DRAFT

National Recovery Strategy for Northern and Southern Resident Killer Whales

(*Orcinus orca*)

March 2005

Disclaimer

This draft National Recovery Strategy for northern and southern resident killer whales (*Orcinus orca)* has been prepared in cooperation with the members of the Resident Killer Whale Recovery Team. It defines the recovery goals, approaches and objectives that are deemed necessary to protect and recover the species. It does not necessarily represent the views of all individual members of the recovery team, or the official positions of the organizations with which the individual team members are associated. The goals, objectives and recovery approaches identified in the strategy are based on the best existing knowledge and are subject to modifications resulting from new findings and revised objectives. Implementation of the plan is subject to appropriations, priorities and budgetary constraints of the participating jurisdictions and organizations. Further details will be provided in one or more associated Action Plans.

Acknowledgements

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COSEWIC Assessment Summary

Common Name:	killer whale, orca,
Scientific Name:	*Orcinus orca*
Assessment Summary:	Assessed in 1999, reviewed and revised in 2001
COSEWIC Status:	'Southern resident' killer whales are listed as endangered, 'northern resident' killer whales as threatened
Reason for Designation:	The southern resident killer whale population is small, with recent declines of 17% between 1995 and 2001, and currently contains 85 members. The northern resident killer whale population is small at 205 members, with recent declines of 7% between 1997 and 2003. Seasonally, they are exposed to high levels of boat traffic. The availability of their prey is reduced relative to historic levels. High levels of persistent organic pollutants may be compromising their reproductive and immune systems, leading to reduced calving and/ or increased mortality rates.
Range in Canada:	Pacific Ocean
Status History:	In April 1999, the two North Pacific 'resident' killer whale populations were designated threatened. In November 2001, the southern resident population was designated endangered while the northern resident population remained threatened.

EXECUTIVE SUMMARY

Two distinct populations of killer whales (Orcinus orca), known as the northern and southern residents, occupy the waters off the west coast of British Columbia. In 2001, COSEWIC designated southern resident killer whales as 'endangered', and northern resident killer whales as 'threatened'. Both populations are listed in Schedule 1 of the Species at Risk Act (SARA). These two populations are acoustically, genetically and culturally distinct.

Resident killer whale populations in British Columbia are presently considered to be at risk because of their small population size, low reproductive rate, and the existence of a variety of anthropogenic threats that have the potential to prevent recovery or to cause further declines. Principal among these anthropogenic threats are environmental contamination, reductions in the availability or quality of prey, and both physical and acoustic disturbance. Even under the most optimistic scenario (human activities do not increase mortality or decrease reproduction), the species' low intrinsic growth rate means that the time frame for recovery will be more than one generation (25 years).

The southern resident killer whale population experienced declines of 3% per year between 1995 and 2001, and had 85 members in 2003. During the summer and fall, southern residents are primarily found in the trans-boundary waters of Haro Strait, Boundary Pass, the eastern portion of the Strait of Juan de Fuca, and southern portions of the Strait of Georgia. This area is proposed as 'critical habitat' based on consistent and prolonged seasonal occupancy. Some members of the population typically remain in the same general area in winter and spring, but others appear to range over much greater distances, and have been reported as far south as Monterey Bay, California, and as far north as Haida Gwaii (the Queen Charlotte Islands). Winter and spring critical habitat has not been identified for the latter group. During the summer and fall, the principal prey of southern residents appears to be chinook and chum salmon, (*Onorchynchus tshawytscha* and *O. keta*); little is known of their diet in the winter and spring. The lack of information about winter diet and distribution of the southern residents is a major knowledge gap that impedes our understanding of the principal threats facing the population.

The northern resident killer whale population experienced a decline of 7% between 1997 and 2003, and had 205 members in 2003. The population appears to spend the majority of its time from Campbell River and Alberni Inlet northwest to Dixon Entrance, but has been sighted as far south as Grays Harbor, Washington, and as far north as Frederick Sound, Alaska. A portion of the population is regularly found in Johnstone Strait and southeastern portions of Queen Charlotte Strait (and adjoining channels) during the summer and fall, and this area is identified as proposed critical habitat based on this seasonal occupancy. Other areas are likely very important to northern residents during this time but they have yet to be clearly identified. Similarly, areas that may constitute critical habitat during the winter and spring are not yet known. Northern residents also appear to target chinook and chum salmon during the summer and fall. However, like southern residents, very little is known of their winter distribution and diet, and this knowledge gap must be addressed to fully understand the principal threats affecting the population.

The goal of the resident killer whale recovery strategy is to:

Ensure the long-term viability of resident killer whale populations and sustain their genetic diversity and cultural continuity by reducing human threats, including noise and pollutants, and protecting their habitat and prey.

In order to achieve this goal, five principal objectives have been identified. These include:

Objective 1: *To ensure the long term viability of resident killer whale populations by achieving and maintaining demographic conditions that preserve their reproductive potential, genetic variation, and cultural continuity.*

Objective 2: *Ensure that resident killer whales have an adequate and accessible food supply to allow recovery.*

Objective 3*: Ensure that chemical and biological pollutants do not prevent the recovery of resident killer whale populations.*

Objective 4*: Ensure that disturbance from human activities does not prevent the recovery of resident killer whales.*

Objective 5: *Protect proposed critical habitat for resident killer whales and identify additional potential core areas for critical habitat designation and protection.*

Numerous broad strategies are outlined herein to achieve these objectives. However, significant gaps in knowledge about killer whales remain and numerous actions have been identified to address these knowledge gaps and to identify further directions for recovery. Six recovery implementation groups (RIGs) are recommended to address the threats and issues of 1) knowledge gaps regarding resident killer whale population dynamics and demographics, 2) reduced prey availability, 3) environmental contaminants, 4) physical disturbance, 5) acoustic disturbance, and 6) critical habitat. These RIGS will develop an appropriate Action Plan within two years of the acceptance of the recovery strategy by the competent minister

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BACKGROUND

1. CURRENT STATUS

1.1. Species Description

The killer whale is the largest member of the dolphin family, Delphinidae. Its size, striking black and white colouring and tall dorsal fin are the main identifying characteristics. Killer whales are mainly black above and white below, with a white oval eye patch, and a grey saddle patch below the dorsal fin. Each killer whale has a uniquely shaped dorsal fin and saddle patch, as well as naturally acquired nicks and scars. Individual killer whales are identified using photographs of the dorsal fin, saddle patch, and sometimes eye patches (Ford et al. 2000). They are sexually dimorphic. Maximum recorded lengths and weights for male killer whales are 9.0 m, and 5,568 kg respectively, whereas females are smaller at 7.7 m and 4,000 kg (Dahlheim and Heyning 1999). The tall triangular dorsal fin of adult males is often as high as 1.8 m, while in juveniles and adult females it reaches 0.9 m or less. In adult males, the paddle-shaped pectoral fins and tail flukes are longer and broader and the fluke tips curl downward (Bigg et al. 1987).

Currently, most authorities consider killer whales to be one species, *Orcinus orca*, having regional variations in diet, size, colouration, and vocal patterns (Heyning and Dahlheim 1988, Ford et al. 2000, Barrett-Lennard and Ellis 2001). Two and possibly three distinct species have recently been proposed for Antarctic populations (Mikhalev et al. 1981, Berzin and Vladimorov 1983, Pitman and Ensor 2003), but they are not yet widely accepted (Reeves et al. 2004). In addition, recent genetic studies report little global variation in mitochondrial DNA suggesting that the population segregation indicated by the morphological differences described above is relatively recent (Barrett-Lennard 2000, Hoelzel et al. 2002).

Three distinct forms, or ecotypes, of killer whale inhabit Canadian Pacific waters: transient, offshore and resident. These forms are sympatric but socially isolated and differ in their dietary preferences, genetics, morphology and behaviour (Ford et al. 1998, 2000, Barrett-Lennard and Ellis 2001). Transient killer whales feed on marine mammals; particularly harbour seals (*Phoca vitulina*), porpoises, and sea lions (Ford et al. 1998). They travel in small, acoustically quiet groups that rely on stealth to find their prey (Ford and Ellis 1999). To the experienced eye, the dorsal fins of transient whales tend to be pointed and their saddle patches are large and uniformly grey (Ford et al. 2000). Offshore killer whales are not as well understood as residents and transients, but they are thought to feed on fish (Ford et al. 2000, Heise et al. 2003). They travel in large acoustically active groups of 30 or more whales, using frequent echolocation and social calls (Ford et al. 2000). The dorsal fins of offshore killer whales are more rounded than those of transients, and their saddle patches may either be uniformly grey or may contain a black region.

Resident killer whales are the best understood of the 3 ecotypes. They feed exclusively on fish and cephalopods and travel in acoustically active groups of 10 to 25 or more whales (Ford et al. 2000). The tips of their dorsal fins tend to be rounded at the leading edge and have a fairly abrupt angle at the trailing edge. Their saddle patches may be uniformly grey or contain a black region. The social organization of resident killer whales is highly structured. Its fundamental unit is the *matriline,* which comprises a matriarch, her offspring, and the offspring of her daughters. Both sexes remain within their natal matriline for life (Bigg et al. 1990). Social systems in which both sexes remain with their mother for life has only been described in one other mammalian species, the long-finned pilot whale, *Globicephala melas* (Amos et al. 1993). Bigg et al (1990) defined *pods* as groups of closely related matrilines that travel, forage, socialize and rest with each other at least 50% of the time, and predicted that pods, like matrilines, would be stable over many generations. However, Ford and Ellis (2002) showed that inter-matriline association patterns in the northern residents have evolved over the past decade such that some of the pods identified by Bigg et al. now fail to meet the 50% criterion. Their analysis suggests that pods are best defined as transitional groupings that reflect the relatedness of recently diverged matrilines.

Each resident pod has a unique dialect made up of approximately a dozen discrete calls (Ford 1989, 1991). These dialects can be distinguished, providing each pod with a unique acoustic signature. Dialects are learned from mothers and other associated kin and are highly stable over time (Ford et al. 2000). Their function is not entirely understood, although it appears that they play an important role in mate selection (Barrett-Lennard 2000, discussed below in Section 3.2.7. Culture). Despite having distinct dialects, some pods share certain calls and call variants. Pods that share one or more calls belong to a common *clan*.

Resident killer whales that share a common range and that associate at least occasionally are considered to be members of the same *community*, or population. There are two communities of resident killer whales in British Columbia, the *northern residents*, and the *southern residents*. They have not been observed interacting and genetic studies have revealed that the two populations rarely if ever interbreed (Barrett-Lennard and Ellis 2001). The northern resident community consists of three clans, and the southern resident community, one clan.

The existence of two distinct populations of resident killer whales using the waters of Washington and British Columbia has been recognized by both the Canadian and US governments. In 2001 COSEWIC assigned northern residents 'threatened' status, and southern residents 'endangered' status. In the United States, marine mammals are afforded federal protection under both the Marine Mammal Protection Act (MMPA) and, when listed, under the Endangered Species Act (ESA). The southern residents were listed as 'depleted' under the MMPA in 2003. The National Marine Fisheries Service (NMFS) is currently proposing designating the southern residents as 'threatened' under the ESA, and invites public comment until March 22, 2005. In June 2004, the Washington State Department of Fish and Wildlife added southern resident killer whales to their endangered species list.

1.2. Distribution

1.2.1. Global Range

Killer whales are found in all oceans, and are most common in areas associated with high ocean productivity in mid to high latitudes (Forney and Wade In Press). They are able to tolerate temperatures ranging from those found in polar waters to the tropics, and have been recorded in water ranging from shallow (several metres) to open ocean depths (Baird 2001).

1.2.2. Canadian Pacific Range

Killer whales are found in all three of Canada's oceans, as well as occasionally in Hudson Bay and in the Gulf of St. Lawrence, but they appear to be uncommon in the Atlantic and the Arctic (COSEWIC 2003). In British Columbia (BC), they have been recorded throughout almost all salt-water areas, including many long inlets, narrow channels and deep embayments (Baird 2001). The three ecotypes of BC killer whales (offshore, transient, and resident) do not appear to interact socially despite their overlapping ranges (Ford et al. 2000). Offshore killer whales are most often sighted on the continental shelf off the outer coast, but they are occasionally found in protected inside waters (Ford et al. 2000). Transient killer whales range throughout the area, as do resident killer whales (Ford and Ellis 1999, Ford et al. 2000). Residents and transients have occasionally been seen in close proximity to each other, but rarely interact (Ford and Ellis 1999). Figure 1 shows many place names mentioned in the text, as well as the general ranges of northern and southern residents.

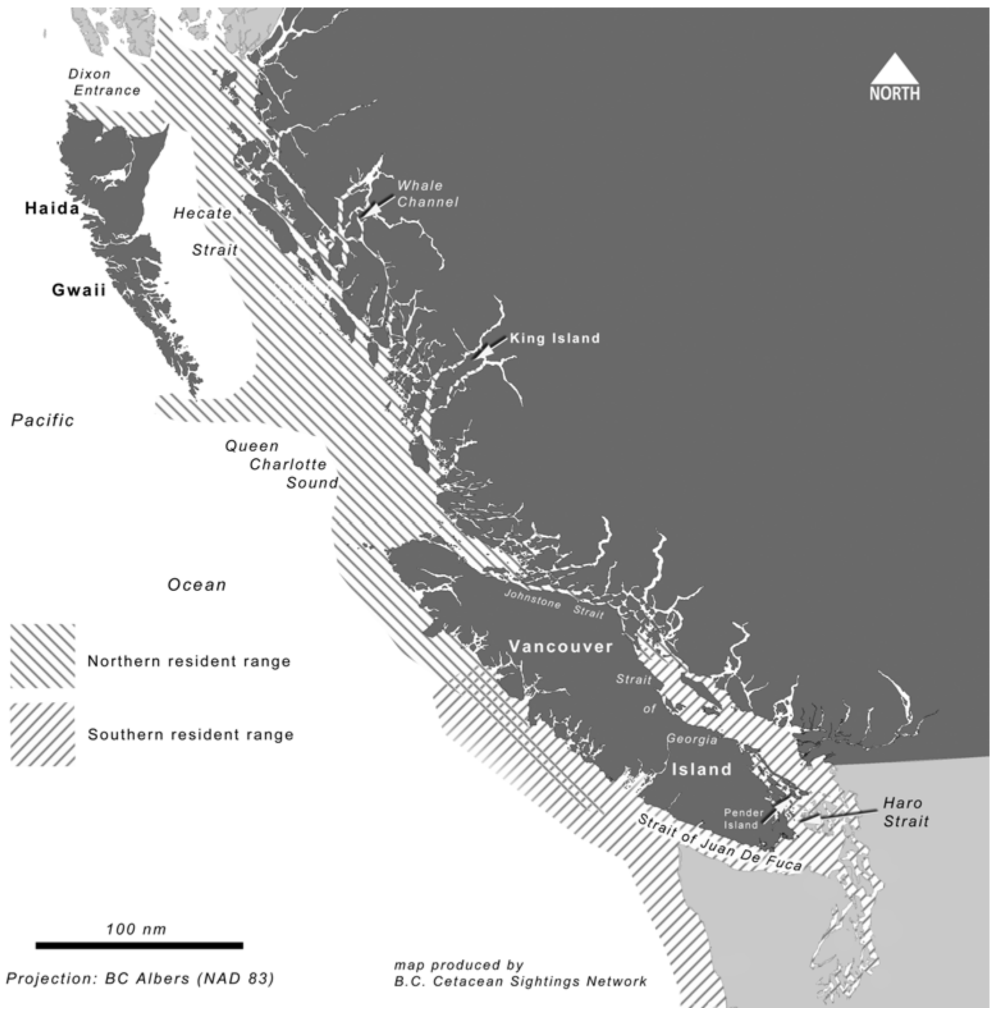

Figure 1 The coast of British Columbia showing the general ranges of northern and southern resident killer whales.

1.2.2.1. Southern Residents

The community of southern residents comprises a single acoustic clan, J clan, which is composed of three pods (referred to as J, K, and L) containing a total of 20 matrilines (Ford et al. 2000). The known range of this community is from northern British Columbia to central California

(Ford et al. 2000; unpublished data, Cetacean Research Program, Pacific Biological Station, Nanaimo, BC [CRP-DFO]). During summer, its members are usually found in waters off southern Vancouver Island and northern Washington State, where they congregate to intercept migratory salmon. The core area for southern residents is Haro Strait and vicinity off southeastern Vancouver Island (Figure 2), but they are commonly seen in Juan de Fuca Strait, and the southern Strait of Georgia (Ford et al. 2000). Of the three southern resident pods, J pod is most commonly seen in inside waters throughout the year, and appears to seldom leave the Strait of Georgia-Puget Sound-Strait of Juan de Fuca region (Ford et al. 2000). K and L pods are more often found in western Juan de Fuca Strait and off the outer coasts of Washington State and Vancouver Island. Unlike J pod, K and L pods typically leave inshore waters in winter and return in May or June. Their range during this period is poorly known, but they have been sighted as far south as Monterey Bay, California and as far north as Langara Island, off Haida Gwaii (Ford et al. 2000, Black et al. 2001, unpublished data CRP-DFO).

