A Preliminary Assessment of the Status of Marine Mammal Populations and Associated Research Needs for the West Coast of Canada

by

Jonathan H. Money

and

Andrew W. Trites

Marine Mammal Research Unit
Fisheries Centre, University of British Columbia
2204 Main Mall, Vancouver, B.C. Canada, V6T 1Z4

August 28, 1998

Executive Summary

There is a lack of information on the biology and distribution of marine mammals inhabiting the Pacific coast of Canada. The Department of Fisheries and Oceans has concentrated the majority of its recent efforts on three species: harbour seals, killer whales, and Steller sea lions. Little or no information exists on the other 22 species of marine mammals known to occur in British Columbia and what little does exist has largely been collected by a handful of independent researchers. This document reviews the information available on marine mammals in British Columbia and presents research needs on each of the species, identifies those species of greatest concern, and proposes a comprehensive census of marine mammals in the province.

Conservation needs suggest that the species needing more research attention are harbour seals, harbour porpoise, and Steller sea lions. Information is needed on trends in population size, distribution, and productivity. This will require annual or biannual surveys of areas frequented by these species and, in the case of harbour seals and Steller sea lions, long-term (7 -10 years) population studies using marked individuals at dedicated census sites.

Provincial trends in population abundance of these and other marine mammal species in British Columbia can be obtained by either surveying the entire coastline or, if this is not financially feasible, by surveying randomly chosen areas and extrapolating to the entire coastline. Average density from all surveyed sections can then be used to estimate total abundance and relative distribution in the province. The same areas should be resurveyed on a regular basis to provide information on changes in abundance and distribution.

A significant amount of research on marine mammals in B.C. waters has been conducted by universities and other groups who have provided considerable insight and depth to the amount of knowledge currently available on the marine mammals inhabiting B.C. However, a province-wide research plan is nonexistent. DFO can play a pivotal role in providing guidance, information, and a comprehensive research plan to address and identify research needs and future goals in British Columbia.

Table of Contents

Introduction

Little or no information exists on the biology and distribution of most of the marine mammals inhabiting the Pacific coast of Canada. The earliest marine mammal research in British Columbia focussed on measuring and sampling the great whales slaughtered at sea or at shore-side whaling stations. As whales disappeared from the BC coast, researchers began concentrating on harbour seals, Steller sea lions and killer whales that were thought to negatively affect commercially important fish species such as salmon (Baird and Guenther 1995). Diet, abundance and distribution of these 3 species have remained the heart of current marine mammal research within the Department of Fisheries and Oceans (DFO). There has been little or no research by DFO into the other 22 species of marine mammals that inhabit British Columbia's coastal waters. Independent researchers have filled some of this void.

Today, much of the Canadian public is not only concerned with the impact of marine mammals on commercial species of fish, but with the impact of fisheries on marine mammals. An increasingly greater segment of society (as shown by the growth of whale-watching and eco-tourism) appears to be interested in the conservation of marine life rather than its exploitation, preferring to watch it in the wild than to see it on a dinner plate or next to someone's skin. There is also a greater awareness of the possible effects of pollutants, toxins, entanglement and the loss of habitat on marine mammals, but a dearth of information to address the questions being posed.

Currently, DFO employs one marine mammal biologist and one technician to study, survey, and address concerns of both public and commercial interests along the entire Pacific coast of Canada. Growth in eco-tourism (particularly whale-watching), aquaculture, and the sport fishing industries in British Columbia have brought a new set of issues involving marine mammals to the forefront which will need to be resolved in the near future. The current low level of staffing for DFO on the Pacific coast will likely be stretched thinner at the expense of meaningful and useful research.

Universities and other groups have conducted a significant amount of research on marine mammals in British Columbia waters. Researchers at the University of British Columbia, Simon Fraser University, University of Victoria, Vancouver Aquarium, West Coast Whale Foundation, and the Marine Mammal Research Group have provided considerable insight and depth to the amount of knowledge currently available on the marine mammals inhabiting B.C. However, the development of a province-wide research plan does not exist. DFO can play a pivotal role in providing guidance, information, and a comprehensive research plan for the province to help identify research needs and goals. Marine mammal research is a complex puzzle that takes a long-term commitment to place all the pieces together.

