forestry, rangeland, or conservation reserve program lands.

17.2.1. Alabama.

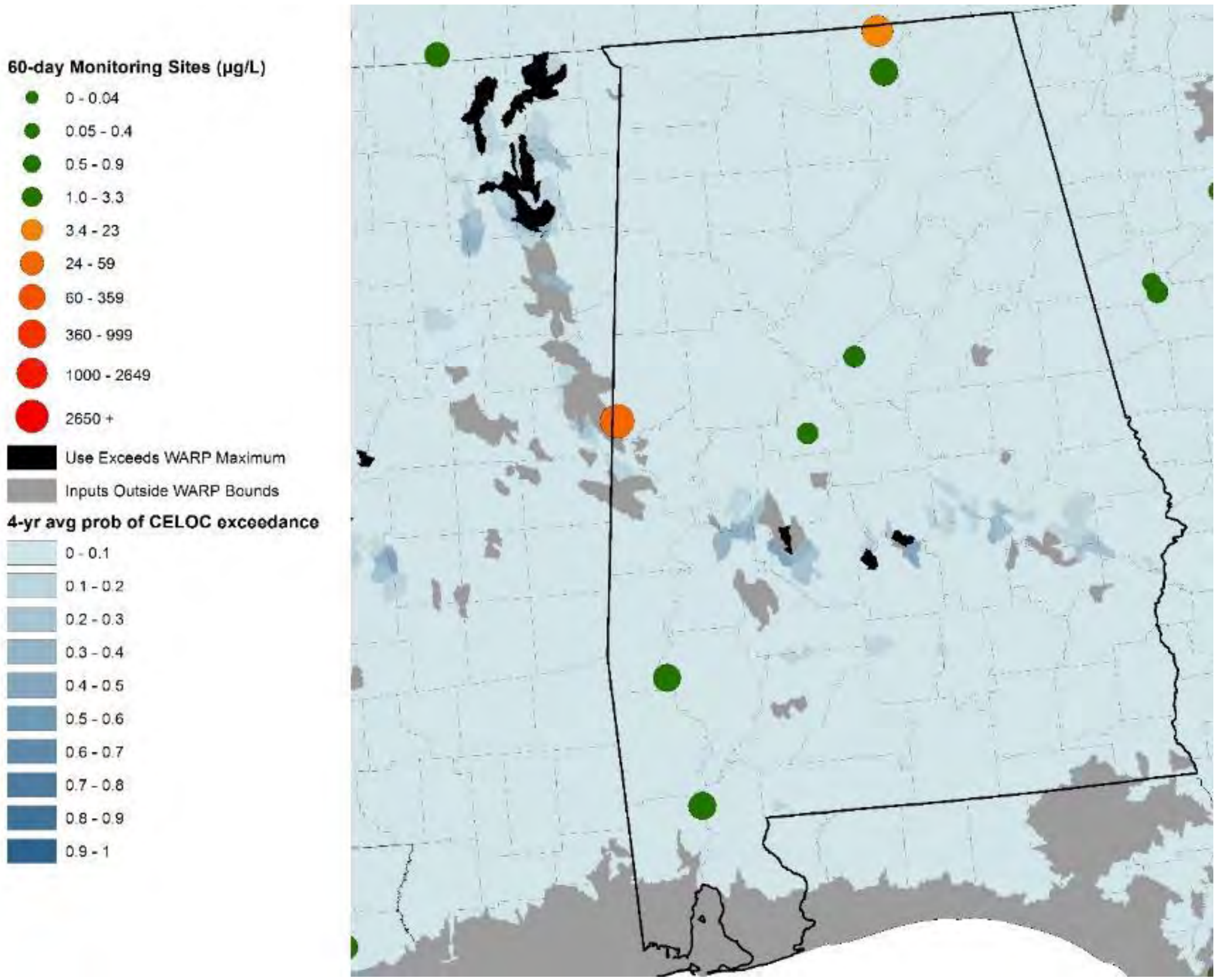
Monitoring Data Summary: Bias Factors were not used for Alabama (see Section 7.4.1.4). Based on these data there were exceedances of several aquatic animal and aquatic plant LOCs.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years		56	270	39	19
Maximum Measured Exposure Concentrations (ug/L)	**Maximum**	3.16	136.00	11.77	201.00
	Maximum 21-day Average	2.54	82.10	11.77	135.28
	Maximum 60-day Average	1.56	33.55	4.64	54.29
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0
	Chronic FW Fish	0	9	0	2
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	9	0	2
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	1	0	2
	Acute EM Inverts	0	4	0	4
	Chronic EM Inverts	0	12	2	4
	Non-Vascular Plants	4	42	19	10
	Vascular Plants	0	10	1	2
	CELOC	0	11	1	4

<u>Alabama</u>: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Alabama had 87 watersheds shown as excluded in the map below, 4 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1406	1402	1406	1405	1402
Max 4-day average concentration (µg/L)		3.47	32.43	5.57	20.76	14.55
Max 21-day average concentration (µg/L)		2.48	19.98	3.81	13.45	9.20
Max 60-day average concentration (µg/L)		1.64	11.72	2.33	8.08	5.48
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	5	0	2	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	5	0	2	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	1	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	22	88	77	97	76
	Vascular Plants	0	17	4	14	9
	CELOC	0	10	0	6	3

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.2. Alaska.

Few data were available for the surface waters of Alaska. Bias Factors were not used for Alaska (see **Section 7.4.1.4**). The WARP model was not used for this state because there is little to no reported use in the available WARP input use matrix. Aquatic LOCs were not exceeded based on these data.

State		AK	AK	AK
Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		10	13	2
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.00	<0.01	0.04
	Maximum 21-day Average	<0.01	<0.01	0.01
	Maximum 60-day Average	<0.01	<0.01	0.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0
	Chronic FW Fish	0	0	0
	Acute EM Fish	0	0	0
	Chronic EM Fish	0	0	0
	Acute FW Inverts	0	0	0
	Chronic FW Inverts	0	0	0
	Acute EM Inverts	0	0	0
	Chronic EM Inverts	0	0	0
	Non-Vascular Plants	0	0	0
	Vascular Plants	0	0	0
	CELOC	0	0	0

17.2.3. Arizona.

Few data were available for the surface waters of Arizona. Bias Factors were not used for Arizona (see **Section 7.4.1.4**). Aquatic LOCs were not exceeded based on these data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		69	83	11	4
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.05	0.71	0.42	0.04
	Maximum 21-day Average	0.02	0.07	0.31	0.04
	Maximum 60-day Average	0.01	0.07	0.19	0.02
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Arizona: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Arizona had 703 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		3201	2585	3201	3201	2585
Max 4-day average concentration (µg/L)		0.84	0.25	0.61	0.58	0.57
Max 21-day average concentration (µg/L)		0.64	0.20	0.47	0.45	0.44
Max 60-day average concentration (µg/L)		0.44	0.14	0.33	0.31	0.31
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.4. Arkansas.

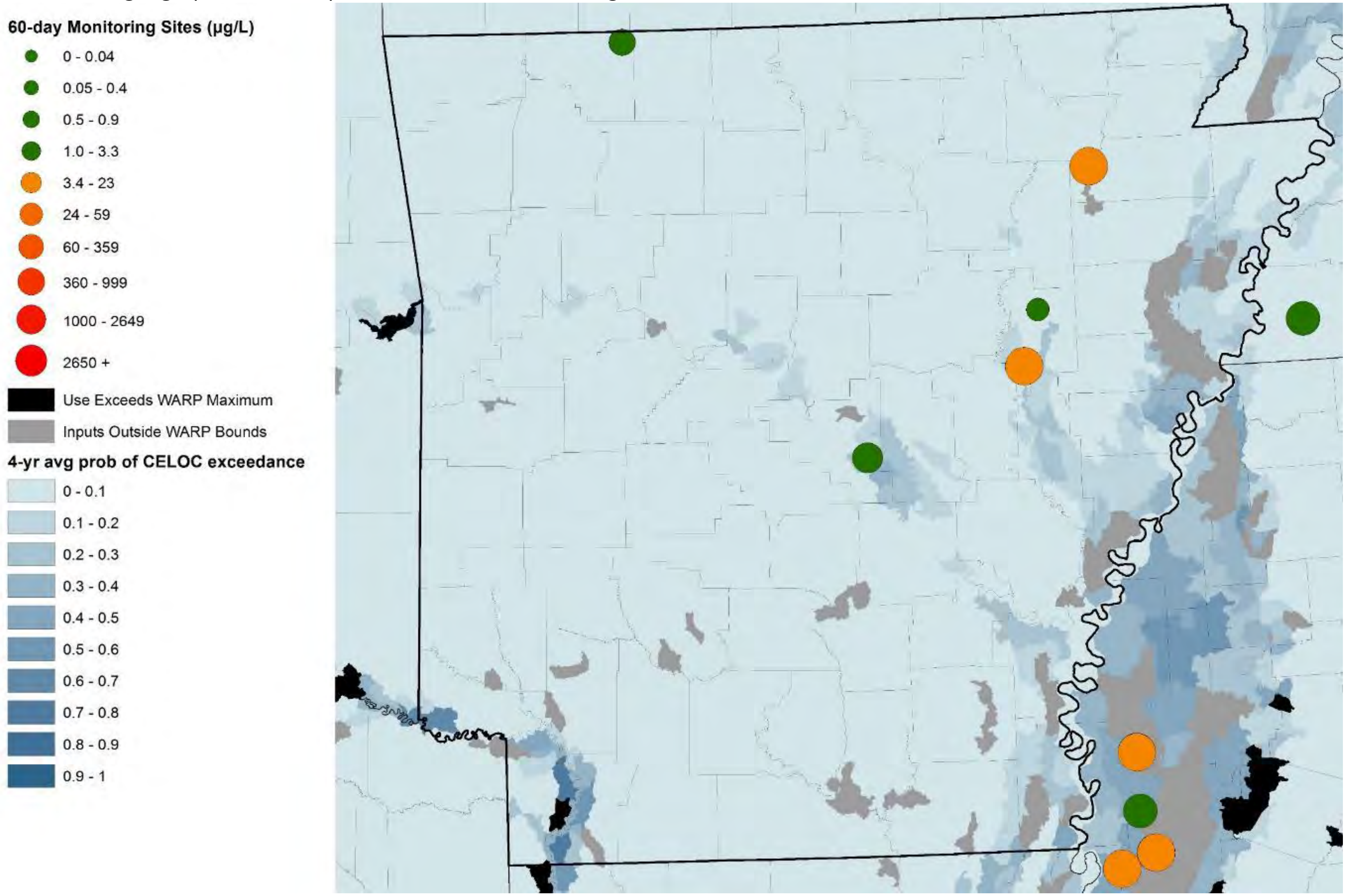
Bias Factors were not used for Arkansas (see **Section 7.4.1.4**). There were relatively few sites with 12 or more samples collected in a year, however based on these data there were frequent exceedances of the Chronic Fish, and Non-Vascular Aquatic Plant LOCs and the CELOC...

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		62	656	7	12
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.17	21.70	0.83	21.68
	Maximum 21-day Average	1.15	21.70	0.83	21.68
	Maximum 60-day Average	0.91	13.57	0.83	13.56
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	2	0	1
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	2	0	1
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	1	0	1
	Chronic EM Inverts	0	3	0	3
	Non-Vascular Plants	3	24	0	5
	Vascular Plants	0	2	0	1
	CELOC	0	2	0	3

Arkansas: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Arkansas had 47 watersheds shown as excluded in the map below, 3 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		1508	1508	1509	1508	1507
Max 4-day average concentration (µg/L)		33.68	59.33	112.27	141.88	68.04
Max 21-day average concentration (µg/L)		22.53	39.09	72.61	91.46	44.68
Max 60-day average concentration (µg/L)		14.04	24.01	44.34	54.92	27.48
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	2	5	7	16	6
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	2	5	7	16	6
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	1	2	0
	Acute EM Inverts	1	2	3	8	3
	Chronic EM Inverts	0	0	0	2	0
	Non-Vascular Plants	32	140	224	261	207
	Vascular Plants	2	22	59	53	27
	CELOC	2	11	26	29	9

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.5. California.

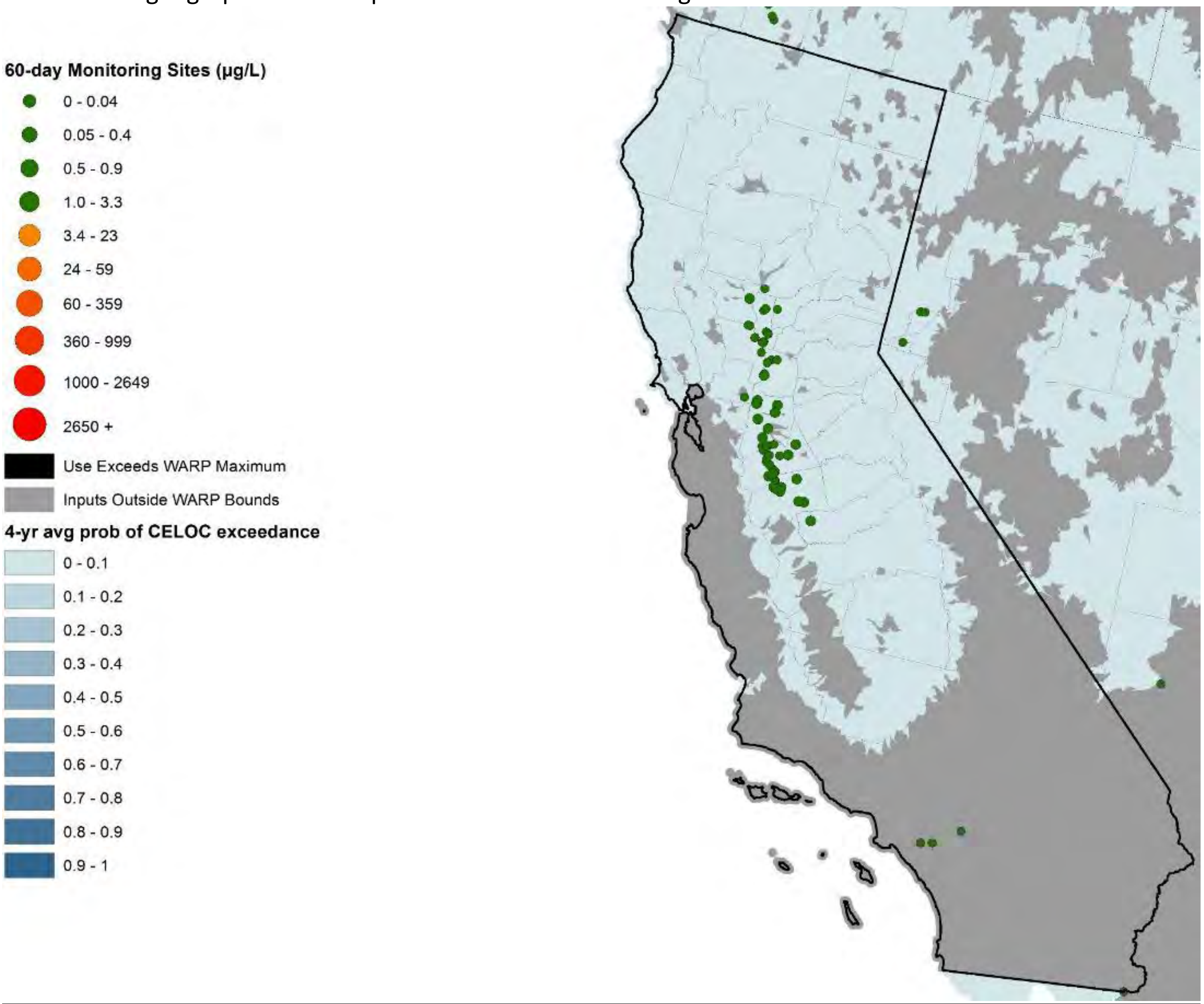
Bias Factors were not used for California (see **Section 7.4.1.4**). Based on these data there were few exceedances of the non-vascular plant LOCs in the more recent and highly sampled monitoring data. The less sampled data had frequent exceedances of the non-vascular and vascular aquatic plant LOCs and one instance of exceeding the estuarine/marine invertebrate LOC.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1041	1203	104	189
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	2.66	5.30	1.30	0.25
	Maximum 21-day Average	2.66	5.30	1.23	0.25
	Maximum 60-day Average	2.16	3.73	1.09	0.17
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	1	0	0
	Non-Vascular Plants	5	2	2	0
	Vascular Plants	0	0	0	0
	CELOC	0	1	0	0

California: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. California had 1984 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		4045	2742	3789	4045	2486
Max 4-day average concentration (µg/L)		0.57	0.59	0.41	0.51	0.52
Max 21-day average concentration (µg/L)		0.46	0.47	0.33	0.41	0.42
Max 60-day average concentration (µg/L)		0.35	0.36	0.26	0.32	0.32
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.6. Colorado.

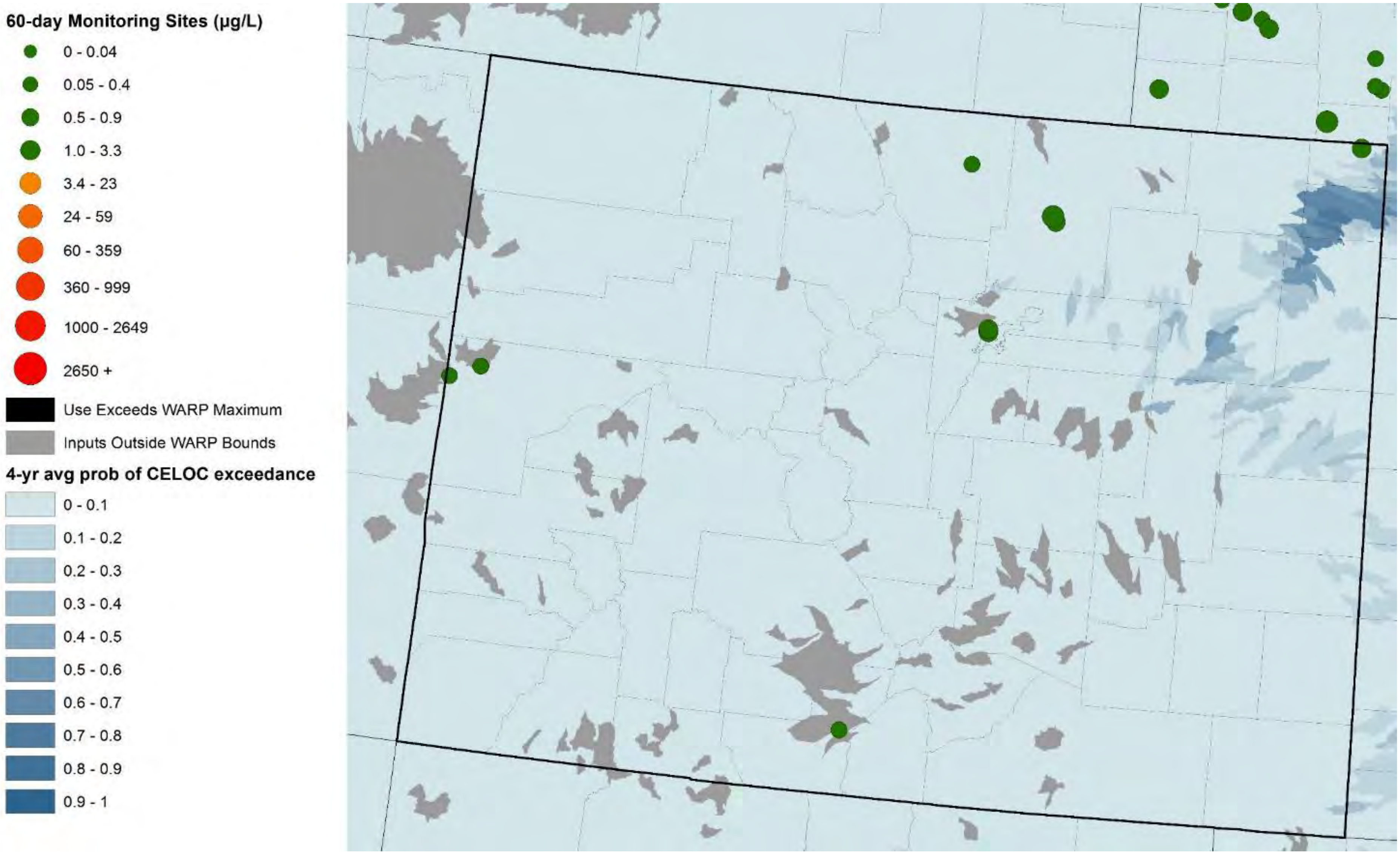
Bias Factors were not used for Colorado (see **Section 7.4.1.4**). Based on these data there were few exceedances of the Chronic Fish LOCs in the 2005 and older monitoring data.

State		CO	CO	CO	CO
Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		69	293	7	36
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	6.82	1.04	0.62	2.70
	Maximum 21-day Average	6.82	0.25	0.28	2.34
	Maximum 60-day Average	3.89	0.25	0.18	0.91
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	1	0	0	0
	Non-Vascular Plants	1	1	0	4
	Vascular Plants	0	0	0	0
	CELOC	1	0	0	0

Colorado: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Colorado had 140 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		3022	3022	3022	3022	3022
Max 4-day average concentration (µg/L)		5.84	35.55	20.75	21.99	18.10
Max 21-day average concentration (µg/L)		4.36	24.86	14.60	15.57	12.92
Max 60-day average concentration (µg/L)		3.12	16.81	9.69	10.34	8.89
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	20	15	16	14
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	20	15	16	14
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	11	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	126	284	160	279	225
	Vascular Plants	5	49	29	37	32
	CELOC	0	30	21	27	22

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.7. Connecticut.

Bias Factors were not used for Connecticut (see **Section 7.4.1.4**). Based on these data there were few exceedances of the acute estuarine/marine invertebrate, non-vascular and vascular aquatic plant LOCs in the low sample monitoring data. The WARP model has identified 182 HUC-12 watersheds of which 2 may exceed the chronic fish LOC, and none which may exceed the CELOC.

State		CT	CT	CT	CT
Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		13	77	3	30
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.04	4.60	1.43	0.07
	Maximum 21-day Average	0.04	4.60	0.55	0.07
	Maximum 60-day Average	0.04	4.60	0.20	0.06
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	1	0	0
	Non-Vascular Plants	0	3	1	0
	Vascular Plants	0	1	0	0
	CELOC	0	1	0	0

Connecticut: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Connecticut had 0 watersheds excluded.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		182	182	182	182	182
Max 4-day average concentration (µg/L)		2.78	2.61	1.13	0.08	1.65
Max 21-day average concentration (µg/L)		1.99	1.79	0.81	0.07	1.16
Max 60-day average concentration (µg/L)		1.26	1.12	0.52	0.05	0.73
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	2	2	1	0	1
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.8. Delaware.

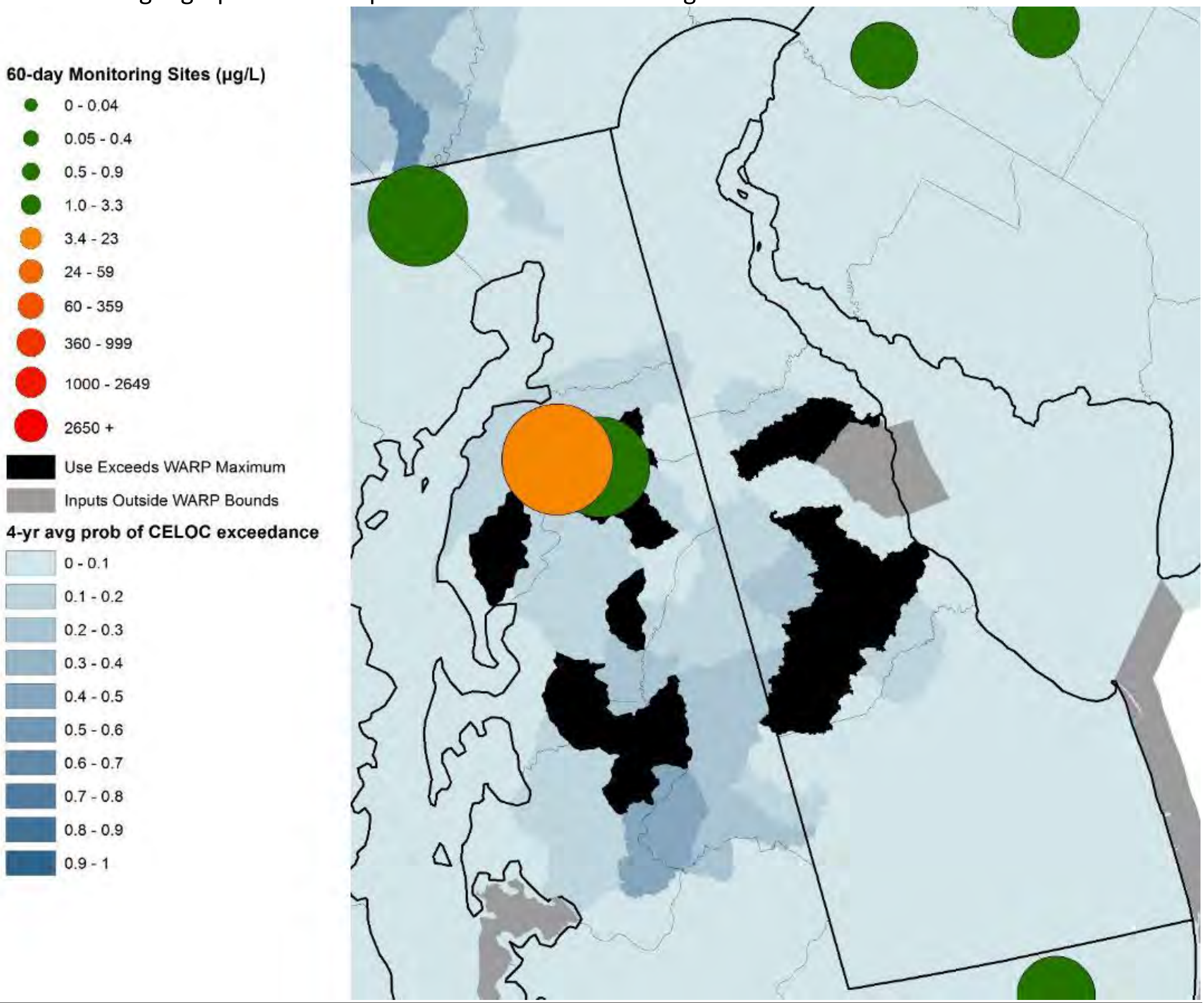
Few data were available for the surface waters of Delaware. Bias Factors were not used for Delaware (see **Section 7.4.1.4**).

<table>
<tr><th colspan="2">Description of Data Summary and Bias Factor Use</th><th>Unadjusted < 12 Samples Prior to 2006</th></tr>
<tr><td colspan="2">Number of Site-Years (WARP Watersheds)</td><td>43</td></tr>
<tr><td rowspan="3">Maximum Measured or Predicted Exposure Concentrations (ug/L)</td><td>Maximum</td><td>30.00</td></tr>
<tr><td>Maximum 21-day Average</td><td>16.07</td></tr>
<tr><td>Maximum 60-day Average</td><td>8.50</td></tr>
<tr><td rowspan="11">Number of Site-Years Exceeding Non-Listed Species Levels of Concern</td><td>Acute FW Fish</td><td>0</td></tr>
<tr><td>Chronic FW Fish</td><td>1</td></tr>
<tr><td>Acute EM Fish</td><td>0</td></tr>
<tr><td>Chronic EM Fish</td><td>1</td></tr>
<tr><td>Acute FW Inverts</td><td>0</td></tr>
<tr><td>Chronic FW Inverts</td><td>0</td></tr>
<tr><td>Acute EM Inverts</td><td>1</td></tr>
<tr><td>Chronic EM Inverts</td><td>1</td></tr>
<tr><td>Non-Vascular Plants</td><td>2</td></tr>
<tr><td>Vascular Plants</td><td>1</td></tr>
<tr><td>CELOC</td><td>1</td></tr>
</table>

Delaware: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Delaware had 14 watersheds shown as excluded in the map below, 11 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		98	98	87	88	87
Max 4-day average concentration (µg/L)		3.53	6.93	6.94	6.73	3.93
Max 21-day average concentration (µg/L)		2.53	4.62	4.55	4.35	2.72
Max 60-day average concentration (µg/L)		1.60	2.83	2.69	2.56	1.69
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	47	32	13	25	31
	Vascular Plants	0	3	3	5	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.9. District of Columbia.

Few data were available for the surface waters of the District of Columbia. Bias Factors were not used for the District of Columbia (see **Section 7.4.1.4**).

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		17
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.15
	Maximum 21-day Average	0.15
	Maximum 60-day Average	0.11
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0
	Chronic FW Fish	0
	Acute EM Fish	0
	Chronic EM Fish	0
	Acute FW Inverts	0
	Chronic FW Inverts	0
	Acute EM Inverts	0
	Chronic EM Inverts	0
	Non-Vascular Plants	0
	Vascular Plants	0
	CELOC	0

<u>District of Columbia:</u> WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Washington DC had 0 watersheds excluded.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		6	6	6	6	6
Max 4-day average concentration (µg/L)		0.13	0.08	0.15	0.37	0.18
Max 21-day average concentration (µg/L)		0.11	0.06	0.12	0.28	0.14
Max 60-day average concentration (µg/L)		0.08	0.05	0.09	0.20	0.10
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.10. Florida.

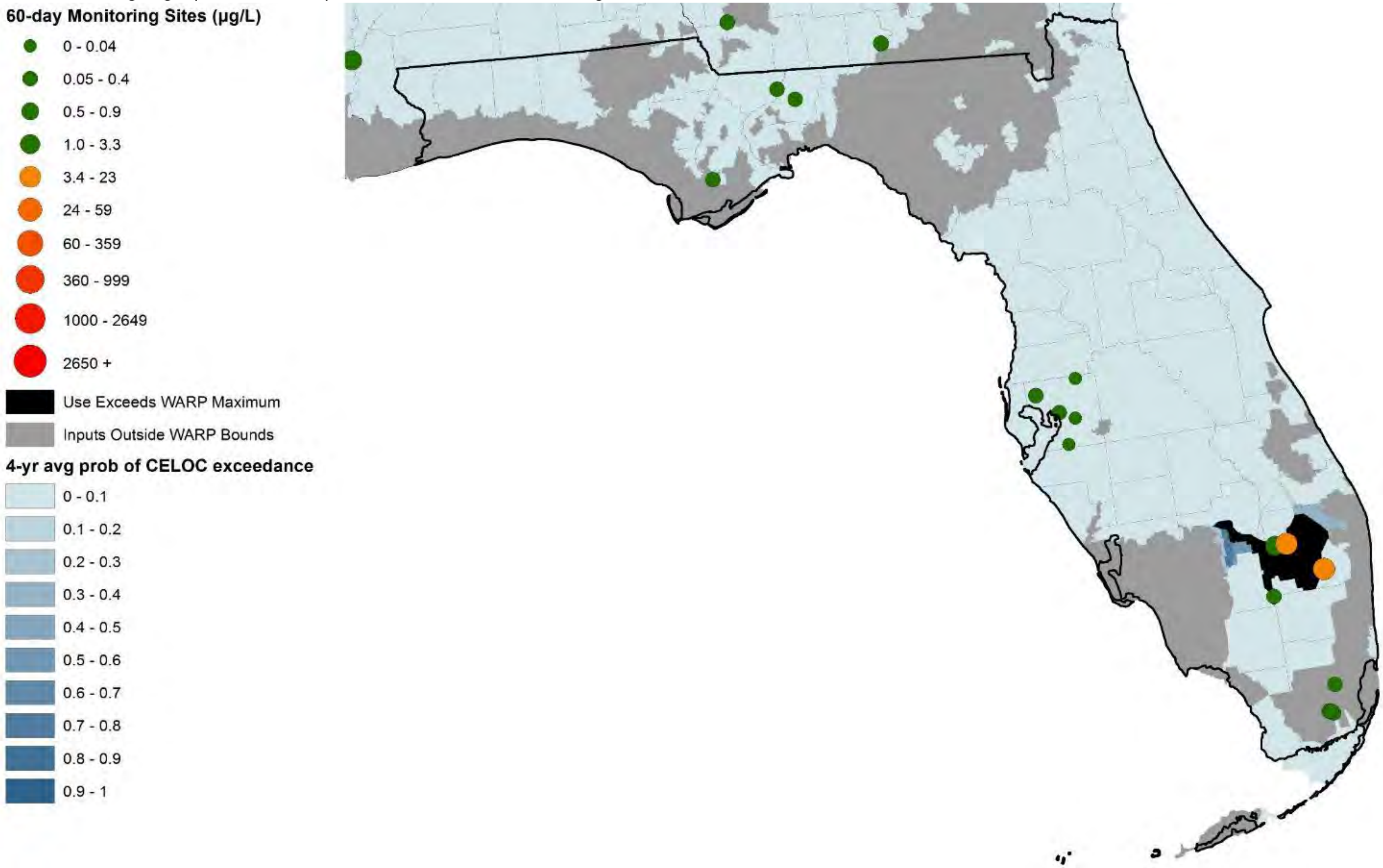
Bias Factors were not used for Florida (see **Section 7.4.1.4**). Based on these data there were frequent exceedances of the Chronic Fish LOCs in older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		454	1069	24	29
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	23.00	18.00	40.50	12.00
	Maximum 21-day Average	6.90	18.00	3.19	9.70
	Maximum 60-day Average	6.90	18.00	1.49	8.50
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	2	23	0	5
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	2	23	0	5
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	1	0	1	0
	Chronic EM Inverts	2	46	0	6
	Non-Vascular Plants	38	250	11	8
	Vascular Plants	2	31	0	5
	CELOC	2	42	0	5

Florida: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Florida had 463 watersheds shown as excluded in the map below, 6 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		885	885	885	885	885
Max 4-day average concentration (µg/L)		20.24	15.25	12.19	33.27	19.00
Max 21-day average concentration (µg/L)		13.60	10.37	8.40	22.60	12.94
Max 60-day average concentration (µg/L)		8.16	6.23	5.13	13.48	7.80
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	1	1	1	2	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	1	1	1	2	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	1	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	6	6	7	13	8
	Vascular Plants	3	2	2	5	3
	CELOC	1	2	1	4	2

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.11.Georgia.

