Status of Killer Whales, *Orcinus orca*, in Canada*

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Killer Whales can be found in all three of Canada's oceans, as well as occasionally in Hudson Bay and in the Gulf of St. Lawrence. Little is known about their occurrence or biology in the Atlantic or Arctic, but Killer Whales appear to be uncommon in most parts of these areas. In the Canadian Arctic and western Atlantic small numbers were killed historically in commercial whaling operations (or shot incidentally to such operations), and small numbers have been documented taken by natives. Predictable concentrations of killer whales are found in British Columbia, and populations in British Columbia's nearshore waters are among the most well-known populations of cetaceans world-wide. Killer whales off the Pacific coast can be classified into two distinct "types" or "forms" (termed *residents* and *transients*), which differ in diet (*residents* feed on fish, *transients* feed on marine mammals), morphology, genetics and behaviour. The exact taxonomic relationship between these two types is unclear, though some authors have termed them "races", others consider them separate species. Regardless, from both a scientific and management perspective these populations should be treated as distinct. Within British Columbia waters *residents* appears to be sub-divided into three geographic communities or populations (termed the "northern" and "southern" *residents*, and "offshore" killer whales), based on association patterns, genetics and morphology. Relatively little is known of the "offshore" population of Killer Whales. All populations (including *transients* and the three *resident* populations) are small (in the low hundreds), and have low potential rates of increase. No trend information is available for "offshore" or *transient* killer whales. The "northern" *resident* population has been growing steadily in size since the 1970s (when live-capture fisheries stopped and shooting declined), while the "southern" *resident* population has been growing only sporadically, and is currently smaller than the pre-live-capture population estimate from the 1960s. Given the small population sizes and their low potential rates of growth, Killer Whales are potentially at risk from anthropogenic influences in two primary ways: due to immunotoxic affects of persistent toxic chemicals (levels in "southern" *residents* are three times higher than levels known to cause immunotoxicity in harbour seals), and due to a reduction in prey availability. It is also possible that the large and growing commercial and recreational whale watching industry on the west coast may be having an impact, though such impacts are as yet unclear. In terms of natural factors, periodic events such as mass strandings or entrapments in narrow inlets or ice have the potential to drastically reduce local populations. Since virtually all of these factors should impact Killer Whales throughout Canadian waters, all populations, at the least, should be considered vulnerable, that is, as "species of special concern because of characteristics which make them especially sensitive to human activities or natural events". As the "southern" *resident* population is extremely small (89 individuals in 1998), has declined by 10% in the last three years due to an increase in mortality rates (primarily of adult females), is more subject to anthropogenic influences than other populations, and these influences are not expected to decrease in the foreseeable future, it should be listed as threatened by COSEWIC. Further research, particularly on Arctic, Atlantic and "offshore" populations, is clearly needed.

Key Words: Killer Whale, *Orcinus orca*, Epaulard, Canada, British Columbia, status, cetacean, sympatric populations.

The Killer Whale or épaulard, *Orcinus orca* (Linnaeus 1758) is found in all three of Canada's oceans (Figure 1). In the Pacific they are the most well-known cetacean both to the scientific community and to the general public. In fact, off the British Columbia coast long-term studies of Killer Whales have led to a greater understanding of these animals than of almost any other species of cetacean (Baird 2000). In the Canadian Arctic and Atlantic, Killer Whales are seen only occasionally and no in-depth scientific studies have been undertaken. Yet, because of their relatively large size, distinctive appearance, and the publicity this species has garnered in books, magazine articles, television, and in aquaria, Killer Whales are known by and recognizable by virtually everyone. In this report I review what is known of the general biology and ecology of Killer Whales in Canadian waters, including population discrimination, sizes and trends, behaviour, life history and limiting factors. Gaps in the available data are identified that may be relevant to their long-term status assessment. This review has been undertaken on behalf of the Fish and Marine Mammal Subcommittee of COSEWIC, the Committee on the Status of Endangered Wildlife in Canada.

*Reviewed and approved by COSEWIC, April 1999 — status assigned North Pacific "resident populations" Threatened, North Pacific "transient" populations Vulnerable, North Atlantic and Arctic populations Indeterminate.

Status reviewed again by COSEWIC, November 2001 — status assigned "southern resident" population Endangered, "northern resident" population Threatened, NE Pacific offshore population special concern, Northwest Atlantic (Eastern Arctic populations Data Deficient).

FIGURE 1. Map showing world-wide distribution of Killer Whales. Shaded areas indicate records of sightings or strandings; however unshaded areas may be part of the normal range with no sightings documented. Map courtesy of Marilyn Dahlheim, National Marine Mammal Laboratory, NMFS, Seattle.

Description

The distinctive black and white pattern, blunt head, and tall dorsal fin in the middle of the back, are the primary identifying characteristics of Killer Whales (Figure 2). Adult males are substantially larger than females, although very few accurate measurements are available. Reports of maximum lengths of 9.75 m for males and 8.53 m for females given in the literature (e.g., Perrin and Reilly 1984) are actually estimates. The maximum length measured for males and females is 9.0 m and 7.7 m, respectively (Heyning and Brownell 1990). There is some suggestion of differences in size for individuals from different populations (cf. Berzin and Vladimirov 1983; Heyning and Brownell 1990), and more accurate measurements from different parts of their range are needed before average lengths of individuals from any one population can be characterized. From the few measurements available for adult individuals from British Columbia (e.g., Bigg and Wolman 1975), it is clear that the average length of adult individuals is much smaller than the maxima noted above. Adults are sexual dimorphic in appendage size, with adult males having a tall triangular dorsal fin which may reach up to 1.8 m in height, while in juvenile males and adult females it reaches 0.9 m or less and is generally more falcate (Figure 3). Pectoral fins and tail flukes are also sexually dimorphic, being much larger in adult males, with the fluke tips also bending downwards. As well, pigmentation in the genital area differs between males and females (Bigg et al. 1987).

FIGURE 2. An adult female *transient* Killer Whale porpoising off Victoria, British Columbia, showing the main features for identification; the striking black and white colouration, a blunt head and a tall, centrally-placed dorsal fin. Photo© by the author.

Population Discrimination

The question of population segregation or division (fragmentation) is critical to any evaluation of status (IUCN 1996). If more than one distinct population exists, and factors which affect each population differ in any way, then each population must be monitored and managed independently.

"Residents" and "Transients"

In the case of Killer Whales in the Canadian Arctic and North Atlantic, no information is available to assess whether any population differentiation has occurred (Mitchell and Reeves 1988; Anonymous 1993). For the Pacific coast of Canada, clear evidence is available for differentiation of Killer Whales into two distinct "types" or "forms", termed "resident" and "transient" (Table 1; Figure 4; Bigg et al. 1976). The names "resident" and "transient" have become entrenched in the literature even though it has been demonstrated that they are not accurate as descriptions of the site fidelity and movement patterns of the two forms (Guinet 1990; Baird et al. 1992). As the names are frequently mis-interpreted as descriptive categorizations, they are referred to

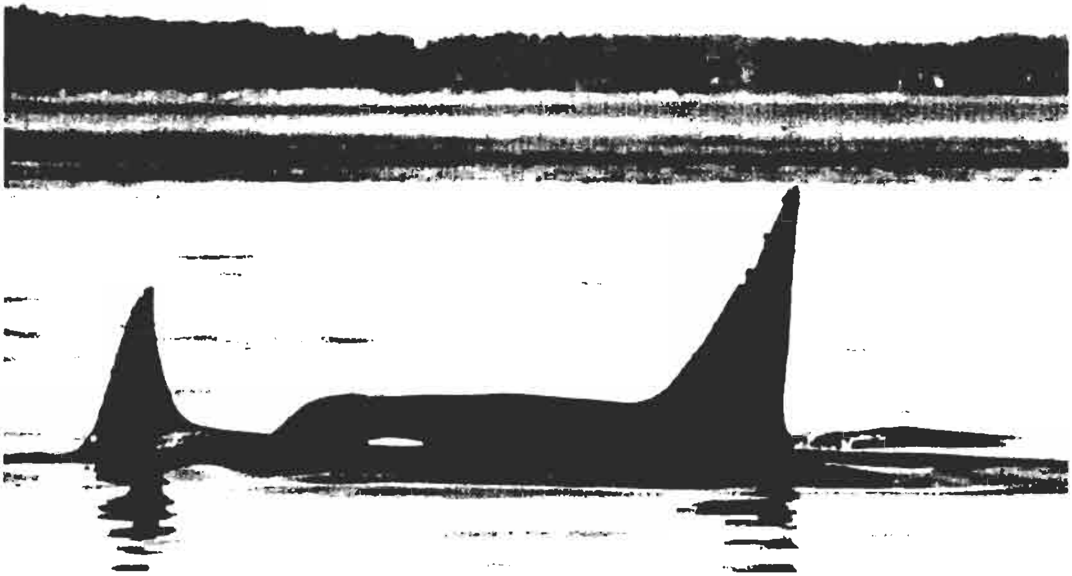

FIGURE 3. Photograph of two *transient* Killer Whales off Victoria, British Columbia, showing the clear sexual-size dimorphism, with the male (right) having a tall, straight dorsal fin and the female (left) having a shorter, falcate, dorsal fin. Photo© by the author.

hereafter as *resident* and *transient* to try to prevent such confusion.

Several studies have documented a variety of behavioural, ecological, morphological and genetic differences between *transients* and *residents* (Table 1; Bigg et al. 1987; Baird and Stacey 1988; Morton 1990; Baird et al. 1992; Baird and Dill 1995, 1996; Barrett-Lennard et al. 1996; Hoelzel et al. 1998; Matkin et al. 1998; Ford et al. 1998). One of the most important differences is diet; *residents* appear to feed almost entirely on fish, while *transients* appear to feed almost entirely on marine mammals (for more detailed discussion, see Feeding Habits, below). Association patterns, in terms of observations of individuals traveling together in a group, and vocal dialects, are also used to discriminate *residents* from *transients* (Black et al. 1997). Interactions between *residents* and *transients* have only been reported on a small number of occasions (Jacobsen 1990; Morton 1990; Barrett-Lennard 1992; Baird

TABLE 1. Characteristics which differ between *resident* and *transient*-type Killer Whales in the nearshore waters of the eastern North Pacific.