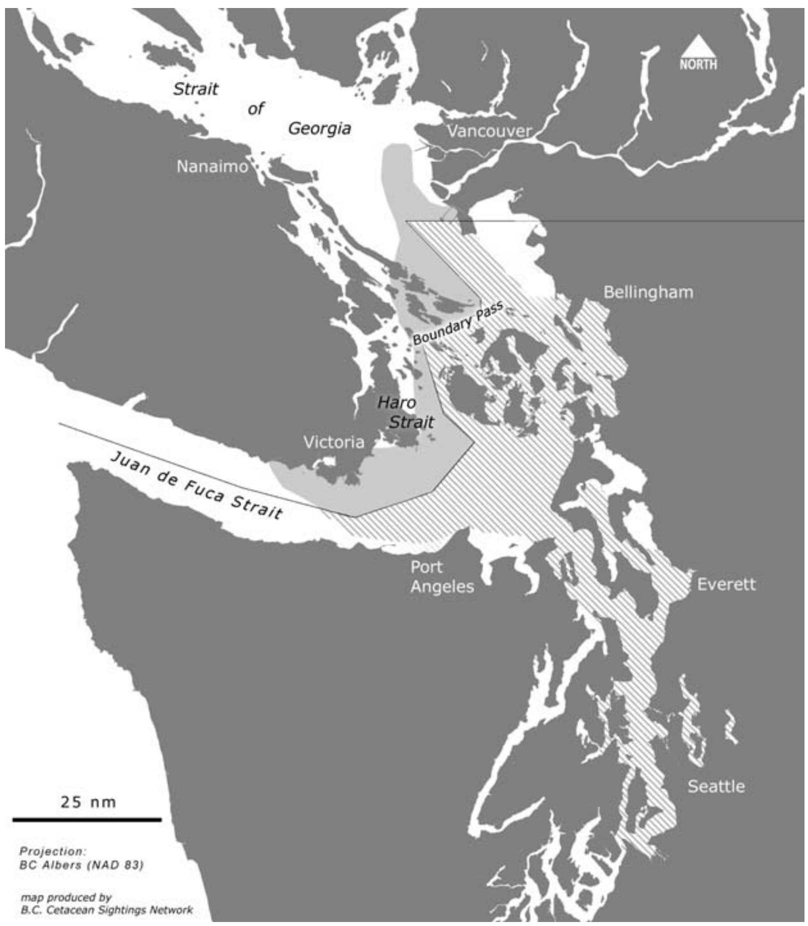

Figure 2 The known critical habitat for southern resident killer whales in late spring summer and fall, in British Columbia. The hatched area shows suggested critical habitat for Washington State. Other core areas have not yet been identified.

1.2.2.2. Northern Residents

The northern resident killer whale community comprises three acoustic clans (A, G, and R) containing 34 matrilines, which range from Frederick Sound, Alaska to Grays Harbour, Washington (Ford et al. 2000, unpublished data CRP-DFO). From June to October, they frequent areas from mid Vancouver Island to southeastern Alaska, particularly Johnstone Strait and Queen Charlotte Strait (Figure 3), off northeastern Vancouver Island (Ford et al. 2000). Their range at other times of the year is poorly understood. Small groups of northern residents are sometimes seen in Johnstone Strait and other inshore waters along the BC coast in winter (Ford et al. 2000) but such sightings are rare even when seasonal changes in observer effort is taken into account.

There is no evidence that clans are restricted to specific regions within the range of their community, but some show an apparent preference for particular areas (Ford et al. 2000). For example, the most commonly sighted whales off northeastern Vancouver Island belong to A-clan, whereas most of the whales sighted off the west coast of Vancouver Island belong to G-clan, and R-clan seems to prefer the northern part of the community's range. The range of northern residents overlaps with southern residents and with a community referred to as the southern Alaskan residents. Northern residents have never been seen associating with members of the southern resident community, and while they were observed travelling in proximity to a southern Alaskan resident pod on one occasion (Dahlheim et al. 1997), it is not clear that social mixing took place. Genetic studies have not ruled out the possibility of occasional breeding between the northern resident and southern Alaskan resident communities (Barrett-Lennard and Ellis 2001).

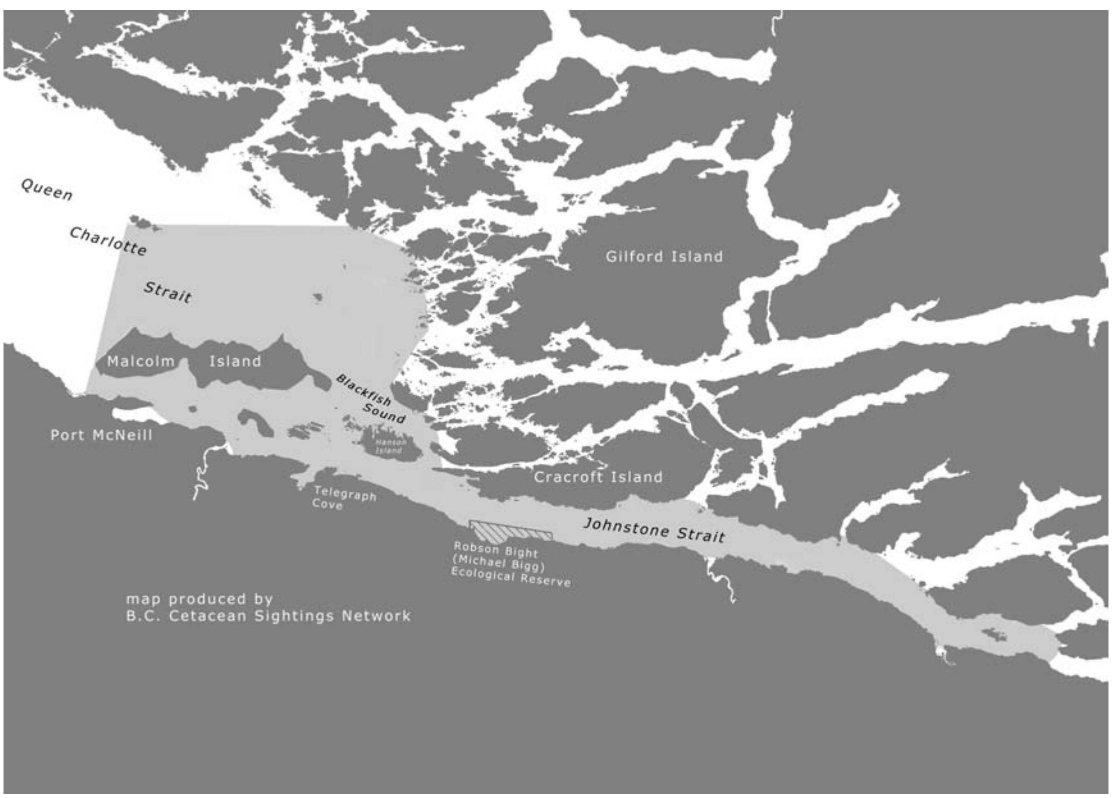

Figure 3 The known critical habitat for northern resident killer whales in summer and fall in British Columbia. Other core areas have not yet been identified**.**

2. POPULATION SIZE AND TRENDS

2.1. Global

Little is known of the historic abundance of killer whales, except that they were "not numerous" (Scammon 1874). Since the early 1970s, photo-identification studies have provided reasonable population estimates for killer whales in the nearshore waters of the northeastern Pacific (Washington, British Columbia, Alaska, and California), and similar work is now underway in several other coastal regions (e.g. the Sea of Cortez (Mexico), the Russian Far East, New Zealand, Patagonia, Iceland and Norway). In other areas line transect surveys have been used to provide population estimates. These include the Antarctic (25,000 whales, Branch and Butterworth 2001) and the Eastern Tropical Pacific (8,500 whales, Wade and Gerodette 1993). As such, the worldwide abundance of killer whales is probably between 40,000 and 60,000 whales (Forney and Wade In Press). Trend data for killer whales is generally not available, with the exception of resident populations of whales in British Columbia (discussed below) and southern Alaska (population increasing, Peter Olesiuk, personal communication November 2004) and for a small population of transients in Prince William Sound (AT1s, currently in decline, not likely to recover, Saulitis et al. 2002).

2.2. British Columbia

There are no population estimates for killer whales in British Columbia prior to 1960. Population censuses for killer whales are now conducted annually using photo-identification of individuals. Population trends vary by community and clan. For the purposes of the Recovery Strategy, data held by the Centre for Whale Research (CWR), Friday Harbor, Washington, was used to describe the population status and trends of southern resident killer whales. Data held by the Cetacean Research Program, DFO Nanaimo, BC (CRP-DFO), was used to describe the northern resident killer whale population. Whales are censused slightly differently by each group.[1]

The southern resident count includes all whales that are seen during a calendar year, and mortalities are included in the count depending on when they occur. For example, a whale that is not seen from March onwards is assumed to be dead. There is less certainty that a whale that is not seen in November or December is dead, and it may be included in the count. In recent years, observer effort has been high and members of the southern resident community are photographed annually, so the count is reasonably precise.

The northern resident count includes all whales that are known to be alive on July 1 of each year. However, not all members of the resident community are seen each year, so the count data are generally less precise than for the southern residents.

In 2003, there were a total of 290 northern and southern resident killer whales (unpublished data, CWR, and CRP-DFO). By comparison there are approximately 220 transient and 200 offshore killer whales, although these numbers are less precise than the resident counts, because not all individuals are encountered each year (Ford et al. 2000).

[1] Note that there are also small discrepancies in the southern resident counts in the literature due to different methods of recording when whales are considered to enter or leave the population. For example Krahn et al. (2004) report 83 southern residents in 2003.

2.2.1. Southern Residents

The size of the southern resident community has been known since the first complete photo-identification census in 1976, and was estimated for the years prior to that (Olesiuk et al. 1990, unpublished data CWR). Figure 4 shows the size of each pod as well as the fluctuation in the total population of the southern resident community from 1974-2003.

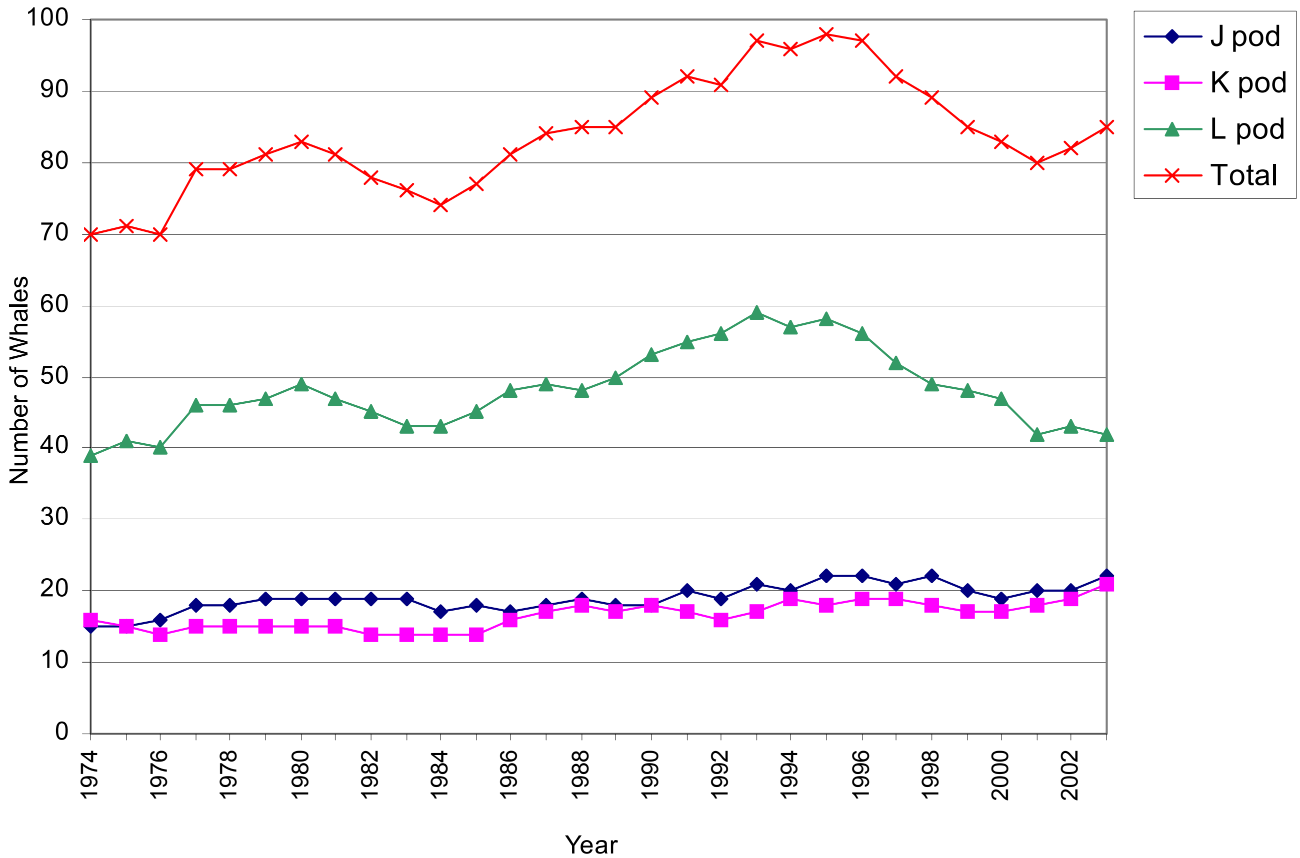

Figure 4 Population size and trends for southern resident killer whales from 1974-2003. Source: Unpublished data from the Centre for Whale Research.

Although the southern resident community was likely increasing in size in the early 1960s, the number of whales in the community dropped dramatically in the late 1960s and early 1970s due to live capture for aquariums (Bigg and Wolman 1975). A total of 47 individuals that are known or likely to have been southern residents were captured and removed from the population (Bigg et al. 1990). The population increased 19% (3.1% per year) from a low of 70 after the live-captures ended in 1973 to 83 whales in 1980, although the growth rate varied by pod (Figure 4). From 1981-1984 the population declined 11% (-2.7% per year) to 74 whales as a result of lower birth rates, higher mortality for adult females and juveniles (Taylor and Plater 2001), and lower numbers of mature animals, especially males, which was caused by selective cropping in previous years (Olesiuk et al. 1990). From 1985 to 1995, the number of southern residents increased by 34% (2.9% per year) to 99 animals. A surge in the number of mature individuals, an increase in births, and a decrease in deaths contributed to the population growth. The latest decline began in 1996, with an extended period of poor survival (Taylor and Plater 2001, Krahn et al. 2002) and low fecundity (Krahn et al. 2004) resulting in a decline of 17% (-2.9% per year) to 81 whales in 2001. Since 2001, the number of southern residents has increased slightly to 85 in 2003[2] (unpublished data CWR). The growth has been in J and K pods, whereas L pod has continued to decline.

Population viability analyses (PVA) have been used to estimate the extinction risk of southern resident killer whales (Taylor and Plater 2001, and Krahn et al. 2002, 2004). As would be expected, higher extinction risks are associated with greater frequency and magnitude of catastrophes such as oil spills and disease epidemics. The models predict that if the mortality and reproductive rates of the 1990s persist, there is a 6-100 % probability that the population will be extinct within 100 years, and a 68-100% risk that the population will be extinct within 300 years. Extinction of the southern resident population can be regarded as inevitable in these scenarios under the assumptions of the analyses, and catastrophic events simply hasten its demise. However, when the mortality and reproductive rates of the entire 1974-2000 period are used, the risk of the population going extinct declines to 0-55% over 100 years and 2-100% over 300 years.

In addition to analyses focused solely on the southern residents, Krahn et al. (2002) ran simulations assuming that the southern resident population was part of a larger breeding population including northern and southern Alaskan resident killer whales, which greatly decreased its extinction risk. However this scenario does not reflect present evidence, which suggests that southern residents are genetically isolated from other populations (Barrett-Lennard 2000; Barrett-Lennard and Ellis 2001).

2.2.2. Northern Residents

The northern resident community was likely increasing in size during the early 1960s, but was cropped by the live capture fishery of 1964-1973, during which at least 14 individuals were removed. Twelve of those are known to have been from one pod (A5, Bigg et al. 1990). When first censused in 1974, the northern resident community was estimated to contain approximately 120 whales. Although abundance estimates for northern residents are less precise than those for southern residents, because not all matrilines are seen each year, it appears that the northern community grew steadily during the period 1974 to 1991 (approximately 3.4% per year, Figure 5). The census method used for northern residents is to estimate the population size based on the number of animals that are known to be alive on July 1 of each year. The population increased to a peak of 220 animals in 1997 (growth of 3.0% per year, unpublished data CRP-DFO). Several reasons have been postulated for the northern residents' success relative to southern residents during this period: the population's larger size may have buffered changes in birth and death rates, fewer animals were captured during the live-capture fishery (Olesiuk et al. 1990), and in general they are exposed to less disturbance and environmental contamination. Between 1997 and 2003, the northern resident community declined 7% to 205 whales in 2003 (unpublished data CRP-DFO, Figure 5). As with southern resident killer whales, the cause(s) of the decline are not known. No population viability analysis has yet been conducted for the northern resident killer whales exclusively.

[2] This estimate includes L98 or Luna, discussed in section 3.2.2. Social Organization

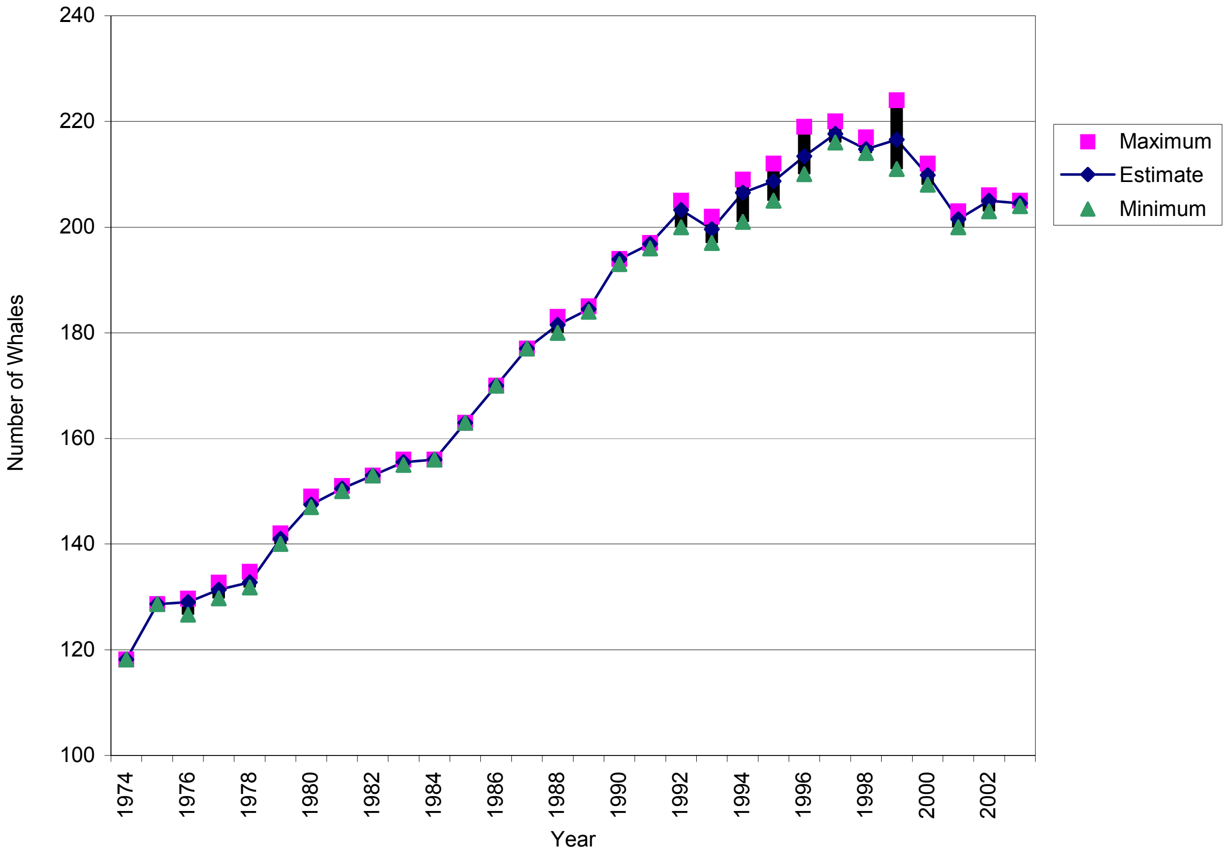

Figure 5 Population size and trends for northern resident killer whales from 1974 to 2003. Values reflect the minimum, maximum and estimated number of animals alive as of July 1 in each year. Source: Unpublished data, Cetacean Research Program-DFO, Nanaimo.

