PETITION TO LIST THE SOUTHERN RESIDENT KILLER WHALE (*ORCINUS ORCA*) AS AN ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT

CENTER FOR BIOLOGICAL DIVERSITY
Petitioner
May 1, 2001

CENTER FOR WHALE RESEARCH, THE WHALE MUSEUM, OCEAN ADVOCATES, WASHINGTON TOXICS COALITION, ORCA CONSERVANCY, AMERICAN CETACEAN SOCIETY, FRIENDS OF THE SAN JUANS, PEOPLE FOR PUGET SOUND, PROJECT SEAWOLF, CASCADE CHAPTER OF THE SIERRA CLUB, RALPH MUNRO

Co-Petitioners

NOTICE OF PETITION

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Petitioner Center for Biological Diversity ("CBD") formally requests that the National Marine Fisheries Service ("NMFS") list the Southern Resident killer whale (*Orcinus orca*) as an endangered species under the federal Endangered Species Act.[1] In the alternative, petitioner formally requests that NMFS list the Southern Resident killer whale as a threatened species under the ESA. In either case, CBD requests that critical habitat be designated concurrent with the listing designation. This petition is filed under § 553(e) of the Administrative Procedure Act,[2] § 1533(b)(3) of the ESA, and 50 C.F.R. § 424.14(b). Because *O. orca* is classified in the order Cetacea, NMFS has jurisdiction over this petition.[3] This petition sets in motion a specific administrative process as defined by § 1533(b)(3) and 50 C.F.R. § 424.14(b), placing mandatory response requirements on NMFS.

The Center for Biological Diversity is a non-profit environmental organization dedicated to protecting endangered species and wild places of western North America and the Pacific through science, policy, education, and environmental law. CBD submits this petition on its own behalf and on behalf of its members and staff, with an interest in protecting the killer whale and the whale's habitat.

The Center for Whale Research is a non-profit organization dedicated to benign studies of whale and dolphin populations for the purpose of determining their status and trends in the marine ecosystem that is being increasingly impacted by human activities. The factual information obtained in these studies is provided to governments, resource managers, other organizations, and the public to further responsible management and education needs.

Founded in 1979, The Whale Museum seeks, through education and research, to encourage responsible stewardship of whales and the marine ecosystems upon which they depend.

Founded in 1967, the American Cetacean Society is the oldest whale conservation group in the world. Its mission is "the protection of whales, dolphins, porpoises, and their habitats and ecosystems through public education, research grants and conservation actions." ACS currently has more than 1000 members consisting of scientists, teachers and others from the United States and 21 other countries.

[1] 16 U.S.C. §§1531-1544 [hereinafter ESA].
[2] 5 U.S.C. §§551-559 [hereinafter APA].
[3] Memorandum of Understanding between the USFWS & NMFS Regarding Jurisdictional Responsibilities and Listing Procedures under the ESA (1974).

People For Puget Sound is a non-profit citizens' group, dedicated to educating and involving people in protecting and restoring the land and waters of Puget Sound and the Northwest Straits. They work to eliminate contamination of our waters, halt the destruction of natural habitats, and sustain the Sound and Straits as a healthy source of peoples' livelihood, enjoyment, and renewal.

Orca Conservancy is dedicated to enhancing public awareness about the plight of the Southern Resident killer whale, to enable a deeper understanding of the importance & interconnectedness of orcas, salmon, watersheds, and healthy marine ecosystems. By focusing on the orca, the Pacific Northwest's beloved & majestic icon, Orca Conservancy engages a wide & diverse audience.

Ocean Advocates is dedicated to the protection of the oceans for the people and wildlife that depend on them for life, livelihood and enjoyment. Over the past five years, Ocean Advocates has established a strong reputation in the Pacific Northwest for the protection of marine and coastal resources along the Olympic Coast, the San Juan Islands and the Strait of Juan de Fuca from the threat of oil spills.

Friends of the San Juans is the voice for the environment of the San Juan Islands and the Northwest Straits Marine Ecosystem. Founded in 1979, Friends of the San Juans has been working 21 years to protect and promote the health and future of the San Juan Islands: land, water, natural, and human communities.

Project SeaWolf, a Washington-based marine mammal protection organization, focuses on creating film and print documentaries and media campaigns about wildlife protection. The group focuses on empowering non-traditional audiences to conduct environmental advocacy programs.

The Cascade Chapter of the Sierra Club organizes and supports grassroots conservation efforts within Washington State, representing thousands of grassroots volunteers and members.

The Washington Toxics Coalition is a non-profit organization dedicated to protecting public health and preventing pollution in industry, agriculture and the home.

Ralph Munro grew up on the west side of Bainbridge Island where his grandparents settled in 1890. He was elected Washington's Secretary of State in 1980 and was re-elected five times, retiring in 2000. Ralph Munro has been frequently honored for his service to the public in areas such as voter participation, historic preservation, volunteerism, helping the developmentally disabled, and protecting the environment.

In addition to the co-petitioners, several organizations and individuals have provided invaluable support to this project. We'd like to thank Jennifer Sampson and the 10,000 Years Institute for their work on section VI.E.1., Dr. Martin Taylor and Dr. David Bain for their work on the population viability analysis, and Dr. Robin W. Baird for his work on the COSWIC petition on killer whales in the Pacific Northwest.

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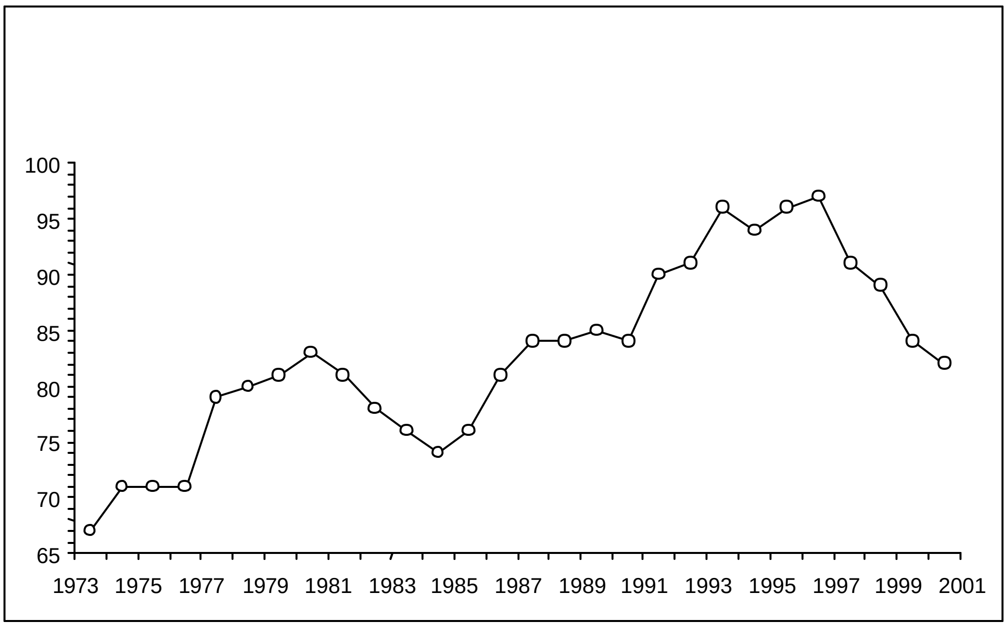
EXECUTIVE SUMMARY

This petition seeks to list the Southern Resident killer whale, *Orcinus orca,* as an endangered species under the Endangered Species Act. The Southern Resident killer whale has experienced alarming population instability over the past 30 years, indicating that the population is unsteady and oscillating toward extinction. Currently the population is experiencing a population decline that is incomparable to any previous population fluctuation in the Southern Residents' known history, and it is now considered the most endangered killer whale population in the world.

Total population of the Southern Resident Killer Whale (1974-2001).[1]

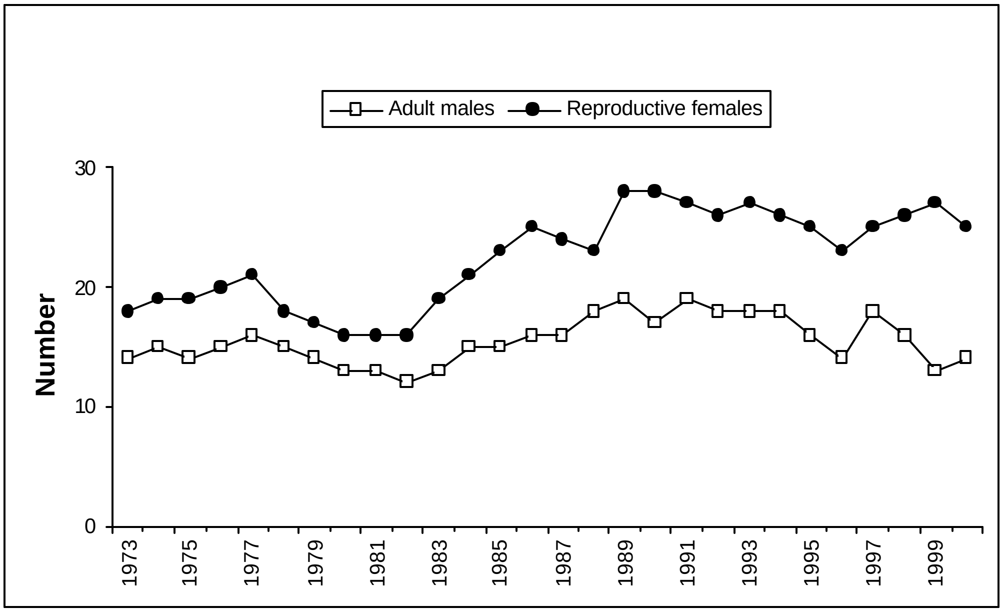


The Southern Residents' extinction trajectory has been caused by several anthropogenic factors. During the late 1960s and early 1970s, approximately 34 Southern Residents were captured and removed for display in aquaria; perhaps a dozen more Southern Residents were killed in the process of capture (Olesiuk et al., 1990). These captures altered the sex and age ratio of the Southern Residents, creating a reproductive gap that led to population declines in the 1980s. Concentrations of organochlorines in Southern Residents have recently been determined to be greater than levels at which harmful effects have been documented in other marine species. The contamination may be affecting the survivability of the population. Chinook salmon stocks—the Southern Residents' main food source—have been declining throughout the Pacific Northwest due to over-harvesting and destruction of salmon habitat. The reduction of this food source may be reducing the carrying capacity of the Southern Residents' historical range, and may be enhancing the effects of bioaccumulated toxic chemicals. Disturbances caused by whale-watching and shipping vessels are also a likely factor in the Southern Resident killer whale's decline. Vessel traffic can affect individual whale behavior and lead to fatal collisions with ships

[1] final new calf numbers for 2001 are not yet known.

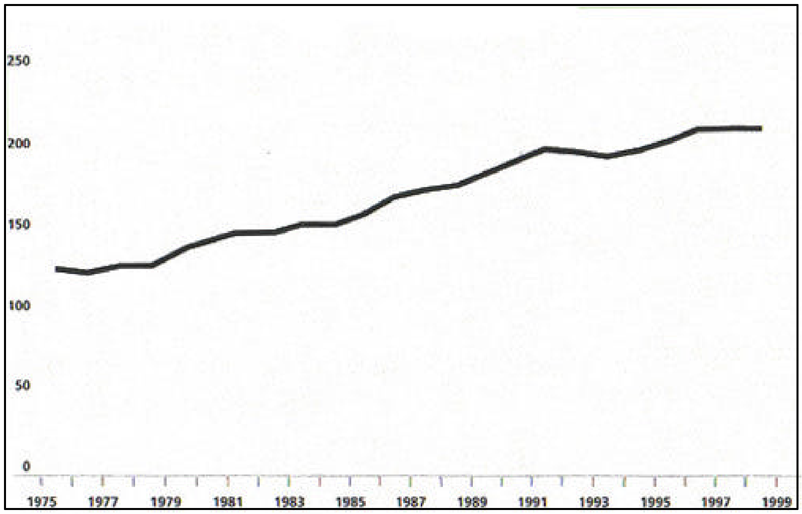
(Ford et al., 2000). All of these factors are particularly worrisome today because the Southern Residents' effective population is now so low that these anthropogenic threats are compounded by the risks inherent in a small population.

The low numbers of reproductive males and females indicates that the Southern Residents' effective population has not been above 50 in the past 30 years.



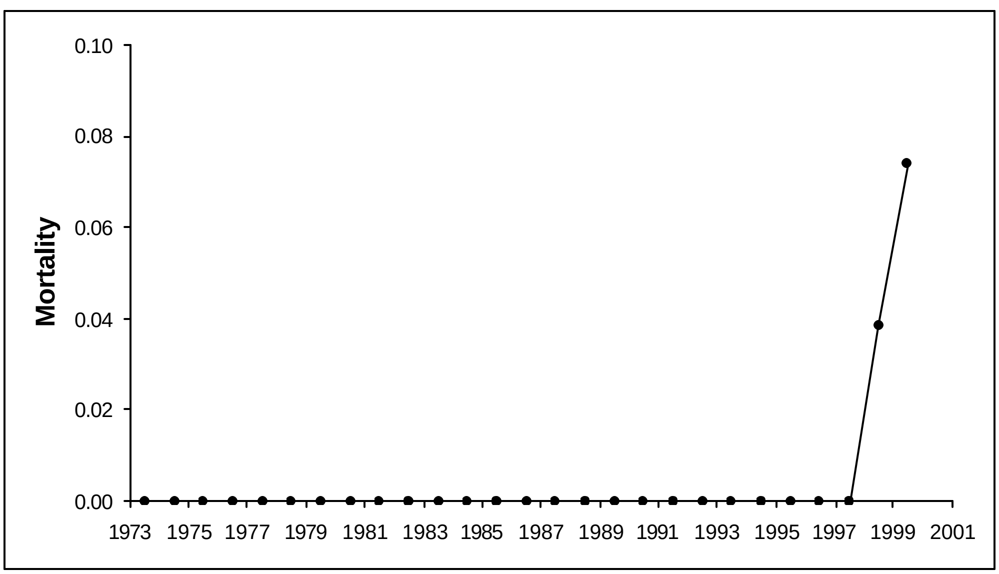
The population instability observed over the past 30 years could be improperly interpreted as a normal or even an expected component of killer whale population dynamics. However, when examined closely it becomes clear that the fluctuations are instead indicative of an unstable trend toward extinction. Each decline that has occurred in the known history of the Southern Resident killer whale has been caused by distinct threats, and subsequent periods of recovery can be linked to the cessation of those threats. Furthermore, if this fluctuation were a normal attribute of killer whale population dynamics, other killer whale populations would be expected to show similar population variances. However, the Northern Resident population—the most comparable population to the Southern Residents—has not shown any indication of population-wide cyclical variation in its known history, and in fact has shown a steady increase in population size over the past 30 years.

Northern Residents have shown a consistent increase in population during the same period that the Southern Residents have shown population instability.



The current decline in the Southern Resident killer whale is especially disconcerting. The scale of the decline—a 15.5% decline since 1996—is a sharp reversal of the population trajectory seen in the previous decade. The individuals lost during the current decline include juveniles and reproductively active females, demographic groups that normally have extremely low mortality rates.

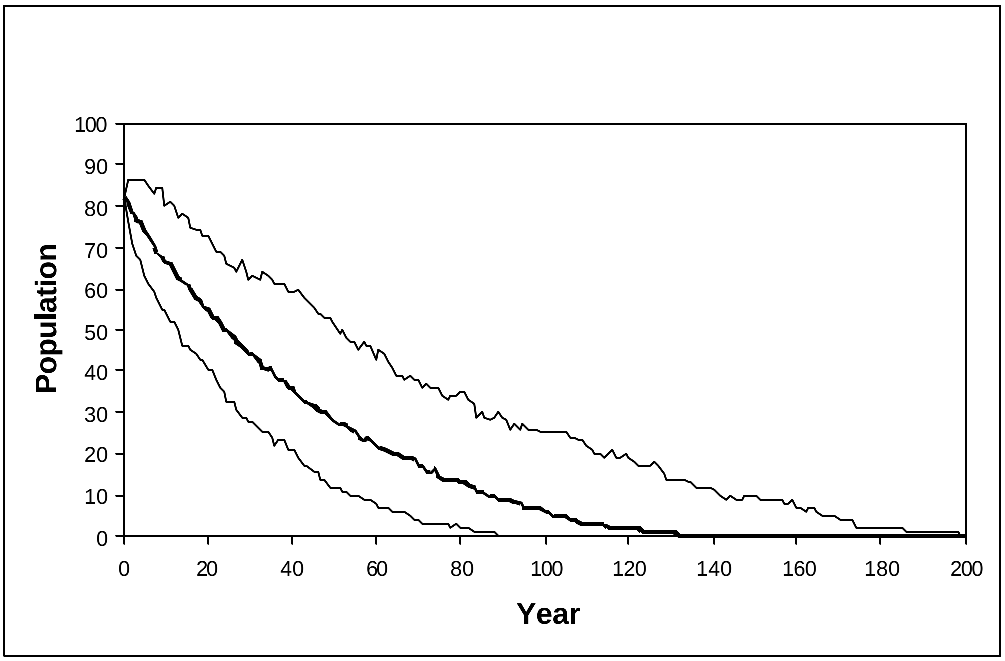
Reproductive female mortality has increased dramatically the past two years.



Reversing this decline will require a strong commitment to preserving this population because the factors contributing to the decline are far-reaching and systemic in nature. Yet even if the current decline is halted, the observed life history patterns for the Southern Residents indicate that extinction is likely if the underlying causes of the instability in the population are not addressed. To determine the probability of the Southern Resident killer whale going extinct with statistical accuracy, we conducted a population viability analysis ("PVA") based on the known life history parameters of the Southern Resident killer whale and the population data collected over the past quarter century by the Center for Whale Research.

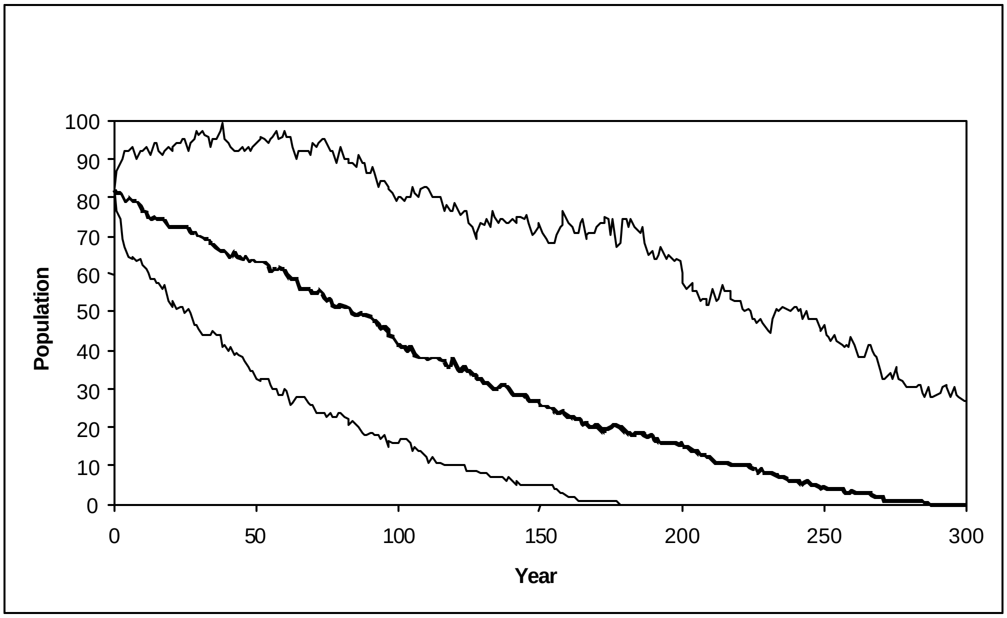
According to the PVA, the Southern Residents have a 100% chance of extinction within the next 200 years if the current population decline continues. The median time to extinction under this scenario is 113 years.

Extinction trajectory graph if current decline continues.



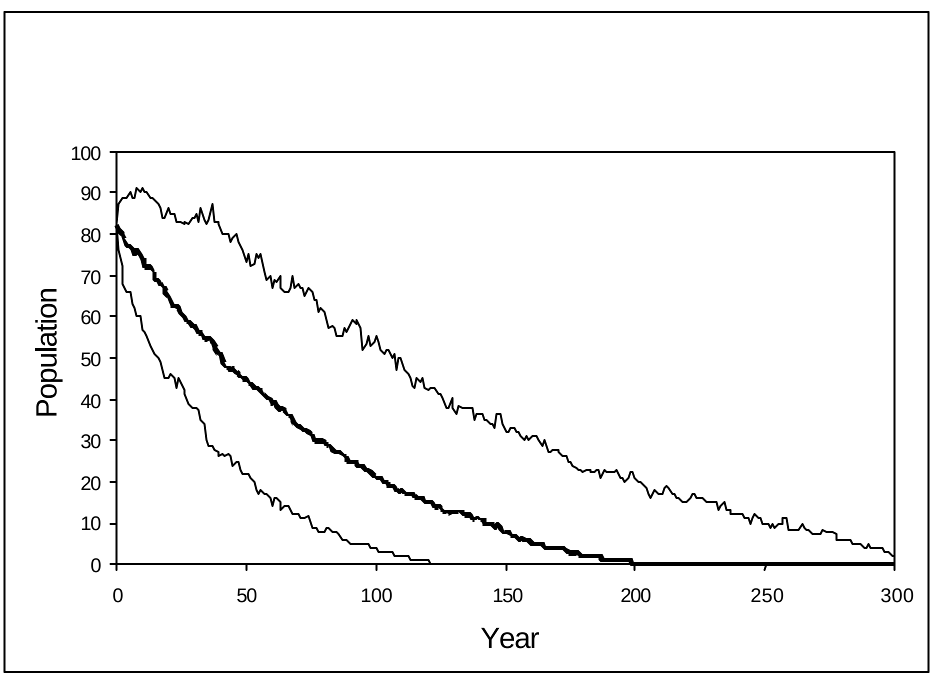
If the current decline is arrested and the general population trends seen over the past 30 years resume, it is likely that the Southern Residents will still go extinct. Under this scenario, a 1% possibility of a catastrophic event—such as the Exxon Valdez oil spill—occurring in any particular year and the detrimental effects of inbreeding are factored into the analysis. This model indicates that the Southern Residents have at least a 62% chance of becoming extinct in the next 300 years, with a median time to extinction of 265 years under this model.

Extinction trajectory graph if current decline is arrested.



However, because the reproductive female mortality noted in the population has never been seen before, it is possible that the trend in reproductive female mortality will continue. This would accelerate the time to extinction substantially, particularly when considered with the likelihood of a catastrophe and inbreeding effects occurring in the population. Under this scenario, the population has a 99% possibility of being extinct within 300 years, with a median time to extinction of 186 years.

Extinction trajectory if reproductive female mortality continues.



Alarmingly, the high probabilities of extinction modeled by the PVA are conservative. The PVA incorporated several conservative assumptions about killer whale ecology and biology. For example, the PVA assumed that the Southern Residents could mate at random with all other individuals of breeding age. However, because of the Southern Residents' social structure, random mating does not occur. Rather, males will generally only mate with females from different pods. Although this cultural practice may reduce the effects of inbreeding on the population, it also limits breeding opportunities, and therefore may increase extinction probabilities.

The Southern Resident killer whale can be sustained if the protective provisions of the ESA are put into place. As a discrete and significant population segment, the Southern Resident killer whale is a listable entity under the ESA. The threats facing the Southern Residents—habitat modification caused by over-fishing and pollution, overuse for recreational and commercial purposes by recreational whale watching vessels, and other factors such as the risks associated with small population size—are not adequately addressed by existing regulatory mechanisms. As such, the listing of the Southern Resident killer whale as endangered throughout its range is warranted.

I. SYSTEMATICS AND NATURAL HISTORY OF *O. ORCA*

A. SPECIES DESCRIPTION

Killer whales are large-brained, intelligent, social predators, with a pattern of ontogenetic development that is closer to humans than any other species (Olesiuk et al., 1990; Osborne, 1990; Heimlich-Boran and Heimlich-Boran, 1999; Osborne, 1999). Killer Whales are globally cosmopolitan in their distribution, culturally and genetically distinct by population and/or region, and feed upon a variety of organisms throughout the upper trophic levels of marine food webs. They are one of the top predators of all oceans, with no history of being preyed upon by another vertebrate species, except very recently by humans in a few instances (Jefferson et al., 1991; Hoyt, 1990).

The underpinning of killer whale social structure is the matriline, a matriarchal family unit varying in size from a minimum of 2 (a mother and her calf) to many individuals belonging to an extended family unit. Matrilines in turn congregate into larger social groups known as pods. In general, breeding only occurs between pods; this mating strategy reduces the risks associated with inbreeding, but limits overall breeding opportunities (Bigg et al., 1987; Hoelzel and Dover, 1991).

Evidence from several different fields suggests that killer whales possess culture (Osborne, 1990; Morton, 1990; Heimlich-Boran and Heimlich-Boran, 1999; Ford 1990; Whitehead, 1998). Cultural conveyance in killer whales is suggested by their long life span, extended childhood learning periods, advanced central nervous system, and complex learned communication system.

B. IDENTIFYING CHARACTERISTICS OF *O. ORCA*

1. Coloration

The killer whale is perhaps the most strikingly pigmented cetacean in the world, easily identified by even the most casual observer of marine mammals. Practiced observers can use these characteristics to identify individuals and an individual's home range, since individual and geographical variations in pigmentation patterns are well established (Carl, 1946; Evans et al., 1982).

Killer whales have a black body with distinctive white markings. The white region extends from the tip of the lower jaw towards the flippers, where it constricts medially, and then widens slightly as it ends caudal of the urogenital region. A lateral white flank patch that connects to the ventral white patch on each side of the whale gives the ventral patch a trident-like design. The ventral side of the fluke is also white or a light gray, and may be bordered in black. A conspicuous white patch is located slightly above and behind the eye. A variable gray or white saddle is usually present behind the dorsal fin. The shape of the saddle varies among individuals, pods, and from one side of an individual to the other (Baird & Stacey, 1988). The saddle patch is indistinct in young individuals, becoming more obvious as the individual matures.

2. Size and Shape

Sexual dimorphism occurs in the body size, flipper size, and height of the dorsal fin in killer whales. Females attain a body length of up to 7.7 meters, while males can reach 9.0 meters. In adult males, the dorsal fin is erect and may be from 1.0 to 1.8 meters tall, whereas the dorsal fins of females are less than 0.7 meters and distinctly falcated, i.e., they curve to a point.

The head of the killer whale is somewhat rounded with a slight demarcation of a beak. The relatively large ovate flippers are positioned about one-fourth of the distance from the snout to the flukes. The flipper shape contrasts sharply with the sickle-shaped flippers of most delphinids. Flipper length may attain 20% of the body length in males and 11-13% of the body length in females. Total spread of the flukes may be over one-fifth of the body length for both sexes (Heyning and Brownell, in prep.). Although few animals have been weighed, weights of 3810 kg for a 6.7 m female and 5568 kg for a 6.75 m male have been obtained.

