Status of Marine Mammals in the Strait of Georgia, Puget Sound and the Juan de Fuca Strait and Potential Human Impacts

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ABSTRACT

Nine species of marine mammals commonly occupy the transboundary waters of British Columbia and Washington (BC/WA). Individuals of all species move across this international border. Of the four pinniped species common to these waters, harbour seals are the most numerous and the only one that breeds in the transboundary area. Approximately 27,000 harbour seals occur in the transboundary area, and the population has been increasing at 5–15% per year. Elephant seals are found in the transboundary area in small numbers, and their occurrence in the area has increased in recent years. The number of California sea lions in the area increased in the 1980s and appears to have stabilized. While declining through most of its range, the number of Steller sea lions which use this area appears to be stable, although well below historical levels. Of the five cetacean species common to the waters, harbour and Dall's porpoise are the most abundant and number in the several thousands. Harbour porpoise numbers in some areas have declined since the 1940s, though little data are available to assess current trends in populations of these two species. Two populations of killer whales utilize the transboundary area. The 'resident' population is growing and is currently larger than it was prior to a live-capture program in the 60s and 70s. Over 20,000 gray whales migrate past the entrance to Juan de Fuca Strait and some individuals spend prolonged periods feeding during the spring and summer in BC/WA waters. A small number of minke whales use this area for feeding, primarily during the spring, summer, and fall.

Marine mammals are vulnerable to human activities in the BC/WA transboundary waters. High concentrations of contaminants, especially chlorinated hydrocarbons and some metals, have been identified in these animals. Highest concentrations of contaminants have been found in harbour seals (from southern Puget Sound), harbour porpoise and killer whales. Determination of the impacts of these contaminants on marine mammals in these waters has been inconclusive, though in other areas contaminant exposure has been linked to reproductive failure and immunosuppression. Marine mammals are killed incidental to commercial fishing operations, particularly harbour porpoise and Dall's porpoise. Information to assess human impacts on most marine mammals and to adequately evaluate their current status is extremely limited.

INTRODUCTION

The transboundary waters of British Columbia and Washington, including Puget Sound, the Strait of Georgia, and Juan de Fuca Strait, are used by a variety of marine mammals for feeding and breeding (Osborne et al. 1988; Everitt et al. 1980). Despite the cross-border movement of marine mammals, management of marine mammals has largely been conducted independently within each country due to legal and logistical constraints. The status of management of marine mammals is of great interest to many people for many reasons. Populations of many marine mammals species were severely depleted by human exploitation prior to their legal protection. Today, many people feel a strong emotional attachment to marine mammals, though to some fishermen, marine mammals are viewed as competition for limited fish resources.

A variety of human activities potentially impact marine mammal species in the transboundary waters. Pinnipeds and odontocetes (toothed cetaceans) are especially vulnerable to the impacts of stable environmental contaminants because they feed high on the food chain. Extremely high concentrations of contaminants have been found in tissues of marine mammals in the transboundary area (Calambokidis et al. 1984, 1991a). Marine mammals are also vulnerable to mortality incidental to commercial fishing activities and to human disturbance in the transboundary area.

In this report we summarize what is known about the status of marine mammals that occur in the transboundary area, examine potential human impacts on marine mammals, and make research recommendations. Place names mentioned in the text are shown in Figure 1.

