PEER REVIEW OF THE PROPOSAL TO LIST SOUTHERN RESIDENT KILLER WHALES UNDER THE ENDANGERED SPECIES ACT

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Scope of this Review

NMFS responded to the petition from the Center for Biological Diversity and co-petitioners (Plater 2001) to list Southern Resident killer whales by considering all North Pacific killer whales. NMFS determined that Southern Residents are part of the same taxon as the Eastern North Pacific Resident Stock of killer whales. Therefore, I include consideration of the implications of the status of Southern Residents to this taxon in my peer review of the rule proposing to list Southern Residents as Threatened under ESA (Federal Register 2004).

DPS determination

As noted by the BRT (Krahn *et al*. 2004), there is disagreement within the scientific community over the taxonomy of killer whales. NMFS concluded Southern Residents were part of an unnamed subspecies consisting of North Pacific Resident killer whales. This falls within the range of Residents having specific status (Cope in Scammon 1869, 1874) to there being a single subspecies of killer whale world-wide (Krahn *et al*. 2002). For reasons detailed below, I believe the Eastern North Pacific Southern Resident Stock (Carretta *et al*. 2004) is a subspecies, and that the Eastern North Pacific Northern Resident Stock (Angliss and Lodge 2004) is another subspecies of the species Scammon and Cope (1869, 1874) described as *O. ater*. Subspecific status would make Southern Residents eligible for listing under ESA. However, even if all Residents only have subspecific status as determined by the BRT, Southern Residents were correctly identified as a discrete and significant population that is eligible for listing.

Krahn *et al*. (2004) reported mtDNA data show Southern Residents are likely monotypic, and their genotype is found in other places in the North Pacific and North Atlantic. The nuclear DNA data suggest a stronger break between Southern Residents and the adjacent Northern Resident Community (A1, A4, A5, B1, C1, D1, G1, G12, H1, I1, I2, I11, I18, I31, R1 and W1 pods, Ford *et al*. 2000) than between resident populations within the Eastern North Pacific Northern Resident Stock (Northern Resident Community, Southeast Alaska, Prince William Sound, and Western residents--Angliss and Lodge 2004). Nuclear DNA differences with Offshores are stronger still, although there is little difference in mtDNA sequences. Transients show both marked nuclear and mtDNA differences from Residents.

LeDuc and Taylor (2004) presented some tentative thoughts on how this pattern may have originated, and I will expand on those here. They described killer whales as a ring species. That is, the overall range was large, local populations adapted to local conditions existed, there was limited gene flow between adjacent populations, but there was negligible gene flow between distant populations. The existence of small, local populations isolated from other populations was proposed by Arnason *et al.* (1980) based on chromosome banding patterns.

The common ancestors of modern killer whales probably originated as a ring species in the Southern Ocean. Several lineages have separated from this population over time. One lineage moved into the Antarctic ice and split into two additional species (Species B and C of Pitman and Ensor 2003—Species C is probably the same as *O. nanus* Mikhalev et al. 1981 and *O. glacialis* Berzin and Vladimirov 1983). Other lineages moved into the Pacific. One of these lineages (the "T" clade) radiated into West Coast Transients, AT1's and Gulf of Alaska transients.

The "R" clade also sent at least one line directly into the Pacific. The "R" clade also moved into the Atlantic a few times. One lineage moved into the Southwest Atlantic. Another lineage moved into the North Atlantic. One part of this lineage moved from the North Atlantic to the Pacific where it became Residents. A second part of this lineage moved from the Northeast Atlantic into the Pacific where it became Offshores. Invasions of the North Pacific from the North Atlantic probably occurred during the period of global warming approximately 120,000 years ago. When the climate cooled, the North Pacific parts of the R line were geographically isolated from the Atlantic part. Upon entering the Pacific, matrilines would have spread southward. The southernmost extremes would have had the smallest mtDNA diversity, while populations close to the Bering Sea would have retained more mtDNA diversity.

This interpretation is based on the assumptions that the large genetic diversity in the Antarctic A samples (LeDuc and Taylor 2004) is due to the presence of many old matrilines, and that diversity in the ETP is due to many independent invasions (separate early invasions from the south by the "R" and "T" clades, and later invasions by the "R" clade from the north).

During the glacial maximum approximately 18,000 years ago, coastal British Columbia and much of Alaska were covered in ice. As a result, this region would not have supported resident killer whales. There would have been a Western Pacific Resident Population centered in Russia and Japan, and an Eastern Pacific Population centered in California and Oregon. As the ice melted, British Columbia would have been re-colonized by both populations, bringing Western Pacific and Eastern Pacific killer whales into secondary contact after thousands of years of separation. In contrast to the non-zero gene flow between adjacent Western Pacific killer whale populations (= Eastern North Pacific Northern Resident Stock) that likely persists, it appears that a behavioral barrier to gene flow between Southern and Northern Residents has evolved, as have barriers to gene flow between Residents and other trophic morphs of killer whales (Bain 1988).

This suggests Southern Residents have been reproductively isolated from other killer whales for over 18,000 years. This is a long enough period of time to merit subspecific status. Residents have been isolated from Offshores and Atlantic killer whales for over 100,000 years. This is enough time to merit specific status.

The low genetic diversity among killer whales has been cited as evidence that modern killer whales are recent in origin (Hoelzel 2004). However, Whitehead (2005) noted that killer whale social organization and the important role of cultural traits in their behavior may lead to reduced genetic diversity. As a result, it is unclear whether killer whale lineages are older than lineages in other species with similar genetic diversity, or there was a recent bottleneck in world-wide killer whale abundance, with a single population responsible for expansion to the modern range, as suggested by Hoelzel. That is, small genetic diversity may be due to a bottleneck, or it could be that the descendants of a relatively small fraction of killer whales out-competed the descendants of most others where samples have been collected to date.

The taxonomic status of killer whale populations remains unresolved. This is due in part to the definition of "species" itself being in flux (Reeves *et al*. 2004). The classic definition is based on reproductive isolation. That is, animals that choose not to interbreed or are unable to interbreed due to morphological or genetic differences, or are geographically isolated from each other, were considered separate species (Mayr 1963). However, in recent times, additional criteria have been added. Molecular measures, such as DNA or protein sequence differences, are used to assess differences that have accumulated during reproductive isolation. Accumulation of morphological differences is another factor sometimes considered. These additional criteria will lead to failure to recognize reproductively isolated lineages as species until long after the speciation event. However, they will prevent incorrectly recognizing temporary isolation due to factors like mate choice or habitat that temporarily became discontinuous as evidence that lineages have irreversibly diverged.

Reeves *et al*. (2004) noted that in general there are two reasons for lack of consensus regarding taxonomic status. First, the differences in the animals themselves may not be sufficient to determine whether speciation is complete or there is still the potential for independent lineages to reticulate in the future. The other is that proposed taxonomic revisions may fail to meet the standards of the International Code of Zoological Nomenclature (see Schevill 1986). In the case of killer whales, reviewers have recognized that the best available science indicates there are now numerous species or subspecies (e.g., Heyning and Dahlheim 1988, Krahn *et al*. 2002 and 2004), but the science is not perfect and existing names may not stand the test of time (holotypes were not preserved, diagnostic features were not adequately detailed, etc.). Although killer whales have speciated over the last 5 million years, no one in the scientific community has properly documented it.