MORPHOLOGY/GENETICS
Shape of the dorsal fin (Bigg et al. 1987; Bain 1989)
Saddle patch pigmentation (Baird and Stacey 1988)
Possibly eye patch pigmentation (D. Ellifrit, personal communication, cited in Baird 1994)
Mitochondrial and nuclear DNA (Stevens et al. 1989; Hoelzel and Dover 1991; Hoelzel et al. 1998; Matkin et al. 1998)
BEHAVIOUR/ECOLOGY
Diet (Bigg et al. 1987; Morton 1990; Baird and Dill 1996; Ford et al. 1998)
Travel patterns/habitat use (Heimlich-Boran 1988; Morton 1990; Baird and Dill 1995)
Respiration patterns (Morton 1990)
Vocalizations (Ford and Hubbard-Morton 1990; Morton 1990)
Echolocation (Barrett-Lennard et al. 1996)
Amplitude of exhalations (Baird et al. 1992; Baird 1994)
Possibly diving patterns (Baird 1994)
Group size (Bigg et al. 1987; Morton 1990; Baird and Dill 1996)
Pattern and extent of natal philopatry (Bigg et al. 1987; Baird and Dill 1996; Baird and Whitehead 2000)
Seasonal occurrence (Guinet 1990; Morton 1990; Baird and Dill 1995)
Geographic range (Bigg et al. 1987)

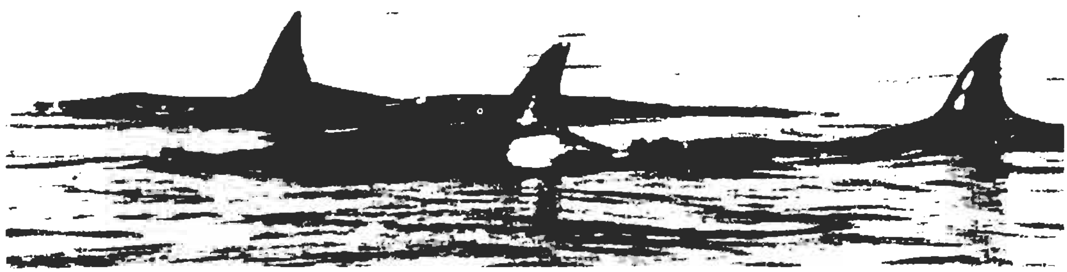

FIGURE 4. Morphological differences between *residents* (left) and *transients* (right) include differences in dorsal fin shape (with *residents* typically having more rounded fins) and saddle patch pigmentation patterns (with *transients* typically having less complex patterns). Overlap in the characteristics exist, so they cannot always be used to distinguish type. Photos© by the author.

and Dill 1995). On eight of those occasions no change was recorded in the behaviour of either form as they passed within a couple of kilometers of each other. *Transients* have been seen changing direction away from *residents* (avoiding them) on eight occasions, *residents* avoiding *transients* twice, and both avoiding each other twice. Since *residents* vocalize more frequently than *transients* (Morton 1990; Barrett-Lennard et al. 1996), *transients* may detect the presence of *residents* much sooner, and more frequently than the other way around (Baird and Dill 1995). Cases of *residents* showing no reaction when near *transients* may be due simply to them being unaware that *transients* were nearby. One observations of aggression between the two forms involved a large group of *residents* attacking a small group of *transients* (Ford and Ellis 1999), and one other observation of apparent aggression has also been observed (P. Spong, H. Symonds, personal communications).

The exact taxonomic relationship of these two forms is unclear. Bigg et al. (1987) termed these two types of Killer Whales "races", and this term has been adopted, uncritically, by many investigators. "Races" are usually defined in a geographic sense, implying geographically isolated populations which are typically given subspecific designation (Mayr and Ashlock 1991). Baird et al. (1992) outlined how these two forms may have evolved, and termed them incipient species. Baird (1994) subsequently argued that they should be considered separate species, although no formal description of each species has been presented. Heyning and Dahlheim (1993) have argued that insufficient information is available to determine the level of isolation between them. Hoelzel (personal communication) estimated genetic migration between these two forms at one male per five generations and one female per 20 generations (see Hoelzel et al. 1998).

Regardless of such disagreements and uncertainty in taxonomic relationship between these two forms, there is sufficient evidence to suggest that these forms or types should be treated as separate populations for management. Considering the differences in behaviour and ecology which have been documented (e.g., Table 1), it is also prudent not to apply behavioural or life history characters from one form to another, nor indeed from these populations of Killer Whales to Killer Whales elsewhere.

The suggestion that there may be more than one species in the genus *Orcinus* is not new. Mikhalev et al. (1981) and Berzin and Vladimirov (1983) described two species in the Southern Ocean, *O. nanus* and *O. glacialis*, respectively, both of which seem to refer to the same population of smaller individuals (Heyning and Dahlheim 1988). As well as differences in body size, other differences in morphology, behaviour and diet were noted, with one species feeding primarily on fish and the other feeding primarily on marine mammals, similar to the situation off Canada's west coast (Berzin and Vladimirov 1983). Neither of these species designations have been generally accepted (Perrin 1982; Heyning and Dahlheim 1988).

"Southern", "Northern" and "Offshore" Residents

A further level of population differentiation appears to exist within the *resident* form. Based on association patterns, pigmentation patterns and genetics, *residents* within British Columbia appear to be divided into three distinct, largely geographically based communities or populations (Bigg et al. 1987; Baird and Stacey 1988; Bain 1989; Ford et al. 1994a; Hoelzel et al. 1998; Matkin et al. 1998). One population, found generally around southern Vancouver Island and in Washington state, has been termed the "southern" *resident* community, one found generally off northern Vancouver Island and in southeast Alaska has been termed the "northern" *resident* community, and a third putative *resident* population is termed "offshore" Killer Whales, which appear to inhabit offshore waters along the entire coast. It should be noted that while based on mitochondrial DNA "offshore" Killer Whales are closely related to northern and southern *residents* (Hoelzel et al. 1998; Matkin et al. 1998), relatively little is known about other aspects of their biology, and it is unclear whether "offshore" Killer Whales share behavioural or ecological characteristics with northern or southern *residents*. British Columbia northern *residents* have been observed associating, and share the same mitochondrial DNA haplotype, with other *resident*-type Killer Whales in southeast Alaska (Dahlheim et al. 1997; Hoelzel et al. 1998). The *resident*-type whales from Alaska have not been documented in British Columbia, but based on both association patterns and genetics are likely part of the same population. These southeastern Alaska *residents* have in turn been observed interacting with *residents* in Prince William Sound, Alaska (Matkin et al. 1997), suggesting that gene-flow between northern *residents* and these other whales may exist. Similarly, both "offshore" Killer Whales and *transients* documented in British Columbia have also been seen off Alaska, Washington and/or California (Dahlheim et al. 1997; Black et al. 1997), suggesting that these individuals are part of larger populations. The U.S. National Marine Fisheries Service evaluates each of the *resident* populations, and the *transient* population, independently (Barlow et al. 1997; Hill et al. 1997).

The northern and southern *resident* communities have been reported to have ranges which do not overlap (e.g. Bigg et al. 1990; Felleman et al. 1991), but there are data which indicate their ranges overlap by over 120 km on both the east and west coasts of Vancouver Island (Bigg et al. 1976; M. A. Bigg, personal communication 1990; Ford et al. 1994a). "Offshore" Killer Whales similarly overlap in range with both northern and southern *residents*, though observations of "offshore" Killer Whales in or near the core areas of the other two groups are rare (e.g., Walters et al. 1992; Ford et al. 1994b*). Regardless, behavioural interactions have not been observed between individuals from northern, southern and "offshore" *resident* communities, and differences in mitochondrial DNA and physical appearance suggest the communities are reproductively isolated (Baird and Stacey 1988; Stevens et al. 1989; Hoelzel and Dover 1991; Walters et al. 1992; Ford et al. 1994a; Hoelzel et al. 1998; Matkin et al. 1998). The northern and southern *resident* communities also appears to have distinct behavioural characteristics (Osborne 1986; Hoyt 1990); whether "offshore" Killer Whales exhibit such distinctive behavioural characteristics is unknown, simply due to the relative paucity of work that has been undertaken on that population. Regions identified as high use areas ("core areas") for northern and southern *residents* are separated by about 400 km (two and a half days of travel at 3.5 knots — Bigg 1982).

Distribution and Movements

Killer Whales are cosmopolitan, having been observed in all oceans of the world (Leatherwood and Dahlheim 1978; Dahlheim and Heyning 1998). However, concentrations generally occur in colder regions and in areas of high productivity (Bigg et al. 1987; Heyning and Dahlheim 1988; Guinet and Jouventin 1990). In polar areas the occurrence of Killer Whales is thought to be limited by the presence of pack ice in winter months (Reeves and Mitchell 1988a), thus some north-south movements would have to occur in such areas. A recent sighting by Gill and Thiele (1997) of Killer Whales deep in Antarctic sea ice in winter indicates that not all individuals move away from the poles. Gill and Thiele (1997) suggest that the extreme seasonal differences in the number of observers in polar regions could be party responsible for the perception that Killer Whales do migrate. In general, no clear evidence of seasonal north-south migrations is available. In the southern hemisphere, based on sightings from whaling vessels, Mikhalev et al. (1981) described seasonal migrations from low-latitude areas in the winter months to higher latitude areas in summer. However, no information was presented on potential seasonal biases in effort, so it is difficult to judge the validity of such conclusions (Perrin 1982).

Within British Columbia, Killer Whales have been documented throughout virtually all salt-water (and some-fresh water) regions, including many long inlets, narrow channels and deep embayments. Both *resident* and *transient* Killer Whales have been recorded year-round in British Columbia. Presence of *resident* Killer Whales seems to be closely tied with peak abundance of various species of salmon, one of their primary prey (Heimlich-Boran 1986; Bigg et al. 1987; Nichol and Shackleton 1996). Several authors have suggested that *residents* are rare in the core study areas of Johnstone Strait and Haro Strait during winter months. However, in both areas one pod (A5 in Johnstone Strait, J1 in Haro Strait) is recorded during most winter months (D. Ellifrit, P. Spong, H. Symonds, personal communications). Broad scale shifts in distribution are apparent, though they are more conclusive for northern *residents* than southern *residents*, since there are two year-round land-based research projects being undertaken in or near the core area for northern *residents* (Morton 1990; P. Spong, H. Symonds, personal communications). There are several seasonal biases in effort which should be taken into account in terms of the seasonal distribution of southern *residents*, and the seasonal distribution of northern *residents* outside of the core area of Johnstone Strait. Inclement weather conditions and low daylight hours during winter months likely decrease the probability of visually detecting Killer Whales when they are present, and little winter work has ever been undertaken. Some evidence is available to suggest that northern *residents* decrease their frequency of vocalizing during winter months (Bain personal communication); this may confound examinations of winter occurrence using this method. Similarly, southern *residents* appear to travel further from shore during winter months (Baird unpublished; D. Ellifrit, personal communication), biasing detection based on shore-based observations. As such, more thorough examinations of seasonal movements (perhaps using satellite telemetry) and winter habitat use are warranted.