3. FACTORS AFFECTING POPULATION VIABILITY AND RECOVERY

It is important to appreciate that northern and southern resident killer whales have been studied primarily in protected waters during the months of May to October (Ford et al. 1998, 2000). Their behaviour and ecology in other areas and seasons is poorly known.

3.1. Habitat Requirements

Little is known of the habitat requirements of killer whales. As they are found in all oceans of the world, they are likely not limited by physical characteristics associated with temperature, salinity, visibility etc. Observations suggest that killer whales require clean water, healthy prey populations and a physical and acoustical environment that is large and quiet enough for them to maintain communication, locate and capture prey without disruption, and maintain other vital life functions.

In British Columbia, habitat use and preferences of resident killer whales are likely learned traditions strongly influenced by the experiences of older members of the matrilineal group (Ford et al. 1998). The habitat preferences of residents differ from those of transients, likely a result of the major differences in the prey preferences of the two ecotypes.

During summer and fall, the distribution of resident killer whales is strongly associated with 'core areas' of abundant salmon (Bigg et al. 1987, Felleman et al. 1991, Ford et al. 2000, Heimlich-Boran 1986, 1988, Nichol and Shackleton 1996). They are frequently seen foraging within 50-100 m of shore, using steep underwater slopes to corral fish (Ford et al. 1998). Although they generally travel within the upper 30 m of the water column, tagging studies have revealed that they may dive much deeper during foraging (Baird et al. 2003). Two areas have been proposed as seasonally important critical habitat for resident killer whales and these are discussed in more detail in section 5 (Critical Habitat). Other areas are also likely important, but there is insufficient information to propose them as critical habitat at the present time.

Much less is known about resident killer whales' habitat use along the outer coast, or during the winter and spring. Reduced sightings during winter and spring may largely be due to movement to outside waters, but may also reflect seasonally biased effort (Ford et al. 2000). Poor weather conditions and limited daylight hours also limit our knowledge of the winter distribution and range of killer whales.

3.2. Biological Limiting Factors

The following description of the biology of killer whales is based on data from both the northern and southern resident populations. Essentially, resident killer whales feed on fish and do not switch to marine mammals when their principal prey species are not abundant. They are long-lived animals with no natural predators. On average females produce a single calf every 5 to 6 years during a 25 year reproductive period, and as a result the population has an inherently slow rate of growth. Resident killer whales have strong cultural traditions that influence their association and mating behaviours, which also limits the capacity for the population to grow. More detailed information on the factors which may limit the ability of resident killer whale populations to grow is provided below.

3.2.1. Diet

Although globally killer whales feed on a wide range of prey species, northern and southern resident killer whales are dietary specialists, feeding primarily on fish (Ford et al. 1998). Unlike transient killer whales, resident killer whales do not feed on marine mammals and the breadth of their diet appears to be quite limited. During the months of May through October, 135 surface observations of feeding resident killer whales and the collection of prey fragments have revealed that their preferred prey is salmon, particularly chinook salmon (65% *Oncorhynchus tshawytscha*) (Ford et al. 1998). Over 75% of these observations were of northern residents and the remaining was of southern residents. Additional research conducted since 1998 supports the finding that chinook salmon are important in the diet of resident killer whales (unpublished data CRP-DFO).

Interestingly, even when fishery data show that sockeye salmon (*O. nerka*) are far more abundant than chinook salmon, northern resident killer whales still retain their preference for chinook. This may be because chinook are large, have a high fat content, and can typically be found in coastal waters throughout the year (Ford et al. 1998). In BC chinook usually remain in nearshore waters rather than migrating offshore (Healey 1991). Killer whales feeding at Langara Island in Haida Gwaii (Queen Charlotte Islands) are known to feed on chinook from stocks returning to rivers from as far north as the Skeena River near Prince Rupert to as far south as the Columbia River in Oregon. Recent observations have shown that northern resident killer whales also feed on chum salmon in the fall (*O. keta*) (unpublished data CRP-DFO). Steelhead (*O. mykiss*), coho (*O. kisutch*), sockeye and pink salmon (*O. gorbuscha*) probably do not comprise a significant portion of the diet of northern resident killer whales. Preliminary analysis of prey remains collected recently from southern residents support a similar pattern to the northern residents of chinook preference in the summer, with additional feeding on chum in the fall (DFO, CWR unpublished data).

Despite over 30 years of study in British Columbia, only 14 stomachs from resident killer whales have been recovered (Ford et al. 1998, unpublished data CRP-DFO). The extent to which stranded individuals provide accurate insight into the dietary preferences of healthy, free-ranging killer whales is not certain. However salmon was identified in all 7 stomachs that contained prey, including 4 in which chinook was positively identified. Two contained squid and one also contained bottom fish. Bottom fish (including ling cod, kelp greenling and various species of rock cod), as well as squid, may be an important component of killer whale diet in some areas or during certain times of the year, but more research is needed to determine the year-round diet of killer whales.

It is not known whether resident killer whales depend on specific salmon runs, but their occurrence has been correlated in several studies. The role of these geographical correlations with regard to prey selection is uncertain, since some of these species (sockeye and pink salmon) are not taken in significant numbers compared to chinook salmon (Ford et al. 1998, unpublished data CRP-DFO). The southern residents' presence in the mouth of the Fraser River and the San Juan Islands from late spring to early fall occurs when salmon are abundant and sockeye and pink runs pass through Haro Strait and vicinity (Osborne 1999). Heimlich-Boran (1986) presented evidence based on sport fishing catch statistics that killer whale occurrence was positively correlated with salmon abundance in the San Juan Islands and portions of Puget Sound (Heimlich-Boran 1986). Fall movements of southern resident pods into Puget Sound were roughly correlated with chum and chinook salmon runs (Osborne 1999). Recent sightings of southern resident killer whales in California were coincident with large runs of chinook salmon (unpublished data CRP-DFO). In Johnstone Strait, northern resident occurrence is related to strong seasonal runs of sockeye and pink salmon, along with chum salmon to a lesser extent (Nichol and Shackleton 1996).

3.2.2. Social Organization

The social structure of killer whales in British Columbia appears to be complex and differs among the three ecotypes (Ford and Ellis 1999, Ford et al. 2000). The social structure of resident killer whales is the best understood, and one of its unique features is that there is no dispersal of either gender from the natal group. The basic social unit of resident killer whales is the matriline, composed of an older female (or matriarch) her male and female offspring, and the offspring of her daughters (Ford et al. 2000). Because matriarchs have long life spans, some matrilines may contain up to four generations. In over three decades of study, immigration and emigration have rarely been observed (Bigg et al. 1990, Ford et al. 2000). Two recent cases of juvenile whales leaving their matrilines and traveling alone are considered to be exceptional, isolated incidents. One, a female calf referred to as A73, or Springer, left her pod shortly after her mother died and became isolated after a brief period of association with a pod from another clan. She was subsequently reunited with her pod and joined another matriline. The second incident involved a male calf L98, or Luna, which became isolated from his pod and all other killer whales for unknown reasons in 2001. Although individuals do not disperse from their natal group, adult females often begin to spend more and more time apart after their mother dies, and their own matrilines may eventually become socially independent (Bigg et al. 1990, Ford et al. 2000, Ford and Ellis 2002).

3.2.3. Reproductive Parameters

Females reach sexual maturity, defined as the age of first successful pregnancy, at 14.9 years on average (range 12-18 years, Olesiuk et al. 1990). Males reach sexual maturity, defined as when the dorsal fin shape changes sufficiently to distinguish males from females, at 15 years on average (range, 10 -17.4 years). Males reach physical maturity (when the dorsal fin reaches its full height) at about 20 years. The gestation period of killer whales is typically 16 to 17 months, one of the longest of all whales (Walker et al. 1988, Duffield et al. 1995). Only single calves are normally born. A report of twins (Olesiuk et al. 1990) more likely represented an example of within pod adoption, based on genetic analysis (Barrett-Lennard 2000).

Approximately equal number of males and females are born (Dahlheim and Heyning 1999) and newborn calves are between 218 and 257 cm long (Olesiuk et al. 1990). Haenel (1986) estimated that calves are weaned at 1.0-1.5 to 2 years of age. The interval between calving is usually about 5.2 years for northern residents and 6.2 years for southern residents (unpublished data CRP-DFO). However the interval is highly variable, and ranges from 2 to 12 years, and increases with age until menopause (Olesiuk et al. 1990). Overall, females have an average of 5.25 viable calves in a 25.2 year reproductive lifespan (Olesiuk et al. 1990). Calving occurs year round in the northern resident community, but appears to peak between fall and spring. Southern residents do not appear to calve in the summer (unpublished data CWR).

3.2.4. Mating Behaviour

Mating behaviour between male and female killer whales has rarely been observed in the wild. However, genetic evidence has revealed that resident killer whales have a propensity to mate outside their matriline (and clan, in the case of northern residents) but inside their community (Barrett-Lennard 2000, Barrett-Lennard and Ellis 2001). This minimizes the possibility of inbreeding very effectively, but restricts the options for mating if the population becomes very small. For example, in the southern resident community there may be an extreme shortage of sexually mature males, particularly for L pod females, assuming females select mates outside their pod.

3.2.5. Survival and Longevity

Survival of resident killer whales varies with age. Neonate mortality (from birth to six months of age) is high, reported at approximately 43% for all residents (Olesiuk et al. 1990), and 42% for northern residents (Bain 1990). Accordingly, average life expectancy is reported for an animal that survives the first six months, and is estimated to be 50.2 years for females and 29.2 years for males (Olesiuk et al. 1990). Maximum longevity for females is an estimated 80-90 years and for males is 50-60 years (Olesiuk et al. 1990). Although a typical trait in most mammals, the shorter lifespan of males could be related to sexual selection (Baird 2000) or to higher levels of persistent chemicals, such as PCBs (Ross et al. 2000). The bioaccumulation of toxins is discussed in greater detail in Section 4.2.1. Recent evidence suggests that declines in both the northern and southern resident populations can be attributed to an increase in mortality rates (unpublished data, CRP-DFO) as well as a decrease in fecundity for southern residents (Krahn et al. 2004). The potential causes of the population declines are discussed in Section 4.

3.2.6. Reproductive Senescence

The average life span of female resident killer whales is approximately 50 years, but on average they produce their last calf at 39, and a significant number live to 70 years or more (Olesiuk et al. 1990). The 'grandmother hypothesis' suggests that the presence of older females in a group can increase the survival of offspring, and this may indeed be true for killer whales (see discussion in 3.2.7 Culture below). In any case, when evaluating the status of killer whale populations, it is important to consider the age structure of the population and to note that post reproductive adult females are no longer able to contribute directly to population growth. In an endangered population of transients in southern Alaska (AT1s), no calves have been born since 1984. Since the remaining females are near or beyond their reproductive years, the population is on the verge of extinction (Saulitis et al. 2002), with virtually no prospect for recovery, even though it may persist for many more years.

3.2.7. Culture

Culture is a body of traditions, social conventions and other information that is transferred from generation to generation solely by learning. Until recently, culture was generally considered a distinguishing feature of human societies. Of late, the concept of culture has been broadened to include non-human mammals and birds (reviewed in Rendell and Whitehead 2001) and there is strong evidence for it in both northern and southern resident killer whales, and southern Alaskan resident killer whales (Ford 1991, Ford et al. 1998, Barrett-Lennard et al. 2001, Yurk et al. 2002). There is also evidence for culture in other cetaceans, such as sperm whales (Whitehead and Rendell 2004), although not to the same extent as for resident killer whales (Rendell and Whitehead 2001).

Dialects are the best studied form of culture in killer whales. A calf learns its dialect from its mother and other closely related adults, retains it for life, and passes it on to the next generation with few modifications (Ford 1991, Deecke et al. 2000, Miller and Bain 2000). These culturally-transmitted dialects may play an important role in inbreeding avoidance, since females apparently prefer males from dialect groups other than their own (Barrett-Lennard 2000, Yurk et al. 2002). Culture also appears to play an important role in feeding, with dietary preferences and probably foraging techniques and areas passed on culturally (Ford et al. 1998). Culture may also select for longevity in killer whales, as it provides a mechanism for older individuals to increase the fitness of their offspring and relatives by transferring knowledge to them (Barrett-Lennard et al. 2001). In African elephants, older matriarchs are better able to discriminate between threatening and non-threatening disturbances than younger animals, and pass this knowledge on to other members of their group (McComb et al. 2001).

Culture may help animals to learn to adapt to changing environments by allowing them to learn from each other in addition to learning from experience. For example, based on differences in foraging success by sympatric clans of sperm whales under different climatic regimes, Whitehead et al. (2004) suggest that cultural diversity may be even more significant than genetic diversity in helping sperm whales to deal with changing ocean climate. While we do not know if this is true for resident killer whales, we do know that they do respond culturally to anthropogenic changes in their environment. In Alaska, resident killer whales responded to longline fishing in areas of Alaska by learning to raid the gear and take fish, and this behaviour spread rapidly throughout the population (Matkin and Saulitis 1994).

3.2.8. Depensation

Resident killer whale populations are at risk simply by virtue of their low population size. In general, small populations generally have an increased likelihood of inbreeding and lower reproductive rates, which can lead to low genetic variability, reduced resilience against disease and pollution, reduced population fitness, and elevated extinction risks due to catastrophic events. Pacific resident killer whale populations are considered small, at 85 southern residents in 2003[3] (unpublished data, CWR), and 205 northern residents in 2003 (unpublished data, CRP-DFO). If either resident population continues to decline, they may be faced with a shortage of suitable mates. Among the southern residents, L pod females may be particularly vulnerable to this scenario because of the small number of reproductive males in J and K pod. Even under ideal conditions, the population will recover slowly because killer whales calve relatively infrequently.

Inbreeding appears to be less of a risk for resident killer whales than might be expected based on the small size of their populations. They may avoid inbreeding and its inherent risks through mate selection. Resident killer whales select mates from outside their natal pod, which may make small populations of killer whales more genetically viable than would be expected from population size alone (Barrett-Lennard and Ellis 2001).

3.2.9. Natural Mortality

Killer whales have no recorded predators, other than humans. There are several potential sources of natural mortality that may impact killer whales: entrapment, accidental beaching, disease, parasitism, biotoxins, and starvation (Baird 2001). However, it cannot be ruled out that anthropogenic factors may make killer whales more vulnerable to natural sources of mortality. For example, disturbance from intense noise may cause animals to strand (Perrin and Geraci 2002). The proximate cause of death, stranding, is a natural source of mortality, but the death is ultimately human-caused.

3.2.9.1. Entrapment and/or Accidental Beaching

Accidental beaching and entrapment are sometimes a source of mortality for killer whales. At least four mass strandings involving more than 36 individuals occurred in BC in the 1940s (Carl 1946, Pike and MacAskie 1969, Mitchell and Reeves 1988, Cameron 1941). Although the causes of mass strandings in toothed whales are uncertain, disease, parasitism, and disturbance from intense underwater noise have been suggested as possible causes (Perrin and Geraci 2002). Temporary entrapment has been reported twice recently for southern resident killer whales (Shore 1995, 1998). In 1991, J-pod spent 11 days in Sechelt Inlet. In 1997, nineteen killer whales spent 30 days in Dyes Inlet, Puget Sound, possibly due to abundant prey (chum salmon) or because they were reluctant to pass under a noisy bridge (Shore 1998). There was also an unusually large return of chum salmon to the inlet during this period.

[3] including L98 or Luna, discussed in section 3.2.2. Social Organization

3.2.9.2. Disease and Parasitism

Diseases in captive killer whales have been well studied, but little is known of diseases in wild killer whales (Gaydos et al. 2004). Causes of mortality for captive killer whales include pneumonia, systemic mycosis, other bacterial infections, and mediastinal abscesses (Greenwood and Taylor 1985). Of 16 pathogens identified in killer whales, three have been detected in wild individuals: marine *Brucella*, *Edwardsiella tarda*, and cetacean poxvirus (Gaydos et al. 2004). A severe infection of *E. tarda* resulted in the death of a southern resident male in 2000 (Ford et al. 2000). Marine *Brucella* may cause abortions and reduced fecundity in killer whales (Gaydos et al. 2004). Cetacean poxvirus can cause mortality in calves and causes skin lesions (Van Bressem et al. 1999). Twenty-seven additional pathogens have been identified in sympatric odontocetes that may be transmittable to killer whales (Gaydos et al. 2004).

External parasites of killer whales have been reported in Mexico (Black et al. 1997), but none have been observed on killer whales in BC (Baird 2001). Internal parasites of killer whales include various trematodes, cestodes, and nematodes (Heyning and Dahlheim 1988, Raverty and Gaydos 2004). These endoparasites are usually acquired through infected food, but the amount of infestation and their contribution to killer whale mortality are not known at this time.

3.2.9.3. Harmful Algal Blooms

Harmful algal blooms (HABs) are blooms of algae that produce biotoxins such as paralytic shellfish poison, domoic acid, saxitoxin and brevitoxin. Such toxins can accumulate in the tissues of species that ingest them and are magnified up the food chain. Mortality of humpback whales (*Megaptera novaeangliae*) off Massachusetts in 1987 and California sea lions (*Zalophus californianus*) in California in 1998 have been linked to biotoxin exposure (Geraci et al. 1989, Scholin et al. 2000). Several species of marine mammals have been shown to have a potential susceptibility to the neurotoxic effects of biotoxins (Trainer and Baden 1999). Given the apparent increase in HAB event frequency, and the potential for toxic effects in killer whales, there may be some risk to resident killer whales exposed to biotoxins through HABs, although the risk is thought to be low (Krahn et al. 2002).