Noteworthy work overlooked by the BRT includes the work of Cope, which was based on the observations of Scammon (1869, 1874). They described two species of killer whale on the West Coast of North America.

Cope and Scammon described *O. ater* as having falcate dorsal fins and distinct saddles and ranging from Oregon to the Aleutians, with concentrations in Juan de Fuca Strait, Georgia Strait, the North End of Vancouver Island, and the Aleutians. This corresponds well with the morphology, range, and core areas, of the resident subspecies recognized by the BRT (Krahn *et al*. 2004). Scammon described this species chasing fish as Residents do, but also described predation on mammals, suggesting they failed to discriminate Residents from Transients.

Cope also described *O. rectipinna*. This species ranged from California south and had straight and tall dorsal fins and indistinct saddles. It appears to correspond to an ETP population described by the BRT (Krahn *et al*. 2004) as part of a subspecies separate from residents.

In previous comments, I suggested killer whales had radiated into several niches based on prey type and water temperature. Their cultural plasticity allows generalists to occupy a vacant niche. Natural selection would then lead to specialization. At first the specialization would be cultural. Patterns of seasonal occupation of areas, optimal foraging times and places (depths, distance from shore, etc.), search images for prey by species and size, optimal group sizes, structure of echolocation and communication signals, etc. would be culturally transmitted from one generation to the next. The importance of cultural traits to the speciation process reinforces NMFS' decision to incorporate cultural differences as a factor in the significance of Southern

Residents. Morphological specializations would follow. Once specialized, the specialist would out-compete the generalist, establishing selection for reproductive isolation between geographically overlapping populations. Thus speciation would take place through mate choice, though evolutionary time would be required for sufficient differences to accumulate for those working only on morphology or genetics to recognize what is apparent to behavioral biologists. Specialization on prey type (irreversible divergence) appears to have evolved independently more than once (LeDuc and Taylor 2004), implying that adaptive radiations take place on a regional rather than global scale.

Significance

The BRT found that one of the reasons Southern Residents are significant is that they are the sole population of the unnamed subspecies occupying the California Current system. The California Current system is significant because it represents a large geographic area, and it represents a habitat type not occupied by other Residents (Krahn *et al*. 2004). As a result, their loss would result in a significant gap in the range of their taxon. Thus it is unclear why NMFS did not also find this would mean the loss of Southern Residents would lead to extinction of Residents in a significant portion of their range.

The BRT correctly noted that Southern Residents differ markedly in mtDNA and nuclear DNA from all other killer whales.

The BRT correctly noted that Southern Residents maintain a unique suite of cultural traits, and these traits make them better adapted to their home range than morphologically similar killer whales that lack these traits would be. Thus they correctly considered culture as an "other" factor that contributed to the significance of Southern Residents.

Risk assessment

IUCN uses a variety of criteria to classify species (IUCN 2001). Table 1 shows the relationship between IUCN status and ESA status for marine mammal species considered by both IUCN and NMFS. The BRT correctly found Southern Residents were Critically Endangered by IUCN criteria (Krahn *et al.* 2004). As can be seen, other species considered Critically Endangered by IUCN were consistently considered Endangered by NMFS. Even species considered Endangered rather than Critically Endangered by IUCN were considered Endangered by NMFS (the exception is that Steller Sea Lions were subdivided into two populations by NMFS, one Endangered and one Threatened, while IUCN only considered the species as a whole). The IUCN Vulnerable category seems to roughly correspond to the ESA Threatened category, though in most cases Vulnerable species were listed as Endangered by NMFS.

IUCN classifies species based on whether they meet any one of five criteria based on three factors: population trend, population extent, and population size, with the combination of population size and trend, and overall population viability forming the other two criteria. A key component of their classification system is that any one criterion is sufficient to justify the most serious classification.

Criterion A for critically endangered is whether there is a projected 80% decline over three generations. For killer whales, this corresponds to a decline of 2.2% per year. For Endangered, the criterion is 70% or 1.6% per year. Southern Residents met the criterion for critically endangered during the period of steepest decline. However, there has been an overall increase in population since annual censuses began in the mid-1970's. Further, there has been an increasing trend the last few years, suggesting that Southern Residents may not meet this criterion currently.

Criterion B addresses geographic extent. At times, Southern Residents meet the criterion for critically endangered (they are all in a single location and there is an observed decline in the number of mature individuals). However, in general, they are sufficiently dispersed that they would not meet this criterion. In my opinion, consideration needs to be taken of the fact that Southern Residents are sometimes in a small enough area that the entire population would be vulnerable to an oil spill or other local catastrophe. Thus it is unclear whether Southern Residents meet this criterion, and it is perhaps best to treat population extent as a factor in population viability.

Criterion C, a small population combined with decline, meets the criterion for critically endangered, using the last 10 years or so to project the decline. However, if a longer record is used to project the population trend, Southern Residents would not meet this criterion.

Criterion D, the population consists of fewer than 50 mature individuals, is sufficient by itself for Southern Residents to qualify as Critically Endangered under IUCN criteria. This criterion recognizes that small populations are vulnerable to many threats (e.g., habitat destruction, Allee effects, disease outbreaks, etc.), and the joint probability of surviving all of them is inherently low. The criterion for Endangered is 250 mature individuals and the criterion for Vulnerable is 1000 mature individuals. 250 mature Southern Residents is an achievable goal over the next hundred years, but 1000 is never likely to be achieved. The total number of adult Residents (including both the Northern and Southern Eastern North Pacific Resident Stocks) is probably below 500, and even adding in juveniles from both stocks the total of known individuals is far below 1000 (Angliss and Lodge 2004).

Criterion E, the probability of extinction within three generations, is difficult to predict. The BRT ran a range of population viability analyses. By IUCN criteria, only the worst case scenario reached the Vulnerable level (10% probability of extinction within 100 years). However, using the quasi-extinction criterion, the Endangered level was reached in some runs (20% within 100 years). While PVA's produce precise estimates of the probability of extinction, the probability that any given PVA applies to the real world (that is, the probabilities that the assumptions are accurate) also needs to be determined.

The BRT considered a variety of options in its PVA's. The first decision was regarding the time frame for the data. The BRT reported that population trends are cyclical (Krahn *et al*. 2002). Thus the best population projection is likely to be based on the last full cycle (Scenario B), adjusted for the factors listed below. That is, rather than making projections based on arbitrary periods, such as the last ten years, all data available, the period of steepest decline, or the last few years when the population has been slowly growing, the last 14 years is probably the best baseline to use.

When deciding which PVA is most credible, NMFS should consider whether in the absence of regulatory action, factors believed to be contributing to the current decline will worsen, and whether other factors that have not contributed in recent times will contribute in the future. To approximate this, NMFS incorporated “catastrophes” as modifications to the scenarios. This is a good approach for true catastrophes such as oil spills or disease outbreaks, but fails to capture future changes in factors like disturbance and bio-accumulative toxins.

For example, whale watching has grown dramatically over the last 15 years. In the absence of regulatory action, slow growth can be expected over the summer months, and rapid growth can be expected in the spring, fall, and early winter. Thus whale watching is a factor that should be considered when adjusting the PVA. The adjustment will be larger for Scenario A, which includes data from a time frame in which whale watching was limited, than for Scenario B which is based on data in which whale watching was extensive for about half the time frame.