3. Internal Anatomy

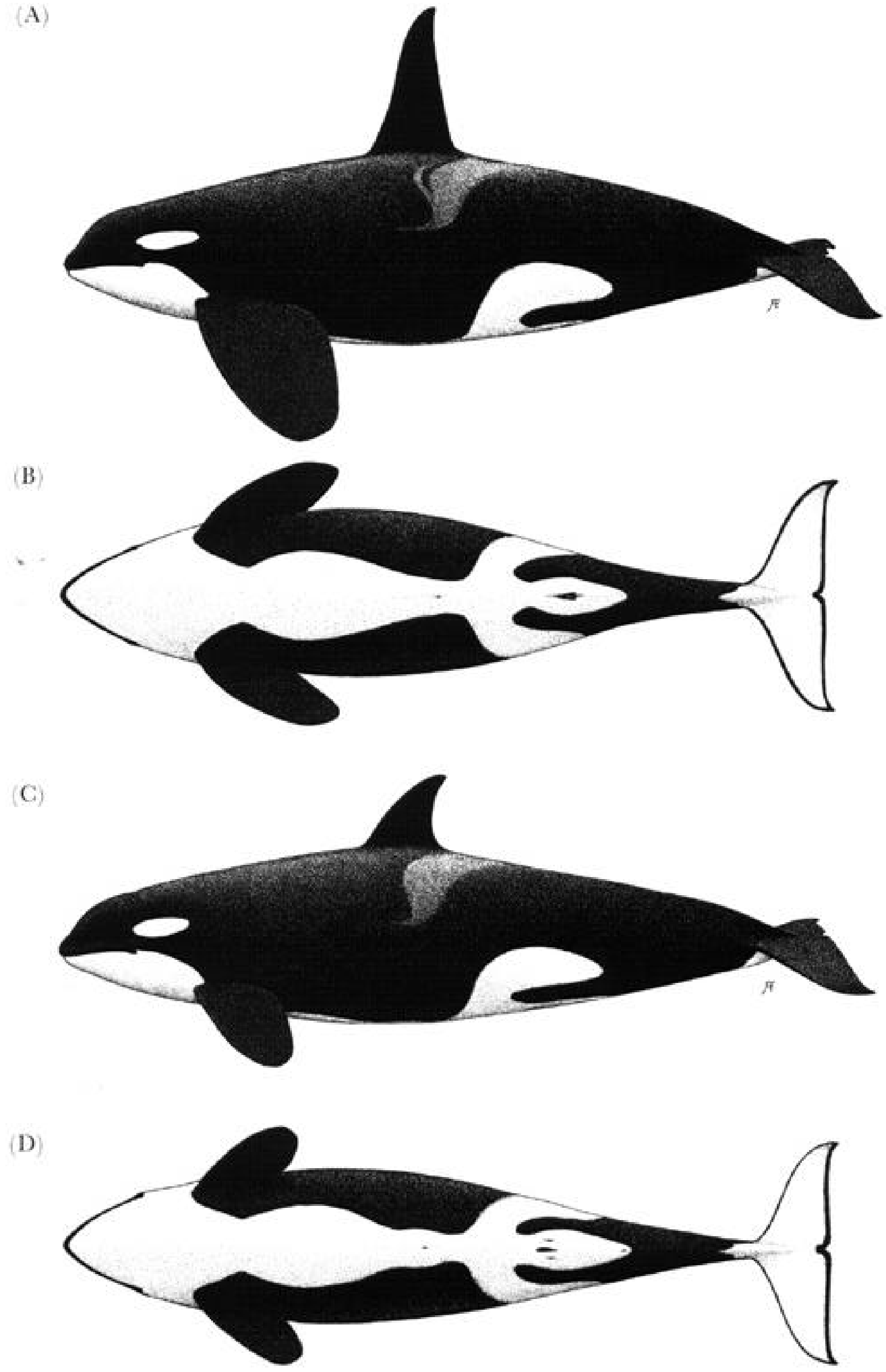
Skulls of adult killer whales typically are distinguished from those of other species of delphinids by their large size, dental formula, and large teeth. Skulls from sub-adult killer whales can be confused with skulls of false killer whales (*Pseudorca crassidens*). When the jaws close, the teeth interlock. Older animals may exhibit extensive wear on the teeth (Caldwell and Brown, 1964).

Killer whales have a total of 50-54 vertebrae. Rib counts range from 11 to 13 per side, with the anterior six or seven ribs attached to the vertebrae by both the capitulum and tuberculum and the remainder attached only by the tuberculum. Ribs 1-6 attach to the sternum.

The phalanges are wider than they are long. The ends of the phalanges and most carpal elements were composed of cartilage for an adult male examined by Eschricht (1866). Harmer (1927) hypothesized that the accelerated secondary growth of flippers in maturing males was related to the continued growth of these cartilages.

The general plan of the digestive system in killer whales is similar to that of other delphinids. The fore stomach is large and extremely distensible in order to accommodate large prey items.

Figure 1. Male [(A) side (B) ventral] and female [(C) side (D) ventral] dimorphism.
Adapted from Dahlheim & Heyhing (1999).



C. TAXONOMIC CLASSIFICATION OF THE KILLER WHALE

1. Scientific Classification

The killer whale is the only extant member of the genus *Orcinus*. Although some taxonomists have suggested that there may be more than one species of killer whale, modern taxonomists classify all killer whales as *Orcinus orca*. The distinct genetic and morphologic variations observed between populations of killer whales are generally considered to be variation within a single species (Perrin, 1982; Heyning & Dahlheim, 1988). However, recent genetic evidence has shown that Transient and Resident killer whales have large genetic differences (Hoelzel et al., 1998). These results and other studies indicate that separate species status may be warranted (Baird, 1994). In addition, the Southern Resident killer whales were shown to have genetic differences from Northern Residents (Hoelzel et al., 1998).

The genus *Orcinus* is typified by species that have numerous, large, delphinoid teeth. "Orcinus" is derived from the Latin word "orcus," which means "of the netherworld." "Orca" is Latin for a kind of whale.

Table 1. Taxonomic classification of the killer whale.

Kingdom	Phylum	Class	Order	Family	Genus	Species
Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Orcinus	orca

2. Common Names

Early whalers coined *O. orca's* common name when they noted the whale's predatory behavior. Originally known as "whale killer," *O. orca's* common name transposed to the more apt "killer whale" over time. Although killer whale is the most frequently used common name in the United States, "orca" is also generally used. Common names used in other countries include "blackfish" in the United Kingdom, "kasatka" in Russia, "sakamata" in Japan, "orque" in France, "hahyrna" in Iceland, "spekkhugger" in Norway, "spächuggare" in Sweden, "zvarrdwalvis" in the Netherlands, and "swordfish" in Newfoundland. Many Native American's historically referred to *O. orca* as "blackfish." The Tlingit refer to killer whales as "Keet," Haida as "skana" (which means "killer demon or supernatural power"), and the Aleut of Kodiak Island, Alaska refer to the killer whale as "polossatik" (which means "the feared one") (Dahlheim & Heyning, 1999).

II. CLASSIFICATION OF KILLER WHALES IN THE PACIFIC NORTHWEST

Killer whales in the Pacific Northwest are classified into three distinct forms: Residents Transients, and Offshores. Although the names imply distinct movement patterns, they do not accurately reflect the site fidelity and movement patterns of the forms. However, the three forms do exhibit differences in morphology, ecology, behavior, and genetic composition. See Table 2.

A. THE TRANSIENT FORM

The most distinguishing characteristic of Transient killer whales is that they primarily prey on other marine mammals, while Residents primarily subsist on fishes (Morton, 1999). Other documented differences between Transients and Residents include measurable differences in morphology, differences in group size and social organization, and differences in acoustic repertoire (Ford and Ellis, 1999; Bain, 1989; Baird, 1994). The genetic composition of Transients is also very different from Residents (Hoelzel et al., 1998). The northern limit for the

Pacific Northwest's Transient form appears to be the Icy Strait and Glacier Bay region of southeast Alaska, and its southern boundary is believed to be Puget Sound and the outer Washington coast.

The Transient form is completely sympatric with the Resident form; genetic evidence suggests that they do not interbreed (Bigg et al., 1987; Hoelzel et al., 1998). Behavioral evidence in fact suggests that Transients actively avoid Residents; interactions between Residents and Transients have only been reported on a small number of occasions (Jacobsen, 1990; Morton, 1990; Barrett-Lennard 1992; Baird and Dill, 1995).

Table 2. Characteristics that differ between Resident and Transient forms.

Morphologic/Genetic Differences	**Behavior/Ecology Differences**
Shape of dorsal fin (Bigg et al., 1987; Bain, 1989)	Diet (Bigg et al., 1987; Morton, 1990)
Saddle patch pigmentation (Baird & Stacey, 1988)	Travel patterns/habitat use (Heimlich-Boran, 1988; Morton, 1990)
Mitochondrial and nuclear DNA (Stevens et al., 1989; Hoelzel & Dover, 1991)	Respiration patterns (Morton, 1990)
	Vocalizations (Ford & Hubbard-Morton, 1990; Ford, 1990)
	Echolocation (Barrett-Lennard et al., 1996)
	Amplitude of exhalations (Baird et al., 1992)
	Group size (Bigg et al., 1987; Morton, 1990)
	Seasonal occurrence (Guinet, 1990; Morton, 1990)
	Geographic range (Bigg et al., 1987)

B. THE OFFSHORE FORM

The Offshore killer whale is not as well understood as the other killer whale forms in the Pacific Northwest. This is due to their recent discovery and an incomplete photo-identification catalog of Offshore individuals. They apparently live in the coastal and open ocean areas of the Eastern North Pacific. Most everything that is known about this population has come through opportunistic encounters in these areas.

The Offshores are believed to total between 200 and 300 individuals, assembled in large Resident-like pods (NMFS, 2000). They range from Southeast Alaska to California. Genetic analysis indicates that although they are believed to be reproductively isolated, the Offshores are more closely related to Southern Residents than Northern Residents (Hoelzel et al., 1998).

C. THE RESIDENT FORM

The Resident form in the Pacific Northwest is comprised of two populations. Each population has distinct association patterns, pigmentation patterns, and genetic composition (Bigg et al., 1987; Baird and Stacey, 1988; Bain, 1989; Ford et al., 1998; Hoelzel et al., 1998; Matkin et al., 1998). The first population, found generally off northern Vancouver Island and in southeast Alaska, has been termed the "Northern" Resident killer whale. The second population, which is the focus of this petition, is found generally around southern Vancouver Island and in the waters of Washington State, and has been termed the "Southern" Resident killer whale.

The Resident populations have partially overlapping ranges. However, behavioral interactions have not been observed between individuals from different Resident populations, and differences in mitochondrial DNA and physical appearance suggest that the populations are reproductively isolated (Baird and Stacey, 1988; Stevens et al., 1989; Hoelzel and Dover, 1991). The Northern and Southern Resident killer whales appear to have distinct behavioral characteristics, but due to limited data on Offshores it is not known if Offshores also have distinctive behavior (Fellemen et al., 1991; Hoyt, 1990).

1. The Northern Resident Killer Whale

The Northern Resident killer whale contains approximately 200 individuals in 16 pods (Ford et al., 2000). Its range extends from the Northern Georgia Strait along the coast of British Columbia into Southeast Alaska (Ford et al., 1994). The Northern Resident killer whale shares many ecological and behavioral characteristics with the Southern Resident killer whale, more so than any other killer whale population.

The Northern Resident killer whale has been seen associating with other Resident-type killer whales in southeast Alaska that do not have Puget Sound as a component of their range. Genetic evidence shows that the Northern Residents share a mitochondrial DNA haplotype with these individuals (Dahlheim et al., 1997; Hoelzel et al., 1998). This indicates that the Northern Residents are a component of a meta-population through which genetic information can be passed and risks of rarity can be mitigated.

2. The Southern Resident Killer Whale

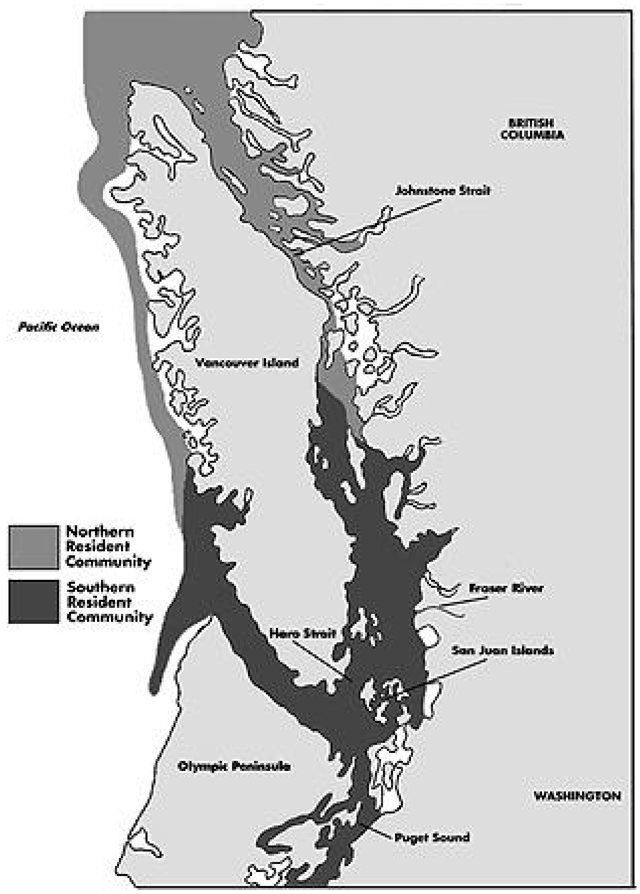
The Southern Resident killer whale consists of three pods: the J pod, the K pod, and the L pod. The J pod is seen most frequently along the western shore of San Juan Island and is the only pod seen on a semi-regular basis in Puget Sound throughout winter (Heimlich-Boran, 1988; Osborne, 1999). The K pod is most frequently seen during May and June when they search the western shore of San Juan Island almost daily for salmon. The L pod is the largest of the Southern Resident pods (Ford et al., 1994). Because it is such a large pod, L pod frequently breaks off into separate subgroups. It is relatively rare to see the entire pod traveling together.

A large part of the Southern Residents' year-round home range includes the international inland waters of Puget Sound, Juan de Fuca Strait, and Georgia Strait. Although not well documented, it is believed that their home range also includes regions outside the entrance to

Juan de Fuca Strait, extending south to the Columbia River, and north to Cape Scott on Vancouver Island (Ford et al., 1994). Recently Southern Residents were spotted off of Monterey Bay.

It is likely that the Southern Resident killer whale is the same ancestral line of killer whales that are first described in the human record, beginning with the art and folklore of Coast Salish peoples (Drucker, 1965; McMillan, 1988; Osborne, 1999). By July 1, 2000, the last full year of data available, the total population of the Southern Residents was 82 individuals.[1] The biology and ecology of the Southern Resident killer whale will be more fully explored below.

Figure 2. Range map for Transient and Resident killer whales. The Transients are sympatric with Northern and Southern Residents.



Map courtesy of the Whale Museum: http://www.whale-museum.org/rangemap.html

III. THE SOUTHERN RESIDENT KILLER WHALE IS A LISTABLE ENTITY UNDER THE ESA

The ESA provides for the listing of all species that warrant the protections afforded by the Act. The term "species" is defined broadly under the act to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or

[1] 2 killer whales have subsequently been born in the Southern Resident population. Because the mortality rate for killer whale calves is high, and because an annual census including these births will not be available in the data set until July 1, 2001 (the closing of the census period), these births are not analyzed in this petition.

wildlife which interbreeds when mature." 16 U.S.C. § 1532 (16).

NMFS and the U.S. Fish and Wildlife Service ("USFWS") have published a policy to define a "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the ESA. 61 Fed. Reg. 4722 (February 7, 1996). Under this policy, a population segment must be found to be both "discrete" and "significant" before it can be considered for listing under the Act. The Southern Resident killer whale meets both of these tests, and thus is a listable entity under the ESA.

A. DISCRETENESS

Under the joint NMFS/FWS policy, a population segment of a vertebrate species is considered discrete if it satisfies either of the following conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.

2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.

61 Fed. Reg. 4725. The Southern Resident killer whale satisfies both of these criteria.

1. Southern Residents are Separated from Other Killer Whales by Distinct Factors

Southern Residents are markedly separated from other types of killer whales found in the Pacific Northwest. The separation is indicated by a variety of factors, and applies to a different degree to each unit of killer whale found within the range of the Southern Residents. The physical, physiological, ecological, and behavioral factors that show that the Southern Residents are markedly separated are discussed in comparison with each form in this section.

<u>a. Southern Residents are Markedly Separated From Transients</u>

i. Physiological Factors

Although the Transient form is completely sympatric with the Residents, genetic evidence suggests that they do not interbreed (Bigg et al., 1987; Hoelzel et al., 1998). In fact, the mtDNA genetic differentiation between the Transient and Resident whales in Puget Sound is as great as the differences between killer whales from different oceans (Hoelzel et al., 1998). Microsatellite DNA polymorphism at three loci also shows significant genetic differentiation between Residents and Transients (Hoelzel et al., 1998). Significant levels of genetic differentiation at mitochondrial and nuclear loci were also found in an examination of five Resident and two Transient killer whales from Washington State and British Columbia (Hoelzel & Dover, 1991). These results indicate that Transients have been reproductively isolated for thousands of years (Ford & Ellis, 1999). The differences between Residents and Transients are greater than the genetic differences between killer whales from different oceans.

Measurable differences in morphology have been documented by several studies (Ford and Ellis, 1999; Bain, 1989; Baird, 1994). Bigg et al. (1987) observed that the tip of the dorsal fin in Residents is rounded and positioned over the dorsal fin's posterior insertion in the whale's back, while in Transients the tip of the dorsal fin is pointed and is centered between the fin's anterior and posterior insertion points in the whale's back. Baird & Stacey (1988) showed that Transients only exhibited two of the five saddle patch pigmentation patterns they cataloged in the Eastern North Pacific, while Residents exhibited all five. The authors quantified this difference, showing that the difference was statistically significant ($?^2 = 122.957$, $p < 0.0001$). These results indicate that the genetic differences reported by Hoelzel et al. (1998) are expressed as distinct morphological characteristics between the two forms.

ii. Ecological Factors

Transient killer whales primarily prey on other marine mammals, while Southern Residents subsist primarily on fishes (Morton, 1999). This is perhaps the most telling difference between the two forms. This difference places the two forms at different trophic levels. Transients eat at a higher trophic level, with a diet comprised of fish-eating pinnipeds, cetaceans, and other marine mammals. They do not compete with each other for food resources. The two forms thus have different ecological niches, and their roles in the Puget Sound ecosystem are distinct.

Transient killer whales have a much larger range than Residents, with some estimates indicating that the Transients range over at least twice the area of Residents. They are seen infrequently in a given area, bolstering the claim that they are wide-ranging (Baird & Dill, 1995; Bigg, 1982; Bigg et al., 1987). The seasonal distribution of the Transients is also distinctly different from Residents. While Residents tend to congregate in certain areas at certain times to intercept salmon migrations, Transients have no clearly defined pattern of occurrence (Guinet, 1990; Morton, 1990).

Transients not only traverse larger swaths of potential habitat at different times of the year, but they also use that habitat in a different manner by exhibiting distinct travel patterns throughout their range (Heimlich-Boran, 1988; Morton 1990). Transients tend to hug the shoreline and travel in small groups. Their movements are erratic with frequent changes in direction and velocity, and include extended dives that are often twice the duration of Residents' dives. Southern Residents tend to travel in larger groups that are more conspicuous, with clearly defined patterns of occurrence. They use areas of high-relief subsurface topography along salmon migratory routes, while Transients tend to feed in shallow protected areas around concentrations of marine mammals. These activities indicate that Transients are ecologically distinct from the Southern Residents throughout the range of the forms.

iii. Behavioral Factors

Transient behavior, culture, and social organization are distinct from the Southern Residents. The forms' different feeding strategies likely determine these behavioral differences, and the exclusivity of each feeding strategy likely explains the forms' sympatric distribution. Respiration patterns (Morton, 1990), the use of echolocation (Barrett-Lennard et al., 1996), and the amplitude of exhalations (Baird et al., 1992) all markedly separate Residents and Transients.

Transients are very quiet whales compared to Residents (Ford & Ellis, 1998). They have a markedly different dialect that has fewer discrete calls, none of which are used by Residents, and the different dialects within Transient groups are less varied relative to Residents.

The group structure and size of Transients is different from Southern Residents. The Southern Residents do not exhibit offspring dispersal for either sex, with offspring traveling with their mother's matriline for their entire lives. Transients exhibit offspring dispersal in both sexes, with females dispersing from their maternal pod with their first offspring to form a new pod, and males dispersing at the onset of adulthood. Only the first-born male stays with the maternal pod for life (Baird, 1994). This structure leads to a smaller group size for Transients, with pods ranging in size from 1 to 15 individuals, whereas Resident pods will range from 10 to 50.

Behavioral evidence suggests that Transients actively avoid the Resident pods; interactions between Residents and Transients have only been reported on a small number of occasions (Jacobsen, 1990; Morton, 1990; Barrett-Lennard 1992; Baird and Dill, 1995). Over the past 30 years, Transients and Residents have not been seen traveling together, even though they are sympatric (Bigg et al., 1990).

<u>b. Southern Residents are Markedly Separated from Offshores</u>

i. Physical Factors

The Southern Residents' range includes areas around the southern end of Vancouver Island, exclusive of areas in which the Northern Residents reside. These areas include the international inland waters of Puget Sound, Juan de Fuca Strait, and Georgia Strait. See Figure 2. The Offshores are found in the coastal and offshore areas of the Eastern North Pacific.

ii. Physiological Factors

The Offshore and Southern Residents are considered markedly different from each other based on their reproductive isolation (Hoelzel et al., 1998). Genetic evidence has also indicated that the Offshores and Residents are discrete (Barrett-Lennard, 2000). The Offshores are not closely related genetically to either Residents or Transients (Barrett-Lennard, 2000).

iii. Ecological Factors

The Southern Residents occupy a unique ecological environment compared to the other killer whales in the Pacific Northwest. The Southern Residents occupy the most urbanized habitat of any killer whale in the world, and they occupy this area exclusive of other killer whales in the Pacific Northwest. Although other killer whales may enter the Southern Residents' habitat on occasion, there is no evidence that other killer whales persist within the Southern Residents' range for an extended period of time. Differences in temperature, turbidity, chemical alteration, and ship traffic all make the Southern Residents' habitat ecologically unique.

iv. Behavioral Factors

Due to limited data on Offshores, it is unclear if Offshores have distinctive behavior compared to the Southern Residents.

<u>c. Southern Residents are Markedly Separated from Other Residents</u>

i. Physical Factors

The two populations of Resident killer whales found in the Pacific Northwest have largely exclusive ranges. The Northern Residents have a range extending from the Northern Georgia Strait along the coast of British Columbia into Southeast Alaska (Ford, et al., 1994). The Southern Residents' range includes areas around the southern end of Vancouver Island, exclusive of areas in which the Northern Residents reside. These areas include the international inland waters of Puget Sound, Juan de Fuca Strait, and Georgia Strait. See Figure 2. The two resident pods almost never violate the established boundaries, with only one known boundary violation occurring in the past 30 years (Rasmussen & Walker, 2000).

These distinct geographic ranges are maintained through a variety of factors. Each range has distinct temperature, visibility, and habitat characteristics, with the Southern Residents' range being the most turbid and perhaps warmest.

ii. Physiological Factors

Southern Residents have genetic compositions that are distinct from the Northern Residents (Hoelzel et al., 1998). The Southern Resident Killer Whale Workshop, convened at the National Marine Mammal Laboratory in Seattle, WA on April 1-2, 2000, noted this distinction. This distinction remained clear even though the Resident populations occasionally overlap geographically. Hoelzel et al. (1998) showed that the Northern Residents and Southern Residents have markedly different haplotypes, with a fixed 1 base pair difference in their genetic composition.

Baird & Stacey (1988) showed that the variation in saddle patch pigmentation between the Northern and Southern Residents indicate that the populations are reproductively isolated and genetically distinct. The saddle patch variation was quantified by the authors and shown to be significantly different ($?^2$ = 92.005, $p < 0.0001$). Evidence of morphological or genetic differences in animals from different geographic regions indicates that these populations are reproductively isolated. Reproductive isolation is proof of demographic isolation, and thus separate management is appropriate when such differences are found.

iii. Ecological Factors

The Southern Residents occupy a unique ecological environment compared to the other Resident whales in the Pacific Northwest. The Southern Residents occupy the most urbanized habitat of any killer whale in the world, and they occupy this area exclusive of other Resident whales. Although other Resident whales may enter the Southern Residents' habitat on occasion, there is no evidence that other Resident whales persist within the Southern Residents' range for an extended period of time. Differences in temperature, turbidity, chemical alteration, and ship traffic all make the Southern Residents' habitat ecologically unique.

iv. Behavioral Factors

The Northern and Southern Residents appear to be markedly separated by distinct behavioral characteristics (Osborne, 1999; Hoyt, 1990). Behavioral distinctions have been noted in the acoustic repertoire, association patterns, and seasonal distribution between Northern and Southern Residents.

The Residents also exhibit distinct behavioral boundaries between each populations' range. After 30 years of study, there is still no evidence of dispersal through migration or recruitment through immigration in Resident pods or populations (Hoelzel et al., 1998), and behavioral interactions have never been observed between individuals from different Resident populations.

2. Southern Residents are Delimited by Significant Jurisdictional Boundaries

Because killer whales regularly move between Canada and the United States, protection measures in Canada are directly relevant to the conservation of killer whales in the U.S. Within Canada, management of killer whales has varied considerably over time, and both the Canadian federal government and the British Columbia provincial government ("B.C.") have been involved in management activities (Osborne, 1999).

Prior to 1970 no laws were in place to control or regulate captures or other interactions. Reports of deaths during capture of killer whales in the 1960's prompted widespread public pressure for the implementation of protective legislation. Such legislation was first introduced in 1970. Prior to 1982, the B.C. provincial government's Wildlife Branch considered killer whales "wildlife," and possession permits could be issued for holding these animals in captivity. In 1982 the provincial Wildlife Branch re-wrote the "Wildlife Act" and deleted killer whales from the list of wildlife, in response to a federal move to include all cetaceans under the "Cetacean Protection Regulations" (under the Fisheries Act of Canada of 1867). These regulations prohibited "hunting" without a license. "Hunting" was defined as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner." No scheme, however, was in place to enforce such regulations, and aboriginal hunting could be undertaken without a license.

In 1993, the federal government consolidated various marine mammal regulations, including the Cetacean Protection Regulations, under the new "Marine Mammal Regulations." These regulations stated that "no person should disturb a marine mammal except when under...the authorities of these regulations," with "marine mammal" defined as all species listed under a particular appendix. However, many species of cetaceans, including killer whales, were not listed under that appendix, and thus no legal protection was afforded killer whales. The definition of "marine mammal" was revoked in 1994, thus extending coverage to all species of marine mammals (Osborne, 1999; Heimlich-Boran, 1988).

The Committee on the Status of Endangered Wildlife in Canada recently listed the Southern Resident killer whale as "threatened." Although this is a positive first step in the preservation of the population, without additional protections in the U.S. the protective status in Canada will not provide meaningful conservation for the population. Thus, listing under section 4 of the ESA is necessary and appropriate.

3. Southern Resident Killer Whales Comprise a "Stock" Under the MMPA

The Southern Residents are classified as a "stock" under the Marine Mammal Protection Act ("MMPA"). While the analysis of whether a given marine mammal population is a separate "stock" differs somewhat from that of the NMFS/USFWS listing policy, the finding that a population is a separate stock greatly supports a finding that the population is a listable entity under the ESA. NMFS follows the phylogeographic approach of Dizon et al. (1992) in classifying stocks. This approach involves a four-part analysis of (1) distributional data, (2) population response data, (3) phenotypic data, and (4) genotypic data. In the risk-averse approach, negative evidence (evidence for a lack of difference) is used to coalesce smaller units into larger ones. As a result, an appreciation of the relative statistical power of the data being evaluated is required. A demonstration of sufficient statistical power is required before a recommendation of larger stock units is accepted (Barlow, 1995).

The Southern Residents satisfy all of the stock criteria. First, the distributional data shows that Southern Residents utilize distinctly separate summer and winter areas from those of other populations. The population satisfies the second criterion also, as the documented decline of the Southern Residents is occurring independently from that of any other killer whale population for which information is available. The third criterion is satisfied by the observed differences in morphology, and the fourth criterion is met by the distinctiveness in mitochondrial DNA observed. It would be inappropriate to classify the Southern Residents with Offshores, Transients, or other Resident populations without additional statistical evidence that indicates a larger population should be considered for designation as a distinct population segment.

B. SIGNIFICANCE

According to the listing policy, once a population is established as discrete, its biological and ecological significance should then be considered. This consideration may include, but is not limited to, the following:

1. Persistence of the discrete population segment in an ecological setting unusual or unique to this taxon.

2. Evidence that loss of the discrete population would result in a significant gap in the range of a taxon.

3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range.

4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

61 Fed. Reg. 4722. The Southern Resident killer whale meets three of the "significance" criteria, as well as other criteria that highlight the significance of the population.

1. The Southern Resident Killer Whale Occupies a Unique Ecological Setting

As noted above, the Southern Resident killer whale is a discrete population. It also occupies a unique ecological setting. The population has the most urbanized habitat of any killer whale population in the world, centered on the Puget Sound and Strait of Juan de Fuca in Washington State.