The following contains a series of species summaries for 25 species of marine mammals inhabiting BC waters (Table 1). Each summary contains a brief synopsis of current knowledge about their life history, diet, abundance, distribution, population status, fishery interactions and research needs. The summaries are by no means exhaustive and

are presented as a first attempt to document the current status of research and knowledge about marine mammals in British Columbia. Researchers are encouraged to point out shortcomings and omissions to expand the summaries and make them more complete.

Research Needs

The research needs we propose in the species summaries are suggested lines of research and approaches that we feel will provide baseline information and expand current levels of knowledge. Again we encourage other researchers to contribute their ideas and suggestions so that this document might act as a blueprint to assist future research.

There are many lines of research that can be pursued with marine mammals. They span the fields of ecology, physiology, behaviour, genetics, toxicology, and anthropology, to name a few. All are valid areas of research, making the task of identifying research needs and priorities difficult. The guiding principle we have applied throughout this document is a need for conservation of marine mammal species. Research that enhances conservation must, by necessity, take precedence over other types of marine mammal research. For if there are no individuals of a species alive to study, all lines of research become moot.

Applying the conservation principle means that the highest research priority should be a comprehensive aerial survey of marine mammals on the Pacific coast. This survey should consist of zig-zag transects flown from shore to at least the 1000m isobath. Multiple observers (2 to 3) will be needed to insure sighting accuracy and species identification. Randomly chosen sections of the coast should be initially surveyed in summer and late fall/early spring. This will allow for extrapolation of population estimates to the entire coastline. Eventually, a full census of the entire coastline should be performed. This will provide a baseline for assessing future impacts of aquaculture, eco-tourism, fisheries, and disease on these populations.

The second major research priority should be to focus greater research attention on species that are at risk of extinction (i.e. harbour porpoise and Steller sea lions) or which are in the greatest conflict with other resources or users (i.e. harbour seals). The species reviews contained in the following pages suggest that trends in population size, distribution, and productivity should be determined for harbour seals, harbour porpoise, and Steller sea lions. Harbour seals are the most prolific predators of salmon and other commercially valuable fish stocks. A better understanding of the population dynamics and the extent of predation on salmon will help to determine what measures need to be taken, if any, to mediate the perceived conflicts. This is important for both fisheries and seals, since high seal densities can lead to die-offs through nutritional stress and disease epidemics.

Harbour porpoise numbers appear to be declining along the Pacific coast of Canada. These small porpoises come into regular contact with pollutants and are also incidentally caught in gillnets placed close to shore. Very little information is available on these animals in British Columbia. Harbour porpoise may be an excellent sentinel species for

Table 1. The abundance and seasons of residence of marine mammals in the waters of British Columbia.

Species	Abundance*			Season of residence			
	C	U	R	Sp	Su	F	W
Pinnipeds							
Harbour Seal	X			X	X	X	X
Steller Sea Lion		X		X	X	X	X
California Sea Lion		X		X		X	X
Northern Elephant Seal				X	X	X	
Northern Fur Seal		X		X	X		
Porpoises							
Harbour Porpoise		unknown		X	X	X	X
Dall's Porpoise		X		X	X	X	X
Dolphins							
Killer Whale	X			X	X	X	X
Pacific White-sided Dolphin	X			X	X	X	X
N. Right Whale Dolphin		unknown		X	X	X	
Risso's Dolphin		unknown			unknown		
False Killer Whale		X			unknown		
Short-finned Pilot Whale			X		unknown		
Striped Dolphin			X		unknown		
Toothed Whales							
Sperm Whale	X				unknown		
Beaked Whales		unknown			unknown		
Baleen Whales							
Humpback Whale		X		X	X	X	X
Gray Whale		X		X	X	X	
Minke Whale	X			X	X	X	X
Fin Whale		X		X	X	X	X
Northern Right Whale			X		unknown		
Sei Whale		X			X		

* C = common, U = uncommon, R = rare

detecting high levels of pollutants in nearshore waters. Information is needed immediately to assess the status of the harbour porpoise population in British Columbia.

Steller sea lions populations in Alaska have undergone one of the most drastic declines ever recorded for a marine mammal not being actively hunted. The population in Canada is thought to be currently stable or growing slowly, but the future is uncertain for this species. One of the major problems that Steller sea lion researchers in Alaska have faced is the lack of sufficient data from the populations before the decline began. Without baseline data, assessing changes in the population structure and ultimately finding the cause for population changes is very difficult. Baseline information on Steller sea lions is needed to assess their status in Canada (they are currently listed as threatened with extinction in southeast Alaska) and determine if measures are needed to further protect the Canadian populations.