3.2.9.4. Regime Shifts

In the North Pacific, there are widespread changes that occur in the circulation and physical properties of the ocean. These changes take place on decadal time scales and are referred to as 'regime shifts' (see reviews in Francis et al. 1998, Benson and Trites 2002). Such shifts may happen quite quickly, and result in dramatic changes in the distribution and/ or abundance of many species, ranging from zooplankton to fish and possibly marine mammals and seabirds. If the distribution or abundance of resident killer whale prey changed significantly following a regime shift, it is possible that killer whales could be impacted.

4. THREATS

4.1. Historic Threats

Pliny the Roman scholar first described a killer whale as an "enormous mass of flesh armed with savage teeth" during the first century AD. Since then written records have often depicted killer whales as savage, destructive, ferocious, and a danger to humans. However, they were rarely hunted, with the exception of Japanese, Norwegian and Russian whalers. Contemporary fishermen have viewed the killer whale as a competitor for their fish and a threat to their livelihood (Olesiuk et al. 1990; Ford et al. 2000). The live capture of killer whales for aquariums in the 1960s and early 1970s reduced local populations, some drastically.

4.1.1. Harvest and Live Captures

Killer whales were hunted commercially, but whaling operations generally targeted other species of whales. In Canada, there are only a few harvest records of killer whales, most of which took place on the east coast and in the Arctic (e.g. Mitchell and Reeves 1988, Reeves and Mitchell 1988). However, large numbers of whales were taken in other areas of the world. The Japanese killed 60 killer whales per year between 1948 and 1957 (Nishiwaki and Handa 1958). Norwegian whalers culled 2, 345 killer whales between 1938 and 1981 (Oien 1988). The former USSR captured approximately 25 killer whales per year in the Antarctic and harvested 906 whales in one season (Berzin and Vladimirov 1983). In 1982, the International Whaling Commission recommended a halt to the harvest of killer whales until the impact on populations was better understood. No killer whales have been reported taken since then, though small numbers may continue to be caught but remain unreported. For example, genetic testing has revealed the presence of killer whale in meat sold in Japanese and Korean markets (Baker et al. 2000).

In the late 1960s and early 1970s, killer whales were sought extensively for display in public aquariums. While they were captured from various areas throughout the world, the majority came from the waters of the northeastern Pacific Ocean. Between 1962 and 1974, 68 killer whales were taken from this area, 47 of which are known or assumed to be southern residents (Olesiuk et al. 1990). This cropping clearly had a major impact on the southern resident community, which numbered only 70 animals in 1974, and likely affected productivity of the community for many years after the live captures ended in 1975.

4.1.2. Intentional Shootings

Historically, negative attitudes towards killer whales in BC led to efforts by both government and individuals to cull local populations through shooting. In 1960, the federal Fisheries Department mounted a land-based machine gun near sports fishing lodges near Campbell River to reduce the number of killer whales (Ford et al. 2000). Fortunately it was never fired. In the 1960s and 1970s, approximately one quarter of whales live captured for aquaria had gunshot wounds (Ford et al. 2000). Societal attitudes towards killer whales have changed since 1974, and fresh bullet wounds are now rarely, if ever, seen on whales in BC and Washington (Ford et al. 2000), although even occasional shootings could limit population growth.

4.1.3. Acoustic Harassment Devices

Aquaculture farms in Washington and BC have used acoustic harassment devices (AHDs) that emit loud signals underwater to reduce depredation by harbour seals and sea lions. Some signals may be heard from up to 50 km away (Morton and Symonds 2002). Their use at a farm near northern Vancouver Island was associated with significant declines in the use of nearby waters by both resident and transient killer whales (Morton and Symonds 2002). Harbour porpoise (*Phocoena phocoena*) abundance was also found to drop dramatically when AHDs were in active use (Olesiuk et al. 2002). AHDs are no longer used at fish farms in BC or in Washington. They are still used at Ballard Locks in Seattle to deter sea lions, but the configuration of the canal limits the amount of noise escaping to the open ocean (Bain 1996).

4.2. Current Threats

A variety of threats may directly impact northern and southern resident killer whale populations in British Columbia, particularly because of their small population size. Threats include environmental contaminants (including oil spills), reduced prey availability, disturbance, and noise pollution, each of which is discussed in more detail below. Other threats such as mortality in fishing gear, have posed a threat to cetacean populations in other areas, and could potentially impact resident killer whales. Climate change is impacting entire ecosystems, and it is likely that in order to survive, killer whales will have to adapt to the consequences of local changes in their prey base. How any of the current threats may act synergistically to impact killer whales is unknown, but in other species multiple stressors have been shown to have strong negative and often lethal effects, particularly when animals carry elevated levels of environmental contaminants (Sih et al. 2004).

The extent to which northern and southern resident killer whales are impacted by anthropogenic threats varies, depending on the threat. For example, northern resident killer whales may be more vulnerable to seismic surveys on the north coast, particularly if the moratorium on oil and gas exploration is lifted, whereas southern residents, by virtue of the waters they spend significant time in, may be more vulnerable to environmental contaminants.

4.2.1. Environmental Contaminants

There are numerous chemical and biological pollutants that may directly or indirectly impact resident killer whales, ranging from antibiotic resistant bacteria and pathogens, to persistent organic pollutants (POPs). Below we describe the major types of contaminants, their sources and their potential effects on killer whales (where known). For a list of the acronyms mentioned below, see Appendix I. There have been only a handful of studies that have measured contaminant levels in killer whales, and no controlled experiments have been done to assess how these contaminants may affect them directly. However, the effects of contaminants on other species such as pinnipeds are better understood, and in many cases can be generalized to killer whales, particularly because the physiological processes of mammals are similar across different species.

Although it is important to assess the direct effects of contaminants, Fleeger et al. (2003) make an important case for considering their 'indirect' effects on community structure, as well as on individual organisms and their behaviour. In a review of 150 studies, contamination resulted in changes in species abundance and community structure. Sixty percent of the communities that were experimentally manipulated showed a reduction in upper trophic level predators, which masked, enhanced or confused the interpretation of any direct effects of contaminants on individual organisms or species.

4.2.1.1. Persistent Organic Pollutants (POPs)

There are likely thousands of chemicals to be found in the free-ranging killer whales of BC, but a few key classes are of particular concern today. Recent studies of environmental contaminants in resident and transient killer whales in BC and Washington have revealed that they are among the most contaminated mammals in the world (Ross et al. 2000, 2002). Killer whales are vulnerable to accumulating high concentrations of Persistent Organic Pollutants (POPs) because they are long-lived animals that feed high in the food web (Ross et al. 2000, 2002, Rayne et al. 2004).

POPs are generally persistent, bioaccumulate in fatty tissues, and are toxic, features which have led to increased regulatory scrutiny of these chemicals by authorities around the world. POPs include 'legacy' contaminants such as PCBs, and the pesticide DDT, that are no longer widely used in industrialized countries, but persist in the environment. They also include the dioxins and furans, by-products of incomplete combustion, of pesticide manufacture, and of the (now regulated) use of elemental chlorine and pentachlorophenol (PCP) in pulp and paper bleaching and wood treatment processes, respectively. In recent years, regulations have resulted in a reduction in the release of such contaminants into the marine environment (Hagen et al. 1997). Contaminants of 'current concern' include the new generation of PBT flame retardants such as PBDEs as well as currently used pesticides. Table 1 lists the POPs that are a concern for resident killer whales, and the reader is referred to Grant and Ross (2002), for a more thorough synthesis of what is known about the risks that contaminants pose to southern resident killer whales. The acronyms used for many of the contaminants are listed in Appendix I.

PCBs

Surprisingly high concentrations of PCBs are found in both southern and northern resident killer whales relative to marine mammals from other areas (Ross et al. 2000). The PCB levels found in transients and southern residents exceed those found in St. Lawrence beluga whales (*Delphinapterus leucas*) by a factor of 2-4 times, and are considerably higher than thresholds for PCB-associated reproductive impairment, skeletal abnormalities, immunotoxicity and endocrine disruption in pinnipeds (reviewed in Ross 2000). Ross et al. (2000) found that PCB concentrations increase with age in male killer whales, but decline in reproductively active females. Consistent with observations in other mammals, including humans, reproductive females pass PCBs to their offspring, particularly the first born, during gestation and lactation (Tanabe and Tatsukawa 1992, Borrell et al. 1995, Ylitalo et al. 2001).

Dioxins and Furans

Levels of dioxins and furans were found to be low in the blubber of resident or transient killer whale populations in BC (Ross et al. 2000). this may be partly explained by low levels of dioxins and furans in their diet, but killer whales may also metabolize and excrete dioxin-like compounds more effectively than PCBs (Ross 2000).

Table 1. Persistent organic pollutants that may pose a risk to resident killer whales.

Pollutant	Use/Source	Persistent	Bio-accumulate	Risk
DDT	pesticide used in some countries, banned in North America, persists in terrestrial runoff 30 years post ban, enters atmosphere from areas where still in use	yes	yes	reproductive impairment, immunosuppression, adrenal and thyroid effects
PCB	electrical transformer and capacitor fluid, limited use in North America but enters environment from runoff, spills and incineration	yes	yes	reproductive impairment, skeletal abnormalities, immunotoxicity and endocrine disruption
Dioxins and Furans	by product of chlorine bleaching, wood product processing and incomplete combustion. Mills less of a source now. Current sources include burning of salt-laden wood, municipal incinerators, and residential wood and wood waste combustion, in runoff from sewage sludge, wood treatment	yes	yes	thymus and liver damage, birth defects, reproductive impairment, endocrine disruption, immunotoxicity and cancer
PAHs	by product of fuel combustion, aluminium smelting, wood treatment, oil spills, metallurgical and coking plants, pulp and paper mills	yes	no	carcinogenic
flame retardants, esp. PBBs and PBDEs	electrical components and backings of televisions and computers, in textiles and vehicle seats, ubiquitous in environment. PBDEs banned in Europe	yes	yes	endocrine disruption, impairs liver and thyroid
PFOs	stain, water and oil repellent (included in Scotchgard until recently), fire fighting foam, fire retardants, insecticides and refrigerants, ubiquitous in environment	yes	yes but in blood, liver, kidney and muscle	promotes tumour growth
TBT, DBT	antifoulant pesticide used on vessels	yes	Yes	unknown but recently associated with hearing loss
PCPs (polychlorinated paraffin's)	flame retardants, plasticizers, paints, sealants and additives in lubricating oils	yes	yes	endocrine disruption
PCNs	ship insulation, electrical wires and capacitors, engine oil additive, municipal waste incineration and chlor-alkali plants, contaminant in PCBs	yes	Yes	endocrine disruption
APEs	detergents, shampoos, paints, pesticides, plastics, pulp and paper mills, textile industry found in sewage effluent and sediments	moderate	moderate	endocrine disruption
PCTs	fire retardants, plasticizers, lubricants, inks and sealants, enters environment in runoff	yes	yes	endocrine disruption and reproductive impairment

References: Primarily Grant and Ross 2002, but also Lindstrom et al. 1999, Hooper and MacDonald 2000, Kannan et al. 2001, Hall et al. 2003; Van deVijver et al. 2003, Rayne et al. 2004, Song et al. 2005

PBDEs

Preliminary evidence suggests that flame retardants may be a significant concern for resident killer whales. Moderate levels of the as-yet largely unregulated PBDEs were observed in 39 biopsy samples collected between 1993-1996 from southern resident and transient killer whales, and relatively low levels in northern residents (Rayne et al. 2004). Unlike an earlier study on PCB levels in resident killer whales (Ross et al. 2000), Rayne et al. (2004) did not find any significant age-related trends in PBDE levels, but that may have been an artefact of their small sample size or the fact that PBDEs were relatively new in the environment in the 1990s. In a sample of 70 long-finned pilot whales in the North Atlantic, Lindstrom et al. (1999) found that juveniles had 2 to 3 times higher levels of PBDEs than did adults (Lindstrom et al. 1999), suggesting that reproductive females may pass PBDEs on to their offspring during gestation and lactation. Although the toxicity of PBDEs is not well understood, they have been associated with endocrine disruption in laboratory animals (Darnerud, 2003). Although no conclusive link could be established as a result of the numerous other lipophilic contaminants present, PBDE concentrations were negatively associated with thyroid hormones in grey seals (*Halichoerus grypus,* Hall et al. 2003). As more than 10 years have passed since some of the killer whale samples were collected, and since PBDE levels persist in the environment and their use has been increasing exponentially (Hooper and McDonald 2000), it is likely that killer whales in 2004 are carrying significantly higher loads of these contaminants than were found in whales sampled in the mid 1990s.

Using this weight of evidence as a foundation, it is not possible to ignore the substantial risks that PCBs and other POPs present to killer whales in the NE Pacific. Transients from Prince William Sound, Alaska (AT1 population) are highly contaminated, and have had no successful reproduction since 1984, providing perhaps a population-level glimpse into the effects of high POP burdens (Ylitalo 2001). High levels of toxic chemicals may also make killer whales more vulnerable to disease (Ross, 2002). Jepson et al. (1999) found that harbour porpoises that died from infectious diseases had 2 to 3 times higher concentrations of PCBs than those that died from trauma.

4.2.1.2. <u>Biological Pollutants</u>

Biological pollution may also threaten the health of resident killer whales, their habitat and their prey. These pollutants may take the form of pathogens, antibiotic- resistant bacteria or exotic species. Emerging infectious diseases are a growing concern for marine life, as naturally occurring host-pathogen relationships are altered through human activities such as disturbance, over-fishing, habitat destruction or pollution (Ross 2002). Killer whales whose immune system is compromised through chemical contaminants may be especially vulnerable to biological pollutants. Although no disease-related mass mortalities have been observed among BC's marine mammals, *Morbillivirus* has been detected in marine-dwelling river otters (Mos et al. 2003), highlighting the potential risk of this or related pathogens to killer whales. In other areas, *Morbillivirus* outbreaks have caused mass mortalities of seals (Grachev et al. 1989, Kennedy et al. 2000) and dolphins (Aguilar and Borrell 1994). Pathogens such as *Morbillivirus* are capable of spreading extremely quickly (3000 km/yr), likely because in the marine environment there are few barriers to dispersal (McCallum et al. 2003).

The introduction of exotic species has changed habitats in other areas (e.g. zebra mussels in the Great Lakes, Eurasian milfoil into freshwater lakes) and introduced species have the potential to impact local ecosystems here. In British Columbia, Atlantic salmon that have escaped from fish farms have successfully spawned in freshwater (Volpe et al. 2000). The extent to which this is occurring and how Atlantic salmon would compete with Pacific salmon, the preferred prey of residents (Ford et al. 1998), is not well known at this time.

4.2.1.3. Trace Metals

Trace metals occur naturally in the marine environment, but elevated concentrations sufficient to be a concern to marine mammals may be found in localized areas such as urban and industrial centers (Grant and Ross 2002). Some, such as cadmium, mercury, copper and lead may have toxic effects even at relatively low concentrations, and could impact killer whales, although effects on their prey and/ or habitat are more likely.

Little information is available on the levels and effects of trace metals on marine mammals in the Pacific. However, in a small sample of stranded killer whales, residents showed higher levels of mercury than transients (Langelier et al. 1990). In the western Pacific, all odontocete meat sampled from Japanese markets contained amounts of mercury that exceeded the level permitted for human consumption (Endo et al. 2003). However, the historical exposure of high trophic level marine mammals to naturally elevated concentrations of mercury in prey has resulted in their evolved ability to detoxify this toxic metal through the formation of mercury: selenium crystal in the liver (Martoja and Berry, 1980).

4.2.1.4. Sources of Contaminants

Monitoring the sources and levels of environmental contaminants is particularly challenging given that each year, up to1000 new chemicals are released into the environment globally (Haggarty et al. 2003). The high contaminant levels found in southern residents may arise from consuming prey that are from industrialized areas near the BC-Washington border, which may be more contaminated than the prey of northern residents (Ross et al. 2000). In Japan, odontocetes that travelled in more industrialized areas carried higher contaminant loads than those found in more remote areas (Endo et al. 2003). In a study of harbour seals in British Columbia and Washington, Ross et al. (2004) found that although PCB levels were a concern in all areas, seals from Puget Sound are seven times more contaminated with PCBs than were seals from the Strait of Georgia. Chinook salmon, one of the resident killer whales' preferred prey species (Ford et al. 1998), feed in the upper trophic levels in the food web, and those from Puget Sound are contaminated with PCBs (O'Neill et al. 1998).

Although DDT was banned in Canada and the United States over 30 years ago, it continues to enter the ocean from terrestrial runoff (Hartwell 2004) as well as from atmospheric transport from countries where it is still in use. Dioxins (PCDDs) and furans (PCDFs) represent highly toxic by-products of chlorine bleaching and associated wood treatment, and incomplete combustion. Source controls and regulations have greatly reduced their input in to the coastal environments of BC and Washington over the past 15 years.

Contaminants enter the marine environment from local, regional and international sources. These are discussed in detail in Haggarty et al. (2003). Local point sources of contaminants into the marine environment include:

- pulp and paper mills,

- wood treatment facilities,
- municipal effluent outfalls,
- petrochemical facilities,
- mines.

Indirect sources (non-point source pollutants) include

- sewer overflows,
- urban runoff and storm-water drainage,
- agriculture (pesticides, herbicides, animal waste, antibiotics),
- forestry (pesticides, fire-control chemicals, anti-sapstain chemicals, log booms and storage areas),
- aquaculture (organic waste, chemical contaminants [antibiotics, feed additives, pesticides, antifouling on nets]).

Garrett and Ross (In press) describe the Canadian and US federal, provincial and state agencies responsible for the monitoring, mitigation and regulation of environmental contaminants and their sources.

Shipping also represents a risk to the ecological integrity of coastal regions by introducing exotic and invasive species carried on ship hulls and in ballast water. Numerous invasive invertebrates have been found in the ballast water of ships at anchor in Vancouver harbour (Levings et al. 2004), although the ecological significance of such introductions is unclear. In other areas, invasive species have dramatically altered the habitats they have colonized (e.g. European green crabs, zebra mussels, the algae *Caulerpa taxifola*).