In contrast, prey abundance ought to improve as recovery efforts for salmon are implemented. The current cycle is probably based on a time frame in which prey availability was lower than during the entire period for which data are available. However, steps to recover salmon stocks are only being implemented slowly, and natural factors such as disease and natural climate change will make improvement unsteady. Indeed, global warming could easily offset any gains made through management actions (Hare *et al*. 1999, Mantua *et al.* 1997).

As for other risk factors identified by the BRT, chronic exposure to noise from shipping can be expected to increase (Osborne 1999). Recovering fish stocks might increase impact from commercial fishing and recreational boating. Whether exposure to high levels of noise from sources such as airguns, sonar, and military exercises will increase or decrease depends on future regulatory decisions. New toxins, such as PBDE’s (Rayne *et al.* 2004), can be expected to significantly increase in impact, while legacy toxins, such as PCB’s, are unlikely to decline at a substantial rate (Krahn *et al.* 2004). Hormones in waste water can be expected to increase as the human population increases.

While it is clear that avoiding catastrophes is essential to the survival of Southern Residents, it is not clear which adjusted scenario best represents future expectations. The BRT cites a near miss involving an oil spill in December of 2003 in an area Southern Residents frequent that time of year. Another near miss that could have been cited was the New Carissa incident on the Oregon Coast in February and March, 1999 (Hazardous Materials Response Division 1999). Southern Residents were known to be on the Oregon Coast in April of that year, and in March of the following year. Thus oil spill impacts may be more frequent than modeled by the BRT, but the impacts of these more frequent spills will likely be smaller than for some of the larger spills envisioned by the BRT models.

Future setbacks due to factors not believed to have contributed to the recent decline, such as oil spills, introduced species, disease outbreaks, harmful algal blooms , etc. (Krahn *et al.* 2002) make the outlook less bright than under the conditions in recent times. The small number of adult males currently in the population make it likely that an unusually high number of matings between paternal half sibs will take place a generation from now, and this is likely to result in an additional negative impact in the future.

PVA's need to anticipate how such future events, in the absence of the decision to list, would affect the probability of extinction. Obviously, it will be difficult to make such predictions with confidence. As a result, PVA's are not a good way to assess the probability of extinction. Rather, they are a good way to assess the change in probability of extinction due to a change in management. E.g., PVA's with and without oil spills factored in are useful for assessing the importance of oil spill prevention. PVA's with different carrying capacities are useful for understanding the importance of increasing the prey base.

The comparison of quasi-extinction and extinction was informative. In general, the probability of extinction was similar to the probability of quasi-extinction 100 years before. This illustrates the fact that ***extinction will become inevitable long before it becomes imminent*** (in addition to the hundred years following quasi-extinction, the last individual born could live for decades after the population becomes extinct by the BRT definition—all individuals are the same sex). That is, the foreseeable future is long for killer whales, so it makes more sense to evaluate probability of extinction over a time frame like ten generations than it does to evaluate the probability of extinction over a period of time like 100 years (only about four generations, Olesiuk *et al.* 1990).

Status

Since Southern Residents clearly meet Criterion D, they are **CRITICALLY ENDANGERED** by IUCN standards. While the recent small increase in numbers has reduced the number of criteria for Critically Endangered Southern Residents meet, meeting one is sufficient to justify that listing. Since NMFS has consistently listed Critically Endangered species as Endangered under ESA, Southern Residents should be listed as **ENDANGERED** rather than Threatened under ESA. Further, many factors that could negatively affect the population are expected to worsen in the future (implying the more pessimistic PVA's are more likely to be accurate than PVA's based on the status quo), but management action could improve the probability of long-term survival of the taxon throughout its range.

Even if NMFS concludes that extinction resulting in a significant gap in the range is not synonymous with extinction in a significant portion of the range, the Eastern North Pacific Stock should be considered for listing in its own right. Whaling for killer whales was extensive in Japanese waters (Nishiwaki and Handa 1958), and many of the habitat issues are similar or worse there. Thus it is possible there exists a DPS at the southwest end of the range that is also endangered. Oil and gas development is underway in the Russian portion of the resident range, so there may be developing problems there (UNEP unpublished). Western Alaska residents have been shot during interactions with the blackcod longline fishery (Yano and Dahlheim 1995ab). Prince William Sound residents also had mortalities associated with fishery interactions and the Exxon Valdez oil spill (Dahlheim and Matkin 1994, Matkin *et al*. 1994). Population trends for the Eastern North Pacific Northern Resident Stock as a whole are unknown (Angliss and Lodge 2004). Although additional residents remain to be identified in the western portion of the resident range, it is unlikely that there are at least 1000 mature individuals given that the total (including all ages in all populations from California through Alaska) known North American population was estimated at about 800 in 2003. Thus all Residents should be listed as **ENDANGERED**, although NMFS could consider taking an approach similar to that for northern sea lions, and classify the Northern Resident Stock as **THREATENED,** and the Southern Resident Stock as **ENDANGERED**.

Conservation of genetic diversity

Following the end of collections for public display, Northern and Southern Residents exhibited the ability to grow at about 3% per year, resulting in roughly a doubling of population size each generation. With that rate of population growth, each single copy gene has four opportunities to be passed on to the next generation. With a 50% chance of being passed on at each opportunity, one in 16 (6.25%) single copy genes would be lost each generation. This rate of loss is probably unavoidable. However, if the population were to remain constant, each gene would only have two opportunities to be passed on, and 25% of single copy genes would be lost in the same time period. If the population declined, the proportion of single copy genes lost would increase further. As a result, a steady increase in population size early in the recovery process is critical to maintaining as much genetic diversity as possible.

A population model developed by Peter Olesiuk indicated that residents would grow at their intrinsic (maximum) rate of increase up to 80-85% of carrying capacity (Dahlheim *et al*. 2000). As a result, a 20-25% increase in carrying capacity, followed by a 3% per year increase in carrying capacity, would be sufficient to maintain the growth rate identified above. It is possible Southern Residents were at carrying capacity when the population bottomed out in 2001. A large increase in carrying capacity may have occurred with the shift in the PDO (Peterson and Schwing 2003, Bond *et al*. 2003) and the adoption of new best practices by whale watch operators (Whale Watch Operators Association Northwest 2004) designed to reduce the effects of noise. This would account for the increase in abundance of Southern Residents over the last few years, and suggest that only small (~3%), steady improvements in habitat quality are needed in the future to conserve as much genetic diversity as possible.

Conservation Measures

NMFS notes positive steps it has taken to educate boaters about proper conduct around killer whales. However, killer whales on the West Side of San Juan Island spend about 30% of the day with boaters not in compliance with NMFS guidelines (Bain *et al*. unpublished data). This indicates that this program needs to be expanded to be effective.

NMFS notes that the State of Washington has recognized killer whales as endangered. Since the federal government has jurisdiction over marine mammal protection, it is important that NMFS be responsive to initiatives by state and local governments to enact conservation measures (e.g., San Juan County hoped to implement stricter regulations on whale watching, but abandoned the effort when it learned it lacked the authority to do so).