Seasonal influxes of Killer Whales into near-shore areas where pinnipeds are abundant have been noted at Marion Island, the Crozet Archipelago, and Punta Norte, Argentina (Condy et al. 1978; Guinet 1992; Hoelzel 1991). Baird and Dill (1995) showed that a strong seasonal peak in occurrence of *transient* Killer Whales in southern British Columbia coincided with the period when harbour seal pups were being weaned. However, only some pods appeared to preferentially use the area during that time, while others were seen regularly year-round (Baird and Dill 1995). Those pods which used the area year-round also tended to travel further from shore, where land-based observers or spotters were less likely to detect them. Because of this seasonal difference in use of near-shore areas, Baird and Dill (1995) and Baird (1995a) suggested that many studies which are shore-based may be biased when examining seasonal presence.

Killer Whales have been documented moving long distances, with some individual *transients* and "offshore" Killer Whales identified both in central California and southeastern Alaska, a 2660 km one-way distance (Goley and Straley 1994; Black et al. 1997). Actual home range sizes are unknown, since virtually no photo-identification work has been done in offshore areas (though see Black et al. 1997), and no animals have been satellite-tagged. Using the northern- and southern-most sightings of particular individuals, combined with the limited knowledge of onshore-offshore movements, the largest documented range for a *transient* in British Columbia is 140 000 km^2, while the largest documented range for a *resident* is approximately 90 000 km^2 (Baird 2000). Both *residents* and *transients* have been documented to move up to 160 km in one 24 hour period, but pods of both types also spend extended periods in small areas.

A comprehensive review of all records available for Killer Whales in the eastern Canadian Arctic and the western North Atlantic was last undertaken in the 1980s (see papers in Sigurjonsson and Leatherwood 1988). Sergeant and Fisher (1957) stated that Killer Whales migrated northwards in the spring along the coasts of Labrador and Newfoundland, though a more comprehensive review by Mitchell and Reeves (1988) concluded that biases in effort precluded the determination of any obvious pattern of distribution or movements. Killer Whales are occasionally recorded in virtually all areas off eastern Canada, including Nova Scotia (Katona et al. 1988), in the Gulf of St. Lawrence (Wenzel and Sears 1988), off Newfoundland and Labrador (Lien et al. 1988), and in Hudson Bay and the Canadian Arctic (Reeves and Mitchell 1988a), with one record from 81°N. Records from these compilations end in the early 1980s, thus another review incorporating more recent records is warranted. Based largely on records collected since the earlier review, it appears that there are only a couple of areas where Killer Whales appear to be somewhat regular in their occurrence. These include the Mingan Islands, Quebec, where R. Sears (Mingan Island Cetacean Study, personal communication) has observed the same small group of whales a number of times since 1984 (see Wenzel and Sears 1988), the western end of the Strait of Belle Isle (R. Sears, personal communication), off Battle Harbour, Labrador (S. Todd, College of the Atlantic, personal communication), and around Pond Inlet, Cumberland Sound, and the Lancaster Sound region, where regular, and possible annual visitation has been noted (Reeves and Mitchell 1988a). In the western Canadian Arctic, some published distribution maps show the presence of Killer Whales (Jefferson et al. 1991; Dahlheim and Heyning 1998; Figure 1) in the Canadian side of the Beaufort Sea. According to two sources (T. Barry, L. Harwood, personal communications), native elders recall sightings of Killer Whales in the area in the 1940s or 1950s, however numerous researchers who have undertaken surveys there in the last thirty years have never seen this species (M. Fraker, L. Harwood, D. Ljungblad, S. Moore, W. J. Richardson, personal communications). Any Killer Whales which do travel into the Canadian Beaufort Sea are likely part of the Bering Sea population (Dahlheim 1997).

Protection

Two factors are important in the legal protection of a species, the system that is in place to prohibit or regulate hunts or other threats, and the system for monitoring and enforcing regulations. Where information is available, each of these is discussed below.

International

Two international management measures/agencies are relevant to the protection of Killer Whales, CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1973) and the IWC (International Whaling Commission).

All species of cetaceans are listed by CITES under one of two appendices. Appendix I includes species threatened with extinction (and which may be affected by trade), while Appendix II includes species which may become threatened with extinction unless trade is regulated, as well as species which must be subject to regulation in order that trade in threatened species of similar appearance may be controlled (Klinowska 1991). Killer Whales (and all species of cetaceans not listed under Appendix I) are listed under Appendix II for the latter of the above reasons. As such, international trade of Killer Whales or parts thereof by any countries which are Parties to CITES requires export permits from the country of origin. According to Klinowska (1991) the European Community treats all cetaceans as if they were listed in CITES Appendix I — thus trade requires permits from both exporting and importing countries and such trade must not be primarily for commercial purposes. Some other countries (e.g., USA) also have similar domestic rules, requiring both export and import permits for Appendix II species. As of October 1998 there were 144 Parties to CITES, leaving approximately 90 countries world-wide which were not members (CITES Secretariat statistics). This latter group includes Iceland, which has been actively involved in trade (see Limiting Factors below). Listing on CITES Appendix II does not provide protection *per se*, though it does mandate recording of international trade. In recent years, the only international trade of Killer Whales documented through CITES has been in small numbers of live animals between aquaria, a few scientific samples, and small numbers of teeth and carvings. Trade in teeth and carvings have primarily involved the transfer of these items between Greenland (a dependency of Denmark) and Denmark (CITES Secretariat statistics). Although all trade in Appendix II species from a CITES member should be documented, during a recent review of all Killer Whales kept in captivity (Hoyt 1992), E. Hoyt (personal communication) noted that some trade involving CITES countries had not been reported.

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

National

Canada: Within Canada, management of Killer Whales has varied considerably over time, and both the federal government and one provincial government (British Columbia) have been involved in management activities. Prior to 1970 no laws were in place to control or regulate captures or other interactions. Hoyt (1992) notes that news reports of deaths during captures and the out-of-country destinations of captured Killer Whales in the 1960s prompted wide-spread public pressure for the implementation of protective legislation. Such legislation was first introduced in 1970. Prior to 1982, Killer Whales were considered "wildlife" by the British Columbia provincial government's Wildlife Branch, and possession permits could be issued for holding these animals in captivity. In 1982 the provincial Wildlife Branch re-wrote the "Wildlife Act", and deleted Killer Whales from the list of wildlife, in response to a federal move to include all cetaceans under the "Cetacean Protection Regulations" (under the Fisheries Act of Canada of 1867). These regulations prohibited "hunting" without a license. "Hunting" was defined as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner". No scheme, however, was in place to enforce such regulations, and aboriginal hunting could be undertaken without a license. In 1993, the federal government consolidated various marine mammal regulations, including the Cetacean Protection Regulations, under the new "Marine Mammal Regulations". These regulations stated that "no person should disturb a marine mammal except when under.... the authorities of these regulations", with "marine mammal" defined as all species listed under a particular appendix. However, many species of cetaceans, including Killer Whales, were not listed under that appendix, and thus no legal protection appears to have been in place. The definition of "marine mammal" was revoked in 1994, thus extending coverage to all species of marine mammals. Currently, hunting of Killer Whales can occur if a "Fishing License" is obtained (except for Aboriginals who can hunt without a license), but fees for such licenses are low ($5). However, no such licenses have been issued, and issuance is at the discretion of the federal Minister of Fisheries and Oceans. It is unlikely any would be issued in areas such as British Columbia, due to widespread public interest in these animals.

In terms of minimizing negative interactions between boats and Killer Whales, "whale watching guidelines" have been produced and disseminated by the Department of Fisheries and Oceans. There are also several ongoing efforts of self-regulation by the commercial whale watching industry in British Columbia, involving the production of guidelines and codes of conduct (Baird et al. 1998b). Among commercial operations in certain specific areas, the levels of awareness of and adherence to these guidelines is fairly high, though awareness and adherence by general members of the public (which make up the majority of boats with whales in some areas – see Figure 5) is currently unknown. As with the Cetacean Protection Regulations, virtually no official monitoring or enforcement activities take place, and enforcement itself is complicated by the difficulty in defining and measuring "harassment" in the field (see Limiting Factors, below). N. Bhaloo (DFO Conservation and Protection, Enforcement Unit, personal communication) notes that no violations of the Marine Mammal Regulations involving Killer Whales have been documented between 1993 and 1997, although there is one charge of harassment, involving a sports fishing operation outside of either of the two core areas for *residents*, pending from 1998 (E. Lochbaum, DFO, personal communication).

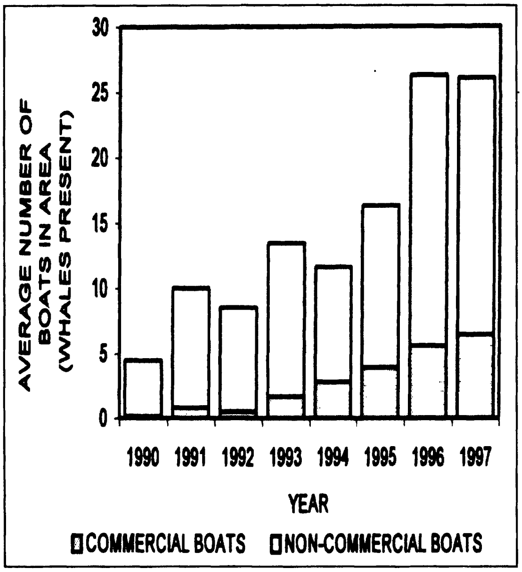

FIGURE 5. Trend in the average number of boats (both commercial whale watching operations and total boats) with southern *resident* Killer Whales as they pass the Lime Kiln Lighthouse on San Juan Island, Washington state, from 1990 through 1997. Data were collected from mid-May through mid-August each year, seven days per week, from 0900 till 1700 h. No such increasing trend was apparent when no whales were present. Data from R. Otis (see Baird et al. 1998b).