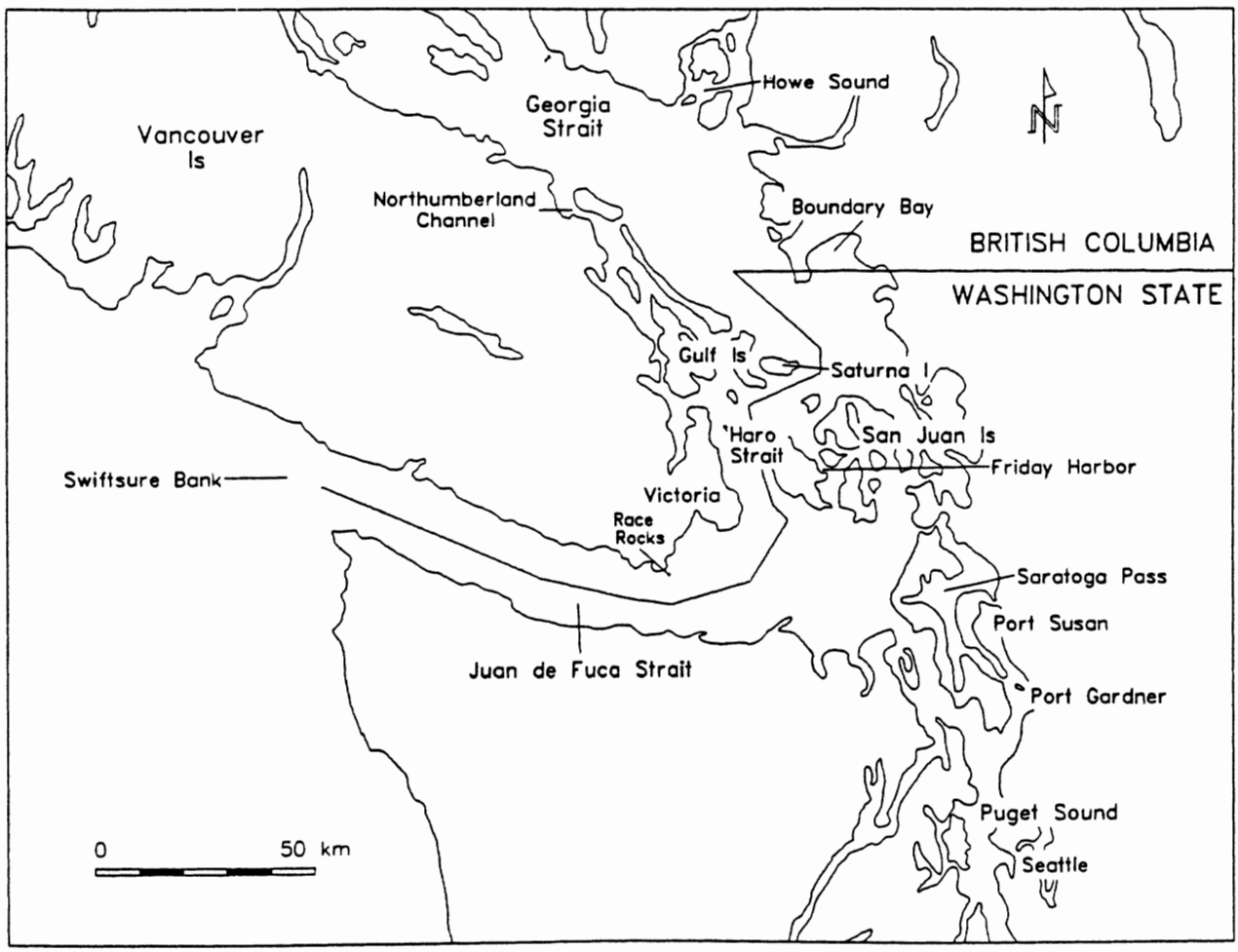

Figure 1. Map of trans-boundary area showing place names mentioned in text.

SPECIES ACCOUNTS

Harbour Seals *(Phoca vitulina)*

Harbour seals are the most abundant marine mammal in the transboundary area; they breed and occur year-round in these waters (Osborne et al. 1988). They use numerous rocks, beaches and log booms throughout the area to haul out to rest, give birth and nurse their young (Scheffer and Slipp 1944; Osborne et al. 1988; Olesiuk et al. 1990a; Huber et al. 1993). Harbour seals were killed under bounty and other control programs in both British Columbia and Washington State due to purported predation on commercial fish species (Scheffer and Slipp 1944; Newby 1973a; Bigg 1969). Harbour seals, like other marine mammals, have been protected since 1970 in British Columbia and 1971 in Washington State (by state law prior to protection in 1972 under the U.S. Marine Mammal Protection Act).

Harbour seal abundance has been increasing at an average annual rate of 12.5% in British Columbia (Olesiuk et al. 1990a) and generally between 5% to 15% for most sites in Washington State (Calambokidis et al. 1979, 1985; Jeffries 1985; S.J. Jeffries and H.R. Huber pers. comm.). In recent years, numbers may have stabilized or decreased in northern Hood Canal (Evenson and Calambokidis 1993). Absolute abundance estimates of harbour seals have been made for the transboundary area although methodologies to correct counts have varied somewhat between British Columbia (Olesiuk et al. 1990a) and Washington (Huber et al. 1993). The abundance of harbour seals in the Strait of Georgia was estimated at 15,810 for 1988 (Olesiuk et al. 1990a) and 11,800 for Juan de Fuca Strait, San Juan Islands, and the embayments just north of Puget Sound in 1992 (Huber et al. 1993). Continued monitoring of harbour seal numbers as well as aspects of their biology and human impacts in the transboundary area is underway.

Harbour seals are considered non-migratory, but long-distance movements among sites in the North Pacific have been documented (Scheffer and Slipp 1944; Pitcher and McAllister 1981; Brown and Mate 1983; Jeffries 1986; Huber et al. 1993). Radio tagging of harbour seals in the San Juan Islands, Gulf Islands, and Boundary Bay demonstrated extensive movements of harbour seals among sites in this area, with many animals documented moving across the international border (Huber et al. 1993).

Conflicts between the growing populations of humans and harbour seals have increased. Harbour seals are opportunistic foragers and feed in the transboundary area on a wide variety of fish species and to a more limited degree on cephalopods and crustaceans (Scheffer and Slipp 1944; Fisher 1952; Spalding 1964; Everitt et al. 1981; Calambokidis et al. 1978, 1989; Olesiuk 1993). Primary prey species within the Strait of Georgia are hake and herring (Olesiuk 1993). Conflicts with commercial fisheries include predation on commercially valuable fish, removal or damage of fish caught in gillnets, and damage to gear. In rare circumstances, particularly due to loss of salmon breeding habitat and overfishing, harbour seals may have a serious impact on some salmon runs (Bigg et al. 1990a). Harbour seals have also been implicated with closure of commercial shellfish beds near some haul-out areas in Puget Sound due to high concentrations of fecal coliform contamination (Calambokidis et al. 1989). Harbour seals are the primary prey of transient killer whales in this area with large numbers taken at some haul-out sites, such as Race Rocks (Baird and Dill 1994).

California Sea Lion *(Zalophus californianus)*

California sea lions breed on islands off Baja, Mexico and southern California with primarily males migrating north to feed in the transboundary area (Everitt et al. 1980). The breeding population in southern California has been increasing at about 5% a year (DeMaster et al. 1982). California sea lion occurrence in the transboundary area increased sharply in the late 1970s and early 1980s (Everitt et al. 1980; Bigg 1985; Steiger and Calambokidis 1986). Counts of California sea lions in the transboundary area totalled just under 3,000 by the mid-1980s (Bigg 1985; Gearin et al. 1986). In recent years the number of sea lions has stabilized or decreased in some portions of the transboundary area (Gearin et al. 1988).