Species Summaries

The length of each of the 25 species summaries that follow generally reflect the overall importance of the species in the province or the amount of effort that has been spent studying it. A number of marine mammal species occur only incidentally in the waters off British Columbia. Many of these species are migratory and are sighted only seasonally. Others are at the extreme limit of the range and are considered rare in the province (Table 1). Brief summaries of their occurrence and importance in British Columbia appear at the end of each group section (pinnipeds, porpoises, dolphins, toothed whales, and baleen whales).

In writing the species summaries, we found we repeatedly outline three basic research strategies. The first concerns a generalized approach to estimating population abundance by surveying populations in randomly selected areas of British Columbia, and extrapolating the results to estimate province-wide abundance. The second research strategy involves collecting data from marked individuals (either natural or man-made) to gather information about life history and to estimate population parameters (birth rate, death rate, longevity, etc.). The third is to establish a sighting and stranding information database through coordinated and incidental observations.

Population abundance and trends can be obtained by either surveying the entire coastline or by surveying randomly chosen areas and extrapolating to the entire coastline. The cost of surveying the entire British Columbia coastline is high and can be reduced by dividing the coast into equal sections (in km). Several sections could then be chosen at random and surveyed. Average density from all surveyed sections can then be used to estimate total abundance and relative distribution in the province. The same areas should be resurveyed on a regular basis to provide information on changes in abundance, distribution and trends.

Much of the success of studying killer whales in British Columbia has come from the ability to recognize individual animals from distinctive natural markings on their dorsal

fins and saddle patches. Resighting individually recognizable animals provides life history information and data to calculate population parameters (e.g. life tables) and population growth rates. The types of markings that can be used are species specific as discussed in each of the species summaries. For large cetaceans, photographic identification using patterns on the dorsal fins and flukes is possible, whereas man-made mark (tags, brands, etc.) can be applied to identify individual pinnipeds and smaller cetaceans. Censuses should be conducted annually or biannually when populations are concentrated at rookeries, haul-outs and feeding grounds.

A sighting and stranding information database that draws upon the collective expertise of people living on the coast can provide a wealth of information about marine mammals in British Columbia. Coordinated and incidental observations can be obtained from mariners (fishermen, whale-watchers, etc.) and other interested people through logbooks and scheduled questionnaires. Data quality can be enhanced through training seminars on species recognition and data recording. Several identification guides specific to the Pacific coast have already been produced and may be useful references for observers. Observers would be expected to record effort (hours of observation, number of observers and equipment used) to ensure greater estimate precision and to help correct for seasonal differences in observer effort. They can also be enlisted to report stranded animals or to take biopsy and genetic samples for future analyses.

Involving local people and groups (schools, eco-tourists, fishermen, and environmentalists) will foster a sense of responsibility and stewardship in our coastal ecosystems. A closer liaison between DFO and the public may also help to reduce misunderstandings / misconceptions and improve cooperation in the future.

Maintaining public input and interest will require that the people volunteering their time are provided meaningful feedback. A world-wide-web site (or an additional page on the existing DFO web-site) is a rapid and inexpensive way to communicate and exchange information. It will allow for uploading of individual sightings or logs and can be used to distribute information to observers. This may be especially useful for maintaining contact with observers in more remote parts of the province. The ability to publish high quality photos of species will provide a readily accessible and updatable database to increase individual and species recognition. Providing reasonably up-to-date reports on sightings and movements will increase public awareness and interest in the studies.

Species Summaries

Harbour Seal (*Phoca vitulina richardsi)*

Harbour seals occur primarily in coastal and estuarine habitats throughout British Columbia (Figure 1). Harbour seals are considered non-migratory, but have been known to travel 300-500 km to find food or breeding sites (Herder, 1986). Local movements have been associated with such factors as tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Harbour seals haulout on the mainland as well as offshore islands, sandbars, rocky shores, and beaches. Individuals show strong preferences for particular haulout sites (Pitcher and Calkins 1979, Pitcher and McAllister 1981).