In addition, some pollutants such as PCBs, DDT and other chemicals, are transported through atmospheric processes and ocean currents, and may travel to the west coast of North America from as far away as Asia in less than 5-8 days (Wilkening et al. 2000). Indeed the northeastern Pacific may be a sink for globally produced POPs (Ross et al. 2000, 2004).

Certain 'legacy' POPs such as PCBs and DDT have been phased out of industrialized countries and their concentrations are slowly decreasing in the marine environment (Muir et al. 1999), although these declines have levelled off (Addison and Stobo 2001). However, levels of other 'new' POPs such as the flame retardant PBDEs have increased exponentially over the past 25 years, and represent the PCBs of the future (Hooper and McDonald 2000). Unlike PCBs, which were generally used in a limited range of applications such as electrical transformers and capacitors, PBDEs are widely used in many industrial and consumer applications and are incorporated into plastics, textiles and foam.

4.2.2. Reduced Prey Availability

Answering the question as to whether killer whales may be prey limited is complex. While the complete diet of resident killer whales is not known, at certain times of the year salmon, particularly chinook and chum, appear to be important prey (see section 3.2.1. Diet). However, unlike many baleen whales that go through a seasonal fasting period, resident killer whales feed year round. Unfortunately there is very little known about the prey of resident killer whales, and its distribution and abundance, between November and April. This is due to the inherent challenges of studying whales during the winter months, and the possibility that they may move further offshore. Thus when considering the availability of prey to resident killer whales, it should be noted that we have very little knowledge of what other prey species may be important to them, and the discussion below focuses on species that we know are important prey.

4.2.2.1. Changes in Salmon Abundance and Availability

Assessing the status of salmon stocks and their availability to resident killer whales is challenging to interpret and often fraught with controversy. Until the middle of the 20th century, many wild salmon stocks experienced significant declines due to overfishing, habitat degradation and changes in ocean productivity (summarized in Krahn et al. 2002 and Wiles 2004). The situation changed between 1975 and 1993, and the total abundance of north Pacific salmon doubled (Bigler et al. 1996) due to hatchery enhancement, changes in fisheries management practices and a favourable climatic regime in the ocean (Bigler et al. 1996, Beamish et al. 1997). Since the early 1990s many of these stocks have declined in number, and controversy as to whether hatchery fish are detrimental to wild stocks of salmon has arisen (Beamish et al. 1997, and reviewed in Gardner et al. 2004). At present 26 of 52 different wild Pacific salmon stocks in the lower 48 states of the US are considered at risk under the US Endangered Species Act (NWR 2004). In British Columbia, salmon from one-third of the spawning rivers in southwestern BC had been lost or were seriously depleted by 1990 (Riddell 1993). Recognizing that many salmon stocks are under threat, Fisheries and Oceans Canada announced a new wild salmon policy in December 2004 (DFO-WSP 2004), designed to restore and maintain healthy and diverse wild salmon populations and their habitat. If these actions are successful, salmon may gradually become more available to resident killer whales.

Resident killer whales tend to be found in 'core areas' (discussed in 3.2.1 Diet and in Section 5, Critical Habitat) during the period when salmon are returning to rivers to spawn. This likely reflects the fact that salmon are not as widely dispersed at this time as they are during the rest of their life cycle. There is a great deal of diversity in the timing of the spawning period for salmon. For example, the Upper Columbia River has a spring run and a summer/fall run of chinook. These runs are considered distinct stocks because they do not interbreed. The spring run is endangered under the ESA in the US, yet the summer/ fall run is not at risk (NWR 2004). This illustrates the need to consider the timing of the spawning period of each salmon stock when assessing the availability of salmon for killer whales, in order to ensure an adequate year round food supply.

It has recently come to light that salmonid aquaculture may be contributing to the decline of wild salmon stocks due to the unusually high occurrence of sea lice associated with open net pen salmon farms (Gardner and Peterson 2003, Morton et al. 2004). Wild juvenile pink and chum salmon in the vicinity of fish farms in the Broughton Archipelago carried loads of sea lice that are potentially lethal (Morton et al. 2004). Juvenile chinook salmon in the area have also have been recorded with sea lice (Morton and Williams 2003). Sea lice associated with salmon farms have been implicated in the declines of wild fish stocks in both Norway and Scotland (Bjorn et al. 2001, Penston et al. 2004). With the lifting of the moratorium on new fish farm licenses in British Columbia in September 2002, the impact of the expansion of this industry on the health of juvenile salmon populations must be examined. This is of particular concern because of the importance of chinook and chum salmon in the diet of resident killer whales.

Depressed Chinook Stocks

Chinook salmon, the principal prey of resident killer whales, is one of the least abundant species of salmon in BC (Riddell 2004). However, unlike other salmon, they remain in nearshore waters during the ocean phase of their life cycle. As a result they are available on a more year round basis to killer whales, but are also more vulnerable to pollution (discussed in 4.2.1 Environmental Contaminants).

Chinook abundance dropped in the 1970s and 1980s, but escapements increased until the early 1990s in some rivers, primarily due to hatchery production (Beamish et al. 1997). In Washington, hatchery fish now account for about 75% of all harvested chinook (Mahnken et al. 1998 in Wiles 2004). In un-enhanced river systems in central and northern British Columbia, chinook numbers remain depressed (Riddell 2004) and 10 of 17 chinook stocks in Washington, Oregon and California are listed under the ESA (NWR 2004). Thus it is plausible that chinook may be limiting for killer whales. This may explain why southern resident killer whales have appeared in places as distant as off the Columbia River and off northern California to the south and off Langara Island in the north (unpublished data CRP-DFO). Their presence was associated with unusually large returns of chinook salmon, which they may have had to seek out because of less abundant prey within their traditional range. When prey availability is reduced, killer whales may be forced to spend more time and travel greater distances to forage for their food, or switch to less optimum prey, which could lead to lower reproductive rates and higher mortality rates.

4.2.3. Disturbance

All cetaceans, including resident killer whales, are being subjected to increasing amounts of disturbance from vessels, aircraft, and anthropogenic noise (IWC 2004). Both private and commercial boat traffic have increased dramatically in recent years, and killer whales must navigate in increasingly busy waters (Osborne 1999, Foote et al. 2004). Industrial activities such as dredging, drilling, construction, seismic testing, and military sonar and other vessel use of low and mid-frequency sonars also impact the acoustic environment (Richardson et al. 1995, NRC 2003). The means by which physical and/ or acoustic disturbance can affect resident killer whales at both the individual and population level are not well understood, but may depend on whether the disturbance is chronic (such as whale watching) or acute (such as seismic surveys). Other factors, including the animal's condition, previous exposure (potentially causing sensitization or habituation), age, sex, and behavioural state also influences how disturbance affects whales. In addition, environmental factors, such as the El Nino event that may change the availability of prey, may make animals more vulnerable to disruption than they would be otherwise. The sources of both physical and acoustic disturbance and their potential impact on resident killer whales are discussed in greater detail below.

A current challenge in studying the effects of disturbance is in finding informative ways to describe and measure them, and to date the question of whether a source of disturbance is likely to result in effects at the population level can be difficult to answer. Responses to disturbance may range from slight differences in surfacing and breathing rates to active avoidance of an area. Even if the disturbance causes immediate death, carcasses are rarely recovered. (Regardless of the cause of death, only 6% of killer whale carcasses are recovered, unpublished data CRP-DFO). As well, animals may show no obvious behavioural responses to disturbance, yet still be negatively affected. For example, Todd et al. (1996) found that humpback whales remained in the vicinity of underwater explosions, and showed no obvious behavioural responses to them. However they experienced significantly higher entanglement rates during this time, and necropsies of two whales that drowned in nets revealed acoustic trauma (Ketten et al. 1993). Thus a lack of a measurable behavioural response to a stimulus does not necessarily imply the disturbance does not have negative consequences. A parallel may exist with humans, since people exposed to chronic noise lose their hearing more quickly than those that are not exposed to chronic noise. The consequences of hearing loss for cetaceans are likely serious.

Measures for changes in behaviour may also not be subtle enough to detect disturbance. Whitehead (2003) reanalyzed data that were reported to show that sperm whales did not show behavioural responses to surveys using high-intensity sound. He segregated the responses according to whale density in the area and found that contrary to earlier conclusions, when whale density was low, sperm whales avoided seismic activity. When densities were high, whales remained in the vicinity. He suggested that whales may have been reluctant to leave a rich feeding area despite the disturbance.

4.2.3.1. Whale Watching

Commercial whale watching has grown dramatically in British Columbia, with just a few boats carrying less than 1,000 passengers per year in the late 1970s and early 1980s to 80 boats carrying half a million passengers per year in 1998 (Osborne 1991, Baird 2002, Osborne et al. 2003). Whale watchers tend to target resident killer whales in their most predictable locations, Haro Strait and Johnstone Strait. In the summer, an average of 19-22 boats have been observed near southern resident killer whales in Haro Strait, commonly from 9 am to 9 pm (Osborne et al. 2003) although some begin as early as 6 am (personal communication David Bain, February 2005). These include privately owned kayaks, sailboats and powerboats as well as commercial vessels. Concerns over the effects of whale watching on killer whales have grown with the industry itself, and have resulted in studies that have attempted to detect responses of the whales to such focused attention (Kruse 1991, Williams et al. 2002a, b), as well as the behaviour of boaters around whales (Jelinski et al. 2002). Whale watching activities have the potential to disturb marine mammals through both the physical presence and activity of boats, as well as the increased underwater noise levels boat engines generate.

Under the Fisheries Act in Canada and the MMPA in the US, disturbance (harassment) of marine mammals, including killer whales, by the public is prohibited. No special provisions or exemptions to this prohibition have been made for commercial whale watch operators and the commercial fleet is subject to the same regulatory restrictions as recreational boaters. It is not known what the biological significance of disturbance is to resident killer whales, but voluntary whale watching guidelines for Canadian vessels have been developed (Be Whalewise, DFO 2004). From June through to November, an additional set of guidelines has been developed to minimize disturbance to whales when whales are in the Special Management Zone in Johnstone Strait (see www.straitwatch.org for details). The Whale Watch Operators Association Northwest has developed an even more comprehensive 'Best Practices Guidelines' for commercial operators to follow when observing southern residents (WWOAN 2004). These guidelines have evolved over a 10 year period to reflect new knowledge and minimize the negative effects of vessel traffic. They remain a work in progress and will evolve as further research reveals if and how whale watching may have population level consequences for resident killer whales.

There are several projects that focus on educating the boating public both on and off the water about appropriate conduct in the vicinity of marine mammals. They also monitor vessel activity in the presence of whales. Projects include the *Soundwatch Boater Education Program* in the San Juan Islands, the *Marine Mammal Monitoring Project* in Victoria, BC, and *Straitwatch* in Johnstone Strait. All these programs are run by non-profit organizations that do not have guaranteed funding. Smith and Bain (2002) found that commercial operators increased their compliance with a voluntary 0.4 km 'no boat' zone in the San Juan Islands from less than 80% to over 90% when Soundwatch was present on the water.

Boat activity has been linked to short-term behavioural changes in resident killer whales (Kruse 1991, Smith and Bain 2002, Williams et al. 2002a, b). They have been known to swim faster, travel in less predictable paths, alter dive lengths, move into open water, and alter normal behaviour patterns at the surface in response to vessel presence (Kruse 1991, Williams et al. 2002a, b). Foote et al. (2004) found that southern resident killer whales significantly increased the duration of their calls when boats were present, suggesting that it was an adaptation to the masking effects caused by increased noise levels.

Although studies have shown short- term responses of killer whales to whale watching vessels, the long- term effects of whale watching on the health of killer whale populations are not known (Trites et al. 2002). Increased whale watching operations between the mid-1980s and 2001 may have resulted in a potential 20% increase in energetic expenditures of killer whales due to increased swimming velocity (Kriete 1995, 2002). Bain (2002) found that although the decline of southern residents followed the increase in commercial whale watching, the relationship was much more complex. He suggested that other variables, such as changes in the availability of prey, were also likely significant. Whether whale watching is a significant threat to killer whales or not, both the northern and southern resident populations continue to return to their traditional summer ranges despite increased whale watching activity. This may reflect their strong cultural behaviours or the distribution of their prey.

4.2.3.2. Underwater Noise

At the time the COSEWIC status report on killer whales was written (Baird 2001), relatively little was known about the effects of underwater noise on marine mammals. Since then, there has been a rapidly growing awareness that noise may be a significant threat to animals that degrades habitat and adversely affects marine life (IUCN 2004, IWC 2004). It is estimated that ambient (background) underwater noise levels have increased an average of 15 dB in the past 50 years throughout the world's oceans (NRC 2003).

Killer whales have evolved in the underwater darkness using sound much the way terrestrial animals use vision: to detect prey and predators, to communicate and to acquire information about their environment. Excessive noise can interfere with all these activities in critically important ways, by disrupting natural behaviours, displacing prey, and potentially impairing hearing, either temporarily or permanently (Barrett-Lennard et al. 1996; Erbe 2002, NRC 2003).

The challenges of using and interpreting behavioural responses of marine mammals to noise as a measure of disturbance were discussed above in Section 4.2.3. Opportunities to measure physiological responses to anthropogenic noise are much rarer, but provide insight into the mechanisms by which noise could impact animals at the individual, and potentially population level. Physiological responses to anthropogenic noise that have been measured in marine mammals include both temporary and permanent hearing threshold shifts, the production of stress hormones, and tissue damage, likely due to air bubble formation or as a result of resonance phenomena (Ketten et al. 1993, Crum and Mao 1996, Evans and England 2001, Finneran 2003, Jepson et al. 2003, Fernandez et al. 2004). Marine mammals, including killer whales, may be particularly vulnerable to resonance because of the air-filled cavities in their sinuses and middle ear, their lungs, and small gas bubbles in their bowels. While the mechanism by which high-intensity sound can cause lethal and sub-lethal effects on cetaceans is not completely understood (Piantadosi and Thalmann 2004, Fernandez et al. 2004), loud anthropogenic sources of noise, particularly low and mid-frequency military sonars, have been implicated in mass stranding and mortality events around the world, and the subject urgently merits further study. Animals already affected by anthropogenic stressors such as environmental contaminants may be particularly vulnerable to additional stresses such as noise (Sih et al. 2004).

Sounds travel as waves much more quickly through water than air (1500 vs. 300 m/s). The 'highness' or 'lowness' of a sound is described in terms of its frequency, and is measured in hertz (Hz). Human hearing ranges from approximately 20 to 20,000 Hz (20 kHz), and is best between 600 and 2000 Hz. The peak hearing frequency of killer whales is approximately 20 kHz, although they show behavioural responses to sounds between 75 Hz and 100 kHz (Hall and Johnson 1972, Syzmanski et al. 1999) and likely hear to below 500 Hz, the lower limit of their communication signals.

The 'loudness' of a sound is described in terms of its pressure. For the purposes of consistency, the units of measure used here are dB re 1 μPa measured at 1 m from the underwater sound source. In general, the further away from a sound source, the quieter the received sound level, although physical and oceanographic features of the marine environment can affect how quickly a sound attenuates (gets quieter). Higher frequency sounds attenuate much more quickly than low frequency sounds. The characteristics of some underwater noise sources are briefly described in Table 2. It is important to consider both the length of time that animals are exposed to sounds, and their loudness and frequency. As well, some sounds are continuous, whereas others are pulses of sound that are generated at specific intervals. The frequency range is also variable, ranging from broadband sounds such as seismic surveys, to narrowband sounds such as military sonar that are only broadcast across a limited range of frequencies. In the United States, NMFS considers that received sounds in excess of 160 dB have the potential to disrupt marine mammal behaviour, and sounds in excess of 180 dB may cause physical injury. These standards are currently under re-evaluation.

Table 2 Signal structure, frequency range and source level of anthropogenic noise. Modified from Table 2-1b in NRC (2003) and Table 6.8 in Richardson et al. (1995).

Source	Signal Structure	Frequency Range	Source Level (dB re 1 µPa at 1 m)
Seismic surveys	impulsive	broadband >0 Hz to >100kHz	>240
Military Sonar			
surveillance	pulsed tones	<1kHz	>230
tactical	pulsed tones	>1kHz to < 10kHZ	200 to 235+
weapon/ counter weapon	pulsed tones and wideband pulses	>0kHz to 100kHz	190 to 220
Construction	broadband and tones	<10kHz to 10+kHz	NA
Dredging	broadband and tones	<10Hz to <10kHz	NA
Explosions	impulsive	broadband	>240
Commercial shipping	continuous	10Hz to >1kHz	160 to 200
Commercial sonars	pulsed tones	28kHz to >200kHz	160 to 210

Military Sonars

Active military sonars are used in military operations for target detection, localization and classification (NRC 2003). Unlike passive sonars, which listen for sounds, active sonars transmit pulses of tones at frequencies from <1 to >100 kHz and source levels of 200-235 (or more) dB re 1 µPa at 1 m depending on the application (Evans and England 2001). Military sonar signals may be heard underwater for 10's to 100s of kms, depending on the frequency (Tomaszeski 2004), and there is now a growing weight of evidence that these sources of underwater noise may pose a significant threat to cetaceans. Active military sonars have been associated with increased strandings of beaked whales and humpback whales, and with displacing western North Pacific gray whales from their feeding grounds (numerous incidents summarized in IWC 2004). In October 2004, the European Parliament called on its member nations to suspend the use of all high-intensity military sonar until further research can determine what effects it may have on marine life (Bosch 2004).

For security reasons, information on the specifications of active military sonars is difficult to obtain, and much of what is available comes from military vessels from the United States. Given that the US Navy engages in joint operations with the Canadian military in both the Strait of Georgia and off the west coast of Vancouver Island, and that both northern and southern resident whales travel in US waters, the threat that active sonars may pose must be considered. Southern resident killer whales may be especially vulnerable because they spend significant time in the waters of Washington State, where a large naval exercise area runs parallel to the coast.