The J pod of the Southern Resident killer whale is the only population of killer whales to spend the winter within the waters of the Puget Sound on a semi-regular basis. The regular use of this setting as a winter habitat is unique to the Southern Residents. All other killer whale populations are known to generally migrate out to sea during the winter, although the exact locations of their winter habitats is currently not known. The year-round site fidelity of the J-pod is a unique ecological characteristic, maintaining a seasonal range distinct from other populations of killer whales.

In addition, the Southern Residents are the only Resident killer whale to occupy the majority of this habitat. Although Transients are sympatric, they play a separate role in the ecosystem in this area, and thus the Southern Residents are the only members of *O. orca* to occupy this unique ecological setting.

2. Loss of the Southern Residents Will Result in a Gap in the Species' Range

A loss of the Southern Residents would create a significant gap in the range of the taxon, as it would eliminate the only Resident killer whales known to persist in this environment. This is particularly true because of the J pod's tendency to winter in Puget Sound: if the Southern Residents were to go extinct, the loss of the J pod would create a distinct gap in the winter range of the killer whale. There is no evidence to show that migration from other killer whale populations into the Southern Residents' range would be successful. Even if such migration were possible, because killer whales are long-lived, highly cultured species, and because their ranges are partially based on discrete and significant cultural differences, it is possible that Offshore or Northern Residents might not attempt to occupy this habitat for many generations.

3. Southern Residents Differ Markedly from Other Killer Whales

As noted above, the Southern Residents differ markedly from other populations of killer whales, in behavior, morphology, ecology, and range. Although the Transient form is completely sympatric with the Residents, genetic evidence suggests they do not interbreed (Bigg et al., 1987; Hoelzel et al., 1998). Behavioral evidence suggests that Offshores and Transients avoid the Resident pods, and interactions between Residents and Transients or Offshores are rare (Jacobsen, 1990; Morton, 1990; Barrett-Lennard 1992; Baird & Dill, 1995). Distinct feeding habits exist, with Transient killer whales primarily preying on other marine mammals, and Southern Residents primarily subsisting on fishes (Morton, 1999). This places the Transient and Resident whales at different trophic levels. Other documented differences between Transients and Residents include measurable differences in morphology, behavioral differences in group size and social organization, and acoustic repertoire (Ford and Ellis, 1999; Bain, 1989; Baird, 1994). See Table 2. Offshores and Residents have been noted to have distinct dorsal fin shapes (Ford & Ellis, 2000).

Furthermore, Southern Residents have association patterns, pigmentation patterns, and genetic compositions that are distinct from the Northern Residents (Bigg et al., 1987; Baird & Stacey, 1988; Bain 1989; Ford et al., 1998; Hoelzel et al., 1998; Matkin et al., 1988). Behavioral interactions have not been observed between individuals from the different Resident populations, and differences in mitochondrial DNA and physical appearance suggest that the communities are reproductively isolated (Baird and Stacey, 1988; Stevens et al., 1989; Hoelzel & Dover, 1991). The Northern and Southern Residents appear to have distinct behavioral characteristics, but due to limited data on Offshores it is unclear if Offshores also have distinctive behavior (Osborne, 1986; Hoyt, 1990; Felleman et al., 1991).

Genetic differences between the populations are pronounced, and have been reported recently by Hoelzel et al. (1998). The Northern and Southern Residents have different haplotypes, with a fixed one base pair difference between the two populations. Although this difference is not as great as the difference noted between Transients and Residents, this difference is significant because it is manifested in notable differences in the morphology of the Southern Residents. The Southern Residents are known to have a statistically significant difference in saddle patterns and pigmentation than the Northern Residents (Baird & Stacey, 1988). These differences are indicia of genetic differentiation between the two populations. This genetic difference may have other undetected differences that could be important for the survival of the species. For example, the Southern Residents may contain genetic information that makes them more resistant to particular parasites, diseases, or even chemical pollutants. In the event of a catastrophic event striking the species, the Southern Residents' genetic specialization could act as a reservoir of resistance to the catastrophe and thereby insure the continued existence of the species.

Southern Residents also are markedly distinct from the Offshore form (Barrett-Lennard, 2000). The Offshores were not found to be closely related to either the residents or the transients.

4. The Southern Residents are Culturally Significant in the Pacific Northwest

A loss of the Southern Residents would create a significant gap in the range of the taxon, as it would eliminate a significant portion of killer whales in the most accessible viewing location in the United States.

This area has been an important area for human interaction with killer whales for thousands of years: it is believed that the Southern Residents in this area are the direct descendants of the first killer whales noted in the human record, and human interactions continue to this day with an active whale watching industry.

The effects of a range gap in Puget Sound would not only be a blow to the species, but would also impact the culture and identity of people in the Pacific Northwest. The earliest known interactions between humans and killer whales are believed to have occurred with the ancestors of the current Southern Residents in the Puget Sound area. Ever since, Pacific Northwesterners have considered killer whales an important component of their bio-geographic identity. The Southern Residents in particular have become a cultural landmark with people throughout the range of the 3 pods. Their loss would be a significant blow to the economy and spirit of the Pacific Northwest.

5. Southern Resident Killer Whales Comprise a "Stock" Under the MMPA

As noted above, the Southern Residents are currently considered a stock under the MMPA. Although the definition of "stock" under the MMPA is slightly different from the definition of "DPS" under the ESA, the classification of the Southern Residents as a stock indicates that NMFS already believes that the Southern Residents are significant for the purposes of management. In defining a management unit appropriate under the MMPA, NMFS is trying to avoid the local extirpation of any species, as well as conserve ecosystem functionality. NMFS has already designated the Southern Residents as an appropriate management unit for this purpose: in the 2000 Stock Assessment for Southern Residents, NMFS states that the Southern Residents are considered to be a distinct stock based on data regarding association patterns, acoustics, movements, genetic differences, and potential fishery interactions (NMFS, 2000). This indicates that NMFS believes that the loss of the Southern Residents would lead to the local extirpation of Resident killer whales in at least some portion of the Southern Residents' current range. Because local extirpation may result in a gap in the range of Resident *O. orca* for at least some period of time, this indicates that the Southern Residents are already thought to be significant to the taxon as a whole.

IV. ECOLOGY AND BIOLOGY OF THE SOUTHERN RESIDENT KILLER WHALE

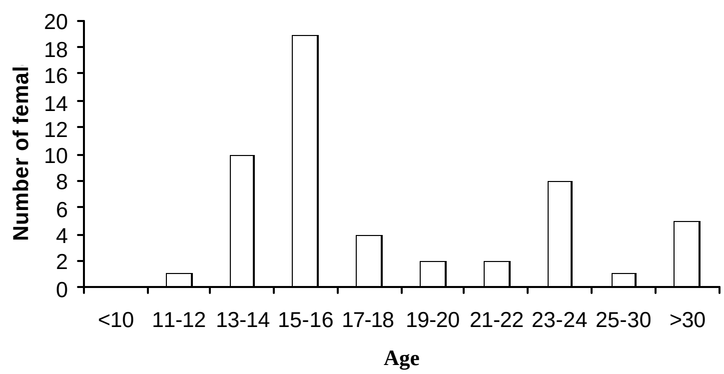
A. LIFE HISTORY

Killer whales have a life history pattern that is remarkably similar to humans. The life cycle begins with a gestation period of approximately 17 months (Walker et al., 1988). The first year of infancy is marked by a mortality rate of up to 50% (Olesiuk et al., 1990). Annual calf mortality averaged 11.5% for the period 1974-2000. If the calf survives the first year, it faces much lower annual mortality rates, averaging 2.4% for the period 1974-2000. Nursing occurs throughout the first and second year of rearing, although there is evidence that calves will also eat some solid foods shortly after birth (Heyning, 1988). A juvenile period of up to 10 years follows, extending into an adolescent period of 3-5 years (Olesiuk et al., 1990).

Sexual maturity for males is defined as the time the male's dorsal fin can be distinguished from a female's dorsal fin (Baird & Stacey, 1988; Bigg et al., 1987). This occurs between 11 and 17 years of age, with an average of 15 years of age. Female sexual maturity is defined as the time when the female first gives birth to a viable calf. This generally occurs between the ages of 12 and 16 years, with an average of 15. On average females remain reproductive until around 40 years of age. Calving intervals average around 5 years, indicating that an average female killer whale will produce between four and five calves during her lifetime (Olesiuk et al., 1990).

The age of sexual maturity of females in the Southern Residents differs slightly from the general averages noted by Olesiuk et al. (1990); females may mature slightly earlier on average than the averages noted by Olesiuk et al.

Figure 3. Age distribution of first reproduction for female Southern Residents.



The age of reproductive senescence was found to differ from the averages described by Olesiuk et al. The average age of last reproduction for all Southern Resident females that have died is 33.2, with a standard deviation of 8.5. There are some difficulties in calculating senescence from the survey data that could lead to an inaccurate calculation of this life history statistic. In order to minimize error, only dead whales were used to determine senescence, because not all live whales have entered senescence and therefore would bias the results. However, looking at only dead whales may underestimate age of reproductive senescence because some females may have died before reaching senescence. The maximum-recorded age of a mother giving birth was 45, and the penultimate recorded age was 42. These are necessarily estimates of age however, as birth years were not known from direct observation. Direct observation by census has only proceeded in systematic fashion since 1974.

Killer whales are considered polygamous. Females come into estrus or "heat" several times during the year. Observations of females in zoological parks indicate that killer whales undergo periods of multiple estrus cycling, interspersed with periods of non-cycling. This period is highly variable, as is the period of non-cycling, both for one whale over time, and between whales. Breeding may occur in any season, but it is most common in the summer.

Average life expectancy for Residents has been calculated at approximately 29 years for males and 50 years for females, with an expected maximum longevity of 50-60 years for males, and 80-90 for females (Olesiuk et al., 1990). The Southern Resident data show that the average age at female death was 50, and maximum 68. The average age at death for males was 27.6, with a maximum of 43.

Causes of natural mortality are difficult to determine because killer whale carcasses tend to sink. There are no records of killer whales being attacked by any other predators, although predation on infants and/or sick individuals cannot be ruled out. Parasitism and disease have been recorded for killer whales from the region, but no severe infestations or epidemics have been recorded (Calambokidis & Baird, 1994; Baird, 1999).

Human induced mortality has been a significant factor in the Southern Residents. Humans have killed or removed Southern Residents through random shooting, live captures, and military target practice (Hoyt, 1990; Olesiuk et al., 1990; Osborne, 1999). In addition, indirect human impacts from pollution and habitat deterioration are also a factor in current killer whale mortality. These factors will be explored more fully below.

B. Spatial Requirements

The geographic distribution of Southern Residents appears to be year-round in the adjoining waters of Puget Sound, Georgia Strait, Juan de Fuca Strait, and the outer coastal waters of the continental shelf. However, within these waters, the Southern Residents appear to make seasonal movements. In the summer months, the majority of the population is distributed in the northern Juan de Fuca Strait, Haro Strait, and southern Georgia Strait. The area is considered to be the core habitat of the Southern Residents. In the fall, the J-pod tends to migrate into Puget Sound, while the rest of the population makes increasingly extended trips through the Juan de Fuca Strait. In the winter, the K and L pods retreat from inland waters, and are seldom detected in the core areas until late spring. The J pod generally remains in the inland areas throughout the winter, with most of their activity in the Puget Sound.

Southern Residents make full use of the water column, including regular access to the ocean surface to breathe and rest. (Bateson, 1974; Herman, 1991). They remain underwater 95% of the time, with 60-70% of their time spent between the surface and a depth of 20 meters, while diving regularly to depths of over 200 meters (Baird, 1994; Baird et al., 1998). The Southern Residents spend less than 5% of their time between depths of 60 and 250 meters.

C. Food Requirements

The Southern Residents have specialized to consume salmon as their primary food (Balcomb et al., 1980; Bigg et al., 1987). Ford et al. (1998) estimated that chinook salmon (*Oncorhynchus tshawytscha*) comprise 38% of the diet of the average Southern Resident, pink salmon (*O. gorbuscha*) comprise 10%, coho (*O. kisutch*) and chum (*O. keta*) salmon comprise 4% each, Sockeye salmon (*O. nerka*) comprise 3.5%, Steelhead (*O. mykiss*) represent 2.5%, with an additional 31% of their diet comprised of unidentifiable salmon species (Osborne, 1999).

Southern Residents have been reported anecdotally to exhibit predatory behavior on pups or calves of common seal and porpoise species, but these reports have not been verified. Other fish species comprise a significant but small portion of the Southern Residents' diet, as indicated by the amount of time Southern Residents spend at great depths in the ocean, presumably hunting non-salmon fish species (Ford et al., 1998).

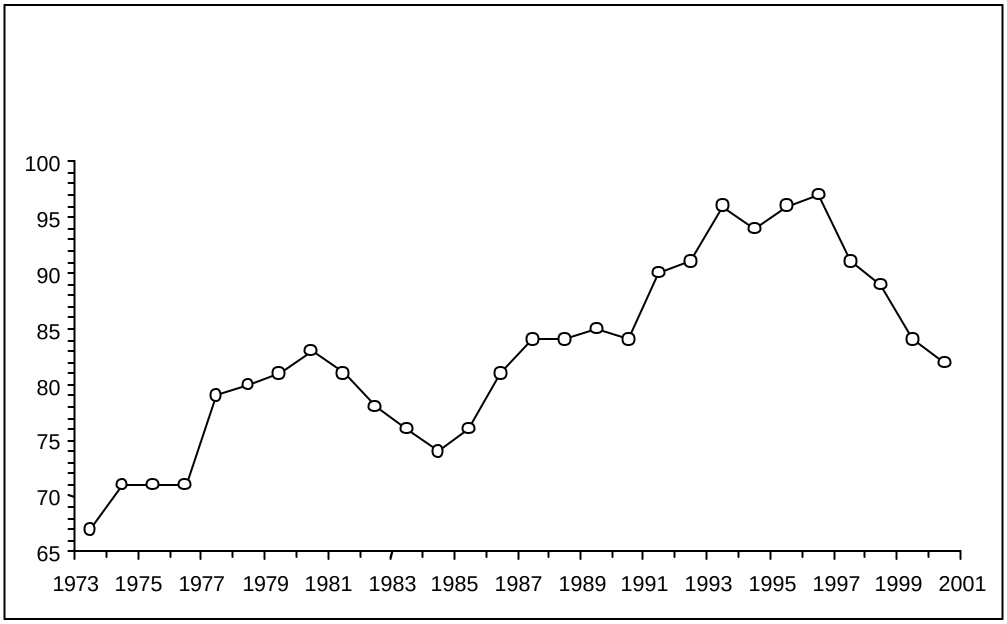
Kriete (1995) estimated killer whale energetic requirements using both wild and captive animals as subjects. In general, immature killer whales require 85,000 kcal per day, juveniles 100,000 kcal per day, adult females 160,000 kcal per day, and adult males require 200,000 kcal per day. On average, this requires each whale to consume 25 salmon per day in order to maintain energetic requirements (Osborne, 1999). Averaged out over all the Southern Residents, the whale population would require 800,000 salmon annually just to maintain current numbers and metabolic rates (Osborne, 1999).

V. ABUNDANCE AND POPULATION TRENDS

There are no worldwide population estimates available for killer whales. However, reliable population estimates for Southern Residents exist. A census of the Southern Residents has been taken annually since 1974. Records from capture operations extend the record back to 1960, supplementing the census information. Population levels before 1960 are not known with any accuracy, but are presumed to be greater than even the highest levels seen in the past 40 years.

The Southern Residents numbered over 100 individuals in the mid-1960s. Since that time, three major declines have occurred in the population. The first decline occurred between 1967 and 1973, and was caused by live-capture operations for public display. Approximately 34 whales were taken during this period, leading to a decline of at least 30% in the Southern Residents. The second decline occurred between 1980 and 1984, when the population declined by 12%. Both of these declines were followed by periods of limited population growth. The third recorded decline began in 1996 and continues today. During this time, the Southern Residents have declined from 97 adults and juveniles at the beginning of 1996 to 82 at the beginning of 2000, a 12.8% decline.

Figure 4. Total population of the Southern Resident Killer Whale (1974-2001).[2]



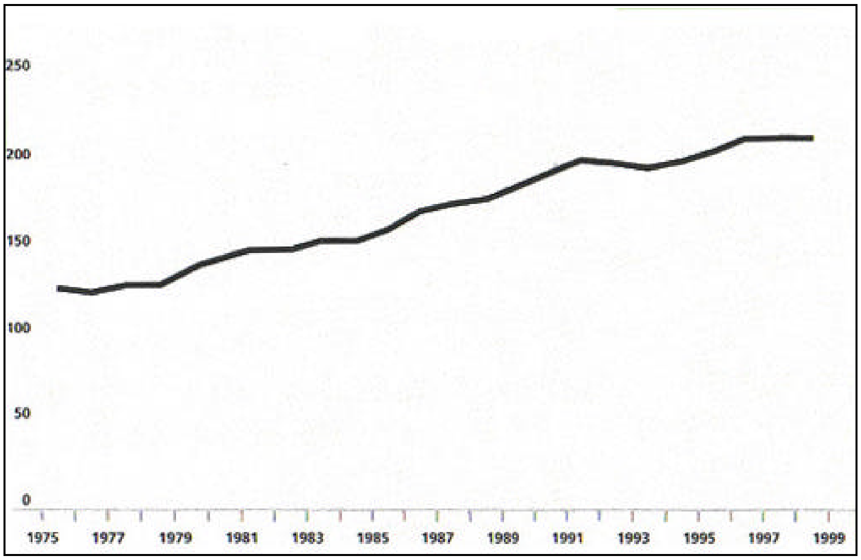
Several attributes of the current decline make it unique and alarming. First, the decline is driven by inexplicable increase in mortality of young adults and juveniles, without substantial reduction of calving. See Appendix A. Second, the concentration of organochlorine pollutants in Southern Resident individuals has recently been determined to be greater than levels found in other marine mammals where deleterious effects have been documented (Ross et al., 2000). Third, the Southern Residents' main food source is known to be declining. Fourth, disturbances caused by whale watching and vessel traffic have increased dramatically, potentially disrupting killer whale behavior.

A. COMPARISON TO OTHER WHALE POPULATIONS

The Southern Residents' current decline is particularly worrisome when compared to the relatively stable population growth rates seen for Northern Residents, the Southern Residents' most comparable population. During the same period that the Southern Residents have gone through these major population fluctuations, the Northern Residents have shown a relatively steady increase in numbers, showing no major population variation. (Olesiuk et al., 1990).

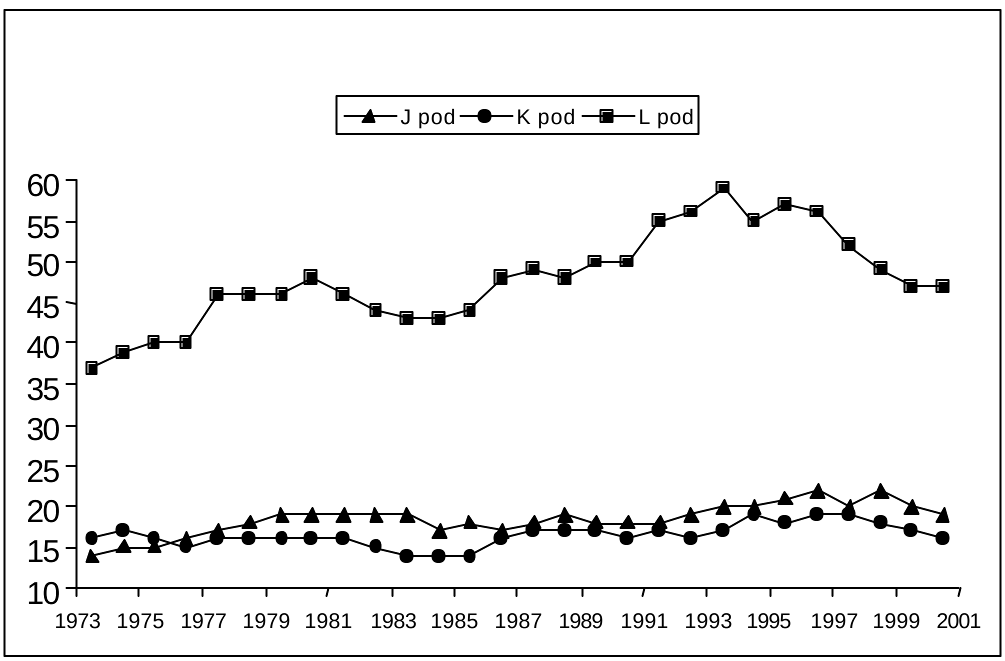
[2] final new calf numbers for 2001 are not yet known.

Figure 5. Northern Residents have increased in population while the Southern Residents have shown population instability. Graph based on Ford et al. (2000).



Furthermore, the population instability has been disproportionately found in the L pod, while the J and K pods have remained relatively stable.

Figure 6. Population of J, K, and L pod over time.



This indicates that the Southern Residents' population instability is not natural population cycles, but rather an unstable trend toward extinction caused by changing environmental conditions. Earlier declines can be directly attributable to particular anthropogenic factors that reduced fecundity, while the current decline has been caused by an increase in mortality. The decline beginning in 1981 was caused by a reduction in fecundity caused by the delayed demographic effects of the live captures of the early 1970s. The live captures created a fertility gap in the population, reducing the number of fertile individuals capable of replacing older whales as they reached senescence. The current decline is caused by increases in mortality in what was heretofore thought to have been the age and sex grouping with the lowest mortality rates.

In order to identify possible causes of the decline as well as determine the probability of long-term survival of this population, we analyzed life history data for the Southern Resident Killer Whale collected by the Center for Whale Research and the Whale Museum. The results of this study are attached to this petition as Appendix A, and are summarized in this section.

B. POPULATION VIABILITY ANALYSIS FOR THE SOUTHERN RESIDENTS

The Vortex v. 8.41 algorithm (Lacey et al., 2000) was used to estimate the extinction risk for the Southern Residents. This algorithm is more detailed and precise than crude estimates of extinction that have been published in recent years, such as Caswell et al. (2000).

As with all predictive models, Vortex uses simplifying assumptions to make future predictions. These assumptions were set conservatively to insure that the extinction probability was not exaggerated by the PVA. The strengths and limitations of the assumptions in the PVA are discussed in Appendix A.

Several models were run using the Vortex algorithm in order to isolate the effects of specific factors and to create the most accurate extinction rate estimate. The most plausible model accounted for several factors that are believed to be effecting the survival of the population, including a skewed sex ratio, inbreeding, the possibility of catastrophe, and reduced fecundity at low population levels.[3] The most plausible model relied on calculated life history parameters of fecundity and mortality over the period 1974-2000.

The results of this model without the possibility of catastrophe indicate that the Southern Residents have a 64% probability of extinction within the next 300 years, the standard time frame for calculating species viability. The median time to extinction for the distribution of 200 iterations of this model was 269.

When the possibility of a moderate catastrophe occurring in the range of the Southern Residents once every century was incorporated, the extinction rates was higher. The Exxon Valdez oil spill in Alaska was followed by the death of about one third of all members of one Northern Resident Killer Whale pod (Matkin and Saulitis, 1997). To model the effect of such a catastrophe on Southern Residents, a one-year stoppage of all reproduction and death of 11% of all Southern Residents was incorporated with a chance of one such event per one hundred years. These parameters are consistent with what occurred in the AB Northern Resident pod after the Exxon Valdez oil spill. This further reduced predicted median extinction time to 232 years, increasing extinction probability to 79.5%.

[3] This fecundity phenomenon is known as an Allee affect; as population size decreases, it becomes more difficult for individuals to find suitable mates, and therefore fecundity declines.

C. STATUS OF SOUTHERN RESIDENT MATRILINEAL LINES

1. Pod Sex and Class Structure

The Southern Resident killer whales are grouped into three familial pods (J, K, and L). Females in one pod generally mate only with males from the other two pods, although ome level of endogamy is possible in the population. This population structure reduces the potential for inbreeding depression, but it also limits breeding opportunities: if there are too few breeding age males in two pods, the females in the third pod may have limited opportunities to breed. The balance of males and females between pods may be an important conservation issue because it affects the growth potential (i.e. breeding opportunities) of the population as a whole. Analysis of the sex and age class structure is a necessary augment to the PVA because the PVA necessarily, but inaccurately, assumes that any reproductive female can mate with any reproductive male. The PVA, therefore, overestimates the growth potential of the population and underestimates the likelihood of decline and extinction.

Optimistically assuming that males begin breeding at age 11 (the actual number may be as high as 17), there are half as many breeding age males as females in the Southern Residents See Table 3. Females in the smaller J and K pods are not likely to be limited by this imbalance because there are more reproductive males in the much larger L pod than females in either J or K pod. The 13 reproductive age females in L pod, however, have only two potential breeding partners in K pod and none in J pod. If the actual reproductive age of males is 15, then L pod females currently have no potential breeding partners. The PVA showed no statistical evidence of the breeding rate being male limited over the period 1974-2000. It also found no evidence of successful, within-year polygamous mating. An exogamous/polygamous mating strategy would be male limited if no breeding age males were available, and would probably be male limited if the ratio of reproductive females to available reproductive male was very high, but the point at which the limitation would occur is not known. An exogamous/monogamous mating strategy would suffer male limitation at lower levels of sex ratio imbalance.

Table 3. Size and reproductive age class structure of J, K, and L pods as of July 2000.

Pod	# of whales	# reproductive males (11-42 years old)	# reproductive females (13-42 years old)	Breeding opportunities per female
J	19	0	6	2.2
K	16	2	6	1.8
L	47	11	13	0.2
TOTAL	82	13	25	

2. Matriline Sex and Class Structure

Each of the pods is made of up of several matrilines, matriarchal family trees consisting of a female and all generations which descend from her. Orcas are grouped this way because offspring tend to remain with their mothers throughout their lives.

J Pod has had four known matrilines since the 1970's, K Pod five, and L Pod 12. See Table 4. Based on the current demographic structure only (i.e. ignoring environmental affects to fecundity and mortality) it is possible to project the future status of some of the matrilines. Two of the matrilines are extinct. Two will become extinct because of lack of breeding females. Two have high likelihood of extinction and eight are likely to decline because of an age and gender class structure which will likely result in deaths outnumbering births in the future. Four are likely to be stable or to increase, and three are of unknown status.

Table 4. Extinction probabilities for Southern Resident matrilines.

Pod	Matrilines	Extinct	Extinction Inevitable	Extinction Likely	Decline Likely	Stable or Likely to Increase	Unknown
J	4				2: J-A J-C	2: J-B J-D	
K	5	1: K-B		1: K-D	1: K-C	2: K-A K-E	
L	12	1: L-D	2: L-C L-G	1: L-K	5: L-A L-B L-E L-F L-J		3: L-H L-I L-L

VI. THE SOUTHERN RESIDENT KILLER WHALE QUALIFY AS ENDANGERED UNDER THE ESA

NMFS is required to determine, based solely on the basis of the best scientific and commercial data available, whether a species is endangered or threatened because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. 16 U.S.C. §1533(a)(1) and 1533(b).

At least four of these factors apply to the decline of the Southern Residents.

A. MODIFICATION OF SOUTHERN RESIDENT HABITAT

1. Cherry Point Developments

The area stretching from Point Whitehorn to Sandy Point, referred to as Cherry Point, is an ecologically critical area that supports what has been the largest and most important herring stock in Washington State. Pacific herring are a vital food source of Chinook salmon, the Southern Residents preferred prey, and it is believed that they are also directly eaten by the Southern Residents. The Cherry Point reach provides spawning and pre-spawning holding habitat for the Cherry Point herring stocks. This stock has a unique ecological role in the system because it spawns through June, which is months later than other herring stocks.

ARCO Products Company owns and operates a petroleum oil refinery on the banks of Puget Sound at Cherry Point.[4] ARCO's pier currently has only one platform, which serves to accept crude from inbound tankers and to also load refined products onto outbound tankers and barges. ARCO's pier is located in an ecologically critical area referred to as "Cherry Point" (Point Whitehorn to Sandy Point), which is a shoreline of statewide significance. A relatively high-energy exposed intertidal zone characterizes this area, as this shoreline is subject to strong wave energy. The intertidal zone supports a wide variety of biological habitats.