NMFS should be encouraged to continue its cooperation with Canada. The simultaneous releases of the preliminary Draft Conservation Plan by NMFS and the draft Killer Whale Recovery Strategy by DFO are a positive sign.

Although funding for killer whale research has significantly increased while the petition was being considered, the research program supported by the Northwest Fisheries Science Center is severely underfunded, resulting in research projects with sample sizes that are smaller than they should be and important research being post-poned until adequate funding becomes available. For example, research to identify critical habitat has been limited. While NMFS has not yet proposed critical habitat, Canada's Killer Whale Recovery Team indicated it believed its own proposal for critical habitat was too limited because data on Southern Resident distribution is based on average on where fewer than half the whales are and for Northern Residents it was based on sightings of on average less than 5% of the population (Killer Whale Recovery Team 2005). It is important that funding for killer whale research and other conservation activities (such as boater education programs) be increased in the immediate future by millions of dollars per year, and that a stable level of funding for long-term projects be established.

As mentioned above, maintaining an increasing population early in the recovery process is critical to preserving genetic diversity, so completion of research on causes and implementation of initial conservation measures is urgent.

Prohibitions and Protective Measures

Coastal Development

Coastal development will require careful management. Resident killer whales feed, travel, and socialize within a few feet of shore at times. (Transient killer whales even feed on land on occasion, although residents are not known to do so, pers. obs.). The near-shore environment is also critical to the prey base, so activities that have no direct effect may have indirect effects. Killer whales use narrow passages, so near-shore activities that block travel through an area will have an impact over a much larger area than the activity itself. Of course, some activities, such as shore-based whale watching, appear to have no negative effect. Minor habitat modifications, such as mooring buoys and small docks also have little or no direct impact.

An example of planned coastal development that is of particular concern is a gravel mine to be expanded to include a loading pier on Maury Island. The pier would disrupt habitat important to the prey base and form a physical barrier across a traditional travel route. Further, the noise from the loading process may discourage whales from passing the site (in contrast, whales are likely to go around a quiet, passive structure, leading to only minimal loss of habitat), which is located in a narrow body of water, leading to loss of a large fraction of the winter range. Tugs pulling barges would add to ambient noise, degrading habitat critical to survival when food is scarce, and mothers are trying to rear newborn calves.

Oil and gas development

Oil and gas development would pose a significant risk to Southern Residents. Since the entire population is sometimes in a small area, there is potential for the entire population to be eliminated by a single accident. Seismic surveys associated with exploration involve the production of noise sufficiently powerful to cause immediate injury or death, so would need to be carefully regulated. Further, noise associated with construction and operation of infrastructure would degrade habitat.

Discharges

See comments on water quality under critical habitat below.

Waste disposal

Waste disposal practices will need to be improved. High levels of PBDE's in Puget Sound biomass suggest that chemicals in solid waste are entering the marine ecosystem. Better solid waste management practices will need to be developed. Existing toxic chemicals will need to be prevented from entering biomass in the marine ecosystem through clean-up actions.

Chemical contaminant practices

Use of chemical contaminants needs to be carefully controlled. Prevention of use of chemicals should be explored, as agricultural and urban run-off will be difficult to control. For example, non-smokers who live in buildings with sprinkler systems may not need products treated with flame retardants.

Land Use

The primary mechanisms for land use to impact killer whales will be indirect, unless the activity is sufficiently noisy to have a direct effect. Changes in quantity and chemical and biological composition of run-off as a result of land use changes need to be considered for potential direct and indirect effects.

Water use

Commercial and sport fishing are two activities with potential to have impact on killer whales through direct mechanisms. There is potential for entanglement (Carretta *et al*. 2004). This is not known to be a significant problem for Southern Residents, although this should be revisited as proposed gear modifications are considered, and the range of Southern Residents becomes better known. Noise from fishing fleets is a concern, particularly since fishing boats tend to concentrate where fish concentrate. The use of noise to reduce marine mammal-fishery interactions may or may not be of concern depending on whether the noise is intended to inflict pain or simply enhance the detectability of gear (Bain 2002). The need to maneuver around boats and gear is another concern (Williams *et al*. 2002b).

However, fishing should not take the brunt of conservation efforts. Fishing can be limited to times and places where impact on whales will be minimal. As more fish become available for whales through habitat restoration (Merz *et al.* 2004, Hanrahan *et al.* 2004, Deriso *et al.* 2001), more fish will be available to fishers.

Fish farming poses significant direct and indirect risks to killer whales. Fish farms may introduce toxic chemicals into the environment and provide a vector for disease transmission to wild fish (Morton *et al.* 2004, Fast *et al.* 2002). Farm fish may consume juvenile wild fish. Escaped fish may become invasive species disrupting natural ecosystems. Farms and their protective devices may form barriers to travel for whales (Morton and Symonds 2002). Further, the availability of farmed fish reduces human reliance on wild fish, and hence impairs the public will to maintain habitat for wild fish and the species that depend on them.

Noise

Anthropogenic noise can be a key component of killer whale habitat. Loud noises can cause immediate injury or death (Richardson *et al.* 1995). Noise can also preclude use of habitat (Morton and Symonds 2002). Chronic noise can impair the ability of killer whales to locate food with echolocation (Bain and Dahlheim 1994), and coordinate biologically important activities over long distances with communication signals, even at levels that do not lead them to abandon habitat. Levels as low as 105 dB disrupt normal behavior patterns (Williams *et al.* 2002ab) to the degree that long-term exposure (months) is biologically significant to the population (Bain *et al*. in prep.), 135 dB is sufficient to cause major behavioral changes (of a magnitude that in combination with other factors could lead to injury or death of small numbers of individuals in the short-term—Bain 1995), and higher levels of noise could be expected to cause immediate injury or death, although the level needed to cause such effects is unknown.

It will be important to regulate both chronic exposure to low levels of noise in critical habitat, and to regulate short-term exposure to high levels of noise throughout the range.

Noise attenuates with distance from its source. Since whale watching boats typically operate close to whales for extended periods of time, noise from this source needs to be carefully addressed. The commercial operators themselves have already taken steps beyond those proposed by NMFS to limit noise (Whale Watch Operators Association Northwest 2004), but this has little impact on private boat operators. Shipping noise is of concern because large vessels operate 24 hours a day, and many have high source levels. Although, ships generally don't operate in close proximity to killer whales for extended periods of time, as the number of ships transiting an area increases, the proportion of the day that the area is subjected to noise increases, as would the cumulative impact.

There are many types of sonar. All have high source levels (Richarson *et al.* 1995). However, from the killer whales' perspective, high-frequency sonars (fish finders) have a few advantages. Many are so high in frequency that killer whales are unlikely to hear them. They tend to have beams directed downward, so unless the boat is directly above whales, whales are unlikely to be exposed to direct paths. High frequencies attenuate more rapidly with distance than lower frequencies, so received levels will be lower at a given distance. Since the short potential travel distance means echoes will return quickly, pulses tend to be short and have little total energy.

In contrast, mid-frequency sonars have many disadvantages. Their frequencies are well matched to the frequencies killer whales hear best. They tend to be used for horizontal scanning, and so ensonify large volumes of water. Mid-frequencies travel well, and so maintain high received levels over moderate distances. The potential for long-distance use allows longer pulses to be used, since seconds may pass before echoes return, leading to more total energy per pulse.