Table 2 lists the 3 main classes of active military sonars that are used by the military: low, mid and high-frequency sonars. Low Frequency Active Sonars (LFA sonars) send out pulses or 'pings' to detect submarines, and operate at frequencies below 1 kHz. Their range can extend

10s to 100s of km (Tomaszeski 2004). Their use has been controversial because of concerns about their effects on marine life. The US Navy is now forbidden from deploying these units except in an area in the western Pacific Ocean and during periods of war (Malakoff 2003), but this ruling is currently being appealed by the US government. The Canadian military has developed its own low-frequency sonar, a Towed Integrated Active Passive Sonar (TIAPS) which is currently being tested off the Atlantic coast (Bottomley and Theriault 2003).

Mid-frequency tactical sonars operating between 1-10 kHz are used to detect mines and submarines. They have been associated with mass stranding events in the Bahamas, Canary Islands, Greece and the Gulf of California (IWC 2004). Mid-frequency sonar exercises conducted by the *USS Shoup* on May 5, 2003 in Haro Strait were reported to correspond with reports of unusual behaviour in nearby members of J pod that were in a foraging area at the time, and ultimately resulted in the pod dividing and rapidly leaving the area in different directions (personal communication K.C. Balcomb in Wiles 2004). Up to 100 Dall's porpoises and a minke whale were also seen leaving the area at high speed. The sonar exercise was associated with an almost 50% increase in the number of harbour porpoise stranding mortalities, although a US Navy inquiry concluded that sonar had no adverse effects on marine mammals (US Navy 2004). Extensive examination of 11 of the harbour porpoise mortalities found no definitive signs of acoustic trauma, but the cause of death could not be determined for 6 animals, and the possibility of acoustic trauma as a contributory factor in the deaths of the remaining 5 porpoises could not be ruled out (NMFS 2004).

Little information is available on the characteristics and use of low and mid-frequency active sonars in British Columbian waters by both US and Canadian military vessels. Resident killer whales may be vulnerable to the use of these sonars, especially during winter months when little is known of their distribution. Mid-frequency sonars are suspended into the water by helicopters (helicopter dipping sonars, MARPAC 2005), and some classes of Canadian military vessels are equipped with hull-mounted mid-frequency sonars (Wainwright et al. 1998). It is not clear whether mitigating protocols are used when military sonars are operating in the waters of British Columbia. During tests of the TIAPS sonar in the Atlantic, mitigation measures are based on visual and acoustic detection of marine mammals, and sonar use is discontinued if odontocetes are observed within 1 km of the ship (Bottomley and Theriault 2003). These measures are likely inadequate given what is now known about the affects of high intensity low frequency sound on marine life.

Seismic surveys

Seismic surveys are used in geophysical surveys and to detect and monitor oil and gas deposits beneath the sea floor. The following information on the characteristics of seismic surveys comes from NRC (2003) unless mentioned otherwise. Like military sonar, seismic surveys generate high intensity sounds. Most of their energy is concentrated at frequencies between 5-300 Hz and maximum pressure levels of 260 dB re 1μPa at 1 m. However, unlike military sonars, airgun arrays used for seismic surveys generate broadband noise that extends to 100 kHz (Calamokidis et al. 1998).

Current survey methods use one or more airguns that are towed behind a ship. Airgun arrays range in size from 2000-8000 cu in, depending on the application. The pulses of noise fired from these guns penetrate the seafloor surface for distances of up to 10 km deep. The arrays are towed at approximately 2.6 m/s (5 knots) and the airguns are fired every 10-12 seconds. The question of whether killer whales could sustain swimming the long distance necessary to avoid these sound sources needs to be addressed. Seismic surveys using powerful airgun arrays have been detected at distances of over 3,000 km from their source (Niekurk et al. 2004).

DFO receives occasional applications for permits for geophysical surveys from industry, government agencies such as Natural Resources Canada, and from universities.
At the time the COSEWIC status report on killer whales was written (Baird 2001) both the federal and provincial moratorium on oil and gas exploration was in place. Since 2001, the BC provincial government has lifted the moratorium on oil and gas exploration and has requested that the federal government do the same. As awareness is growing on the potential threats of high intensity sound on marine life (IUCN 2004, IWC 2004), the potential impacts of low frequency broadband high energy noise on killer whales must be considered. DFO is currently developing standards for seismic surveys, and have drafted a policy for the mitigation of seismic surveys. They are soliciting public comment until mid-April 2005 (DFO 2005).

Systematic observations of cetaceans during seismic surveys have been carried out in UK waters, and have shown that killer whales and other cetaceans were generally seen further away during periods when airgun arrays were firing (Stone 2003). Behavioural studies in other areas have shown mixed responses to seismic surveys. Gray and bowhead whales appeared to avoid seismic surveys (Malme and Miles 1987, Lungblad et al. 1988, Myrberg 1990). Male sperm whales and feeding humpback whales did not avoid seismic surveys (Malme et al. 1985, Madsen et al. 2002). A seismic survey in Puget Sound showed mixed results between species, with some, such as gray whales, exhibiting ambiguous responses to the survey while others, such as harbour porpoises, tolerating only relatively low exposure levels before leaving the area (Calambokidis et al. 1998).

For obvious ethical reasons, there are no experimental studies of the physical effects of seismic surveys on cetaceans. However the internal structure of the cetacean ear resembles that of both fish and terrestrial mammals (Fay and Popper 2000). A small (20 cu in) airgun has been shown to cause permanent hearing loss in caged fish (McCauley et al. 2003), so it is possible that airguns may be capable of damaging cetacean ears if the whales cannot avoid the sound source. Since killer whales are known to be exquisitely dependent on sound for orientation, navigation, locating and catching food, communication, and social interactions, it is likely that the survival costs of hearing loss would be severe.

Commercial Sonar

Commercial sonar systems are used in a wide variety of vessels for fishing, navigation (depth sounders), bottom-mapping and detecting obstacles (e.g. side scan sonars). They are generally standard equipment on any vessel over 5 m. These sonars typically generate narrowband sounds at higher frequencies and lower power than military sonars. High frequency sounds are more easily focused into narrow beams and attenuate more quickly than low frequency sounds. There are many models of commercial sonars, but it is only the units that operate below 100 kHz, the upper limit of killer whale hearing, that are of concern. Whales may be able to avoid these sources of sound when boats are widely dispersed, but when boats are concentrated in high traffic areas killer whales may have no choice but to travel through heavily ensonified areas.

Shipping

Commercial shipping has increased dramatically in recent years. For example, between 1995 and 1999 the worldwide commercial shipping fleet increased 12% (NRC 2003). There are few studies that have measured changes in the background underwater noise levels over time, but those that do suggest that increased vessel traffic is responsible for the increase in ambient noise over the last 100 years (e.g. Andrew et al. 2002). In the northern hemisphere, shipping noise is the dominant source of ambient noise between 10 to 200 Hz (NRC 2003). The consequences of these chronic sources of noise on killer whales have not been assessed.

4.2.3.3. Permitted Close Approaches

Certain activities have the potential to disturb and / or injure whales because they require physical contact with whales or close approaches by boats for extended periods of time. As a result, in both Canada and the United States, researchers and filmmakers must obtain federal permits if their projects require close approaches or physical contact with killer whales. Close approaches can disturb whales both physically and acoustically. Much of the research on killer whales is conducted using boats ranging in size from a few meters to vessels over 30 m, although some is land based (e.g. Orcalab on Hanson Island, the Warden Program on West Cracroft Island, Johnstone Strait). A boat at 10 m from a whale will be approximately 20 dB louder than a boat at 100 m (personal communication, David Bain University of Washington January 2005). Photo-identification studies require that all whales in the group be photographed before the encounter is considered complete, and good quality photographs typically mean that whales must be approached to within 30 m. Prey fragment sampling, which is providing insight into the diet of resident killer whales, involves approaching the area where a whale has surfaced after it has finished actively feeding. Biopsy darting, a method used in genetic and contaminant studies, also involves close approaches by boats, and recent recommendations arising from the NOAA Cetacean Systematics Workshop in La Jolla California, in April-May 2004 include darting juveniles (Waples and Clapham 2004). The possible health risks of darting young calves have not been evaluated. Satellite tags and the use of time-depth recorders (TDRs) are applied externally to killer whales. They are used to monitor the movements of whales, but may disturb them during the initial application and /or during the time that they adhere to the skin. Newer technologies involving satellite tags and TDRs that are implanted in the skin or muscle pose the additional risk of injuring killer whales.

4.2.3.4. Other Forms of Disturbance

The number of boats on the water has increased dramatically in recent years. This increase in traffic has the potential to disrupt killer whales simply because more vessels are passing through their habitat and potentially disturbing how whales move through the available space. This is most evident when whales are interrupted from their normal activities in order to avoid a collision. While collisions between whales and vessels are relatively rare, when they do occur they can cause significant injury or death (Ford et al. 2000).

Personal watercraft (PWC) or 'jet skis' may be another potential source of disturbance or injury to killer whales. PWC are capable of much more erratic or unpredictable manoeuvres than traditional high speed vessels. As a result they pose a collision risk to killer whales and other wildlife. PWC have been banned in the San Juan Islands and in portions of the Monterey Bay National Marine Sanctuary, but they are not banned in the coastal waters of British Columbia, with the exception of the inner waters of Vancouver harbour. The underwater noise levels of PWC have not been reported.

While resident killer whales must travel in high vessel traffic areas such as Johnstone Strait and the Strait of Georgia, they also must negotiate with both commercial and recreational sports fishing boats specifically targeting salmon in 'hot spots' that are also good feeding areas for killer whales. This includes areas in the vicinity of sports fishing lodges. Conflict for space may force killer whales to alter their foraging behaviour in order to successfully capture prey or to avoid collision or entanglement.

Certain industrial activities such as construction, drilling, pile driving, pipe laying and dredging may also disrupt killer whales. Construction is also a source of underwater noise. Physical structures, including net pens for aquaculture and permanent structures (e.g. wharves), may damage foraging habitat such as kelp beds, or physically displace resident killer whales from areas they have historically travelled in. If the fish farm industry continues to expand on the north coast, the placement of net pens may become an issue for northern residents. The southern residents live and travel in areas that have already been heavily altered by human activities.

4.2.4. Oil Spills

Southern resident killer whales may be particularly at risk of an oil spill because of the large volume of tanker traffic that travels in and out of Puget Sound and the Strait of Georgia (Baird 2001, Grant and Ross 2002). In 2003, 746 tankers and barges transported over 55 billion litres of oil and fuel through the Puget Sound (WDOE 2004). If the moratorium on oil and gas exploration and development is lifted in British Columbia, the extraction and transport of oil may put northern resident killer whales at additional risk as well.

Killer whales do not appear to avoid oil, as evidenced by the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska. Less than a week after the spill, resident whales from one pod were observed surfacing directly in the slick (Matkin et al. 1999). Seven whales from the pod were missing at this time, and within a year, 13 of them were dead. This rate of mortality was unprecedented, and there was strong spatial and temporal correlation between the spill and the deaths (Dahlheim and Matkin 1994, Matkin et al. 1999). The whales probably died from the inhalation of the petroleum vapours (Matkin et al. 1999). Exposure to hydrocarbons can be through inhalation or ingestion, and has been reported to cause behavioural changes, inflammation of mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Geraci and St. Aubin 1982).

4.2.5. Incidental Mortality in Commercial Fisheries

Killer whales are rarely entangled in commercial fishing gear, based on anecdotal accounts and an absence of net marks in identification photographs, but the actual numbers of whales caught are unknown (Baird 2001). A few entanglements have been reported from BC, Alaska, and California (Pike and MacAskie 1969, Guenther et al. 1995, Barlow et al. 1994, Heyning et al. 1994), but they usually have not resulted in death. It is likely that commercial fisheries pose little direct threat to killer whale populations at present. However, as described in Section 3.2.7 Culture, killer whales in other areas have learned to take fish from fishing gear and once this behaviour is adopted, it can spread quickly throughout a population. Thus it is possible that this behaviour could become a problem for both whales and fisheries in the future.

5. CRITICAL HABITAT

"Critical habitat" is defined under *SARA* as *"the habitat that is necessary for the survival or recovery of a listed wildlife species that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species"* (*SARA* s.2 (1)). Under *SARA*, defining critical habitat for killer whales to the extent possible is a legal requirement (*SARA* s.41 (1)(c)). Once critical habitat is legally identified by the minister, conservation and protection measures needed to ensure the whales' continued use of the habitat must be described.

Defining critical habitat for any species is challenging, but especially so for mobile marine animals such as killer whales. Resident killer whales travel over large geographical distances and members of the northern and the southern resident communities may be spread over hundreds of kilometres at any given point in time. As well, much of what we know about killer whales comes from the very short period of time they spend at the surface where we can see them, and the ways in which they travel and utilize their three dimensional underwater habitat are not at all well understood. The underwater vocalizations of resident killer whales provide some insight into their behavioural state, but tell us little about how geographic features of the environment are used. According to the best knowledge at this time, the habitat most important to killer whales in the summer and fall are channels, shorelines, or other topographic or oceanographic features that concentrate their migratory prey, salmon.

There is little evidence to suggest that killer whales require or are limited by specific physical features of their environment, other than features that make prey available to them. Indeed, as top level predators, killer whales in general are not known to require refugia and they inhabit a wide range of both nearshore and pelagic habitats worldwide. The presence of resident killer whales is closely associated with the presence of salmon (Heimlich-Boran 1988, Felleman et al. 1991, Osborne 1999, Nichol and Shackelton 1996, Ford et al. 1998), and it is this overwhelming feature of the environment that affects their distribution, although knowledge is limited temporally to summer and fall months. For the rest of the year there is much less information available on their diet or distribution and movement patterns. Clearly, establishing criteria for the identification of potential critical habitat for resident killer whales, as well as identifying and designating other critical habitat areas, must be specific objectives for the Action Plan. Such criteria will need to take into account the likelihood that changes in the relative strength of major salmon stocks may cause corresponding shifts in the geographic location of critical habitat for resident killer whales.

5.1. Proposed Critical Habitat

Two seasonal concentration areas, also known as 'core areas' for resident killer whales off northeastern and southeastern Vancouver Island have been well documented and appear to meet the requirements for designation as critical habitat under *SARA*. These areas are both characterized by narrow channels with strong currents, and appear to be geographical 'funnels' that tend to concentrate migrating salmon bound for the Fraser River, which has the largest salmon production in the region (Northcote and Larkin 1989), and other smaller river systems flowing into the Strait of Georgia and Puget Sound. There are likely other core areas that are extremely important for killer whales at various times, but these have not yet been studied in sufficient detail to be identified with confidence. Measures to identify and effectively protect other critical habitat areas will be described in the Action Plan that follows this Recovery Strategy.

5.1.1. Southern Residents

A core area for southern resident killer whales includes the transboundary waters of British Columbia and Washington. These include Haro Strait and Boundary Pass and adjoining areas in the Strait of Georgia and the eastern end of the Strait of Juan de Fuca, as depicted in Figure 2. The occurrence of southern residents in this core area is strongly correlated with the timing of salmon migration through these waters (Heimlich-Boran 1988, Felleman et al. 1991, Osborne 1999). Within this area, locations that appear particularly important for foraging are the nearshore waters along the west and southwest sides of San Juan Island, the southern tip of Vancouver Island, Swanson Channel off North Pender Island, and off the mouth of the Fraser River (Heimlich-Boran 1988, Hoelzel 1993, Ford et al. 2000; unpublished data CWR and CRP-DFO).

The core area is utilized regularly by all three southern resident pods during June through October in most years (Osborne 1999, Wiles 2004). J pod appears to be present in the area throughout much of the remainder of the year, but the two southern resident pods, K and L, are often absent during December through April. The southern resident core area is clearly of great importance to the entire southern resident community as a foraging range during the period of salmon migration, and thus meets the definition of critical habitat as described in the Species at Risk Act. It is likely that this core area for southern residents extends west along the Strait of Juan de Fuca and out to Swiftsure and La Perouse Banks off the west coast of Vancouver Island, but further study is needed to determine if the area should be proposed as critical habitat.

Much of the proposed critical habitat area for resident killer whales falls within US jurisdiction, and thus such a legal designation would apply only to the portion of the core area that is within Canadian waters (Figure 2). The United States is currently preparing a Conservation Plan for southern resident killer whales under the US Marine Mammal Protection Act (MMPA), and has proposed listing the population as ‘threatened’ under the Endangered Species Act (ESA). Should this listing occur, the US will complete an evaluation of habitat essential to the conservation of the species in areas under US jurisdiction, including the inland waters of Washington State. Similarly, the State of Washington has included killer whales on the state list of endangered wildlife and will assess critical habitat within the state. To some extent, measures to protect water quality and biological resources within Puget Sound are already being addressed through the actions of the Puget Sound Action Team, a partnership between Washington State agencies, as well as First Nations and local governments.

5.1.2. Northern Residents

The waters of Johnstone Strait and southeastern Queen Charlotte Strait, and the channels connecting these straits, represent a very important concentration area for northern resident whales. This area, hereafter referred to as the ‘Johnstone Strait’ area, has long been the focus of research and whale watching activity involving the northern resident community (JSKWC 1991). Northern residents frequent the area on most days during July through October, with peak numbers generally in mid-July to mid-September (JSKWC 1991, Nichol and Shackleton 1996). Whales become more sporadic in the area during November, and are scarce from December through May. Although all northern resident pods have been identified in the area, it is used most frequently by only part of the community, particularly groups belonging to A Clan (Ford 1984, Nichol and Shackleton 1996). Members of G Clan tend to be seen in the area more often in September and October than during summer in some years (Nichol and Shackleton 1996, unpublished data CRP–DFO). Northern resident killer whales in the Johnstone Strait area spend the majority of time foraging for salmon, primarily chinook during July-September and chum in October (Ford 1989, Ford et al. 1998, unpublished data CRP-DFO). Other activities undertaken in the area include resting, socializing, and beach rubbing.

Beach rubbing appears to be an important activity for northern resident killer whales. Ninety percent of whales in Johnstone Strait visit the rubbing beaches, and spend 10% of their time there (Briggs 1991). During this time they are very sensitive to disturbance. In recognition of the importance of this habitat to killer whales, the province of British Columbia in 1982 established the Robson Bight–Michael Bigg Ecological Reserve to protect a portion of western Johnstone Strait and the foreshore near Robson Bight, where the rubbing beaches are located (Figure 3). However, in response to growing concerns about the impacts of human activities in and around Robson Bight, in 1990 the British Columbia and Canadian governments jointly appointed the Johnstone Strait Killer Whale Committee to develop management recommendations to ensure the conservation and protection of killer whales (JSKWC 1991, 1992). One of the key recommendations of the Committee called for the establishment of a Special Management Zone to encompass a larger marine area than the existing Ecological Reserve, and establish a seasonal patrol vessel program to monitor whale-oriented vessel activity and mitigate potential disturbance.