The 1997 Oceans Act provides for the establishment of marine protected areas (MPAs) in federal waters. One of the specific justifications listed for establishing MPAs is to conserve and protect marine mammals and their habitats. However, as with other federal legislation regarding marine mammals, establishment of marine protected areas and exclusion of activities which might jeopardize Killer Whales or other marine mammals are up to the discretion of the Minister of Fisheries and Oceans, rather than mandated. Regardless, there are general concerns about the efficacy of using MPAs to "protect" cetaceans (see below, as well as Phillips 1996; Whitehead et al. 2000), due primarily to the large range of most species and the lack of boundaries in the marine environment. Whitehead et al. (2000) note that most marine protected areas have provided little or no change in the level of threats faced by cetaceans in an area.

One example of an MPA specifically created to "protect" Killer Whales is the Robson Bight/Michael Bigg Ecological Reserve, a provincial designation in a core area for northern *residents*. This designation provides some protection to the shoreline habitat and limits human access by land. Its main relevance to Killer Whales is the protection of the terrestrial portion of several "rubbing beaches" which are regularly used by northern *residents*. However, its validity as a "whale sanctuary" has been questioned. Duffus and Dearden (1992) state that this designation "holds a fairly limited potential to protect a marine area", since it is the federal government that has jurisdiction over marine shipping and marine fisheries, and this is a provincial designation. They also note that the "boundary is highly permeable, and buffers of outside impacts are almost non-existent" (Duffus and Dearden 1992). They warn against the "fallacy of tokenism — that is, giving the public the appearance of protecting an important whale habitat, when neither the importance of the site to the whales, nor the veracity of the protection is established — creat[ing] a political "success" that may mask an ecological failure" (Duffus and Dearden 1992). Other than this effort by the British Columbia provincial government, no other province or territory within Canada has legislated protection for this species.

Other Countries: Considering that Killer Whales regularly move between Canada and other countries (the U.S. on both coasts and almost certainly Greenland, see Heide-Jorgensen 1988, 1993; Mitchell and Reeves 1988), protection measures in these countries are directly relevant to the conservation of Killer Whales in Canada. In the United States, all cetaceans are protected through the Marine Mammal Protection Act of 1972, as well as through the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of the Fisherman's Protective Act. These regulations allow for observers on fisheries that have a high probability of killing marine mammals, and also provide for limited monitoring and enforcement activities regarding boat/whale interactions. There are no management measures in Greenland that provide protection for Killer Whales, and kills in that area (see Limiting Factors, below) could affect Canadian populations.

Population Sizes and Trends

No world-wide population estimates are available. Regional population estimates, where available, have been derived through photo-identification surveys and/or line-transect surveys. Line-transect surveys have generally been used in areas where more intensive photo-identification studies are impractical (e.g., the Southern Ocean), but are also accompanied by large confidence limits (see e.g., Matkin and Saulitis 1994). Furthermore line-transect surveys do not allow for discrimination of individuals from sympatric populations.

In British Columbia, four separate populations must be considered, *transients*, "northern" and "southern" *residents*, and "offshore" Killer Whales (which should probably be considered "offshore" *residents*, see discussion above). The most detailed information is available for northern and southern *residents*, as all of the southern *resident* pods and many of the northern *resident* pods are censused each year. As all individuals are recognizable, the census provides an actual count of the number of individuals in the population. As of 1998, the southern *resident* population numbered 89 individuals (van Ginneken and Ellifrit 1998). While the population has grown since the cessation of the live-capture fishery in 1973, the current population is smaller than the population near the start of that fishery (Figure 6), and has declined for the last three years (1996–1998). Such a decline is not unprecedented (Olesiuk et al. 1990; Figure 6); since the cessation of the live-capture fishery the population showed a similar decline from 1980 through 1984. As discussed under Limiting Factors (below), this earlier decline was likely due in part to the removal of animals in the live-capture fishery (Olesiuk et al. 1990). The most recent decline appears to have resulted from an increased death rate. Using data presented by van Ginneken and Ellifrit (1998), the average per capita death rate between the years 1995 to 1998 (mean of 0.052) is significantly higher (Mann-Whitney U-test, $p = 0.0084$) than the average for the preceding 19 years (mean of 0.021 from 1976 through 1994). The per capita birth rate for this same period (mean of 0.034) is similar to the average for the previous 19 years (mean of 0.038). In the period from 1995 to 1998, age-specific mortality rates for mature females between 35 and 65 years of age are four to five times higher than reported by Olesiuk et al. (1990; see Table 2). It is unclear however whether this current population decline may be due to demographic stochasticity, or even perhaps delayed effects of the removal of animals in the live-capture fishery, and a study modeling the probability of such effects occurring by chance or due to selective removals is warranted.

As of 1993 the number of northern *residents* thought to occupy British Columbia waters (if only seasonally) numbered approximately 200 individuals (Ford et al. 1994a). More recent surveys have been undertaken, but the Department of Fisheries and Oceans, Pacific Region, which undertakes these surveys, has not released current data. This "population" has been growing at a relatively stable rate since the 1960s (Oleisuk et al. 1990; Ford et al. 1994a). Because of the associations and shared mtDNA haplotypes with *residents* in Alaska, the effective population size for northern *residents* should probably be considered larger than the absolute number recorded within British Columbia waters, and the overall trend in the larger population is unknown (since less complete information is available for Alaskan *residents*). Population estimates for several regions of Alaska are available and are summarized by Matkin and Saulitis (1994). Taking into account only those whales documented in British Columbia, there was no evidence of density-dependent effects as of the late 1980s (Meyers 1990), but data collected since then have not yet been examined. Brault and Caswell (1993) examined pod-specific demography of *residents*, and concluded that most of the variance in individual pod growth rates was due to variance in adult reproductive output, rather than effects of pod size or structure.

Population size is not known for "offshore" Killer Whales. The first "offshore" Killer Whales groups were encountered in the mid-1980s, and about 200 "offshore" Killer Whales had been documented as of 1993 (Ford et al. 1994a). These whales have been identified over a relatively short period of time, thus while natural mortality should only have accounted for a few deaths, new individuals are being regularly documented (Walters et al. 1992; Ford et al. 1994a). Of 56 "offshore"-type whales documented off California, 23 were direct matches with "offshore" Killer Whales recorded off Oregon, Washington, British Columbia and southeast Alaska (Black et al. 1997). No trend information is available for this population.

For *transient* Killer Whales, the total population size is unknown but probably numbers in the low hundreds. Seventy-nine *transients* had been photo-identified in British Columbia and Washington up to 1986 (Bigg et al. 1987), and a further 90 or more have been documented in the 10 years since (Ford et al. 1994a). Considering their wide-ranging move-

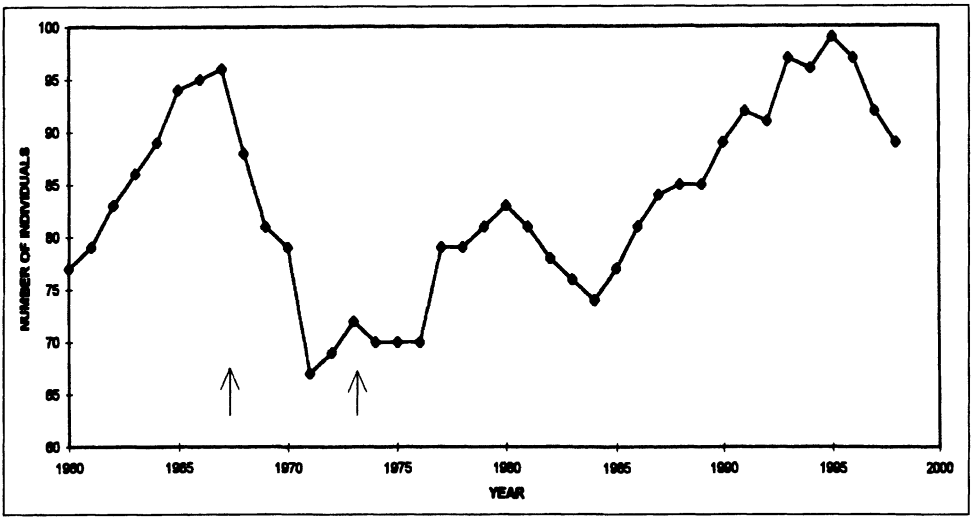

FIGURE 6. Population numbers and trends for southern *resident* Killer Whales. Data in this graph are from van Ginneken and Ellifrit (1998) and Olesiuk et al. (1990). Where differences exist between the two sources I have followed van Ginneken and Ellifrit (1998). The left arrow marks the beginning of large catches of whales from this population in the live capture fishery (small numbers had been taken prior to that point), while the right arrow marks the cessation of that fishery. Data from 1975 on are counts of animals using photo-identification; prior to that point numbers given are projections from a matrix model (Olesiuk et al. 1990). While there has been an increase since the end of live-captures, readers should compare the unsteady growth of this population since 1973, with the relatively steady continual increase of the northern *resident* population (Olesiuk et al. 1990; Figure 26).

ments, known associations, and shared genetic haplotypes, *transients* from bordering areas should be considered part of the same population which uses B.C. waters (Black et al. 1997). Of 79 *transients* documented in southeast Alaska, 69 have been observed in British Columbia (Dahlheim et al. 1997; Ford and Ellis 1999). One hundred and five *transients* have been documented off California, and at least 10 of those have been documented in British Columbia, Washington, or further north in Alaska (Black et al. 1997). New individuals are occasionally being recorded in some areas (e.g., van Ginneken et al. 1998). Because of the long-resighting interval for some *transients*, it is not possible to determine deaths in the same way as for *residents*, thus some of the whales already documented are probably no longer living. The use of mark-recapture models for estimating *transient* population size is not appropriate, as the probability of encountering *transients* in any particular area differs between groups (see Baird and Dill 1995, and differences between regional catalogues, e.g., Black et al. 1997; Palm 1997; van Ginneken et al. 1998). Population trend information is unavailable.

No population estimates are available for the Canadian Arctic or Atlantic waters, though compilations of records have been presented by Lien et al. (1988), Mitchell and Reeves (1988), Reeves and

TABLE 2. Comparison of age-specific mortality rates for all mature female southern *residents* from 1995–1998 (data from van Ginneken and Ellifrit 1998) with values presented by Olseiuk et al. (1990).

Age group	Olesiuk et al. 1990 *residents*	1995–1998 southern *residents*
15.5–24.5	0.0000	0.0
25.5–34.5	0.0036	0.0
35.5–44.5	0.0109	0.05
45.5–54.5	0.0250	0.125
55.5–64.5	0.0328	0.14
>65	0.069	0.05

Note: While sample sizes are small, and this is a post-hoc comparison looking only at a four-year period where a decline in the population has been noted, mortality rates for mature females between 35 and 65 years of age are four to five times higher than the rates calculated by Olesiuk et al. (1990).