Low frequency sonars are intermediate in impact. Killer whales do not hear low frequencies well (Szymanski *et al.* 1999 , Hall and Johnson 1972). However, low frequency sonars ensonify large volumes of water, low frequencies travel very efficiently over long distances, and very long pulses containing a lot of energy can be used (United States Navy and National Marine Fisheries Service 2002).

Mid-frequency sonar is known to cause major behavioral change in killer whales and other cetaceans (United States Navy 2004), above and beyond what is seen to lower intensity noise such as boat engines at long distances, and has the potential to cause immediate injury or death at short range (United States Department of Commerce and Secretary of the Navy 2001, Norman *et al*. 2004, Erbe 2002, Williams et al. 2002ab). When used in confined waterways where effective avoidance responses are not possible, stress reactions are to be expected as well (Romano *et al.* 2004).

Airguns are a source of loud, broad-band noise. Like low frequency sonars, they have the potential to affect large areas. Unlike low frequency sonars, in addition to strong low frequency components, they produce significant noise at frequencies that killer whales hear well (Calambokidis *et al*. 1998). They produce major behavioral changes in cetaceans comparable to mid-frequency sonar, although I am not aware of observations of their use in the presence of killer whales. The low frequency component of air-gun noise can travel long distances, although the higher frequencies are subject to excess attenuation as are mid- and high-frequency sonar.

A potential source of noise in the future is offshore energy farms (Reynolds 2005, Skilling 2005). While it is too early to anticipate the consequences of these, they should be examined carefully before deployment is allowed to proceed, particularly in critical habitat.

Critical Habitat

The definition of critical habitat identifies both occupied habitat and unoccupied habitat as eligible for designation as critical habitat. The reliance of killer whales on anadromous fishes means inland habitat where salmon spawn is critical to their survival, although killer whales are rarely found in rivers themselves (Shepherd 1932, Nossiter 1977). Thus critical habitat should consist of waters with a high occupancy rate by killer whales, restricted waterways where habitat degradation could prevent access to high occupancy portions of the range, and habitat essential to the food supply, whether marine waters where juvenile salmon, bait fish, and killer whales all reside, or fresh water where salmon spawn but killer whales would not be expected to be found. In addition, habitat that historically had high occupancy, but is not currently occupied due to habitat degradation, should be designated.

Since Residents cross international boundaries, it will be important to promote conservation of critical habitat and other actions in consultations with Canada, the First Nations, and tribal governments, as well as in consultations with states.

Occupied habitat

The range of southern residents includes thousands of square miles of marine habitat. Some of this range is core habitat, which whales occupy for many days each year. Other habitat consists of corridors for movement between core areas. Some habitat is degraded habitat, which was probably occupied at high rates in the past, but has been occupied only infrequently in recent years. Some habitat may be lightly used by killer whales, but critical to maintaining their prey base.

Known high occupancy waters are shown in Figure 1. This represents most of the inland waters of Washington State. Excluded areas include the portion of Puget Sound south of the Tacoma Narrows, some inlets on the periphery of Puget Sound, Bellingham Bay, and Hood Canal.

Hood Canal is an example of habitat known to be occupied historically, but only infrequently occupied in recent years. It is possible that with habitat improvement (replacement of the Hood Canal Bridge and reduction in eutrophication), this body of water would be occupied more often. The potential contribution of this body of water to increasing the prey base for Southern Residents would make it a critical component of the habitat of a recovering population.

Additional high occupancy areas probably exist in offshore waters, and should be added as they become known. These areas are likely to be characterized by offshore features that concentrate prey, such as banks, islands, ridges, and canyons. Rivers that have high numbers of large salmonids returning in a short period of time may also attract killer whales. Examples of areas that additional research may indicate warrant critical habitat designation include the waters of Monterey Canyon, the Farallon Islands, Cordell Bank, Cape Mendocino, Heceta Bank, Stonewall Bank, Astoria Canyon, and Gray's Canyon. The Fraser River is a major source of salmon for Southern Residents, with the Columbia and Sacramento rivers historically producing enough large salmonids to attract killer whales. Many smaller rivers along the Pacific Coast may have sufficient runs to justify occupied critical habitat designation in nearby marine waters.

Unoccupied habitat

Two types of freshwater habitat would be critical to killer whales. One would be critical habitat for listed salmonids. These waters would have the potential to significantly increase their productivity as depleted stocks recover. Such waters have been described as part of the ESA process for salmonids (Protected Resources Division 2004ab). The other would be waters with healthy populations of large salmonids that presently form an important part of the prey base. Degradation of such habitat would have a deleterious effect on Southern Residents. Large salmonids, such as chinook and chum, are probably more important to Southern Residents than smaller salmonids like sockeye and pinks (Ford *et al*. 1998).

Water Quality

As with other habitat issues, this needs to be addressed at both a direct and indirect level. Since killer whales don't drink much water, dissolved chemicals are unlikely to be much of a direct problem unless they are discharged in close proximity to whales. This can be prevented through regulating terrestrial waste water discharge in critical habitat, and vessel discharges throughout the range.

However, small quantities of water are inhaled when whales breathe. Thus chemicals that float at the water's surface, such as petroleum products, pose a health risk. Pathogens pose a risk of causing diseases of terrestrial origin (Gaydos *et al*. 2004). Introduction of such contaminants in all habitat needs to be minimized.

Water quality is probably more important to killer whales on an indirect level. Herring are an important component of the prey base, and susceptible to very low levels of contaminants (Carls *et al.* 2002, Kocan *et al.* 1987). Similarly, juvenile salmon are vulnerable to low contaminant levels (Kao and Scholz 2004, Scholz *et al.* 2000). Further, prey can concentrate contaminants, and bioaccumulation can lead to harmful levels in killer whales (Ross et al. 2000). When setting standards for water quality in critical habitat, it will be important to take indirect consequences as well as direct consequences into account.

Prey

The reduction in salmon abundance over the last 150 years is probably the primary factor in the reduction of Southern Resident to numbers warranting listing. In addition to the reduction in number, a reduction in average body mass has also occurred in all species (Weitkamp *et al.* 1995, Bigler *et al.* 1996). This reduction in mass is probably due to factors such as artificial selection in hatcheries and loss of upstream habitat that only large salmon could successfully reach. While the evidence for salmon being an important component of the diet is strong, stomach contents have suggested other prey species such as squid and bottomfish may also be important (Ford *et al*. 1998). Even healthy salmon stocks experience important fluctuations under natural conditions, so the availability of other species needs to be considered as an important component of habitat quality (Gregory-Eaves *et al.* 2004, Lawson *et al*. 2004, Mueter *et al.* 2002).

Since killer whales are high level predators, their habitat quality depends on the quality of the habitat as perceived by small fish and their prey, not just on the quality of the habitat as perceived by the species killer whales consume.

Noise

See discussion of noise above.

Safe passage

Southern Residents use narrow passages where habitat degradation may prevent safe passage. This includes the waters around Vashon Island, Boundary Pass, the waters on the East Side of San Juan Island, and waters in the Gulf Islands of British Columbia such as Swanson Channel and Active Pass.