The Special Management Zone includes the primary foraging areas for killer whales utilizing the Johnstone Strait area, as well as at least six beaches used to various degrees by these whales for rubbing, and is included within the shaded area in Figure 3. Given the importance of this area to a significant component of the northern resident community for a major portion of the salmon feeding season, and the traditional use of rubbing beaches located there, this area should be considered for designation as critical habitat as defined in the Species at Risk Act. There may be additional critical habitats for northern residents during other parts of the year, and for northern resident groups that infrequently utilize the Johnstone Strait area during summer and fall, but there is insufficient information to characterize them at present. This knowledge gap will be addressed in the Action Plan. Potential candidates might include portions of Dixon Entrance, Caamano Sound, Whale Channel, and the channels surrounding King Island on the central BC mainland coast. Northern resident whales frequent all these locations in at least some years, especially during May to early July (Nichol and Shackleton 1996, unpublished data CRP-DFO). Several rubbing beaches have also been identified in other locations on northern Vancouver Island and the mainland coast, and might also warrant protection as critical habitats because of the importance of this behavioural tradition to the cultural diversity of resident populations.

5.2. Threats to Critical Habitat

Many of the threats that face resident killer whales also impact their habitat, and this is of particular concern for the proposed critical habitat core areas. The threats to the core areas are briefly listed here, but the reader is referred to Section 4 for a more thorough discussion. As previously mentioned, it is important to recognize that the definition and identification of critical habitat for resident killer whales is complex, and incorporates both abiotic and biotic features of the habitat. It is also important to note that there are many gaps in our understanding of critical habitat, and that this will be a focus for research in the Action Plan.

5.2.1. Threats to Abiotic Features of Critical Habitat

Geophysical Disturbance

A key physical feature of both the northern and southern resident killer whale's proposed critical habitat is that these areas by virtue of their underwater topography funnel salmon into areas where they concentrate before spawning. Thus, any large scale physical disturbance, such as an earthquake, could significantly alter the channelling of salmon and could be considered a serious threat. However, such catastrophic events are not predictable and have a low probability of occurrence. Industrial activities such as construction, drilling, pile driving, pipe-laying and dredging are the most likely sources of habitat destruction in core areas. Fisheries using nets that drag along the bottom (accidentally or intentionally) also damage habitat. Vessel anchors damage the seabed and may serve to alter a rubbing beach or cause displacement. Physical structures such as wharves and net pens for aquaculture may displace killer whales. Both the placement of individual structures and the cumulative effect of multiple structures should be assessed against the needs of killer whales in critical habitat.

A key feature of the northern resident killer whale proposed critical habitat is the presence of several rubbing beaches. Any destruction of rubbing beaches, or disturbance of the animals while in these areas should be considered a threat. Rubbing beaches may also be vulnerable to disturbance through flooding and landslides in areas adjacent to the beach.

Acoustic Degradation

There is growing awareness that the underwater acoustic environment is extremely important to cetaceans (IUCN 2004, IWC 2004) and it is important that this physical feature be protected in critical habitat, in order that killer whales can maintain communication, and detect and capture prey while in the area. There are many threats to the acoustical integrity of critical habitat, and these are discussed in detail in Section 4.2.3.2. They include seismic surveys, military and commercial sonars, vessel noise, construction and dredging.

Chemical and Biological Contamination

The degradation of water quality due to environmental contaminants poses a particularly serious threat to killer whales, their prey and their habitat. These contaminants and their sources are discussed in Section 4.2.1. While many contaminants are airborne and dispersed throughout the coastal waters of British Columbia, the waters surrounding the lower mainland and Vancouver Island are particularly at risk due to their proximity to human settlement. This includes the risks to habitat associated with the introduction of exotic species. Urban land use represents a significant concern for the health of coastal ecosystems (Grant and Ross 2002) and a growing population makes this situation unlikely to improve. By 2020 the Canadian portion of this area is predicted to have a population of over 3.8 million (BC Statistics 2004), and the state of Washington which borders this area is projected to have over 7.7 million people (OFM 2004).

The threat of a spill of oil or other toxic material within the areas of proposed critical habitat pose not only an immediate and acute risk to the health of resident populations (see Section 4.2.4), but have the potential to make these important core areas un-inhabitable for an extended period of time.

5.2.2. Threats to Biotic Features of Critical Habitat

Presence and Availability of Salmon

As the presence of salmon is key to the presence of killer whales in the proposed critical habitat areas (Heimlich-Boran 1998, Nichol 1990, Nichol and Shackelton 1996, Osborne 1999), threats that result in changes to the quantity, quality and availability of salmon are a threat to an important feature of their critical habitat. Many of these threats are listed in detail in Section 4.2.2 and include overfishing, destruction of spawning habitat, disease, parasites and climate change.

Prey must be physically accessible to resident killer whales in critical habitat, yet killer whales and fishing vessels targeting the same prey compete with each other for space, particularly in fishing hotspots. The presence of fishing vessels also alters fish behaviour (Mitson and Knudsen 2003) potentially making them less accessible to killer whales, although this is an area for further research.

5.3. Schedule of Studies Related to Critical Habitat

Table 3 Schedule of studies to identify critical habitat and its threats. (*The time frame for these studies will be identified following public consultations.*)

Study	Status
Year-round comprehensive surveys to identify areas of occupancy	Underway
Identify key feeding areas throughout the year to determine whether they should be proposed as potential critical habitat	Underway
Identify activities other than foraging that may be important components of critical habitat	Proposed
Identify sources of acoustic disturbance that may negatively impact or affect access to critical habitat	Proposed
Identify sources of physical disturbance that may negatively impact or affect access to critical habitat	Underway
Identify sources of biological and chemical contaminants that may negatively impact critical habitat	Underway
Identify and mitigate factors that may negatively affect an adequate and accessible supply of prey in areas of critical habitat	Underway (due to salmon initiatives)

5.4. Mechanisms for the Protection of Critical Habitat

There are various mechanisms for the protection of resident killer whale critical habitat, including; legislative tools such as acts, regulations, government policy and programs, as well as best practices, education and stewardship programs. As the proposed critical habitat for southern resident killer whales borders the waters of Washington State, where additional core habitat exists, it is important that transboundary cooperation in protecting habitat is fostered.

Within Canada, the *Fisheries Act* provides for the protection of habitat from physical alteration and the introduction of deleterious substances. The *Marine Mammal Regulations (MMR, Section 7)* of the *Fisheries Act* prohibit the disturbance of marine mammals, including activities such as the emission of high energy sounds (seismic surveys, low-mid frequency sonars) or sounds associated with various industrial activities. Garrett and Ross (In press) provide a thorough summary of the existing legislation and regulations regarding contaminants into the marine environment. Proactive efforts, to insure that activities are assessed and controls and/or mitigative measures are implemented, are vital to the protection of the proposed critical habitat identified for killer whales. Screening activities, such as those required under the *Canadian Environmental Assessment Act (CEAA)* and *Integrated Management (IM)* as described by the *Oceans Act (OA)* are essential mechanisms for protecting critical habitat. Monitoring and enforcement of all regulations is essential and complements the programs listed above to ensure compliance.

Measures to protect the biotic features of the critical habitat, primarily salmon, can be accomplished through management activities, directed by annual Integrated Fisheries Management Plans (IFMPs), authorized under the *Fisheries Act.* An ecosystem based approach to the management of salmon stocks that explicitly accounts for the dietary needs of killer whales should be evaluated and considered as one approach to protecting food resources.

Non-government education and stewardship programs (such as the Green Boater Program and Toxic Smart) will complement government programs and engage Canadians to take action at an individual level to protect proposed critical habitat. In areas where critical habitat falls within traditional territories held by First Nations, their cooperation in protection should be encouraged. The following table summarizes the most understood potential threats to the critical habitat, along with a description of measures to protect it currently in place and additional measures that are needed for protection, based on the current understanding of critical habitat and the associated threats. As a greater understanding develops of the important features of the habitat necessary to ensure the survival of these populations and the threats to this habitat, the mechanisms and measures needed to protect it will require revision.

Table 4 Schedule of studies to identify critical habitat and its threats. (*The time frame for these studies will be identified following public consultations.*)

Threat	Current Mechanisms	Recommended Additional Measures
Geophysical Disturbance	Fisheries Act and the Canadian Environmental Assessment Act (CEAA) screening Integrated management (IM) planning in northern resident core area	Ensure all habitat alterations and marine use planning incorporate assessment of killer whale critical habitat Consider IM planning for southern resident core Apply precautionary approach in areas where critical habitat have not yet been identified
Geophysical Disturbance at Rubbing Beaches	HPR CEAA screening BC Parks Ecological Reserve & Monitoring program (Robson Bight) Remote surveillance technology (e.g. Orcalab)	Prohibit habitat alteration at rubbing beaches Establish MPA's (Oceans Act) at Robson Bight Fisheries management actions (Fisheries Act) within rubbing beach areas Evaluate need for protection at other rubbing beaches Ensure all habitat alterations and marine use planning (e.g. fishing) incorporates assessment of rubbing beaches.
Acoustic Degradation - Seismic	CEAA screening for some seismic programs and mitigation required Non-CEAA seismic programs reviewed regionally Marine Mammal Regulations (MMR) on disturbance	Evaluate recently developed draft standards for mitigation of seismic exploration Apply precautionary approach in areas where critical habitat have not yet been identified Amend MMR to provide for licensing (control) of disturbance activities Require screening and authorization for all seismic activities Encourage trans-boundary cooperation in mitigation measures
Acoustic Degradation-Sonar	Protocols for military sonar use MMR regulations on disturbance	Review existing military sonar use and protocols to ensure adequacy, revise as necessary Amend MMR to provide for licensing (control) of disturbance activities Encourage trans-boundary cooperation in mitigation measures Apply precautionary approach in areas where critical habitat have not yet been identified
Acoustic Degradation – Industrial Activity	MMR disturbance regulations DFO policy prohibits use of acoustic harassment devices	Consider and limit, as necessary, acoustic alteration from construction/development projects Amend MMR to provide for licensing (control) of disturbance activities

Threat	Current Mechanisms	Recommended Additional Measures
Chemical & Biological Contaminants in Canadian waters[4]	Stockholm Convention on POPs Georgia Basin Action Plan (Environment Canada) NGO environmental education programs (e.g. Green Boater Program, Toxic Smart etc.) BC Environmental Management Act CEPA Fisheries Act Industry initiatives (e.g. Clean Print BC) Integrated Pest Management Act (IPMA, Health Canada) Canada-Wide Standards of Canadian Council of Ministers of the Environment Fertilizers Act	Better identification and understanding of key contaminants and their sources Increased enforcement of existing regulations Increased funding for education at the individual, municipal and sector level Evaluate and strengthen BC Environmental Management Act Evaluate and strengthen the Canadian Environmental Protection Act Continue to upgrade water treatment plants Evaluate and strengthen the Integrated Pest Management Act, Fertilizers Act
Biological and Chemical Contaminants in US waters	Numerous acts to protect critical habitat from contamination are listed in Garrett and Ross (In Press)	Strengthen transboundary cooperation in reducing contaminants Detailed recommendations in EVS (2003) including actions
Oil & Toxic Chemical Spills	HPR regulations for deleterious substances Canadian/ US spill response plan (CANUSPAC) in southern transboundary waters CANUSDIX joint response plan in northern transboundary waters (Dixon Entrance) BC Marine Oil Spill Contingency Plan 1992 Federal Marine Spills Contingency Plan Regional Environmental Emergencies Team (REET) Washington State Department of Ecology	Develop and incorporate into existing oil spill response plans measures specific to killer whales
Presence & Availability of Salmon	Integrated Salmon Management Plan (FA authority) provides for conservation of salmon Regulations under the FA to manage harvest activities	Evaluate resident killer whale prey and ensure that management plans incorporate adequate supply of prey for resident killer whales, even in changing climate scenarios

6. KNOWLEDGE GAPS

While resident killer whales are among the best studied cetaceans in the world, it is clear that key information is still needed to affect their recovery. In part this is due to the fact that although

[4] Source: Garrett and Ross. In press.

studies of killer whales have been ongoing over the last 30 years, killer whales spend the majority of time underwater, and their whereabouts are unknown during much of the year. As well, opportunities to learn from killer whale carcasses occur relatively infrequently. Only 7 to 8 carcasses are recovered around the world each year (Raverty and Gaydos 2004). In a 30 year period, only 14 resident carcasses have been found and necropsied in British Columbia (Ford et al. 1998), a recovery rate of 6%.

Listed below are the key areas where further knowledge is needed:

- The year round distribution and behaviour of resident killer whales
- Critical and important habitat for killer whales
- The historical abundance of resident killer whales
- The year round diet and energetic requirements of resident killer whales
- The consequences of changes in key prey populations on resident killer whales, as well as their historic trends
- The long- and short-term effects of physical disturbance (shipping, whale watching, aircraft) on resident killer whales
- The long- and short-term effects of acoustic disturbance (whale watching, seismic surveys, military sonar, researchers and film makers) on resident killer whales
- The full range of anthropogenic environmental contaminants to which killer whales and their prey are exposed, over time and in space, with special attention paid to the identification of sources
- The effects of environmental contaminants on resident killer whales, their prey and their habitat
- The population size that is needed to maintain the cultural and genetic diversity of resident killer whales
- The population level consequences of low population size and its effects on the sustainability and viability of resident killer whales
- The effects of environmental catastrophes on resident killer whales, their prey and their habitat
- The effects of climate or environmental change on resident killer whale prey and their habitat

RECOVERY

7. RECOVERY FEASIBILTY

Resident killer whales populations are not expected to achieve high abundances that might automatically trigger a de-listing decision for other species, due to their ecological position as upper trophic-level predators coupled with their apparent propensity to live in relatively small populations. Despite this, and despite gaps in our knowledge, the recovery team views the recovery of both populations to a more robust and sustainable status as technically and biologically feasible. Both populations have males, reproductive and pre-reproductive females, and the capacity to grow. During past periods of population growth, annual increases of approximately 3% have been recorded (see sections 2.1.1 and 2.1.2 in Population Status and Trends). Growth is unlikely to exceed these levels due to the low reproductive rate of the species, and the recovery of northern and southern resident killer whales can be expected to take more than one generation. The southern resident killer whale population will be vulnerable to catastrophic events and continue to have a high risk of extinction during this period.

Technologies and methodologies currently exist to reduce many of the threats facing killer whales, their prey and their habitat. As well, the identification of additional core areas and the protection of proposed critical habitat areas from further degradation will ensure that resident killer whales have sufficient habitat for recovery. Effective implementation of initiatives such as Environment Canada's Georgia Basin Action Plan (EC-GBAP 2005) and Fisheries and Oceans Canada's Wild Salmon Policy (DFO-WSP 2004) will complement the objectives in this recovery strategy, to improve both the quality and abundance of killer whale prey and their habitat. There are also individuals and interest groups that have already shown initiatives in mitigating threats to killer whales, such as the 'Best Practices Guidelines' developed by the industry based Whale Watch Operators Association- Northwest (WWOAN 2004). These are designed to reduce the impact of whale watching on southern resident killer whales. As killer whales travel regularly across international borders, it is timely that both the Washington State and the United States federal governments are engaged in developing a conservation plan for the southern resident population that should complement and enhance Canadian efforts towards population recovery.

8. RECOVERY GOAL AND OBJECTIVES

The recovery goal reflects the complex social and mating behaviour of resident killer whales and the key threats that may be responsible for their decline. In the absence of historical data, it does not identify a numerical target for recovery because our current understanding of killer whale population demographics is not adequate for setting a meaningful value at this time. This will be revisited in five years when the recovery strategy is re-evaluated.

8.1. Recovery Goal

Ensure the long-term viability of resident killer whale populations and sustain their genetic diversity and cultural continuity by reducing human threats, including noise and pollutants, and protecting their habitat and prey.

8.2. Objectives and Broad Strategies to Achieve Recovery

Given our current knowledge, the prime threats to the long-term survival of northern and southern resident killer whales appear to be 1) their low population size and limited growth potential, 2) reduced prey availability, 3) environmental contaminants, 4) disturbance, and 5) gaps in our knowledge regarding critical habitat. We have identified five objectives that directly address these threats and contribute to achieving the recovery goal of population viability and sustaining genetic diversity and maintaining cultural continuity (as stated above). The numerical values do not reflect any priority among the objectives. These objectives provide direction for the broad strategies that can be used to specifically mitigate and/or eliminate each of the threats facing resident killer whales, and to better address gaps in our knowledge.

Objective 1: Ensure the long term viability of resident killer whale populations by achieving and maintaining demographic conditions that preserve their reproductive potential, genetic variation, and cultural continuity.

Killer whales are top-level predators, and as such will always be far less abundant than most other species in their environment. In addition, they have an innate tendency to segregate into small populations that are closed to immigration and emigration, such as the northern and southern resident communities. Furthermore, their capacity to grow is limited by a suite of life history and social factors, including late onset of sexual maturity, small numbers of reproductive females and mature males, long calving intervals, and dependence on the cultural transmission of ecological and social information. Unfortunately, little is known concerning the historic sizes of killer whale populations, or the factors that ultimately regulate them. Genetic diversity is known to be low in both populations, particularly the southern residents, but the consequences of this lack of diversity have not been examined. In light of these inherent characteristics and uncertainties, the following have been identified as conditions required for recovery:

1) Maintenance of a non-negative long-term growth rate for populations currently at known historic maximum levels and a positive long-term growth rate for populations' currently below known historic maximum levels;
2) Maintenance of sufficient numbers of females in the population to ensure that their combined reproductive potential is at replacement levels for populations at known historic maximum levels and above replacement levels for populations below known historic maximum levels;
3) Maintenance of sufficient numbers of males in the population to ensure that breeding females have access to multiple potential mates outside of their own and closely related matrilines;
4) Maintenance of matrilines comprised of multiple generations to ensure continuity in the transmission of cultural information affecting survival.

These conditions will be met by reducing the identified threats and mortality factors, as outlined in Objectives 2, 3 and 4. The following research based strategies are necessary for defining specific numerical targets for recovery and identifying when recovery is achieved.

<u>Strategies for Objective 1</u>

- Routinely monitor resident killer whale population numbers, sex- and age-composition, social structure and genetic diversity.