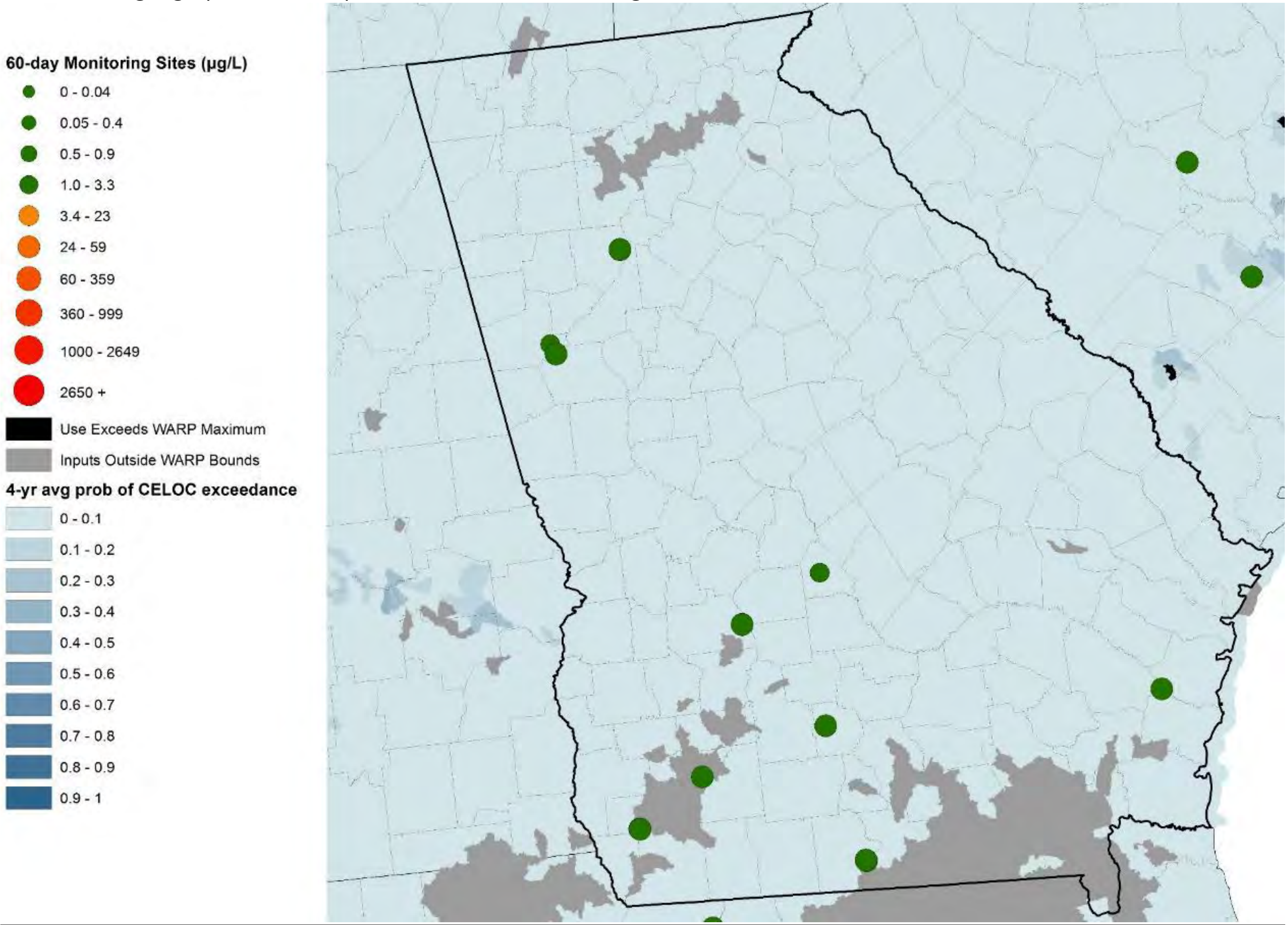
Bias Factors were not used for Georgia (see **Section 7.4.1.4**). Based on these data there were frequent exceedances of the non-vascular and vascular aquatic plant LOCs in monitoring data with less than 12 samples per year.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		90	631	31	56
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.15	0.61	0.45	0.90
	Maximum 21-day Average	1.15	0.61	0.45	0.54
	Maximum 60-day Average	1.11	0.61	0.40	0.36
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	2	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Georgia: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Georgia had 122 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1741	1741	1741	1741	1741
Max 4-day average concentration (µg/L)		1.00	3.61	4.87	3.11	1.72
Max 21-day average concentration (µg/L)		0.70	2.27	3.33	2.04	1.20
Max 60-day average concentration (µg/L)		0.44	1.29	2.10	1.20	0.77
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1	18	3	46	6
	Vascular Plants	0	0	1	0	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.12. Hawaii.

Few data were available for the surface waters of Alaska. Bias Factors were not used for Alaska (see **Section 7.4.1.4**). The WARP model was not used for this state because model was not calibrated for Hawaiian environmental and weather conditions.

State		HI	HI
Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		23	38
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	2.05	0.04
	Maximum 21-day Average	<0.01	0.04
	Maximum 60-day Average	<0.01	0.03
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0
	Chronic FW Fish	0	0
	Acute EM Fish	0	0
	Chronic EM Fish	0	0
	Acute FW Inverts	0	0
	Chronic FW Inverts	0	0
	Acute EM Inverts	0	0
	Chronic EM Inverts	0	0
	Non-Vascular Plants	1	0
	Vascular Plants	0	0
	CELOC	0	0

17.2.13. Idaho.

Bias Factors were not used for Idaho (see **Section 7.4.1.4**). Based on these data there were few exceedances of the non-vascular and vascular aquatic plant LOCs in older monitoring data with less than 12 samples per year.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		24	243	8	22
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.02	0.50	0.04	0.05
	Maximum 21-day Average	0.01	0.02	0.04	0.03
	Maximum 60-day Average	0.01	0.02	0.04	0.02
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

<u>Idaho</u>: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Idaho had 376 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2196	2196	2196	2196	2196
Max 4-day average concentration (µg/L)		0.09	0.07	0.09	0.19	0.11
Max 21-day average concentration (µg/L)		0.07	0.06	0.07	0.15	0.09
Max 60-day average concentration (µg/L)		0.06	0.04	0.06	0.11	0.07
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.14. Illinois.

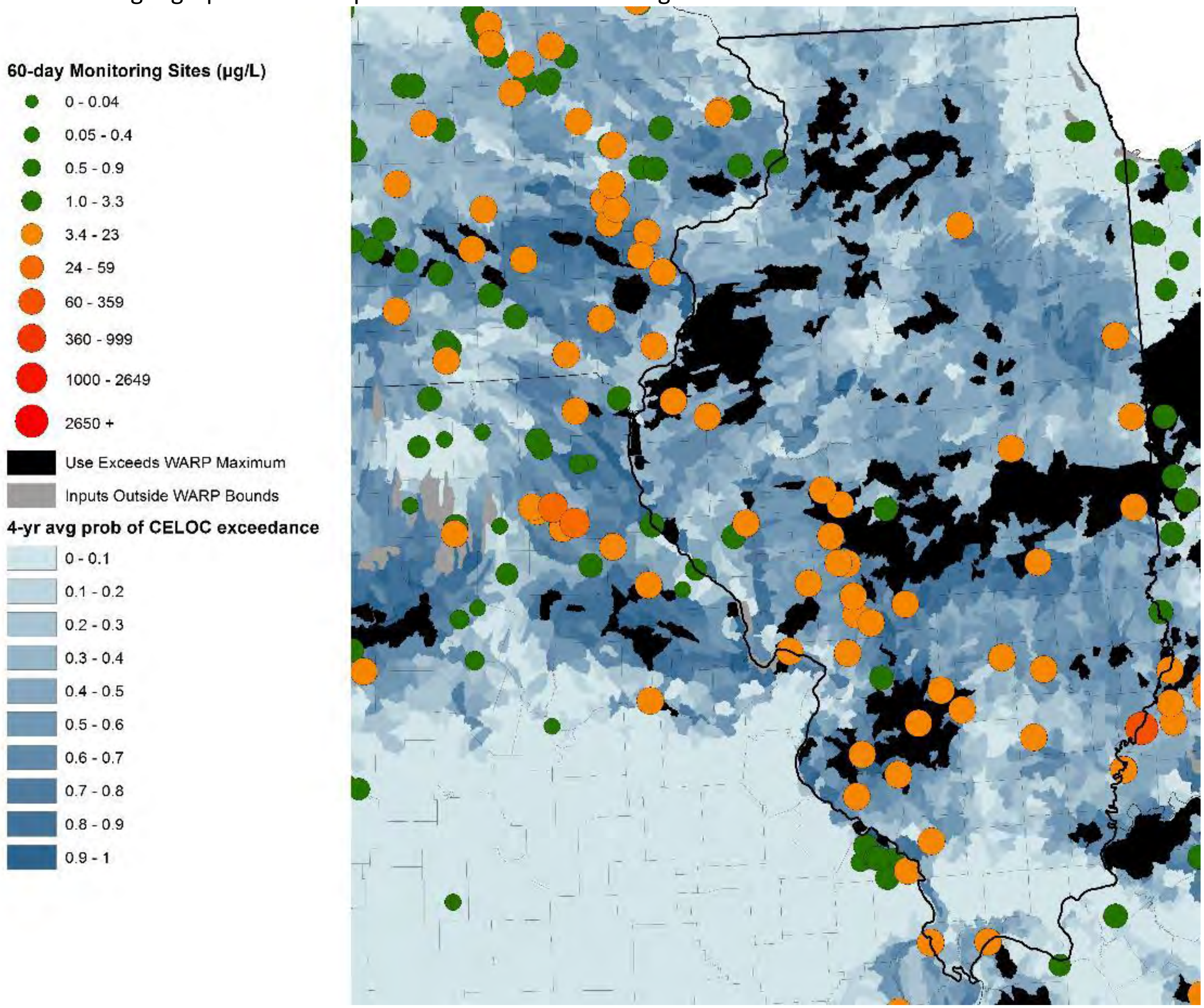
Three different Bias Factors were used for adjusting monitoring data in Illinois (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		2	37	15	6	7	61	43	1	13	2	192	382	209	166
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.26	574.05	70.65	11.91	17.01	218.83	152.88	0.39	8.15	16.24	30.00	127.00	228.18	108.00
	Maximum 21-day Average	0.28	64.02	11.54	7.97	15.98	44.66	52.22	0.33	6.05	11.29	30.00	108.00	45.65	39.99
	Maximum 60-day Average	0.21	22.74	10.52	6.42	15.45	17.12	22.45	0.27	5.04	7.03	24.62	108.00	18.15	20.20
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	0	24	2	1	1	33	21	0	1	1	10	25	62	50
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	0	24	2	1	1	33	21	0	1	1	10	25	62	50
	Acute FW Inverts	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	1	0	0	0	0	0	0	0	0	0	2	0	0
	Acute EM Inverts	0	30	5	0	0	30	14	0	0	0	2	11	33	20
	Chronic EM Inverts	0	27	7	3	3	44	30	0	3	1	27	53	110	95
	Non-Vascular Plants	1	37	14	4	4	59	40	0	8	2	84	202	177	159
	Vascular Plants	0	37	13	3	3	53	33	0	4	1	12	29	73	60
	CELOC	0	25	4	2	3	41	23	0	1	1	18	44	87	77

Illinois: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Illinois had 318 watersheds shown as excluded in the map below, 312 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1755	1625	1753	1811	1557
Max 4-day average concentration (µg/L)		77.22	112.74	91.05	60.08	85.28
Max 21-day average concentration (µg/L)		50.70	73.20	60.84	40.67	56.35
Max 60-day average concentration (µg/L)		31.97	45.63	38.44	26.02	35.51
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	149	295	303	216	224
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	149	295	303	216	224
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	1	1	0	0
	Acute EM Inverts	25	53	56	42	40
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1386	1393	1412	1406	1400
	Vascular Plants	941	1067	1035	1037	1053
	CELOC	373	713	619	546	616

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.15. Indiana.

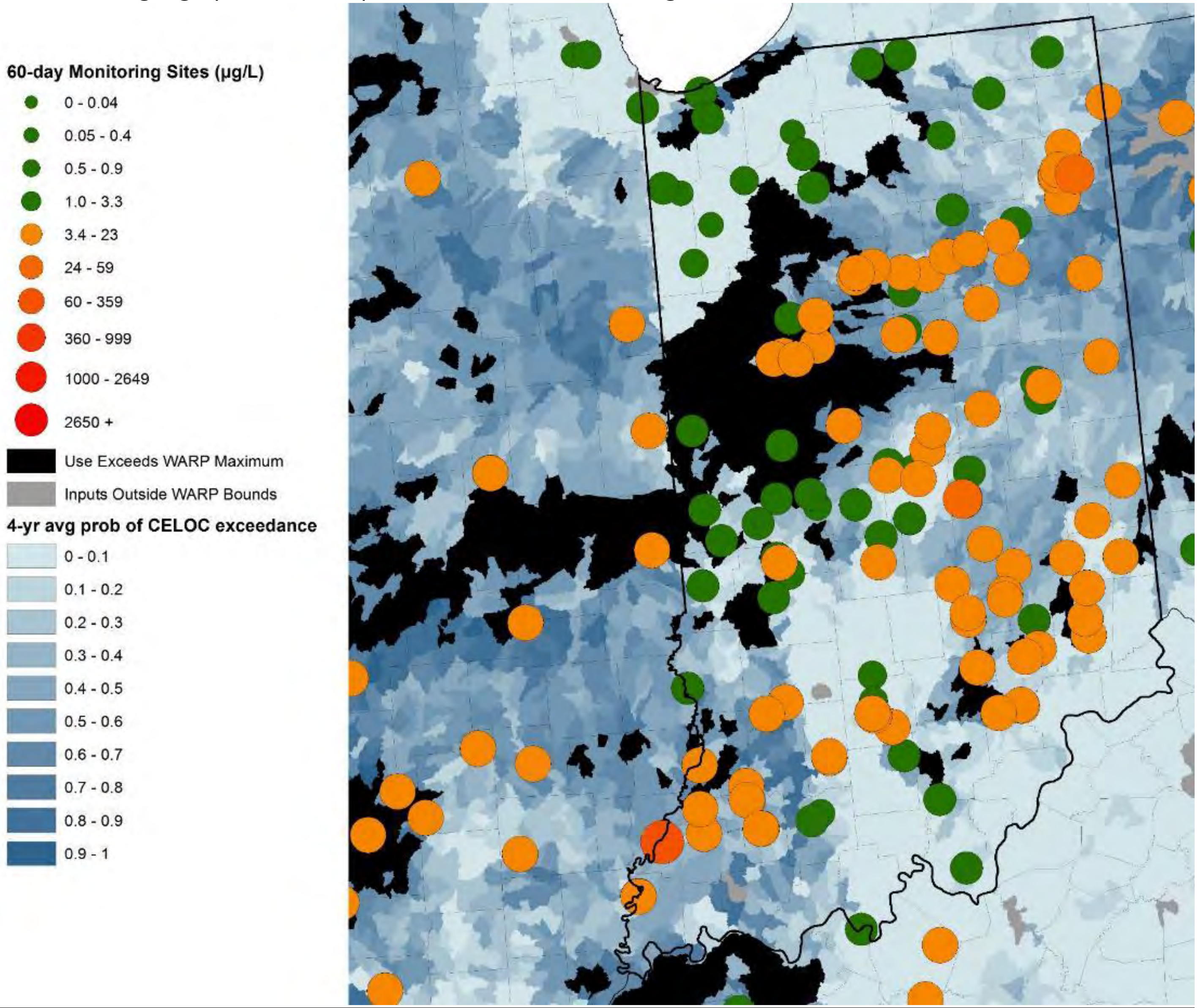
Three different Bias Factors were used for adjusting monitoring data in Indiana (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 < 12 Samples Prior to 2006	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		3	13	32	62	11	28	55	148	1	2	7	4	260	318	141	239
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	37.31	1070.11	134.58	1261.96	29.42	331.01	83.52	295.63	0.04	3.17	41.35	38.70	19.00	237.50	51.87	208.76
	Maximum 21-day Average	10.63	225.47	35.60	353.60	21.01	145.94	38.04	173.62	0.04	2.20	20.57	28.48	14.80	73.00	26.47	111.31
	Maximum 60-day Average	5.85	113.69	23.55	167.05	17.17	127.43	16.99	110.38	0.03	1.84	10.54	19.59	14.80	73.00	15.89	89.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	1	6	11	33	3	10	16	77	0	0	3	3	12	43	23	83
	Acute EM Fish	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	1	6	11	33	3	10	16	77	0	0	3	3	12	43	23	83
	Acute FW Inverts	0	3	0	8	0	1	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	3	0	11	0	3	0	3	0	0	0	0	0	2	0	3
	Acute EM Inverts	1	8	21	45	1	9	13	62	0	0	2	2	0	17	12	37
	Chronic EM Inverts	1	11	21	53	5	20	36	114	0	0	4	3	21	67	72	160
	Non-Vascular Plants	3	13	32	62	6	27	55	146	0	2	7	4	121	211	123	225
	Vascular Plants	1	13	30	60	5	22	43	127	0	0	6	3	13	45	31	98
	CELOC	1	7	13	42	3	13	28	95	0	0	4	3	21	58	44	123

Indiana: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Indiana had 256 watersheds shown as excluded in the map below, 253 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1514	1355	1499	1534	1323
Max 4-day average concentration (µg/L)		40.63	44.06	53.39	40.50	34.19
Max 21-day average concentration (µg/L)		26.59	29.56	35.43	26.78	22.55
Max 60-day average concentration (µg/L)		16.22	18.52	22.30	16.39	13.83
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	95	66	71	65	65
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	95	66	71	65	65
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	10	5	4	8	7
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	921	1007	962	977	984
	Vascular Plants	558	537	454	525	543
	CELOC	257	191	196	193	196

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.16. Iowa.

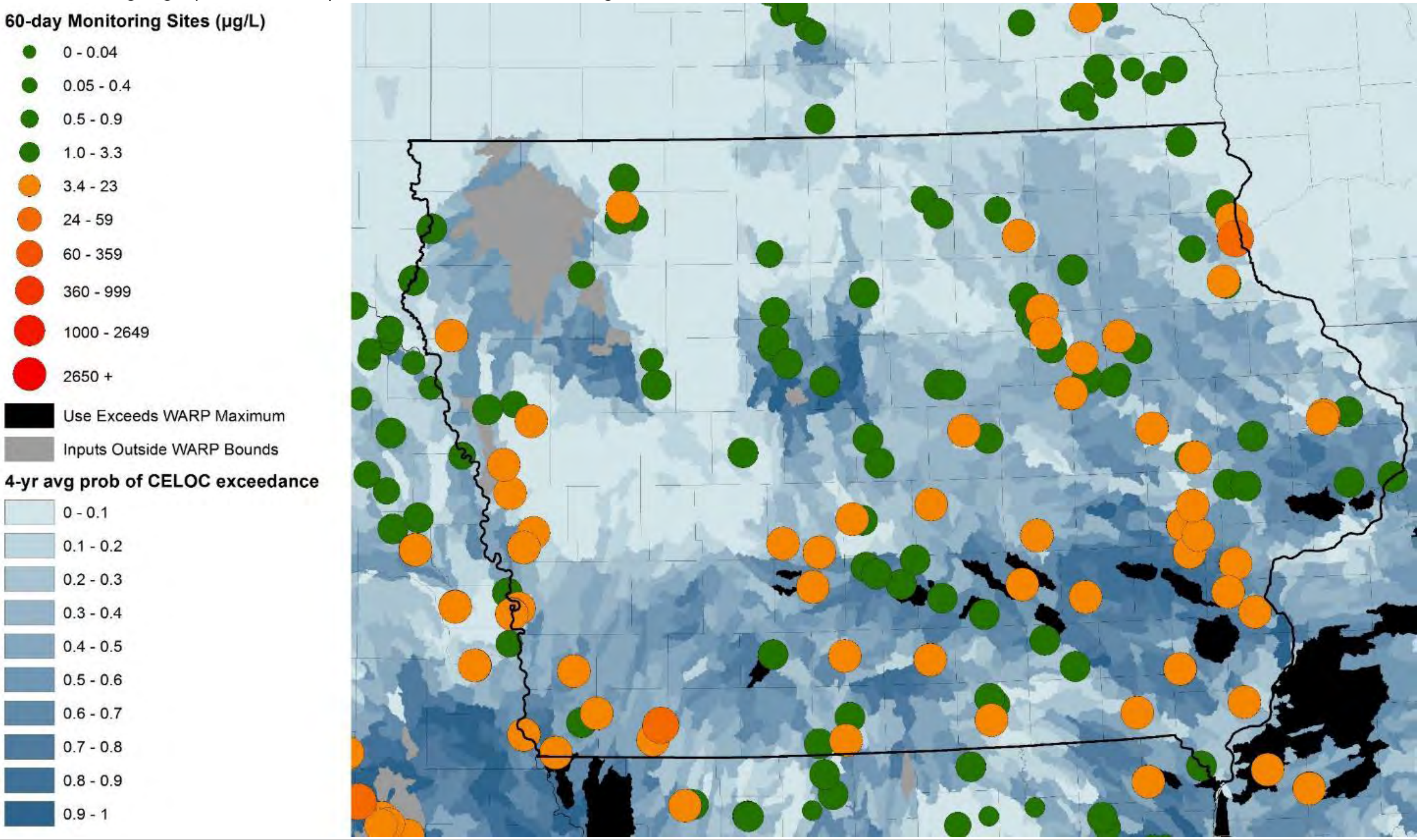
Three different Bias Factors were used for adjusting monitoring data in Iowa (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		2	1	22	28	45	24	36	49	4	6	858	2345	117	625
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	21.33	271.99	869.69	424.32	29.63	173.57	331.03	104.60	6.85	4.15	36.50	76.50	344.26	53.00
	Maximum 21-day Average	5.60	74.27	328.54	114.30	20.98	93.82	228.95	61.96	5.45	3.32	36.50	41.08	233.58	53.00
	Maximum 60-day Average	2.88	66.70	127.92	88.82	11.22	46.51	96.24	59.90	4.35	2.96	20.99	41.08	96.60	50.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	0	1	17	6	5	18	19	11	0	0	44	39	19	48
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	0	1	17	6	5	18	19	11	0	0	44	39	19	48
	Acute FW Inverts	0	0	3	1	0	0	1	0	0	0	0	0	1	0
	Chronic FW Inverts	0	1	2	3	0	2	1	2	0	0	0	0	1	0
	Acute EM Inverts	1	1	19	9	2	15	18	11	0	0	2	31	16	13
	Chronic EM Inverts	1	1	19	12	7	21	25	22	1	0	72	78	38	117
	Non-Vascular Plants	2	1	22	28	39	23	34	46	4	6	230	860	86	412
	Vascular Plants	1	1	20	23	9	22	26	27	2	0	47	43	21	55
	CELOC	0	1	17	8	6	20	22	13	1	0	59	60	26	74

<u>Iowa</u>: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Iowa had 77 watersheds shown as excluded in the map below, 28 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1663	1652	1650	1661	1637
Max 4-day average concentration (µg/L)		43.23	52.35	104.61	57.93	60.40
Max 21-day average concentration (µg/L)		29.42	36.14	72.52	39.91	41.73
Max 60-day average concentration (µg/L)		19.00	23.36	46.26	25.20	26.85
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	136	268	390	143	221
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	136	268	390	143	221
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	3	0	0
	Acute EM Inverts	13	53	86	40	37
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1545	1507	1556	1431	1539
	Vascular Plants	684	812	988	565	840
	CELOC	305	479	727	271	451

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.17. Kansas

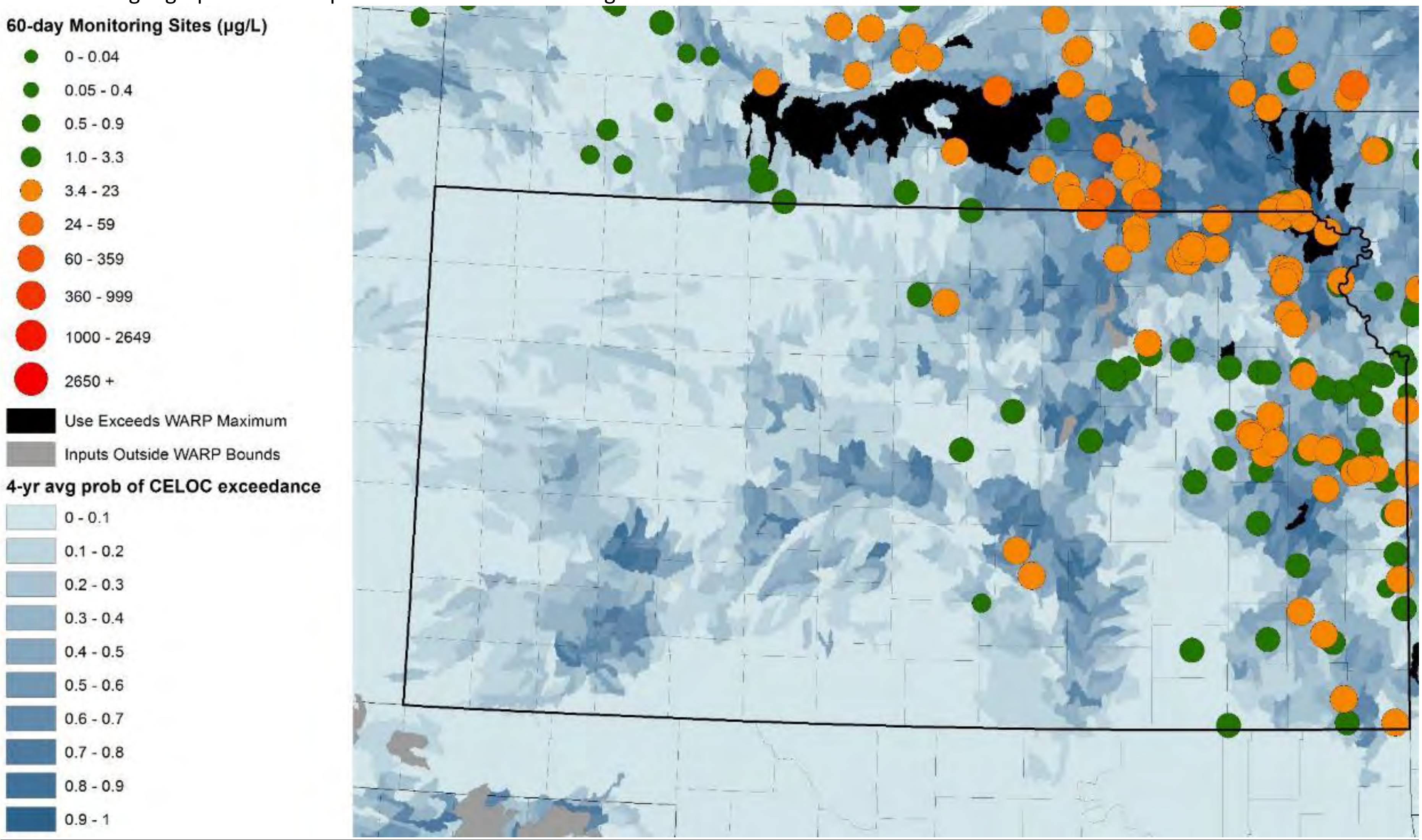
Three different Bias Factors were used for adjusting monitoring data in Kansas (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		5	8	15	40	13	28	47	118	2	6	6	3752	8791	251	350
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	108.65	141.24	173.18	531.10	47.24	164.74	85.69	131.24	2.73	6.27	10.86	50.00	105.00	68.89	63.00
	Maximum 21-day Average	33.99	57.69	31.57	152.72	37.59	119.75	61.24	77.93	2.21	5.00	7.15	34.00	105.00	29.99	44.80
	Maximum 60-day Average	23.71	46.23	15.37	51.07	16.74	58.42	33.58	29.40	2.11	3.52	5.65	34.00	61.50	27.56	18.96
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	2	2	6	39	6	11	23	61	0	0	2	21	74	29	104
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	2	2	6	39	6	11	23	61	0	0	2	21	74	29	104
	Acute FW Inverts	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	1	0	7	0	1	1	3	0	0	0	0	2	0	0
	Acute EM Inverts	2	2	14	39	4	8	21	39	0	0	0	28	48	17	30
	Chronic EM Inverts	2	4	14	39	7	13	35	98	0	3	3	27	106	89	221
	Non-Vascular Plants	5	8	15	40	11	23	47	117	2	6	6	1300	3139	226	331
	Vascular Plants	3	6	15	39	7	14	39	104	0	4	5	21	80	35	111
	CELOC	2	4	12	39	6	13	27	85	0	2	3	26	100	52	151

Kansas: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Kansas had 14 watersheds shown as excluded in the map below, 9 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		2046	2052	2049	2051	2043
Max 4-day average concentration (µg/L)		83.95	55.72	98.94	72.86	63.10
Max 21-day average concentration (µg/L)		56.51	39.00	67.58	46.73	43.71
Max 60-day average concentration (µg/L)		36.36	25.02	42.44	28.26	28.50
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	96	165	271	102	159
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	96	165	271	102	159
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	2	0	0
	Acute EM Inverts	18	14	75	14	15
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1227	1535	1591	1477	1522
	Vascular Plants	347	534	677	378	503
	CELOC	191	316	448	216	299

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.18. Kentucky.

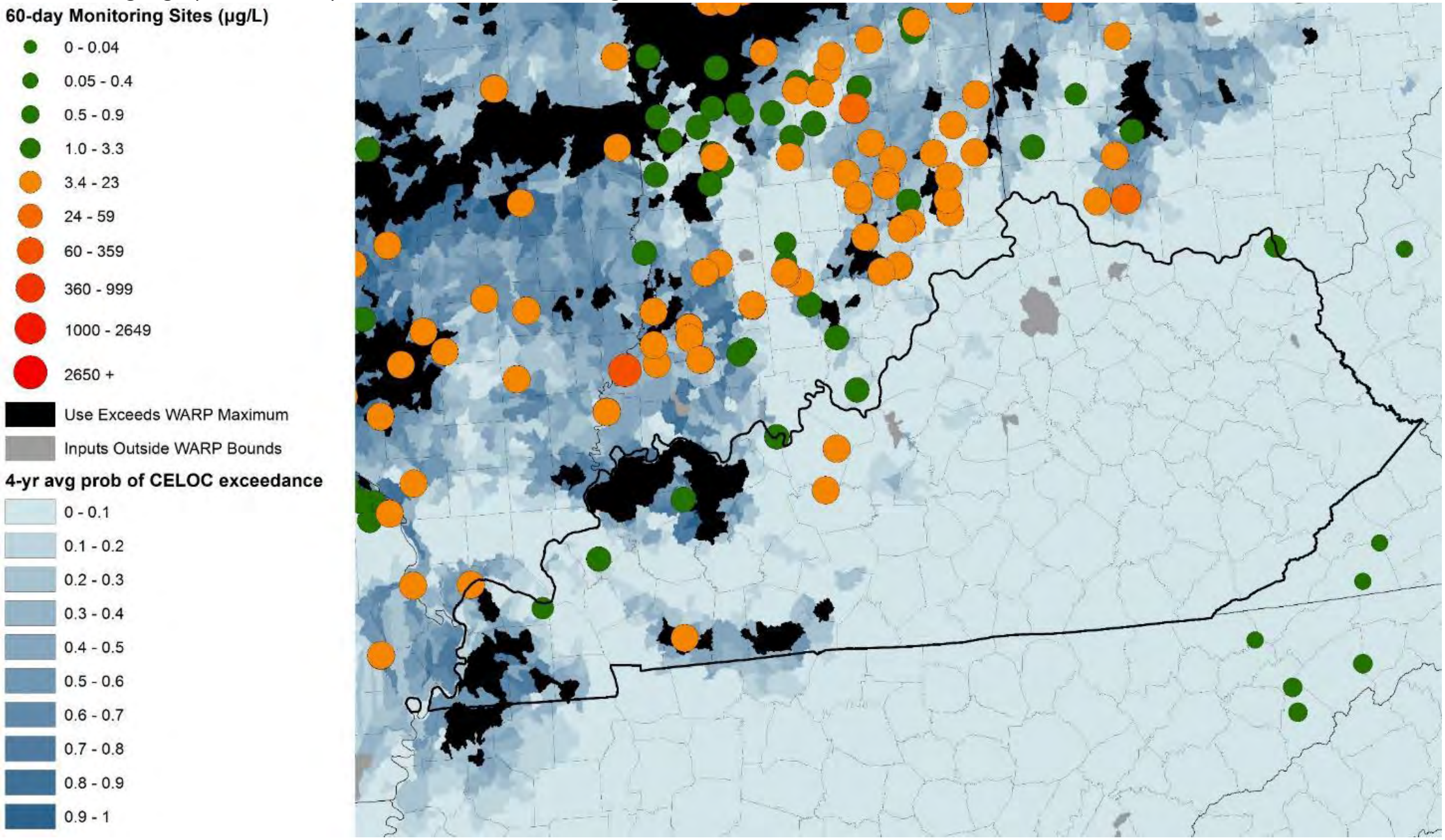
Three different Bias Factors were used for adjusting monitoring data in Kansas (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1	6	2	4	3	15	8	8	1	6	3	66	200	31	20
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	15.35	494.06	71.51	443.26	3.11	85.78	25.03	83.42	0.05	6.05	6.54	18.80	26.40	22.40	24.60
	Maximum 21-day Average	5.36	120.30	8.07	106.98	2.37	47.59	5.29	44.67	0.04	4.36	4.48	1.05	17.12	5.51	17.76
	Maximum 60-day Average	3.87	57.16	3.72	30.69	1.97	29.12	3.71	14.88	0.04	3.80	3.46	1.02	14.30	3.43	7.11
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	0	3	0	3	0	6	0	3	0	0	0	0	8	0	3
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	0	3	0	3	0	6	0	3	0	0	0	0	8	0	3
	Acute FW Inverts	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0
	Acute EM Inverts	0	3	2	3	0	6	1	3	0	0	0	0	2	1	2
	Chronic EM Inverts	1	3	2	3	0	8	7	4	0	1	1	0	13	6	4
	Non-Vascular Plants	1	6	2	4	1	13	8	8	0	6	3	19	54	22	13
	Vascular Plants	1	5	2	4	0	8	8	5	0	2	2	0	8	0	3
	CELOC	1	3	1	3	0	7	1	3	0	1	1	0	12	2	3

Kentucky: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Kentucky had 76 watersheds shown as excluded in the map below, 64 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1277	1231	1256	1277	1213
Max 4-day average concentration (µg/L)		29.26	73.82	38.23	35.23	43.87
Max 21-day average concentration (µg/L)		19.69	47.28	25.18	23.78	28.88
Max 60-day average concentration (µg/L)		12.41	28.80	15.48	14.94	17.91
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	7	19	29	17	16
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	7	19	29	17	16
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	1	9	5	1	1
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	207	294	212	289	250
	Vascular Plants	44	90	82	70	74
	CELOC	19	46	44	28	32

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.19. Louisiana.