In 1996 the United States Army Corps of Engineers ("Army Corps") approved a request by ARCO to further expand its operations in Puget Sound by adding a second pier, and an extension of the permit was granted in 2000. The expansion of the pier to two platforms will result in an increase in tanker traffic, and an increase in the potential for oil spills in Puget Sound. The dock expansion will have potential significant adverse environmental impacts on Pacific herring and Puget Sound chinook. The proposed ARCO dock expansion is related to other actions that will cumulatively degrade the habitat of the Southern Residents. Other proposals to construct dock facilities at Cherry Point, in particular the Pacific International Terminals bulk cargo pier one mile south of the ARCO facility, raise similar issues involving the impacts of pier operations on Southern Resident habitat.

2. Development of Salmon Habitats

Habitat degradation is the major cause for the decline in chinook salmon stocks. Dams in historical spawning habitat are a major factor in decline or extinction of chinook salmon stocks. Of the stock extinctions in the coast wide region, 76% were dam related (Myers et al., 1998). Forty-eight of the spring- and summer-run stocks found to be in decline were affected by dams.

Logging and agricultural land use/water diversion (including diking) are also major factors in the destruction of chinook habitat. The Nooksack Technical Group (1987) indicated that sedimentation from logging activities had seriously impacted the quality of the spawning habitats in both the North and South Forks of the Nooksack River. PRO-Salmon (1994) considered water diversion for agricultural use to be a major contributor to the decline of the Dungeness River spring run. Overall, it is estimated that logging was responsible, in part, for 60% of the declines and 6% of the extinctions among the stocks surveyed (Myers et al., 1998). Similarly, agriculture, water withdrawal, mining and urbanization factors were implicated in 58% of the declines and 9% of the extinctions among the 417 stocks surveyed.

The National Research Council Committee on Protection and Management of Pacific Northwest Anadromous Salmonids identified habitat problems as a primary cause of declines in wild salmon runs. Some of the habitat impacts identified were the fragmentation and loss of available spawning and rearing habitat, alteration of streamflows and stream bank and channel

[4] Because the British Petroleum (BP) Amoco Group recently purchased ARCO Products Company, the refinery and dock are now owned and operated by BP Amoco. While technically BP Amoco is the current owner and operator, this petition refers to ARCO Products Company because the permit was issued to ARCO and ARCO continues to exist as a wholly owned subsidiary of the BP Amoco Group.

morphology, migration delays, degradation of water quality, alteration of ambient stream water temperatures, sedimentation, loss of spawning gravel, pool habitat and large woody debris, removal of riparian vegetation, and decline of habitat complexity.

3. Reduction in Food Availability

Under natural conditions, several factors may combine to limit the growth of the Southern Residents. These factors may include disease, food resource depletion, and unpredictable catastrophic accidents. However, over the last 100 years anthropogenic effects have contributed to a reduction in the carrying capacity of this area by overexploiting salmon and other fishes and thereby reducing food availability for Southern Residents.

The reduction in carrying capacity becomes particularly acute when looked at from the seasonal scale. Although some summertime runs of salmon may be relatively abundant in some years, the fall, winter, and spring runs of salmon are at historically low levels. Thus, the salmon available to killer whales are not distributed evenly throughout their feeding periods; in turn leading to salmon deprivation during some months even when salmon resources are abundant in other months.

The elimination of salmon in the Southern Residents' habitat to the point where the killer whales were unable to subsist on the salmon was unthinkable a few years ago. However, direct human exploitation of salmon resources through over-fishing, introduced hatchery salmon, and the destruction of salmon habitat has now managed to diminish these salmon resources to the point that some stocks are considered threatened under the ESA. As a result, the Southern Residents' main food source is threatened with extinction.

The human activities that have caused the salmon decline include commercial and sport fishing, interference with pelagic food webs through over-fishing and climate change, habitat destruction of upland streams through development, grazing, dams, the alteration of fresh water flow rates, temperatures, and silting by forest harvesting, and the elimination of estuaries through coastal development.

Salmon have historically been the primary food source of Southern Residents, but as seasonal salmon depletion increases the Southern Residents may be increasing consumption of ground fish. While the ability of the population to adapt to new food sources is promising, because ground fish carry higher toxic loads than salmon, the Southern Residents may be compounding toxic chemical exposure (Calambokidis and Baird, 1994). The decline of this food source also increases the release of toxins stored in lipids as Southern Residents use more of their fat reserves for nourishment.

The protection and restoration of salmon in the Pacific Northwest has been receiving extensive attention lately from both federal and state governments. Serious efforts are underway to stop further salmon habitat destruction, and to begin rebuilding the seasonal stocks that killer whales have depended upon for feeding. In setting recovery goals and allowable take, the consumption of fishes by killer whales must be included in any estimate of allowable take of these species by people in the Pacific Northwest. These efforts will be crucial in the ultimate survival of the Southern Residents.

4. Other Habitat Changes

Many other factors are contributing to the decline of suitable habitat for Southern Residents in and around Puget Sound. Dredging activities, shoreline development, increased vessel traffic, increasing pollution, factory trawling, excavation of the sea floor, and global climate change are all having impacts on the Southern Residents' habitat. These changes may ultimately affect the survivability of the Southern Residents.

B. Overutilization for Recreational and Commercial Purposes

1. Capture and Removal of Southern Residents for the Live Capture Industry

The Southern Residents lost a large portion of its population in the 1960's when killer whales were captured for public display. Thirty-four of the individuals removed from the Puget Sound area are believed to have come from the Southern Residents, and an additional 12 individuals killed during capture attempts are believed to have been Southern Residents (Olesiuk et al., 1990; Howard Garrett, pers. Comm.). This resulted in a change in the age structure of the population, as a large proportion of calves produced in the 1960s were removed. Of the calves born from 1959-1970, 34 were taken for public display, while only 11 survived to be censused in 1974. Furthermore, 23 of the 34 known-sex individuals were male, causing the sex ratio of the population to be skewed.

A changing age and sex structure of the Southern Residents has been implicated in the current decline. Delayed effects such as a possible gap in reproductive age females and an insufficient number of males available to breed, may be contributing to the current decline. Additional study is required to determine the current effects of the capture era.

2. Whale Watching Disturbance

In recent years, whale watching has increased dramatically in Washington State and British Columbia, and may affect the survivability of the species. A variety of concerns have been raised about the potential of whale watching to harm killer whales (Kruse, 1991; Osborne, 1991; Duffus and Dearden 1993; Phillips and Baird 1993; Williams et al., 1998). Numerous behavioral changes have been reported in response to close approaches by boats, although some of the studies undertaken have serious methodological problems, causing researchers to question their validity (Duffus and Dearden, 1993).

Studies have focused both on Northern Residents in Johnstone Strait and Southern Residents in Haro Strait. A number of differences between these sites, such as the populations of whales that use them, the number and types of boats found in the two areas, and the research methodologies being used at each site, preclude any simple comparison of results from the two areas. Changes in behavior in response to approaches by boats have been demonstrated for Northern Residents (Trites et al., 1996). The implications of such changes in behavior on reproduction or mortality are unclear. While similar behavioral changes have not yet been demonstrated for Southern Residents, there does appear to have been a substantial decrease in the proportion of time Southern Residents engage in resting behavior during daylight hours, coincident with the large increase in whale watching activity (Osborne, 1986). Furthermore, the noise level of boats circling killer whales is already considered to be very close to the critical level assumed to cause permanent hearing loss over prolonged exposure (Erbe, 2000).

However, at least in some areas and at some times of the year, such impacts could be important. In the last few years, it is not uncommon for killer whales to be accompanied by 10-20 boats when traveling during summer months, and such large numbers of boats seem more likely to impact foraging success. In one area in Washington State, the number of vessels found around groups of Southern Resident killer whales has been increasing, and in 1997 groups were accompanied by an average of 25 vessels (only one-quarter of which are commercial whale watching vessels) during daylight hours in the summer months (Baird et al., 1998). Of particular concern is the number of unlicensed, non-commercial whale watching boats, which comprise most of the growth in whale watching vessels. Levels of awareness of, and adherence to, whale watching guidelines are largely unknown (except in a few specific localities during summer months), and virtually no official monitoring or enforcement of whale watching guidelines takes place.

A more direct impact of boats on whales involves injuries or deaths from collisions. Considering the large number of vessels interacting with killer whales during the summer months in British Columbia, vessel collisions are extremely rare. One well-documented case in British Columbia has been reported (Anonymous, 1974), with an animal apparently fatally wounded after a collision with a large vessel. Ford et al. (1994) note that the animal struck may have been part of the Northern Resident population. Several other live animals have been seen with scars that might be attributable to vessel interactions, although the evidence for this is circumstantial. One vessel collision with a Southern Resident killer whale in Haro Strait, Washington, was witnessed in 1998, but the vessel was moving slowly and the animal did not appear to be injured as a result of the collision. A Northern Resident was struck by a speedboat in 1995 and received a wound to the dorsal fin.

Figure 7. Trends in the average number of whale watching boats observing Southern Residents at Lime Kiln lighthouse.

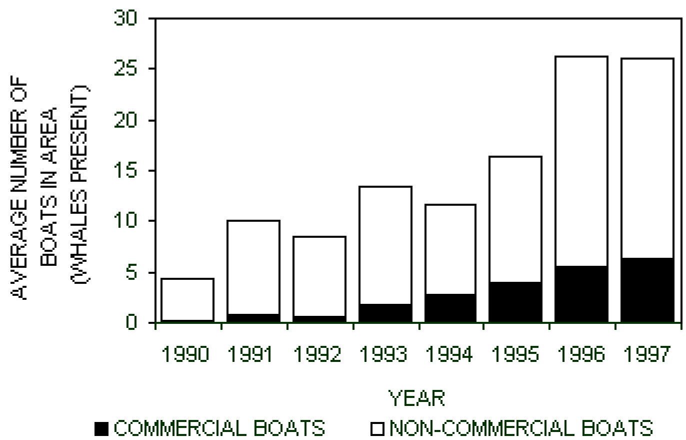


Figure from Baird, 1999.

C. DISEASE OR PREDATION

1. Disease

A variety of endoparasites have been recorded in killer whales, including trematodes, cestodes, and nematodes (see review in Heyning and Dahlheim, 1988). Transmission of such parasites is primarily through ingestion of infected food items, but the role and extent of such parasites in causing natural mortality is unknown. Killer whales have been seen with barnacles on the rostrum and trailing edge of flukes, and with a species of cyamid ectoparasite. The current understanding of the diseases and disease processes affecting killer whales is relatively advanced, as a result of the study of animals in aquaria. Relatively little of this research has been published however.

Mortality due to biotoxins has not been reported for killer whales, though a number of large-scale mortality events in other cetaceans have been linked to this source (e.g., Geraci et al., 1999). Large-scale mortality events due to viral infections have been recorded in several populations of marine mammals in recent years, and while the occurrence of such die-offs is unpredictable, given their magnitude and apparently increasing frequency of occurrence, they should be taken into account in conservation planning and population viability analysis.

2. Natural Predation

No natural predators of killer whales have been recorded, but young or sick whales are potentially at risk from attacks by large sharks in some areas, and attacks by other killer whales may also pose a risk. However, the overall effect of predation on the population is insignificant.

3. Human Predation

Killer whales have been historically hunted for meat and other products in many areas, although all the major fisheries have been discontinued. However, small numbers of killer whales may still be being taken in some areas. There has not been a recorded harvest of killer whales from the Southern Residents in many years, and human predation is an insignificant factor in the current decline of the population.

Killing of killer whales by fishermen in response to losses of fish may have significant effects on the local population. However, there has not been any record of Southern Resident killer whales being killed by fishermen in recent years. Because of the extremely low potential growth rate of killer whale populations, even occasional shooting could limit population growth, and some monitoring of such activities is warranted.

D. INADEQUACY OF EXISTING REGULATORY MECHANISMS

There are currently no regulatory mechanisms that adequately address the problems facing the Southern Residents. There are no state, federal, or international laws or programs in place that are adequate to address the threats currently faced by this population.

1. State Law

Washington State currently provides no special protection to the Southern Residents under state law. The primary state agency in charge of protecting endangered species in Washington State is the Washington Department of Fish and Wildlife ("WDFW"). WDFW categorizes killer whales at the species level, failing to account for the distinct ecological, behavioral, morphological, and genetic differences between killer whale populations in the Pacific Northwest. As a consequence of this categorization scheme, WDFW does not recognize the current plight of the Southern Residents, and no state-level protective provisions are currently provided, other than general wildlife protection rules.

WDFW does consider the killer whale to be a "criterion two" priority species, and has listed it on the Department's Priority Habitat and Species list. A criterion two species includes those species or groups of animals susceptible to significant population declines, within a specific area or statewide, by virtue of their inclination to aggregate. However, this status provides no mandatory protection for the Southern Residents: it only serves to provide information to individuals about the status of the whale.

The Washington State Fish and Wildlife Code provides some level of protection for Killer Whales by prohibiting unlawful and unauthorized take of unclassified species. 77 RCW 15. However, because human induced mortality and/or live capture of Southern Residents is not a current threat to the population, these regulations do not address the most pressing threats facing the population. The state regulations are inadequate to prevent extinction of the Southern Residents.

Furthermore, federal law may preempt regulatory protections provided by Washington State. As a marine mammal, killer whales have specific federal regulatory mechanisms in place that may limit the ability of state regulation to apply to conservation efforts.

2. Federal Law

a. Marine Mammal Protection Act ("MMPA")

The Southern Residents are managed as a distinct stock under the MMPA. The stock is not currently recognized as either a "strategic" or "depleted" stock under the MMPA, because there has been no mortality directly caused by human fishing and/or hunting activities in recent years. Indeed, the Stock Assessment Report for this population allows for a Potential Biological Removal ("PBR") of .8 individual whales per year (NMFS, 2000).

Currently, the MMPA not only fails to protect the Southern Residents from further population declines, but also allows for the removal of a small but critical number of individuals from the population (NMFS, 2000). Because the population is already declining and is faced with numerous threats, the MMPA as currently administered is clearly inadequate to protect the Southern Residents.

Furthermore, even if the MMPA were to provide protective status to the Southern Residents, the protections available under this law are not adequate to effectuate a recovery of the population. The MMPA is not capable of addressing most of the major threats facing the Southern Residents, such as the imbalanced age structure of the population, the poisoning of Southern Resident habitats with organochlorines and other toxic chemicals, and the reduction in carrying capacity caused by reduced salmon runs throughout the Pacific Northwest. This indicates that the statute is inadequate to protect the Southern Residents from extinction.

b. Clean Water Act ("CWA")

Although the CWA's goal is to "restore and maintain the physical, chemical and biological integrity of the Nation's waters," the CWA has proven to be insufficient in protecting the Southern Residents from declining. The CWA has not adequately addressed the problems of bioaccumulation of toxic components in Southern Residents. Furthermore, the reduction of salmon populations in the Pacific Northwest can also be attributed to failures of the CWA: non-point source pollution, destruction of riparian habitat, and dams and water diversions have combined to reduce salmon populations, and are all inadequately addressed by the CWA. The CWA provides only indirect protection for the Southern Residents, and is not capable of being used to eliminate the most pressing threats currently facing the species in the absence of ESA protection.

3. Canadian Law

The Canadian Federal government has established Marine Mammal Regulations that protect all marine mammals. The regulations do allow for hunting of killer whales with the purchase of a fishing license at a nominal fee, but granting the license is at the discretion of the federal Minister of Fisheries and Oceans, and no such licenses have yet been granted. Whale watching guidelines have also been promulgated to limit interactions with shipping and whale-watching vessels.

In April of 1999 the Committee on the Status of Endangered Wildlife in Canada ("COSEWIC") listed Resident populations of killer whales as threatened, indicating that the Residents are likely to become endangered if nothing is done to reverse the threats facing the populations. However, COSEWIC currently has no legal mandate, and unless the proposed Species at Risk Act ("SARA") is passed, the listing will only serve an advisory role.

4. International Law

The Convention on International Trade in Endangered Species of Wild Fauna and Flora ("CITIES") lists killer whales as an Appendix II species, because commercial products made from killer whales may be indistinguishable from commercial products made from critically endangered whales. As such, international trade of killer whales or parts thereof by any countries that are parties to CITES requires export permits from the country of origin. However, other then requiring documentation of trade between countries, Appendix II listing provides no substantive protection for killer whales, and there are no special rules to protect subpopulations of the killer whale. Furthermore, threats from capture and trade are not pressing issues facing the Southern Residents. Thus, the CITIES regulations are not adequate to preserve this population.

Killer whales are considered "small cetaceans" by the International Whaling Commission ("IWC"), and there is currently considerable disagreement within the Commission as to whether small cetaceans are covered by the Convention. However, in 1980, in response to a large Russian take of killer whales in the Antarctic in the 1979/80 season, the IWC added a new sentence to Schedule paragraph 9(d), officially including killer whales in their moratorium on factory ship whaling (IWC, 1981). Other IWC management measures (e.g., the Southern Ocean Sanctuary, moratorium on commercial whaling, etc.) do not apply to killer whales.

E. OTHER FACTORS

1. Increased Levels of Toxic Chemicals

Southern Residents are contaminated with persistent organochlorines, including DDT and its metabolites, PCBs (polychlorinated biphenyls), dioxins (polychlorinated dibenzo-p-dioxins), and furans (polychlorinated dibenzofurans). Ross et al., (2000) and Jarman et al. (1996) provide the only documentation to date of the extent of organochlorine contamination in the Southern Residents, and are discussed below.

a. Contamination Levels of Southern Resident Killer Whales

Ross et al. (2000) analyzed blubber samples from Northern Residents (N = 26), Southern Residents (N = 6), and Transients (N=15). They analyzed these samples for PCB, dioxin, and furan congeners. In all three populations, total PCB concentrations were high relative to concentrations of PCBs in marine mammals measured elsewhere (Kamrin and Ringer, 1994; Eisler and Belisle, 1996). Southern Resident males were less contaminated than Transient males, but more contaminated than Northern Resident males. Southern Resident females were more contaminated than Northern Resident females, and had nearly the same level of contamination as the Transient females.

Table 5. Summary of PCB concentrations in killer whales recently sampled near the coast of British Columbia (Ross et al., 2000).

Mean total PCB concentrations mg/kg lipid weight (N)		Population
Males	Females	
146.3 ±32.7 (4)	55.4 ± 19.3 (2)	Southern Residents
37.4 ± 6.1 (8)	9.3 ± 2.8 (9)	Northern Residents
251.2 ± 54.7 (5)	58.8 ± 20.6 (5)	Transients

Lower concentrations of dioxins (1050 ? 258 ng/kg lipid weight) and furans (55 ? 6 ng/kg lipid weight) were observed in the Ross et al. (2000) study. There were no significant differences in dioxin and furan concentrations between the three populations. These results are consistent with observations of pinnipeds and cetaceans elsewhere (Jarman et al., 1996; Muir et al., 1996; Kannan et al., 1989). The relatively low levels of dioxins and furans may be the result of relatively low exposures, or an ability of these animals to metabolize and excrete certain dioxin congeners and structurally related compounds (Tanabe et al., 1988) including some of the PCB congeners. Of the dioxin-like organochlorine compounds known to contaminate Southern Resident killer whales, PCBs appear to constitute the overwhelming majority (Ross et al., 2000).

Jarman et al. (1996), the only other study in which whales from these populations were analyzed for persistent chemicals, corroborates the results in Ross et al. (2000). Jarman et al. (1996) examined the blubber of six killer whales found dead between 1986 and 1989, five of which were recovered within the range of the Southern Resident population, and reported that the geometric mean concentration of total PCBs in blubber of killer whales sampled was 24.2 mg/kg lipid weight.[5] Jarman et al. (1996) also reported concentrations of a wide range of organic pollutants. Notable concentrations of DDT and its metabolites were reported, with a geometric mean total DDT in blubber samples of 35.2 mg/kg DDT lipid weight.[6] Of the mean total DDT concentration, 87.5 percent was *pp'*-DDE, a toxic and persistent metabolite of DDT.

b. Notes On Interpreting Data

Because it is impossible to conduct controlled toxicological studies on killer whales, there are no direct assessments of DDT, PCB, dioxin, and furan toxicities in this species. However, concentrations of PCBs and dioxins in Southern Resident killer whales can be interpreted by comparing concentrations reported by Ross et al. (2000) and Jarman et al. (1996) with concentrations in other mammals in which toxic effects have been observed, or by comparing total dioxin equivalents (TEQs) in Southern Residents to TEQ thresholds.[7] This

[5] Geometric mean calculations tend to be lower than arithmetic mean calculations.

[6] Jarman et al. (1996) reported an average of 91 percent lipid in killer whale tissues. Average organochlorine concentrations (mg/kg) reported as wet weight were divided by 0.91 to estimate lipid weight concentrations.

[7] Certain PCB, furan, and dioxin congeners exhibit toxicological similarities to 2,3,7,8 – tetrachlorinated dibenzo-*p*-dioxin (2,3,7,8 – TCDD). These compounds are called 'dioxin-like' congeners, and are believed to act through the same mechanism in causing some toxic effects. Scientists have derived a system of toxic equivalency factors (TEFs) which relate the potency of each individual 'dioxin-like' congener to that of 2,3,7,8 – TCDD, the most potent of these chemicals. The TEQ is the sum of all the individual dioxin-like congener concentrations multiplied by their respective TEFs, and can be compared to other TEQs known to cause adverse effects, or to

discussion focuses on DDTs and PCBs because of their relatively high concentrations in the Southern Residents, while dioxins and furans are considered only as additive with PCBs, through calculation of TEQs

Many studies have been conducted to characterize the role of organochlorine contaminants in the morbidity and mortality of marine mammals (O'Shea, 1999). Most studies have been of wild mammals or have been conducted using wild foods, exposing test animals to a mixture of contaminants, which can confound interpretation of a specific compound as the direct "cause" of an illness or death. In much of the available research, as in Ross et al. (2000) and Jarman et al. (1996), animals were exposed to substantially higher concentrations of PCBs and DDT and its metabolites relative to concentrations of other chemicals. Therefore, much of the published literature is useful for understanding how PCBs and DDTs may be affecting the Southern Residents.

Metabolism of many toxic PCB congeners appears to be poor in cetaceans relative to other mammals (Tenabe et al., 1988; 1994; Kannan et al., 1989), although studies in both pinnipeds (seals and sea lions) and cetaceans indicate that these taxa metabolize some highly toxic dioxin-like organochlorines more readily than other mammals (Kannan et al., 1989; Ross et al., 2000). Pinnipeds metabolize some of the more toxic PCB congeners more rapidly than cetaceans, and there appears to be some variation among different cetacean species in the ability to metabolize coplanar PCBs (Duinker et al., 1989; Kannan, 1989). Because their metabolic capacities are similar, and because controlled toxicity studies in cetaceans are rare, toxicity studies of pinnipeds provide the best model for understanding toxicity of organochlorine mixtures in cetaceans.

Because of many confounding factors in toxicant effects studies of wild populations, scientists are careful to avoid conclusions of direct causality between organochlorine contamination and mortality or illness in the wild. However, given direct observations of the effects of organochlorines in laboratory studies described below, it is also inappropriate to conclude that organochlorines play no role in killer whale survival. Moreover, killer whales have to survive many stressors simultaneously, including reproductive effort, migration, storms, and local reductions in prey abundance; contaminant exposures must be interpreted in the context of life in the wild. In his review, Geraci (1999) makes this observation regarding immunotoxicity:

> "Starvation and malnutrition can affect a marine mammal's susceptibility to disease by more than one mechanism (Suskind, 1977; Seth and Beotra, 1986). For example, the associated weakness and stress might result in immunosuppression and increased likelihood of secondary infection. The utilization of blubber may lead to the release of fat soluble toxins into the blood stream, with possible consequences to immune function."

Organochlorine concentrations in Southern Resident killer whales exceed known adverse effects thresholds. Their susceptibility to toxicant effects must be considered in light of

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concentrations of just 2,3,7,8 – TCDD known to cause effects. For a complete explanation of this method, see Safe (1994).

reductions in the availability of food and other stressors in their environment.

c. Exposure Pathways of Southern Resident Killer Whales

Ingestion is the primary route of exposure of wildlife to organochlorine contaminants because concentrations of organochlorines in prey are so large relative to concentrations in other media (air or water) to which wildlife are exposed. Complete resolution of the sources and pathways of exposure of Southern Resident killer whales to PCBs and dioxins is not possible with existing information. The high trophic level, known sources of contamination in their habitat, and the fairly long life span of killer whales likely combine to result in the high exposures observed in this population.

Below, available data on Southern Resident killer whale diets and environment are reviewed to aid understanding of how the individuals sampled in the Ross et al. (2000) study could have become so contaminated, and why those individuals are likely not anomalous, but in fact are representative of the Southern Resident population.

The available data indicate that Southern Resident killer whales are 5^{th} or 6^{th} level consumers in Puget Sound and Strait of Juan de Fuca food webs. Specific data describing the Southern Resident killer whale diet are rare. Existing information shows that killer whales feed on both pelagic and epibenthic fish species, and that Pacific salmon, particularly chinook (*Oncorhynchus tshawytscha*) are a primary prey item for Southern Residents. Ford et al. (1998), collected remnants from prey capture events by Southern Resident killer whales and analyzed these "leftovers" (i.e., food particles left behind after a predation event) to identify prey species. Although there are some limitations to this study and biases acknowledged by the authors, the data showed that 96% of observed prey capture events were of salmonids, and of these, 62 percent were chinook salmon. Although chinook were the most common prey, they were not the most numerically abundant of the available fish, which suggests that killer whales seek this species when foraging. In another study, Heimlich-Boran (1988) observed Resident whales in Washington State and southern British Columbia feeding along major routes of salmon migration. These studies do not quantify chinook in the diet of Southern Residents, but illustrate that chinook and other salmonids play an important role in the Southern Resident diet.

Other observations include stomach content information from whales found stranded on beaches and autopsied (Ford et al., 1998). The majority of the killer whales identified as Resident were found to have remains of chinook and other salmon species. Other ingested items included salmon lures and halibut hooks. Also, in two separate stomachs (25 percent of the beached-whale sample) were multiple non-salmon, epibenthic species, including four species of sole, flounder, and several sculpins.

Observations of sole and halibut hooks in the guts of killer whales are important because they indicate that killer whales forage on epibenthic fish assemblages. Southern Residents have regularly been observed diving to greater than 100m depth by Baird et al. (1998). Other data for killer whales in Washington State describe a very diverse diet in killer whales (Scheffer and Slipp 1948), including salmon, birds and other marine mammals, suggesting that this species is opportunistic and responsive to changing availability of prey. These authors stated that killer whales in Puget Sound have been observed feeding in near shore waters of estuaries, possibly an important source of contaminants to the Southern Resident population. Scheffer and Slipp's (1948) observations were made in the 1930s and 1940s at various locations within Puget Sound. They did not distinguish between fish-eating Residents and mammal-eating Transients.

Killer whale experts have emphasized the role of chinook salmon in the diet of killer whales (Osborne, 1999; Ford et al., 1998). It is plausible that killer whales target chinook because they are, on the average, the largest of the Pacific salmon, and they congregate in groups in the pelagic zone. Salmon may be preferred over epibenthic species because diving to the benthic zone is energetically more costly than capture of salmon within the top 40m of the water column. However, the availability of chinook and other salmon is variable – depending on migrations and annual stock abundance. The degree to which Southern Residents must use other species for food may be dependent on water temperature and seasonal availability. Observations of epibenthic fish remains and halibut hooks in killer whale stomachs suggest that, even if salmon are a primary prey, killer whales may rely on a large variety of fish stocks. Species observed to be killer whale prey are relatively long-lived, feed on or near the bottom, or are themselves predators. These characteristics of killer whale prey contribute to higher exposures to bioaccumulative contaminants among killer whales.

A survey of near shore marine food webs in Washington by Simenstad et al. (1979) identified 16 food webs in Puget Sound and the Strait of Juan de Fuca. Of the discrete food webs that exist in nearshore habitats of the study region, the killer whales belong to the 2 neritic food webs, and the shallow sublittoral food web. These food webs are complex, with 38 and 41 nodes, respectively, and link the killer whales to near shore materials, including contaminated sediments. Simenstad et al. (1979) describe killer whales as third or fourth level consumers in diagrams of both neritic and shallow sublittoral food webs. Juvenile salmon are included in this description, but adult chinook and other salmon are considered to be outside the "nearshore" food webs.