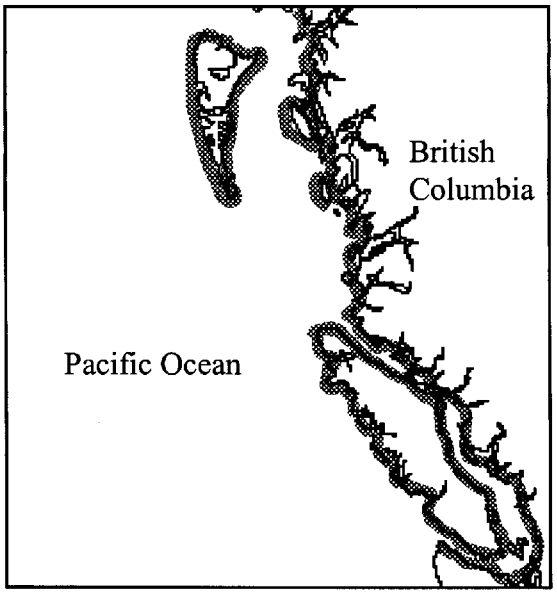

Figure 1. The occurrence of harbour seals on the coast of British Columbia.

Harbour seals tend to be solitary when swimming (except for females with pups), but may form groups of up to several hundred when hauled out. Harbour seals may also forage in groups of 2 to 6 individuals when hunting larger prey (Olesiuk et al., 1990a).

Female harbour seals give birth to a single pup. Pups are precocious and able to swim at birth (Bigg, 1981). Pupping occurs in July and August in the southern British Columbia population. In the northern parts of the province, pupping starts in June and extends into July (Bigg, 1969). Differences in the timing of pupping reflect the genetic uniqueness of the populations of harbour seals that inhabit British Columbia (Burg et al., 1996).

Diet

The harbour seal is an opportunistic predator with a diet that varies regionally and seasonally with prey availability. The diet of harbour seals in Georgia Strait is composed primarily of Pacific hake and herring (42.6% and 32.4% of the overall diet, respectively, Olesiuk, 1990b). Hake, moving to shallower water after spawning were the primary prey consumed from April to November. Herring had the greatest prevalence in scat samples from December to March. This coincides with their annual emigration into the Strait of Georgia.

Salmonids are a seasonal component of harbour seal diets comprising 4.0% of the overall diet (Olesiuk et al., 1990b). Seasonal movements of harbour seals into estuaries are related to movement of prey species, particularly salmon. Olesiuk et al. (1990b) found

the majority of samples containing salmonid remains were from estuaries. Approximately 5% to 17% of the harbour seals in British Columbia are estimated to occur in estuary areas.

Abundance, Distribution and Population Status

Three genetically distinct populations of harbour seals have been identified in British Columbia (Burg et al., 1996). Genetic analysis of tissue and blood samples revealed the existence of a northern population, a southern population, and a smaller genetically distinct group of seals on southern Vancouver Island (Figure 2). Management of the harbour seal population in British Columbia may require different strategies for each population.

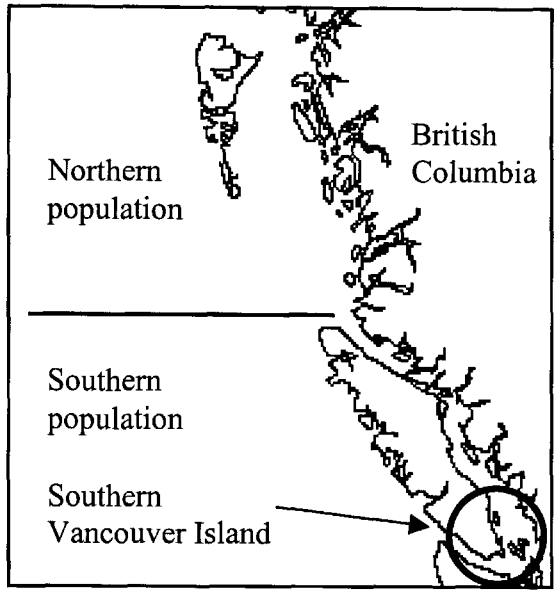

Figure 2. Harbour seal populations in British Columbia based on genetic differences.

Life history parameters specific to this province are needed to assess the net population growth rate for harbour seals in British Columbia. Estimates of age specific birth and mortality rates will allow the production potential of the species to be evaluated. A mark/recapture-resight strategy using marked individuals is the most suitable method for achieving this goal.