California sea lions are present in the transboundary area from late August to June of each year (Everitt et al. 1980; Bigg 1985; Steiger and Calambokidis 1986; P. Gearin pers. comm.). They leave and enter the area through Juan de Fuca Strait, for migrations to and from their breeding grounds in California (Calambokidis et al. 1987). California sea lions use numerous locations to raft in the water or to haul out (Everitt et al. 1980; Bigg 1985; Gearin et al. 1988). Although these sites some-

times change over time, areas of concentration in recent years have included Race Rocks and Northumberland Channel in British Columbia and Port Gardner in Puget Sound. They can also be found in small numbers throughout all marine areas and into major rivers.

California sea lions come to the transboundary area primarily to feed. Primary prey of California sea lions in the study area include hake, walleye pollock, herring, and spiny dogfish (Everitt et al. 1981; Gearin et al. 1988; Olesiuk and Bigg 1988). California sea lion predation on steelhead trout and coho salmon at the Ballard Locks in Seattle has become a major concern since the mid-1980s (Gearin et al. 1986, 1988). Predation rates on this already small run have been high enough to endanger the survival of the steelhead run. Attempts to reduce the predation through seal bombs, underwater sounds, nets, and relocation of animals have so far been unsuccessful. Continued research on the status of this species and ways to reduce predation on steelhead is underway. Within the transboundary area both California and Steller sea lions are occasionally eaten by transient killer whales (Bigg et al.. 1987; Baird and Dill 1994).

Steller (Northern) Sea Lion
(Eumetopias jubatus)

Steller sea lions are year-round residents in British Columbia, and seasonal visitors to Washington State. Within B.C. they breed only in the central and northern parts of the province (Bigg 1988), and are largely seasonal visitors to the transboundary area (Everitt et al. 1980). Steller sea lions are currently listed as threatened in the U.S. (Marine Mammal Commission 1991), but are not listed as endangered or threatened in Canadian waters (Bigg 1988). Populations in Alaska and California have declined by over 50% in the last 30 years (Loughlin et al. 1992), while the population in British Columbia appears to be stable, but at levels far below the original levels which existed prior to intensive culling programs (Bigg 1988).

Within the transboundary area, other than an occasional animal seen between June and August, Steller sea lions move into the area in September, and depart in May. The majority of Steller sea lions within this area appear to be males, with females remaining closer to their breeding colonies. High numbers of Steller sea lions (of both sexes) are seen on the northern Washington coast with peak numbers from August to March (P. Gearin pers. comm.). The majority of sea lions appear to enter the transboundary area through Juan de Fuca Strait, thus peak numbers occur earlier in the season at haul-out sites in this area. Steller sea lions can be predictably found at about 10 haul-out or rafting sites within the transboundary area, usually intermixed with numbers of California sea lions (Bigg 1988; Everitt et al. 1980; Osborne et al. 1988). They also range in small numbers throughout the study area. Numbers within the transboundary area may surpass a thousand individuals during the winter.

Within British Columbia and Washington, Steller sea lions have been recorded eating octopus, squid, lamprey, skate, spiny dogfish, ratfish, herring, eulachon, hake, rockfish, halibut, lingcod and salmon (Pike 1958; Spalding 1964). Salmon only makes up a few percent of their diet (Olesiuk and Bigg 1988). In Alaska, Steller sea lions have occasionally been recorded feeding on harbour seals and on northern fur seal young (Gentry and Johnson 1980; Pitcher and Fay 1982).

Little research has been undertaken on this species in the transboundary area, other than periodic surveys of animals hauled out (Steiger and Calambokidis 1986; Bigg 1988; Gearin et al. 1988), and regular counts of numbers at Race Rocks, one of the larger haul-out sites within the transboundary area (Baird unpubl. data).

Northern Elephant Seal
(Mirounga angustirostris)

Northern elephant seals are found within the transboundary area in small numbers year-round (Baird 1990, and unpubl. data), although they do not breed there. This species is abundant and increasing within its range in the eastern North Pacific (Campbell 1987). Adult animals congregate around several breeding colonies in California and Mexico during the winter; but even during this time small numbers of juveniles and sub-adults are found in Juan de Fuca Strait and surrounding areas. The transboundary area is used by elephant seals both to feed and to haul-out. Small numbers of juveniles haul out throughout this area for periods of over a month to moult. Haul-out areas in the transboundary region are not as predictable as for the other species of pinnipeds found there. Only one site (Race Rocks, at the southern tip of Vancouver Island) has been identified as a regular haul-out area for ele-

phant seals (primarily juveniles), where they have been observed with harbour seals or sea lions (Baird unpubl. data). In recent years up to four elephant seals have simultaneously used this site for extended periods (up to several months). Adult elephant seals can be found foraging in deeper water (typically greater than 100 m) throughout the transboundary area, although few records are available for the central and northern Strait of Georgia. While no estimate of population size within the transboundary area is available, the number of elephant seals using this area appears to be increasing (Baird unpubl. data; Everitt et al. 1980).