Economic factors

Killer whales are an important component of the regional economy. In addition to direct expenditures, whale watchers contribute economically by spending for transportation, lodging, meals, and other purchases (Duffus and Dearden 1993, Hoyt and Hvenegaard 2002, Jelinski *et al.* 2002) The number of people who go whale watching is similar to the number of people who attend professional football or basketball games, and ticket prices are similar (Osborne 1999, Foote *et al*. 2004). There are also hundreds of thousands of people who watch for whales from land at no cost (Osborne *et al*. 2003). Public funding has been used to retain professional sports teams (Chansanchai 2005), suggesting it is worth hundreds of millions of dollars to preserve such an important economic resource. This provides a minimum estimate for how much money could easily be justified for conservation spending.

It should be pointed out that occupancy of habitat is seasonal. As a result, human activities that temporarily modify habitat could take place at times of year that Southern Residents are not present. The effects of permanently modified habitat could be mitigated by restoration of habitat elsewhere in the range. This should be considered in the economic assessment phase of critical habitat designation.

Summary of Conclusions

Southern Residents are Critically Endangered by IUCN criteria, and NMFS has consistently listed such species as **Endangered** rather than Threatened. NMFS has relied on PVA's that are optimistic about the future of Southern Residents to justify a Threatened listing. However, a review of factors likely to have contributed to the decline suggest that only one is likely to improve significantly without listing (prey availability due to ESA based action to recover salmon stocks). Others are likely to show little or no improvement (e.g. legacy toxins, disturbance from vessel traffic), some are expected to worsen (new toxins such as PBDE's), and intermittent factors such as oil spills and disease are likely to have more impact in the future than they have had in the recent past. Therefore, Southern Residents should be listed as **Endangered**.

Southern Residents are a subspecies of the same species as the Northern Resident Stock, which constitutes a second subspecies. Since the extinction of Southern Residents would lead to a significant gap in the range of the species to which they belong, that species is at risk of becoming extinct in a significant portion of its range. Therefore, **all Residents** should be considered **Endangered**.

In contrast to my conclusion that Southern Residents are a subspecies within the same species as Northern Residents, the BRT found Southern Residents are a DPS within the same subspecies as the Northern Resident stock. Under the BRT taxonomy, extinction of Southern Residents would lead to a significant gap in the range of the Resident subspecies. This would result in the extinction of the subspecies in a significant portion of its range. As above, the conclusion is that **all Residents** should be considered **Endangered**.

Marine habitat that is frequently occupied by Southern Residents should be designated as critical habitat. In addition, some marine habitat that is unoccupied or rarely occupied is critical to the population reaching sufficient size that it could be de-listed. Further, fresh water habitat is critical to the survival of adequate prey to support a recovered population, although such habitat would not be occupied by killer whales. Occupied critical habitat in the inshore waters of Washington and British Columbia can be designated at this time. Designation of occupied critical habitat in the Pacific must await better understanding of year-round distribution. Data that form the basis for designating critical habitat for salmon could be reviewed to designate unoccupied critical habitat for killer whales. Potentially occupied critical habitat will be more challenging to designate, but may become more apparent as the population recovers.

Literature cited

Angliss, R. P., and K. L. Lodge. 2004. Alaska marine mammal stock assessments, 2003. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-144, 230 p.

Arnason, U., R. Lutley and B. Sandholt. 1980. Banding studies on six killer whales, an account of C-band polymorphisms and G-band patterns. Cytogenet. Cell Genet. 28:71-78.

Bain, D. E. 1988. An evaluation of evolutionary processes: studies of natural selection, dispersal, and cultural evolution in killer whales (*Orcinus orca*). Ph.D. Dissertation. University of California, Santa Cruz.

Bain, D. E. 1995. The use of sound to guide killer whales (*Orcinus orca*) entrapped in Barnes Lake, Alaska, to open water. Poster presented to the Society for Marine Mammalogy Conference. Orlando, FL.

Bain, D. E. 2002. Acoustical properties of pingers and the San Juan Island commercial gillnet fishery. NMFS Contract Report No. 40ABNF701651. 14 pp.

Bain, D. E. and M. E. Dahlheim. 1994. Effects of masking noise on detection thresholds of killer whales. In (T. R. Loughlin, ed.) Marine Mammals and The Exxon Valdez. Academic Press. N.Y. 243-256.

Bain, D. E., R. Williams and A. W. Trites. in prep. Potential effects of whale watching on killer whale (*Orcinus orca*) population dynamics: insights from three models.

Berzin, A. A. and V. L. Vladimirov. 1983. A new species of killer whale (Cetacea, Delphinidae) from Antarctic waters. Zool. Zhurn. 62:287-295. In Russian.

Bigler, B. S., D. W. Welch and J. H. Helle. 1996. A review of size trends among North Pacific salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 53:455-465.

Bond, N. A., J. E. Overland, M. Spillane and P. Stabeno. 2003. Recent shifts in the state of the North Pacific. Geophysical Res. Letters. 30(23) #2183. 4 pp.

Calambokidis, J., D. E. Bain and S. D. Osmek. 1998. Marine mammal research and mitigation in conjunction with air gun operation for the USGS “SHIPS” seismic surveys in 1998. Contract Report submitted to the Minerals Management Service.

Carls, M. G., G. D. Marty and J. E. Hose. 2002. Synthesis of the toxological impacts of the Exxon Valdez oil spill on Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, U.S.A. Can. J. Fish. Aquat. Sci. 59:153-172.

Carretta, J. V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, and M. Lowry. 2004. U.S. Pacific marine mammal stock assessments: 2003. NOAA-TM-NMFS-SWFSC-358. 295 pp.

Chansanchai, A. 2005. Suit challenging Hawks' naming-rights deal tossed, $75 million should go to facility, taxpayer group argues. Seattle Post-Intelligencer. March 11, 2005.

Dahlheim, M., D. Bain, D. DeMaster and C. Sims. 2000. Southern resident killer whale workshop, National Marine Mammal Laboratory, Seattle, WA, 1-2 April 2000. NMFS Report.

Dahlheim, M. E. and C. O. Matkin. 1994. Assessment of injuries to Prince William Sound killer whales. In (T. R. Loughlin, ed.) Marine mammals and the Exxon Valdez. Academic Press. NY. 281-322.

Deriso, R. B., D. R. Marmorek and I. J. Parnell. 2001. Retrospective patterns of differential mortality and common year-effects experienced by spring and summer Chinook salmon (*Oncorhynchus tshawytscha*) of the Columbia River. Can. J. Fish. Aquat. Sci. 58:2419-2430.

Duffus, D. A. and P. Deardon. 1993. Recreational use, valuation, and management, of killer whales (*Orcinus orca*) on Canada's Pacific Coast. Environmental Conservation. 20:149-156.

Erbe, C. 2002. Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic model. Mar. Mamm. Sci. 18:394-418.

Fast, M. D., N. W. Ross, A. Mustata, D. E. Sims, S. C. Johnson, G. A. Conboy, D. J. Speare, G. Johnson and J. F. Burka. 2002. Susceptibility of raimbow trout *Oncorhynchus mykiss*, Atlantic salmon *Salmo salar* and coho salmon *Oncorhynchus kisutch* to experimental infection with sea lice *Lepeophtheirus salmonis.* Dis. Aquat. Org. 52:57-68.

Federal Register. 2004. Endangered and threatened wildlife and plants: proposed threatened status for Southern Resident Killer Whales. Federal Register. 69:76673-76682.