Groot and Margolis (1991) summarized the literature on chinook food habits in the region inhabited by Southern Resident killer whales. Because the data were derived from the commercial fishery, larger chinook are emphasized. In the Strait of Georgia, small fish, particularly herring, constituted 28 to 63 percent of the diet of chinook. In a separate study, 79 percent of chinook stomach contents were fish in the Strait of Georgia. Pelagic invertebrates were also important to adult chinook. In the waters of British Columbia, herring, sand lance and pilchards were most important to chinook diets, with herring dominating stomach contents in many studies. Coho salmon, also prey of killer whales, begin to eat fish as smolts, and use fish and marine invertebrates during the early part of their marine life stage. In the Strait of Georgia, coho also use herring, sand lance, and other fish, and pelagic invertebrates. Overall, coho and chinook salmon have very similar diets, but the coho use a greater proportion of invertebrates than chinook (Groot and Margolis, 1991). Thus, coho and chinook are at roughly equivalent trophic levels. Their predation on fish makes them at least third, and possibly fourth level consumers, making Southern Resident killer whales fourth and possibly fifth level consumers.

d. Sources of Contaminants

Because the prey of Southern Resident killer whales consists of wide-ranging species such as chinook and coho salmon, and killer whales are themselves wide ranging, it is not possible to pinpoint a single source of persistent organochlorines to the killer whale diet. Several factors can be considered to understand the likely pathways of contaminants to the Southern Resident killer whales.

i. Organochlorine sources in Puget Sound

According to the Environmental Protection Agency, there are 16 Superfund sites in the Puget Sound Basin at which PCBs are a contaminant of concern, and at least 7 of those include marine or freshwater sediment contamination. See Appendix D. Many are also sources of DDTs, heavy metals, and other pesticides. Most of these were the site of industrial operations conducted over 20 to 70 years of the 20th century, and most of these sources are either now contained, or undergoing containment. Several important point sources of organochlorines exist in Puget Sound, including Elliott Bay, Commencement Bay, Port Hadlock, the Whidbey Island Naval Air Station (Ault Field), The Puget Sound Naval Shipyard Complex, and the Keyport Undersea Warfare Engineering Station.

Even though the most concentrated areas of contamination at these sites may be addressed through the Superfund process, available data suggest that ecological processes have contributed to the dispersal of these contaminants throughout Puget Sound. See Appendix C.

ii. Contamination of the killer whale food web

The proximity of Southern Resident killer whales to Puget Sound hazardous materials sites likely explains their high organochlorine exposures relative to the Northern Resident killer whales (Ross et al., 2000), which have a diet similar to that of Southern Resident killer whales (Ford et al., 1998). Data summarized in Appendix C shows that marine organisms (mussels and sole) collected from highly contaminated urban waterways such as Commencement Bay and Elliott Bay are very contaminated, but also that PCBs are dispersed fairly broadly into rural bays such as Useless Bay at the southern end of Whidbey Island (Ylitalo et al., 1999).

When contaminant concentrations in samples from various points across the entire range of Puget Sound, the Strait of Juan de Fuca, and southern Georgia Strait are averaged, both DDT and PCB contamination of the food web seem substantial. Average PCB concentrations in fish from this region ranged from 0.39 to 10.07 mg/kg lipid weight, and DDTs ranged from 0.34 to 2.82 mg/kg lipid weight. In contrast, Kawano et al. (1986) reported PCBs in salmon from the Pacific Ocean and the Bering Sea at 0.090 mg/kg lipid weight, and total DDTs at 0.076 mg/kg lipid. Puget Sound chinook analyzed by O'Neill et al. (1995, 1998) had an average concentration 28 times higher than this chum salmon from the Pacific, and the average coho from Puget Sound was 19 times more contaminated than open ocean chum. The maximum PCB concentration in Puget Sound chinook was more than 80 times higher than the mean reported by Kawano et al. (1986). The relative concentrations of DDT in Puget Sound salmon were also elevated, with the average DDT concentrations in coho and chinook 11 and 26 times more than Kawano et al.'s (1986) chum, respectively.

Some of the killer whale prey reported by Ford et al. (1998) do not migrate great distances, and will transfer contaminants to killer whales according to contaminant levels in their local habitats (e.g., Puget Sound harbor seals of Hong et al., 1996). While chinook and coho may migrate to open ocean habitats to mature, there is evidence of "resident" chinook stocks in inside waters of Washington. In mark-recapture studies reviewed by Groot and Margolis (1991), there was limited dispersal of chinook tagged in inside waters of British Columbia and Washington State. The existence of a chinook stock restricted to the inside waters of Washington State could explain why chinook consistently have higher PCB concentrations than coho (there is no evidence of a restricted stock of coho in inside waters), even after lipid content is accounted for (O'Neill et al. 1995), and could explain why chinook from Puget Sound are much more contaminated than open ocean chum reported by Kawano et al. (1986). A chinook stock with limited migrations outside of Puget Sound and the Straits of Juan de Fuca and Georgia would undoubtedly constitute an important part of the Southern Resident killer whale diet, and, if O'Neill et al.'s (1995, 1998) data are representative of such a stock, could explain the very high levels of persistent organochlorines in Southern Resident killer whales.

iii. Global atmospheric transport

Transfer of persistent organochlorines to marine environments via the atmosphere is also substantial (Iwata et al., 1993). On the basis of the Henry's Law constants of individual congeners, Iwata et al. (1993) estimated the potential of long range transport of PCBs and DDTs. They concluded that marine environments in the northern latitudes are a sink for PCBs released to the global atmosphere. DDTs are less likely to be transported across long distances, and tend to be absorbed into marine waters close to the point of release.

e. Bioaccumulation of Persistent Organic Contaminants

Increasing concentrations of organic contaminants at higher trophic levels is well established (e.g., Eisler, 1986; Mamontov et al., 1997). DDTs, PCBs, dioxins and furans are readily absorbed following ingestion (e.g., studies reviewed by Smith, 1991; O'Connor, 1984), and only some of the congeners are metabolized and excreted, while others remain in the body. In longer lived species, the effect is cumulative as the animals build up the contaminants to which they have been exposed over the years. Whales live a long time and, with the exception of breeding females, their body burdens generally increase with age (Ross et al., 2000). Bioaccumulated contaminants can be mobilized in time of stress such as when reductions in food supplies require that the animals draw on their fat reserves for energy, or during reproduction.

The chronic, low-level inputs of atmospheric sources and the slow distribution of PCBs and DDTs from point sources in Puget Sound are the most likely sources of persistent organochlorines in the diet of Southern Resident killer whales. The length and complexity of the food webs in Southern Resident killer whale habitats, and the long-term exposure of individuals explain how low levels of persistent contaminants in abiotic media become dangerously high in top predators.

f. Organochlorine Toxicity

Numerous adverse health effects have been observed in many mammal species following exposure to PCBs, dioxins, and furans. The severity and types of effects observed depend on the age and sex of the animal, the species, and the route and duration of exposure. Safe (1994) summarized the range of effects that have been observed in laboratory studies using commercial mixtures (i.e., PCB mixtures used in commercial applications, such as Aroclors):

> "acute lethality, hepatomegaly [enlarged liver cells], fatty liver and other indications of hepatotoxicity, porphyria, body weight loss, dermal toxicity, thymic atrophy, immunosuppressive effects, reproductive and developmental toxicity, carcinogenesis, other genotoxic responses, modulation of diverse endocrine-derived pathways, and neurotoxicity."

In general, the effects of chronic ingestion of DDT and its metabolites are similar. A summary of DDT effects in mammals (Smith, 1991) includes increased risk of mortality and liver tumors, alteration of metabolic and other enzyme systems, neurological effects (e.g., tremors), estrogenicity, reproductive effects such as failure to reach estrus and poor survivorship of young, and cancer promotion.

i. Immunotoxicity

Brouwer et al. (1989) conducted a two-year controlled laboratory study in which harbor seals (*Phoca vitulina*) were exposed to fish from a DDT- and PCB-contaminated source (the Wadden Sea, Netherlands) and compared to seals fed fish from relatively uncontaminated waters. Seals were exposed to 1.5 mg/d PCBs and 0.4 mg/d pp'-DDE (treatment group), or 0.22 mg/d PCBs and 0.13 mg/d pp'-DDE (control). Comparison of biochemical indicators between the two groups showed that chronic exposures of the seals to this mixture of organochlorine compounds resulted in reductions in plasma proteins and thyroid hormone levels. Brouwer et al. (1989) interpreted these biochemical alterations to be sufficient to cause reproductive impairment and immunotoxicity in these seals. In a series of studies (summarized by Ross et al., 1996a) harbor seals were fed Baltic Sea fish containing high levels of total DDTs (2,155 µg/kg lipid weight), total PCBs (4,398 µg/kg lipid weight), and some dioxins and furans for 2 years. This level of exposure resulted in dose-related reductions in T-cell function, natural killer cell activity, and vitamin A levels, all indicators of immunotoxicity.

Ross et al. (2000) calculated TEQs in the average middle-aged adult Southern Resident killer whales and compared them to TEQs known to cause suppression of immune function in pinnipeds.[8] According to Ross et al.'s (2000) analysis, all of the male Southern Resident killer whales analyzed in their study, and most of the females, currently have body burdens which exceeded immunological effects thresholds established for seals (DeSwart et al., 1996; Ross et al., 1996b).

Examples of high organochlorine concentrations in marine mammals stricken by viral

[8] These effects-threshold TEQs were derived by Ross et al. (2000) using toxicity thresholds derived from laboratory studies. See Ross et al. (2000) for the derivation of this TEQ threshold for pinnipeds.

epizootics are common in the literature (Geraci et al., 1999). An epizootic of morbillivirus killing 18,000 harbor seals (*Phoca vitulina*) in northern Europe in April of 1988 partly occurred in areas of high contamination in the Wadden and North Seas. Seals that were found dead after this disease outbreak had concentrations of 0.96 – 7.99 mg/kg wet weight total DDT in blubber and 5 – 46 mg/kg PCBs (Hall et al., 1992), levels lower than the average in Southern Resident killer whales. Striped dolphins (*Stenella coeruleoaba*), which succumbed to an epizootic in the Mediterranean Sea in 1991, contained high levels of PCBs (100 – 500 mg/kg lipid; Aguilar and Borell, 1994). PCB and DDT concentrations in Baikal seals (*Phoca sibirica*) are among the highest in pinnipeds anywhere in the world (3.5- 64 and 4.9-160 mg/kg lipid, respectively; Nakata et al., 1995; Kucklick et al., 1994). This population suffered a reduction of several thousands due to a viral epizootic in 1987 (Grachev et al., 1989). In St. Lawrence beluga whales (*Delphinapterus leucas*), the frequent occurrence of infections due to relatively mild infectious bacteria has been interpreted to be the result of immunosuppression due to chronic organochlorine exposures in this population (DeGuise et al., 1995). These whales had an average DDT concentration of 81.1 mg/kg lipid in blubber, and average total PCB concentration of 78.9 mg/kg lipid, somewhat higher, but within an order of magnitude, of mean concentrations in Southern Resident killer whales.

ii. Reproductive Toxicity

In another study of Wadden Sea harbor seals, Reijnders (1986) did not detect alteration of two blood hormones (oestradiol-17ß, progesterone), but did document significantly lower reproductive success in seals chronically exposed to PCBs and metabolites of DDT. Concentrations of contaminants in the food of the seals were not reported by Reijnders (1986), but estimated doses were reported as 1.5 mg/d PCBs and 0.4 mg/d pp'-DDE in seals with poor reproduction, and 0.22 mg/d PCBs, and 0.13 mg/d pp'-DDE in control seals. Reijnders (1986) noted that hormone profiles of the affected group indicated that the reproductive failure occurred around the implantation stage. This finding is significant because it corroborated observations of the process of reproductive failure in PCB-dosed mink, suggesting that the same toxicological mechanism is in effect in both species.

Impaired reproduction has been observed in studies of sea lions (*Zalophus californianus*) in environments contaminated with PCBs and dioxins (summarized by Kamrin and Ringer, 1996). These studies, while lacking the control of laboratory experiments, inform assessment of risk to Southern Resident killer whales. In two separate studies, sea lions giving birth prematurely on the west coast of the United States had significantly higher concentrations of PCBs in blubber (mean = 112 ppm wet weight, or about 133 ppm lipid weight) than in females bearing young normally (mean = 17 ppm wet weight or about 20 ppm lipid weight; DeLong *et al.* 1973). DeLong et al. (1973) observed concentrations of total DDTs 8 times higher in blubber of sea lions bearing young prematurely (mean = 824 ppm wet weight or about 980 ppm lipid weight) than in sea lions bearing young normally (mean =103 ppm wet weight or about 121 ppm lipid weight). Gilmartin *et al*. (1976) observed similarly high total DDTs (mean = 651 ppm wet weight) and PCBs (mean = 57.2 ppm wet weight) in female sea lions bearing young prematurely. While sea lions in both of these studies had very high total DDTs, their PCB levels in blubber are comparable to those observed in Southern Resident killer whales.

Other studies attempting to correlate PCB exposures with reproductive effects in wild pinnipeds are difficult to interpret due to low sample sizes and confounding variables.

iii. Endocrine Disruption

The role of organochlorines as endocrine disrupters in mammals is complex. The evidence for alteration of endocrine systems in marine mammals is mixed, showing that some endocrine pathways are clearly affected by organochlorines administered through food (Brouwer et al., 1989) while other endocrine biomarkers are unaffected by the same chemical mixtures (Reijnders, 1986). One additional study of endocrine effects in marine mammals is worth noting. Subramanian et al. (1987) documented a significant negative correlation between concentrations of DDE (7.61 – 16.5 mg/kg wet weight) in the blubber of Dall's porpoises (*Phocoenoides dalli*) and testosterone in the blood of these specimens. Also, a negative correlation between PCBs in blubber (5.62 – 17.8 mg/kg wet weight) and reduced testosterone was non-significant but "apparent," according to the authors, from a scatter plot. A second hormone (aldosterone) functionally not directly connected to reproduction but to regulation of blood sodium, showed no correlation at all with organochlorine exposure. DDT and PCB concentrations in blubber of Southern Resident killer whales exceed concentrations in blubber of affected porpoises in the Subramanian et al. (1987) study.

iv. Effects on Early Life Stage Development

In mammals, fats stored by the female directly support the life of a developing fetus and are also transferred to the young following birth via lactation. Because organochlorine contaminants are stored in fats, juveniles in a contaminated population begin to be exposed to organochlorines very early in their development, probably shortly after conception. In Southern Resident killer whales, adult females have the lowest body burdens of fat-soluble organic contaminants of any segment of the population (Ross et al., 2000). This is because during the processes of fetal development and lactation, breeding females impart substantial loads of organic contaminants to their young, from 20 to 90 percent of the mother's organochlorine load in pinnipeds and cetaceans studied (Nakata et al., 1998). Because the milk of cetaceans and pinnipeds is very high in fat, the majority of the dose received by juveniles prior to weaning is thought to be through lactation (Nakata et al., 1995).

Early life stage exposure to DDT and metabolites, PCBs, dioxins and furans is an important risk factor for this population. In rats, perinatal exposures to the mix of organochlorines present in Baltic Sea fish (discussed above) resulted in more severe immunotoxicity than exposures in previously unexposed adults (Ross et al., 1996a and supporting studies). Only after dosing ceased did the juvenile rats begin to recover from the immunotoxicity. Perinatal exposures of humans to PCBs has been linked to defects in cognitive functioning (Jacobson et al., 1990), and perinatal exposures in non-human primates has been linked to long-term behavioral dysfunction (Schantz et al., 1991). In addition, estrogenicity or other endocrine-like reactions of these chemicals can affect the "organization" of developing embryos (Guillette et al., 1995). Embryos are particularly susceptible to the action of hormones and hormone-like compounds because many embryonic cells have receptors for hormones even before the embryo itself is synthesizing hormones. Thus the developing embryo will be responsive to the presence of hormones and hormone-like compounds to which it is exposed *in utero*, via the mother's bloodstream. Because hormones and hormone-like materials affect the organization of the developing organism, the effects are permanent. For example, female guinea pigs neonatally dosed with testosterone exhibited altered (masculine) mating behavior as adults (Phoenix et al., 1959). On the basis of the guinea pigs' behavior and physiology, the authors of this study concluded that the prenatal exposures affected both neural and genital tissues. *In utero* and early life stage (*post-partum*) exposure of Southern Resident killer whales to organochlorines which are immunotoxic, neurotoxic, and estrogenic or otherwise endocrine-disrupting increases the susceptibility of the Southern Resident population to lasting effects of organochlorine toxicity.

v. Other Possible Toxic Effects

On the basis of studies in other mammals, additional adverse health effects of DDT and metabolites, PCBs, dioxins, and furans are possible in killer whales, and even likely in individuals with high exposure. Exposure to mono-*ortho* and di-*ortho* PCB (non dioxin-like) congeners and metabolites may result in effects not mediated by the same biochemical pathways as 2,3,7,8-TCDD, and therefore not predicted by TEQs. Such effects include neurobehavioral, neurochemical, carcinogenic, and endocrinological changes (Ahlborg et al., 1992). Because these types of effects are difficult to observe in wild populations, there is no way to account for such effects in Southern Resident killer whales with available information.

Direct assessments of DDT, PCB, dioxin, and furan effects in many species of mammals (as well as fish and birds) have proven these organochlorines to be potent agents of numerous adverse health effects (Eisler and Belisle, 1996; Eisler, 1986; Smith, 1991). For example, Beland et al. (1993) and DeGuise et al. (1995) documented high incidences of tumors, including malignant neoplasms, in St. Lawrence beluga whales contaminated with several organochlorine types, including DDT and metabolites (3.36 – 389 mg/kg lipid weight in blubber), PCBs, (8.3 – 412 mg/kg lipid weight in blubber) and lower levels of dioxins and furans (Muir et al. 1996). From a population estimated at 500 animals, 18 collected post-mortem had tumors, a rate of 3.6 percent. The possibility that such effects occur in Southern Resident killer whales is relevant to its risk of extinction: an animal fighting an infection or the development of a tumor, one that has neurobehavioral abnormalities, liver disease or an altered endocrine system, or some combination of these effects, will be less fit for survival in the wild.

<u>g. Summary</u>

Contaminant concentrations measured in Southern Resident killer whales are likely sufficient to result in adverse health effects in these animals. Total dioxin equivalents (TEQs) in Southern Resident killer whales exceed TEQ thresholds of immunotoxicity derived for pinnipeds. Concentrations of DDTs and PCBs in Southern Resident killer whales exceed those found in pinnipeds and cetaceans stricken by morbillivirus in Europe and central Asia. Exposure of early life stages to organochlorines may be enhancing susceptibility to immunotoxicity, as well as causing permanent physiological alterations via endocrine disruption during development, and possibly altering neurological functioning. Reproductive effects may be occurring in the population via reductions in testosterone in males, and implantation failure in females, both of which have been observed in similarly exposed pinnipeds. Poor survivorship of young after birth is also possible given existing body burdens in Southern Resident killer whales relative to affected pinnipeds in southern California. Concentrations of organochlorines in Southern Resident killer whales are within the range of those in St. Lawrence beluga whales, 3.6 percent of which have cancerous and other tumors.

Because Southern Resident killer whales occupy a high trophic level, live for a relatively long time, and regularly forage in Puget Sound which is the location of numerous sites contaminated with PCBs and DDTs, and because these contaminants do not readily degrade, exposures in this population can be expected to continue to be high for many years to come. The presence of other environmental stressors such as changing weather patterns, reductions in prey abundances, and human encroachment on habitats is likely to exacerbate the role of contaminants in the decline of this population.

2. Risks of Rarity

It is clear that the effective population of the Southern Residents is quite small. The low number of individuals within the population makes the Southern Residents particularly susceptible to stochastic perturbations. There are four types of stochastic perturbations that small populations may be subject: demographic stochasticity, environmental stochasticity, genetic stochasticity, and natural catastrophes.[9]

Demographic stochasticity refers to accidental variations in birth rate, death rate, and the ratio of the sexes. Environmental stochasticity refers to fluctuations in weather, in food supply, and in the population levels of predators, competitors, parasites, and disease organisms that may affect the killer whale population. Genetic stochasticity refers to the loss of specific alleles through the processes of genetic drift, and the increased expression of the genetic load of the population. All of these stochastic effects create survival risks for populations. Indeed, these stochastic factors, combined with the effects of natural catastrophes, can interact in a dire feedback cycle by which a small population spirals to extinction.

In general, when the effective population of a species falls below 500 individuals, the population faces an overall net-loss of genetic variability through the loss of rare alleles, known as genetic drift. In populations below this size, the gains of genetic diversity brought on through mutation are outpaced by the loss brought on by genetic drift. As the population continues to decline, the rate of loss tends to increase, because smaller populations have smaller rates of mutation. Overall, this effect leads to a loss of long-term genetic adaptability within the population. (Franklin, 1980).

Further genetic risks occur when a population declines to 50 individuals. At this point, the population becomes susceptible to inbreeding depression, i.e., the increased expression of deleterious alleles. For populations with a large genetic load, inbreeding can be particularly devastating. However, a population that historically has low population numbers will likely have a low genetic load (otherwise the relatively small population would not have survived over time),

[9] *See* Mark L. Shaffer, Determining Minimum Viable Population Sizes: A Case Study of the Grizzly Bear (*Ursus arctos L.*), (1978) (unpublished Ph.D. dissertation, Duke University).

whereas a population that had historically large numbers, and therefore could harbor a larger genetic load, will be extremely vulnerable to inbreeding depression, since the large genetic load may be expressed in a proportionately higher number of the individuals within the population (Franklin, 1980).

The total population of the Southern Residents is 83 individuals, well below the threshold of 500 effective individuals. Furthermore, the effective population size of the Southern Residents is currently below 50 as only approximately 29 individuals are of reproductive age. This indicates that the population may already be losing genetic variation over the long-term through the process of genetic drift, and may also be affected by inbreeding depression that is limiting the ability of the species to breed successfully. Mitigating the problem of inbreeding is the behavioral avoidance of inbreeding by breeding between pods. Clearly, however the population is still likely to face inbreeding problems.

However, this does not mean that the extinction of this population is inevitable. The generalized rule, known as the 50/500 rule, is incomplete and simplistic. The risk factors affecting the killer whale's continued existence interact in a complex, multidimensional, and context-specific way, which cannot be reflected accurately in the generalized 50/500 rule. For example, because it is a long-lived mammal, the killer whale is relatively more resistant to demographic stochasticity than other species, while it may be more vulnerable to the effects of inbreeding and toxic chemicals due to its rapid decline in numbers caused by extensive hunting before accurate survey work was conducted.

The current decline in the Southern Residents may in part be due to the effects of rarity. Some of these effects have been compounded by human activities. For example, the high levels of organochlorines in individual killer whales may have reduced effective population even further by rendering reproductive-age killer whales infertile. The chemical effects on an already small population may have delayed the recovery of the species, and threaten to preclude the possibility of recovery all together.

3. Oil Spills

Killer whales spend a large portion of there time at or near the surface of the Ocean. This makes them susceptible to contamination from oil spills. Oil can poison killer whales through a variety of pathways. Inhaling high concentrations of volatile hydrocarbons can result in inflammation of the mucous membranes, lung congestion, and pneumonia, and in severe cases may result in sudden death. Volatile hydrocarbons may accumulate in the brain and liver, causing long-term neurological damage and liver disorders (Geraci & St. Aubin, 1982). Oil spills can also contaminate the food web upon which killer whales rely, and can therefore indirectly affect the health and well being of the whales.

The risk of a large oil spill in the Southern Residents' habitat is not unfounded. A partial list of oil spills that have occurred since the 1970's indicates that oil spills are relatively common and avoiding a catastrophic spill will be difficult. See Appendix E for a partial listing of spills and their impacts.

The Exxon Valdez oil spill in Prince William Sound provides an example of oil spill effects on killer whales. The AB Resident pod and the AT1 Transient pod are believed to have sustained long-term consequences from the Exxon Valdez spill. The AB Resident pod was photographed swimming in oil-slicked waters on March 31, 1989, six days after the oil spill. At the conclusion of the survey year of the summer of 1989, seven whales were reported dead: three adult females and four juveniles. These deaths were alarming because adult females and juveniles normally have the lowest mortality rates among killer whales. By the spring of 1990 an additional six whales from the AB pod were missing and are now confirmed dead (Matkin et al., 1994). The dorsal fins of two adult males folded following the oil spill (a sign of poor health) and both of these whales died in 1991.

These deaths resulted in an unusually high mortality rate in the years immediately following the oil spill (19.4% in 1989 and 20.7% in 1990). The AB pod has also shown signs of social breakdown within the group, with one matrilineal group leaving to join a different pod. This is a phenomenon never seen before among these killer whales. Thus, the oil spill is not only implicated in increasing mortality in killer whales, but also reducing fecundity by disrupting the social structure of the pods and by killing reproductively successful individuals within the pod.

The AB pod has not recovered to pre-spill population numbers, even as killer whales as whole throughout the region have increased. Between 1996-98, five calves were recruited and only two adults were lost in the AB pod, resulting in a net gain of three individuals. However, this recruitment is not considered to be sufficient to constitute recovery of the pod. There are currently 24 individuals alive in the AB pod, down from a high of 36 in 1988. Until evidence of sustained recruitment or at least population stability can be shown, the AB pod will not be considered recovered (Matkin & Saulitis, 1997; Matkin, Pers. Comm., 2001).

The AT1 Transient group has 11 whales that are missing since the oil spill. These whales are all thought to be dead, and most of these whales disappeared during the 1989-1990 winter (Matkin & Saulitis, 1997). Transients are believed to have received oil contamination through a variety of sources, including eating soiled marine mammals after the oil spill. The AT1 group has not successfully recruited any calves since 1984. The failure to recruit calves is believed to be caused by the high levels of contaminants found in this population, which in turn was affected by eating soiled mammals after the Exxon Valdez oil spill.

The Southern Residents live in the most urbanized environment of any population of killer whales on Earth. The population's close proximity to industrialized activities makes the possibility of oil contamination more plausible. The consequences of an oil spill can be expected to be similar to what has happened to the AB and AT1 pods in Prince William Sound. Increased mortality, disrupted social structure, lower calf recruitment, and long-term health consequences could affect the Southern Residents dramatically. The potential affects of such a spill were modeled in the PVA attached to this petition in Appendix A.

4. Entanglement in Fishing Gear

Incidental mortality in fisheries through accidental entanglement in fishing gear appears to be rare for this species. A few gear entanglements have been reported in British Columbia, though not all have resulted in death of the entangled animals (Baird et al., in press).

Entanglements have also been reported from other areas where individuals from the B.C. population range (e.g., Heyning et al., 1994). Entanglement appears to be an insignificant factor in the current decline, but efforts should be made to ensure that killer whales are not entangled in the future.

F. SYNERGISTIC EFFECTS

The threats facing the Southern Residents are particularly troublesome because of their interrelated nature. The effects of these threats are synergistic, indicating that addressing each threat independently will not be sufficient to preserve the population. For example, a decrease in chinook salmon not only increases the amount of toxins released from lipids as the whales use their fat reserves for energy, but also increases the risk of further accumulation of toxic substances as the Southern Residents feed on bottom-feeding fish that may have higher toxic loads. With higher toxic loads, the Southern Residents are at greater risk of adverse affects from harassment from whale watching vessels, which may prevent the whales from feeding efficiently and increase the stress of the whales, which in turn makes it more likely that additional toxin loads will be released from lipids into killer whales.

G. SOUTHERN RESIDENTS SATISFY THE IUCN "CRITICALLY ENDANGERED" CRITERIA

The World Conservation Union ("IUCN") has published criteria for determining threats to survival of species around the world. The IUCN categorizes species based on these criteria. On a species level, *Orcinus* orca is considered to be a species that is at lower risk of extinction, but will qualify for a higher conservation status if current protections are eliminated. When looking at the Southern Residents exclusively under the IUCN criteria, it is clear that they should be categorized as "Critically Endangered," the IUCN category with the highest risk of extinction. A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the five listing criteria. The Southern Residents satisfy at least one of these criteria.