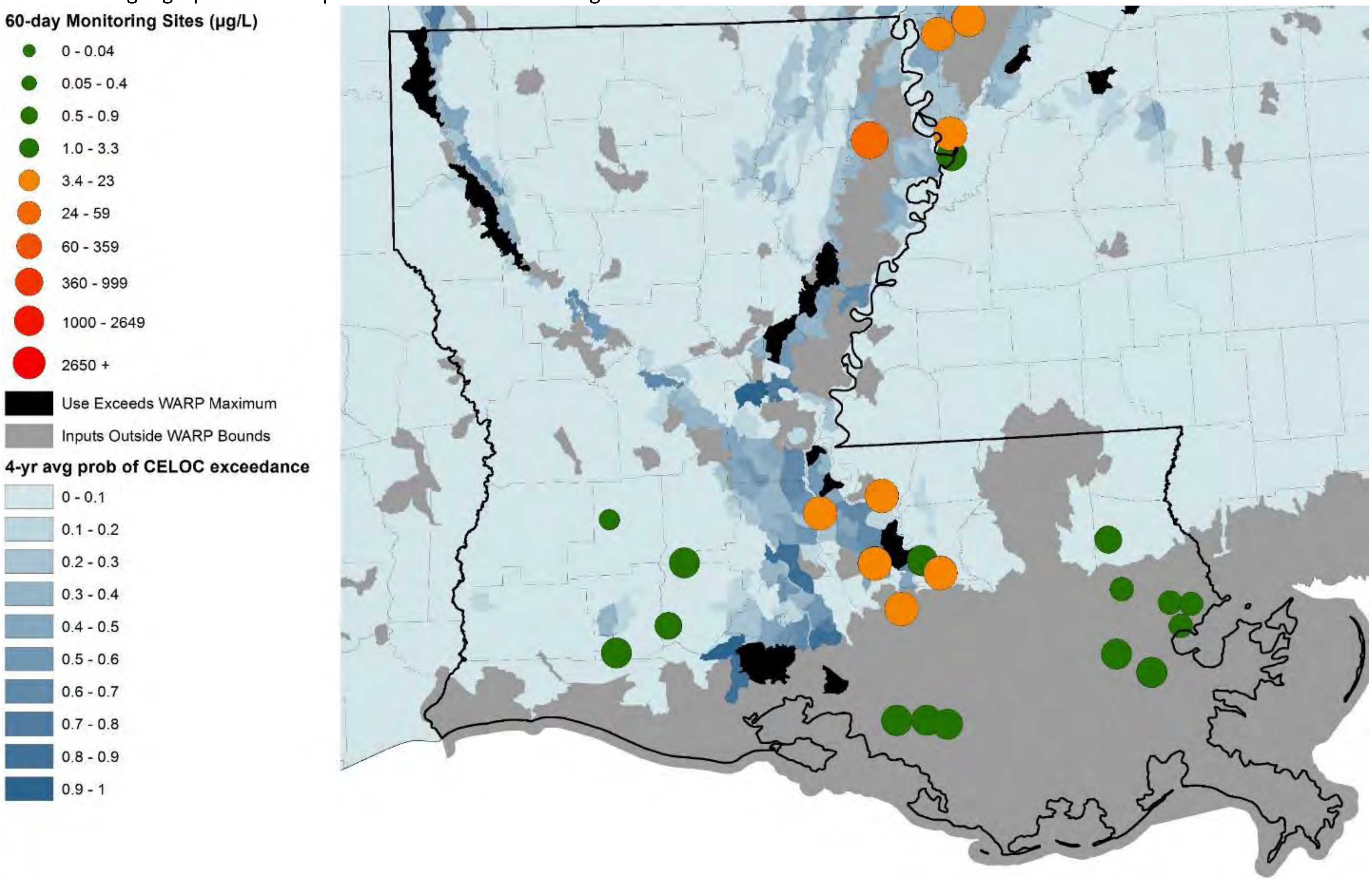
Three different Bias Factors were used for adjusting monitoring data in Kansas (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 < 12 Samples Prior to 2006	AMP2 ≥ 12 Samples 2006-2014	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		10	2	7	2	24	20	5	4	2	236	372	122	79
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	494.17	20.08	6.45	6.54	187.42	173.22	0.78	2.14	0.53	165.00	37.70	193.65	92.30
	Maximum 21-day Average	77.65	6.63	3.61	4.61	53.97	108.45	0.70	1.45	0.45	2.45	37.70	54.79	67.36
	Maximum 60-day Average	36.14	4.82	3.01	3.74	27.22	59.88	0.68	1.31	0.39	2.45	20.94	27.38	40.67
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	9	1	0	0	8	5	0	0	0	0	12	15	9
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	9	1	0	0	8	5	0	0	0	0	12	15	9
	Acute FW Inverts	3	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	2	0	0	0	0	3	0	0	0	0	0	0	2
	Acute EM Inverts	9	0	0	0	8	5	0	0	0	3	3	15	9
	Chronic EM Inverts	10	2	2	1	12	9	0	0	0	0	16	27	17
	Non-Vascular Plants	10	2	6	1	21	16	0	3	0	72	133	99	66
	Vascular Plants	10	2	4	1	15	11	0	0	0	0	12	16	10
	CELOC	10	2	0	1	9	7	0	0	0	0	19	20	12

Louisiana: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Louisiana had 425 watersheds shown as excluded in the map below, 28 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		858	856	864	857	845
Max 4-day average concentration (µg/L)		81.36	91.36	78.84	141.88	63.25
Max 21-day average concentration (µg/L)		50.21	59.28	50.86	91.46	39.63
Max 60-day average concentration (µg/L)		29.61	36.07	30.93	54.92	23.88
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	21	19	11	54	22
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	21	19	11	54	22
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	1	0
	Acute EM Inverts	10	5	5	24	8
	Chronic EM Inverts	0	0	0	1	0
	Non-Vascular Plants	116	176	156	205	191
	Vascular Plants	57	60	54	113	87
	CELOC	39	32	24	78	47

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.20. Maine

Few data were available for the surface waters of Maine. Bias Factors were not used for Maine (see **Section 7.4.1.4**). Based on these data there were no exceedances of the LOCs or CELOC.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		5	4
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	<0.01	<0.01
	Maximum 21-day Average	<0.01	<0.01
	Maximum 60-day Average	<0.01	<0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0
	Chronic FW Fish	0	0
	Acute EM Fish	0	0
	Chronic EM Fish	0	0
	Acute FW Inverts	0	0
	Chronic FW Inverts	0	0
	Acute EM Inverts	0	0
	Chronic EM Inverts	0	0
	Non-Vascular Plants	0	0
	Vascular Plants	0	0
	CELOC	0	0

Maine: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Maine had 20 watersheds excluded, 1 was excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1028	1028	1028	1028	1028
Max 4-day average concentration (µg/L)		3.02	1.14	0.84	1.66	1.66
Max 21-day average concentration (µg/L)		2.05	0.77	0.57	1.14	1.13
Max 60-day average concentration (µg/L)		1.25	0.48	0.36	0.70	0.70
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1	1	0	1	1
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.21. Maryland

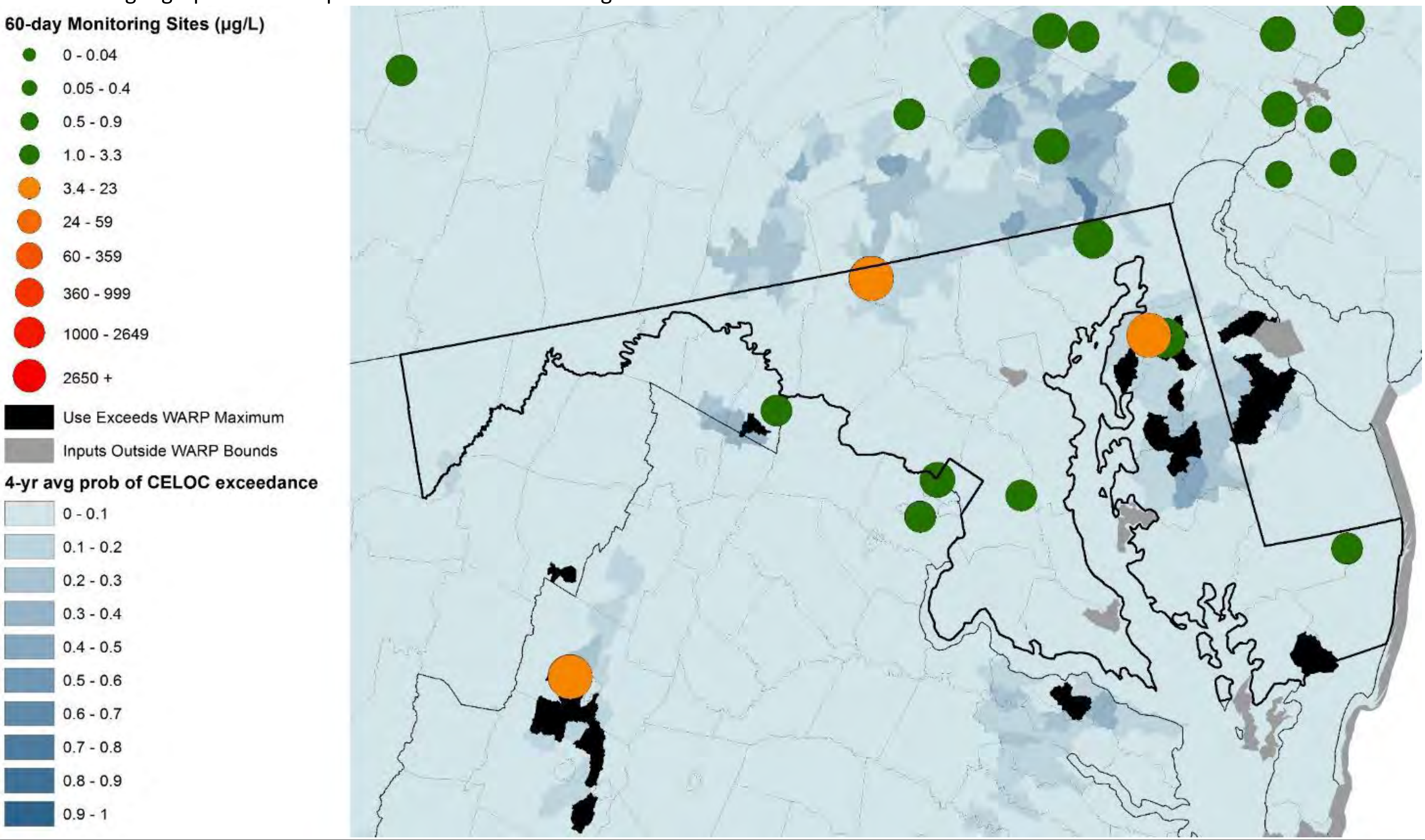
Bias Factors were not used for Maryland (see **Section 7.4.1.4**). Based on these data there were few exceedances of the Chronic Fish and non-vascular plant LOCs in the 2005 and older monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		13	265	3	15
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.38	8.00	1.38	25.00
	Maximum 21-day Average	1.38	8.00	1.38	9.73
	Maximum 60-day Average	1.38	6.20	1.38	4.72
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	2	0	2
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	2	0	2
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	2
	Chronic EM Inverts	0	4	0	6
	Non-Vascular Plants	2	16	1	10
	Vascular Plants	0	2	0	3
	CELOC	0	2	0	5

Maryland: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Maryland had 18 watersheds shown as excluded in the map below, 12 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		393	384	393	394	383
Max 4-day average concentration (µg/L)		20.54	18.46	7.00	11.29	12.36
Max 21-day average concentration (µg/L)		13.92	12.10	4.84	8.00	8.41
Max 60-day average concentration (µg/L)		8.58	7.39	3.07	5.16	5.24
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	2	4	0	1	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	2	4	0	1	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	133	88	18	143	107
	Vascular Plants	7	17	2	11	5
	CELOC	5	4	0	4	3

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.22. Massachusetts.

Bias Factors were not used for Massachusetts (see **Section 7.4.1.4**). Based on these data there were no exceedances of the LOCs or CELOC.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		35	102	4	6
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.02	0.02	0.03	0.01
	Maximum 21-day Average	0.02	0.02	0.02	0.01
	Maximum 60-day Average	0.02	0.02	0.02	0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Massachusetts: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Massachusetts had 7 watersheds shown as excluded in the map below, 7 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		241	241	243	242	241
Max 4-day average concentration (µg/L)		3.73	2.18	0.89	1.25	2.01
Max 21-day average concentration (µg/L)		2.74	1.52	0.66	0.91	1.45
Max 60-day average concentration (µg/L)		1.75	0.97	0.44	0.59	0.93
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	6	5	0	2	3
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.

17.2.23. Michigan.

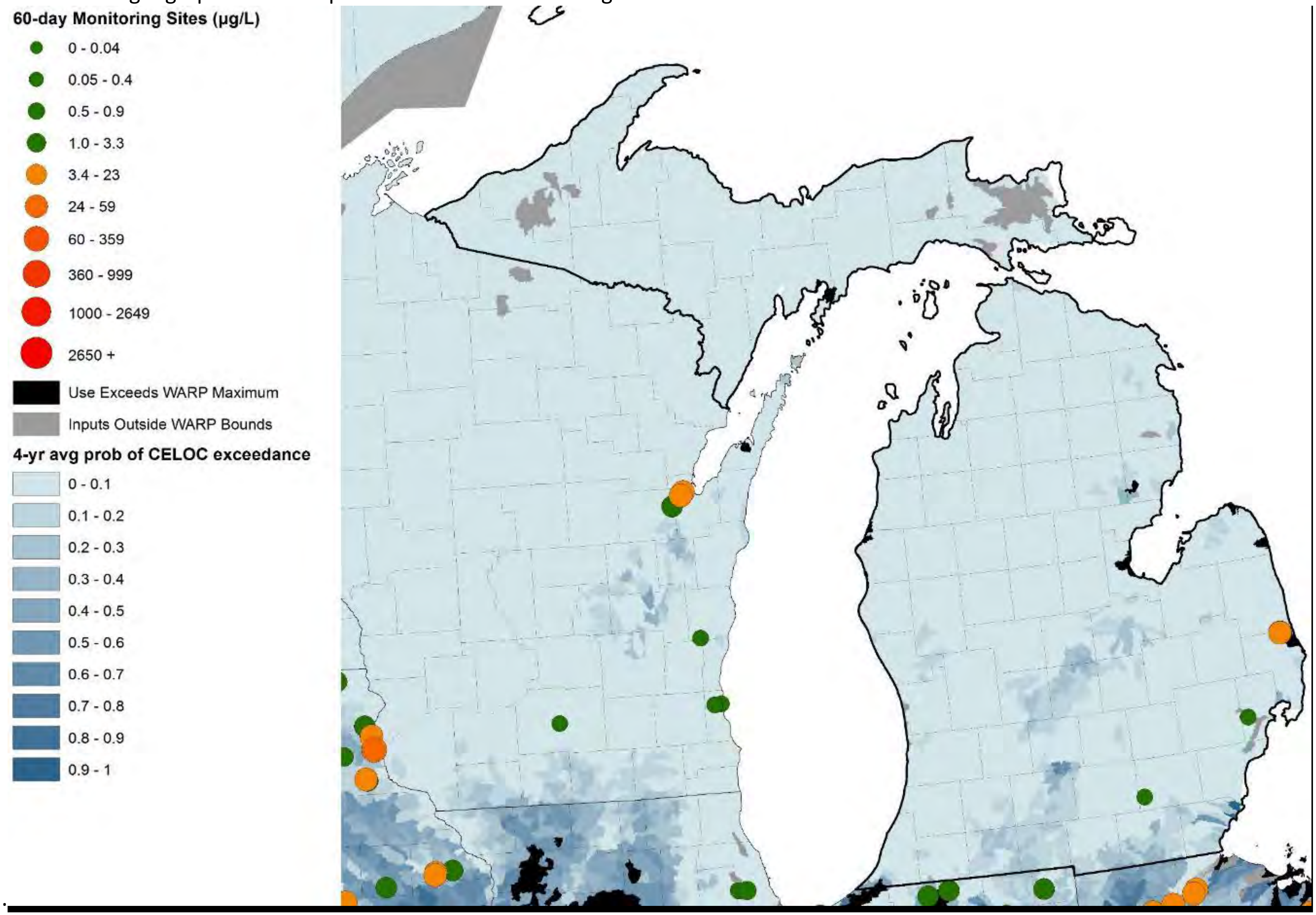
Bias Factors were not used for Michigan (see **Section 7.4.1.4**). There are limited number of available monitoring data for Michigan. Based on the available data there were exceedances of the Chronic Fish, non-vascular and vascular plant LOCs in the 2005 and older monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		30	66	6	6
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.25	11.90	0.26	7.32
	Maximum 21-day Average	<0.01	7.08	0.21	6.55
	Maximum 60-day Average	<0.01	5.34	0.16	3.92
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	2	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	2	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	2	0	2
	Non-Vascular Plants	0	7	0	2
	Vascular Plants	0	2	0	0
	CELOC	0	2	0	2

Michigan: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Michigan had 47 watersheds shown as excluded in the map below, 10 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-Year Average
Number of HUC12s		1785	1785	1783	1787	1781
Maximum 4-day average concentration (ug/L)		52.19	57.20	33.63	44.51	34.36
Maximum 21-day average concentration (ug/L)		35.49	37.29	23.20	29.56	23.63
Maximum 60-day average concentration (ug/L)		22.91	23.41	15.18	18.77	15.42
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	4	5	2	3	2
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	4	5	2	3	2
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	1	3	1	1	1
	Chronic EM Inverts	21	24	23	17	13
	Non-Vascular Plants	343	372	372	339	364
	Vascular Plants	27	26	39	24	22
	CELOC	5	11	9	6	6

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.24. Minnesota.

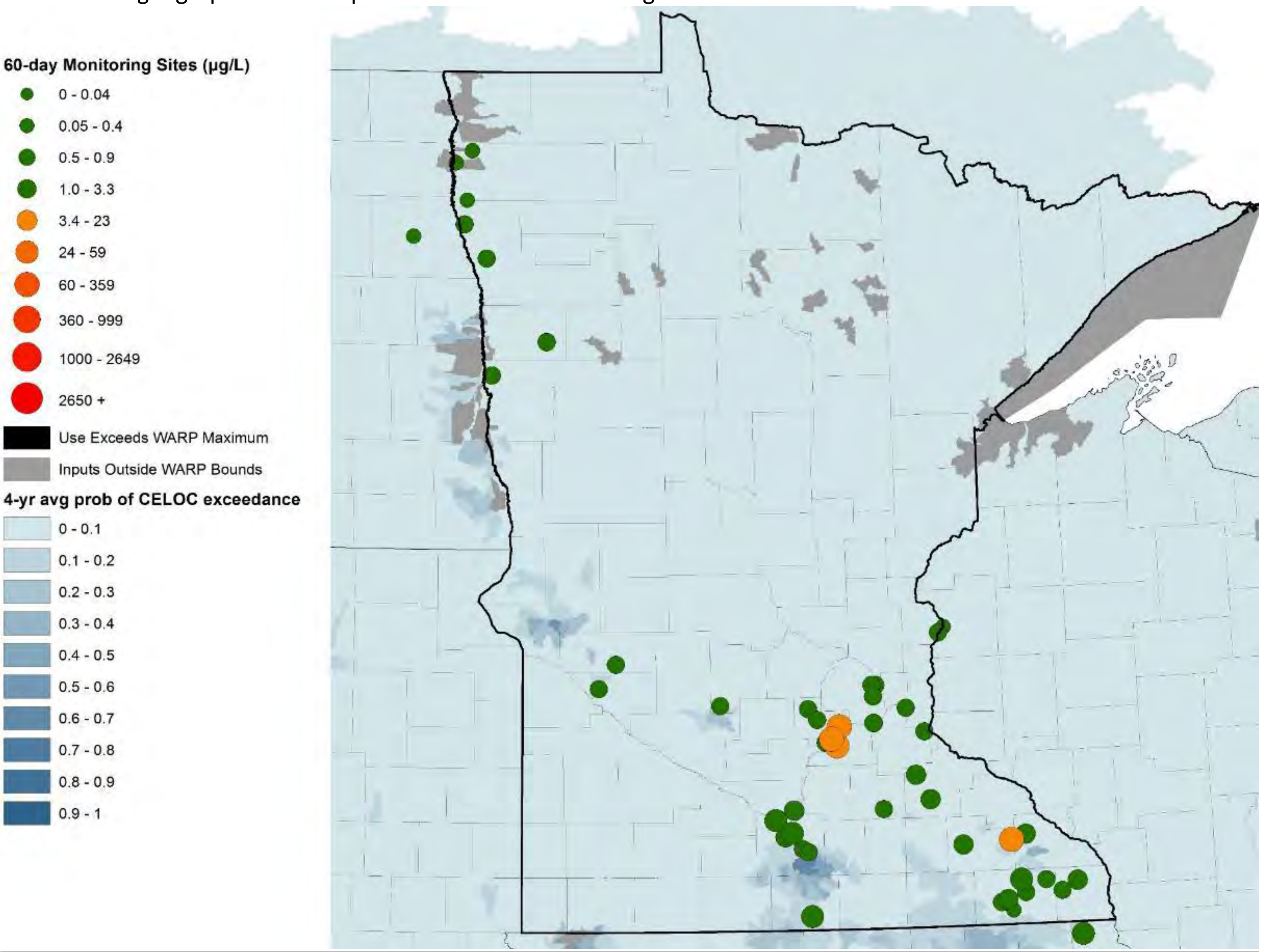
Two different Bias Factors were used for adjusting monitoring data in Kansas (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs and less frequently the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		29	10	27	48	169	33	78	136	904	613	85	149
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	37.14	7.05	34.60	275.64	7.99	23.86	10.19	68.48	4.15	310.00	4.77	33.20
	Maximum 21-day Average	13.22	2.35	8.30	37.50	6.74	15.58	3.53	19.21	4.00	6.74	1.99	11.12
	Maximum 60-day Average	7.55	1.73	2.27	11.41	6.10	5.03	1.50	8.57	4.00	4.80	0.95	5.37
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	2	0	0	7	1	1	0	7	0	2	0	2
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	2	0	0	7	1	1	0	7	0	2	0	2
	Acute FW Inverts	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0	0	0	0	0	0	0	0
	Acute EM Inverts	2	0	1	18	0	1	0	9	0	4	0	4
	Chronic EM Inverts	3	0	1	11	5	4	0	18	1	7	0	13
	Non-Vascular Plants	21	8	22	47	65	16	39	115	39	73	25	107
	Vascular Plants	9	4	9	34	11	4	6	47	0	3	0	3
	CELOC	2	0	0	7	2	3	0	10	1	3	0	7

Minnesota: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Minnesota had 57 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2424	2424	2424	2424	2424
Max 4-day average concentration (µg/L)		18.42	9.89	11.07	10.63	11.40
Max 21-day average concentration (µg/L)		13.09	7.21	8.04	7.70	8.26
Max 60-day average concentration (µg/L)		8.83	4.98	5.53	5.29	5.66
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	4	0	1	1	2
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	4	0	1	1	2
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	464	294	334	211	349
	Vascular Plants	24	8	8	5	11
	CELOC	9	3	3	2	3

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.25. Missouri.

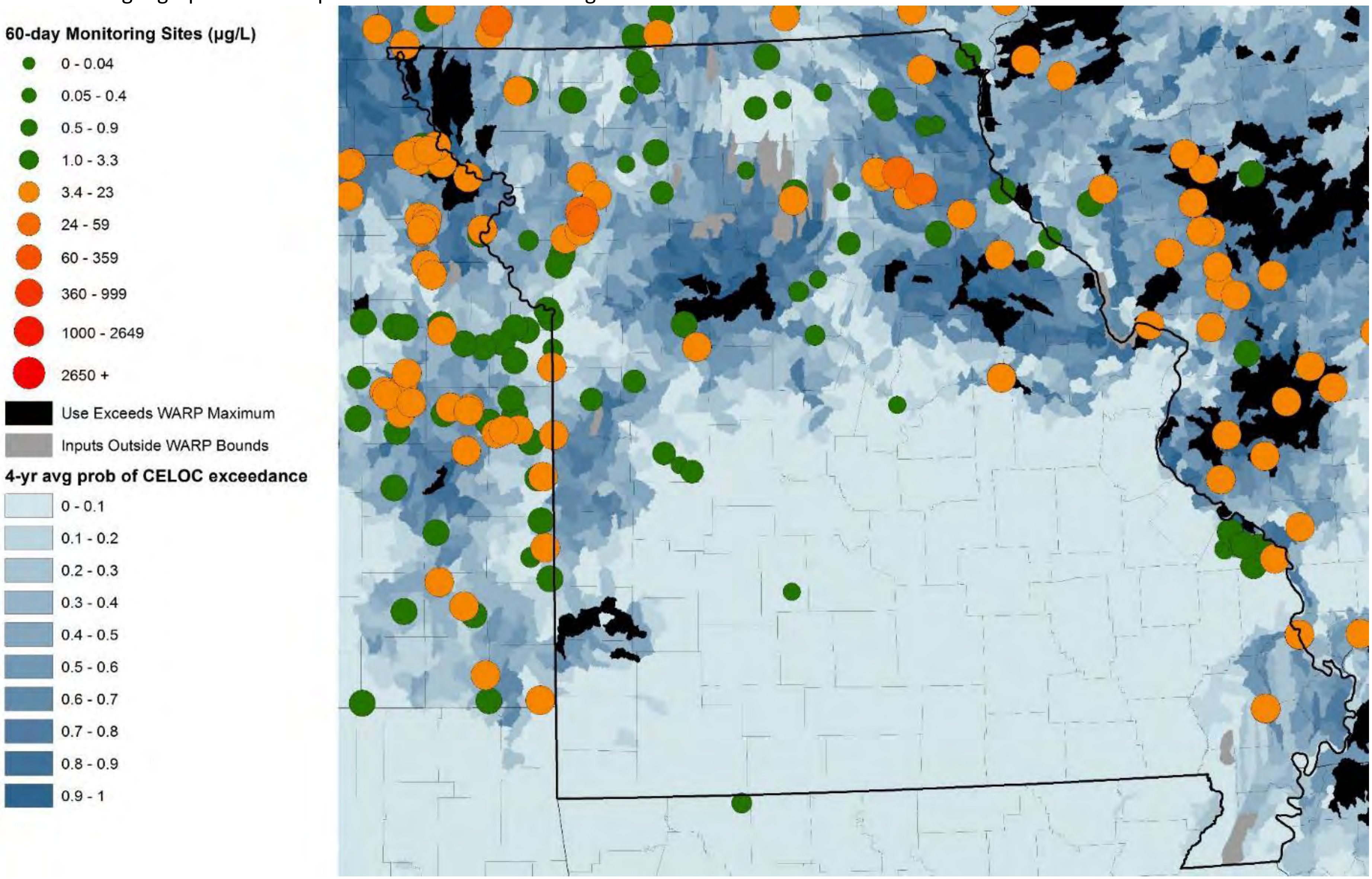
Three different Bias Factors were used for adjusting monitoring data in Kansas (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples 2006-2014	AMP2 < 12 Samples Prior to 2006	AMP2 ≥ 12 Samples 2006-2014	AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		6	20	57	12	9	27	68	39	2	34	9	17	273	1304	192	146
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	64.14	744.19	719.81	589.03	22.54	225.27	274.30	205.45	0.17	71.56	9.46	14.93	37.60	155.50	285.86	182.75
	Maximum 21-day Average	11.80	349.72	181.09	96.33	11.77	206.59	126.30	59.65	0.13	32.82	7.11	9.35	24.70	155.50	129.05	54.19
	Maximum 60-day Average	9.93	301.46	91.15	74.18	7.11	196.80	68.62	48.40	0.10	17.12	5.01	6.68	13.99	155.50	68.96	38.20
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	1	18	40	11	3	21	39	33	0	16	2	1	10	84	67	32
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	1	18	40	11	3	21	39	33	0	16	2	1	10	84	67	32
	Acute FW Inverts	0	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	12	3	6	0	5	1	2	0	0	0	0	0	2	1	0
	Acute EM Inverts	1	17	51	11	2	20	39	23	0	8	0	0	1	23	72	15
	Chronic EM Inverts	3	18	53	11	3	22	56	38	0	21	2	2	24	135	107	52
	Non-Vascular Plants	6	18	57	11	7	24	66	38	0	34	7	17	109	455	168	110
	Vascular Plants	5	18	56	11	3	22	63	38	0	23	3	4	10	99	71	37
	CELOC	1	18	45	11	3	22	47	37	0	18	2	1	18	124	89	48

Missouri: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Missouri had 82 watersheds shown as excluded in the map below, 54 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		1965	1945	1971	1952	1921
Max 4-day average concentration (µg/L)		99.94	111.19	89.21	114.74	84.78
Max 21-day average concentration (µg/L)		65.63	72.94	59.17	76.92	56.17
Max 60-day average concentration (µg/L)		41.00	45.44	37.16	48.43	35.26
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	151	313	218	300	252
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	151	313	218	300	252
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	2	3	0	2	0
	Acute EM Inverts	32	99	46	79	60
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	927	1042	998	989	1003
	Vascular Plants	420	627	577	609	593
	CELOC	258	459	391	448	404

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.26. Mississippi.

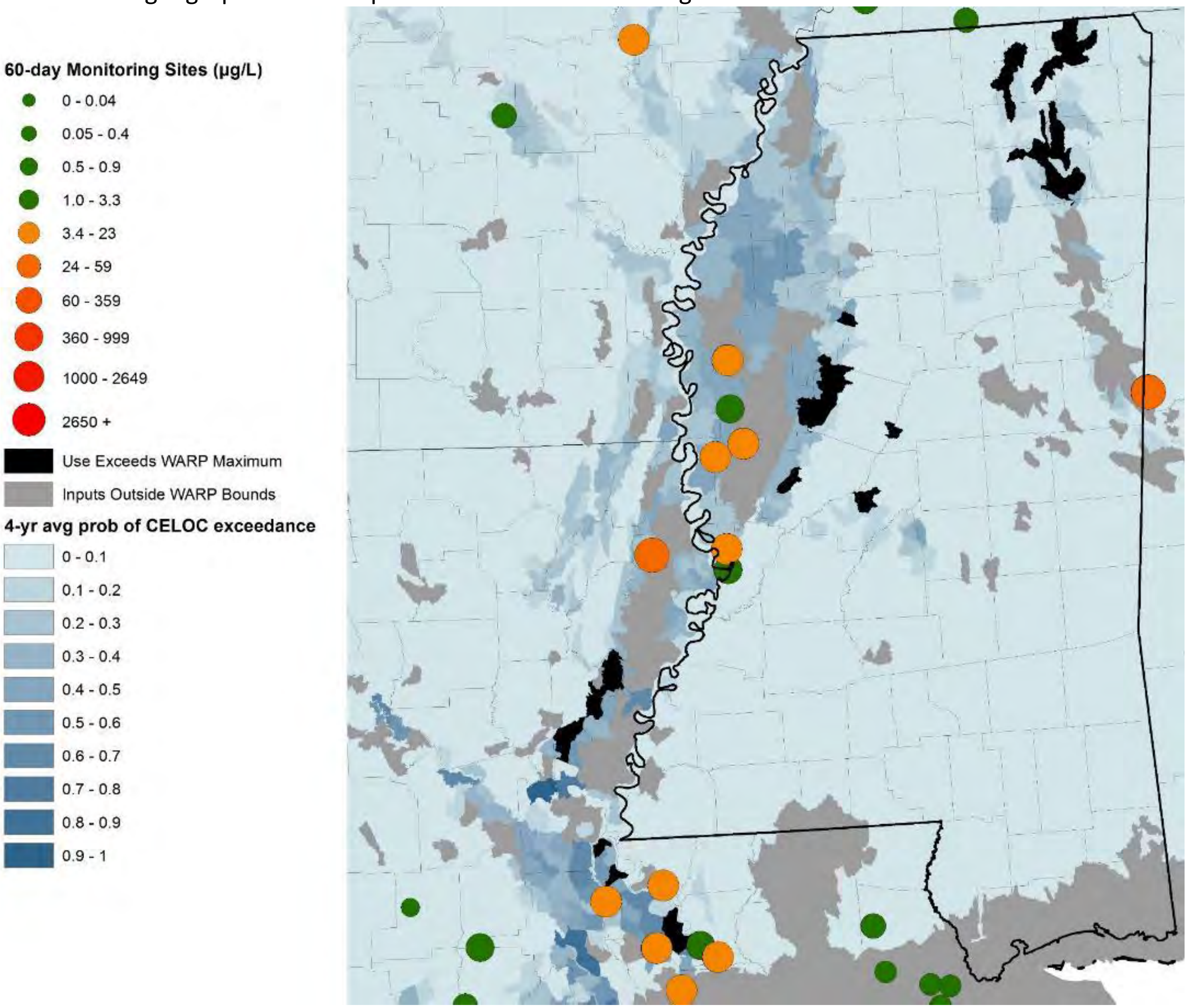
Bias Factors were not used for Mississippi (see **Section 7.4.1.4**). There are limited number of available monitoring data for Mississippi. Based on the available data there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		12	153	23	31
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.85	252.00	25.60	23.20
	Maximum 21-day Average	1.47	176.00	18.83	11.40
	Maximum 60-day Average	0.83	151.30	12.44	6.70
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	2	4	4
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	2	4	4
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	1	0	0
	Acute EM Inverts	0	4	4	2
	Chronic EM Inverts	0	11	8	18
	Non-Vascular Plants	2	61	20	30
	Vascular Plants	0	4	4	6
	CELOC	0	6	4	11

Mississippi: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Mississippi had 178 watersheds shown as excluded in the map below, 31 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1208	1188	1197	1208	1177
Max 4-day average concentration (µg/L)		7.77	80.08	55.47	77.82	23.39
Max 21-day average concentration (µg/L)		5.35	49.37	35.72	51.06	15.22
Max 60-day average concentration (µg/L)		3.47	29.10	21.42	31.21	9.44
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	26	4	17	13
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	26	4	17	13
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	17	2	8	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	72	118	118	116	137
	Vascular Plants	7	58	20	31	45
	CELOC	1	38	8	26	23

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.27. Montana.