Foote, A. D., R. W. Osborne, and A. R. Hoelzel. 2004. Whale-call response to masking boat noise. Nature. 428:910.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. Balcomb III. 1998 Dietary Specializations in two sympatric populations of killer whales *(Orcinus orca*) in Coastal British Columbia and adjacent waters. Can. J. Zool. 76:1456-1471.

Ford, J. K. B., G. M. Ellis and K. C. Balcomb. 2000. Killer Whales (2nd eddition). UBC Press. Vancouver, BC.

Gaydos, J. K., K. C. Balcomb, R. W. Osborne and L. Dierauf. 2004. Evaluating potential infectious disease threats for southern resident killer whales, *Orcinus orca*: a model for endangered species. Biological Conservation. 117:253-262.

Gregory-Eaves, I., B. P. Finney, M. S. V. Douglas and J. P. Smol. 2004. Inferring sockeye salmon (*Oncorhynchus nerka*) population dynamics and water quality changes in a stained nursery lake over the past ~500 years. Can. J. Fish. Aquat. Sci. 61:1235-1246.

Hall, J. D. and C. S. Johnson. 1972. Auditory thresholds of a killer whale *Orcinus orca* Linnaeus. J. Acoust. Soc. Amer. 51:515-517.

Hanrahan, T. P., D. D. Dauble and D. R. Geist. 2004. An estimate of chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat and redd capacity upstream of a migration barrier in the upper Columbia River. Can. J. Fish. Aquat. Sci. 61:23-33.

Hare, SR, NJ Mantua, RC. Francis. 1999. Inverse production regimes: Alaskan and West Coast Salmon. Fisheries 24(1):6-14.

Hazardous Materials Response Division. 1999. New Carissa home page. Office of Response and Restoration, NOAA. http://www.incidentnews.gov/incidents/incident_1.htm

Heyning, J. E. and M. E. Dahlheim. 1988. *Orcinus orca*. Mammalian Species. 304:1-9.

Hoelzel, A. R. 2004. Report on killer whale population genetics for the BRT review on the status of the Southern Resident population. Paper presented to BRT.

Hoyt, E. and G. T. Hvenegaard. 2003. A review of whale-watching and whaling with applications for the Caribbean. Coastal Management. 30:381-399.

IUCN. 2001. IUCN Red List categories and criteria. Version 3.1. IUCN Species Survival Commission. IUCN. Cambridge. UK. 32 pp.

Jelinski, D. E., C. C. Krueger, and D. A. Duffus. 2002. Geostatistical analyses of interactions between killer whales (*Orcinus orca*) and recreational whale-watching boats. Applied Geography 22:393-411.

Kao, T. and N. Scholz. 2004. Effects of copper on mechanosensory structures in developing fish embryos and larvae. 2003 Georgia Basin/Puget Sound Resarch Conference Proceedings. Puget Sound Action Team, Olympia, WA.

Killer Whale Recovery Team. Draft National Recovery Strategy for Northern and Southern Resident Killer Whales (Orcinus orca). Prepared for Public Consultations, Spring 2005, for Fisheries and Oceans Canada, on behalf of the Resident Killer Whale Recovery Team. 70 pp.

Kocan, RM, HV Westerhagen, ML Landolt, G Furstenberg. 1987. Toxicity of sea-surface microlayer: II. Effects of hexane extract on Baltic herring (*Clupea harengus*) and Atlantic cod (*Gadus morhua*) embryos. Mar. Environ. Res. 23:291-305.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein and R. S. Waples. 2002. Status review of southern resident killer whales (*Orcinus orca*) under the Endangered Species Act. U. S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-54.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, B. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein and R. S. Waples. 2004. 2004 status review of southern resident killer whales (*Orcinus orca*) under the Endangered Species Act. U. S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-62. 73 pp.

Lawson, P. W., E. A. Logerwell, N. J. Mantua, R. C. Francis and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 61:360-373.

LeDuc, R. G. and B. L. Taylor. 2004. Mitochondrial sequence variation in North Pacific killer whales. Paper presented to BRT.

Mantua, NJ, SR Hare, Y Zhang, JM Wallace, RC Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Amer. Meteor. Soc. 78(6):1069-1079.

Matkin, C. O., G. E. Ellis, M. E. Dahlheim and J. Zeh. 1994. Status of killer whales in Prince William Sound, 1984-1992. In (T. R. Loughlin, ed.) Marine mammals and the Exxon Valdez. Academic Press. NY. 141-162.

Mayr, E. 1963. Animal species and evolution. Harvard University Press. Cambridge.

Mikhalev, Y. A., M. V. Ivashin, V. P. Savusin, and F. E. Zelenya. 1981. The distribution and biology of killer whales in the Southern Hemisphere. Rep. Int. Whal. Commn. 31:551-566.

Merz, J. E., J. D. Setka, G. B. Pasternack and J. M. Wheaton. 2004. Predicting benefits of spawning-habitat rehabilitation to salmonid (*Oncorhynchus* spp.) fry production in a regulated California river. Can. J. Fish. Aquat. Sci. 61:1433-1446.

Morton, A. R. Routledge, C. Peet and A. Ladwig. 2004. Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada. Can. J. Fish. Aquat. Sci. 61:147-157.

Morton, A. B. and H. K. Symonds. 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. ICES J. Mar. Res. 59:71-80.

Mueter, F.J. , R.M. Peterman and B.J. Pyper. 2002. Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (*Oncorhynchus* spp.) in northern and southern Areas. Can. J. Fish. Aquat. Sci. 59: 456–463

Nishiwaki, M. and C. Handa. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. Sci. Rep. Whales Res. Inst. 13:85-96.

Norman, S.A., Raverty, S., McLellan, B., Pabst, A., Ketten, D., Fleetwood, M., Gaydos, J.K., Norberg, B., Barre, L., Cox, T., Hanson, B., and Jeffries, S. 2004. Multidisciplinary investigation of stranded harbor porpoises (*Phocoena phocoena*) in Washington State with an assessment of acoustic trauma as a contributory factor (2 May – 2 June 2003). U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-NWR-34, 120 p.

Nossiter, B. D. 1977. Lost Whale Frolics in Ulster River; 'Dopey Dick' Distracts Londonderry's Feuding Protestants, Catholics. The Washington Post. Washington, D.C.: Nov 12, 1977. pg. A13.

Olesiuk, P. F., M. A. Bigg and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12:209-243.

Osborne, R. W. 1999. A historical ecology of Salish Sea "resident" killer whales (*Orcinus orca*): with implications for management. Ph.D. thesis. U. Victoria. Victoria, BC.

Osborne, R. W., K. Koski and R. Otis. 2003. Trends in whale watching traffic around southern resident killer whales. The Whale Museum. Friday Harbor, WA.

Peterson, W. T. and F. B. Schwing. 2003. A new climate regime in Northeast Pacific ecosystems. Geophysical Research Letters, 30(17), #1896. 4 pp.

Pitman, R. L. and P. Ensor. 2003. Three forms of killer whales (*Orcinus orca*) in Antarctic waters. J. Cet. Res. Manag. 5: 131-139.