1. Population Estimated to Number Less Than 50 Mature Individuals

The Southern Residents are known to have only 82 living individuals at this time. However, not all of the individuals constitute "mature" individuals. Under the IUCN criteria, only individuals known, estimated or inferred to be capable of reproduction are considered to be mature. Although individual maturation may vary, female killer whales may become sexually mature as early as age 13, while males may mature as early as 11. Females remain fertile for 40 years on average, while it is not known when male fertility ceases, if ever.

The number of mature Southern Residents has never exceeded 50 for any given year between 1974 and 2000. This qualifies the Southern Residents for the Critically Endangered criterion defined by the IUCN.

VII. THE SOUTHERN RESIDENTS SHOULD HAVE CRITICAL HABITAT DESIGNATED

A. CRITICAL HABITAT IS BENEFICIAL TO LISTED SPECIES

Critical habitat is defined by Section 3 of the ESA as:

> (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
>
> (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species.

16 U.S.C. §1532(5).

The designation and protection of critical habitat is one of the primary ways in which the fundamental purpose of the ESA, "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved," is achieved.[10]

The designation of critical habitat provides listed species with additional protections under Section 7 of the ESA. The Section 7 consultation requirements provide that no action authorized, funded, or carried out by any federal agency will "jeopardize the continued existence of any endangered species or threatened species *or result in the destruction or adverse modification of [critical habitat].*"[11] "Destruction or adverse modification" is further defined in the implementing regulations as an "alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species."[12] This prohibition is in addition to the prohibition against actions which "jeopardize the continued existence of" a species.[13]

Critical habitat designation offers an added layer of protection to ensure that a listed species' habitat—the loss of which is widely recognized to be the primary reason for most species' decline—will not be harmed. Without critical habitat designation, a listed species' protection under Section 7 of the ESA is limited to avoiding "jeopardy" to the species in its occupied habitat, without separate consideration of the potential for "destruction or adverse modification" of habitat or suitable unoccupied habitat which may be essential to the species' recovery. The U.S. Fish and Wildlife Service nicely summarized this distinction in the final rule designating critical habitat for the northern spotted owl:

> The Act's definition of critical habitat indicates that the purpose of critical

[10] 16 U.S.C. §1536(a)(2) (1994).
[11] 16 U.S.C. §1536(a)(2) (1994) (emphasis added).
[12] 50 C.F.R. §402.02 (1999).
[13] "Jeopardize the continued existence of" is defined as "to reduce appreciably the likelihood of both the survival and recovery of a species by reducing the reproduction, numbers, or distribution of that species." 50 C.F.R. § 402.02.

> habitat is to contribute to a species' conservation, which definition equates to recovery. Section 7 prohibitions against the destruction or adverse modification of critical habitat apply to actions that would impair survival and recovery of the listed species, thus providing a regulatory means of ensuring that Federal actions within critical habitat are considered in relation to the goals and recommendations of a recovery plan. As a result of the link between critical habitat and recovery, the prohibition against destruction or adverse modification of the critical habitat would provide for the protection of the critical habitat's ability to contribute fully to a species' recovery. *Thus, the adverse modification standard may be reached closer to the recovery end of the survival continuum, whereas, the jeopardy standard traditionally has been applied nearer to the extinction end of the continuum.*[14]

This added protection would be implemented through the issuance of a biological opinion under 16 U.S.C. §1536(b)(3)(A), which must suggest reasonable and prudent alternatives by which a finding of jeopardy or adverse modification may be avoided.

Critical habitat designation also protects species by helping to define the meaning of "harm" under Section 9 of the ESA, which prohibits unlawful "take" of listed species, including harming the species through habitat degradation. Although "take" through habitat degradation is not expressly limited to harm to "critical habitat," it is practically much easier to demonstrate the significance of the impact to a species' habitat where that habitat has already been deemed "essential," or "critical," to the species' continued survival.[15]

Critical habitat also helps species by providing for agency accountability through the citizen suit provision of the ESA. The citizen suit provision permits members of the public to seek judicial review of the agency's compliance with its mandatory statutory duty to consider the habitat needs of imperiled species. Also, the designation of critical habitat provides valuable information for the implementation of recovery plans.

Additional benefits of critical habitat were described by NMFS in the Final Rule designating critical habitat for the Atlantic population of the northern right whale:

> A designation of critical habitat provides a clearer indication to Federal agencies as to when consultation under section 7 is required, particularly in cases where the action would not result in direct mortality or injury to individuals of a listed species.…The critical habitat designation, describing the essential features of the habitat, also assists in determining which activities conducted outside the designated area are subject to section 7....For example, disposal of waste material in water adjacent to a critical habitat area may affect an essential feature of the designated habitat (water quality) and would be subject to the provisions of section 7….

[14] 57 Fed. Reg. 1796 at 1822 (emphasis added).

[15] *See Palila v. Hawaii Department of Land and Natural Resources*, 852 F. 2d 1106 (9th Cir. 1988).

58 Fed. Reg. 29186 at 29187.

NMFS goes on to state that critical habitat also assists federal agencies in planning future actions because critical habitat establishes in advance those areas that will be given special consideration in section 7 consultations.[16] The designation allows conflicts between development and listed species to be identified and avoided early in the planning process.[17] NMFS also states that critical habitat provides a benefit to species by focusing federal, state, and private conservation and management efforts in areas designated critical habitat.[18] Recovery efforts can then address special considerations needed in critical habitat areas, including conservation regulations to restrict private as well as federal activities.[19] Finally, NMFS points out that there may be other federal, state, or local laws that provide special protection for areas designated as critical habitat.

VIII. RECOMMENDED CONSERVATION MEASURES

Several other measures should be taken to insure the survival of the Southern Resident killer whales. If undertaken, these measures will help mitigate the effects of the threats outlined in this petition and increase survivability within the Southern Residents. All of these efforts should also be undertaken in Canada, and an international dialogue on conservation efforts should be instituted.

A. INCREASE FUNDING FOR SOUTHERN RESIDENT RESEARCH AND CONSERVATION EFFORTS

Although the Southern Resident population is very likely the most often observed and studied population of killer whales in the world, there is still much to learn about their genetics, biology, and ecology. Increasing funding for field and laboratory research will be essential to learning more about the Southern Residents before they are extirpated. Funding is also needed to promote the conservation and recovery of the Southern Residents. Many activities can be undertaken with relatively small investments that will provide conservation benefits to both the Southern Residents and the ecosystem upon which the Southern Residents depend. The following recommendations should be funding priorities:

?? **Funding for an enhanced and coordinated stranding network.** The stranding network would provide immediate response to reports of killer whale and other marine mammal stranding events in order to resuscitate sick and injured animals. If the animal is unable to be saved, the stranding network must be able to collect samples for chemical and biological information, assess the cause of stranding and death, and appropriately dispose of the carcass.

?? **Funding for shore-based observations of vessel and whale interactions.** Vessel traffic is potentially threatening the existence of the Southern Residents. Commercial and recreational whale watching boats may be altering the behavior of the killer

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[16] *Id.*
[17] *Id.*
[18] *Id.*
[19] *Id.*

whales, high-speed ferries are increasing the risk of collisions, and the increased level of commercial traffic has increased acoustic pollution and risks of oil spills. More research is needed to determine how these interactions are affecting Southern Resident behavior and survival. Observations of ballast water discharge and compliance of laden tankers with tug escort laws should also occur.

?? **Funding for continuing and new photo-identification studies.** The photo identification studies undertaken by institutions such as the Center for Whale Research are the most important tool available for assessing the health of the Southern Resident killer whales. Continued support for these efforts are essential to insure that population changes within the Southern Residents do not go undetected. Furthermore, additional funding can increase our understanding of the social, behavioral, and ecological habitats of the Southern Residents, insuring that recovery efforts are tailored appropriately.

B. PROTECT AND RESTORE THE HABITAT OF SOUTHERN RESIDENTS AND THEIR PREY

Habitat destruction is affecting the survival of the Southern Residents by altering the ecosystem in which they live, and also by destroying important habitats for their preferred species of prey. Perhaps the most effective way of preserving the Southern Residents would be to insure that current areas of suitable habitat are maintained and degraded areas are restored. Some priorities for habitat preservation for the Southern Residents include:

?? **Protecting Puget Sound herring and forage fish habitat.** Protecting Puget Sound herring is critical for the survival of the Southern Residents. Herring are an important prey species for chinook salmon, which in turn is the preferred prey of Southern Residents. It is also believed that killer whales may eat herring directly. Chinook are a threatened species, and further loss of herring may result in additional declines in chinook populations. Further development of important herring habitat, including commercial shellfish rafts, salmon farms, pier and dock development, and development at Cherry Point, must be halted. Surf smelt and sand lace are also important forage fish for chinook, and protecting nearshore habitats will be important to the recovery of both salmon and killer whales.

?? **Protect and restore estuarine, riparian, and shoreline habitats.** The most important threat to salmon that run through the Southern Residents' habitat is habitat destruction. In order to insure that the Southern Residents' food source remains viable, aquatic, riparian, and shoreline habitats must be preserved and restored. Elwha dam removal should be expedited to take advantage of oceanographic conditions associated with the PDO, and additional restoration areas need to be identified and restored to insure suitable numbers of salmon continue to support the Southern Residents. Furthermore, protection of existing habitats from shoreline armoring should continue, and removing or modifying shoreline armoring to restore shoreline functions should occur in other areas where feasible.

?? **Support NMFS's Technical Review Teams working on salmon recovery**. Recovery efforts for salmon will be crucial, and recovery efforts along the coast should be prioritized. Likewise, he efforts being made to preserve marine resources by state agencies should also be supported. Recovery goals that include a fish quota for the killer whales should be encouraged.

C. REDUCE POLLUTION IN THE HABITAT OF SOUTHERN RESIDENTS

Reducing the source of contaminants is crucial to preserving the Southern Residents. In addition to the funding needed to address the pollution problems that were noted above, additional pollution strategies should be undertaken to insure the survival of the Southern Residents:

?? **Review NPDES permits to insure water quality is suitable for Southern Residents.** The permits issued within Southern Resident and chinook habitat should be reviewed for discharges of persistent chemicals to determine whether the collective pollution levels of all current permits are affecting Southern Resident and chinook survival. Monitoring data from permitted outfalls should be analyzed to determine the cumulative loading rates of persistent anthropogenic toxicants. Analysis of cumulative toxicant loadings from non-point source discharges, including municipal combined sewer overflows in Seattle, Tacoma and other Puget Sound cities, should also be conducted. Municipal discharges from both sides of the border should be reviewed and addressed.

?? **Clean up and remediation of contaminated sites.** Organochlorine contamination is a major threat to the continued existence of the Southern Residents. Because these pollutants bioaccumulate, it is important to eliminate the sources of pollution before the contaminants can work their way into the lipids of top predators. Current sources of these contaminants must be reviewed, including current and past military bases, so that an appropriate clean up and remediation strategy can be drafted. The clean up and remediation plan must be fully funded so that the contaminant threat can be mediated. Contaminant transport through marine food webs should be modeled to evaluate whether sediment clean-up standards that have been implemented at NPL sites are sufficient to protect long-lived, top predators. New cleanup standards for persistent organochlorine contaminants should be developed and implemented throughout Puget Sound and the Strait of Juan de Fuca, regardless of whether a site has been previously 'remediated' under CERCLA. The reduction and elimination of persistent bioaccumulative toxins from point and storm-water discharges should be required of all contaminated sites.

?? **Coordinated efforts to reduce and respond to oil spills.** Oil spill prevention and vessel safety improvements should include permanently stationed, year round, fully equipped rescue tugs capable of responding within one hour to vessel distress in the Strait of Juan de Fuca, Haro Strait, Boundary Pass, Georgia Strait and Rosario Strait. A permanent rescue vessel at Neah Bay should be included in this network.

D. ADDITIONAL CONSERVATION EFFORTS

?? **Reintroduction of captive Southern Residents.** Pending successful results from release attempts for other killer whales, and assurances that the captive whales do not carry communicable diseases, captive killer whales taken from the Southern Residents should be re-introduced to the population. The effects of the capture period on current population numbers should also be further studied.

?? **Reduce impacts of whale watching.** Whale Watching vessels should be encouraged to use four-stroke engines rather than two-stroke engines to reduce the pollution generated in the Southern Residents' habitat. Limitations should be placed on recreational whale watching vessels to insure the safety of the Southern Residents.

?? **Support decisions to eliminate the use of the most harmful chemicals.** Several governmental agencies and other organizations have begun to indicate that certain toxins should be banned. For example, the UN recently adopted a resolution banning the use and production of twelve of the most dangerous POPs, and the Washington State Department of Ecology recently proposed to ban the use and production of seven toxic chemicals. These efforts should be encouraged.

IX. PROCESSING OF THIS PETITION

This petition is submitted under the provisions of the ESA, 16 U.S.C. §§1531 et seq., 50 C.F.R. 424.14, and the APA, 5 U.S.C. §533. As a petition to revise critical habitat, NMFS is bound to process this petition within a predetermined time frame as defined by CFR 424.14(c) to the maximum extent practicable. The regulations require NMFS to make a finding within 90 days of receipt of this petition as to whether the petition presents substantial scientific information indicating that the revision may be warranted. The finding shall be promptly published in the Federal Register. 50 CFR 424.14(c)(1). Within 12 months of receiving this petition, NMFS is required to determine how it will proceed with the requested revision, and shall promptly publish notice of such intention in the Federal Register. 50 CFR 424.14(c)(3). Petitioner fully expects NMFS to comply with these mandatory deadlines.

SIGNATURE PAGE

This PETITION TO LIST THE SOUTHERN RESIDENT KILLER WHALE (ORCINUS ORCA) AS AN ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT is hereby submitted to the Secretary of Commerce.

Respectfully submitted May 1, 2001.

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For:
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American Cetacean Society
Orca Conservancy
People for Puget Sound
Friends of the San Juans
Washington Toxics Coalition
Cascade Chapter of the Sierra Club
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APPENDIX A. POPULATION VIABILITY ANALYSIS OF THE SOUTHERN RESIDENT KILLER WHALE (*ORCINUS ORCA*).

INTRODUCTION

Once abundant throughout the waters of the Pacific Northwest, the Southern Resident killer whale, *Orcinus orca,* has been declining since 1996 and is now the most imperiled killer whale population in the world. The decline has been attributed to several anthropogenic factors, including a depletion of preferred food stocks, toxic pollution, and disturbance from whale watching boats.

Killer whales in the Pacific Northwest

There are three forms of killer whales in the Pacific Northwest: Transients, Residents, and Offshores. The three forms are distinct genetically, behaviorally, and morphologically (Baird 1999). Although the term "subspecies," or even "species" should perhaps be applied to distinguish these distinct types of killer whales, all are currently classified as one species. We will continue to use the term "population" or "stock" to describe these different types.

Residents are in turn categorized into two stocks: Northern Residents and Southern Residents. The Resident populations have partially overlapping ranges. However, behavioral interactions have not been observed between individuals from different Resident populations, and differences in mitochondrial DNA and physical appearance suggest that the populations are reproductively isolated (Baird and Stacey, 1988; Stevens et al., 1989; Hoelzel and Dover, 1991). The Northern and Southern Resident killer whales appear to have distinct behavioral characteristics, but due to limited data on Offshores it is not known if Offshores also have distinctive behavior (Fellemen et al., 1991; Hoyt, 1990). Southern residents have low genetic diversity for several nuclear and mitochondrial DNA markers implying that inbreeding depression is very likely for this stock (Hoelzel and Dover 1991, Hoelzel et al. 1998).

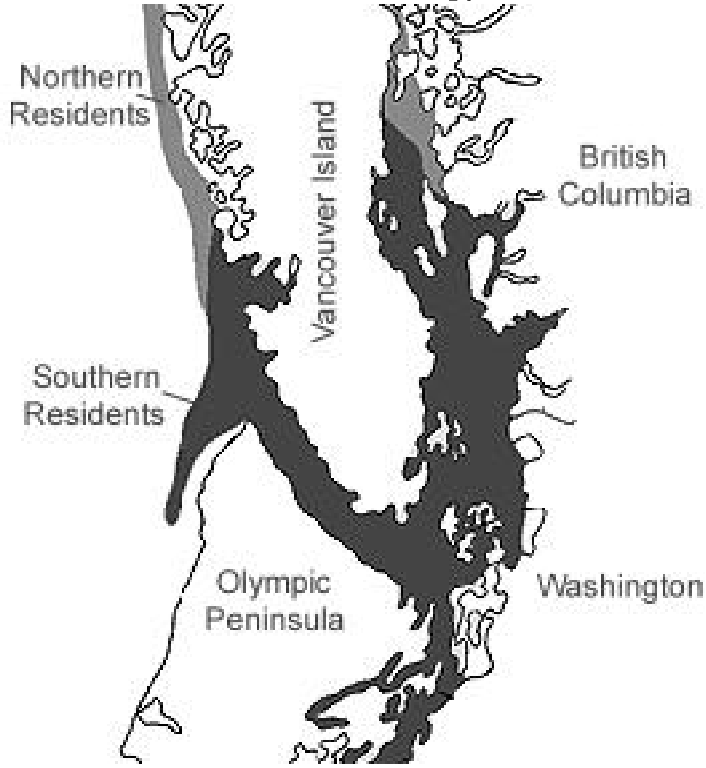
Transient killer whales primarily prey on other marine mammals such as seals, while Residents primarily subsist on fish (Morton 1990). Transients and Residents differ in morphology, group size, social organization, acoustic repertoire, and genetic composition (Ford and Ellis 1999, Bain 1989, Baird 1994, Hoelzel et al. 1998). Transient and Resident populations have overlapping ranges. However, genetic evidence suggests that they have been reproductively isolated for thousands of years (Bigg et al. 1987, Hoelzel et al. 1998). Transients actively avoid Resident pods, and interactions have been rarely reported (Jacobsen 1990, Morton 1990, Barrett-Lennard 1992, Baird and Dill 1995).

Southern Resident demography

The Southern Residents' home range includes the international inland waters of Puget Sound, Juan de Fuca Strait, and Georgia Strait. Although not well documented, it is believed that their home range also includes regions outside the entrance to Juan de Fuca Strait, extending south to Monterey Bay, and north to Cape Scott on Vancouver Island (Figure 1, Ford et al. 1994).

The Southern Residents are divided into three "pods" that tend to travel and feed together in particular "territories." Within pods, Southern Residents are matrifocal, that is, siblings tend to stay in close proximity with their mothers. There is evidence that pods are not necessarily composed of close relatives (Dahlheim and Heyning 1999 p 296). Mating is thought to occur primarily outside of a pod, but within pod mating cannot be ruled out (Hoelzel et al. 1998).

Figure 1. Range map for Resident Killer whales. The Transients overlap ranges of both Northern and Southern Residents. Offshores occupy waters further into the ocean.



Map Courtesy of the Whale Museum

METHODS

The published record of births and deaths for the period 1974-2000 (van Ginneken et al. 2000) with corrections by Dr. David Bain were used to calculate age and sex distributions, and annual mortality and fecundity statistics. These data are shown in the Appendix. Annual age and sex distributions, fecundities and mortalities were calculated from the individual life histories and analyzed by probit regressions and time series analysis in the program SYSTAT to quantify possible trends, cycles, and cross correlations. Probit regressions of mortality and fecundity on time were used with the caveat that the assumption of year-to-year independence is clearly violated. Before doing such regressions, autocorrelations within series were examined before probit regression to confirm that autocorrelations were not substantial or significant.

Averages for life history parameters were then calculated and environmental components of variances estimated by removing pure demographic variance using the method of Lacey et al. (2000). Best estimates of life history variables were then used for successive simulations of the Vortex modeling algorithm (Lacey et al. 2000). Estimates were varied systematically to model the effects of plausible changes in parameters on population extinction probabilities.

The Center for Whale research uses a census year defined as July 1 to June 30. This means that any year cited in the following discussion such as 1973 refers to the year beginning July 1, 1973 and ending on June 30, 1974.

RESULTS AND DISCUSSION

Population trends

A census of the Southern Residents has been taken annually since 1973 by the Center for Whale Research. Records from capture operations extend the record back to 1960, supplementing that census information.

The Southern Resident population numbered at least 100 individuals in the mid-1960s, but is thought to have been much higher (Osborne, Whale Museum, pers. comm.). Since that time, three major declines have occurred in the population (Fig. 2).

The first decline occurred between 1967 and 1972, and was caused presumably by live-capture operations for public display. Approximately 34 Southern Residents were taken during this period, leading to a population decline of at least 30%. The Southern Residents were down to 67 going into the July 1973 census period, the lowest on record (Fig. 2).

After several years of steady recruitment — including a good calf crop in 1976—and low mortality, the population grew to a peak in 1980 (Fig. 2). The second decline occurred from 1980 to 1984, when the population declined from 83 to 74 in four years, a 3% annual rate of decline. L pod appears to have suffered the greatest reduction, while J pod appeared to be unaffected during this period. This period of decline seems to have resulted from elevated mortality of older females and juveniles in concert with lower fecundities (Figs 2-4).

A period of steady recovery continued until 1996 (Fig. 2) when mortalities rose and fecundity declined (Fig. 4). All classes have been affected by this population decline, and all three pods suffered concurrent declines (Fig. 3). As in the 1980-1984 decline, juvenile and post-reproductive female mortalities were elevated. However unlike the earlier decline the recent decline also involves deaths of older juveniles, reproductive females and young adult males. Whatever was causing the deaths may also have eliminated fecundity in 1996. Fecundity thereafter seems to have been reduced relative to the mid-1990s (Figs. 2, 3).

From 1996-2000, the Southern Resident stock has declined from 97 to 82, approximately 4.5% per year. Several factors make this recent decline unique and alarming:

- The decline is the largest on record without an obvious cause such as captures or hunting, and has not been seen in other Resident killer whale stocks.
- The decline is driven by an increase in mortality across all age and sex classes but particularly of young adults, along with lower fecundity.
- The concentration of organochlorine pollutants in Southern Resident individuals has recently been determined to be greater than levels found in other marine mammals where pathological effects have been documented (Ross et al. 2000).
- The Southern Residents' main food source is known to be declining.
- Disturbances caused by whale watching and water traffic have increased dramatically, potentially disrupting normal behavior.

Figure 2. Southern Resident population 1973-present

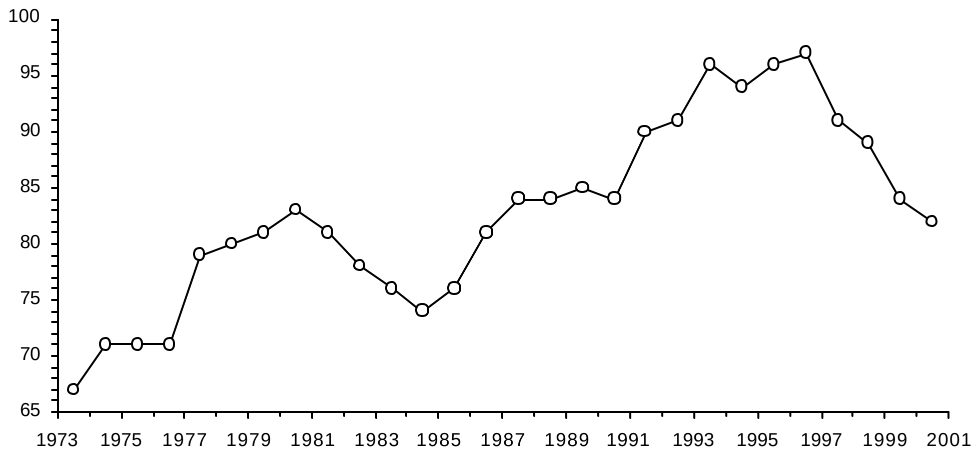
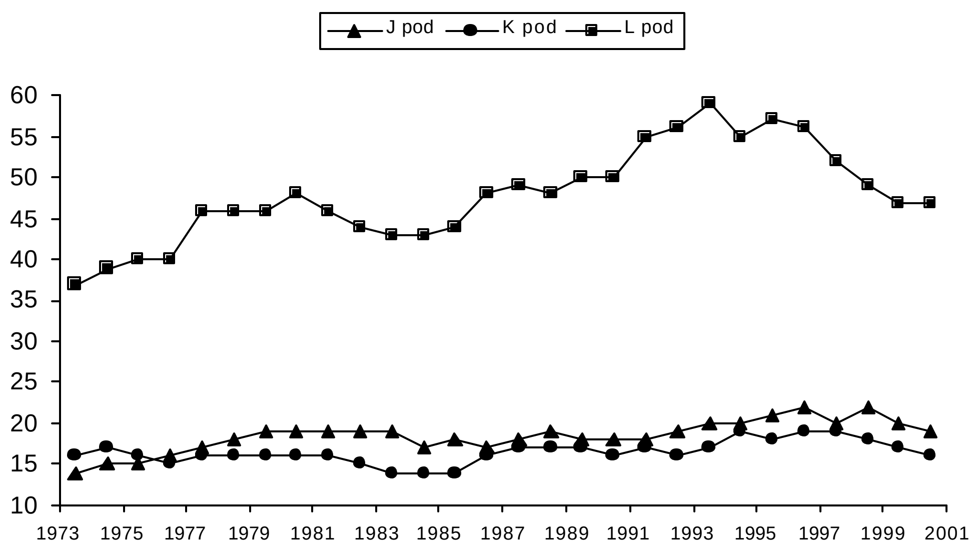


Figure 3. Populations of each pod



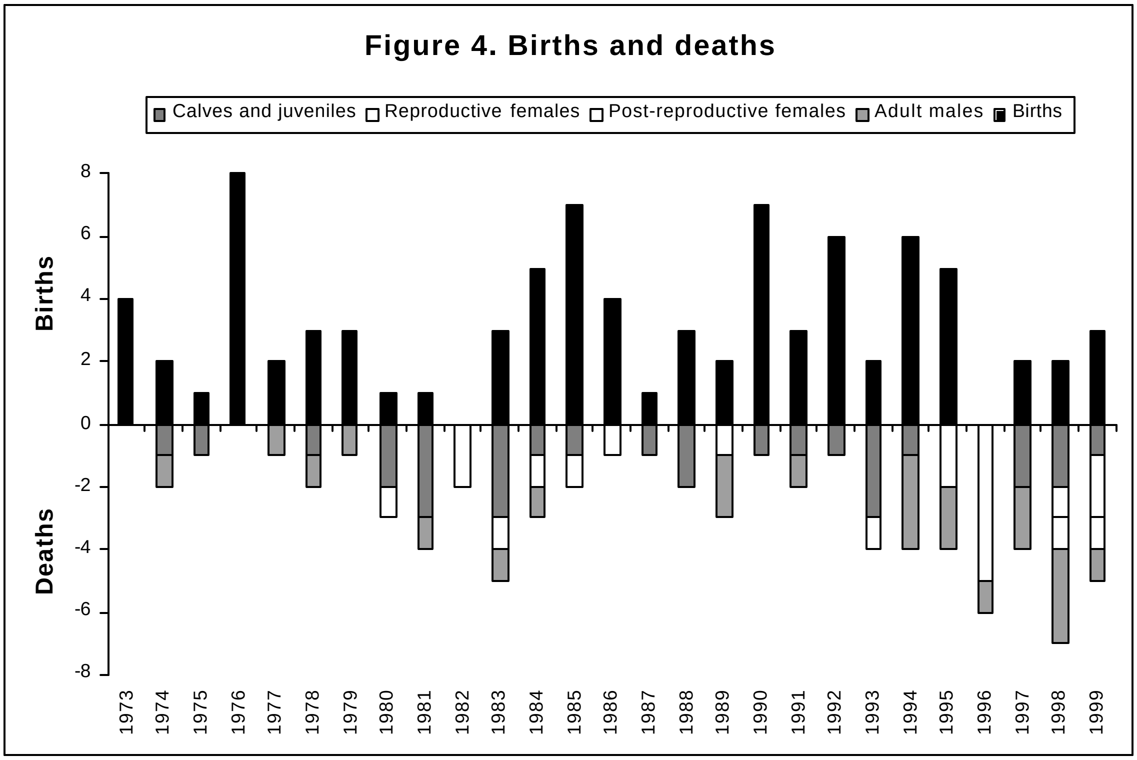


Figure 4. Births and deaths
Calves and juveniles
Reproductive females
Post-reproductive females
Adult males
Births
Births
Deaths
8
6
4
2
0
-2
-4
-6
-8
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

Sex ratio, mating system, and mate limitation

The total of 65 births observed since 1973 show a male-biased primary sex ratio of 57% males (Binomial SD 6%). This may represent an adaptation to compensate for female-biased sex ratios in adult life that result from higher male mortalities. However, it was not significantly different from 50% sex ratio expected with Mendelian segregation (Binomial test P=0.11).