- Develop models of resident killer whale population dynamics and demographics, including social and genetic structure.
- Develop a quantitative framework to better understanding how key anthropogenic and naturally occurring factors, particularly those identified as threats, affect the dynamics of resident killer whale populations.
- Undertake studies to identify the role of culture in foraging ecology and maintaining genetic diversity in resident killer whales.

Because killer whale populations are closed and animals individually identifiable, routine monitoring provides accurate, detailed life history information, which will be used to determine trends, and to refine and test populations models. These models will lead to a better understanding of achievable targets for population recovery. A better understanding of the anthropogenic and naturally occurring factors that regulate or limit killer whale populations, and of the role and importance of culture, will make it possible to rank threat factors and prioritize recovery actions.

Objective 2: Ensure that resident killer whales have an adequate and accessible food supply to allow recovery.

This objective identifies the need to learn more about the year round diet of killer whales, and to understand and mitigate the threats to key prey populations and their habitat. Food supply can limit the growth and recovery of any population, and there are concerns about both the quality and quantity of resident killer whale prey, as well as their habitat. In some areas, for example, runs of chinook salmon, a principle prey species for residents during the summer, have been listed as either endangered or threatened (NWR 2004). We know very little about what killer whales eat during the winter and spring, and this information is critical to understanding whether the quantity or quality of their food supply could be responsible for the recent decline in killer whale numbers, and may prevent their populations from recovering.

<u>Strategies for Objective 2</u>

- Determine the seasonal and annual diet and energetic requirements of resident killer whales.
- Identify key prey populations and feeding areas for resident killer whales.
- Establish long-term monitoring programs capable of detecting changes in the abundance, distribution and quality of resident killer whale prey.
- Protect the access of resident killer whales to important feeding areas.
- Ensure that resident killer whale prey populations and their habitat are adequately protected from anthropogenic factors such as exploitation and degradation, including contamination that will allow for the recovery of resident killer whales.

Protecting key prey populations and their habitat will also be addressed by strategies in Objective 3 below.

Objective 3: Ensure that chemical and biological pollutants do not prevent the recovery of resident killer whale populations.

Ross et al. (2000) showed that southern resident killer whales are among the most contaminated mammals on the planet, and that northern residents also carry significant pollutant loads. These pollutants are known to impair both immune responses and reproduction in other species, at lower concentrations than currently seen in killer whales. The strategies listed below are intended to improve our understanding of, and mitigate, the contaminant risks that resident killer whales and their prey are exposed to. They also acknowledge the serious risks that pathogens, introduced species, and catastrophic events such as oil spills present to killer whales and their prey.

Strategies for Objective 3

- Investigate the effects of chemical and biological pollutants on the health and reproductive capacity of resident killer whales.
- Monitor chemical and biological pollutant levels in resident killer whales and their prey.
- Identify (and prioritize) key chemical and biological contaminants and their sources.
- Reduce the introduction into the environment of pesticides and other chemical compounds that have the potential to adversely affect the health of killer whales and/or their prey, through measures such as national and international agreements, education, regulation, and enforcement.
- Mitigate the impacts of currently and historically used 'legacy' pollutants in the environment.
- Reduce the introduction of biological pollutants, including pathogens and exotic species, into killer whale habitat and their prey.

These strategies are intended to protect and restore the prey populations and habitat of resident killer whales. In order for them to be successful, it is important that contaminant levels be measured, in order to provide a baseline that can be used to monitor changes in contaminant profiles over time, and to quantify whether attempts at mitigation are successful. Mitigation must occur on scales that range from the local consumer to the international level, as many pollutants originate from sources outside of Canada. Regulations, guidelines, and best practices for the manufacture, storage, transport, use and disposal of hazardous compounds must be followed, and evolve to reflect changing knowledge of contaminants and their adverse health effects on resident killer whales, their prey and their habitat. Education at the individual, corporate and government level (again ranging from local to international) will play an important role in reducing the rate at which contaminants are introduced into the environment. New international treaties, similar to the Stockholm Convention on Persistent Organic Pollutants that Canada ratified in 2001 (but the US has not), should be endorsed.

Objective 4: Ensure that disturbance from human activities does not prevent the recovery of resident killer whales.

Both physical and acoustic disturbance from human activities may be key factors causing depletion or preventing recovery of resident killer whale populations. Sources of acoustic disturbance range from high-intensity sound produced by seismic surveys to chronic sources such as vessel traffic. During periods of high boating activity in the summer months, disturbance may occur from vessel congestion, impairing the ability of whales to move freely and/ or forage effectively. Physical disturbance can be caused by boat or air traffic close to whales, especially during certain behavioural states such as feeding or beach rubbing (Williams 1999). Research to date has identified various immediate responses of whales to disturbance; however we know little about potential long- term effect on whale behaviour, health, and foraging efficiency. The National Research Council (NRC 2005) has recently put forward a detailed listing of approaches to better understand how noise impacts marine mammals, which will be worth examining as the resident killer whale Action Plan moves forward. The strategies listed here more generally address the need for more knowledge about how noise and physical disturbance affect resident killer whales and also provide for mitigation of disturbance as a precautionary measure.

Strategies for Objective 4

- Determine the short and long-term effects of chronic and immediate forms of disturbance, including vessels and noise, on the physiology, foraging and social behaviour of resident killer whales.
- Determine baseline ambient and anthropogenic noise profiles and monitor sources and changes in the exposure of resident killer whales to underwater noise.
- Develop and implement regulations, guidelines, sanctuaries and other measures to reduce or eliminate physical and acoustic disturbance of killer whales.
- Develop protocols, regulations, guidelines and other measures for the use of seismic and high energy sonar testing to reduce disturbance or injury to resident killer whales, where such activities are permitted.

In order to be effective, these strategies will require education and stewardship activities promoting compliance with best practice guidelines, the protection of sanctuaries, and the enforcement of regulations. New technologies, such as those that reduce noise may also contribute to reductions in disturbance over the long term. Existing regulations, guidelines, protocols and other measures should be evaluated for their efficacy in protecting resident killer whales, particularly as new information becomes available.

Objective 5: Protect proposed critical habitat for resident killer whales and identify additional potential core areas for critical habitat designation and protection.

Two coastal areas used consistently by resident killer whales are proposed for designation as critical habitat. One, the trans-boundary waters of Haro Strait and Boundary Pass, is used by southern residents year-round. The other, the waters of Johnstone and Queen Charlotte Straits and their adjoining channels, is used by many of the northern residents during the summer and fall. These areas represent a relatively small proportion of the total range of each population. Preliminary data suggest that other core areas may exist in other locations and at different times of the year, but are not sufficient to warrant proposing these habitats as critical without further research. The strategies listed here provide measures for the protection of the proposed critical habitats referred to above, as well as direction for the identification of additional critical habitat.

Strategies for Objective 5

- Develop a year-round comprehensive survey program for resident killer whales
- Identify key feeding areas and other critical habitat of resident killer whales throughout the year
- Protect the access of resident killer whales to their proposed critical habitat
- Protect proposed critical habitat areas through assessment and mitigation of human activities that result in contamination, and physical and acoustical disturbance

- Ensure that prey are available to killer whales in their proposed critical habitat
- Ensure trans-boundary cooperation in the identification and protection of critical habitat

The first two strategies listed above focus on determining additional areas that should be proposed for critical habitat designation. The remaining strategies, as well as those in Objectives 2, 3 and 4, will help to preserve and protect critical habitat.

8.3. Effects on Non-Target Species

Objectives 2, 3 and 4 protect resident killer whale prey populations and their habitat from exploitation and degradation including contaminants and noise. The spin-off effects of this are likely to be widespread and will be beneficial to human health as well as to a wide variety of organisms ranging from fish to sea birds, since all are affected by contaminants and exploitation. It is likely this benefit will far exceed the increased mortality of prey species associated with increased killer whale numbers.

8.4. Evaluation and the Status of Strategies for Recovery

The competent minister must report on the implementation of the recovery strategy, and the progress towards meeting its objectives, within five years after it is included in the public registry… [SARA, S.46].

The recovery team will review the success of the recovery actions annually, and review the goals, objectives and broad strategies in the recovery strategy within five years of its acceptance by the minister. The following are examples of performance measures that may be used to assess the effectiveness of the objectives and strategies, and to determine whether recovery remains feasible. Detailed performance measures will be identified more fully during the development of the Action Plan.

Table 5 Examples of performance measures that may be used to assess the effectiveness of the broad strategies used to achieve the objectives of the resident killer whale recovery strategy. *A thorough listing of performance measures will be included in the Action Plan*

Objective No. /Threat	Broad Strategy	Status	Examples of Performance Measures for Broad Strategies and Objectives
1. Long-term	Monitor population dynamics and demography	Underway	Completion of annual censuses Genetic sampling and analyses completed Evaluation of population status to ensure growth
	Develop population models	Underway	Models developed that incorporate social and genetic structure and explain population trends
	Quantitative framework for understanding effects of threats on population dynamics	Proposed	Models completed that incorporate threats into population dynamic models
	Studies to identify role of culture in foraging ecology	Proposed	Peer-reviewed publications on role of culture in killer whale foraging
	Studies to identify role of culture in maintaining genetic diversity	Underway	Biopsy samples collected and analyzed to identify paternity
2. Ensure adequate and accessible food supply	Determine seasonal/annual diet/ energetic requirements	Underway	Prey fragment samples collected year round for multiple years. Alternative diet sampling methods tested to confirm diet Winter and spring distribution and diet of resident killer whales identified
	Identify key prey populations and feeding areas	Underway	Complete diet sampling of all members of population and during all seasons Prey identified to stock, not just species
	Monitoring prey populations to detect changes in abundance or availability	Underway	Population assessment completed for all stocks identified as important prey for resident killer whales
	Protect access to important feeding areas	Proposed	Guidelines developed for human activities in important whale feeding areas
	Protection of prey populations	Underway	Incorporation of killer whale predation into fisheries management plans
3. Chemical and biological contaminants	Investigate effects of contaminants on health and reproductive capacity of killer whales	Underway	Peer reviewed publication on contaminants in resident killer whales
	Monitor pollutant levels in killer whales	Underway	Extensive sampling of populations to establish baseline contaminant level Completed analyses of contaminants in samples
	Identify and prioritize key chemical and biological pollutants	Underway	Completed sampling and analyses of contaminants in killer whale prey
	Identify and prioritize key sources of chemical and biological pollutants	Underway	Water quality sampling in areas throughout range of resident killer whales

Objective No. /Threat	Broad Strategy	Status	Examples of Performance Measures for Broad Strategies and Objectives
	Reduce introduction of chemical pollutants into environment	Underway	Measurable decline in contaminant levels in environment (prey, sediments etc.)
	Mitigate impacts of currently used pollutants	Underway	Evaluation of effectiveness of legislation completed
	Mitigate impacts of 'legacy' pollutants	Underway	PCB sources identified
	Reduce introduction of biological pollutants	Underway	Evaluation of effectiveness of legislation completed
4. Acoustical and Physical Disturbance	Investigate short term effects of chronic forms of disturbance	Underway	Controlled studies of whale/boat interactions completed
	Investigate short term effects of acute forms of disturbance	Proposed	Complete controlled study of marine mammals in areas where seismic exploration is active
	Investigate long term effects of chronic forms of disturbance	Proposed	Complete model that incorporates effects of increasing ambient noise levels on communication signals of resident killer whales
	Investigate long term effects of acute forms of disturbance	Proposed	Complete controlled study of marine mammals in areas where seismic exploration is active
	Determine baseline ambient and anthropogenic noise profiles	Proposed	Complete acoustic profiles of vessels most likely to be encountered by resident killer whales
	Develop measures to reduce physical disturbance	Underway	Revised whale watching guidelines, and/ or regulations that reflect most recent understanding of effects of chronic physical disturbance
	Develop measures to reduce acoustic disturbance	Proposed	Establishment of acoustic sanctuaries in critical habitat areas
	Develop measures for reducing disturbance to high energy sources of sound	Proposed	Revised protocols for seismic and military sonar that reflect most recent understanding of physiological and behavioural responses to noise
5. Protection of Critical Habitat	Year-round comprehensive surveys to identify important areas for killer whales	Underway	Winter distribution of resident killer whales well understood
	Identify key feeding areas and other critical habitat	Underway	Winter prey of resident killer whales identified
	Protect access of whales to proposed critical habitat	Underway	Sanctuaries within critical habitat established
	Protect critical habitat from contamination, and physical and acoustical disturbance	Proposed	Measurable reduction in contaminants in critical habitat
	Ensure prey available to whales in critical habitat	Proposed	Key prey populations identified in critical habitat
	Ensure trans-boundary cooperation in identification and protection of critical habitat	Proposed	Formal identification of critical habitat recognized by international agreement

8.5. Recommended Approach for Recovery

The recommended approach for recovery of northern and southern resident killer whales encompasses a variety of strategies that focus on the threats to killer whales, their prey and their habitat, and has adopted a single species, but multi-populational approach. At present, the recovery strategy for northern and southern resident killer whales does not directly link to any single species recovery plans currently in progress in Canada. However, US agencies (NOAA and Washington State) are in the process of preparing recovery plans for southern resident killer whales that will likely complement Canadian efforts on recovery. As well, initiatives such as Environment Canada's Georgia Basin Action Plan, DFOs Wild Salmon Policy and Parks Canada's Southern Strait of Georgia National Marine Conservation Area proposal will help to affect recovery by protection of at least a portion of resident killer whale habitat and their prey.

9. TARGET DATE FOR COMPLETION OF ACTION PLANS

Recovery Implementation Groups (RIGs) will be necessary to successfully achieve the objectives and approaches of the resident killer whale recovery strategy. At least six RIGs addressing the issues of 1) population dynamics and demographics, 2) reduced prey availability, 3) contaminants, 4) physical disturbance, 5) acoustic disturbance, and 6) critical habitat, will complete the action plan within two years from the acceptance of the recovery strategy by the competent minister. Sub-committees within the RIGS, such as those examining prey availability and acoustic disturbance, may be necessary due to the complex nature of these issues.

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APPENDIX I - Glossary

Abiotic:	Non-living factors in the environment (e.g. water, air, rocks)
Allee effect:	The reduced likelihood of finding a mate when population numbers are low
Anthropogenic:	Caused or produced by humans
Bioaccumulation:	The process by which (toxic) substances from prey and the environment crease over time in concentration in living organisms.
Biotic:	Living components of the environment (e.g. fish, plankton)
Biotoxin:	Toxin produced by a living organism
dB (decibel):	A unit for measuring the relative intensity of a sound. In this document the sources of sounds are consistently referenced to 1 µPa at 1 m. The sounds that marine mammals hear (received level) depend on their distance from the source of the sound.
Depensation:	When a decline in population numbers leads to reduced survival (due to increased mortality) or reduced reproduction (due to the Allee effect)
Ecotype:	A population that is genetically different from other populations of the same species
Lipophilic:	A substance that dissolves more easily in lipids (fats) than water. Chemicals that are lipophilic tend to bioaccumulate
Matriline:	A female killer whale and all of her descendents
Mediastinal:	Part of the thoracic cavity between the lungs that contains the heart, aorta, esophagus, trachea and thymus
Odontocete:	Toothed whales, dolphins and porpoises
Systemic mycoses:	Fungal infection that affects the whole body
µPa (micro Pascal):	A unit of acoustic pressure
Sympatric:	Closely related populations or ecotypes that overlap in their range but do not interbreed

Contaminant Acronyms

APEs:	Alkylphenol ethoxylates
DBT:	Dibutyltin
DDT:	Dichlorodiphenyl trichloroethane
PAH:	Persistent aromatic hydrocarbons
PBDE:	Polybrominated diphenylethers

PCBs:	Polychlorinated biphenyls
PCDDs:	Dioxins, polychlorinated dibenzo-*p*-dioxins
PCDFs furans:	Polychlorinated dibenzofurans
PCNs:	Polychlorinated napthalenes
PCPs:	Polychlorinated paraffins
PCTs:	Polychlorinated terphenyls
PFOs:	Perfluoro-octane sulfonate
POPs:	Persistent organic pollutants
TBT:	Tributyltin

APPENDIX II – Membership List:

Resident Killer Whale Recovery Team Members:

Marilyn Joyce	Co-Chair: Killer Whale Recovery Team Fisheries & Oceans Canada, Fisheries Management Branch Pacific Region, 200-401 Burrard Street, Vancouver, B.C., V6C 3S4, phone: 604-666-9965, email: joycema@pac.dfo-mpo.gc.ca
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Ken Balcomb	Centre for Whale Research, WA
Jim Borrowman	North Island Whale Watching Community, BC
John Durban	National Marine Fisheries Service, Alaska Fisheries Science Centre, National Marine Mammal Laboratory, WA
Graeme Ellis	Fisheries & Oceans Canada, Science Branch, Conservation Biology Section, BC
John Ford	Fisheries & Oceans Canada, Science Branch, Conservation Biology Section, BC
Christine Garrett	Environment Canada, Environmental Protection Branch, Commercial Chemicals Division , BC
Anna Hall	Whale Watch Operators Association North West, BC
Steve Jeffries	Washington Department of Fish and Wildlife, Marine Mammal Investigations, WA
Linda Jones	National Marine Fisheries Service, Northwest Fisheries Science Centre, National Marine Mammal Laboratory, WA
Brent Norberg	National Marine Fisheries Service, Protected Resources Division, WA
Peter Olesiuk	Fisheries & Oceans Canada, Science Branch, Conservation Biology Section, BC
Rich Osborne	The Whale Museum, WA
Rob Paynter	Ministry of Sustainable Resource Management, BC

Brian Reader	Western Canada Service Centre, Parks Canada Agency, BC
Peter Ross	Fisheries and Oceans Canada, Marine Environmental Quality Section, BC
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RESOURCE PERSONNEL:

Paul Cottrell	Fisheries & Oceans Canada, A/SARA First Nations Coordinator, Treaty & Aboriginal Policy Branch, BC
Carole Eros	Fisheries & Oceans Canada, Species at Risk Recovery Planning Coordinator, Resource Management Pacific Region, BC
Annely Greene	Fisheries & Oceans Canada, Marine Mammal Program Manager, Resource Management Pacific Region, BC
Kathy Heise	Department of Zoology, University of British Columbia, BC
Lara Sloan	Fisheries & Oceans Canada, Communications Officer, Fisheries Management Pacific Region, BC