Bias Factors were not used for Montana (see **Section 7.4.1.4**). There are limited number of available monitoring data for Montana. Based on the available data there were few exceedances of the non-vascular and vascular aquatic plant LOCs in the older and infrequently sampled monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		84	50	12
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.09	0.60	0.33
	Maximum 21-day Average	0.01	0.60	0.22
	Maximum 60-day Average	0.01	0.60	0.08
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0
	Chronic FW Fish	0	0	0
	Acute EM Fish	0	0	0
	Chronic EM Fish	0	0	0
	Acute FW Inverts	0	0	0
	Chronic FW Inverts	0	0	0
	Acute EM Inverts	0	0	0
	Chronic EM Inverts	0	0	0
	Non-Vascular Plants	0	0	0
	Vascular Plants	0	0	0
	CELOC	0	0	0

Montana: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Montana had 212 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		4013	4013	4013	4013	4013
Max 4-day average concentration (µg/L)		0.27	0.70	0.45	0.40	0.38
Max 21-day average concentration (µg/L)		0.22	0.56	0.37	0.32	0.31
Max 60-day average concentration (µg/L)		0.17	0.42	0.28	0.25	0.24
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.28. Nebraska.

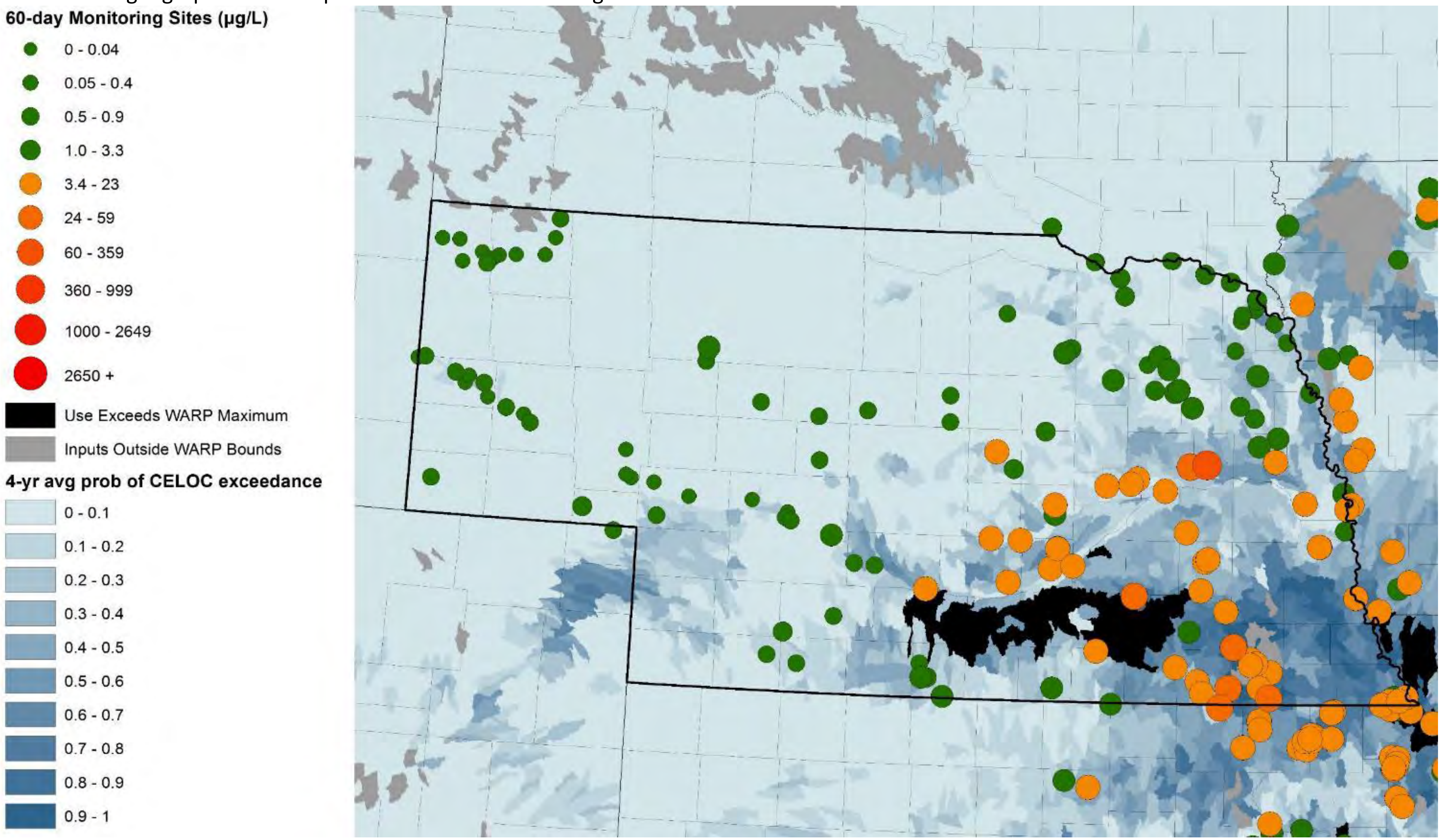
Bias Factors were used for Nebraska (see **Section 7.4.1.4**). Based on the available data there were frequent exceedances of the Chronic Fish, vascular and non-vascular LOCs in the unadjusted and adjusted older and more recent monitoring data. Less frequent exceedances of the acute fish, and acute and chronic invertebrate LOCs were also detected.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples 2006-2014	AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		4	11	67	10	699	667	347	591
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	107.33	1826.63	475.45	193.44	85.47	224.00	189.33	191.00
	Maximum 21-day Average	20.81	556.38	192.53	93.71	85.47	191.00	103.10	191.00
	Maximum 60-day Average	13.21	374.84	170.61	82.99	85.47	191.00	102.35	191.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0
	Chronic FW Fish	2	7	31	6	47	72	63	208
	Acute EM Fish	0	1	0	0	0	0	0	0
	Chronic EM Fish	2	7	31	6	47	72	63	208
	Acute FW Inverts	0	4	3	0	0	0	0	0
	Chronic FW Inverts	0	5	6	1	1	7	3	14
	Acute EM Inverts	3	7	41	8	26	51	49	129
	Chronic EM Inverts	3	9	42	9	86	101	110	274
	Non-Vascular Plants	4	11	56	10	264	324	210	370
	Vascular Plants	4	11	50	10	52	72	67	213
	CELOC	3	7	36	6	67	89	79	241

Nebraska: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Nebraska had 90 watersheds shown as excluded in the map below, 70 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2069	2040	2055	2008	2005
Max 4-day average concentration (µg/L)		83.05	97.17	100.02	111.30	97.89
Max 21-day average concentration (µg/L)		55.49	65.98	68.08	74.06	65.90
Max 60-day average concentration (µg/L)		35.55	42.35	43.70	47.11	42.18
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	103	118	148	138	128
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	103	118	148	138	128
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	2	2	2	2
	Acute EM Inverts	35	37	43	50	40
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	809	913	1056	992	1001
	Vascular Plants	264	365	463	416	373
	CELOC	155	194	261	220	190

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.29. Nevada.

Bias Factors were not used for Nevada (see **Section 7.4.1.4**). Based on the available data there are few exceedances of the non-vascular aquatic plant LOC in the older less frequently sampled monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		41	99	11	24
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.04	0.18	0.04	0.07
	Maximum 21-day Average	0.04	0.02	0.04	0.07
	Maximum 60-day Average	0.04	0.02	0.04	0.03
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Nevada: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Nevada had 850 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1917	1713	1917	1917	1713
Max 4-day average concentration (µg/L)		0.03	0.02	0.02	0.04	0.03
Max 21-day average concentration (µg/L)		0.03	0.02	0.02	0.03	0.02
Max 60-day average concentration (µg/L)		0.02	0.02	0.02	0.03	0.02
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.30. New Hampshire.

Due to low sample numbers in the available monitoring data (n <12) peak values could only be used, thus 21-day average, and 60-day average atrazine concentrations are not provided for the monitoring data. Bias Factors were not used for New Hampshire (see **Section 7.4.1.4**).

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		42
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.04
	Maximum 21-day Average	<0.01
	Maximum 60-day Average	<0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0
	Chronic FW Fish	0
	Acute EM Fish	0
	Chronic EM Fish	0
	Acute FW Inverts	0
	Chronic FW Inverts	0
	Acute EM Inverts	0
	Chronic EM Inverts	0
	Non-Vascular Plants	0
	Vascular Plants	0
	CELOC	0

New Hampshire: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. New Hampshire had 2 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		332	332	332	332	332
Max 4-day average concentration (µg/L)		0.35	0.27	0.20	0.29	0.26
Max 21-day average concentration (µg/L)		0.27	0.21	0.17	0.23	0.20
Max 60-day average concentration (µg/L)		0.19	0.16	0.12	0.16	0.14
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.31. New Jersey.

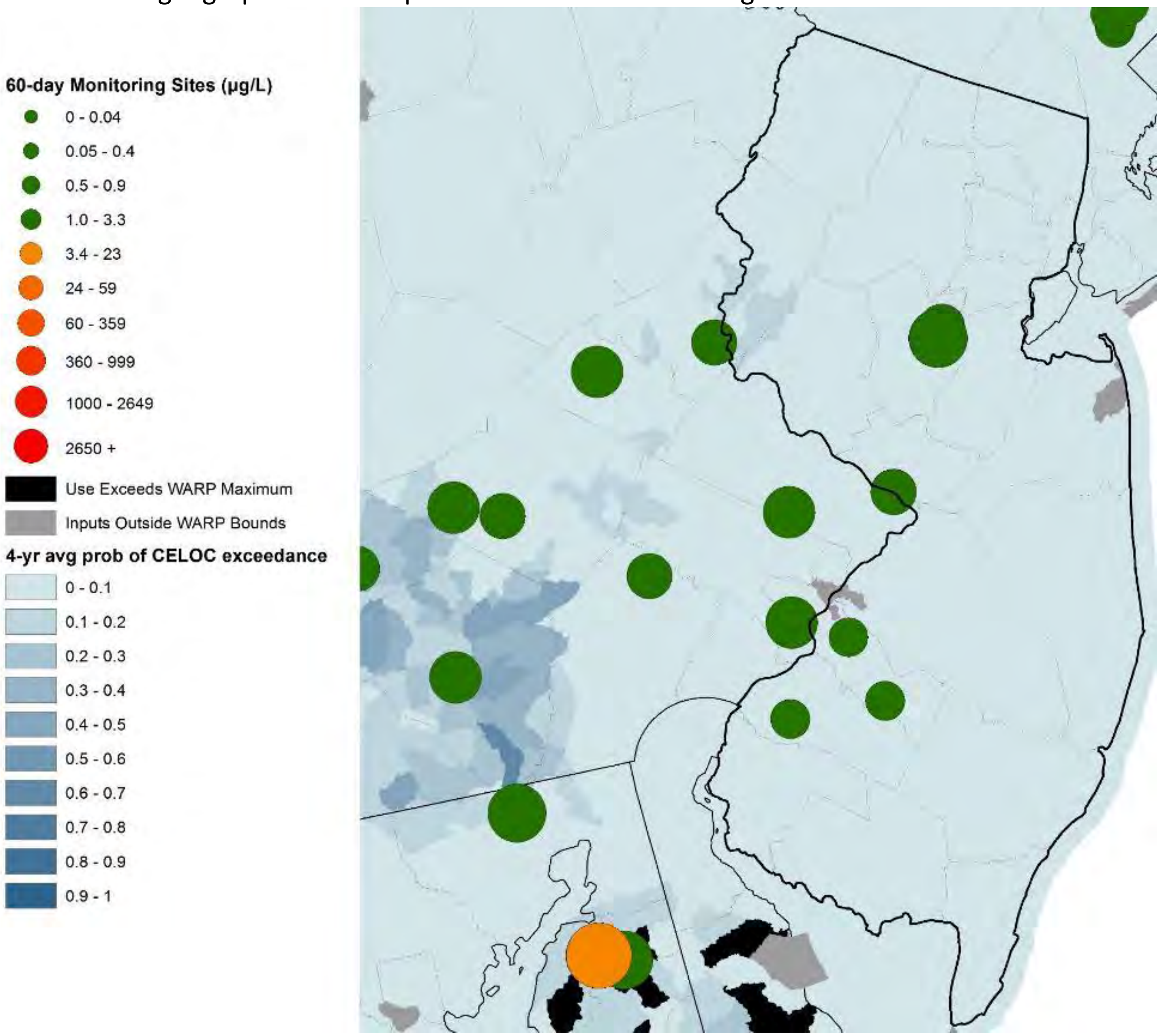
Bias Factors were not used for New Jersey (see **Section 7.4.1.4**). Based on the available data there are exceedances of the chronic fish, non-vascular and vascular aquatic plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		271	574	25	19
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	2.18	13.20	1.53	3.13
	Maximum 21-day Average	0.25	10.00	0.61	2.39
	Maximum 60-day Average	0.25	4.45	0.29	1.63
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	6	0	0
	Non-Vascular Plants	3	13	4	2
	Vascular Plants	0	2	0	0
	CELOC	0	2	0	0

New Jersey: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. New Jersey had 3 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		273	273	273	273	273
Max 4-day average concentration (µg/L)		3.79	2.89	2.17	3.03	2.93
Max 21-day average concentration (µg/L)		2.75	2.06	1.58	2.17	2.12
Max 60-day average concentration (µg/L)		1.80	1.35	1.04	1.38	1.39
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	7	5	4	5	5
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.32. New Mexico

Due to low sample numbers in the available monitoring data (n <12) peak values could only be used, thus 21-day average, and 60-day average atrazine concentrations are not provided for the monitoring data. Bias Factors were not used for New Mexico (see **Section 7.4.1.4**).

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		212	202
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.15	6.61
	Maximum 21-day Average	0.01	0.02
	Maximum 60-day Average	0.01	0.02
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0
	Chronic FW Fish	0	0
	Acute EM Fish	0	0
	Chronic EM Fish	0	0
	Acute FW Inverts	0	0
	Chronic FW Inverts	0	0
	Acute EM Inverts	0	0
	Chronic EM Inverts	0	0
	Non-Vascular Plants	0	4
	Vascular Plants	0	0
	CELOC	0	0

New Mexico: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. New Mexico had 96 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		3086	3086	3086	3086	3086
Max 4-day average concentration (µg/L)		11.60	11.38	14.90	7.17	11.26
Max 21-day average concentration (µg/L)		8.27	8.24	10.57	5.22	8.07
Max 60-day average concentration (µg/L)		5.60	5.61	7.10	3.59	5.47
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	1	1	2	0	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	1	1	2	0	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	22	67	27	31	37
	Vascular Plants	2	4	8	1	3
	CELOC	1	1	5	1	2

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.

.

17.2.33. New York.

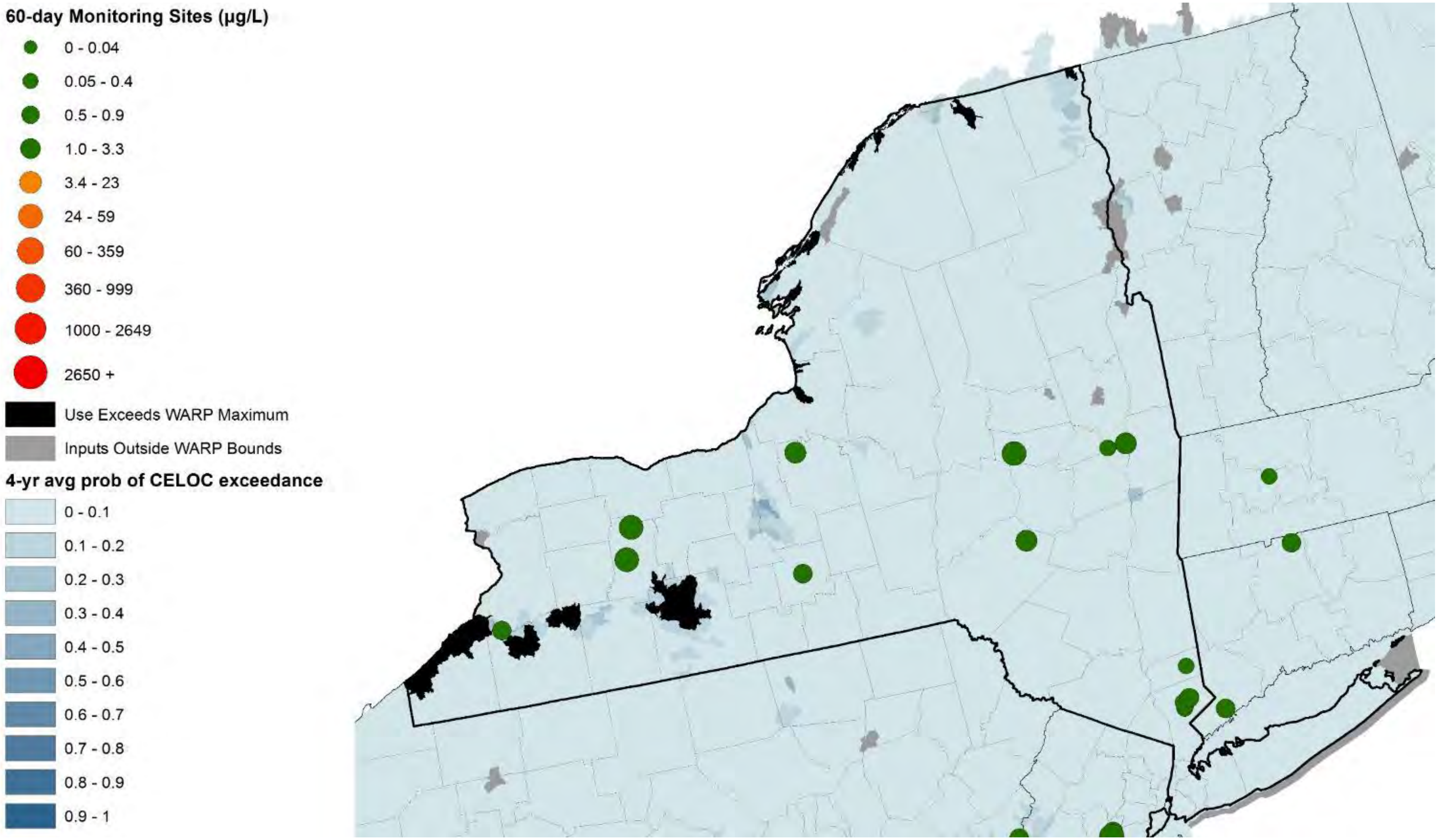
Bias Factors were not used for New York (see **Section 7.4.1.4**). Based on the available data there are exceedances of the chronic fish, non-vascular and vascular aquatic plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		124	708	15	63
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.21	20.70	1.14	20.00
	Maximum 21-day Average	0.07	20.70	0.93	4.48
	Maximum 60-day Average	0.07	8.67	0.49	1.85
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	1	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	1	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	2	0	4
	Non-Vascular Plants	0	18	2	13
	Vascular Plants	0	1	0	0
	CELOC	0	2	0	0

New York: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. New York had 53 watersheds shown as excluded in the map below, 43 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1612	1640	1643	1643	1609
Max 4-day average concentration (µg/L)		20.69	28.64	8.62	4.34	7.54
Max 21-day average concentration (µg/L)		14.00	18.85	5.94	3.06	5.01
Max 60-day average concentration (µg/L)		8.83	11.82	3.81	2.04	3.17
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	5	3	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	5	3	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	1	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	137	92	56	59	102
	Vascular Plants	29	11	2	0	7
	CELOC	15	6	1	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.34. North Carolina.

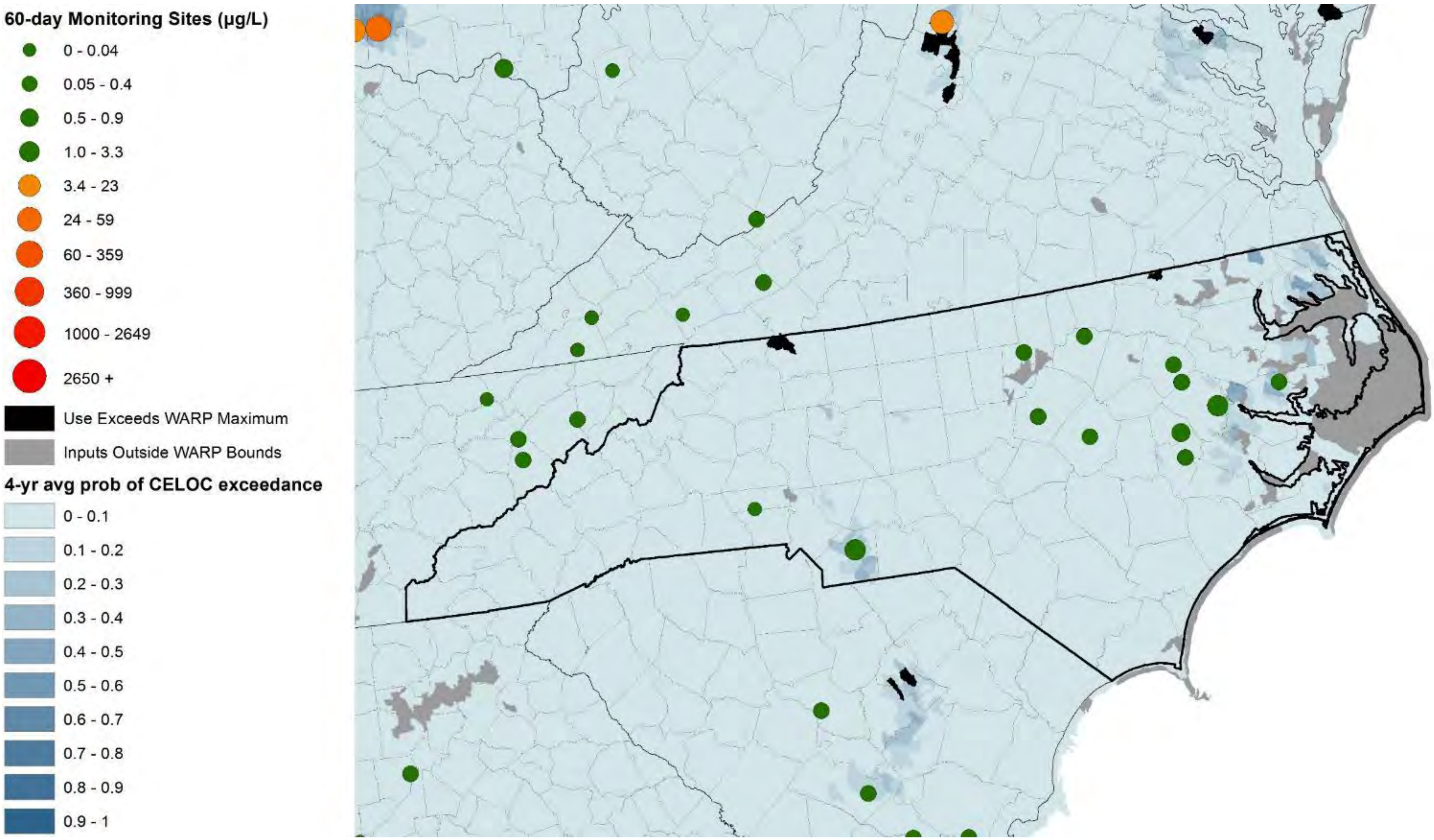
Bias Factors were not used for North Carolina (see **Section 7.4.1.4**). Based on the available data there were exceedances of the Chronic Fish, and non-vascular LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		103	536	46	36
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	1.10	4.90	4.16	2.88
	Maximum 21-day Average	0.50	1.30	3.38	2.81
	Maximum 60-day Average	0.39	0.69	2.94	2.36
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	2	9	12	6
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

North Carolina: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. North Carolina had 105 watersheds shown as excluded in the map below, 3 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1668	1666	1667	1668	1665
Max 4-day average concentration (µg/L)		16.20	9.62	10.79	11.02	9.02
Max 21-day average concentration (µg/L)		11.09	6.51	7.18	7.68	6.14
Max 60-day average concentration (µg/L)		6.97	4.07	4.51	4.99	3.89
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	2	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	2	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	129	205	180	241	186
	Vascular Plants	15	11	8	14	9
	CELOC	5	2	2	3	2

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.35. North Dakota.

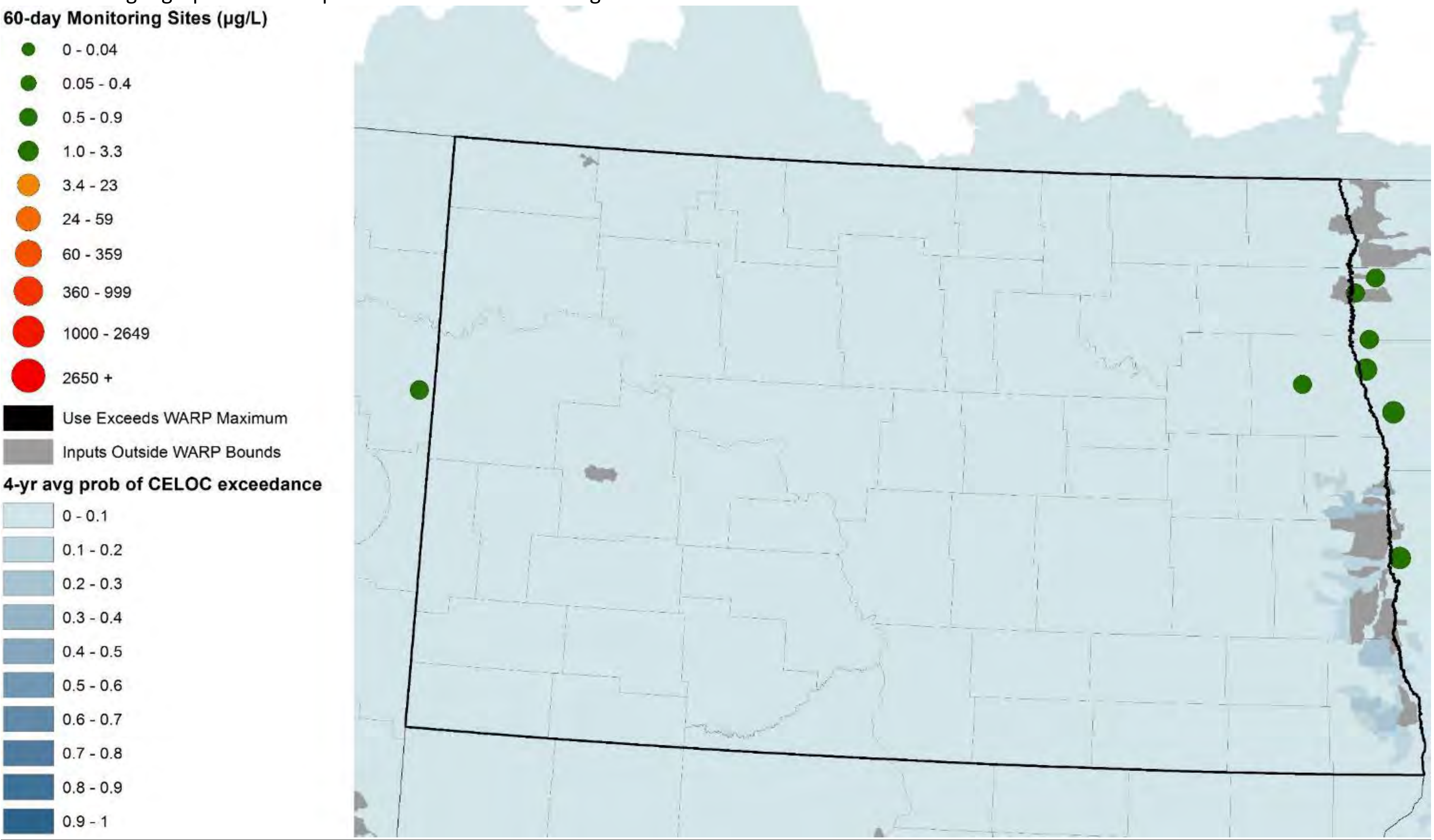
Bias Factors were not used for North Dakota (see **Section 7.4.1.4**). Based on the available data there were exceedances of the non-vascular and vascular aquatic plant LOCs in the 2005 and older low sample monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		60	296	1
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.09	4.50	0.08
	Maximum 21-day Average	0.01	4.50	0.02
	Maximum 60-day Average	0.01	3.60	0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0
	Chronic FW Fish	0	0	0
	Acute EM Fish	0	0	0
	Chronic EM Fish	0	0	0
	Acute FW Inverts	0	0	0
	Chronic FW Inverts	0	0	0
	Acute EM Inverts	0	0	0
	Chronic EM Inverts	0	1	0
	Non-Vascular Plants	0	14	0
	Vascular Plants	0	0	0
	CELOC	0	1	0

North Dakota: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. North Dakota had 24 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		1890	1890	1890	1890	1890
Max 4-day average concentration (µg/L)		3.69	10.13	3.17	1.28	4.16
Max 21-day average concentration (µg/L)		2.72	7.37	2.40	0.99	3.06
Max 60-day average concentration (µg/L)		1.92	5.07	1.72	0.73	2.14
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	0	1	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	1	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	32	69	32	10	40
	Vascular Plants	0	15	0	0	0
	CELOC	0	8	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.36. Ohio.

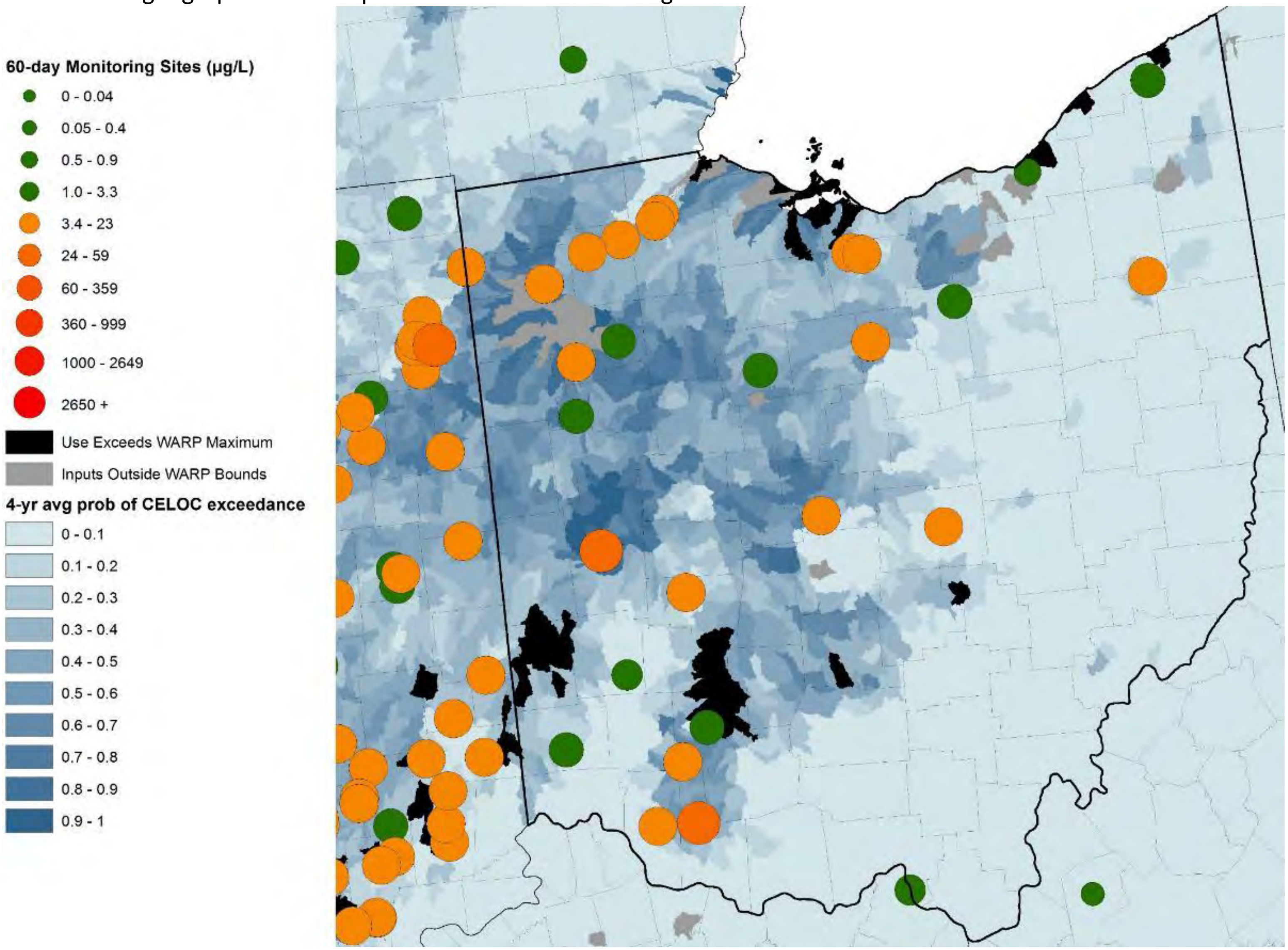
Four different Bias Factors were used for adjusting monitoring data in Ohio (see **Section 7.4.1.4**). Based on the unadjusted as well as adjusted data, there were frequent exceedances of the Chronic Fish, non-vascular and vascular plant LOCs as well as the CELOC in both older and more recent monitoring data. Fewer exceedances of the acute and chronic invertebrate LOCs were detected.