No diet studies have been conducted on northern elephant seals within the transboundary area; knowledge of prey is based on a few anecdotal observations of feeding elephant seals and from studies in more southerly parts of their range. Elephant seals have occasionally been observed eating spiny dogfish at the surface in local waters (e.g., Osborne et al. 1988). Studies on feeding habits off California and Oregon indicate that they feed on a wide variety of prey, both within the water column and bottom dwelling organisms. These include shrimp, pelagic red crabs, numerous species of squid and octopi, tunicates, skates, rays, sharks, ratfish, lamprey and bony fish, such as hake and rockfish (Antonelis et al. 1987; Condit and LeBoeuf 1984).

Juvenile elephant seals are often mistaken for large harbour seals (Everitt et al. 1980). As they are easily approachable on beaches and often appear sick to an uninformed observer (in comparison to normal harbour seal behaviour), such confusion has resulted in the accidental killing of several animals around southern Vancouver Island in the last five years (Baird 1990, unpubl.). Elephant seals are occasionally killed due to entanglement in gillnets. One other occasional source of mortality for elephant seals in the transboundary area is predation by transient killer whales (Baird and Dill 1994). In the transboundary area research has been limited to monitoring hauled animals for tags and moulting status, and examining some strandings.

Harbour Porpoise *(Phocoena phocoena)*

Harbour porpoise are common in coastal waters of the North Pacific and occur year-round and breed in the transboundary area (Osborne et al. 1988). They are considered vulnerable to human activities, and populations in several other portions of their range have declined or been eliminated (Wolff 1981; Otterlind 1976; Prescott and Fiorelli 1980; Leatherwood and Reeves 1983).

Abundance estimates of harbour porpoise for Juan de Fuca Strait and San Juan Island area in 1991 were approximately 3,300 (Calambokidis et al. 1993a). Densities of harbour porpoise were similar in Juan de Fuca Strait and the San Juan Island area but both were lower than in coastal waters of Oregon and southern Washington (Calambokidis et al. 1992b). Harbour porpoise along the coast use primarily near-shore waters shallower than 100 m, but the depth-associated distribution pattern is not as clear in Juan de Fuca Strait and San Juan Islands (Calambokidis et al. 1992b). Harbour porpoise were once considered common in southern Puget Sound (Scheffer and Slipp 1948) but are now rarely seen (Everitt et al. 1980; Calambokidis et al. 1985, 1992b). Reasons for their decline in Puget Sound and other areas are not known, although pollutant effects, avoidance of heavy vessel traffic, and mortality due to entanglement have all been suggested as possible reasons. Additional research is currently underway to further examine harbour porpoise occurrence in Puget Sound. Anecdotal evidence also suggests that harbour porpoise populations in southern British Columbia have decreased since the early part of this century.

Harbour porpoise feed on a variety of smaller fish and squid. Harbour porpoise entangled in gillnets along the northern Washington coast were feeding primarily on herring, squid, smelt, and gadoids (Gearin and Johnson 1990). Treacy (1985) found mostly small schooling fish and squid in the stomachs of seven harbour porpoise found dead near the Columbia River.

An unusually large number of harbour and Dall's porpoise were found dead on southern Vancouver Island in 1993, but the cause of this mortality has not been determined (Baird et al. 1993a). Small numbers of both harbour and Dall's porpoise are eaten by killer whales in the transboundary area (Baird and Dill 1994).

Little information exists on harbour porpoise movements and stock structure in the transboundary area. This is an important concern because of the localized nature of some of the fishery-related mortality. Although it is suspected that harbour porpoise in some areas make extensive migrations (based on seasonal shifts in distribution), no evidence exists for migrations

in the transboundary area. Significant differences in the pollutant ratios of harbour porpoise along the U.S. west coast suggest that harbour porpoise populations may be somewhat discrete (Calambokidis and Barlow 1991).

Dall's Porpoise *(Phocoenoides dalli)*

Dall's porpoise occur year-round and breed in deeper waters (>50 m) of the transboundary area (Baird and Guenther 1991; Everitt et al. 1980; Osborne et al. 1988). Dall's porpoise are not considered depleted and are widely distributed throughout the North Pacific with an estimated abundance of over 1,590,000, though this figure may be overestimated due to vessel attraction (Hobbs and Lerczak 1993). Only limited research has been conducted on this species in the transboundary area.

Dall's porpoise abundance has not been determined for all the transboundary area, though estimates are available for some regions. Estimated abundances were 3,015 for Juan de Fuca Strait and 133 for the San Juan Islands area (Calambokidis et al. unpubl. data). Green et al. (1992) estimated an abundance of 2,149 Dall's porpoise in the waters off Oregon and Washington out to 185 km, but this estimate is probably low because it was not corrected for missed animals. Although Dall's porpoise are killed incidental to fishing operations in the transboundary area, there are no data on population trends or the impact that this is having on the population.

The degree of movement of Dall's porpoise in the transboundary area is not known. The year-round presence of Dall's porpoise in many areas may be indicative of resident animals or it could reflect the presence of different groups moving through the area. In Puget Sound, Dall's porpoise were seen year-round, but the low resighting rate of photographically identified individuals suggested interchange with other sites (Miller 1990). Densities of Dall's porpoise off the coasts of Oregon and Washington were not significantly different by season, although there was a seasonal shift in distribution with higher densities offshore in winter and spring and inshore in summer and fall (Green et al. 1992).

Dall's porpoise feed primarily on squid and small schooling fish (Jefferson 1988). Thirteen Dall's porpoise collected off Washington, including one off Juan de Fuca Strait, had been feeding on squid, capelin, eulachon, and righteye flounder (Stroud et al. 1981).