Mitchell (1988a) and Wenzel and Sears (1988). Some anecdotal evidence suggests that the number of whales which utilize the St. Lawrence has declined in the last 60 years; Vladykov (1944) reports that large numbers of Killer Whales (including groups up to 40 individuals) were found in the area in spring and fall, feeding on belugas. It is clear that numbers which utilize the area today are much smaller (Mitchell and Reeves 1988; Wenzel and Sears 1988). The largest group reported off eastern and Arctic Canada in the last 20 years appears to be of 22 individuals (Finley 1990). Mitchell and Reeves (1988) note that Killer Whales appear to be "uncommon in the western North Atlantic relative to other medium-sized and large cetaceans, and that they may be numerically few" (this view is supported by data presented by Lien et al. 1988). As noted above, a review of western North Atlantic records subsequent to those mentioned above is warranted. Regional estimates for some portions of the eastern North Atlantic suggest relatively large populations (Anonymous 1993). Off West Greenland, considerable survey efforts have been undertaken since 1984, yet few Killer Whales have been recorded, suggesting that Killer Whales are not abundant in that area (Anonymous 1993).

Habitat

Killer Whales do not appear to be as limited by such habitat considerations as depth, water temperature, or salinity, as do some other cetaceans. Killer Whales are found in all oceans, in water ranging in temperature from below zero degrees Celsius (among ice floes) to warm tropical waters. They have been recorded in depths from as shallow as a few meters, to open ocean depths. Killer Whales will also occasionally spend considerable time in brackish water and will even enter rivers (e.g., Scheffer and Slipp 1948), including ascending into the lower reaches of the Fraser River in British Columiba. *Resident* Killer Whales around northern Vancouver Island have been documented using shallow intertidal and subtidal pebble beaches as rubbing sites (Hoyt 1990).

Habitat use by *residents* and *transients* does differ (Heimlich-Boran 1988; Morton 1990; Felleman et al. 1991; Baird et al. 1992; Ford et al. 1994a; Baird and Dill 1995). Both *residents* and *transients* frequent a wide range of water depths, but *residents* tend to spend more time in deeper water. *Residents* will occasionally move into water less than five meters deep, but some *transient* pods spend considerable time in even shallower depths, often foraging in inter-tidal areas at high tides. There appears to be considerable variability in habitat use among *transient* pods, with some spending significantly greater time foraging in very near-shore areas than others (Baird and Dill 1995). Patterns of habitat use of *resident* Killer Whales in Washington state and southern British Columbia were examined by Heimlich-Boran (1988) and Hoelzel (1993). Both studied the same population, but over different time periods; and results presented from the two studies differ somewhat. Heimlich-Boran (1988) noted that *residents* fed more in specific areas with high relief bathymetry along the major routes for salmon migration. Hoelzel (1993) found no correlation between behaviour, bottom topography or specific areas. The reasons for these discrepancies are unclear; habitat use may have shifted somewhat between the two study periods, or differences in methodology may be responsible. For both *residents* and *transients*, given the matrifocal nature of groups, movement patterns and habitat use are likely strongly influenced by learning within the matrilineal unit.

General Biology

Life History/Reproduction

The most detailed information on life history of Killer Whales world-wide is available for northern and southern *residents*. Life history characteristics determined by Olesiuk et al (1990) and summarized below were calculated using data from both northern and southern *residents* (and all references to *residents* in this section apply to both populations except where specified). As many of the characteristics may vary between populations, application of these values to other populations, including "offshore" Killer Whales or *transients*, should be done with caution. Some information, such as gestation period, has best been established with captive animals.

Gestation periods has been reported variously to be between 12–17 months. Using hormone levels of captive animals, gestation period has been measured at 517 days (17 months, SD = 20 days; Walker et al. 1988; Duffield et al. 1995). Duffield et al. (1995) note that successful pregnancies with viable calves occurred from 15–18 months (468-539 days). Length at birth of *residents* (based on the smallest and largest newborn animals documented stranded) ranges from 218 to 257 cm (Olesiuk et al. 1990). The largest fetus recorded world-wide was 270 cm in length (Nishiwaki and Handa 1958). Calving occurs year-round, but there appears to be a peak in births between fall and spring (Olesiuk et al. 1990). Precise age at weaning is not known, but Killer Whale calves begin taking solid food at a very young age. Heyning (1988) noted solid food in the stomach of a 2.6 m long animal from California. No milk was visible in the stomach of that animal, but contents were not tested for the presence of milk lactose. Using the ages at which southern *residents* begin spending more time away from their mother, as well as when they are observed taking fish, Haenel (1986) estimated weaning to occur at between 1.0-1.5 to 2 years of age.

Age at sexual maturity for females can be reported in a variety of ways, including age of first ovulation, age at first pregnancy, and age at first parturition. Olesiuk et al. (1990) defined age at sexual maturity for females as the age at which they first give birth to a viable offspring, and noted that it varies between 12 and 16 years (mean = 14.9 years). Onset of sexual maturity for males, defined as when the dorsal fin shape changes sufficiently enough to distinguish males from females, ranged between 10–17.5 years (mean = 15 years) (Olesiuk et al. 1990). Dorsal fin growth for males continues for at least six years after onset of sexual maturity, and Olesiuk et al. (1990) suggest that physical maturity is reached at the end of that period. These criteria need to be evaluated using hormone levels of captive animals. Calving interval, defined as the interval between births of viable calves, ranges from 2 to 12 years, with a mean of about 5 years (Olesiuk et al. 1990). Calving interval increases slightly with age, but is extremely variable (Olesiuk et al. 1990). Fecundity rate (defined as the proportion of mature females which gave birth to viable calves each year) declines linearly with age (Olesiuk et al. 1990). Olesiuk et al. (1990) provide evidence of reproductive senescence in older females, and note that the mean age of onset of post-reproduction is about 40 years, although one female has given birth at 51 years of age.

Mortality rates vary with age. Neonate mortality (birth to six months of age) is high. Using survival rates of calves first encountered during winter, and the presence of stranded animals, Olesiuk et al. (1990) estimated neonatal mortality of *residents* at 37% and 50%, respectively. Bain (1990) independently estimated neonatal mortality in northern *residents* at 42%, based on the distribution of calving intervals. Because of the high mortality rate during the first six months of life, longevity has usually been reported as the average lifespan of an animal which reaches six months of age. Average longevity has been estimated for male *residents* to be 29.2 years (maximum estimated at 50–60 years), and for females to be 50.2 years (maximum estimated at 80–90 years) (Olesiuk et al. 1990). At birth, average life expectancy is about 29 years for females and 17 years for males (Olesiuk et al. 1990).

Feeding Habits

Information on diet composition is relevant to status assessment both in terms of potential limiting factors, as well as in population delineation. In general, Killer Whales world-wide are apex predators, with a wide range of prey reported, including squid, octopus, bony and cartilaginous fish, sea turtles, sea birds, sea and river otters, dugongs, pinnipeds, other cetaceans, and occasionally terrestrial mammals such as deer, moose and pigs (Heyning and Dahlheim 1988; Guinet 1992; Jefferson et al. 1991). However, individual populations of Killer Whales appear to specialize on particular types of prey, rather than exhibit opportunistic predation (Felleman et al. 1991; Jefferson et al. 1991; Baird et al. 1992). In some areas, Killer Whales regularly steal fish from commercial fisheries (e.g., Leatherwood et al. 1990; Sivasubramanium 1965; Yano and Dahlheim 1994, 1995), or scavenge discards thrown overboard (e.g., Couperus 1994).

Both northern and southern *residents* appear to feed primarily on fish (Ford et al. 1998). More information is available for northern *residents* (126 predation events) than for southern *residents* (35 predation events), and most records of predation are from during the summer months (Ford et al. 1998). Based on collection and identification of scales from fish captured, Ford et al. (1998) note that 96% of the fish kills observed were salmonids, and of these, 65% were of Chinook (*Oncorhynchus tshawytscha*), the largest species occurring in that area. Stomach contents from eight *residents* also indicate this preference for salmon (7 of 8 individuals) and for Chinook (at least 4 individuals), though a variety of other species, including Pacific Halibut (*Hippocampus stenolepis*), Lingcod (*Ophiodon elongatus*) and a variety of other bottom fish were noted from one or two animals, and from occasional observations of predation (Ford et al. 1998). Ford et al. (1998) note that there are several potential biases that could affect diet composition in this type of study. It is possible that prey caught at great depths may be consumed prior to a whale returning to the surface. The limited information available on the depth distribution of salmon in British Columbia and Washington suggest that most species spend the majority of their time in the upper levels of the water column (i.e., less than 30 m — Felleman 1986; Quinn and terHart 1987; Quinn et al. 1989; Ruggerone et al. 1990; Olson and Quinn 1993), though Chinook are the deepest of the species captured. Thus most salmon captured likely have a relatively high probability of being observed, compared to prey which usually inhabit deeper portions of the water column. Southern *resident* Killer Whales regularly dive to depths greater than 100 m (Baird et al. 1998a), and may take a minute or more to return to the surface. While details on handling time of salmon have not been reported, it seems likely that similar-sized fish caught at such depths may be consumed prior to the whale's surfacing. Information on handling time for various species and sizes of fish would be of value for assessing this possibility. Also, there may be a bias towards detecting captures of large prey. Small prey are likely swallowed whole, while large prey may be broken up prior to consumption or shared between individuals, thus increasing the chance that scales may be recovered at the surface. Little information is available on diet of "offshore" Killer

Whales, though they have not been observed feeding on marine mammals (Ford et al. 1994b).

I believe that diet information from most observational studies of *transients* is probably less biased, since marine mammal prey tend to be fairly large and often come to the surface to breathe during attacks, where they are easily seen (Baird and Dill 1996; Ford et al. 1998). Even when live prey are not observed at the surface, prey species can often be inferred, based on location (e.g., a Harbour Seal haulout), and the presence of large quantities of blood or blubber in the water. However, methods in many studies focused on acoustic recordings have required positioning of a research vessel relatively far away (e.g., 100s of meters) from whales under observation, and it may therefore not be possible to compare kill rates from one study to another (Baird 2000). In one observational study, calculated food intake rates were more than sufficient to meet the animals' predicted energetic needs, thus the vast majority of prey actually captured were probably documented (Baird and Dill 1996). Harbour Seals seem to be the preferred prey for *transients*, being both very abundant in many areas of British Columbia, as well as relatively easy to capture (Baird and Dill 1996; Ford et al. 1998). Virtually all other common species of marine mammals whose range overlaps with that of *transients* have also been documented as their prey, as have occasional sea birds and even terrestrial mammals (Pike and MacAskie 1969; Bigg et al. 1987; Jefferson et al. 1991; Stacey et al. 1990; Baird and Dill 1996; Ford et al. 1998).