Description of Data Summary and Bias Factor Use		AEEMP < 12 Samples Prior to 2006	AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	AMP1 < 12 Samples 2006-2014	AMP1 < 12 Samples Prior to 2006	AMP1 ≥ 12 Samples 2006-2014	AMP1 ≥ 12 Samples Prior to 2006	AMP2 < 12 Samples Prior to 2006	NCWQR < 12 Samples Prior to 2006	NCWQR ≥ 12 Samples 2006-2014	NCWQR ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1	12	7	1	6	38	61	3	3	18	46	62	160	178	148
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	23.18	128.07	67.44	0.64	39.81	59.42	61.37	6.44	16.74	74.90	78.00	38.00	84.00	227.00	85.20
	Maximum 21-day Average	11.04	15.26	30.42	0.54	30.64	22.69	24.99	4.63	7.69	25.11	27.78	38.00	75.00	109.65	47.43
	Maximum 60-day Average	10.10	7.81	27.91	0.41	18.09	11.02	20.14	4.10	5.12	11.94	15.42	38.00	43.12	39.85	27.03
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Fish	1	4	5	0	3	11	31	0	2	8	30	9	19	49	50
	Acute EM Fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic EM Fish	1	4	5	0	3	11	31	0	2	8	30	9	19	49	50
	Acute FW Inverts	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
	Acute EM Inverts	1	11	6	0	2	14	19	0	0	9	22	4	30	22	24
	Chronic EM Inverts	1	11	5	0	5	15	47	1	2	10	40	9	26	84	86
	Non-Vascular Plants	1	12	7	0	6	34	58	2	3	18	44	32	107	145	136
	Vascular Plants	1	12	7	0	5	25	50	2	3	12	40	9	20	55	55
	CELOC	1	5	5	0	5	14	38	1	2	10	34	9	21	69	67

Ohio: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Ohio had 70 watersheds shown as excluded in the map below, 35 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		1505	1503	1483	1506	1480
Max 4-day average concentration (µg/L)		54.05	54.60	83.59	39.14	55.46
Max 21-day average concentration (µg/L)		36.26	35.94	55.69	26.28	36.99
Max 60-day average concentration (µg/L)		23.15	22.84	35.16	16.90	23.54
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	142	122	170	67	128
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	142	122	170	67	128
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	16	30	36	7	20
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	855	835	796	777	832
	Vascular Plants	493	426	489	335	472
	CELOC	277	221	300	151	229

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.37. Oklahoma.

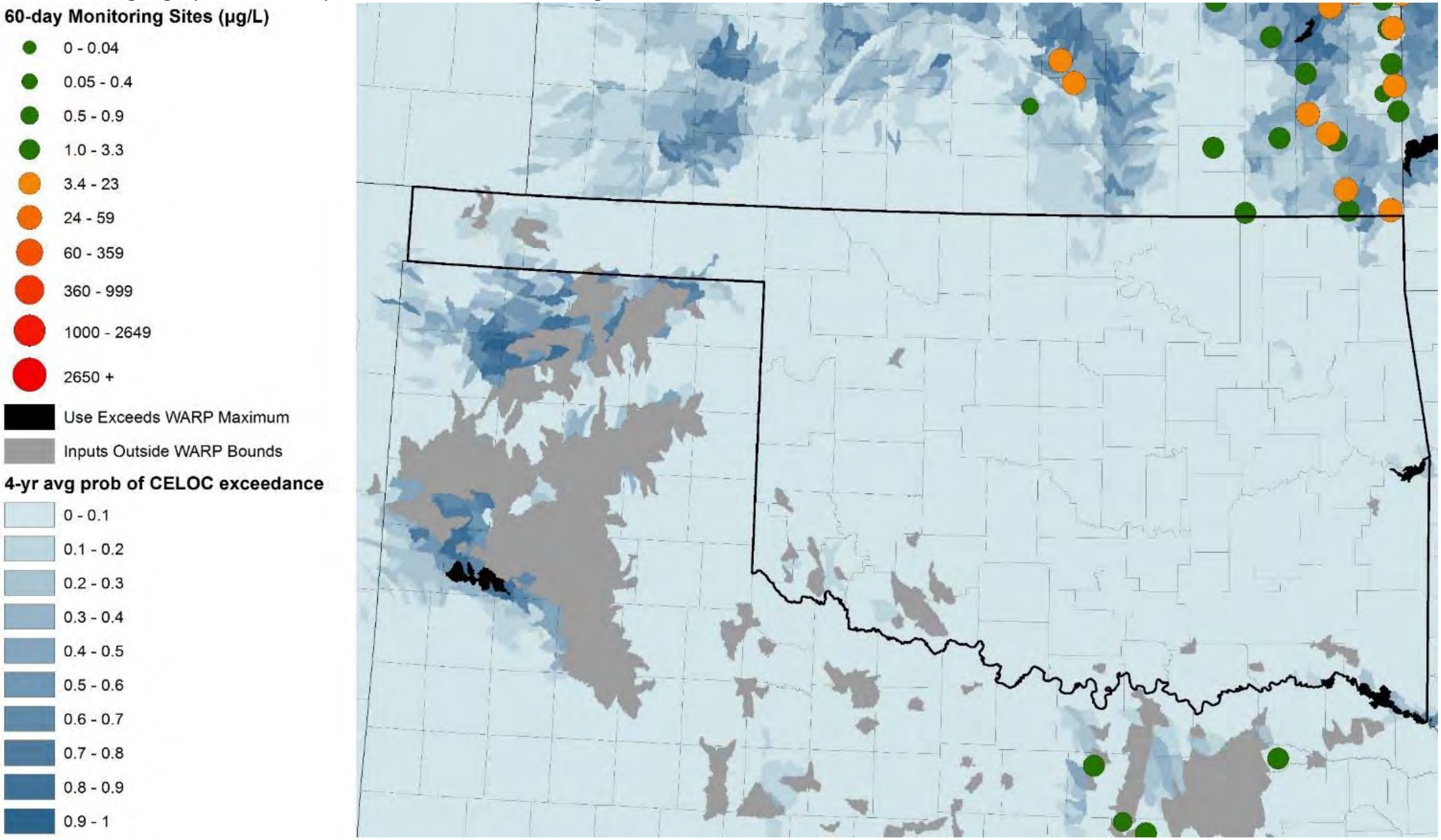
Bias Factors were not used for Oklahoma (see **Section 7.4.1.4**). There are limited number of available monitoring data for Oklahoma. Based on the available data there were exceedances of the chronic fish LOCs in the 2005 and older monitoring data, as well as the acute fish, invertebrate, non-vascular and vascular aquatic plant LOCs.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		71	42	2
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	187.00	1.10	0.75
	Maximum 21-day Average	187.00	0.69	0.75
	Maximum 60-day Average	97.06	0.69	0.75
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0
	Chronic FW Fish	13	0	0
	Acute EM Fish	0	0	0
	Chronic EM Fish	13	0	0
	Acute FW Inverts	0	0	0
	Chronic FW Inverts	1	0	0
	Acute EM Inverts	28	0	0
	Chronic EM Inverts	13	0	0
	Non-Vascular Plants	38	1	0
	Vascular Plants	13	0	0
	CELOC	13	0	0

Oklahoma: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Oklahoma had 49 watersheds shown as excluded in the map below, 6 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2026	2032	2032	2032	2026
Max 4-day average concentration (µg/L)		41.29	20.62	24.19	19.06	16.31
Max 21-day average concentration (µg/L)		26.86	15.01	17.32	13.57	11.85
Max 60-day average concentration (µg/L)		16.24	10.35	11.84	8.91	8.19
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	7	4	5	2	6
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	7	4	5	2	6
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	3	0	1	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	107	140	88	119	110
	Vascular Plants	16	14	18	10	16
	CELOC	10	8	11	4	9

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.38. Oregon.

Bias Factors were not used for Oregon (see **Section 7.4.1.4**). Based on the available data there were few exceedances of the chronic fish and non-vascular aquatic plant LOCs in the older and more recent monitoring data. Lower frequency monitoring data indicates significant exceedance frequencies of the non-vascular and lesser so the vascular aquatic plant LOCs.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		638	227	244	104
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	1.59	4.53	3.91	2.98
	Maximum 21-day Average	1.19	4.53	2.66	2.98
	Maximum 60-day Average	1.19	3.12	2.14	2.82
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	1	0	0
	Non-Vascular Plants	2	6	4	1
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Oregon: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Oregon had 612 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2518	2518	2518	2518	2518
Max 4-day average concentration (µg/L)		0.63	0.42	0.31	0.36	0.43
Max 21-day average concentration (µg/L)		0.47	0.32	0.24	0.28	0.32
Max 60-day average concentration (µg/L)		0.32	0.22	0.17	0.19	0.23
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.39. Pennsylvania.

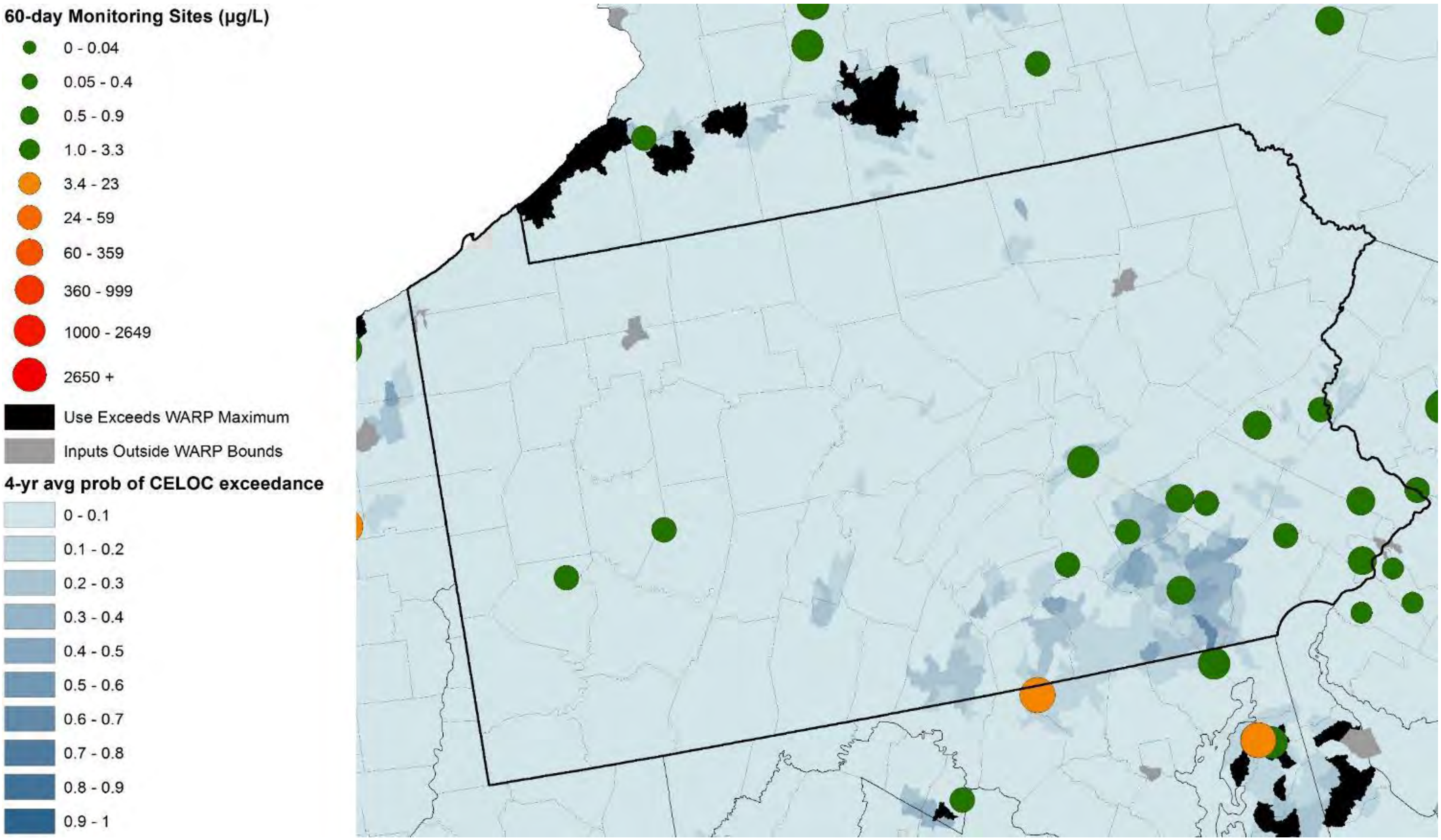
Bias Factors were not used for Pennsylvania (see **Section 7.4.1.4**). There are limited number of available monitoring data for Pennsylvania. Based on the available data there were exceedances of the chronic fish, non-vascular and vascular aquatic plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		4	266	6	27
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.24	12.00	3.54	3.37
	Maximum 21-day Average	0.24	1.43	1.51	3.23
	Maximum 60-day Average	0.19	1.05	0.57	1.63
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	20	2	11
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Pennsylvania: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Pennsylvania had 6 watersheds shown as excluded in the map below, 2 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1468	1470	1470	1470	1468
Max 4-day average concentration (µg/L)		20.54	12.64	7.00	11.29	12.36
Max 21-day average concentration (µg/L)		13.92	8.46	4.84	8.00	8.41
Max 60-day average concentration (µg/L)		8.58	5.25	3.07	5.16	5.24
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	5	1	0	1	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	5	1	0	1	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	271	203	131	229	221
	Vascular Plants	42	18	2	23	20
	CELOC	17	2	0	4	2

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.40. Rhode Island.

Bias Factors were not used for Rhode Island (see **Section 7.4.1.4**). There are limited number of available monitoring data for Rhode Island. Based on the single site-year data there were exceedances of the non-vascular aquatic plant LOC in the 2005 and older monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.12
	Maximum 21-day Average	<0.01
	Maximum 60-day Average	<0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0
	Chronic FW Fish	0
	Acute EM Fish	0
	Chronic EM Fish	0
	Acute FW Inverts	0
	Chronic FW Inverts	0
	Acute EM Inverts	0
	Chronic EM Inverts	0
	Non-Vascular Plants	0
	Vascular Plants	0
	CELOC	0

Rhode Island: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Rhode Island had 0 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		55	55	55	55	55
Max 4-day average concentration (µg/L)		3.00	1.14	0.87	1.34	1.59
Max 21-day average concentration (µg/L)		2.10	0.79	0.61	0.93	1.11
Max 60-day average concentration (µg/L)		1.29	0.49	0.38	0.58	0.69
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	1	1	0	1	1
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.41. South Carolina.

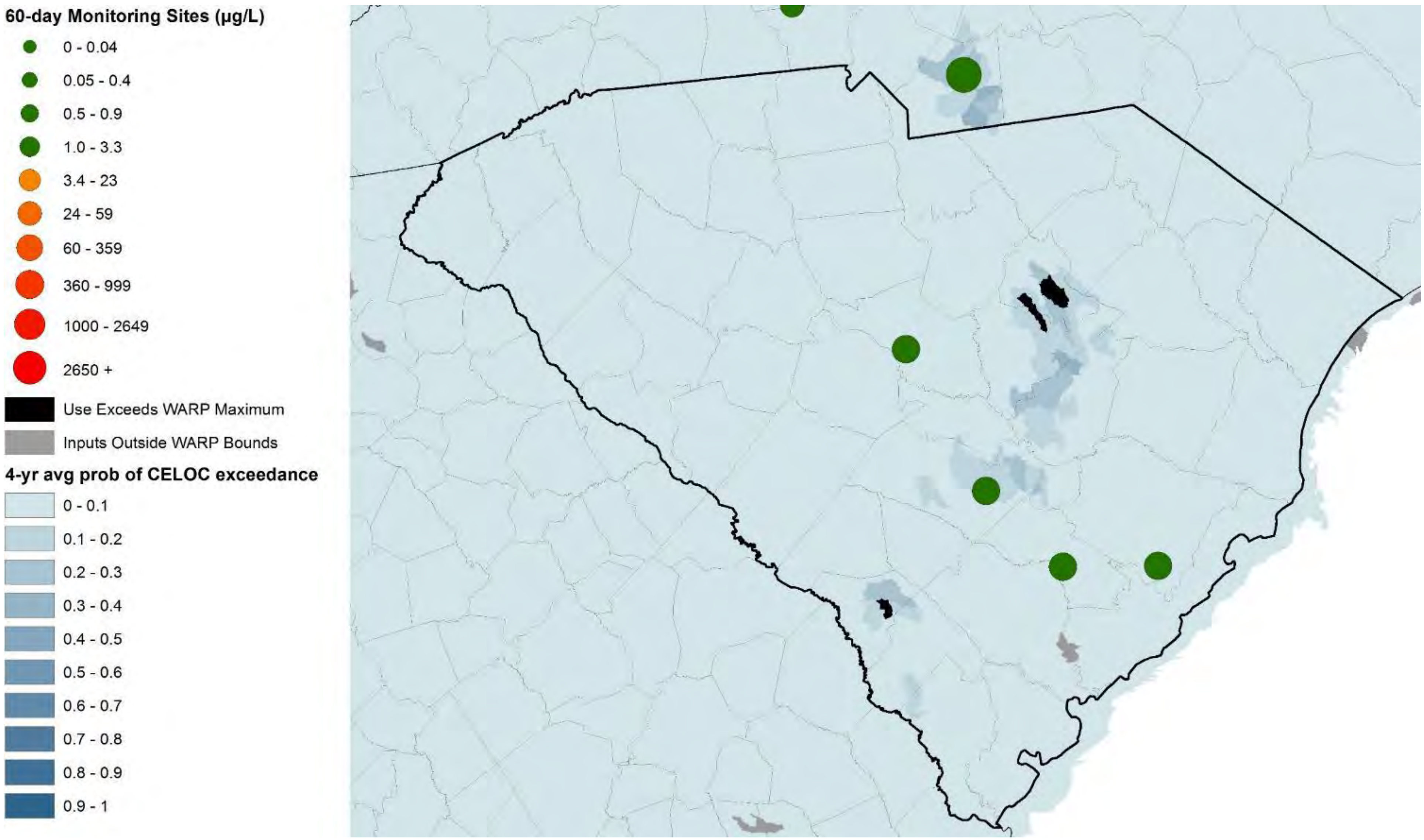
Bias Factors were not used for South Carolina (see **Section 7.4.1.4**). There are limited number of available monitoring data for South Carolina. Based on the available data there were exceedances of the non-vascular and vascular aquatic plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		6	116	8	11
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.10	1.15	0.71	1.10
	Maximum 21-day Average	0.10	1.15	0.51	0.43
	Maximum 60-day Average	0.09	1.15	0.26	0.24
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	1	0	1
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

South Carolina: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. South Carolina had 6 watersheds shown as excluded in the map below, 3 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		971	972	972	970	969
Max 4-day average concentration (µg/L)		14.75	9.62	5.51	13.49	5.97
Max 21-day average concentration (µg/L)		9.73	6.35	3.71	8.97	4.02
Max 60-day average concentration (µg/L)		5.78	3.87	2.30	5.39	2.45
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	1	0	0	1	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	1	0	0	1	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	87	73	31	105	79
	Vascular Plants	5	5	1	26	3
	CELOC	3	1	0	6	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.42. South Dakota.

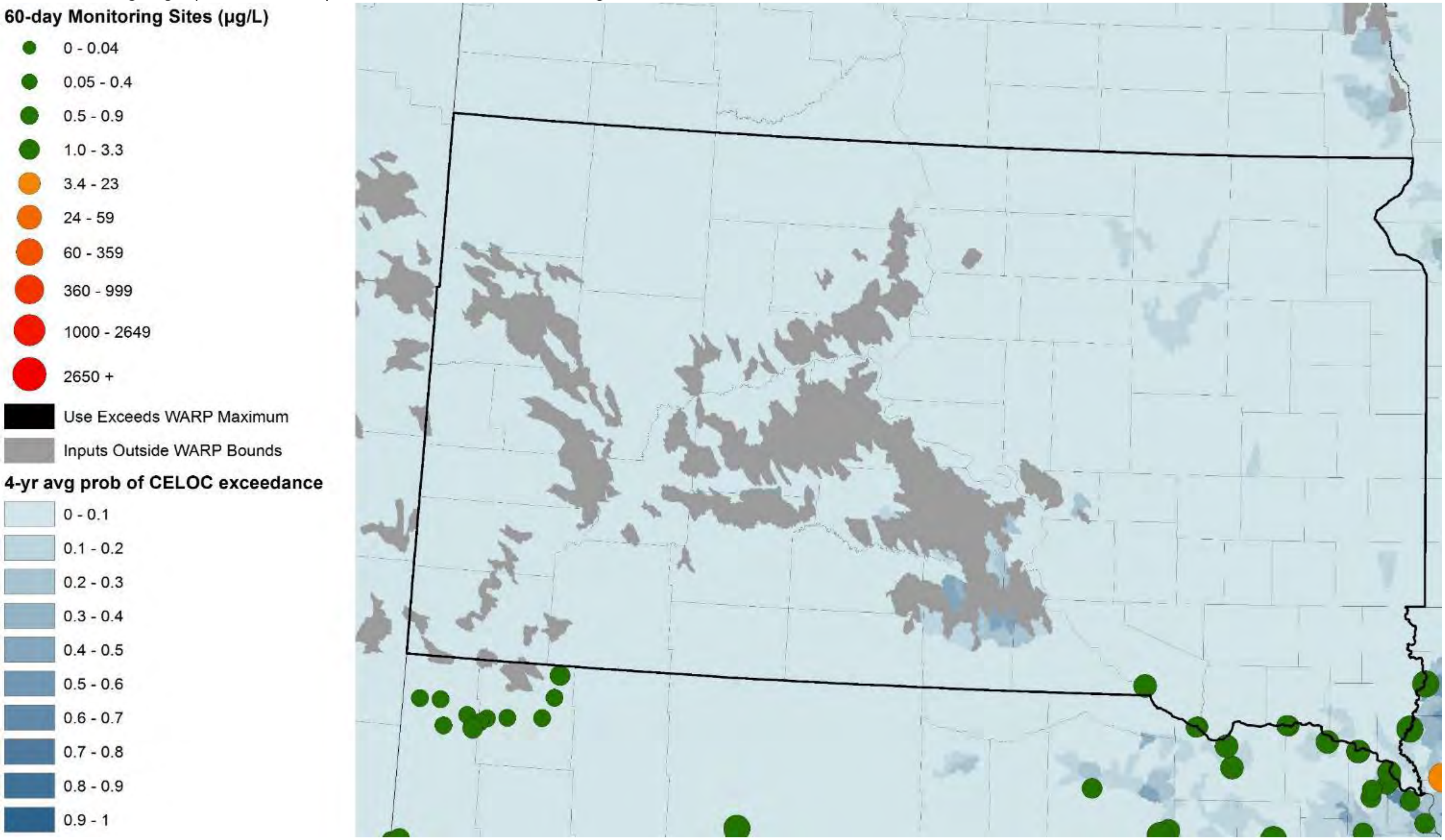
Bias Factors were not used for South Dakota (see **Section 7.4.1.4**). There are limited number of available monitoring data for South Dakota. Based on the available data there were exceedances of the non-vascular and vascular aquatic plant LOCs in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		38	151	2	2
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	29.60	3.11	0.11	1.26
	Maximum 21-day Average	0.10	2.53	0.09	0.87
	Maximum 60-day Average	0.09	2.38	0.09	0.47
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	1	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	8	13	0	1
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

South Dakota: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. South Dakota had 268 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2152	2152	2152	2152	2152
Max 4-day average concentration (µg/L)		3.34	6.19	14.88	5.79	6.52
Max 21-day average concentration (µg/L)		2.41	4.72	11.03	4.17	4.91
Max 60-day average concentration (µg/L)		1.63	3.40	7.73	2.81	3.50
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	3	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	3	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	70	186	84	277	138
	Vascular Plants	0	3	8	6	3
	CELOC	0	1	7	0	2

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.43. Tennessee.

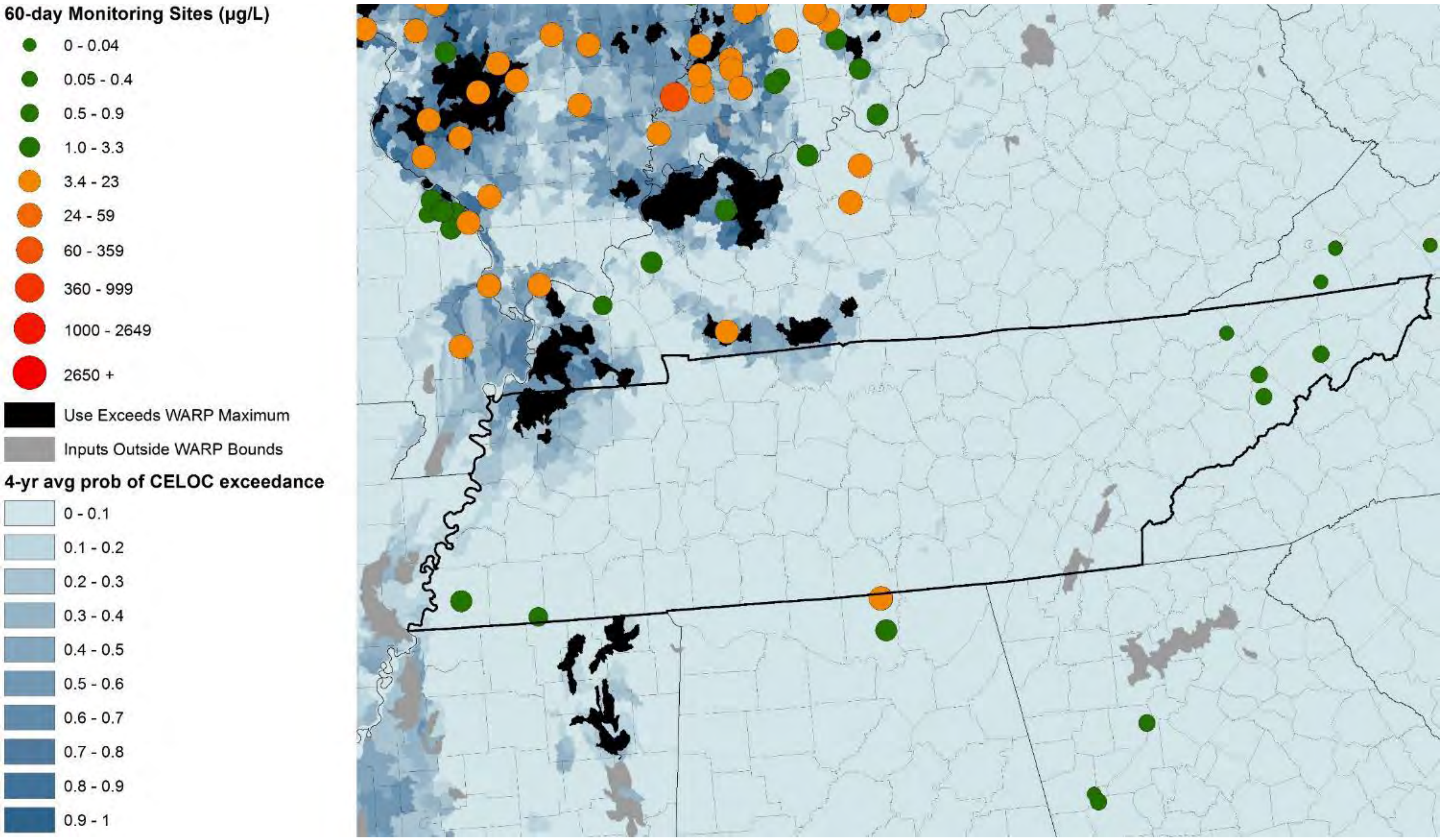
Bias Factors were used for Tennessee (see **Section 7.4.1.4**). There are limited number of available monitoring data for Tennessee. Based on the available data there were exceedances of the chronic fish, non-vascular and vascular aquatic plant LOCs as well as the CELOC in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		AEEMP ≥ 12 Samples Post-2005	AEEMP ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1	1	3	138	4	11
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	34.16	24.10	0.03	36.40	10.70	7.55
	Maximum 21-day Average	5.11	8.08	<0.01	36.40	3.06	4.84
	Maximum 60-day Average	4.55	6.20	<0.01	23.43	2.99	4.07
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0	0
	Chronic FW Fish	0	1	0	2	0	0
	Acute EM Fish	0	0	0	0	0	0
	Chronic EM Fish	0	1	0	2	0	0
	Acute FW Inverts	0	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0	0
	Acute EM Inverts	1	1	0	1	0	0
	Chronic EM Inverts	1	1	0	3	0	1
	Non-Vascular Plants	1	1	0	22	1	4
	Vascular Plants	1	1	0	2	0	0
	CELOC	1	1	0	3	0	1

Tennessee: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Tennessee had 21 watersheds shown as excluded in the map below, 15 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		1122	1120	1109	1122	1107
Max 4-day average concentration (µg/L)		6.77	13.35	31.71	11.20	13.24
Max 21-day average concentration (µg/L)		4.69	8.62	20.26	7.68	8.59
Max 60-day average concentration (µg/L)		2.92	5.25	12.08	4.73	5.21
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	0	1	13	0	1
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	1	13	0	1
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	2	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	71	134	126	117	131
	Vascular Plants	6	35	44	12	25
	CELOC	0	11	23	4	8

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.44. Texas.

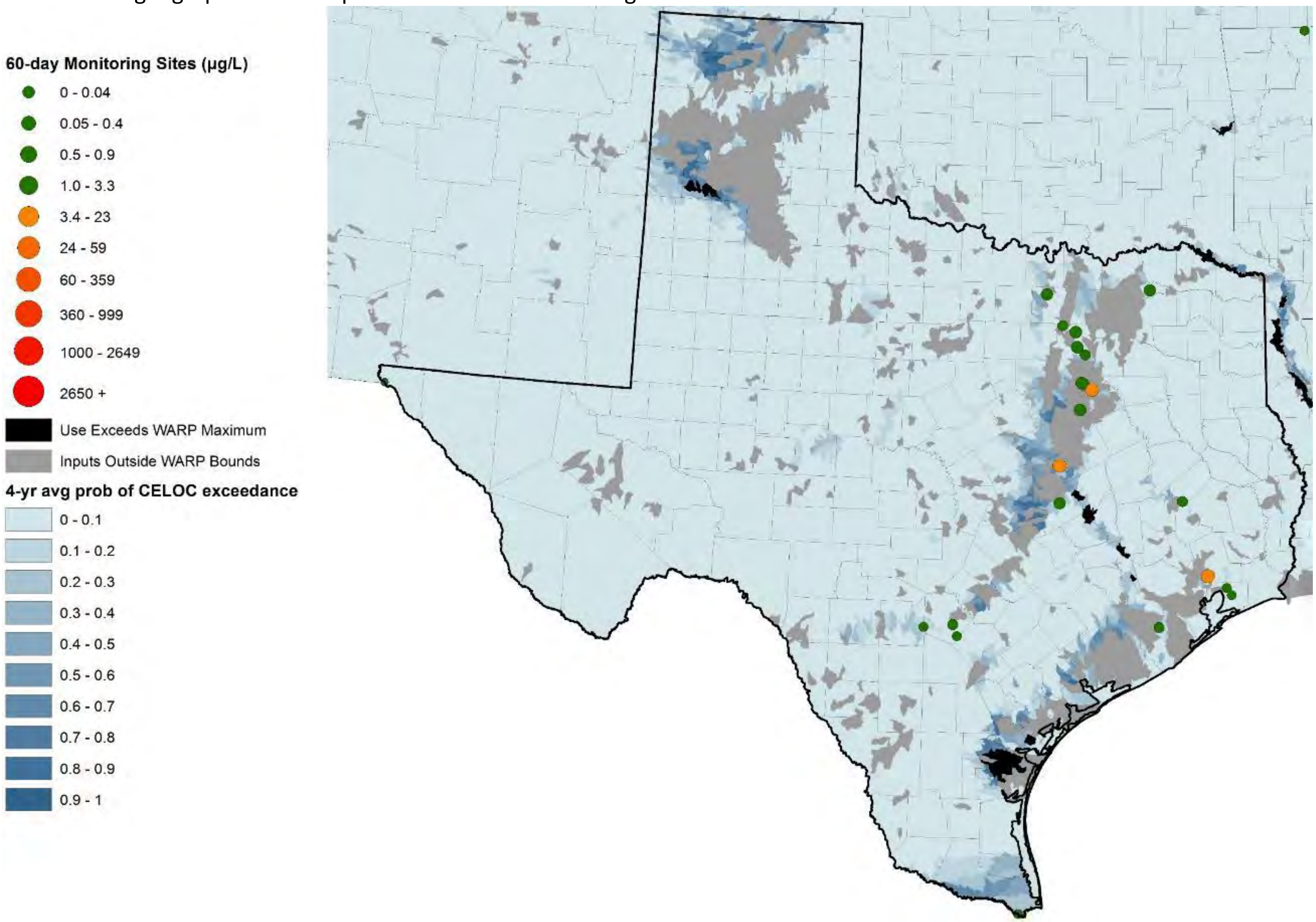
Bias Factors were used for Texas (see **Section 7.4.1.4**). Based on the available data there were significant exceedances of the chronic fish, acute invertebrate, non-vascular and vascular aquatic plant LOCs as well as the CELOC in the unadjusted monitoring data from both older and more recent collection efforts.