Killer Whale *(Orcinus orca)*

Two sympatric populations of killer whales are found within the transboundary area. These populations can be discriminated based on diet; one specializes on marine mammal prey (termed 'transient') and one specializes on fish prey (termed 'resident'). In addition to differences in diet, numerous other differences exist between transient and resident killer whales. These include differences in habitat use, surfacing patterns, vocalizations, group size, and social structure (Baird et al. 1992; Baird and Dill 1994; Bigg et al. 1987; Heimlich-Boran 1988; Morton 1990). Differences in external morphology (Baird and Stacey 1988; Bain 1989; Bigg et al. 1987) and mitochondrial DNA (Stevens et al. 1989; Hoelzel and Dover 1991) imply that these populations are reproductively isolated, and may in fact be incipient species (Baird et al. 1992). While a potential third form (termed 'offshore' killer whales) has also been recorded within the transboundary area (Walters et al. 1992), they have only been seen on one occasion and are not considered in detail here.

Both residents and transients are seen year-round and breed within the transboundary area, and can be predictably encountered in some areas at certain times of the year. Individuals of both forms have long-ranging movements (e.g., one pod of transient killer whales has a documented range of 140,000 km2), and thus regularly leave the transboundary area. Resident killer whales appear to be subdivided into two distinct populations in British Columbia; only one of which crosses the international border between Washington State and British Columbia, while the other ranges from the central Strait of Georgia north as far as southeastern Alaska (Bigg et al. 1976, 1987). This northern population (termed 'northern residents') numbers over 200 individuals, but as the centre of the range of these individuals lies outside of the transboundary area, our focus will be on southern residents and transients. The southern resident population numbers 96 individuals (ca. 1993). This population has been increasing 1.3 to 2.0% per year since live-capture of this species was stopped in 1977, and is now larger than the population size prior to the beginning of the live-capture program in 1962 (Olesiuk et al. 1990b). The range of the south-

ern resident population overlaps with the northern resident population by approximately 125 km on both the east and west coasts of Vancouver Island, but the core of the southern resident range lies within the waters of Haro Strait, the southern Strait of Georgia and eastern Juan de Fuca Strait. The population size for transient killer whales in BC/WA is unknown, but numbers at least 160 animals. New adult individuals are regularly discovered, so the total population size is probably much greater. No information is available on population trends however. To date, over 85 individual transients have been documented in the transboundary area, and additional individuals are documented in this area yearly (Baird unpubl.; M.A. Bigg unpubl. data; Baird and Dill 1994; Bigg et al. 1987).

The majority of prey recorded for resident killer whales have been salmon (Bigg et al. 1990b), but observations of prey taken are limited to those brought to the surface. Stomach contents from stranded animals implies that bottom fish are also regularly taken. Transient killer whales within the study area have been recorded feeding on both species of porpoises, both species of sea lions, elephant seals and several species of sea birds. By far the most important prey taken in this area is harbour seals however, comprising 96% of 136 marine mammals kills observed between 1986 and 1993 around southern Vancouver Island (Baird and Dill 1994).

Intensive research on this species has been undertaken in the transboundary area since the mid-1970s. In fact, the resident population is one of the most well-studied populations of cetaceans in the world. Ongoing research includes year-round monitoring of movements, photo-identification studies to monitor births and deaths in the populations, and behavioral studies.

Gray Whale *(Eschrichtius robustus)*

Over 20,000 gray whales migrate past Juan de Fuca Strait en route between their breeding grounds in Baja, Mexico and their primary feeding grounds in the Bering Sea (Buckland et al. 1993; Rice and Wolman 1971). Commercial hunting for gray whales reduced their numbers to under 2,000 earlier in the century. The eastern Pacific stock of gray whales has made a strong recovery since that time and is now thought to be close to its historical abundance. The U.S. National Marine Fisheries Service has recently recommended that the gray whale be removed from the endangered species list. The Korean stock of gray whales, in the western North Pacific, has not been so fortunate, however, and remains at precariously low levels (Rice and Wolman 1971).

Sightings of gray whales have been made in the transboundary area in all months of the year (Flaherty 1983), but most sightings in recent years have been in spring and summer (Calambokidis et al. 1992a). During and following the migration of gray whales past Washington and British Columbia in the spring, a small number of gray whales enter the transboundary area and spend extended periods feeding. Photographically identified individual gray whales have stayed for up to 4 months (Calambokidis et al. 1987, 1991c, 1992a) in these waters and some have returned for at least 4 consecutive years (Calambokidis et al. 1993b, in prep.). A number of gray whales have been identified feeding on both sides of the BC/WA boundary. Studies of the abundance and movements of gray whales in the transboundary area using photographic identification is continuing. Gray whales feeding for extended periods through the spring and summer in areas south of the Bering Sea have also been found off northern California (Mallonee 1991), Oregon (Sumich 1984), and along the west coast of Vancouver Island (Darling 1984).

Throughout the transboundary area, gray whales primarily use shallow areas close to shore for feeding. Gray whales feed primarily on amphipods and crustaceans that they capture by filtering water and sediment from the bottom (Nirini 1984). Prey types identified for gray whales in the transboundary area include ghost shrimp around Port Susan and Saratoga Pass (Weitkamp et al. 1992), and mysids (Murison et al. 1984) and ampeliscid amphipods (Oliver et al. 1984) along the west coast of Vancouver Island.