Killer Whales in the Canadian Arctic and Atlantic have primarily been documented feeding on other marine mammals (Whitehead and Glass 1985; Mitchell and Reeves 1988), though some evidence of Killer Whales scavenging fish from around longlining vessels is also available (Sergeant and Fisher 1957).

Social Organization

Globally, Killer Whales have been observed traveling alone and in groups of up to several hundred individuals (Perrin 1982). However, larger groups appear to be temporary associations of smaller, more stable groups. In all areas where long-term studies have been carried out, evidence suggests stable multi-year associations between individuals with limited dispersal from maternal groups (Lopez and Lopez 1985; Bigg et al. 1990; Guinet 1991a; Simila and Ugarte 1993; Baird and Dill 1996; Baird and Whitehead 2000). Such evidence is most conclusive for Killer Whales in British Columbia and Washington (both *transients* and northern and southern *residents*), where there are extensive data on variability in group size, structure and stability. Differences in these characteristics do occur between the sympatric *residents* and *transients*. Little is known about the social organization of "offshore" Killer Whales.

Bigg et al. (1990) studied the social organization of northern and southern *residents*, and noted the average pod size in the two populations combined was about 12 individuals (range of 3–59 individuals). No dispersal from *resident* pods has been documented. *Resident* pods are thought to form by the gradual splitting of a single pod into two (Ford 1990). Ford's (1984; 1990) research on Killer Whale acoustics demonstrated the existence of stable pod-specific dialects, and showed that some pods shared a number of calls. He suggested that these reflected common ancestry. Ford (1990) defined acoustic clans, comprised of pods which share one or more calls, and identified four acoustic clans from the British Columbia coast, three within the northern *resident* community, and one in the southern *resident* community.

For *transient* Killer Whales, average pod size reported by Baird and Dill (1996) was of about two individuals, with a range in pod size from one to four individuals. Those pods which consist of only a single individual (ie., individuals who do not associate with others for more than 50% of their time) appear to be of two types, either lone adult males which tend to spend much of their time alone (and only occasionally associates with other groups; Baird 1994), or adult females which always associate with other groups, although none in a stable manner (Baird and Whitehead 2000). *Transient* pods are fairly stable, with some associations between individuals documented lasting 15 years or more (Baird and Whitehead 2000). However, dispersal from *transient* pods has been recorded on two occasions (Bigg et al. 1987; Baird and Dill 1996), and extensive indirect evidence of dispersal exists (Baird 2000). *Transient* pods often associate with one another, and no evidence of *transient* communities, as noted for *residents*, has been found. Associations between *transient* pods do not appear to be completely random however; they depend in part on pod size and the age and sex of all pod members (Baird 2000), and in part on the foraging tactics exhibited by the pod, which appear to be pod-specific (Baird and Dill 1995).

Limiting Factors

Natural Mortality

Potential sources of natural mortality fall into several categories: predation, parasitism, disease, biotoxins, accidental beaching, entrapment, and starvation. No predators of Killer Whales have been recorded, but young or sick whales are potentially at risk from attacks by large sharks in some areas, and attacks by other Killer Whales may also pose a risk (see above). The relatively high incidence of scarring on animals also suggests that intraspecific aggression occurs (see Visser 1998).

A variety of endoparasites have been recorded from Killer Whales, including trematodes, cestodes, and nematodes (see review in Heyning and Dahlheim 1988). Transmission of such parasites is primarily through ingestion of infected food items, but the role and extent of such parasites in causing natural mortality is unknown. External parasites have not been documented in British Columbia Killer Whales, but Killer Whales elsewhere have been seen with barnacles on the rostrum and trailing edge of flukes, and with a species of cyamid ectoparasite. The current understanding of the diseases and disease processes (e.g., Ridgway 1979) affecting Killer Whales is relatively advanced, as a result of the study of animals in aquaria (J. McBain, Sea World San Diego, personal communication). Relatively little of this research has been published however. Mortality due to biotoxins has not been reported for Killer Whales, though a number of large-scale mortality events in other cetaceans have been linked to this source (e.g., Geraci et al. 1989). Large-scale mortality events due to viral infections have been recorded in several populations of marine mammals in recent years (Osterhaus and Veder 1988; Duignan 1995), and while the occurrence of such die-offs is unpredictable, given their magnitude and apparently increasing frequency of occurrence, they should be taken into account in conservation planning and population viability analysis (Young 1994; Simmonds and Mayer 1997).

Accidental beaching and entrapments of Killer Whales are an occasional source of natural mortality. Several cases of beaching of live animals have been reported in British Columbia and off eastern Canada, both with large groups (Carl 1946; Dearden 1958; Emery 1960) and lone individuals (Hoyt 1990). There is one recent unpublished record of two adult individuals which live stranded and died during a storm on 28 January 1998, near Terranceville, Fortune Bay, Newfoundland (R. Hudson, personal communication). Mass strandings have also been reported from Alaskan waters (Hanson and Spraker 1996). The cause(s) of large group strandings are usually unclear (though Dearden 1958 reports animals being forced ashore by ice), but it seems more likely to occur for "offshore" whales traveling on a rare occasion in inshore waters, than it does for inshore groups. Hoyt (1990) noted one *transient* individual apparently accidentally stranded while chasing porpoise in shallow water. Ice entrapments have been reported in the Canadian Arctic (Reeves and Mitchell 1988a), off Newfoundland (Lien et al. 1988) and in the Antarctic (Taylor 1957). Several cases of animals becoming entrapped in tidal lakes or inlets with narrow, shallow openings have also been noted (Emery 1960; Mitchell and Reeves 1988; Bain 1995). In many cases such entrapment has led to mortality of all or part of a group. Considering the small size of inshore populations of Killer Whales, such periodic events could seriously affect populations. Temporary "entrapment" in narrow inlets has been documented for southern *resident* Killer Whales twice in recent years (Shore 1995, 1998). In the most recent case, occurring in southern Puget Sound in 1997, the whales' reluctance to move under a bridge across the mouth of the inlet was suggested as a possible factor preventing their leaving the enclosed area (Shore 1998). Two of the 19 whales which were in the inlet died at some point in the six months after they left the inlet, though it is unknown whether the "entrapment" was a contributing factor to this mortality (Anonymous 1998).

Anthropogenic Influences

Potentially negative interactions with humans fall under two broad categories. Some impacts may have acute (immediate) effects on individuals or a population, such as directed takes (whaling, culling), live-capture fisheries, entanglement in fishing gear, collisions with vessels, or exposure to acute pollutants (e.g., oil spills). Immunotoxic affects due to accumulation of persistent toxic chemicals may also have an acute impact by increasing susceptibility to diseases, thus causing an increase in mortality. Besides these acute impacts, there are a number of less tangible, longer-term potentially negative human influences, including a reduction in reproductive rates due to accumulation of persistent toxic chemicals, reduced prey availability due to human activities, and disturbance or displacement by vessel traffic or other sources of underwater sounds (Table 3). While each of these is treated independently below, it should also be taken into account that cumulative impacts of all of these factors could be important (or in the case of longer-term stressors, synergistic interactions between impacts could occur; Whitehead et al. 2000).

Killer Whales have been hunted for oil and meat (for human or animal consumption, fertilizer or bait) in many areas (e.g., Reeves and Mitchell 1988b; Oien 1988; Berzin and Vladimirov 1983; Miyazaki 1983; Anonymous 1992; Kishiro and Kasuya 1993; Price 1985; Bloch and Lockyer 1988; Barnes 1991; Yu 1995, though the largest fisheries were discontinued in the early 1980s (Norway and Russia) or early 1990s (Japan). Small numbers are probably still taken elsewhere however. Information on catches is currently reported by many countries that are members of the International Whaling Commission through their Annual Progress Reports, though not all countries submit Annual Progress Reports, and some countries may not include Killer Whales in their lists of catches, as they are considered "small cetaceans" and are thus not covered under the auspices of the IWC. Small numbers of animals may be

TABLE 3. A summary of causes of mortality or disturbance to Killer Whales and their potential role in population limitation. Those sections which are bold are considered to be the most serious threats or limiting factors for Killer Whale populations in Canada.

Threat	Known or thought to cause population decline	Potential to cause substantial population decline	Trend in threat
NATURAL			
Predation	No	No	NA
Die-offs	No (but yes with marine mammals elsewhere)	Yes	Unknown
Mass stranding or entrapment in ice or narrow inlets	Yes	Yes	Steady?
ANTHROPOGENIC			
Culling/direct killing	Yes	Unlikely on west coast, possible in Arctic Canada	Decreasing on west coast, unknown in eastern and Arctic
Incidental mortality	No	No	Steady?
Live capture	Yes	No	Decreasing
Vessel harassment	No	No (but possible contributing)	Increasing
Vessel collision	No	No	Increasing
Acoustic deterrents from aquaculture operations	No	Unlikely	Steady but potential to increase
Immunotoxicity	No (but yes with marine mammals elsewhere)	Yes	Steady or increasing?
Oil spills	No (but yes with other populations)	Yes	Increasing?
Reduction in prey base	No (but yes with marine mammals elsewhere	Yes	Decreasing for mammal-eating Killer Whales, unknown for fish-eating

taken by non-member countries, and such catches would probably be largely unreported. In Canadian Arctic waters, Killer Whales are only taken very occasionally by native people; Reeves and Mitchell (1988a) noted that there was no tradition of hunting of Killer Whales in this area. Fourteen Killer Whales were killed by native hunters in the Canadian Arctic in 1977, but these were individuals that had been trapped in a tidal lake (Mitchell 1979). Small numbers were taken commercially off of Newfoundland and Nova Scotia in the 1940s through 1960s (Sergeant and Fisher 1957; Mitchell and Reeves 1988), and it is possible that more animals were taken but not reported in an early fishery for pilot whales (Sergeant 1962; Mitchell and Reeves 1988). Catches in the 1960s and 1970s off Norway were both age- and sex-biased, and impacts on the current population may still be apparent (Vongraven and Bisther 1995).