Plater, B. 2001. Petition to list the Southern Resident killer whale (*Orcinus orca*) as an endangered species under the Endangered Species Act. The Center for Biological Diversity. Berkeley, CA.

Protected Resources Division. 2004a. Initial Assessment of NOAA Fisheries' Critical Habitat Analytical Review Teams For 13 Evolutionarily Significant Units of Pacific Salmon and O. mykiss. NOAA Fisheries Protected Resources Division. Portland, Oregon. 569 pp.

Protected Resources Division. 2004b. Preliminary findings of National Marine Fisheries Service's (NMFS) critical habitat development and review teams for seven salmon and *O. mykiss* evolutionarily Significant Units (ESUs) in California. NMFS Protected Resources Division. Long Beach, CA. 21pp + appendices.

Rayne, S., M. G. Ikonomou, P. S. Ross, G. M. Ellis and L. G. Barrett-Lennard. 2004. PBDEs, PBBs, and PCNs in three communities of free-ranging killer whales (Orcinus orca) from the Northeastern Pacific Ocean. Environ. Sci. Technol. 38:4293-4299.

Reeves, R. R., W. F. Perrin, B. L Taylor, C. S. Baker and S. L Mesnick. 2004. Report of the workshop on shortcomings of cetacean taxonomy in relation to needs of conservation and management, April 30-May 2, 2004 La Jolla, California. NOAA-TM-NMFS-SWFSC-363.

Reynolds, C. 2005. Power play: a wave electricity-generating project could shrink a popular surf break. Los Angeles Times. February 15, 2005.

Richardson, W. J., C. R. Greene, C. I. Malme and D. H. Thompson. 1995. Marine mammals and noise. Academic Press. San Diego, CA.

Romano, T. A., M. J. Keogh, C. Kelly, P. Feng, L. Berk, C. E. Schlundt, D. A. Carder and J. J. Finneran. 2004. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Can. J. Fish. Aquat. Sci. 61:1124-1134.

Ross, P. S., G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard, and R. F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, Orcinus orca: effects of age, sex and dietary preference. Mar. Poll. Bull. 40:504-515.

Scammon, C. M. 1869. On the cetaceans of the western coast of North America. In (Cope, E. D., ed.) Proc. Acad. Nat. Sci. Philadelphia. 1869:13-63.

Scammon, C. M. 1874. The Marine Mammals of the Northwestern Coast of North America Together with an Account of the American Whale-Fishery. Dover. New York.

Schevill, W. E. 1986. The International Code of Zoological Nomenclature and a paradigm: the name *Physeter catadon* Linneaus 1758. Mar. Mamm. Sci. 2:153-157.

Scholz, N. L., N. K. Truelove, B. L. French, B. A. Berejikian, T. P. Quinn, E. Casillas, and T. K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha*). Can. J. Fish. Aquat. Sci. 57: 1911–1918.

Shepherd, G.S. 1932. Killer whale in a slough at Portland, Oregon. J. Mammal. 13:171-172.

Skilling, D. 2005. EnCana partners to enable Pearson college – EnCana – clean currentTidal power demonstration project at Race Rocks, BC. http://www.racerocks.com/racerock/energy/tidalenergy/pressrelease.pdf.

Szymanski, M. D., D. E. Bain, K. Kiehl, K. R. Henry, S. Pennington and S. Wong. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. J. Acoust. Soc. Amer. 106:1134-1141.

UNEP. Unpublished. Northwest Pacific Region. www.unep.ch/regionalseas/pubs/profiles/nowpap.doc

United State Department of Commerce and the Secretary of the Navy. 2001. Joint Interim Report: Bahamas Marine Mammal Stranding Event of 15-16 March 2000. 59 pp.

United States Navy. 2004. Report on the Results of the Inquiry into Allegations of Marine Mammal Impacts surrounding the Use of Active Sonar by USS SHOUP (DDG 86) in the Haro Strait on or about 5 May 2003. 52pp.

United States Navy and National Marine Fisheries Service. 2002. Biological opinion. http://www.nmfs.noaa.gov/pr/readingrm/ESAsec7/7pr_surtass-2020529.pdf.

Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Tech. Memo. NMFS-NWFSC-24. 266 pp.

Whitehead, H. 2005. Genetic diversity in matrilineal whales: models of cultural hitchhiking and group-specific non-heritable demographic variation. Marine Mammal Science. 21:58-79.

Williams, R., D. E. Bain, J. K. B. Ford and A. W. Trites. 2002a. Behavioural responses of killer whales to a "leapfrogging" vessel. J. Cet. Res. Manage. 4:305-310.

Williams, R., A. Trites and D. E. Bain. 2002b. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. J. Zool. (Lond.). 256:255-270.

Whale Watch Operators Association Northwest. 2004. Best practices guidelines. www.nwwhalewatchers.org/guidelines.html.

Yano, K. and M. E. Dahlheim 1995a. Behavior of killer whales *Orcinus orca* during longline fishery interactions in the southeastern Bering Sea and adjacent waters. Fisheries Science. 61:584-589.

Yano, K. and M. E. Dahlheim 1995b. Killer whale, *Orcinus orca*, depredation on longline catches of bottomfish in the southeastern Bering Sea and adjacent waters. Fish. Bull. 93:355-372.

Tables and Figures

Table 1. Comparison of the Status of Species listed by IUCN and NMFS.

Species	IUCN Red List	ESA
Caribbean monk seal	CRITICALLY ENDANGERED	ENDANGERED
Chinese river dolphin	CRITICALLY ENDANGERED	ENDANGERED
Mediterranean monk seal	CRITICALLY ENDANGERED	ENDANGERED
bowhead whale	CRITICALLY ENDANGERED, ENDANGERED, VULNERABLE	ENDANGERED
gray whale *Western North Pacific*	CRITICALLY ENDANGERED	ENDANGERED
cochito	CRITICALLY ENDANGERED	ENDANGERED
Hawaiian monk seal	ENDANGERED	ENDANGERED
Indus River dolphin	ENDANGERED	ENDANGERED
Steller sea lion	ENDANGERED	ENDANGERED, THREATENED
blue whale	ENDANGERED	ENDANGERED
fin whale	ENDANGERED	ENDANGERED
right whale	ENDANGERED	ENDANGERED
Sei whale	ENDANGERED	ENDANGERED
Guadalupe fur seal	VULNERABLE	THREATENED
humpback whale	VULNERABLE	ENDANGERED
sperm whale	VULNERABLE	ENDANGERED

Figure 1. Proposed occupied critical habitat for Southern Residents. Known occupied habitat is shown in red. Rarely occupied habitat that is likely to become frequently occupied (and hence is critical to the recovery of the population) is shown in green.


Blaine
Bellingham
Mt Baker
10785
Skagit
Anacortes
Mount Vernon
Port Angeles
Lakewood
Marysville
Everett
Forks
OLYMPIC
Mt Olympus
7969
Lynnwood
Seattle
Redmond
Bellevue
Bremerton
Quinault River
MTS
Renton
Tacoma
Federal Way
Enumclaw
Puyallup
Olympia
Lacey
Aberdeen
Mt Rainier
14410
Raymond
South Bend
Centralia
Chehalis
Morton
Cowlitz River
Longview
Kelso
Mt St Helens
8365
Battle Ground
Vancouver
Camas
PACIFIC
OCEAN
CASCADE