Varying numbers of gray whales wash up dead each year in the transboundary area, primarily in spring and summer. Starting in 1984, there has been concern and controversy regarding the role of pollutants in these deaths (Fouty 1984; Malins et al. 1984; Calambokidis 1992; Varanasi et al. 1993). Gray whales' ingestion of bottom sediments during feeding potentially exposes them to elevated concentrations of contaminants that occur in the upper layers of sediment in contaminated areas. Many of the animals that died in Puget Sound and Juan de Fuca Strait had very low fat reserves and were likely in poor nutritional condition (Varanasi et al. 1993). Causes of death of gray whales stranded in

Washington and British Columbia have included gillnet entanglements, boat collisions, and killer whale attacks (Baird et al. in press; Geiger and Jeffries 1983; Calambokidis et al. unpubl. data).

Minke Whale *(Balaenoptera acutorostrata)*

Minke whales have been reported from the transboundary area year-round (Everitt et al. 1980; Baird unpubl. data), although the majority of records are from March through November. World-wide, minke whales appear to be the most abundant species of baleen whale (U.S. Department of Commerce 1988). Population size and trends in the eastern North Pacific remain unknown however. Thirty individuals were photographically identified from the transboundary area around the San Juan Islands over a ten year period, and individual whales appeared to exhibit high site-fidelity, with many re-sightings of individuals in specific areas both within and between years (Dorsey et al. 1990). Population size within the transboundary area is unknown, but up to 19 individuals were photo-identified from around the San Juan Islands in a single year (Dorsey et al. 1990). Minke whales appear to be more common around the San Juan Islands than in other parts of the transboundary area, but little research effort has been extended in most other areas (particularly the Strait of Georgia and western Juan de Fuca Strait).

The transboundary area appears to function primarily for feeding; calving and mating in this species presumably occurs during the winter in lower latitudes. Most minke whales seen within the transboundary area are adults or subadults; the presence of calves has only been confirmed with two stranded animals (R. Osborne pers. comm.). Individual whales within the area seem to differ in foraging techniques, with some individuals primarily engaging in lunge-feeding, and others feeding in association with birds (Hoelzel et al. 1989). Feeding around the San Juan Islands appears to be concentrated in waters between 20–100 m in depth over submarine slopes with moderate inclines (Hoelzel et al. 1989). Regular sightings of travelling minke whales at East Point, Saturna Island, imply that some areas in The Strait of Georgia must be frequently used for feeding (Baird unpubl.). Two prey species have been identified in association with feeding minke whales in this area; juvenile herring and juvenile sandlance (Hoelzel et al. 1989).

Current research on this species within the transboundary area is limited to the collation of sighting records by the Marine Mammal Research Group in B.C. and by The Whale Museum in Washington State, and opportunistic photographic identification of individuals in the area around the southern tip of Vancouver Island and the San Juan Islands (e.g., Osborne et al. 1988; Dorsey et al. 1990).

Other Species

At least 16 additional species of marine mammals have been recorded within Juan de Fuca Strait, Puget Sound and the Strait of Georgia. Sea otters *(Enhydra lutris)* occur just outside the transboundary area on the northern Washington coast and the northwest coast of Vancouver Island, but a few sightings have been made inside Juan de Fuca Strait (Calambokidis et al. 1987; Jameson et al. 1986; Nagorsen 1986). The northern fur seal *(Callorhinus ursinus)*, typically an offshore species in this area, is an occasional visitor to these waters, usually with one or two records per year. Two species of baleen whale (right, *Eubalaena glacialis*, and fin, *Balaenoptera physalus*) were likely once seen occasionally in these areas until their populations were seriously depleted by commercial whaling, and they are no longer found here accept accidentally.

Humpback whales *(Megaptera novaeangliae)* were once considered common to the transboundary area including Puget Sound and the Strait of Georgia (Scheffer and Slipp 1948; Pike and MacAskie 1969). Though catch data from early years are not complete, several thousand humpback whales were killed primarily during summer months from 1905 to 1965 from whaling stations on the west coast of Vancouver Island (Pike and MacAskie 1969) and 1,933 were taken from 1911 to 1925 from a whaling station on the Washington coast (Scheffer and Slipp 1948). A smaller number of humpback whales were also taken commercially in the Strait of Georgia in two periods, from 1866–1873, and 1907–1908 (Merilees 1985). Sightings in the transboundary area are now uncommon, although a few humpback whales have entered and spent prolonged periods in these waters in recent years (Calambokidis and Steiger 1990). Humpback whales are regularly seen during summer months at Swiftsure Bank at the mouth of Juan de Fuca Strait (Calambokidis et al. unpubl. data).

Seven species of toothed whales have only been recorded in these waters as stranded animals. These include common dolphin *(Delphinus delphis)*, striped dolphin

(Stenella coeruleoalba), bottlenose dolphin *(Tursiops truncatus)*, Cuvier's beaked whale *(Ziphius cavirostris)*, a beaked whale of the genus *Mesoplodon*, Baird's beaked whale *(Berardius bairdii)*, and pygmy sperm whale *(Kogia brevirostris)* (Baird et al. 1993b, 1994; Osborne et al. 1988; Ferrero and Tsunoda 1989). Four additional species of toothed whales have been found in this area. Risso's dolphins *(Grampus griseus)* have been recorded in these inshore waters, but the last documented sighting was in 1977 (Baird and Stacey 1991). There are several sightings and one stranding record of short-finned pilot whales *(Globicephala macrorhynchus)* within the transboundary area within the last 20 years, but this species is very rare in this area (Baird and Stacey 1993). Besides a single record from Washington State in 1937, false killer whales *(Pseudorca crassidens)* were first regularly seen in this area in 1987 (Stacey and Baird 1991a). Since 1990, a lone false killer whale has been repeatedly seen in the transboundary area, generally ranging from Howe Sound in the north to southern Puget Sound. Pacific white-sided dolphins *(Lagenorhynchus obliquidens)* are occasionally seen in the northernmost part of the Strait of Georgia and in western Juan de Fuca Strait, but are generally only rare visitors to the transboundary area (Stacey and Baird 1991b).