Culling (intentional shooting) of animals, because of their perceived (or documented) threat to fisheries, has also occurred in British Columbia (Carl 1946; Olesiuk et al. 1990), off eastern Canada (Lien et al. 1988), and elsewhere (e.g., Heide-Jorgensen 1988). In British Columbia this included the Canadian Air Force using Killer Whales as practice targets (Carl 1946), as well as opportunistic shooting by fishermen and the federal fisheries department. That such culling may have had an impact on populations earlier in this century is apparent in the population growth curves shown by Olesiuk et al. (1990; see also Figure 6), since both the northern and southern *resident* populations were growing (presumably recovering) prior to the initiation of the live-capture fishery. As such, it is possible that the populations today are still recovering. Elsewhere, as in Prince William Sound, Alaska, direct killing by fishermen in recent years in response to losses of fish may still be having significant effects on the local population (Dahlheim and Matkin 1994). Lien et al. (1988) note that the shooting of Killer Whales which congregated around whaling ships to feed on captured baleen whales may have significantly decreased the population in that area (though whaling ceased there in

1972). Kills in Greenland (Heide-Jorgensen 1988) may be from populations which share their range with Canada (Heide-Jorgensen 1993), and whether the ongoing occurrence of such kills is currently having an impact on populations off eastern and Arctic Canada should be investigated. Killer Whales in British Columbia are not reported to regularly take fish off fishing gear (G. Ellis, personal communication), as has been reported elsewhere (e.g., Yano and Dahlheim 1995), thus it seems unlikely that illegal shooting because of perceived threats to fisheries is currently occurring to any great degree. One fatal shooting of an adult female northern *resident* was documented in 1983 (which also appeared to result in the death of her calf), and at least one other northern *resident* has a bullet hole in the dorsal fin (Ford et al. 1994). Because of the extremely low potential growth rate of Killer Whale populations, even occasional shooting could limit population growth, and some monitoring of such activities is warranted. How such monitoring would be undertaken is difficult to envision.

Incidental mortality in fisheries through accidental entanglement in fishing gear appears to be rare for this species. A few gear entanglements have been reported in British Columbia, though not all have resulted in death of the entangled animals (Pike and MacAskie 1969; Jamieson and Heritage 1988; Ford et al. 1994b; Guenther et al. 1995*; Baird et al. in press). Entanglements have also been reported from other areas where individuals from the British Columbia population range (e.g., Alaska — Barlow et al. 1994; California — Heyning et al. 1994). Off the eastern coast of North America, no reports of incidental mortality in Canadian waters appear to have been published (Read 1994), though there is one record of a Killer Whale entangling in a groundfish gillnet (though it did not die) in the U.S. waters of the Gulf of Maine (Waring et al. 1997), and one record of a Killer Whale entangling (but released alive) in a swordfish longline in international waters off of Newfoundland (A. Williams, NMFS, personal communication). As with direct killing, some efforts to estimate the numbers of animals which are killed through incidental mortality are warranted. While questionnaire surveys of fishermen are known to be extremely biased (Lien et al. 1994), reporting of such accidental events might be more likely than reporting of deliberate activities like shooting.

Live-capture fisheries for public display in oceanaria have been focused in two areas, British Columbia/Washington and off Iceland (Asper and Cornell 1977; Bigg and Wolman 1975; Hoyt 1992). The last permit for captures in British Columbia was issued in 1982, although no animals were taken; the last animal taken from British Columbia was in 1977, and it is unlikely any further captures would be allowed, due to widespread public opposition (Hoyt 1990). Of 63 *residents* estimated to be removed from British Columbia/WA, 48 were thought to originate from the southern *resident* community (Olesiuk et al. 1990), which currently numbers only 89 animals (van Ginneken and Ellifrit 1998). These captures substantially reduced the southern *resident* population and it took approximately 20 years to return to levels similar to prior to the fishery (Figure 6). Besides a reduction in numbers, the live-captures also resulted in a skewed age- and sex-composition of the population (Olesiuk et al. 1990), due to selective cropping. Olesiuk et al. (1990) discuss a number of factors which may have resulted in the slow recovery of the southern *resident* population between 1970 and 1985, including the possibility that the selective cropping of males (23 of 35 known-sex individuals were males) may have reduced the number of mature males to below a critical number for optimal productivity (Olesiuk et al. 1990).

In recent years, whale watching focusing on Killer Whales has become particularly prominent in Washington state and British Columbia, and vessel activity of all types (e.g., sports fishing, whale watching, ferry and freighter traffic) has been increasing (e.g., Osborne 1991). Whale watching in particular has raised a variety of concerns among researchers and members of the public about the potential for disturbance (Kruse 1991; Osborne 1991; Duffus and Dearden 1992, 1993; Phillips and Baird 1993; Duffus and Baird 1995; Burgin and Otis 1995; Baird et al. 1998b; Williams et al. 1998). Numerous behavioural changes have been reported in response to close approaches by boats, although some of the studies undertaken have serious methodological problems, causing researchers to question their validity (Duffus and Dearden 1993). Studies have focused both on northern *residents* in Johnstone Strait and southern *residents* in Haro Strait. A number of differences between these sites, the populations of whales which use them, the number and types of boats found in the two areas, and the research methodologies being used in each site, preclude any simple comparison of results from the two areas. Changes in behaviour in response to approach by boats have been demonstrated for northern *residents* (Trites et al. 1996; R. Williams, personal communication). Unfortunately the implications of such changes in behaviour on reproduction or mortality are unclear. While similar behavioural changes have not yet been demonstrated for southern *residents* (Osborne 1991; Burgin and Otis 1995; Baird et al. 1998b), there does appear to have been a substantial decrease in the proportion of time southern *residents* engage in resting behaviour during daylight hours, coincident with the large increase in whale watching activity (Osborne 1986; K. C. Balcomb, R. W. Osborne, personal communications). For *transient*

Killer Whales, Barrett-Lennard et al. (1996) suggested that vessel noise might impair their ability to detect prey. The impact of a single boat would appear negligible, as Baird and Dill (1996) found that under such circumstances observed food intake rates of *transients* were more than sufficient to account for the whale's energetic needs. However, at least in some areas of the province and at some times of the year, such impacts could be serious. In the last few years (since 1993), it is not uncommon for small groups of *transient* Killer Whales to be accompanied by 5–10 boats when travelling off the Victoria area during summer months (Baird, personal observations), and such large numbers of boats seem more likely to impact foraging success in the way suggested by Barrett-Lennard et al. (1996). In one area in Washington state, the number of vessels found around groups of southern *resident* Killer Whales has been increasing (Figure 5), and in 1997 groups were accompanied by an average of 25 vessels (only one quarter of which are commercial whale watching vessels) during daylight hours in the summer months (Baird et al. 1998b; Figure 6). The commercial whale watching fleet in the area (including the ports of Victoria, Sidney and Sooke in British Columbia, and Bellingham and Friday Harbor in Washington) has been increasing rapidly, and numbered over 80 boats in 1997 (Baird et al. 1998b). As noted above (see Protection, National), levels of awareness of, and adherence to, whale watching guidelines are largely unknown (except in a few specific localities during summer months), and virtually no official monitoring or enforcement of whale watching guidelines takes place.

A more direct impact of boats on whales involves injuries or deaths from collisions. Considering the large number of vessels interacting with Killer Whales during the summer months in British Columbia, vessel collisions are extremely rare. One well-documented case in British Columbia has been reported (Anonymous 1974), with an animal apparently fatally wounded after a collision with a large vessel (a ferry). Ford et al. (1994a) note the animal struck may have been part of the northern *resident* population. Several other live animals have been seen with scars that might be attributable to vessel interactions, although the evidence for this is inconclusive. One vessel collision with a southern *resident* Killer Whale in Haro Strait, Washington, was witnessed in 1998 (V. Shore, personal communication), but the vessel was moving slowly and the animal did not appear to be injured as a result of the collision. A northern *resident* was struck by a speed boat in 1995 and received a wound to the dorsal fin, which appeared to heal quickly (P. Spong, H. Symonds, personal communications).

The generation of loud underwater sounds through such sources as acoustic deterrent devices ("seal scarers" or ADDs) at aquaculture operations also has the potential to cause disruption of movement patterns or even abandonment of an area (Morton and Symonds 1998*). Morton and Symonds (1998*) noted a drastic reduction of use of the Broughton Archipelago, off northeastern Vancouver Island, by both *resident* and *transient* Killer Whales, coincident with the installation of several high amplitude ADDs in the area. *Residents* have shown a decline in use of the area (measured as number of days per year observed) of over 75%, while *transient* use of the area has declined by over 50%. The lesser decline by *transients* may be due to their use of specific channels in the area away from the ADDs (Morton and Symonds 1998*). Morton and Symonds (1998*) compared use of the Broughton Archipelago with the nearby Johnstone Strait, and area where no ADDs were in use, and where *resident* use of the area has been more-or-less stable over the same periods. Their study provides evidence of Killer Whale avoidance of areas where ADDs were in operation (Nichol and Sowden 1995 present information on avoidance of another species), thus potential effects by their use by other aquaculture facilities on the British Columbia coast should be studied, and increased use of such devices should be strictly regulated.

More critical conservation problems concern two general areas, the effect of pollutants and the reduction of the prey base due to anthropogenic activities. Two general groups of pollutants warrant discussion: (1) persistent toxic chemicals which bioaccumulate; and (2) petroleum products. Killer Whales from British Columbia and neighboring areas have been shown to accumulate high levels of persistent toxic contaminants (Calambokidis et al. 1990; Jarman et al. 1996; Matkin et al. 1998; Ross et al. 1998). Populations of *resident* Killer Whales in British Columbia spend a large proportion of their time in near-shore waters in close proximity to various sources of pollutants. A recent study using samples collected from free-ranging southern *residents* demonstrated that levels of PCBs and PCDD/Fs in these animals were three times higher than levels known to be immunotoxic for harbour seals (Ross et al. 1998). Levels in individual southern *residents* were three to five times higher than in individuals of equivalent age/sex classes of northern *residents* (P. Ross, personal communication), which live in an area with far fewer sources of pollutants (see Evaluation). *Transients* appear to spend less time in highly polluted areas, but feed almost exclusively on marine mammals, so may accumulate higher levels of many toxins. Matkin et al. (1998) note that levels of PCBs and DDTs in *transients* from Prince William Sound were 14 and 22 times higher, respectively, than for *residents* from the same area. They also note that the group of *transients* with high levels have shown no recruitment since 1984, suggesting that there may be a linkage between the low rate of reproduction and the high contaminant levels. Although sample sizes are smaller and based on stranded animals, levels of mercury appear to be higher in the tissues of *residents* than *transients* (Langelier et al. 1990). One possible candidate for these high levels of toxins in *residents* is consumption of heavily contaminated prey, but consumption of such prey has not become apparent in the studies of foraging undertaken to date. The high levels found in southern *residents* could affect reproduction, immune function and endocrine function (Ross et al. 1996a, 1996b, 1998). Reproductive or endocrine function impacts fall into the long-term category of effect. Immune function affects can result in acute (immediate) impacts on individuals or on the population. For example, it is thought that the 1988 morbilivirus-associated mass mortality of harbour seals in northern Europe, which resulted in a population reduction of over 50%, was exacerbated by such immuotoxic effects of contaminants (Ross et al. 1996a, 1996b; de Swart et al. 1996).