Description of Data Summary and Bias Factor Use		AMP2 ≥ 12 Samples Prior to 2006	Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		1	40	213	81	51
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.81	10.40	33.50	133.89	9.80
	Maximum 21-day Average	0.70	5.15	20.00	56.03	6.80
	Maximum 60-day Average	0.68	5.15	20.00	20.73	4.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	0	2	7	6	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	2	7	6	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	1	6	0
	Chronic EM Inverts	0	2	9	14	5
	Non-Vascular Plants	0	12	45	55	33
	Vascular Plants	0	2	8	7	0
	CELOC	0	2	9	7	3

Texas: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Texas had 809 watersheds shown as excluded in the map below, 26 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		2006	2007	2008	2009	4-yr Avg
Number of HUC12s		5523	5525	5522	5521	5513
Max 4-day average concentration (µg/L)		41.29	142.83	105.38	78.88	50.85
Max 21-day average concentration (µg/L)		26.86	100.13	70.70	50.65	35.25
Max 60-day average concentration (µg/L)		16.24	65.66	45.68	30.96	23.00
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0	0
	Chronic FW Fish	37	118	115	49	92
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	37	118	115	49	92
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	3	2	0	0
	Acute EM Inverts	3	31	43	14	20
	Chronic EM Inverts	0	2	0	0	0
	Non-Vascular Plants	436	833	647	542	656
	Vascular Plants	115	259	240	123	195
	CELOC	78	194	162	81	137

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.45. Utah.

Bias Factors were not used for Utah (see **Section 7.4.1.4**). Based on the available monitoring data there are exceedances of the acute estuarine/marine invertebrate, and non-vascular and vascular aquatic plant LOCs in the lesser sampled older monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		62	323	4	9
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.02	11.00	0.01	0.13
	Maximum 21-day Average	0.02	0.50	0.01	0.13
	Maximum 60-day Average	0.01	0.50	0.01	0.12
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	6	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Utah: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Utah had 673 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1908	1901	1908	1908	1901
Max 4-day average concentration (µg/L)		0.29	0.22	0.29	0.63	0.36
Max 21-day average concentration (µg/L)		0.23	0.18	0.23	0.49	0.28
Max 60-day average concentration (µg/L)		0.17	0.13	0.17	0.36	0.21
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	0	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

17.2.46. Vermont.

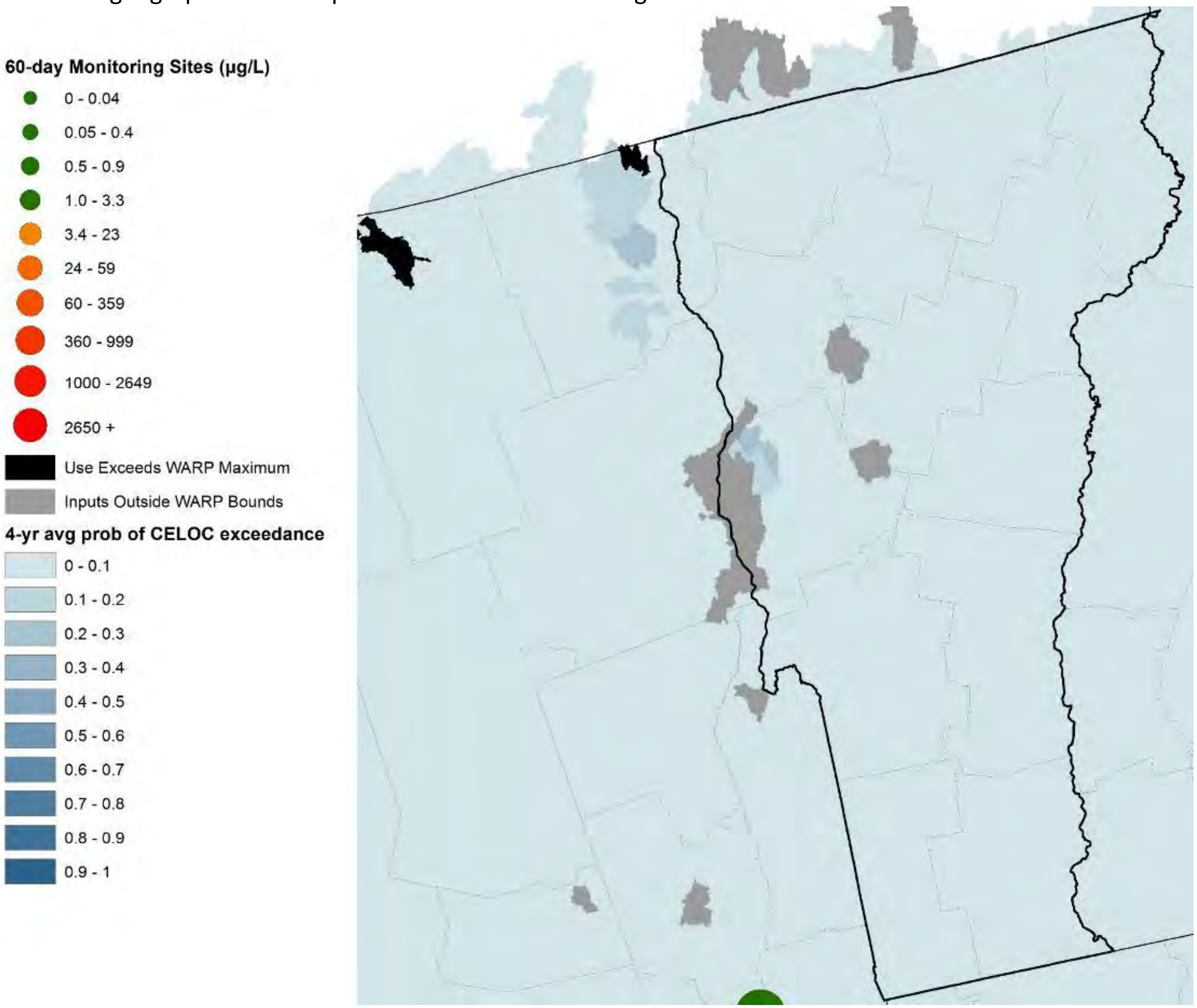
Due to low sample numbers in the available monitoring data (n <12) peak values could only be used, thus 21-day average, and 60-day average atrazine concentrations are not provided for the monitoring data. Bias Factors were not used for Vermont (see **Section 7.4.1.4**). There are limited number of available monitoring data for Vermont. Based on the available data there were exceedances of the non-vascular aquatic plant LOC in the more recent monitoring data.

Description of Data Summary and Bias Factor Use		**Unadjusted < 12 Samples 2006-2014**	**Unadjusted < 12 Samples Prior to 2006**
Number of Site-Years (WARP Watersheds)		5	12
Maximum Measured or Predicted Exposure Concentrations (ug/L)	**Maximum**	0.28	0.03
	Maximum 21-day Average	<0.01	0.03
	Maximum 60-day Average	<0.01	0.03
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0
	Chronic FW Fish	0	0
	Acute EM Fish	0	0
	Chronic EM Fish	0	0
	Acute FW Inverts	0	0
	Chronic FW Inverts	0	0
	Acute EM Inverts	0	0
	Chronic EM Inverts	0	0
	Non-Vascular Plants	0	0
	Vascular Plants	0	0
	CELOC	0	0

<u>Vermont</u>: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Vermont had 6 watersheds shown as excluded in the map below, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		258	258	258	258	258
Max 4-day average concentration (µg/L)		3.67	28.64	3.82	1.32	7.54
Max 21-day average concentration (µg/L)		2.74	18.85	2.76	1.00	5.01
Max 60-day average concentration (µg/L)		1.90	11.82	1.90	0.72	3.17
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	2	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	2	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	1	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	8	11	7	2	9
	Vascular Plants	0	3	0	0	1
	CELOC	0	2	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.47. Virginia.

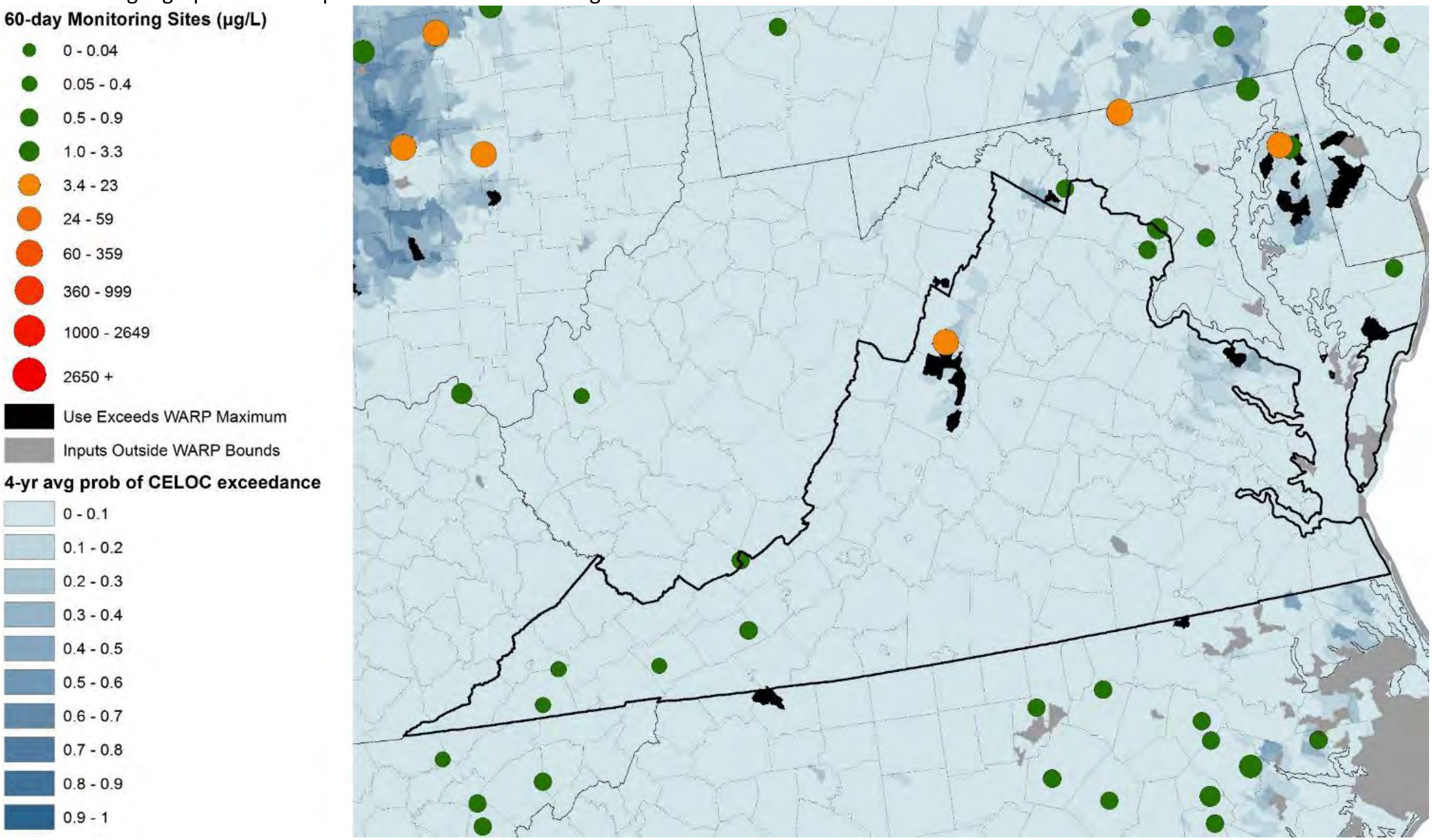
Bias Factors were not used for Virginia (see **Section 7.4.1.4**). Based on the available data there were exceedances of the chronic fish, acute invertebrate, non-vascular and vascular aquatic plant LOCs as well as the CELOC in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		24	229	16	39
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.24	28.50	12.40	25.00
	Maximum 21-day Average	0.24	3.60	5.14	25.00
	Maximum 60-day Average	0.24	3.60	2.76	12.63
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	2
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	2
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	1	0	2
	Chronic EM Inverts	0	1	1	4
	Non-Vascular Plants	0	6	2	12
	Vascular Plants	0	0	0	2
	CELOC	0	1	0	2

Virginia: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Virginia had 33 watersheds shown as excluded in the map below, 17 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1232	1229	1223	1234	1219
Max 4-day average concentration (µg/L)		15.08	13.91	11.55	6.88	8.78
Max 21-day average concentration (µg/L)		9.95	8.74	7.72	4.55	5.78
Max 60-day average concentration (µg/L)		5.92	5.15	4.88	2.77	3.46
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	2	1	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	2	1	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	117	75	83	25	91
	Vascular Plants	19	7	17	3	6
	CELOC	4	1	9	0	1

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.48. Washington.

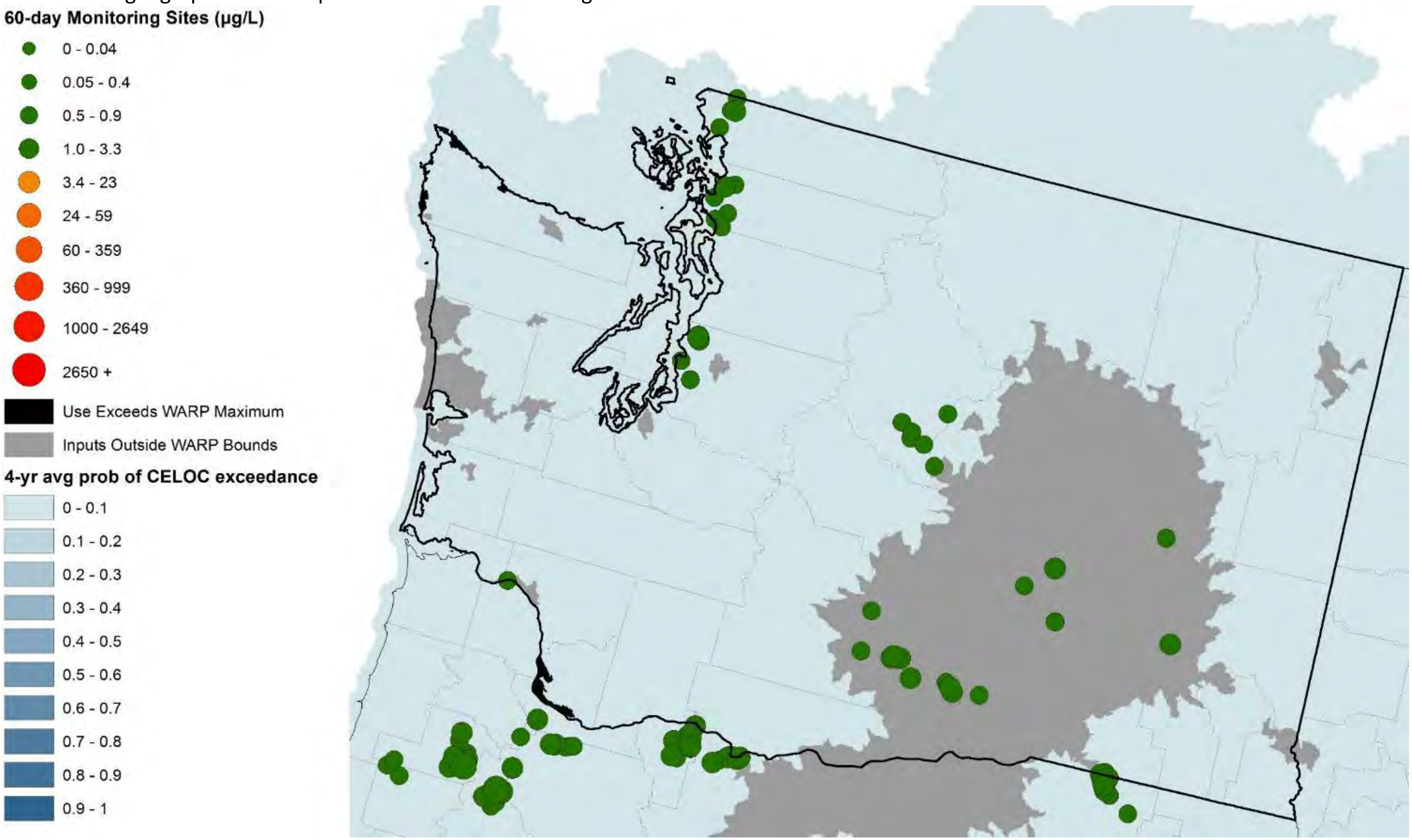
Bias Factors were not used for Washington (see **Section 7.4.1.4**). Based on the available data there were exceedances of the non-vascular and vascular aquatic plant LOCs in the older and more lest frequently sampled monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		77	494	133	80
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.05	0.76	0.25	1.40
	Maximum 21-day Average	0.05	0.76	0.10	1.02
	Maximum 60-day Average	0.05	0.76	0.07	0.38
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	2
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Washington: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Washington had 435 watersheds shown as excluded in the map below, 3 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1560	1560	1560	1560	1560
Max 4-day average concentration (µg/L)		3.91	0.28	0.23	0.22	1.12
Max 21-day average concentration (µg/L)		2.48	0.22	0.18	0.17	0.72
Max 60-day average concentration (µg/L)		1.46	0.15	0.13	0.12	0.43
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	4	0	0	0	1
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.49. West Virginia.

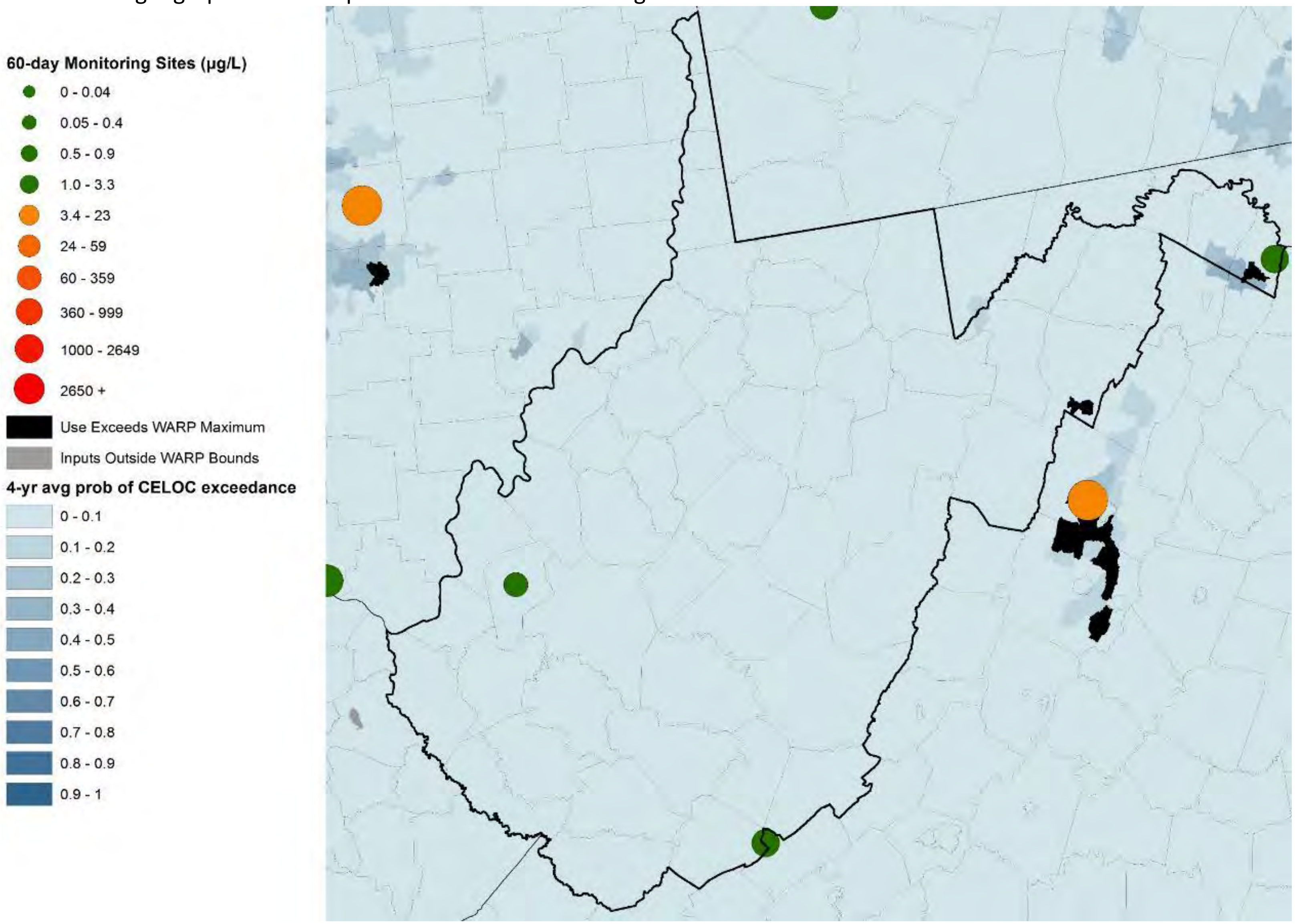
Bias Factors were not used for West Virginia (see **Section 7.4.1.4**). There are limited number of available monitoring data for West Virginia. Based on the available data there were exceedances of the non-vascular and vascular aquatic plant LOCs in the older monitoring data. The WARP model has identified 748 HUC-12 watersheds of which 12 watersheds may exceed the chronic fish LOC and there are no watersheds exceeding the CELOC.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples Prior to 2006	WARP 2006-2009
Number of Site-Years (WARP Watersheds)		6	41	3	331
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.01	0.27	1.00	5.42
	Maximum 21-day Average	<0.01	0.17	0.79	3.89
	Maximum 60-day Average	<0.01	0.17	0.38	2.58
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	1
	Non-Vascular Plants	0	0	1	7
	Vascular Plants	0	0	0	1
	CELOC	0	0	0	0

West Virginia: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. West Virginia had 2 watersheds shown as excluded in the map below, 2 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		748	748	748	748	748
Max 4-day average concentration (µg/L)		4.06	1.66	11.55	6.44	5.78
Max 21-day average concentration (µg/L)		2.91	1.22	7.72	4.44	3.94
Max 60-day average concentration (µg/L)		1.90	0.83	4.76	2.77	2.45
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	9	4	10	11	8
	Vascular Plants	0	0	4	2	2
	CELOC	0	0	2	0	0

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.50. Wisconsin.

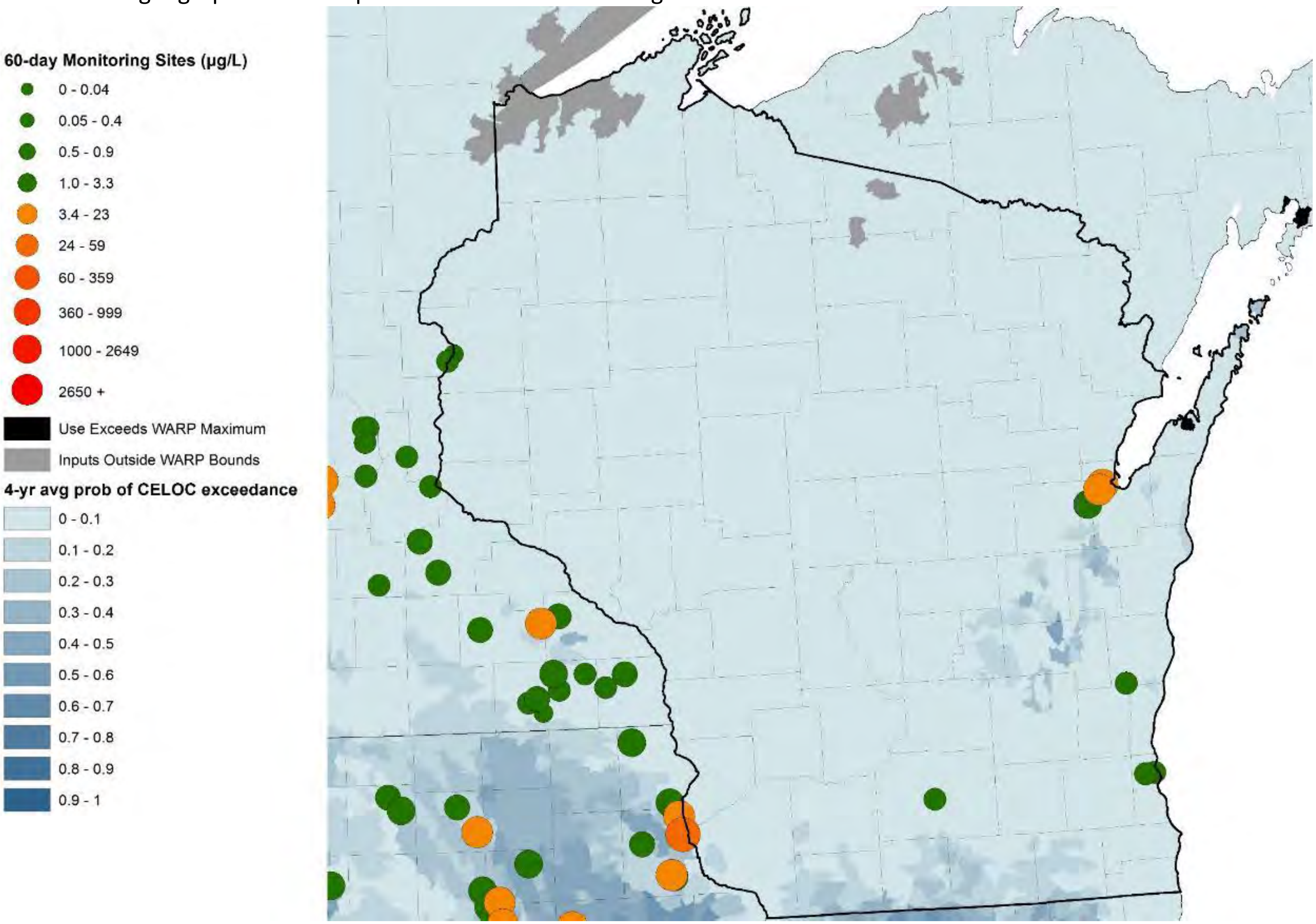
Bias Factors were not used for Wisconsin (see **Section 7.4.1.4**). Based on the available data there were exceedances of the chronic fish, acute invertebrate, non-vascular and vascular aquatic plant LOCs as well as the CELOC in the older and more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		48	354	12	43
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	21.20	97.00	6.49	17.50
	Maximum 21-day Average	21.20	34.00	6.49	17.50
	Maximum 60-day Average	19.60	34.00	3.24	10.03
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	3	4	0	1
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	3	4	0	1
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	1	6	0	0
	Chronic EM Inverts	3	7	1	7
	Non-Vascular Plants	5	52	3	16
	Vascular Plants	3	6	0	1
	CELOC	3	7	0	2

Wisconsin: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Wisconsin had 28 watersheds shown as excluded in the map below, 1 was excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		1778	1778	1778	1778	1778
Max 4-day average concentration (µg/L)		6.61	11.70	7.20	6.80	7.96
Max 21-day average concentration (µg/L)		4.85	8.10	5.30	4.90	5.63
Max 60-day average concentration (µg/L)		3.31	5.10	3.61	3.16	3.60
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	1	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	1	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	340	275	403	228	303
	Vascular Plants	9	11	18	12	11
	CELOC	0	4	1	0	1

In the map below, the WARP model has identified the probability that a watershed may exceed the CELOC. Watersheds with solid black pattern had input atrazine use rates that exceeded the model parameter validation criteria, and grey areas indicate watersheds with other model input parameters that are outside of the model validation criteria. Georeferenced monitoring data are also displayed. The sites that exceed the CELOC indicated in orange to red. These data combined with the monitoring data without latitude and longitude data (described in the tables above) describe the geographic risk to aquatic communities following atrazine use within the state.



17.2.51. Wyoming.

Bias Factors were not used for Wyoming (see **Section 7.4.1.4**). Based on the available data there were few exceedances of the non-vascular aquatic plant LOC in the more recent monitoring data.

Description of Data Summary and Bias Factor Use		Unadjusted < 12 Samples 2006-2014	Unadjusted < 12 Samples Prior to 2006	Unadjusted ≥ 12 Samples 2006-2014	Unadjusted ≥ 12 Samples Prior to 2006
Number of Site-Years (WARP Watersheds)		72	88	1	2
Maximum Measured or Predicted Exposure Concentrations (ug/L)	Maximum	0.14	0.03	0.03	0.01
	Maximum 21-day Average	0.14	0.02	0.03	0.01
	Maximum 60-day Average	0.10	0.01	0.03	0.01
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	Acute FW Fish	0	0	0	0
	Chronic FW Fish	0	0	0	0
	Acute EM Fish	0	0	0	0
	Chronic EM Fish	0	0	0	0
	Acute FW Inverts	0	0	0	0
	Chronic FW Inverts	0	0	0	0
	Acute EM Inverts	0	0	0	0
	Chronic EM Inverts	0	0	0	0
	Non-Vascular Plants	0	0	0	0
	Vascular Plants	0	0	0	0
	CELOC	0	0	0	0

Wyoming: WARP Model Results. Annual estimates and the 4-year average estimates identify the number of watersheds that have estimated concentrations that exceed the LOCs for aquatic taxa and the CELOC. Wyoming had 289 watersheds excluded, 0 were excluded because the estimated use rate exceeded the rate validated in the WARP model.

Year		**2006**	**2007**	**2008**	**2009**	**4-yr Avg**
Number of HUC12s		2112	2112	2112	2112	2112
Max 4-day average concentration (µg/L)		0.37	1.47	0.25	0.71	0.63
Max 21-day average concentration (µg/L)		0.29	1.10	0.21	0.55	0.48
Max 60-day average concentration (µg/L)		0.21	0.76	0.16	0.39	0.34
Number of Site-Years Exceeding Non-Listed Species Levels of Concern	**Acute FW Fish**	0	0	0	0	0
	Chronic FW Fish	0	0	0	0	0
	Acute EM Fish	0	0	0	0	0
	Chronic EM Fish	0	0	0	0	0
	Acute FW Inverts	0	0	0	0	0
	Chronic FW Inverts	0	0	0	0	0
	Acute EM Inverts	0	0	0	0	0
	Chronic EM Inverts	0	0	0	0	0
	Non-Vascular Plants	0	1	0	0	0
	Vascular Plants	0	0	0	0	0
	CELOC	0	0	0	0	0

18. LITERATURE CITED

Abou-Waly, Hoda, M. M. Abou-Setta, H. N. Nigg and L. L. Mallory. 1991. Growth response of freshwater algae, *Anabaena flos-aquae* and *Selenastrum capricornutum* to Atrazine and hexazinone herbicides. Bull. Environ. Contam. Toxicol. 46:223-229.

Allran, J. W. and W. H. Karasov. 2000. Effects of Atrazine and Nitrate on Northern Leopard Frog (Rana pipiens) Larvae Exposed in the Laboratory from Posthatch Through Metamorphosis. Environ.Toxicol.Chem. 19: 2850-2855.

Allran, J. W. and Karasov, W. H. 2001. Effects of Atrazine on Embryos, Larvae, and Adults of Anuran Amphibians. Environ.Toxicol.Chem. 20: 769-775. EcoReference No.: 59251

Andrus, J.M., D. Winter, M. Scanlan, S. Sullivan, W. Bollman, J.B. Waggoner, A.J. Hosmer, R.A. Brain. 2013. Seasonal synchronicity of algal assemblages in three Midwestern agricultural streams having varying concentrations of atrazine, nutrients and sediment. Science of the Total Environment 458-460: 125-139.

Andrus, J.M., D. Winter, M. Scanlan, S. Sullivan, W. Bollman, J.B. Waggoner, A.J. Hosmer, R.A. Brain. 2015. Spatial and temporal variation of algal assemblages in six Midwest agricultural streams having varying levels of atrazine and other physiochemical attributes. Science of the Total Environment 505: 65-89.

Armstrong, D.E. and G. Chesters. 1968. Adsorption catalyzed chemical hydrolysis of atrazine. Environ. Sci. Technol. 2:683-689.

Armstrong, D.E., G. Chesters, and R.F. Harris. 1967. Atrazine hydrolysis in soil. Soil Science Soc. Amer. Proc. 31:61-66.

Arnot, J.A. and F.A.P.C. Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. Environmental Toxicology and Chemistry, 23 (10): 2343-2355.

Atkins, E.L., Greywood, E.A.; Macdonald, R.L. 1975. Toxicity of Pesticides and Other Agricultural Chemicals to Honey Bees: Labo- ratory Studies. By University of California, Dept. of Entomology. UC, Cooperative Extension. (Leaflet 2287; published study.) (MRID 00036935)

Atwood, D., J. Becker, B. Chism. 2015. Memorandum: BEAD comments on EFED atrazine modeling inputs and rate distributions of atrazine on corn, sorghum, and sugarcane. Biological and Economic Analysis Division, U.S.Environmental Protection Agency.

Balu, K. 1991. Responses to the EPA Review of the Field Dissipation Study on Aatrex Nine for Terrestrial Uses on Corn, Ripon, California: Lab Project Number: ABR-91065. Unpublished study prepared by Ciba-Geigy Corp. 111 p (MRID 42165509).

Balu, K. 1991. Responses to the EPA Review of the Field Dissipation Study on AATREX® NINE-O® for Terrestrial Use on Bareground, Ripon, California. (Supplement to EPA MRID Number 40431336). Performed and submitted by Ciba-Geigy Corporation, Greensboro, NC. Project ID: ABR-91067. (MRID 42165506).

Balu, K. 1991. Responses to the EPA Review of the Field Dissipation Study on AATREX® NINE-O® for Terrestrial Use on Bareground, Hollandale, Minnesota. (Supplement to EPA MRID Number 40431337). Performed and submitted by Ciba-Geigy Corporation, Greensboro, NC. Project ID: ABR-91064. (MRID 42165507).