It appears that much of the fluctuation in population is attributable to fluctuations in juvenile and female numbers, while male numbers have been relatively steady (Fig. 5). Reproductive adult sex ratio is consistently female-biased (Fig. 5). The adult sex ratio ranged from 36% in 1980 to 49% in 1988, with an overall mean of 42% males (SD 3.5%).

However, the pod structure of the population results in radically different operational sex ratios for different pods (Fig. 6). Females of one pod tend to mate with males of another, although this is not always the case (Hoelzel et al. 1998). Since L is the largest pod, available J and K adult males as a proportion of all males is less than the proportion of L females in the population, showing that there is a scarcity of available mates for L-pod females (Fig. 6). Conversely the proportion of available mates for J and K pod females is greater than the proportions of females in those pods, showing that mates are in excess for females in these smaller pods (Fig. 6). However, the proportions of all calves produced by each pod are concordant with the relative proportions of reproductive females in the pod (Binomial tests of significance). Fecundity did not differ significantly between pods (Fig. 6).

To test a mate limitation hypothesis for L pod, namely that fecundity within L is limited by adult male numbers in K and J pods, we examined cross correlations between L pod fecundity and sex ratio time series. Operational sex ratio for L pod was calculated as the number of adult males in the K and J pods per reproductive female in the L pod. No significant correlation was found, indicating that mates were not limiting for L females during the period of study.

Although Dahlheim and Heyning (1999) state that killer whales are polygamous, no direct field observation seems to exist to support this claim. Absolute numbers of calves produced by all L pod females were compared with number of possible fathers (adult males in J and K pod). Only L pod was examined because it was the only male-scarce pod of the three, and therefore the most likely to show clear polygamy. In all years, numbers of calves produced were less than the numbers of possible fathers. This was true even assuming a late minimum age of 15 for male sexual maturity. Although polygamy is likely based on morphological evidence, available data do not provide unambiguous evidence of polygamy among Southern Residents.

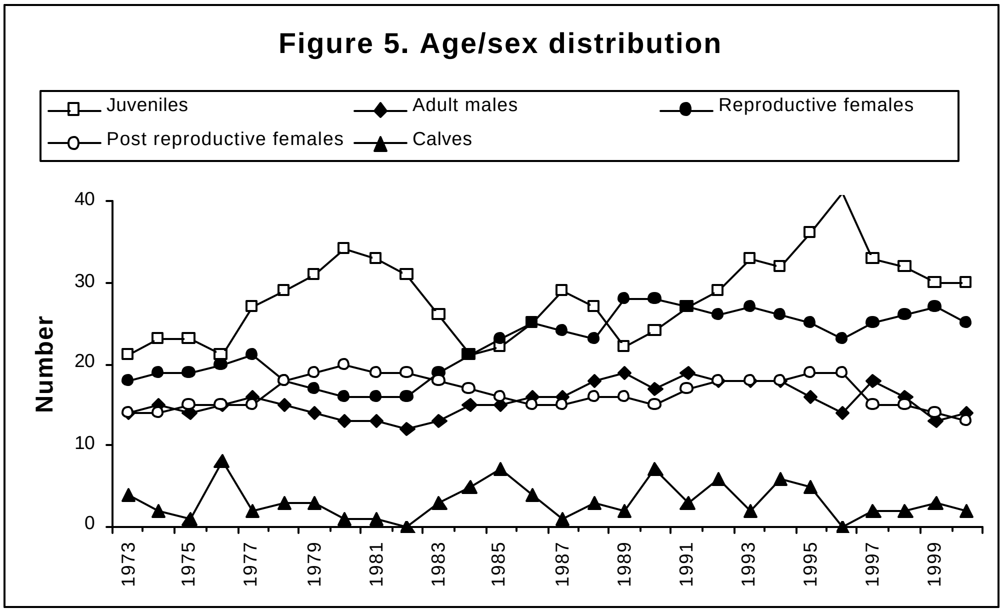


Figure 5. Age/sex distribution
Juveniles
Adult males
Reproductive females
Post reproductive females
Calves
Number
40
30
20
10
0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999

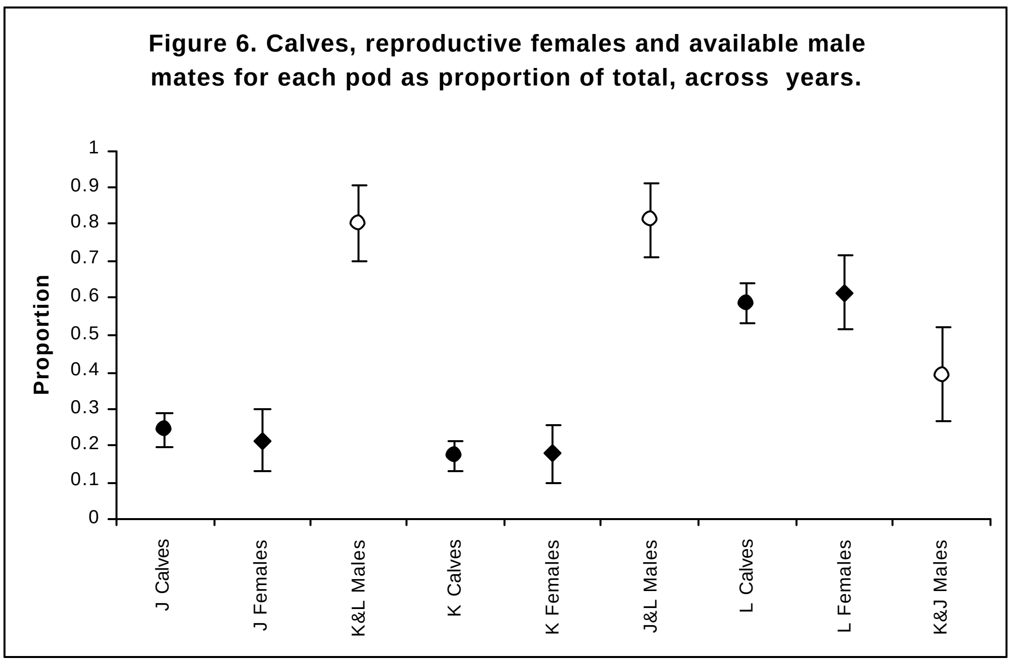


Figure 6. Calves, reproductive females and available male mates for each pod as proportion of total, across years.
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
J Calves
J Females
K&L Males
K Calves
K Females
J&L Males
L Calves
L Females
K&J Males

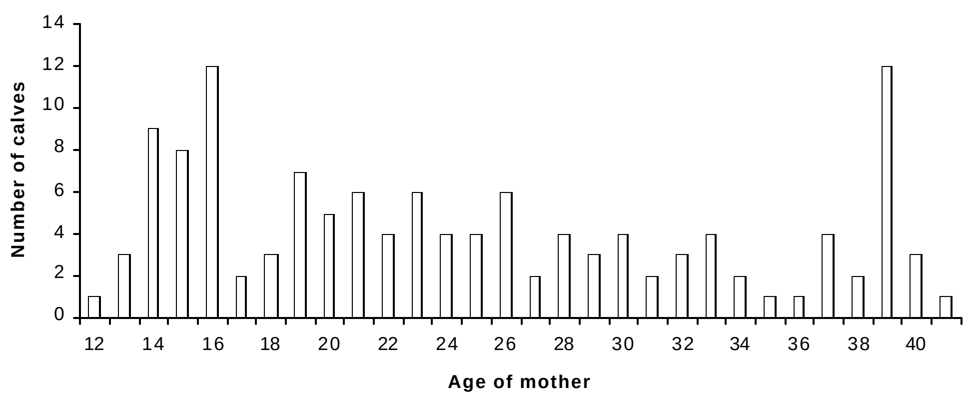
Fecundity

Fecundity is calculated as the number of calves per year per female of reproductive age. The minimum and maximum breeding ages are estimated further below as 13 and 40 respectively for females. Fecundity had a skewed age-specific distribution of high early peak with a slow decline to reproductive senescence, but also with a clear late peak of reproduction just prior to reproductive senescence (Fig. 7). Fecundity showed a suggestion of cyclic variation through time (Fig. 8). However, there were no significant autocorrelations within the series and Fourier analysis of the de-trended series found no significant periodicities.

The possibility of density dependence was examined by calculating cross-correlations between fecundity and population size series. No significant cross-correlations were found. The cross-correlation between fecundity and the population size three years prior was marginally significant (P=.088), suggesting the possibility of lagged density dependence of fecundity. Probit regression of fecundity on year did not show any significant time-trend. However, fecundity during the recent period of population decline is evidently lower than the average across all years.

Other studies have suggested that fecundity is density dependent (reviewed in Dahlheim and Heyning 1999). Brault and Caswell (1993) suggested that variance among pods in population growth rates is largely due to differences in fecundity.

Figure 7. Age specific fecundity across all years



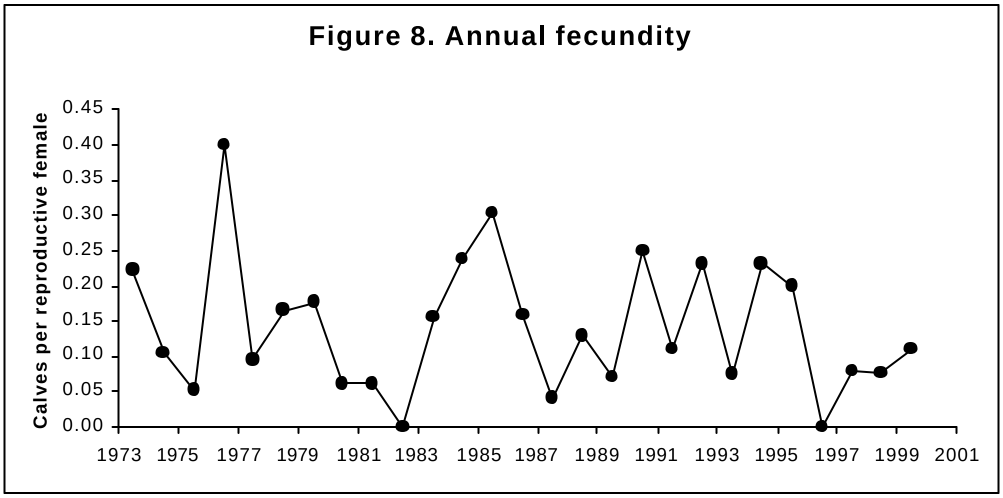


Figure 8. Annual fecundity
Calves per reproductive female
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001

Minimum and maximum breeding ages

The earliest recorded female age at breeding was 12 years (Fig. 7). Although this female's age is known exactly, her calf died within the year.

The next age for first breeding was 13. Three females gave birth at age 13. For two of these female ages were known exactly, not estimated. Olesiuk et al. (1990) cite 15 as the age at which females first gave birth to "viable calves." The available data do not support this observation. Calves of the three 13-year-old mothers all survived their first year. For the purposes of population modeling however, the median age of first reproduction is used, which was 16 for all recorded first births of Southern Resident females.

Olesiuk et al. (1990) found that male sexual maturity, defined as time at which male dorsal fin was distinguishable from female ranged from 10 to 17.5 with mean of 15 for males. Male reproductive success is harder to observe than for females. Male reproductive maturity was assumed for purposes of calculating life history parameters to occur at age 11. However for purposes of population modeling, the average age at birth of first offspring of males is used, as for females. As gestation averages 517 days (Dahlheim and Heyning 1999), an average age at first reproduction of 16 was used for males, the same as the median for females.

Olesiuk et al. (1990) estimated that the age of last breeding averaged 40 years for females. The maximum age of a female giving birth was 41 in the available data (Fig. 9). However, the age of this female and indeed the ages of any females older than 27 were all estimated, not known exactly. Hence an estimate of 40 years for maximum breeding age is the best available.

Female longevity is similar to that for modern humans. The two oldest living females are "Granny" (85) and "Lummi" (84). However, the birth years of these females and hence their ages are estimated, not known.

No maximum age for male sexual reproduction is recorded in the literature. However, males have higher mortalities and shorter lifespans than females. The maximum recorded age for males is 51, the present age of "Ruffles." However, no other male ages above 43 have been recorded, and as for females, the actual ages for males older than 27 are not known with certainty.

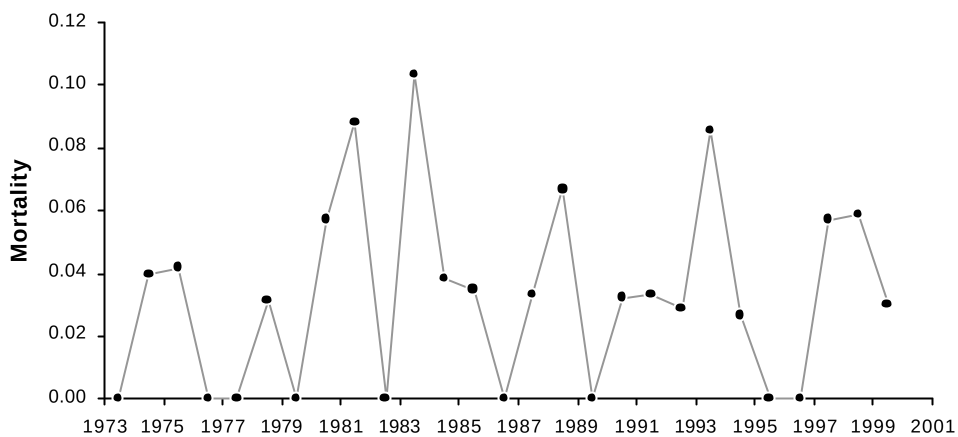
Age 40 was set as the maximum breeding age for both males and females for purposes of population modeling.

Calf and juvenile mortality

The "calf" stage is defined from birth to one year of age. Killer whales face their highest mortality rates during this period, up to 50% according to Olesiuk et al. (1990). However, great variability in mortality estimates is expected from the small numbers of calves birthed in any one year and the limitations of observation. Therefore calves and juveniles were considered as a single class for calculation of life history parameters.

Juveniles were defined as males from 1 to 10 years of age, and females 1-12 years of age. Annual mortality of combined juvenile and calves also showed extreme variability, but the variability showed no significant pattern or trend in time series analysis (Fig. 9). There were no significant cross-correlations between population size and calf or juvenile mortality.

Figure 9. Calf and juvenile annual mortality



Adult mortality

Reproductive-age females are defined as females between the ages of 13 and 40. Reproductive female mortality was zero for every year except 1998 and1999 (Fig. 10). Probit fitted regression on year was not significant, possibly due to low absolute numbers.

Post-reproductive females are defined as females age 41 and over. The data show an increase in mortality in recent years, with a dramatic peak in mortality in 1996 (Fig. 10). Probit regression of post-reproductive female mortality on year was statistically significant.

Figure 10. Female mortality

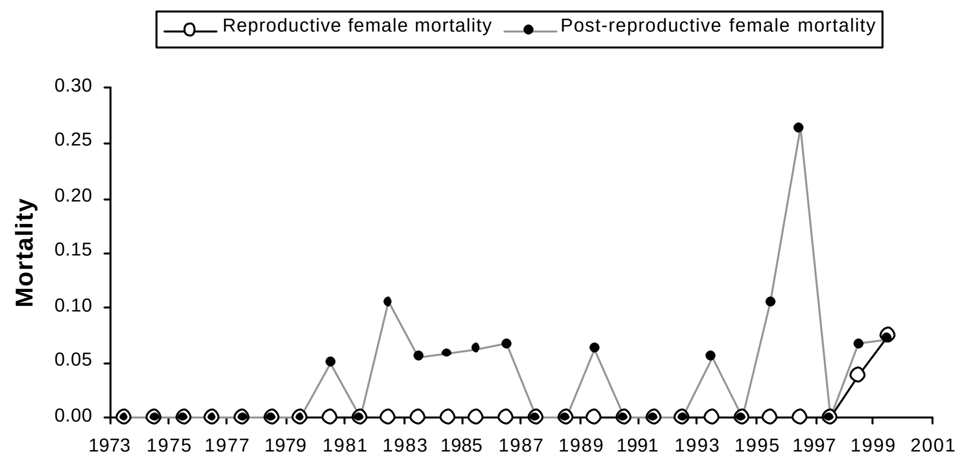
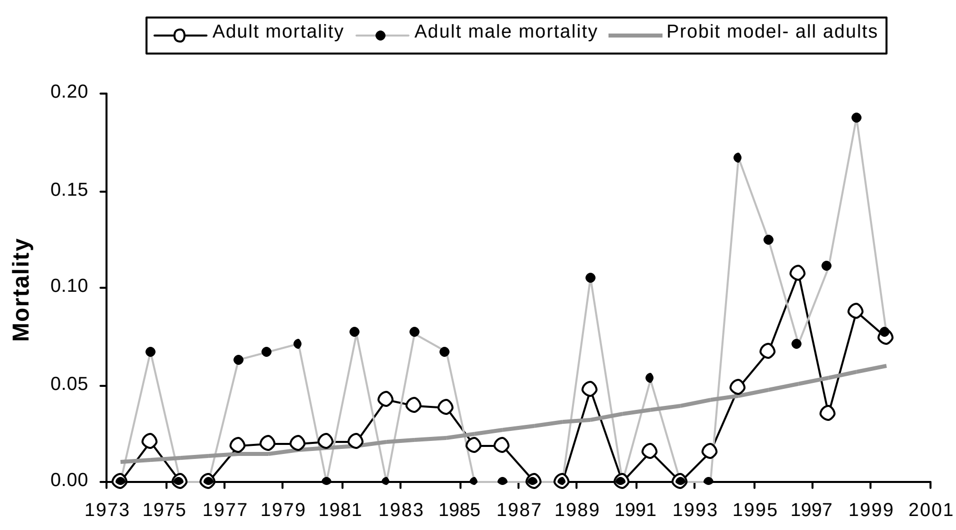


Figure 11. Total adult and adult male mortality



Adult male mortality is defined as mortality for males age 11 and over. Male mortality was highly variable as for other classes analyzed. There was no significant probit regression of adult male mortality on year. However the probit regression of mortality of all adults on year was significant (Fig. 11).

There was no significant cross-correlation between fecundity and mortality of any age/sex class. However, post-reproductive female, adult male and total adult mortality were significantly positively cross-correlated with population size in the previous 2-3 years in time series analysis.

This indicates that either mortality for adults is density dependent, with cyclic population upswings above carrying capacity driving upswings in mortality, or that cycles in exogenous environmental factors drive both mortality cycles and population cycles. Brault and Caswell (1993) have argued that intra-pod growth rates are controlled in a density dependent fashion. Without additional independent evidence, however, it is not possible to determine which of the above hypotheses fit the data. The Vortex population extinction model cannot incorporate lagged density dependence.

The years from approximately 1994-present have seen a significant downturn in adult survival (Fig. 11). This and the reduced fecundity since 1996 (Fig. 8) are the proximate causes of the population decline since 1996. Whether this is a trend that will persist or is part of a longer term demographic or environmentally driven cycle is impossible to determine with present data.

Population Viability Modeling

Stochastic population simulations using the algorithm Vortex v 8.41 (Lacey et al. 2000) were calculated for different sets of parameters, based on the following general criteria and assumptions:

1. 200 iterations were run for a maximum time frame of 300 years.
2. Life table parameters were calculated as described in Methods (see Table 1). Parameters were assumed to vary randomly with time with the estimated environmental variance. Arithmetic means and standard deviations of annual mortalities and fecundities across years were used as basic parameters in the model. Binomial demographic variance[1] was subtracted from sample variance of mortality or fecundity to estimate the environmental component of standard deviation of the parameters. Modeling of trend or cyclic patterns is not possible in Vortex. This assumption is conservative in that it fails to account for possibly declining survival or fecundity due to environmental deterioration.
3. No age structure was defined. Simulations began at the calculated stable age structure and the population size observed on July 1, 2000 of 82 individuals.
4. Mating was assumed freely polygamous in a single, panmictic population, ignoring social structure, without immigration or emigration. This underestimates the extinction probability because it ignores the restricted mating system of killer whales. The probable effects of male limitation at low population sizes were accounted for by incorporating an Allee effect (Fig. 11) at population sizes below 20.
5. Average age of first breeding for both females and males was 16. This parameter was varied in some of the models. All adult males were assumed to be in the breeding pool.
6. Maximum breeding age was 40 for both sexes.
7. Twinning was assumed not to occur. Hence fecundity is equivalent to the percent of reproductive females breeding in any year.
8. Sex ratio at birth was set to the observed sex ratio at birth in the data of 57% males (N=65), including only those births that were recorded with certainty.
9. Carrying capacity was set arbitrarily at 100, just above the maximum population size in the record (Fig. 2).
10. No concordance between environmental variance in mortality and variance in fecundity. Cross-correlations between fecundity and mortality time series were found to be not statistically significant.
11. Models incorporated two levels of inbreeding based on data in Ralls et al. (1988). The number of lethal equivalents per individual for humans and chimpanzees of 2.0 was taken as a conservative minimum. Killer whale longevity and social structure as some similarities to higher primates. However, Cetaceans are closer phylogenetically to Artiodactyls. The means of lethal equivalents calculated for eight species of captive wild-caught artiodactyls from Table 2 of Ralls et al. (1988) was found to be 2.975. Thus a high limit of 3.0 lethal equivalents was also used in Vortex simulations, with 50% of genetic load being due to lethal alleles.

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[1] The average across years of binomial variance p*(1-p)/(N-1) where p is proportion of class dying and N the number in the class.

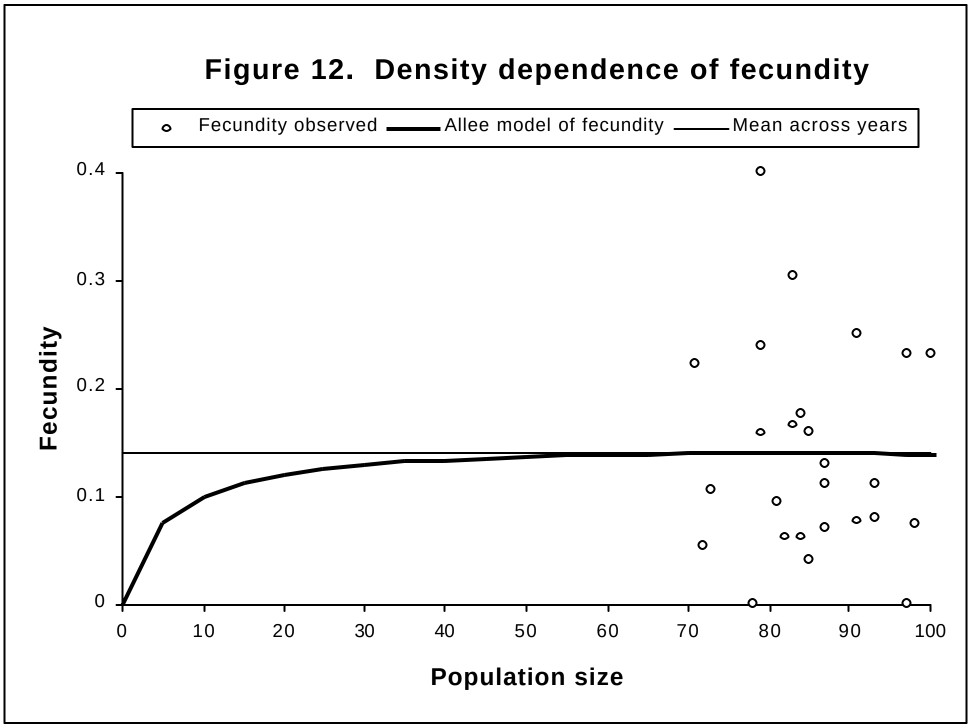


Table 1. Annual mortality and fecundity of Southern Residents: Means across years and environmental components of standard deviation (ESD).

Period		Calf and juvenile annual mortality (%)	Reproductive Female Mortality (%)	Male Mortality (%)	Fecundity (%)
1973-pres	Mean	3.4	0.4	4.9	14.1
	ESD	0.0	1.0	0.6	6.1
1994-pres	Mean	3.7	1.6	10	11
	ESD	0.0	1.6	0	5.1

Table 2: Results of Vortex models for eight sets of parameters.

MODEL PARAMETERS	Model 1 1974-2000 data	Model 2 1974-2000 data + high inbreeding	Model 3 1974-2000 data + Allee effect	Model 4 1974-2000 data + Catastrophes	Model 5 1974-2000 data + high inbreeding + Catastrophes	Model 6 1994-2000 data	Model 7 1974-2000 data + 1994-2000 female mort.	Model 8 1974-2000 data + 1994-2000 female mort. + high inbreeding + Catastrophes
Lethal equivalents per zygote	2	3	*	*	3	*	*	3
Fem fecundity as % giving birth (ESD)	14.1 (6.1)	*	a	*	*	11.0 (5.1)	*	*
Calf and Juvenile Mortality % (ESD)	3.4 (0.0)	*	*	b	b	3.7 (0.0)	*	b
Reproductive female mortality % (ESD)	0.4 (1.0)	*	*	b✍	b✍	1.6 (1.6)	1.6 (1.6)	1.6 c (1.6)
Adult Male Mortality %, (ESD)	4.9 (0.6)	*	*	b	b	10.0 (0.0)	*	b
MODEL RESULTS								
Finite rate of increase ?	.997	.997	.999	.995	.995	0.98	.99	.989
% extinct at 100 yr	0	0	0	0	0	28.5	1.5	5
% extinct at 200 yr	6.5	9.5	17	13.5	20	100	43.5	59
% extinct at 300 yr	35.5	44.5	64	58.5	62	100	92	99
Median years to extinction	>300	>300	269	274	265	113	213	186

* same as baseline model 1.

a - fecundity = $[15 - (15-14.5)*(N/K)^4]*N/(N+5)$ see Fig. 12

b - baseline mortality plus catastrophes at 1% probability of occurrence in any one year, that eliminate all reproduction for a year, and kill 11% of all individuals regardless of age or sex.

c- plus catastrophes as in b.

Model 1. Basic model. This model used all life table data for 1974-2000 incorporating inbreeding depression at the 2.0 average lethal equivalents reported for higher primates. This model forecast population persistence with a low probability of extinction in 300 years. The model is conservative in that it assumes no net future trend or cycles in life history parameters, no mate limitation, no catastrophes and no projected change in environment.

Model 2. Higher inbreeding. Inbreeding depression is highly likely both as a result of small population size and within pod-matings. Genetic diversity in Southern Residents is very low, suggesting that effective population size is low (Hoelzel et al. 1998). Unfortunately no quantitative estimate of inbreeding depression is available for Southern Residents. The best available estimate may be the mean lethal equivalents observed for wild artiodactyls of 3.0 per individual. This is higher than that observed for higher primates but lower than the median for all mammals of 3.14 (Ralls et al. 1988). Predicted extinction risk increased but was still low, after inclusion of inbreeding depression at 3 lethal equivalents per individual.

Model 3. Allee effect. Vortex does not allow explicit modeling of the pod-based social structure of the Southern Residents and thus is likely to underestimate extinction risk. This is especially true when total population gets smaller, and when smaller pods such as J and K are likely to have no males, reducing the chance of females in other larger pods finding a mate. Calculations of binomial probabilities of there being no males in one or more pods show that this possibility becomes significantly different from zero below population size of 20. Fecundity may be reduced for small populations due to stochastic mate scarcity for some females, an Allee effect. Vortex models the Allee effect with a geometrically declining fecundity as a function of population size as shown in Fig. 12. Model parameters were selected to best fit the mean observed fecundity, and to result in appreciably lower fecundities only at population sizes below 20. Introduction of an Allee effect increased predicted extinction risk substantially to 64% in 300 years. Although little empirical evidence is available, it is known that pods are not obligately exogamous making an Allee effect less likely (Hoelzel et al. 1998).

Model 4. Catastrophes. The Exxon Valdez oil spill in Alaska resulted in the death of about one third of all members of one Northern Resident killer whale pod (Matkin and Saulitis 1997). To model the effect of such a catastrophe on Southern Residents, a one-year zero fecundity and death of 11% (A third of one or three pods) of all Southern Residents was incorporated with a chance of one event per one hundred years. This increased predicted extinction risk to a moderate level of 58.5%, with a median extinction time of 274 years.