Large-scale dumping of oil has the potential for detrimental effects on Killer Whale populations. Concurrent with the *Exxon Valdez* spill in Prince William Sound, Alaska, was the unprecedented loss of 14 Killer Whales from one pod which was seen in the area immediately following the spill (Matkin et al. 1994). Dahlheim and Matkin (1994) reviewed the evidence for a cause-and-effect relationship between the spill and the deaths of these whales, and conclude that while there was a strong spatial and temporal correlation between these events, insufficient evidence is available to determine whether the spill caused the deaths, or other factors, particularly fisheries interactions, were responsible. Given the large amount of tanker traffic on the British Columbia and Washington coasts, there is a potential for the loss of a large proportion of a population. In Juan de Fuca Strait, tanker traffic has been increasing, and tankers are aging (existing tankers are not expected to be phased out and replaced with double-hulled tankers until 2015; F. Felleman, personal communication). Thus a population such as the southern *residents* (considering their tendency to congregate in one area during the summer months) may be at risk from a major spill.

It is beyond the scope of this review to undertake an assessment of trends in the abundance of all the potential prey species of Killer Whales, and in fact it is likely that such an assessment is impossible (or nearly so) given the data that are available. Regardless, in terms of a reduction in the prey base available for Killer Whales, it is clear that at least some of the populations of prey species of Killer Whales are substantially smaller today than historically. In terms of salmon, anthropogenic influences on populations have included destruction, degredation and/or prevention of access to breeding habitat through urbanization, slides associated with road or railroad building, dam building, forestry and agriculture, as well as a reduction in numbers through fishing (Groot and Margolis 1991; Nehlsen et al. 1991; Slaney et al. 1996). Recent reviews of stocks from southeast Alaska through to California document large-scale reductions in many stocks, and extinction of others (Nehlsen et al. 1991; Baker et al. 1996; Slaney et al. 1996; see also e.g., Holtby and Finnegan 1997*; Wood et al. 1997*; Bradford 1998; Rutherford et al. 1998*). These reviews focus primarily on evaluating which stocks are at risk of extinction. Killer Whales will be affected by a simple reduction in numbers, rather than only an extinction of stocks. Within British Columbia, the salmon populations most drastically impacted are those in the southern part of the province, particularly the Strait of Georgia (Slaney et al. 1996), coinciding with the population of Killer Whales (southern *residents*) which seems most at risk (see Population Size and Trends, and Evaluation). Some evidence is also available for declines of other potential prey species (e.g., Fargo 1997*; Leaman and McFarlane 1997*; Stanley and Haist 1997*; Ware 1997*; Yamanaka and Kronlund 1997*). Reduced prey availability could result in an increase in the amount of time whales would need to spend foraging, potentially leading to reduced reproductive rates and/or increased mortality rates. Insufficient information is available to assess whether such impacts are currently manifest. Given the inherent difficulty of determining such impacts even if they exist, and the potentially large role they might have on increasing mortality or decreasing reproductive rates, a precautionary approach is warranted (Richards and Maguire 1998).

Special Significance

Among the cetaceans, Killer Whales exhibit several unusual features related to social organization and behaviour. One is the presence of the two sympatric populations (*residents* and *transients*) in the nearshore waters of the eastern North Pacific, each specializing on different prey types, and differing in behaviour, acoustics, and morphology (Baird and Stacey 1988; Bain 1989; Ford and Hubbard-Morton 1989; Morton 1990). Such a situation, with foraging specializations occurring among sympatric populations, is unusual for mammals, as well as for vertebrates in general (see Mayr 1996; Otte and Endler 1989). This system may provide valuable information on the causes and consequences of reproductive isolation between populations (Baird 1994).

One apparent consequence of the differences in diet between the two forms are differences in dispersal patterns. For *residents* no dispersal of either sex occurs; individuals travel in long-term stable groups comprised of several maternal lineages. This situation has not been documented for any other population of cetacean, or any other species of non-human mammal. For *transients*, dispersal of most individuals of both sexes from the maternal group occurs, though not all male offspring seem to disperse (Baird 1994, 1995b, 1998; Baird and Whitehead 2000). Such variability in dispersal patterns between sympatric populations of closely related animals provides a unique opportunity for examining some of the costs and benefits of group living.

The types of foraging specialization found in populations in the eastern North Pacific may also occur elsewhere in the world, though research efforts elsewhere have been generally insufficient to determine whether sympatric forms specializing on different prey types exist. Individuals of some populations feed almost exclusively on other marine mammals. Such predation on marine mammals makes the study of foraging behaviour easier than perhaps for any other species of cetacean. Several interesting findings have come from these studies, including evidence that females teach hunting skills to their offspring (Lopez and Lopez 1985; Guinet 1991b; Guinet and Bouvier 1995), and also a strong relationship between group size and foraging success in one population (Baird and Dill 1996).

Besides these intrinsic characteristics, Killer Whales also hold an unusual fascination for humans. Such fascination is reflected in the large attendance figures at aquaria which hold Killer Whales around the world, through the demand for commercial excursions to see these animals in the wild, and through the large number of popular books, magazine articles and films which have been devoted towards these animals. In the Haro Strait region, a trans-boundary area between Washington state and British Columbia, a large and growing whale watching industry focused on this species exists (Baird et al. 1998b; Figure 5). Ticket sales for this area (in both the U.S. and Canada combined) were estimated to be approximately 5.5 million (U.S.) dollars in 1997 (R.W. Osborne, personal communication).

Evaluation

The taxon *Orcinus* has been evaluated by the IUCN Cetacean Specialist Group, and designated as Lower Risk: Conservation Dependent (IUCN 1996). This category, effectively one level below the IUCN Vulnerable category (which includes species facing a high risk of extinction in the wild in the medium-term future), includes species which are the focus of a continuing conservation program, the cessation of which would result in qualifying for one of the higher (e.g., Vulnerable) categories within a period of five years (IUCN 1996). The COSEWIC classification of "Endangered" is for species "facing imminent extirpation or extinction", "Threatened" is for species that are "likely to become endangered if limiting factors are not reversed", and "Vulnerable" is for those species "of special concern because of characteristics which make [them] particularly sensitive to human activities or natural events" (Campbell 1996). The COSEWIC definition of "species" is particularly important in evaluation of the status of Killer Whales, as it explicitly includes any "subspecies, variety or geographically defined population[s]". Evidence is summarized below regarding Killer Whale populations in Canada relevant to such classification.

Off the British Columbia coast, Killer Whales are subdivided into a number of populations, and these populations are distinct genetically, morphologically, and behaviourally (see e.g., Table 1). Based both on these biological characteristics and the COSEWIC "species" definition, it is clear that these populations could warrant independent evaluation and classification, where appropriate (it should also be noted that these populations are evaluated and listed independently in the U.S. — Barlow et al. 1997; Hill et al. 1997). One of the British Columbia populations, the "northern" *residents*, has been growing since the end of live-capture fisheries in the early 1970s, but the population in British Columbia only numbers just over 200 individuals. The "southern" *residents* have not shown a steady increase, and the population size has declined by 10% in the last three years (1996–1998), to a level below that prior to live-captures (Figure 6). This decline is due to an increase in mortality rate, particularly mortality of adult females. The cause or causes of this increase in mortality are unclear, but there are several possibilities (Table 3). The core area for southern *residents* (Haro Strait) is bounded by the cities of Vancouver, Victoria and Seattle, with over 5.5 million people living in the area, increasing numbers of commercial and recreational vessel traffic, and numerous sources of pollutants. It seems unlikely that either pollution of these waters or vessel traffic will decrease in the near future. Southern *residents* have toxic chemical levels three times higher than levels known to cause immunotoxicity in Harbour Seals, and the most immediate anthropogenic risk to these populations is likely immunotoxic effects from this accumulation of persistent toxic chemicals (see Ross et al. 1996a, 1996b, 1998). Potential impacts of a reduction in prey populations and increasing numbers of commercial and recreational whale watching boats (Figure 5) may also be serious threats, although insufficient information is available to evaluate the magnitude of these threats. In terms of reduction of salmon populations, numbers in the Strait of Georgia, where the southern *residents* spend a large proportion of their time, have been reduced to a larger extent than populations elsewhere in British Columbia (Slaney et al. 1996).

For *transient* and "offshore" Killer Whales in British Columbia, no population trend information is available, though, as with both northern and southern *residents*, population sizes appear to be small. *Transients* feed high on the food web, and are likely also at risk from high levels of contamination by persistent toxins. For Killer Whales in the Canadian Arctic and Atlantic, no information on population identity or trends is available, though populations appear to be very small, and the threats which face British Columbia populations likely also impact eastern Canadian and Arctic populations. Because of their small population sizes (in the low hundreds), Killer Whales are also at risk from natural events (e.g., entrapment or mass stranding) which could drastically impact a local population.

From the above, it is clear that all populations of Killer Whales in Canadian waters should, at the minimum, be considered vulnerable. The only question that remains is whether one of the populations, the southern *residents*, should be considered threatened. The population is extremely small (89 individuals in 1998), has declined by 10% in three years due to an increase in mortality rates, and several threats have been identified which have the potential to cause this population to become endangered. As noted, it is unlikely that at least some of these threats (pollutants, vessel traffic) will be reversed in the foreseeable future. While it is unclear whether the recent (1996–1998) decline is directly due to these anthropogenic factors, or whether the population will continue to decrease, the rate at which this population has declined demonstrates how quickly such a population could become in danger of extirpation. That the threats to the population are insidious, difficult to quantify, and even harder to rectify, all warrant a conservative (precautionary) approach to management (see Richards and Maguire 1998). Without a COSEWIC designation, it seems unlikely that anything will be done regarding mitigation of these impacts, and the population could become endangered well before another evaluation is undertaken. Since the population is a trans-boundary stock, efforts to coordinate actions with U.S. management agencies are also required.

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