HUMAN IMPACTS

Pollutant Impacts

A variety of contaminant types including chlorinated hydrocarbons, heavy metals and other trace elements, and petroleum hydrocarbons potentially impact marine mammals (see Risebrough 1978; Addison 1989; Wagemann and Muir 1984; Calambokidis et al. 1991a, for reviews). Some of the potential impacts are direct and fairly obvious, such as the mortality of sea otters from exposure to petroleum hydrocarbons after oil spills. Other potential effects are indirect and harder to measure. Determination of cause and effect relationships between problems and contaminants is extremely difficult without controlled experiments. Within the transboundary area there has been disagreement among researchers regarding the potential association between gray whale deaths and contaminants (Calambokidis 1992; Fouty 1984; Malins et al. 1984; Varanasi et al. 1993).

Extremely high concentrations of contaminants have been found in marine mammals from different parts of the world which has made these contaminants a primary concern. Coastal marine mammals that feed high on the food chain near contaminated areas, such as many pinnipeds and coastal odontocetes, have the highest concentrations. Among a number of species of marine mammals examined in the transboundary area, highest concentrations of chlorinated hydrocarbons have been found in harbour seals, harbour porpoise, and killer whales (Calambokidis et al. 1984, 1990, 1991b; Varanasi et al. 1993; Baird et al. 1993a; Muir et al. 1991). Concentrations in harbour seals have been highest in southern Puget Sound and have declined from the 1970s to 1991 (Calambokidis et al. 1985, 1991b)

Chlorinated hydrocarbons have been linked with a variety of problems in marine mammals. Premature births in California sea lions have been associated with elevated concentrations of DDT (DeLong et al. 1973; Gilmartin et al. 1976), and PCBs have been implicated in reproductive failure in ringed seals in the Baltic (Helle et al. 1976) and harbour seals in the Wadden Sea (Reijnders 1980, 1986). Recent studies have also implicated chlorinated hydrocarbons with reduced immune response in harbour seals (Brouwer et al. 1989; de Swart et al. 1993; Ross et al. 1993).

Although high concentrations of contaminants have been found in marine mammals from the transboundary area, evidence for their association with dysfunctions has been inconclusive or circumstantial. Newby (1973b) reported high rates of premature births and birth defects in harbour seals from southern Puget Sound in the early 1970s and suggested these were associated with contaminants. Studies since then have shown that PCB concentrations and the incidence of reproductive problems declined subsequently and that concentrations in the 1970s were similar to those reported to cause reproductive problems in other areas (Calambokidis et al. 1988, 1991a; Steiger et al. 1989). High concentrations of aluminum, once suggested as a potential cause of mortality in gray whales in Puget Sound, were not significantly different between animals found in California, Washington, and Alaska, suggesting that these seemingly high concentrations may be 'normal' for gray whales (Varanasi et al. 1993). Although some of the highest concentrations of contaminants have been found in killer whales, it has been difficult to evaluate their potential impacts. Reproduc-

tive rates are generally not known for transient killer whales, which have the highest concentrations of chlorinated hydrocarbons (probably due to their feeding on other marine mammals). In the 1970s and 1980s unexpectedly low reproductive rates were observed in southern resident killer whales that occupy the transboundary area, but these are potentially attributable to other factors besides contaminants (Olesiuk et al. 1990b). Levels of mercury among the highest recorded for any cetacean world-wide have been found in two resident killer whales in B.C., although one was from the northern resident population, which is not exhibiting low reproductive rates (Langelier et al. 1990; Baird unpubl. data).

Disturbance Impacts

The high level of human activities on and near the water in the transboundary area has the potential of disturbing marine mammals. For two species, killer whales and harbour seals, research has been conducted on the rate and potential effects of disturbance.

Killer whales in the transboundary area are regularly approached by pleasure boats, whale watch boats (primarily operating out of Friday Harbour and Victoria), scientific researchers, and commercial transport vessels. The number of boats approaching killer whales in Haro Strait has increased dramatically since the late 1980s (Osborne 1991). No apparent shifts in distribution or behaviour, however, have been observed in this region (Osborne 1991). Kruse (1991) reported that northern resident killer whales in Johnstone Strait (northeast coast of Vancouver Island) increase their speed in the presence of boats, though Duffus and Dearden (1992) dispute her conclusions. A study of killer whale reactions to vessels in the transboundary area by R. Otis (unpubl.) has found no immediate changes in behaviour which correlate to the presence of boats (Phillips and Baird 1993).