Balu, K. 1991. Responses to the EPA Review of the Field Dissipation Study on AATREX® NINE-O® for Terrestrial Use on Corn, Hollandale, Minnesota. (Supplement to EPA MRID Number 40431339). Performed and submitted by Ciba-Geigy Corporation, Greensboro, NC. Project ID: ABR-91066.(MRID 42165508)

Bernanke J. and H. Köhler. 2009. The impact of environmental chemicals on wildlife vertebrates. Rev. Environ. Contam. Toxicol. 198: 1-47.

Birge, W. J., J. A. Black and R. A. Kuehne. 1980. Effects of organic compounds on amphibian reproduction. University of Kentucky, Water Resour. Res. Inst., Res. Rep. 121. 39 p. (USDI, Agreement Numbers: 14-34-0001-7038 (FY 1977), 14-34-0001-8019 (FY 1978), and 14-34-0001-9091 (FY 1979). (MRID # 452083-02).

Blair, J. 1986. Determination of the Mobility of G-30033 in Selected Soils by Soil Thin Layer Chromatography: Laboratory Study No. 6015-306. Unpublished study prepared by Hazleton Laborato- ries America, Inc. 59 p.(MRID 40431334)

Blair, J. 1986. Determination of the Mobility of G-28273 in Selected Soils by Soil Thin Layer Chromatography: Laboratory Study No. 6015-305. Unpublished study prepared by Hazleton Laboratories America, Inc. 36 p. (MRID 40431333)

Blair, J. 1986. Determination of the Mobility of G-28279 in Selected Soils by Soil Thin Layer Chromatography: Laboratory Study NO. 6015-304. Unpublished study prepared by Hazleton Laborato- ries America, Inc. 36 p.(MRID 40431331)

Blair, J. 1986. Determination of the Mobility of G-34048 in Selected Soils by Soil Thin Layer Chromatography: Laboratory Study No. 6015-302. Unpublished study prepared by Hazleton Laboratories America, Inc. 36 p (MRID 40431332)

Boone, M. D. and S. M. James. 2003. Interactions of an Insecticide, Herbicide, and Natural Stressors in Amphibian Community Mesocosms. Ecol.Appl. 13: 829-841

Boutin, C., A.L. White, D. Carpenter. 2010. Measuring Variability in Phytotoxicity Testing Using Crop and Wild Plant Species. Environ. Toxicol. Chem. 29(2): 327-337. EcoReference No.: 152615.

Brady, Donald. 2009. Revisions of input parameter guidance: Guidance for selecting input parameters in modeling the environmental fate and transport of pesticides (Version 2.1, 10/22/2009). Memorandum from Dr. Donald Brady to Environmental Fate Effects Division (11/10/2009).

Brain, R.A., A.J. Hosmer, D. Desjardins, T.Z. Kendall, H.O. Krueger, S.B. Wall. 2012. Recovery of duckweed from time-varying exposure to atrazine. Environ. Toxicol. Chem. 31, 1121-1128

Bringolf, R.B., Belden, J.B., Summerfelt, R.C., 2004. Effects of atrazine on fathead 614 minnow in a short-term reproduction assay. Environ. Toxicol. Chem. 23, 1019-1025

Bringolf, R.B., W.G. Cope, M.C. Barnhart, S. Mosher, P.R. Lazaro, D. Shea. 2007. Acute and chronic toxicity of pesticide formulation (atrazine, chlorpyrifos, and permethrin) to glochidia and juveniles of Lampsilis siliquoidea. Environ. Toxicol. Chem. 26 (10): 2101-2107.

Brodkin, M. A., H. Madhoun, M. Rameswaran, and I. Vatnick. 2007. Atrazine is an Immune Disruptor in Adult Northern Leopard Frogs (Rana pipiens). Environ. Toxicol. Chem. 26(1): 80-84.

Brodeur, J. C., G. Svartz, C.S. Perez-Coll, D. J. G. Marino, and J. Herkovits. 2009. Comparative Susceptibility to Atrazine of Three Developmental Stages of Rhinella arenarum and Influence on Metamorphosis: Non-Monotonous Acceleration of the Time to Climax and Delayed Tail Resorption. Aquat. Toxicol. 91: 161-170 .

Brockway, D.L., P.D. Smith, and F.E. Stancil. (1984). Fate and effects of atrazine on small aquatic microcosms. Bull. Environ. Contam. Toxicol. 32:345-353. (MRID 47543602)

Brust, G. E. 1990. Direct and Indirect Effects of Four Herbicides on the Activity of Carabid Beetles (Coleoptera: Carabidae) . *Pestic.Sci.* 30: 309-320.

Burkhard, N. and J.A. Guth. 1981. Chemical hydrolysis of 2-chloro-4,6-bis (alkylamino)-1,3,5-triazine herbicides and their breakdown in soil under the influence of adsorption. Pesticide Sci. 12:45-52.

Burrell RE, Inniss WE, Mayfield CI. 1985. Detection and analysis of interactions between atrazine and sodium pentachlorophenate with single and multiple algal-bacterial populations. Arch Environ Contam Toxicol 14:167-177.

Cardinale, B.J. 2011. Biodiversity improves water quality through niche partitioning. Nature 472: 86-89.

Caux P-Y, Menard L, Kent RA. 1996. Comparative study on the effects of MCPA, butylate, atrazine, and cyanazine on *Selenastrum capricornutum*. Environ Poll 92:219-225.

Cessna, A. J. 2008. Nonbiological degradation of triazine herbicides: photolysis and hydrolysis. In The Triazine Herbicides: 50 Years of Revolutionizing Agriculture, edited by Homer LaBaron, Janis McFarland, and Orvin Burnside. 1st edition. Copyright 2008. Elsevier, Amsterdam, The Netherlands.

Chetram, R. S. 1989. Atrazine: Tier 2 seed emergence nontarget phytotoxicity test. Lab, Study No. LR 89-07C. Prepared by Pan-Agricultural Laboratories, Inc., Madera, CA.; submitted by Ciba-Geigy Corporation, Greensboro, NC. (MRID No. 20414-03).

Chetram, R. S. 1989. Atrazine: Tier 2 vegetative vigor nontarget phytotoxicity test, Lab, Study No. LR 89-07A. Prepared by Pan-Agricultural Laboratories, Inc., Madera, CA.; submitted by Ciba-Geigy Corporation, Greensboro, NC. (MRID No. 420414-02).

Choung, C. B., R.V. Hyne, R.M. Mann, M.M. Stevens, and G.C. Hose. 2011. Developmental Toxicity of Two Common Corn Pesticides to the Endangered Southern Bell Frog (Litoria raniformis). *Environ. Pollut.* 159: 2648-2655.

Coady, K. K., M. B. Murphy, D. L. Villeneuve, M. Hecker, P.D. Jones, J.A. Carr, K.R. Solomon, E.E. Smith, G. Van der Kraak, R.J. Kendall, and J.P. Giesy. 2004. Effects of Atrazine on Metamorphosis, Growth, and Gonadal Development in the Green Frog (Rana clamitans). *J.Toxicol.Environ.Health Part A* 67: 941-957 .

Coady, K. K., M. B. Murphy, D. L. Villeneuve, M. Hecker, P.D. Jones, J.A. Carr, K.R. Solomon, E.E. Smith, G. Van der Kraak, R.J. Kendall, and J.P. Giesy. 2005. Effects of Atrazine on Metamorphosis, Growth, Laryngeal and Gonadal Development, Aromatase Activity, and Sex Steroid Concentrations in Xenopus laevis. *Ecotoxicol. Environ. Saf.* 62: 160-173.

Conners, D. E. and Black, M. C. (2004). Evaluation of Lethality and Genotoxicity in the Freshwater Mussel *Utterbackia imbecillis* (Bivalvia: Unionidae) Exposed Singly and in

Combination to Chemicals Used in Lawn Care. *Arch.Environ.Contam.Toxicol.* 46: 362-371. EcoReference No.: 74236

Correll, D. L. and T. L. Wu. 1982. Atrazine toxicity to submersed vascular plants in simulated estuarine microcosms. Aquatic Botany 14:151-158. (MRID # 450874-08).

Crain, D. A., L. J., Guillette, Jr., A. A. Rooney and D. B. Pickford. 1997. Alterations in steroidogenesis in alligators (*Alligator mississippiensis*) exposed to naturally and experimentally to environmental contaminants. Environ. Health Perspectives 105(5):528-533.

Crain, D. A., Spiteri, I. D., and Guillette, L. J. Jr. (1999). The Functional and Structural Observations of the Neonatal Reproductive System of Alligators Exposed In Ovo to Atrazine, 2,4-D, or Estradiol. *Toxicol.Ind.Health* 15: 180-185. EcoReference No.: 70208.

Dalton, R.L. 2007. Evaluation of Phytotoxicity Testing: Assessing the Effects of Herbicides on Non-Target Plants Using Microcosm Tests. M.S.Thesis, Carleton University, Ottawa, Canada : 160 p. EcoReference No.: 153813.

Dao, T.H., T.L. Lavy, and R.C. Sorensen. 1979. Atrazine degradation and residue distribution in soil. Soil Sci. Soc. Am. J. 43:1129-1134.

Das, Y. 1989. Photodegradation of Triazine(U)-Carbon14- Atrazine on Soil Under Artificial Sunlight: Lab Project Number:89070. Unpublished study prepared by Innovative Science Services, Inc. 109 p. (MRID 42089905)

Davidson, J.M., P.S.C. Rao,L.T. Ou, W.B. Wheeler, and D.F. Rothwell. 1980. Adsorption, movement and biological degradation of large concentrations of pesticides in soils. EPA-600/2-80-124. Cincinnati, OH: U.S. EPA. 124 p.

De Solla, S. R., Martin, P. A., Fernie, K. J., Park, B. J., and Mayne, G. (2006). Effects of Environmentally Relevant Concentrations of Atrazine on Gonadal Development of Snapping Turtles (Chelydra serpentina). *Environ.Toxicol.Chem.* 25: 520-526. EcoReference No.: 82032

Debelius, B., J.M. Forja, A. Del Valls, L.M. Lubián. 2008. Effect of linear alkylbenzene sulfonate (LAS) and atrazine on marine microalgae. Marine Pollution Bulletin 57: 559-568.

DeLorenzo, M.E., M. Leatherbury, J.A. Weiner, A.J. Lewitus, and M.H. Fulton. 2004. Physiological factors contributing to the species-specific sensitivity of four estuarine microalgal

species exposed to the herbicide atrazine. Aquatic Ecosystem Health & Management 7(1): 137-146.

DeLorenzo, M.E., B. Thompson, E. Cooper, J. Moore, M.H. Fulton. 2011. A long-term monitoring study of chlorophyll, microbial contaminants, and pesticides in a coastal residential stormwater pond and its adjacent tidal creek. Environ. Monit. Assess. 184:343-359.

deNoyelles, F., Jr., W.D. Kettle, and D.E. Sinn. (1982). The responses of plankton communities in experimental ponds to atrazine, the most heavily used pesticide in the United States. Ecology. 63 (5):1285-1293 (MRID 47543607)

deNovelles, Jr., F., W.D. Kettle, C.H. Fromm, M.F. Moffett, and S.L. Dewey. (1989). Use of Experimental Ponds to Assess the Effects of a Pesticide on the Aquatic Environment. Department of Systematics and Ecology, University of Kansas. Entomological Society of America. Miscellaneous Publications No. 75: 41 – 56 (MRID 47543608)

Desjardins, D., Krueger, H., and Kendall, T. 2003. Atrazine Technical: A 14-Day Static-Renewal Toxicity Test with Duckweed (*Lemna gibba* G3) Including a Recovery Phase. Unpublished study performed by Wildlife International, Ltd., Easton, Maryland. Laboratory Study No. 528A-131A. Study sponsored by Syngenta Crop Protection, Inc., Greensboro, North Carolina. (MRID # 461509-01).

Diana, S. G., W. J. Resetarits Jr., D. J. Schaeffer, K. B. Beckmen, and V. R. Beasley. 2000. Effects of Atrazine on Amphibian Growth and Survival in Artificial Aquatic Communities. *Environ.Toxicol.Chem.* 19: 2961-2967

Douglas A. 2010. The symbiotic habit. Princeton University Press, Princeton, NJ

Du Preez, L. H., N. Kunene, G. J. Everson, J.A. Carr, J.P. Giesy, T.S. Gross, A. J. Hosmer, R. J. Kendall, E.E. Smith, K.R. Solomon, and G. J. Van der Kraak. 2008. Reproduction, Larval Growth, and Reproductive Development in African Clawed Frogs (*Xenopus laevis*) Exposed to Atrazine. *Chemosphere.* 71 (3): 546-552.

Fairchild JF, Ruessler DS, Carlson AR. 1998. Comparative sensitivity 998 of five species of 999 macrophytes and six species of algae to atrazine, metribuzin, alachlor, and metolachlor. Environ Toxicol Chem 17:1830-1834.

Faust M, Altenburger R, Boedeker W, Grimme LH. 1993. Additive effects of herbicide combinations on aquatic non-target organisms. Sci Total Environ 113/114:941-951.

Fletcher, J.S., J.E. Nellessen, and T.G. Pfleeger. 1994. Literature review and evaluation of the EPA food-chain (Kenaga) nomogram, an instrument for estimating pesticide residues on plants. *Environ. Tox. Chem.* 13:1383-1391.

Forney DR, Davis DE. 1981. Effects of low concentrations of herbicides on submersed aquatic plants. Weed Sci 29:677-685.

Forson, D. D. and A. Storfer. 2006. Atrazine Increases Ranavirus Susceptibility in the Tiger Salamander, Ambystoma tigrinum. *Ecol. Appl*. 16 (6): 2325-2332.

Fort, D. J., R.L. Rogers, J.H. Thomas, B.O Buzzard, A. M. Noll, and C.D. Spaulding. 2004. Comparative Sensitivity of Xenopus tropicalis and Xenopus laevis as Test Species for the FETAX Model. *J.Appl.Toxicol.* 24: 443-457.

Foy, C.L. and Hiranpradit. 1977. Herbicide movement with water and effects of contaminates on non-target organisms: OWRT Project A-046-VA. Unpublished study received July 19, 1978 under 201-40-3 prepared by Virginia Polytechnic Institute and State University Water Resource Center, Department of Plant Pathology and Physiology, Submitted by Shell Chemical Company, Washington D.C. CDL:23446-AO.

Freeman, J. L. and A,L. Rayburn. 2005. Developmental Impact of Atrazine on Metamorphing Xenopus laevis as Revealed by Nuclear Analysis and Morphology. *Environ.Toxicol.Chem.* 24: 1648-1653.

Gala WR, Giesy JP. 1990. Flow cytometric techniques to assess toxicity to algae. In: Landis WG, van der Schalie WH (eds). Aquatic Toxicology and Risk Assessment: 13th Volume. American Society for Testing and Materials, Philadelphia, PA, USA.

Gambel, D.S., S.U. Khan, and O.S. Tee. 1983. Atrazine hydrolysis: Proton Catalysis at 25^{o}C. Pesticide Science 14:537-545.

Giddings et al. 1999. Community-Level Aquatic System Studies – Interpretation Criteria (CLASSIC). SETAC Press.

Goleman, W. L. and J. A. Carr. 2003. Response of larval *Xenopus laevis* to atrazine exposure: assessment of metamorphosis and gonadal and laryngeal morphology. The Institute of Environmental and Human Health, Texas Tech University, Texas Tech University Health Sciences Center, Lubbock, Texas. Sponsor: Syngenta Crop Protection, Inc., Laboratory Study ID ECORISK Number TTU-01

Gross, T. S. 2001. Determination of potential effects of 10 day neonatal exposure of atrazine on histological and hormonal sex determination in incubated American alligator (*Alligator*

mississippiensis) eggs. Prepared by University of Florida, Wildlife Reproductive Toxicology Laboratory, Gainesville, FL, NOVA98,02a; submitted by Syngenta Crop Protection, Inc., Greensboro, NC. (MRID No. 455453-02).

Gross, T. S. 2001. Determination of potential effects of 10 day neonatal exposure of atrazine on histological and hormonal sex determination in incubated red-eared slider (Pseudemys elegans) eggs. Prepared by University of Florida, Wildlife Reproductive Toxicology Laboratory, Gainesville, FL, NOVA98,02b; submitted by Syngenta Crop Protection, Inc., Greensboro, NC. (MRID No. 455453-03).

Guy, S. 1987. Field Dissipation on Aatrex Nine-0 for Terrestrial Uses on Corn in Donalsonville, GA: Lab Project Number: 1641-86-71-01-06B-26. Unpublished study prepared by Landis International and Others. 325 p. (MRID 42165505)

Guy, S. 1987. Field Dissipation on Aatrex Nine-0 for Terrestrial Uses on Bareground in Donalsonville, GA: Lab Project Number: 1641-86-71-01-21E-27. Unpublished study prepared by Landis International and Others. 317 p. (MRID 42165505)

Guy, S. 1987. Field Dissipation on Aatrex Nine-0 for Terrestrial Uses on Corn in Donalsonville, GA: Lab Project Number: 1641-86-71-01-06B-26. Unpublished study prepared by Landis International and Others. 325 p. (MRID 42165504)

Hall, J.K. 1974. Erosional losses of s-Triazine herbicides. Journal of Environmental Quality 3(2):174-180. (Also In unpublished submission received Jul 19, 1978 under 201-403; sub- mitted by Shell Chemical Co., Washington, D.C.; CDL:234475-O) (Accession No. 00027118)

Hall, J.K. 1977. Quantification of s-Triazine losses in surface runoff: A summary. Proceedings of the Northeast Weed Science Society 31:117-121. (Also in unpublished submission received Jul 19, 1978 under 201-403; submitted by Shell Chemical Co., Washington, D.C.; CDL:234475-U) (Accession No. 00027124)

Hall, J.K.; Pawlus, M.; Higgins, E.R. (1972) Losses of Atrazine in runoff water and soil sediment. Journal of Environmental Quality 1(2):172-176. (Also In unpublished submission received Jul 19, 1978 under 201-403; submitted by Shell Chemical Co., Washington, D.C.; CDL:234475-T)(Accession No. 00027123)

Hance, R.J. 1967. Decomposition of herbicides in soil by nonbiological processes. J. Sci. Food Agric. 18:544-547.

Hance, R.J. 1979. Effect of pH on the degradation of atrazine, dichloroprop, linuron, and propyzamide in soil. Pesticide Sci. 10:83-86.

Haque, A. and W. Ebing. 1983. Toxicity Determination of Pesticides to Earthworms in the Soil Substrate. J. Plant Protec. Disease. 90(4): 395-408

Hayes, T. B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A.A. Stuart, and A. Vonk. 2002. Hermaphroditic, Demasculinized Frogs After Exposure to the Herbicide Atrazine at Low Ecologically Relevant Doses. *Proc.Natl.Acad.Sci.* 99: 5476-5480.

Hayes, T. B., B. Case, S. Chui, D. Chung, C. Haeffele, K. Haston, M. Lee, V.P. Mai, Y. Marjuoa, J. Parker, and M. Tsui. 2006. Pesticide Mixtures, Endocrine Disruption, and Amphibian Declines: Are we Underestimating the Imapct? *Environ.Health Perspect.* 114: 40-50.

Hayes, T., K. Haston, M. Tsui, A. Hoang, C. Haeffele and A. Vonk. 2003. Atrazine-induced hermaphroditism at 0.1 ppb in American leopard frogs (*Rana pipiens*): laboratory and field evidence. *Environ.Health Perspect.* 111: 568-575.
.
Hayes, T. B., V. Khoury, A. Narayan, M. Nazir, A. Park, T. Brown, L. Adame, E. Chan, D. Buchholz, T. Stueve, and S. Gallipeau. 2010a. Atrazine Induces Complete Feminization and Chemical Castration in Male African Clawed Frogs (Xenopus laevis). *Proc. Natl. Acad. Sci. U.S.A.* 107 : 4612-4617.

Hayes, T.B., P. Falso, S. Gallipeau, and M. Stice. 2010b. The cause of global amphibian declines: a developmental endocrinologist's perspective. J. Exper. Bio. 213: 921-933.

Hayes, T.B., L.L. Anderson, V. R. Beasley, S. R. de Solla, T. Iguchi, H. Ingraham, P. Kestemont, J. Kniewald, Z. Kniewald, V. S., Langlois, E. H. Luque, K. A. McCoy, M. Muńoz-de-Toro, T. Oka, C. A. Oliveira, F. Orton, S. Ruby, M. Suzawa, L. E. Tavera-Mendoza, V. L. Trudeau, A. B. Victor-Costa, E. Willingham. Demasculinization and feminization of male gonads by atrazine: consisten effects across vertebrates classes. *J. Ster. Biochem. Mol. Bio*. 127: 64-73.

Hecker, M., J. W. Park, M. B. Murphy, P.D. Jones, K. R. Solomon, G. Van der Kraak, J.A. Carr, E. E. Smith., L. Du Preez, R.J. Kendall, and J.P. Giesy. 2005a. Effects of Atrazine on CYP19 Gene Expression and Aromatase Activity in Testes and on Plasma Sex Steroid Concentrations of Male African Clawed Frogs (Xenopus laevis). *Toxicol.Sci.* 86: 273-280.

Hecker, M., W.J. Kim, J.W. Park, M. B. Murphy, D. Villeneuve, K. K. Coady, P. D. Jones, K. R. Solomon, G. Van der Kraak, J. A. Carr, E. E. Smith, L. Du Preez, R. J. Kendall, and J. P. Giesy. 2005b. Plasma Concentrations of Estradiol and Testosterone, Gonadal Aromatase Activity and Ultrastructure of the Testis in Xenopus laevis Exposed to Estradiol or Atrazine. *Aquatic.Toxicol.* 72: 383-396 .

Hersh CM, Crumpton WG. 1989. Atrazine tolerance of algae isolated from two agricultural 1053 streams. Environ Toxicol Chem 8:327-332.

Hill, E. F., Heath, R. G., Spann, J. W., and Williams, J. D. (1975). Lethal Dietary Toxicities of Environmental Pollutants to Birds. *U.S.Fish and Wildlife Service, Special Scientific Report-Wildlife* 191: 1-61. (MRID # 000229-02). EcoReference No.: 35243

Hill, W.R. and B.C. Harvey. 1990. Periphyton responses to higher trophic levels and light in a shaded stream. Canadian Journal of Fisheries and Aquatic Sciences 47: 2307-2314.

Hill, W.R., M.G. Ryon, and E.M. Schilling. 1995. Light limitation in a stream ecosystem: responses by primary producers and consumers. Ecology 76(4): 1297-1309.

Hill, W.R., P.J. Mulholland and R.R. Marzolf. 2001. Stream ecosystem responses to forest leaf emergence in spring. Ecology 82(8): 2306-2319.

Hinman ML. 1989. Utility of rooted aquatic vascular plants for aquatic sediment hazard evaluation. Ph.D. Thesis. Memphis State University, Memphis, TN, USA.

Hoberg JR. 1991a. Atrazine technical toxicity to the freshwater green algae, *Selenastrum capricornutum.* SLI Report #91-1-3600. Springborn Laboratories, Inc., Wareham, MA, USA.

Hoberg JR. 1991b. Atrazine technical toxicity to the duckweed *Lemna gibba*. SLI Report #91-1-1059 3613. Springborn Laboratories, Inc., Wareham, MA, USA.

Hoberg JR. 1993b. Atrazine technical - toxicity to duckweed (*Lemna gibba*). SLI Report #93-1063 4-4755. Springborn Laboratories, Inc., Wareham, MA, USA.

Hoberg JR. 1993c. Atrazine technical - toxicity to duckweed (*Lemna gibba*). SLI Report #93-1065 11-5053. Springborn Laboratories, Inc., Wareham, MA, USA.

Hoberg JR. 2007. The toxicity of atrazine to the freshwater macrophyte *Elodea canadensis* at three light intensities for 14 days. Report 1781.6691. Springborn Smithers Laboratories, Inc., Wareham, MA, USA.

Hoke, R. A. and G. T Ankley. 2005. Application of frog embryo teratogenesis assay-Xenopus to ecological risk assessment. Environ. Toxicol. Chem. 24 (10): 2677-2690.

Hoerger, F. and E. E. Kenaga. 1972. Pesticide Residues on Plants: Correlation of Representative Data as a Basis for Estimation of their Magnitude in the Environment. In F. Coulston and F. Korte, eds., *Environmental Quality and Safety: Chemistry, Toxicology, and Technology,* Georg Thieme Publ., Stuttgart, West Germany, pp. 9-28.

Hofmann, A. and S. Winkler. 1990. Effects of atrazine in environmentally relevant concentrations on submersed macrophytes. Arch. Hydrobiol. 118(1):69-79. (MRID # 452277-14).

Hollister, T. A and G.E. Walsh. 1973. Differential responses of marine phytoplankton to herbicides: Oxygen Evolution, Bull. Environ. Contam. Toxicol. 9(5):291-295. (MRID # 001587-45).

Hopkin, R. and J. M. Kain. 1978. The effects of some pollutants on the survival, growth and respiration of *Laminaria hyperborea*. Estuarine Coast. Mar. Sci. 7:531-553. (MRID # 452277-15).

Houck, A. and S. K. Sessions. 2006. Could Atrazine Affect the Immune System of the Frog, *Rana pipiens*? *Bios* 77: 107-112.

Howe, G. E., R. Gillis, and R.C. Mowbray. 1998. Effect of Chemical Synergy and Larval Stage on the Toxicity of Atrazine and Alachlor to Amphibian Larvae. *Environ.Toxicol.Chem.* 17: 519-525.

Hughes, R.M., R.F. Noss. 1992. Biological diversity and biological intergrity: current concerns for lakes and streams. Fisheries 17(3): 11-19.

Huisman, J., J. Sharples, J.M. Stroom, P.M. Visser, W.E.A. Kardinaal, J.M.H. Verspagen, and B. Sommeijer. 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. Ecology 85:2960–2970.

Hughes JS, Alexander MM, Balu K. 1988. An evaluation of appropriate expressions of toxicity in aquatic plant bioassays as demonstrated by the effects of atrazine on algae and duckweed. In: Adams W, Chapman GA, Landis WG (eds). Aquatic Toxicology and Hazard Assessment: 10^{th} Volume. Philadelphia, PA: American Society for Testing and Materials.

Hussain, R., F. Mahomood, M. Zargham Khan, A. Khan, F. Muhammad. 2011. Pathological and genotoxic effects of atrazine in male Japanese quail (Coturnix japonica). Ecotoxicol. 20:1-8.

Junk, G.A., R.F. Spalding and R.R, Richard. 1980. Areal, vertical, and temporal differences in groundwater chemistry: II. Organic constituents. J. Environ. Qual. 9(3):479-483.

Jones, T.W., W.M. Kemp, J.C. Stevenson, and J.C. Means. 1982. Degradation of atrazine in estuarine water/sediment systems and soils. J. Environ. Qual. 11:632-638.

Kallqvist T, Romstad R. 1994. Effects of agricultural pesticides on planktonic algae and cyanobacteria – examples of interspecies sensitivity variations. Norw J Agric Sci 13:117-131.

Kerby, J. L. and A. Storfer. 2009. Combined Effects of Atrazine and Chlorpyrifos on Susceptibility of the Tiger Salamander to Ambystoma tigrinum Virus. *EcoHealth* 1-8.

Kegel, B. 1989. Laboratory Experiments on the Side Effects of Selected Herbicides and Insecticides on the Larvae of Three Sympatric Poecilus-Species (Col., Carabidae). *J.Appl.Entomol.* 108: 144-155

Kerney, R. 2011. Symbioses between salamander embryos and green algae. Symbiosis 54(3): 107-117.

Khan, S.U. 1978. Kinetic of hydrolysis of atrazine in aqueous fulvic acid solution. Pesticide Sci. 9:39-43.

Kirby MF, Sheahan DA. 1994. Effects of atrazine, isoproturon, and mecoprop on the macrophyte *Lemna minor* and the alga *Scenedesmus subspicatus*. Bull Environ Contam Toxicol 53:120-126.

Kish, P.A. 2004. Effects of Roundup, Glean, Aatrex, and Their Active Ingredients (Glyphosate, Chlorsulfuron, and Atrazine) on Periphyton Communities Studied by Using Matlock Periphytometer and Bottle Tests. Ph.D.Thesis, Oklahoma State Univ., Stillwater, OK:166 p.

Kline and Company. 2002, 2004, 2006. Klinegroup.com.

Kloas, W., I. Lutz, T. Springer, H. Krueger, J. Wolf, L. Holden, and A. Hosmer. 2009. Does Atrazine Influence Larval Development and Sexual Differentiation in Xenopus laevis? *Toxicol. Sci.* 107: 376-384.

Koprivnikar, J., M. R. Forbes, and R. L. Baker. 2007. Contaminant Effects on Host-Parasite Interactions: Atrazine, Frogs, and Trematodes. *Environ. Toxicol. Chem*. 26 (10): 2166-2170.

Koprivnikar, J. 2010. Interactions of Environmental Stressors Impact Survival and Development of Parasitized Larval Amphibians. *Ecol. Appl.* 20: 2263-2272.

Kurle, C.M. and B.J. Cardinale. 2011. Ecological factors associated with the strength of trophic cascades in streams. Oikos 000: 1-12.

LaFiandra, E. M., K.J. Babbitt, and S.A. Sower. 2008. Effects of Atrazine on Anuran Development are Altered by the Presence of a Nonlethal Predator. *J. Toxicol. Health. Perspect*. 71 (8): 505-511.

Laird, D. A. and W. C. Koskinen. 2008. Triazine interactions in soil. In The Triazine Herbicides: 50 Years of Revolutionizing Agriculture, edited by Homer LaBaron, Janis McFarland, and Orvin Burnside. 1st edition. Copyright 2008. Elsevier, Amsterdam, The Netherlands.

Lampert, W., W. Fleckner, E. Pott, U. Schober, and K.U. Storkel. (1989). Herbicide effects on planktonic systems of different complexity. Hydrobiologia. 188/189:415-424. (MRID 47543511)

Landis International, Inc. 1991. Supplement to Field Dissipation Study on AATREX® NINE-O® for Terrestrial Uses on Corn in Ripon, California. Performed by Minnesota Valley Testing Laboratory, New Ulm, Minnesota. Submitted by Agricultural Division, Ciba-Geigy Corporation, Greenboro, NC. Project ID: 1641-86-71-01-06B-22 (MRID 42089909)

Landis International, Inc. 1991. Supplement to Field Dissipation Study on AATREX® NINE-O® for Terrestrial Uses on Bareground in Ripon, California. Performed by Minnesota Valley Testing Laboratory, New Ulm, Minnesota. Submitted by Agricultural Division, Ciba-Geigy Corporation, Greenboro, NC. Project ID: 1641-86-71-01-06B-21E(MRID 42089910)

Landis International, Inc. 1991. Supplement to Field Dissipation Study on AATREX® NINE-O® for Terrestrial Uses on Bareground in Hollandale, Minnesota, California. Performed by Minnesota Valley Testing Laboratory, New Ulm, Minnesota. Submitted by Agricultural Division, Ciba-Geigy Corporation, Greenboro, NC. Project ID: 1641-86-71-01--21E-25(MRID 42089912)

Landis International, Inc. 1991. Supplement to Field Dissipation Study on AATREX® NINE-O® for Terrestrial Uses on Corn in Hollandale, Minnesota, California. Performed by Minnesota Valley Testing Laboratory, New Ulm, Minnesota. Submitted by Agricultural Division, Ciba-Geigy Corporation, Greenboro, NC. Project ID: 1641-86-71-01—0613-24(MRID 42089911)

Langlois, V. S., A. C. Carew, B. D. Pauli, M. G. Wade, G. M. Cooke, and V. L. Trudeau. 2010. Low Levels of the Herbicide Atrazine Alter Sex Ratios and Reduce Metamorphic Success in Rana pipiens Tadpoles Raised in Outdoor Mesocosms. *Environ. Health Perspect.* 118: 552-557

Larsen DP, DeNoyelles Jr. F, Stay F, Shiroyama T. 1986. Comparisons of single-species, microcosm and experimental pond responses to atrazine exposure. Environ Toxicol Chem 5:179-190.

Larson, S. J., C.G. Crawford, and R.J. Gilliom. 2004. Development and application of watershed regressions for pesticides (WARP) for estimating atrazine concentration distributions in streams. USGS Water-Resources Investigations Report 03-4047. 68 p.

Larson, D. L., S. McDonald, A. J. Fivizzani, W. E. Newton, and S. J. Hamilton. 1998. Effects of the

Herbicide Atrazine on Ambystoma tigrinum Metamorphosis: Duration, Larval Growth, and Hormonal Response. *Physiol.Zool.* 71: 671-679.

Lawton, J.C., P.L. Pennington, K.W. Chung, G.I. Scott. 2006. Toxicity of atrazine to the juvenile hard clam, *Mercenaria mercenaria. Ecotox. Environ. Saf*. 65: 388-394.

Lavy, T.L. 1968. Microenvironment mechanisms of s-triazines in soil. Soil Sci. Soc. Amer. Proceed. 32:377-380.

Leibold, M. A. 1996. A graphical model of keystone predators in food webs: trophic regulation of abundance, incidence and diversity patterns in communities. American Naturalist 147:784–812.

Lichtenstein, E. P., T. T. Liang, and B. N. Anderegg. 1973. Synergism of Insecticides by Herbicides. *Science* 181: 847-849.

Mabey, W. and T. Mill. 1978. Critical review of hydrolysis of organic compounds in water under environmental conditions. J. Phys. Chem. Ref. Data 7:383-415.

Magnusson, M., K. Heimann, P. Quayle, A.P. Negri. 2010. Additive Toxicity of Herbicide Mixtures and Comparative Sensitivity of Tropical Benthic Microalgae. Mar. Pollut. Bull.60(11): 1978-1987

Majewski, Michael S. and Paul D. Capel. 1995. Pesticides in the Atmosphere: Distribution, Trends, and Governing Factors. Ann Arbor Press, Chelsea MI.

Mandelbaum, R.T., M.J. Sadowsky, and L.P. Wackett. 2008. Microbial degradation of s-triazine herbicides. In The Triazine Herbicides: 50 Years of Revolutionizing Agriculture, edited by Homer LaBaron, Janis McFarland, and Orvin Burnside. 1st edition. Copyright 2008. Elsevier, Amsterdam, The Netherlands.