Model 5. Catastrophes and higher inbreeding. Adding the higher limit of inbreeding of 3 letha equivalents per individual to model 4 resulted in only minor increases in extinction risk to 62% in 300 years.

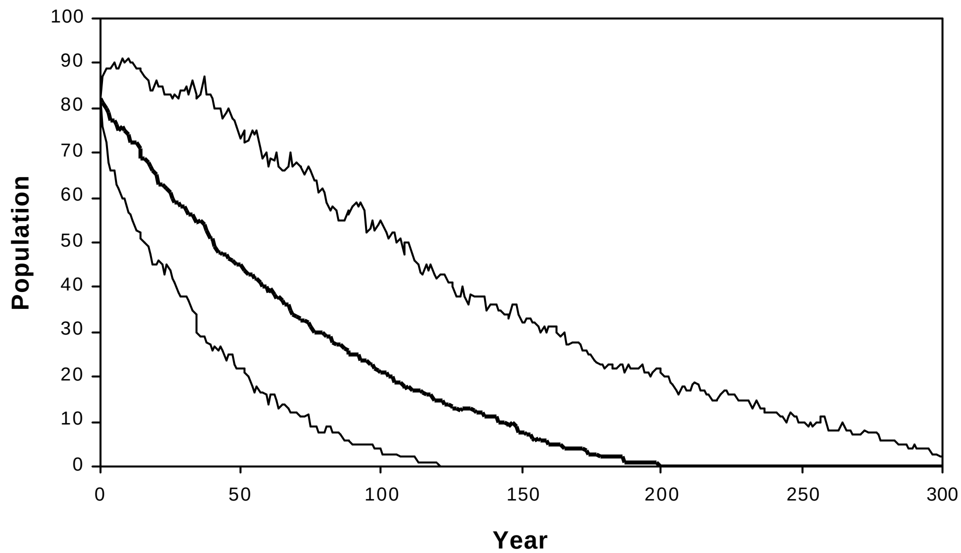
Model 6. Projecting recent reductions in adult survival, fecundity. The assumption in models 1-4 that 1974-2000 estimates of mortality and fecundity will continue indefinitely is conservative. The recent declines in survival and mortality could reflect deterioration in environmental conditions that will persist rather than revert to previous conditions. Only demographic data for the recent years of increased adult mortality and lower fecundity 1994-

2000 were used for this model. Mortality estimates were all higher and fecundity estimates lower than those calculated on the entire data set (Table 1). Predicted extinction risk was drastically lower than for foregoing models, at 100% within 200 years and a median time to extinction of 113 years.

Model 7. Higher reproductive female mortality. It could be however, that the recent decline in juvenile survival, adult male survival and fecundity are temporary phenomena, as these variables have shown considerable fluctuation throughout the record. Reproductive female mortality in contrast, was zero without any fluctuation until the recent years of 1998 and 1999 (Fig. 9). Therefore the recent reduction in survival of this class may be a new phenomenon that could well persist into the future. Model 1 parameters were used with the exception of the higher female mortality observed in recent years. Just this increase in mortality had a dramatic impact on predicted extinction risk, increasing to 92% in 300 years with a median time to extinction of 213 years (Table 2). Extinction risk is clearly very sensitive to reproductive female mortality in the Vortex model.

Model 8. Higher female mortality with higher inbreeding and catastrophes. Both inbreeding depression at a high level and recurrent catastrophes are plausible and likely. Although pod structure may not necessarily result in an Allee effect at low population sizes, inbreeding depression is highly likely both as a result of small population sizes and within pod matings (Hoelzel et al. 1998). When incorporated with elevated female mortality as in Model 6, predicted extinction risk was 99% in 300 years with median extinction time of 186 years (Table 2). Fig. 13 shows the range of population trajectories that are generated. Note that fig. 13 shows medians (and 95% C.I.) for total population sizes in each year, and thus also shows median and 95% C.I. of times at which total population falls to zero. This is not the same as extinction time, however. Extinction time is based on loss of all individuals of one sex, and is always less than than time for population to completely die out.

Figure 13. Model 8 predictions- medians and 95% confidence intervals of population sizes.



Effects of earlier maturity varying carrying capacity, monogamy.

Other model iterations not presented here showed that earlier male maturity, or later maximum breeding age (45) did not significantly affect model 1 predictions. Earlier female maturity did however significantly reduce extinction risk. However, median age of first breeding is well known for females and there is no compelling reason to simulate an earlier age.

Increase of carrying capacity to 150 did not significantly alter predicted extinction risk.

Model predictions were little affected by mating system. Monogamy only slightly increased predicted extinction risk over that found for polygamy.

Complete removal of inbreeding and use of a theoretical 50% sex ratio both substantially reduced predicted extinction risk. Vortex was sensitive to these parameters.

Limitations of the Vortex model

The Vortex model adds more sophistication to extinction prediction than provided by the more elementary approach of calculating intrinsic rate of increase or O. However, use of these additional modeling features is only as good as the data available to estimate model parameters.

Many model parameters that have a substantial impact on predictions are not well known or are known for too short a period to permit strong confidence in conclusions. The model was sensitive to primary sex ratio, Allee effect, inbreeding depression, and female mortality and fecundity, and yet confidence in the long-term predictions for some of these parameters is not high.

Small changes in basic parameters of inbreeding and sex ratio at birth were found to have large impacts on model predictions. All these parameters therefore need more empirical research to permit more realistic prediction. It may be that Vortex is artificially sensitive to these parameters, and alternate modeling may be required to determine whether Vortex predictions are robust.

All the foregoing Vortex models use a "best case" set of assumptions of random mating, uniform age-specific fecundity or reproductive capacity and no net trends in mortality or fecundity. Real life violations of these assumptions are all likely to increase the risk of extinction beyond those predicted here.

In particular there is no provision in Vortex for delayed density dependence or other cyclic dynamics that typically result from multi-species interactions. Incorporation of cyclic dynamics to population models is likely to increase extinction risks for small populations beyond those obtained by Vortex. Other limitations are detailed by Lacey et al. (2000).

Vortex does not permit modeling of the pod mating structure of killer whales. Incorporation of a theoretical Allee effect (Fig. 12) provides an approximation to the mate limitation that may occur in small populations. More explicit modeling of the pod structure and mating system is needed for more accurate prediction of this effect.

CONCLUSIONS

The foregoing models suggest that the Southern Resident population is likely to go extinct in the foreseeable future. All life history parameter sets derived from various sets of the available data generated estimates of intrinsic rates of increase (O) below 1, indicating that the population is expected to decline in the long term, if present life history conditions persist.

None of the foregoing models incorporate density dependence or the cyclic or chaotic dynamics that are expected from delayed density dependence or interactions with prey populations. Cyclic or chaotic dynamics are suggested by the actual population record (Fig. 2) but could not be simulated by Vortex. It is likely therefore that extinction risk has been under-estimated, as cyclic dynamics for small populations are more likely to result in stochastic extinctions.

Although the life history record for the Southern Residents seems extensive, it is in fact quite a small sample for such long-lived animals, and prediction would be greatly improved by further observation. Of greatest concern is the recent rise in reproductive female mortality as part of a significantly rising trend in adult mortality generally (Fig. 11). If the reduced fecundity and adult survival seen in the census years after 1994 continues indefinitely or worsens rather than returning to the low levels seen over the previous 25 years, the risk of extinction of the Southern Resident population is high within the next 100 years. Effort should therefore be directed at identifying the causes of the recent increases in adult mortality, and finding ways of halting or mitigating any human impacts that might be implicated.

Models 5 and 8 may be regarded as the most plausible models obtainable within the limitations of the Vortex algorithm, for estimation of extinction risk. Model 5 may be seen as the best case and Model 8 the worst. Model 8 differs from model 5 only in projecting the recent increase in reproductive female mortality into the future and gives the plausibly worst scenario for extinction risk. Both models incorporate the higher estimate of inbreeding depression, catastrophes at low probability based on known historical events, and the full record of mortality and fecundity.

Although some caution is needed in projecting the possibly temporary circumstance of increased female mortality into the future, the precautionary principle requires that the worst case scenario should be considered probable, therefore warranting protection for this population to achieve recovery to historical levels with an adequate margin of safety that will allow the population to survive likely future catastrophes and perturbations.

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APPENDIX: Life histories of all known Southern Resident killer whales.

Males and sex unknown

No.	Name	Sex	BORN	DIED
J01	Ruffles	M	1949*	
J03	Merlin	M	1952*	1994
J06	Ralph	M	1957*	1998
J15	N/A	M	1975	1981
J18	Everett	M	1977	1999
J21	E.T.	Unk.	1981	1983
J23	N/A	M	1986	1991
J24	N/A	Unk.	1971	1971
J25	N/A	Unk.	1987	1988
J26	Mike	M	1991	
J27	Blackberry	M	1991	
J29	N/A	M	1992	1992
J30	Riptide	M	1994	
J33	Keet	M	1995	
J34	DoubleStuf	M	1997	
J36	N/A	Unk.	1999	
J37	N/A	M	2000	
K01	Taku	M	1954*	1997
K02	N/A	M	1949*	1974
K05	Sealth	M	1952*	1991
K15	N/A	Unk.	1970*	1975
K17	Pacheena	M	1965*	1994
K19	Neptune	M	1952*	1984
K20	Spock	M	1985	
K21	Cappuccino	M	1985	
K23	N/A	Unk.	1988	1988
K24	N/A	Unk.	1990	1990
K25	Scoter	M	1990	
K26	Lobo	Unk.	1992	
K29	Sigurd	M	1995	1998
K31	Tatoosh	M	1998	
K32	N/A	Unk.	2000	
K46	N/A	Unk.	1973	1981
L01	Oskar	M	1958*	
L06	Podner	M	1961*	1983
L08	Moclips	M	1957*	1977
L10	Okum	M	1958*	1997
L13	Orpheus	M	1949*	1979
L14	Cordy	M	1971	1989
L16	N/A	M	1948*	1978
L20	Trident	M	1954*	1981
L33	Chinook	M	1962*	1995
L36	N/A	Unk.	1974	1974
L38	Dylan	M	1964*	1998
L39	Orcan	M	1974	
L41	Mega	M	1976	
L42	Mozart	M	1972*	1994
L44	Leo	M	1973	1998
L48	Flash(1)	Unk.	1976	1983
L49	N/A	Unk.	1978	1980
L50	Shala	M	1972	1989
L52	Salish	Unk.	1979	1983
L56	Disney	Unk.	1977	1981
L57	Faith	M	1976	
L58	Sparky	M	1979	
L59	Fred	Unk.	1978	1978
L61	Astral	M	1972*	1996
L62	Cetus	M	1979	
L63	Scotia	M	1983	1995
L64	Radar	Unk.	1984	1985

Females

No.	Name	BORN	DIED	Offspring				
J02	Granny	1915*		J12?				
J04	Mama	1951*	1995	J11	J15	J19	J21	
J05	Saratoga	1937*	1996	J13?	J17			
J07	Sucia	1938*	1983	J03?	J16			
J08	Spieden	1932*		J04				
J09	Neah	1922*	1985	J05?	J10?			
J10	Tahoma	1961*	1999	J18	J20	J22		
J11	Blossom	1971*		J25	J27	J31		
J12	Sissy	1934*	1996	J24	J14			
J13	N/A	1970*	1980					
J14	Samish	1973		J23	J30			
J16	Slick	1970*		J26	J33	J36		
J17	Princess Angeline	1976		J28	J35			
J19	Shachi	1978		J29				
J20	Ewok	1980	1998	J32				
J22	Oreo	1984		J34				
J28	Polaris	1992						
J31	Tsuchi	1994						
J32	Rhapsody	1995						
J35	Tahlequah	1997						
K03	Sounder	1956*	1998	K15?	K14	K16	K29	
K04	N/A	1931*	1999	K12?				
K07	Lummi	1916*		K11?	K02?	K01?		
K08	Tumwater	1929*	1989	K05?	K03?			
K11	Georgia	1932*		K13				
K12	Sequim	1970		K22	K28	K31		
K13	Skagit	1971		K20	K25	K27		
K14	Lea	1976		K23	K24	K26		
K16	Opus	1984						
K18	Kiska	1947*		K40?	K17?	K46	K21	
K22	Sekiu	1986						
K27	Deadhead	1993						
K28	Raven	1993						
K30	N/A	1928*	1982	K19?				
K40	Raggedy	1962*						
L02	Grace	1953*		L39	L67	L78	L88	
L03	Oriana	1946*		L33?	L51	L59	L74	
L04	Sonar	1950*	1996	L27?	L61?	L55	L86	
L05	Tanya	1963*		L58	L73			
L07	Canuck	1960*		L53	L76			
L09	Hopi	1930*	1996	L03?	L05?			
L11	Squirty	1955*		L42?	L41	L64	L77	L94
L12	Alexis	1930*		L11?	L10?			
L15	Gracie	1929*	1980	L13?	L20?			
L21	Ankh	1937*		L47	L48			
L22	Spirit	1970*		L75	L79	L89		
L23	N/A	1939*	1982	L14?	L49?			
L25	Ocean Sun	1924*		L23?				
L26	Baba	1955*		L60	L52	L71	L90	
L27	Ophelia	1964*		L62	L68	L80	L93	
L28	Misky	1950*	1993	L38?	L69	L85		
L32	Olympia	1954*		L22?	L44	L56	L63	L87
L35	Victoria	1942*	1996	L01?	L50?	L54	L65	
L37	Kimo	1932*	1984	L07?	L43?			
L43	Jelly Roll	1972*		L72	L95			
L45	Asterix	1937*	1995	L36	L57			
L47	Marina	1973		L83	L91	L99		
L51	otka	1972*	1999	L84	L97			
L53	Lulu	1976						
L54	I	1976						

L68 Elwa	M	1984	1994
L69 Sumner	Unk.	1983	1984
L71 Hugo	M	1985	
L73 Flash	M	1985	
L74 Saanich	M	1985	
L76 Mowgli	Unk.	1986	1987
L78 Gaia	M	1988	
L79 Skana	M	1988	
L80 Odessa	Unk.	1989	1993
L81 Raina	M	1989	1997
L84 Nyssa	M	1990	
L85 Mystery	M	1990	
L87 Onyx	M	1991	
L88 Wavewalker	M	1992	
L89 Solstice	M	1992	
L91 Muncher	Unk.	1994	
L92 Crewser	M	1994	
L94 Calypso	Unk.	1994	
L95 Nigel	M	1995	
L96 Bernardo	M	1995	1997
L97 Tweak	Unk.	1998	1999
L98 Luna	Unk.	1999	
L99 N/A	Unk.	1999	

L55 Nugget	1976		L82	L96
L60 Rascal	1970*		L81	L92
L65 Aquarius	1983	1993		
L66 Mata Hari	1923*	1986	L45?	L08?
L67 Splash	1984		L98	
L72 Racer	1985			
L75 Panda	1985	1993		
L77 Matia	1986			
L82 Kasatka	1990			
L83 Moonlight	1990			
L86 Surprise	1990			
L90 Ballena	1992			
L93 Nerka	1994	1998		

NOTES

* birth year was estimated

Birth and death years are years beginning July 1 of year shown.

Individual ID numbers start with pod of whale (J, K or L).

APPENDIX B. DEMOGRAPHIC STRUCTURE OF SOUTHERN RESIDENT KILLER WHALE MATRILINES AS OF 2000

Matriline	Whale	Age	Sex	Reproductive Female (13-42)	Reproductive Male (11-42)	Status
J B A	J-30	5H	M			J-14 is the only reproductive female in the matriline. Her 1987calf died. Her 2001 calf may or may not survive to a full year (it is not recorded here for that reason). With two aged members, one reproductive female, and no known female juveniles, this matriline will likely decline. If the 2001calf dies or is male, the long-term outlook is not good.
	J-14	26	F	Y		
	J-01	49	M			
	J-02	81	F			
J B B	J-31	5	F			J-11 gave birth in 1988, 1991, 1995, and 1998. The 1991 and 1998 offspring survived. J-19 gave birth in 1993 but the calf did not survive. With only one aged whale, two reproductive females, and an adolescent female, this matriline should increase in size.
	J-27	9	M			
	J-19	21	F	Y		
	J-11	28*	F	Y		
	J-08	67	F			
J B C	J-36	1	Unk.			J-16 gave birth in 1991, 1996, and 1999. All three offspring are still alive. This matriline has only one known female. Unless J-36 is a female and survives to breeding age, this matriline may decline.
	J-33	5	M			
	J-26	9	M			
	J-16	28	F	Y		
J - D	J-35	2	F			J-22 successfully gave birth in 1998. J-17 gave successfully birth in 1993 and 1998. With no old whales, two reproductive females and three juvenile females, this matriline should increase in size.
	J-34	3	M			
	J-32	5	F			
	J-28	7	F			
	J-22	15	F	Y		
	J-17	23	F	Y		
K - A	K-31	1	M			K-12 successfully gave birth in 1987, 1994, and 1999. With two reproductive females and one adolescent female, this matriline should increase in size.
	K-28	6	F			
	K-22	13	F	Y		
	K-12	29	F	Y		

Matriline	Whale	Age	Sex	Reproductive Female (13-42)	Reproductive Male (11-42)	Status
K B B						Extinct
K - C	K-27	6	F			K-13 successfully gave birth in 1986, 1991, and 1994. With two aged whales, one reproductive female, and one adolescent female, this matriline will likely decline.
	K-25	9	M			
	K-20	14	M		Y	
	K-13	28*	F	Y		
	K-11	67	F			
	K-07	90				
K - D	K-21	14*	M		Y	K-40 has never given birth and is approaching post-reproductive age. With no juvenile females and the only reproductive female being apparently infertile, this matriline will decline and may well become extinct.
	K-40	37	F	Y		
	K-18	52	F			
K B E	K-26	7	Unk.			K-16 gave birth in 2000 to a calf which will not be recorded here until 2001. K-14 gave birth in 1988, 1990, and 1993. The first two died as calves. The third is still alive. This matriline will likely persist, especially if K-26 is female and the 2000 calf survives.
	K-16	15	F	Y		
	K-14	23	F	Y		
L - A	L-89	7	M			L-22 gave birth in 1986, 1989, and 1993. The latter two are still alive. With only one reproductive female and no adolescent females, this matriline may decline in the future.
	L-87	8	M			
	L-85	9	M			
	L-79	11	M		Y	
	L-22	29	F	Y		
	L-32	45	F			

Matriline	Whale	Age	Sex	Reproductive Female (13-42)	Reproductive Male (11-42)	Status
L - B	L-98	1	Unk.			L-67 successfully gave birth in 1999. With one aged whale, one reproductive female, and only one possible female adolescent, this matriline may decline.
	L-88	7	M			
	L-78	11	M		Y	
	L-67	15	F	Y		
	L-39	25	M		Y	
	L-02	55	F			
L - C	L-25	72	F			With no female calves, female juveniles, or reproductive females, this matriline will become extinct.
L - D						Extinct
L - E	L-94	5	Unk			L-11 gave birth in 1973, 1977, 1985, 1987, and 1995. She is likely post-reproductive. With two post-reproductive females and only one reproductive-age female, this matriline may well decline.
	L-77	13	F	Y		
	L-41	23	M		Y	
	L-11	43	F			
	L-12	67	F			
L - F	L-92	5	M			L-26 gave birth in 1972, 1980, 1986, and 1993. L-60 gave birth in 1990 and 1995. The first died, the latter is still alive. With only one reproductive and one adolescent female, this matriline may decline.
	L-90	7	F			
	L-71	14	M		Y	
	L-60	28	F	Y		
	L-26	44	F			
L - G	L-57	23	M		Y	Having no females, this matriline will become extinct.

Matriline	Whale	Age	Sex	Reproductive Female (13-42)	Reproductive Male (11-42)	Status
L - H	L-95	4H	M			L-43 successfully gave birth 1986 and 1996. L-7 gave birth in 1987 and 1997. The latter calf died. She is close to post-reproduction age and it is not known if she is capable of successful birth. Though the population has two successful reproductive females, one is nearly post-reproductive and the other has produced only one viable offspring since 1987. The two other reproductive females have not given birth, even though one is 23. There are no adolescent females. The matriline status is unclear, it may decline.
	L-72	14	F	Y		
	L-53	23	F	Y		
	L-43	28	F	Y		
	L-07	39	F	Y		
L - I	L-86	9	F			L-27 gave birth in 1980, 1985, 1990, and 1995. The latter three have died. She is close to post-reproductive age. L-55 gave birth in 1990 and 1996. The latter calf died. This matriline has suffered poor reproduction, but still has at least one reproductive female and two adolescent females. Its future is unclear.
	L-82	10	F			
	L-62	20	M		Y	
	L-55	23	F	Y		
	L-27	35	F	Y		
L - J	L-99	1	Unk.			L-47 successfully gave birth 1990, 1995, and 2000. With one aged whale, one reproductive female, and only one known adolescent female, this matriline will likely decline. If L-99 and L-91 are female and survive, the decline may be temporary.
	L-91	5	Unk			
	L-83	10	F			
	L-47	26	F	Y		
	L-21	62I	F			
L - K	L-84	10	M			L-5 has produced two viable offspring, but has not given birth since 1986. She is nearly post-reproductive and may no longer be capable of successful birth. This matriline will likely become extinct.
	L-73	14	M		Y	
	L-74	14	M		Y	
	L-58	20	M		Y	
	L-05	36*	F	Y		

Matriline	Whale	Age	Sex	Reproductive Female (13-42)	Reproductive Male (11-42)	Status
	L-03	54‡	F			
L - L	L-54	23	F	Y		Though in her reproductive mid-years, L-54 has never given birth. It is not known if she is capable of successful birth. This matriline will become extinct if L-54 is infertile.
	L-01	41	M		Y	

† There may be a margin of error of up to one year for this whale.
* It is unclear whether this is an estimated or an actual birth year.
‡ Different data sets have large differences in birth year for these whales. However, these whales would be outside of the breeding age no matter what age was selected from within the range. Results in this table are the best estimates of the actual age of the whale after consulting a variety of sources.

APPENDIX C. SOME PCB AND DDT CONCENTRATIONS [a] IN MARINE BIOTA OF PUGET SOUND AND THE STRAIT OF JUAN DE FUCA

Organism	Medium	Location	total PCB µg/kg ww	Max PCB µg/kg ww	total DDT µg/kg ww	**Max DDT** µg/kg ww	Percent lipid	total PCBs mg/kg lw	total DDT mg/kg lw	Source
Zooplankton	Whole	Puget Sound	NA	NA	NA	NA	NA	2 -16	NA	Pavlou & Dexter 1979
Mussel	whole	Useless Bay	5.5	NA	NA	NA	1.8	0.31	NA	Ylitalo et al. 1999
Mussel	whole	Commencement bay	110	NA	NA	NA	1.6	6.88	NA	Ylitalo et al. 1999
Mussel	whole	Elliott Bay	120	NA	NA	NA	1.6[b]	7.50	NA	Ylitalo et al. 1999
English sole	average muscle	Useless Bay	6.3	NA	NA	NA	1.6	0.39	NA	Ylitalo et al. 1999
English sole	average muscle	Commencement Bay	22	NA	NA	NA	0.65	3.38	NA	Ylitalo et al. 1999
English sole	average muscle	Elliott Bay	320	NA	NA	NA	2.3	13.91	NA	Ylitalo et al. 1999
English sole	average muscle	Throughout Puget Sound	19.67	159.0	4.41	9.40	0.32	6.15	1.38	O'Neill et al. 1995
Quillback rockfish	average muscle	Throughout Puget Sound	11.44	69.0	1.68	6.50	0.41	2.79	0.41	O'Neill et al. 1995
Copper rockfish	average muscle	Throughout Puget Sound	9.23	16.0	1.47	2.00	0.43	2.15	0.34	O'Neill et al. 1995
Pacific cod	average muscle	Throughout Puget Sound	11.08	18.7	3.1	4.00	0.11	10.07	2.82	O'Neill et al. 1995
Chinook	average muscle	Throughout Puget Sound	49.98	216.0	22.17	58.80	2.95	1.69	0.75	O'Neill et al. 1995
Chinook	composite muscle	Central Puget Sound	74.2	NA	NA	NA	2.95[c]	2.52	NA	O'Neill et al. 1998
Chinook	composite muscle	Puget Sound Rivers	49.1	NA	NA	NA	2.95[c]	1.66	NA	O'Neill et al. 1998
Coho	composite muscle	Central Puget Sound	35.1	NA	NA	NA	2.07[c]	1.70	NA	O'Neill et al. 1998
Coho	composite muscle	Puget Sound Rivers	26.5	NA	NA	NA	2.07[c]	1.28	NA	O'Neill et al. 1998
Coho	average muscle	Throughout Puget Sound	26.67	107.0	10.1	18.50	2.07	1.29	0.49	O'Neill et al. 1995
Harbor seal pups	blubber	Southern Puget Sound	13,100	16,000	NA	NA	90[d]	14.6	NA	Hong et al. 1996
Harbor seal pups	blubber	Smith Island, Strait of Georgia	1700	2100	NA	NA	90[d]	1.9	NA	Hong et al. 1996
Killer whales	Male blubber	Georgia/Juan de Fuca Straits	NA	NA	NA	NA	NA	146.3	NA	Ross et al. 2000
Killer whales	female blubber	Georgia/Juan de Fuca Straits	NA	NA	NA	NA	NA	55.4	NA	Ross et al. 2000
Killer whales	average blubber	Strait of Georgia/Outer Coast,	NA	NA	NA	NA	NA	24.2	35.2	Jarman et al. 1996
		Vancouver Island								

a Concentrations are expressed as average values reported in their respective studies unless otherwise noted. Significant figures as reported by primary authors.
b Percent lipid not reported, assumed to be equal to lipids in mussels from Commencement Bay.
c Percent lipid assumed to be equal to that reported for this species by O'Neill et al. 1995.
d Percent lipid in seal blubber not reported, assumed to be 90 percent.
NA – Not available
ww – wet weight
lw – lipid weight

APPENDIX D. SUPERFUND SITES IN THE PUGET SOUND BASIN AT WHICH PCBS ARE A CONTAMINANT OF CONCERN.

Site Name	**Contaminated media**
Western Processing Company	Soils
Whidbey Island Naval Air Station	Soils, marine and freshwater sediments
Northwest Transformer, S. Harkness St	Soils
Midway Landfill	Groundwater
Keyport Naval Undersea Warfare Engineering Station	Marine sediment, shellfish
Harbor Island/Elliott Bay	Soils, freshwater and marine sediments
Pacific Car and Foundry	soils
Queen City Farms	soils
Commencement Bay, Tacoma Tar Pits	soils
Malarky Asphalt site	soil, groundwater, freshwater sediments
Northwest Transformer, Mission Pole	soils
South Tacoma Field	soils
Tulalip Landfill	surface water
Port Hadlock Detachment	soils, groundwater, marine sediment, shellfish

APPENDIX E. MAJOR OIL SPILLS IN THE PACIFIC NORTHWEST (1970-2001)

3/64 1,200,000 gallons United Transport Barge, Grays Harbor Co.

4/71 230,000 gallons, United Transport Barge, Skagit Co.

1/72 2,300,000 gallons, General M.C. Meiggs, Clallam Co.

3/84 200,00 gallons, Tanker SS Mobil Oil, Columbia River

12/85 239,000 gallons, Tanker ARCO Anchorage, Clallam Co.

1/88 70,000 gallons, Barge MCN #5, Skagit Co.

12/88 231,000 gallons, Barge Nestucca, Grays Harbor Co.

3/89 11,000,000 gallons, Tanker EXXON VALDEZ, PWS Alaska

2/90 70,000 gallons, Navy Supply Depot, Kitsap Co.

3/90 130,000 gallons, Texaco, Skagit Co.

8/90 176,000 gallons, Chevron, King Co.

1/91 600,000 gallons, US Oil Refinery, Pierce Co.

2/91 210,000 gallons, Texaco Refinery, Skagit Co.

7/91 400,000 gallons, Tenyo Maru, Canadian waters off Olympic Coast

10/93 264,000 gallons, US Oil Refinery, Pierce Co.

12/94 26,900 gallons, Crowley Barge 101, Rosario Strait

12/96 49,000 gallons, GATX, King Co.