Harbour seals are one of the most wary pinnipeds to approach while hauled out, and typically enter the water upon approach. Harbour seals instinctual fear while hauled out most likely stems from the history of hunting of seals by aboriginal peoples and by other land carnivores (see Steiger et al. 1989 for example). At several haul-out areas in the San Juan Islands in the summer of 1991 and 1992, harbour seals were disturbed 48% and 89% of the days surveyed (Suryan 1993). Powerboats engaged in 'seal watching' were the primary cause of disturbance. Calambokidis et al. (1991d) found that kayaks disturbed harbour seals in Puget Sound at a significantly greater distance than other boats. Potential impacts of disturbance include separation of mothers and pups, interruption of nursing, and abandonment of haul-out areas. Given the rate of increase of harbour seal populations in the transboundary area, the population impacts from the current rate of disturbance cannot be large.

Fishery Conflicts

Marine mammal conflicts with fisheries can be categorized as direct or indirect. Indirect or ecological interactions involve competition for resources which are also used by humans. Declines in the populations of many of the gadoid species in the transboundary area due to over-fishing (Schmitt et al. this volume) could easily impact the many marine mammal species that prey on these species. While indirect interactions could have potentially devastating effects on marine mammal populations, determining the precise impacts of such interactions is difficult, and our discussion will focus on direct interactions. Such interactions include entanglement or collision with fishing gear as well as shooting that may occur in association with sport and commercial fisheries and salmon farming.

Three of the four species of pinnipeds commonly found in the transboundary area (harbour seals, California sea lions and Steller sea lions) are occasionally shot by fishermen. All four species of pinnipeds are killed due to entanglement in gillnets in waters adjoining the transboundary area, although data from within this area is limited. In British Columbia, aquaculture operations can obtain licenses to shoot harbour seals and California sea lions which interfere, or are thought to interfere, with salmon farms. These three species also are occasionally hooked on sports fishing gear. While they appear able to break lines in almost all cases, lodged hooks and trailing gear may interfere with feeding or cause infection. No detailed information is available to determine the impacts of these types of direct interactions between pinnipeds and fisheries in this area, but they likely do not have a significant effect on populations.

Mortality of harbour porpoise in gillnets has been a major concern in many portions of their range (Diamond and Hanan 1986; Hanan et al. 1986; Young et al.

1993). Along the Washington coast, up to a hundred harbour porpoise have been killed annually in a tribal set-net fishery, but this mortality has been dramatically lower in recent years (Gearin et al. 1990, 1993). Both harbour and Dall's porpoise have been recorded killed in fishing operations in the transboundary area. Within this area, harbour porpoise have been caught in commercial salmon drift gillnet fisheries, Native American set gillnet fisheries, and Canadian government test and research fisheries (Baird and Guenther in press; Everitt et al. 1980; S. Osmek pers. comm.; Stacey et al. 1989). For this species, such entanglement can even occur in rivers; one animal was killed in a Canadian government test fishery for salmon approximately 55 km up the Fraser River (Guenther et al. 1993). Dall's porpoise in this area have been caught in commercial drift gillnet fisheries and bottom fish trawl fisheries (Baird et al. 1988; Everitt et al. 1980; Stacey et al. 1989). Both species are occasionally caught in the salmon seine fisheries in this area, but mortality of captured animals in these fisheries appears to be lower than for gillnets, as some animals can be released alive (Stacey et al. 1990). Porpoises are also occasionally hooked on lines from sport fishing operations, but it is not known whether these individuals are killed (Baird unpubl.). Other species are also occasionally caught in fishing gear in the transboundary area. In 1989, a live humpback whale was observed in the northern part of the Strait of Georgia entangled in a salmon drift gillnet (Langelier et al. 1990). No observer programs exist for any of the fisheries for this area, so no information is available on the levels of incidental mortality or their impacts on local populations.

Research Needs

Although some species of marine mammals have received considerable research attention (e.g., harbour seals, killer whales), research on other species within the transboundary area has been extremely limited. Of critical importance to the conservation and management of marine mammals within this area is more information, particularly that necessary for evaluating potential impacts of human activities. Important information includes:

- Estimates of population size (particularly for harbour porpoise, Dall's porpoise and minke whales) within the Canadian waters of the transboundary area. Virtually no research has been undertaken on these species in the Canadian waters of the transboundary area.
- Information is needed on trends in the populations of most marine mammal species in the study area. This is especially critical for harbour porpoise and Dall's porpoise, as they are regularly killed in fisheries. In the case of harbour porpoise, there is circumstantial evidence of long-term declines in some areas, but this needs to be verified.
- A better understanding is needed of the stock structure and movements of marine mammals in the transboundary area. Evaluating the impacts of mortality on a population is not possible without a better understanding of the geographic range of the stock affected.
- The level of harbour porpoise and Dall's porpoise incidental mortality in the various commercial, Native and research fisheries needs to be estimated. Natural causes of mortality in all species of marine mammals within the transboundary area should also be investigated, to examine the effects of viral or bacterial outbreaks, as well as biotoxins, on populations.
- Research is needed on pollutant levels and potential impacts on marine mammals. The research that has been conducted, although limited, has indicated very high concentrations of contaminants in some marine mammal species in the transboundary area. Relatively few samples, obtained from the occasional strandings, have been analyzed. Additional data from biopsies of live animals would allow better evaluation of contaminant concentrations and relationship to reproductive success and other parameters. Marine mammals provide a good method for examining overall trends of contaminants in a broad sector of the marine environment.
- Information is needed on the community ecology of marine mammals. This includes an examination of competition between marine mammals and commercial fisheries. No research has been conducted on the impacts on marine mammals of declines in some of their primary prey due to overfishing.

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