Mann, R. M., R. V. Hyne, C. B. Choung, and S. P. Wilson. 2009. Amphibians and agricultural chemicals: review of the risks in a complex environment. Environ. Poll. 157: 2903-2927.

Mayer, F. L., Jr. 1986. Acute toxicity handbook of chemicals to estuarine organisms. U.S. Environmental Protection Agency, EPA/600/X-86/231. 274 pages. (MRID No. 402284-01).

Mayer P, Frickmann J, Christensen ER, Nyholm N. 1998. Influence of growth conditions on the results obtained in algal toxicity tests. Environ Toxicol Chem 17:1091-1098.

McGregor, E.B, K.R. Solomon, M.L. Hanson. 2008. Effects of Planting System Design on the Toxicological Sensitivity of Myriophyllum spicatum and Elodea canadensis to Atrazine. Chemosphere 73:249-260

McQueen, D.J., M.R.S. Johannes, J.R. Post, T.J. Stewart, D.R.S. Lean. 1989. Bottom-up and top-down impacts on freshwater pelagic community structure. Ecological Monographs 59: 289-309.

Meyer, J.L., D.L. Strayer, J.B. Wallace, S.L. Eggert, G.S. Helfman, and N.E. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association 43(1): 86-103.

Miller, P.S., J. Prenger, L. Zwilling, C. Harbourt, and P. Hendley. 2009. Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Corn/Sorghum Watersheds - SSURGO-Based Characterization of Shallow Impervious/Restrictive Soil Layers. WEI 796.01. April 21, 2009.

Millie DF, Hersh CM. 1987. Statistical characterizations of the atrazine-induced photosynthetic 1125 inhibition of *Cyclotella meneghiniana*. Aquatic Toxicol 10:239-249.

Mola, L., M. A. Sabatini, B. Fratello, and R. Bertolani. 1987. Effects of Atrazine on Two Species of Collembola (Onychiuridae) in Laboratory Tests. *Pedobiologia* 30: 145-149.

Moore A., N. Lower, I. Mayer, L. Greenwood. 2007. The Impact of a Pesticide on Migratory Activity and Olfactory Function in Atlantic Salmon (Salmo salar L.) Smolts. *Aquaculture*273(2/3): 350-359.

Morgan, M. K., P.R. Scheuerman, C.S. Bishop, and R.A. Pyles. 1996. Teratogenic Potential of Atrazine and 2,4-D Using FETAX. *J.Toxicol.Environ.Health* 48: 151-168.

Mosleh, Y. Y., S. M. M. Ismail, M. T. Ahmed, and Y. M. Ahmed. (2003). Comparative Toxicity and Biochemical Responses of Certain Pesticides to the Mature Earthworm Aporrectodea caliginosa Under Laboratory Conditions. *Environ.Toxicol.* 18: 338-346 .

Mosquin, P., Whitmore, R., and Chen W. 2011. Impact of Alternative Monitoring Frequencies on Estimation of Atrazine Rolling Average Environmental Concentrations. Unpublished study from Syngenta Crop Protection, Inc. MRID 48470006

Moyer, J.R., R.J. Hance, and C.E. McKone. 1972. The effect of absorbents on the rate of degradation of herbicides incubated with soil. Soil Biol. Biochem. 4:307-311.

Nakagaki, Naomi, and Wolock, D.M., 2005, Estimation of agricultural pesticide use in drainage basins using land cover maps and county pesticide data: U.S. Geological Survey Open-File Report 2005-1188, 46 p.

National Center for Water Quality Research (NCWQR). 2009. Tributary data download, accessed by Stone and Gilliom (2011) on August 2009 at http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data.

Navarro, S., N. Vela, M. J. Gimenez, and G. Navarro. 2004. Persistence of four s-triazine herbicides in river, sea, groundwater samples exposed to sunlight and darkness under laboratory conditions. Sci. Total Environ. 329:87-97.

Nelson, D.; Schabacker, D. (1991) Summary Report: Soil Metabolism of Carbon 14-Atrazine and Metabolite Characterization/Identific- ation: Lab Project Number: 6015-185: ABR-91073. Unpublished study prepared by Hazleton Labs America, Inc. 321 p. (MRID 42089906)

Noppe, H., A. Ghekiere, T. Verslycke, E. De Wulf, K. Verheyden, E. Monteyne, K. Polfliet, P. van Caeter, C.R. Janssen, H.F. De Brabander. 2007. Distribution and ecotoxicity of chlorotriazine in the Scheldt estuary (B-N1). Environ. Poll. 147: 668-676.

Organization of Economic Cooperation and Development (OECD). 2004. Draft Guidance on Simulated Freshwater Lentic Field Systems (Outdoor Microcosms and Mesocosms).

Oka, T., O. Tooi, N. Mitsui, M. Miyahara, Y. Ohnishi, M. Takase, A. Kashiwagi, T. Shinkai, N. Santo, and T. Iguchi. (2008). Effect of Atrazine on Metamorphosis and Sexual Differentiation in Xenopus laevis. Aquat. Toxicol. 87: 215-226

Olivier, H.M. and B.R. Moon. 2010. The effects of atrazine on spotted salamander embryos and their symbiotic alga. Ecotoxicology 19: 654–661.

Parrish R. 1978. Effects of atrazine on two freshwater and five marine algae. Ciba-Geigy 1131 Corporation, Greensboro, NC, USA.

Plust, S.J., J.R. Loehe, F.J. Feher, J.H. Benedict, and H.F. Herbrandson. 1981. Kinetics and mechanism of hydrolysis of chloro-1,3,5-triazines. Atrazine. J. Organic Chem. 46:3661-3665.

Podola B., M. Melkonian. 2005. Selective Real-Time Herbicide Monitoring by an Array Chip Biosensor Employing Diverse Microalgae. J. Appl. Phycol.17(3): 261-271

Pratt, J.R., N.J. Bowers, B.R. Niederlehrer, and J. Cairns, Jr. (1988). Effects of atrazine on freshwater microbial communities. Arch. Environ. Contam. Toxicol. 17:449-457. (MRID 47543514)

Prenger, J., P. Hendley, C. Harbourt, R. Vamshi, L. Zwilling, P.S. Miller. 2009. Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Corn/Sorghum Watersheds – Development of an NHDPlus Analysis Framework and Associated Tools. WEI 796.01.

Prescott L.M., M.K. Kubovec, D. Tryggestad. 1977. The Effects of Pesticides, Polychlorinated Biphenyls and Metals on the Growth and Reproduction of Acanthamoeba castellanii. Bull. Environ. Contam. Toxicol. 18(1): 29-34.

Prosser, R.S., R.A. Brain, A.J. Hosmer, K.R. Solomon, M.L. Hanson. 2013. Assessing sensitivity and recovery of field-collected periphyton acutely exposed to atrazine using PSII inhibition under laboratory conditions. Ecotoxicology 22: 1367-1383.

Radetski CM, Ferard JF, Blaise C. 1995. A semistatic microplate-based phytotoxicity test. Environ Toxicol Chem 14:299-302.

Relyea, R. A. (2009). A Cocktail of Contaminants: How Mixtures of Pesticides at Low Concentrations Affect Aquatic Communities. Oceanologia (Wroc.) 159: 363-376.

Roberts, T.R. and D.H. Hutson. 1998. Metabolic pathways of agrochemicals, part 2. Royal Society of Chemistry (Great Britain). Pg. 245.

Roberts SP, Vasseur P, Dive D. 1990. Combined effects between atrazine, copper and pH on target and non-target species. Water Res 24:485-491.

Rohr, J. R., Elskus, A. A., Shepherd, B. S., Crowley, P. H., McCarthy, T. M., Niedzwiecki, J. H., Sager, T., Sih, A., and Palmer, B. D. 2003. Lethal and Sublethal Effects of Atrazine, Carbaryl, Endosulfan, and Octylphenol on the Streamside Salamander (Ambystoma barbouri). *Environ.Toxicol.Chem.* 22: 2385-2392.

Rohr, J. R., A. A, Elskus, B. S. Shepherd, P.H. Crowley, T. M. McCarthy, J. H. Niedzwiecki, T. Sager, A. Sih, and B. D. Palmer. 2004. Multiple Stressors and Salamanders: Effects of an Herbicide, Food Limitation, and Hydroperiod. *Ecol.Appl.* 14: 1028-1040.

Rohr, J. R. and B.D. Palmer. 2005. Aquatic Herbicide Exposure Increases Salamander Desiccation Risk Eight Months Later in a Terrestrial Environment. *Environ.Toxicol.Chem.* 24: 1253-1258.

Rohr, J. R. and P. W. Crumrine. 2005. Effects of an Herbicide and an Insecticide on Pond Community Structure and Processes . *Ecol. Appl.* 15: 1135-1147.

Rohr, J. R., T. Sager, T, M, Sesterhenn, and B. D. Palmer. 2006. Exposure, Postexposure, and Density-Mediated Effects of Atrazine on Amphibians: Breaking Down Net Effects into Their

Parts. *Environ.Health Perspect.* 114: 46-50.

Rohr, J. R., T. R. Raffel, S. K. Sessions, and P.J. Hudson. 2008. Understanding the Net Effects of Pesticides on Amphibian Trematode Infections. *Ecol. Appl.* 18: 1743-1753.

Rohr, J. R., A. Swan, T.R. Raffel, and P.J Hudson. 2009. Parasites, Info-Disruption, and the Ecology of Fear. *Oceanologia (Wroc.)* 159: 447-454.

Rohr, J. R. and K.A. McCoy. 2010. A Qualitative Meta-Analysis Reveals Consistent Effects of Atrazine on Freshwater Fish and Amphibians. *Environ. Health. Perspect*. 118(1): 20-32.

Rustum, A. 1988. Aerobic, Aerobic/Anaerobic, and Sterile Soil Metabolism of Carbon 14|-Atrazine: Study No. HLA 6015-185. Un- published study prepared by Hazleton Laboratories America, Inc. 165 p (MRID 40629303)

Rustum, A. 1987. Aerobic, Aerobic/Anaerobic, and Sterile Soil Metabolism of [Carbon 14]-Atrazine: Laboratory Study No. 6015-185. Unpublished study prepared by Hazleton Laboratories America, Inc. 133 p. (MRID 40431321)

Samsoe-Petersen, L. 1995. Effects of 67 Herbicides and Plant Growth Regulators on the Rove Beetle Aleochara bilineata (Col.: Staphylinidae) in the Laboratory. *Entomophaga* 40: 95-104

Schabacker, D. 1991. Summary Report: Aqueous Photolysis of Carbon 14-Atrazine Under Natural and Artificial Light: Lab Project Num- ber: 12112 A: 12112 B. Unpublished study prepared by Agrisearch Inc. 185 p. (MRID 42089904)

Schafer H, Wenzel A, Fritsche U, Roderer G, Traunspurger W. 1993. Long-term effects of selected xenobiotica on freshwater green algae: development of a flow-through test system. Sci Total Environ 113/114:735-740.

Schofield, M. 1986. Combined Field Dissipation and Aquatic Non- target Organism Accumulation Studies on Aatrex Nine-O for Forestry Use at Oregon City, Oregon: Laboratory Study No. 32989. Un- published study prepared by Analytical Bio-Chemistry Laboratories, Inc. 135 p. (MRID 40431340)

Schulz, A., F. Wengenmayer and H. M. Goodman. 1990. Genetic engineering of herbicide resistance in higher plants. Plant Sci. 9:1-15.

Solomon K. R., J. A. Carr, L. H. Du Preez, J. P. Giesy, R. J. Kendall, E. E. Smith and G. J. Van Der Kraak. 2008. Effects of atrazine on fish, amphibians, and aquatic reptiles: a critical review. Crit. Rev Toxicol. 38: 721-722.

Spalding, R.F., M.E. Exnev, J.J. Sullivan, and P.A. Lyon. 1979. Chemical seepage from a tail water recovery pit to adjacent ground water. J, Environ. Qual. 8(3):374-383.

Spalding, R.F., G.A. Junk, and J.J. Richard. 1980. Pesticides in ground water beneath irrigated farmland in Nebraska, August 1978. Pestic. Monit. J. 14(2) :70-73.

Spare, W. 1986. Determination of the Hydrolysis Rate Constants of Atrazine: Laboratory Study No. 1236. Unpublished study prepared by Agrisearch Inc. 33 p. (MRID 40431319)

Spare, W. 1987. Photodegradation of Atrazine on Soil Surfaces Ex- posed to Artificial and Natural Sunlight: Laboratory Study No. 1237. Unpublished study prepared by Agrisearch Inc. 68 p. (MRID 40431320)

Spare, W. 1987. Anaerobic Aquatic Metabolism of Atrazine: Labora- tory Study No. 1231. Unpublished study prepared by Agrisearch, Inc. 69 p. (MRID 40431323)

Spare, W. 1989. Adsorption/Desorption of [Carbon 14]-G-28273: Agrisearch Project ID 12173. Unpublished study prepared by Agrisearch Inc. 55 p. (MRID 41257904)

Spare, W. 1989. Adsorption/Desorption of [Carbon-14]-G-30033: Agrisearch Project ID 12169. Unpublished study prepared by Agrisearch Inc. 57 p.(MRID 41257906)

Spare, W. 1989. Adsorption/Desorption of [Carbon 14]-G-34048: Agrisearch Project ID 12171. Unpublished study prepared by Agrisearch, Inc. 57 p. (MRID 41257902)

Speth, Robert M. 1991. Responses to the EPA Review of the Atrazine Forestry Dissipation Study at Oregon City, Oregon. (Supplement to MRID 40431340). Performed and submitted by Ciba-Geigy Corporation, Greensboro, NC. Project ID: ABR-91067. (MRID 42041405)

Spolyarich, N., R. Hyne, S. Wilson, C. Palmer, and M. Byrne. 2010. Growth, Development and Sex Ratios of Spotted Marsh Frog (Limnodynastes tasmaniensis) Larvae Exposed to Atrazine and a Herbicide Mixture. *Chemosphere* 78: 807-813

Steinman, A.D. 1992. Does and increase in irradiance influence periphyton in a heavily-grazed woodland stream? Oecologia 91: 163-170.

Steinman, A.D., C.D. McIntire, S.V. Gregory, G.A> Lamberti, L.R. Ashkenas. 1987. Effects of herbivore type and density on taxonomic structure and physiognomy of algal assemblages in laboratory streams. Journal of the North American Bethological Society 6 (3): 175-188.

Stomp, M., J. Huisman, G.G. Mittelbach, E. Litchman, and C.A. Klausmeier. 2011. Large-scale biodiversity patterns in freshwater phytoplankton. Ecology, 92(11): 2096–2107.

Stone, W.W., and R.J. Gilliom. 2011. Watershed regressions for pesticides (WARP) for predicting atrazine concentration in Corn Belt streams: U.S. Geological Survey Open-File Report 2011–1141, 18 p.

Stone, W. W., C.G. Crawford, and R.J. Gilliom. 2013.Watershed regressions for pesticides (WARP) for predicting stream concentrations of multiple pesticides. J. Environ. Qual. 42:1838-1851.

Storrs Mendez, S. I., D.E. Tillitt, T.A.G. Rittenhouse, and R.D. Semlitsch. 2009. Behavioral Response and Kinetics of Terrestrial Atrazine Exposure in American Toads (Bufo americanus). *Arch. Environ. Contam. Toxicol.* 57: 590-597.

Storrs, S. I. and J. M. Kiesecker. 2004. Survivorship Patterns of Larval Amphibians Exposed to Low Concentrations of Atrazine . *Environ.Health Perspect.* 112: 1054-1057.

Storrs, S. I. and R.D. Semlitsch. 2008. Variation in Somatic and Ovarian Development: Predicting Susceptibility of Amphibians to Estrogenic Contaminants. *Gen. Compar. Endo*. 156, (3): 524-530.

Stratton GW. 1984. Effects of the herbicide atrazine and its degradation products, alone and in combination, on phototrophic microorganisms. Arch Environ Contam Toxicol 13:35-42.

Sullivan, K. B. and Spence, K. M. 2003. Effects of Sublethal Concentrations of Atrazine and Nitrate on Metamorphosis of the African Clawed Frog. Environ.Toxicol.Chem. 22: 627-635.

Talbert, F.S., R.G. Wien, and E.R. Mansager. 1981. The adsorption of some s-triazines in soil. Weeds 13:46-52.

Tavera-Mendoza, L., S. Ruby, P. Brousseau, M. Fournier, D. Cyr and D. Marcogliese. 2001. Response of the amphibian tadpole *Xenopus laevis* to atrazine during sexual differentiation of the ovary. Environmental Toxicology and Chemistry 21 (6): 1264 - 1267.

Tavera-Mendoza, L., S. Ruby, P. Brousseau, M. Fournier, D. Cyr and D. Marcogliese. 2001. Response of the amphibian tadpole *Xenopus laevis* to atrazine during sexual differentiation of the testes. Environmental Toxicology and Chemistry 21 (3): 527 - 531.

Thelin, G.P., and Stone, W.W., 2013, Estimation of annual agricultural pesticide use for counties of the conterminous United States, 1992–2009: U.S. Geological Survey Scientific Investigations Report 2013-5009, 54 p.

Thuillier-Bruston, F., R. Calvayrac, E. Duval. 1996. Partial molecular analysis of the psbA gene in Euglena gracilis mutants exhibiting resistance to DCMU and atrazine. Z. Naturforsch. 51: 711-720.

Tierney, K.B., C.R. Singh, P.S. Ross, and C.J. Kennedy. 2007. Relating olfactory neurotoxicity to altered olfactory-mediated behaviors in rainbow trout exposed to three currently-used pesticides. Aquatic Tox. 81:55-64.

Tillitt, D.E., Papoulias, D.M., Whyte, J.J., Richter, C.A. 2010. Atrazine reduces reproduction in fathead minnow (*Pimephales promelas*), AquaticToxicology (99) 149-159. Supplemental Information: doi:10.1016/j.aquatox.2010.04.011

Tilman, D. 1982. Resource competition and community structure. Princeton University Press, Princeton, New Jersey, USA.

Torres, A. M. R. and L. M. O'Flaherty. 1976. Influence of pesticides on *Chlorella*, *Chlorococcum*, *Stigeoclonium* (Chlorophyceae), *Tribonema*, *Vaucheria* (Xanthophyceae) and *Oscillatoria* (Cyanophyceae). Phycologia 15(1):25-36. (MRID # 000235-44).

Toth, D., D. Tomascovicova. 1979. Effect of pesticides on survival of Tetrahymena pyriformis in Danube water. Bilologia (Bratislava), 34(3): 233-239.

Triska, F.J., V.C. Kennedy, R.J. Avanzino, B.N. Reilly. 1983. Effect of simulated canopy cover on regulation of nitrate uptake and primary production by natural periphyton assemblages. In: Fontaine III TD, S.M. Bartell (eds) Dynamics of lotic ecosystems. Ann Arbor Science, Ann Arbor, pp 129-159.

Turbak SC, Olson SB, McFeters GS. 1986. Comparison of algal assay systems for detecting waterborne herbicides and metals. Water Res 20:91-96.

U.S. Environmental Protection Agency (USEPA). 1992. Framework for Ecological Risk Assessment. Risk Assessment Forum, Washington, DC, EPA/630/R-92/001. http://www.epa.gov/raf/publications/framework-eco-risk-assessment.htm

U.S. Environmental Protection Agency (USEPA). 1994. Atrazine, simazine and cyanazine: Notice of initiation of special review. Federal Register 59(225), 60412-60443.

U.S. Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum, Office of Research and Development, Washington, D.C. EPA/630/R-95/002F. April 1998. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=30759

U.S. Environmental Protection Agency (USEPA). 2000a. Consultation: National Drinking Water Survey Design for Assessing Chronic Exposure. Prepared for the June 6-9, 2000 FIFRA Scientific Advisory Panel. Document available at **http://www.epa.gov/scipoly/sap** **/**meetings/2000/060600_mtg.htm

U.S. Environmental Protection Agency (USEPA). 2000b. FIFRA Scientific Advisory Panel: Assessment of Pesticide Concentrations in Drinking Water and Water Treatment Effects on Pesticide Removal and Transformation. Prepared for the September 26-29, 2000 FIFRA Scientific Advisory Panel. Document available at **http://www.epa.gov/scipoly/sap**

U.S. Environmental Protection Agency (USEPA). 2003a. Interim Reregistration Eligibility Decision for Atrazine. Completed January 2003. Available at http://www.epa.gov/pesticides /reregistration/atrazine/atrazineadd.pdf

U.S. Environmental Protection Agency (USEPA). 2003b. Memorandum of Agreement Between the U. S. Environmental Protection Agency and Agan Chemical Manufacturing, Dow AgroSciences, Drexel Chemical, Oxon Italia S.P.A., and Syngenta Crop Protection Concerning the Registration of Pesticide Products Containing Atrazine. Available at http://www.epa.gov/ pesticides /reregistration /atrazine/AtrazineMOA.pdfUS EPA. (2003).

U.S. Environmental Protection Agency (USEPA). 2003c. Interim Reregistration Eligibility Decision for Atrazine. Completed October 2003. Available at http://www.epa.gov/pesticides /reregistration/atrazine/atrazineadd.pdf

U.S. Environmental Protection Agency (USEPA). 2003d. FIFRA Scientific Advisory Panel: A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Potential Developmental Effects of Atrazine on Amphibians. June 17 - 20, 2003. Available at EPA-HQ-OPP-2003-0186.

U.S. Environmental Protection Agency (USEPA). 2004. Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs. U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs, Washington DC. January 23, 2004.

U.S. Environmental Protection Agency (USEPA). 2006. Atrazine Reregistration Eligibility Decision Document

U.S. Environmental Protection Agency (USEPA). 2007a. The Potential for Atrazine to Affect Amphibian Gonadal Development. Prepared for October 9 - 12, 2007 FIFRA Scientific Advisory Panel. Document Available at EPA-HQ-OPP-2007-0498

U.S. Environmental Protection Agency (USEPA). 2007b. Preliminary Interpretation of the Ecological Significance of Atrazine Stream-Water Concentrations Using a Statistically-Designed Monitoring Program. Prepared for the December 4 - 7, 2007 FIFRA Scientific Advisory Panel. Document available at EPA-HQ-OPP-2007-0934

U.S. Environmental Protection Agency (USEPA). 2007c. ECOTOXicology Database. Office of Research and Development National Health and Environmental Effects Research Laboratory's (NHEERL's) Mid-Continent Ecology Division (MED). http://cfpub.epa.gov/ecotox/.

U.S. Environmental Protection Agency (USEPA). 2007d. Ecological Incident Information System. http://www.epa.gov/espp/consultation/ecorisk-overview.pdf

U.S. Environmental Protection Agency (USEPA). 2009a. FIFRA Scientific Advisory Panel: A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II). May 12 – 15, 2009 FIFRA Scientific Advisory Panel. Document available at EPA-HQ-OPP-2009-0104

U.S. Environmental Protection Agency (USEPA). 2009b. Potential Risks of Atrazine Use to Federally Threatened California Red-legged Frog (*Rana aurora draytonii*) and Delta Smelt (*Hypomesus transpacificus*) Pesticide Effects Determination. Office of Pesticide Programs, Environmental Fate and Effects Division. February 19, 2009.

U.S. Environmental Protection Agency (USEPA). 2010a. FIFRA Scientific Advisory Panel: A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Re-Evaluation of Human Health Effects of Atrazine: Review of Experimental Animal and In Vitro Studies and Drinking Water Monitoring Frequency. April 26-29, 2010. Document available at EPA-HQ-OPP-2010-0125

U.S. Environmental Protection Agency (USEPA). 2010b. FIFRA Scientific Advisory Panel: A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Re-Evaluation of Human Health Effects of Atrazine: Review of Non-cancer Effects and Drinking Water Monitoring Frequency. September 14-17, 2010. Document available at EPA-HQ-OPP-2010-0481

U.S. Environmental Protection Agency (USEPA). 2011a. FIFRA Scientific Advisory Panel: A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Re-Evaluation of Human Health Effects of Atrazine: Review of Cancer Epidemiology, Non-cancer

Experimental Animal and *In vitro* Studies and Drinking Water Monitoring Frequency. July 26-29, 2011 FIFRA Scientific Advisory Panel. Document available at EPA-HQ-OPP-2011-0399

U.S. Environmental Protection Agency (USEPA). 2011c. Evaluation guidelines for ecological toxicity data in the open literature. Environmental Fate and Effects Division, OPP. (May 16, 2011).

U.S. Environmental Protection Agency (USEPA). 2011b. Screening level Usage Estimate for Atrazine. Biological Effects and Economics Analysis Division, OPP. (November 15, 2011).

U.S. Environmental Protection Agency (USEPA). 2012a. Haddad, S. and B. Phillips to James Hetrick. Memorandum: Use Characterization for Atrazine. Biological Economic Analysis Division, Office of Pesticide Programs. March 22, 2012.

U.S. Environmental Protection Agency (USEPA). 2012b. FIFRA Scientific Advisory Panel: Consultation on common effects assessment methodology developed in the Office of Pesticide Programs and Office of Water. January 31 – February 2, 2012. FIFRA Scientific Advisory Panel. Document available at http://www.regulations.gov/#!docketDetail;rpp=25;po=0;D=EPA-HQ-OPP-2011-0898

U.S. Environmental Protection Agency (USEPA). 2012c. FIFRA Scientific Advisory Panel: Problem Formulation for the Reassessment of Ecological Effects from the Use of Atrazine. June 12-14, 2012. Document available at

U.S. Environmental Protection Agency (USEPA). 2013. Addendum to the Problem Formulation for the ecological Risk Assessment to be Conducted for the Registration Review of Atrazine. Environmental Fate and Effects Division, OPP.

U.S. Environmental Protection Agency (USEPA). 2014. Health Canada Pest Management Regulatory Agency, and California Department of Pesticide Regulation. 2014. Guidance for assessing risk to bees. http://www2.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance

U.S. Environmental Protection Agency (USEPA). 2015. Atrazine (080803) SLUA Report Update in Support of Registration Review. Biological Effects and Economics Analysis Division, OPP. May 18, 2015.

United States Department of Agriculture (USDA). 2007. Census of Agriculture. Online: http://www.agcensus.usda.gov/Publications/2007/index.asp

United States Department of Agriculture (USDA). 2010. NASS Crop Reporting Districts (2006-2010). Online: http://www.ers.usda.govibriefing/arms/resourceregions/resourceregions.htm#nass

United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). 1998. Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act. Final Draft. March 1998.

United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). 2004. 50 CFR Part 402. Joint Counterpart Endangered Species Act Section 7 Consultation Regulations; Final Rule. *Federal Register* Volume 69. Number 20.Pages 47731-47762. August 5, 2004.

United States Geological Survey (USGS). 2010. National Water Quality Assessment Program (NAWQA) website. (http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=02&map=m1362; accessed May 25, 2011).

van der Heever JA, Grobbelaar JU. 1996. The use of *Selenastrum capricornutum* growth potential as a measure of toxicity of a few selected compounds. Water SA 22: 183-191.

van der Kraak, G.; Hanson, M.; Solomon, K.; et al. (2014) Atrazine: Effects of Atrazine in Fish, Amphibians and Reptiles: An Analysis Based on Quantitative Weight of Evidence. Critical Reviews in Toxicology 44(S5):1-66. MRID 49535805.

Vandenberg, L. N., T. Colborn, T. B. Hayes, J. J. Heindel, D. R. Jacobs, Jr., D. Lee, T. Shioda, A. M. Soto, F. S. vom Saal, W. V. Welshons, R. T. Zoeller, and J. P. Myers. 2012. Hormones and endocrine-disrupting chemicals: low-dose effects and nonmonotonic dose responses. *Endo. Rev*. 33(3): 00-00 doi:10.1210/er.2011-1050

Versteeg DJ. 1990. Comparison of short- and long-term toxicity test results for 1202 the green alga,*Selenastrum capricornutum*. In: Wang W, Gorsuch JW, Lower WR (eds). Plants for Toxicity Assessment. Philadelphia, PA: American Society for Testing and Materials.

Villeneuve, D. L., K. Coady, M. Hecker, M. B. Murphy, P. D. Jones and J. P. Giesy. 2003. Methods development for the study of mechanism of action of atrazine in adult and metamophosing *Xenopus laevis* and *Rana clamitans*: aromatase induction. Aquatic Toxicology Laboratory, Michigan State University, National Food Safety and Toxicology Center, E. Lansing, MI. Sponsor: Syngenta Crop Protection, Inc., Laboratory Study ID ECORISK Number MSU-01.

Villeneueve, A., B. Montuelle and A. Bouchez. 2011. Effects of flow regime and pesticides on periphytic communities: Evolution and role of biodiversity. Aquatic Toxicology 102: 123-133.
Wagenet, L.P., A.T Lemley, and R.J. Wagenet. 1987. A review of physical-chemical parameters related to the soil and groundwater fate of selected pesticides used in New York state. Search Agriculture, No. 30, 49 pp. Cornell Univ., Ithaca, NY.

Wall, S. 2006. Summary of Atrazine Use on Woody Plant Species. Syngenta Crop Protection, Inc. 410 Swing Road Greensboro, NC 27409 USA; Laboratory Report Number T003409-06. MRID 46870401.

Walker, A. and R.L. Zimdahl. 1981. Simulation of persistence of atrazine, linuron, and metolachlor in soil at different sites in the USA. Weed Res. 21:255-265.

Walsh, G.E., L.L. McLaughlin, M.J. Yoder, P.H. Moody, E.M. Lores, J. Forester, P.B. Wessinger-Duvall. 1988. *Minutocellus polymorphus*: A New Marine Diatom for Use in Algal Toxicity Tests. Environ. Toxicol. Chem.7(11): 925-929.

Wan, M.T., C. Buday, G. Schroeder, J. Kuo, J. Pasternak. 2006. Toxicity to Daphnia magna, Hyalella azteca, Oncorhynchus kisutch, Oncorhynchus mykiss, Oncorhynchus tshawytshcha and Rana catesbeiana of atrazine, metolachlor, simazine, and their formulated products. Bull Environ. Contam. Toxicol. 76:52-58.

Waring, C. P. and Moore, A. 2004. The Effect of Atrazine on Atlantic Salmon (Salmo salar) Smolts in Fresh Water and After Sea Water Transfer. *Aquat.Toxicol.* 66: 93-104. EcoReference No.: 72625.

Wehtje, G., J. R. C. Leavitt, R. F. Spalding, L.N. Mielke, and J.S. Schepers. 1981. Atrazine contamination of groundwater in the Platte Valley of Nebraska from non-point sources. Sci. Total Environ. 21:47-51. 42/1st, Washington, D.C. Off. Water Res. Technol. OWRT-A-02-NEB. 77 p.

Weidner, C.W. 1974. Degradation in groundwater and mobility of herbicides. NTIS PB-239 242/1st, Washington, D.C. Off. Water Res. Technol. OWRT-A-02-NEB. 77 p.

White, A.L., C. Boutin. 2007. Herbicidal Effects on Nontarget Vegetation: Investigating the Limitations of Current Pesticide Registration Guidelines. Environ. Toxicol. Chem. 26(12): 2634-2643. EcoReference No.: 109542.

White, A.W., A.P. Barnett, B.G. Wright, and J . H . Holladay. 1967. Atrazine losses from Fallow land caused by runoff and erosion. Environ. Sci. Technol. 1(9):740-744. Also In unpublished submission received July 19, 1978 under 201-403; submitted by Shell chemical Co.,(Accession No. 00027119)

White, S. 1987. Field Dissipation Study on Aatrex Nine-O for Terresterial Uses on Bareground, Ripon, California: Laboratory Study No. 1641-86-71-01-21E-23. Unpublished study prepared by Minnesota Valley Testing Labs, Inc. 300 p. (MRID 40431336)

White, S. 1987. Field Dissipation Study on Aatrex Nine-O for Terrestrial Uses on Bareground, Hollandale, Minnesota: Laboratory Study No. 1641-86-71-01-21E-25. Unpublished study prepared by Minnesota Valley Testing Labs, Inc. 356 p. (MRID 40431337)

White, S. 1987. Field Dissipation Study on Aatrex Nine-O for Terrestrial Uses on Corn, Hollandale, Minnesota: Laboratory Study No. 1641-86-71-01-06B-24. Unpublished study prepared by Min- nesota Valley Testing Labs, Inc. 372 p. (MRID 40431339)

White, S. 1987. Field Dissipation Study on Aatrex Nine-O for Terrestrial Uses on Corn, Ripon, California: Laboratory Study No. 1641-86-71-01-06B-22. Unpublished study prepared by Minnesota Valley Testing Labs, Inc. 311 p. (MRID 40431338)

White, K., F. Khan, C. Peck, and M. Corbin. 2013. Guidance on modeling offsite deposition of pesticides via spray drift for ecological and drinking water assessments. USEPA/OPP/EFED.

Widmer, S.K., J.M. Olsen, W.C. Koskinen. 1993. Kinetics of atrazine hydrolysis in water. J. Environ. Sci. and Health. Part B: Pesticides, Food Contaminates and Agricultural Wastes. 28:19-28.

Williams, Ronald W. Jr. 2012. Correspondence from Janis McFarland (Syngenta) to James A. Hetrick (USEPA/OPP). Investigation of atrazine detections near Daykin, NE from May 2002: Nebraska Department of Environmental Quality (NDEQ) Ambient Surface Water Monitoring Data.

Williams, B. K. and Semlitsch, R. D. (2010). Larval Responses of Three Midwestern Anurans to Chronic, Low-Dose Exposures of Four Herbicides. Arch. Environ. Contam. Toxicol. 58: 819-827

Zagorc-Koncan J. 1996. Effects of atrazine and alachlor on self-purification processes in receiving streams. Water Sci Technol 33:181-187.

Zaya, R. M., Z. Amini., A.S. Whitaker, S. L. Kohler, and C.F. Ide. 2011. Atrazine Exposure Affects Growth, Body Condition and Liver Health in Xenopus laevis Tadpoles. *Aquat. Toxicol.* 104: 243-253