The population of harbour seals in British Columbia increased by approximately 12.5% annually from 1973-88 (Olesiuk et al., 1990a). The estimated post-pupping population increased from 9,000-10,500 in 1970 to 75,000-88,000 in 1988 (Olesiuk et al., 1990a). Harbour seals were culled heavily from 1913 to 1969. They were protected in 1970 and are believed to have returned to historical population levels by 1988. Since 1988, the population has continued to increase (Olesiuk, pers. comm.). No density-dependent changes were noted in the population growth rate, suggesting that it had not yet reached carrying capacity in 1988 (Olesiuk et al., 1990a). A net productivity rate was estimated for harbour seals in California at 9.7% (Barlow et al., 1995) and in Oregon at 6-9% (Brown 1986; Harvey 1987). The rate estimated for the British Columbia population is higher.

Population size is most commonly estimated by counting the number of seals ashore during peak haul-out periods (low tide). Haul-outs are photographed from the air and the seals counted from the photographs. This count is multiplied by the inverse of the estimated fraction of seals on land (a correction factor). Olesiuk et al. (1990a) used correction factors between 1.0 and 1.25 for harbour seal population estimates in British Columbia. These correction factors were based on the time interval between pupping and

surveys and the number of animals missed in the survey. Boveng (1988) concluded that a correction factor for harbour seals in California is likely between 1.4 and 2.0. Huber et al. (1993) estimated a mean correction factor of 1.61 (CV=0.062) for harbour seals in Oregon and Washington. This is the value currently used by NMFS to estimate harbour seal population size in U.S. waters (Barlow et al., 1995). Separate correction factors may need to be estimated for both the northern and southern populations in British Columbia.

The average estimated density for 1988 of harbour seals in British Columbia was 3.51 seals/km (Olesiuk et al, 1990a). The greatest estimated harbour seal population densities for 1988 were in the Strait of Georgia (5.01 seals/km) and Lower Skeena River (5.17 seals/km)(Olesiuk et al., 1990a). The lowest densities were recorded in the northeast Queen Charlotte Islands (1.48 seals/km) and Queen Charlotte Strait (1.92 seals/km).

Harbour seals radio-tagged in Boundary Bay and the Gulf Islands traveled up to 50 km (Huber et al., 1996). Animals from Boundary Bay were detected in the Fraser River, Gulf Islands, and San Juan Islands. Seals tagged in the Gulf Islands were observed in the San Juan Islands. More information on population movements needs to be collected. The effect of these movements on repetitive or annual surveys needs to be assessed.

Seal-fishery interactions

Fishermen generally regard harbour seals as a nuisance. Harbour seals occasionally remove or damage fish caught in fishing gear (nets, lines) and prey on commercially valuable fish species (Beach et al., 1985). They have also been reported to "steal" bait and sportfish from hooks. The species of greatest concern in British Columbia are salmonids.

Harbour seals numbers in estuaries increase at times when migrating adult salmon return to spawn (Bigg et al., 1990). Smolts returning to the ocean can also fall prey to harbour seals (Olesiuk et al., 1995; Jurk et al., 1996). Bigg et al. (1990) estimated that 1 - 46% of the fall run of salmonids were consumed by harbour seals at two sites in British Columbia.

Insufficient information is currently available to thoroughly assess the impact of harbour seal predation on commercially important prey species.

Harbour seals are caught incidentally in fishing operations. Set gillnet and drift gillnet fisheries in the U.S. have been implicated in harbour seal kills (Barlow et al., 1995). Harbour seal populations may also be affected by reduction of their prey by fisheries (Olesiuk, 1993). This in turn may impact predators of harbour seals, including killer whales.

Research Needs:

Major questions concerning harbour seals center around their numbers and their impact on salmon. Most of what is currently known about harbour seals is based on studies of

the southern inside-water population. Comparatively little is known about harbour seals in the northern population.

Abundance and Distribution

Harbour seal surveys are currently flown every 2 to 3 years, with the goal of covering portions of the BC coastline. Particular attention needs to be paid to the northern population. Consideration should be given to surveying randomly selected areas every 1 - 2 years.

Data should also be gathered on the survival rates and birth rates of harbour seals. This will allow for estimation of the parameters necessary to monitor the status of the harbour seal population in British Columbia. Currently the only means of gathering this information is by shooting a random sample of individuals, or by marking (e.g. branding) a known cohort. Consideration should be given to branding harbour seal pups and putting effort into resighting individuals in subsequent years.

Significant die-offs of harbour seals and other pinnipeds have been reported at various times around the world. Typically, government agencies have been at a loss to explain these declines to the public because insufficient historic information was available. Die-offs caused by disease, man-made toxins, or dinoflagellates can be distinguished if samples from the dead and dying are compared to archived samples. Blood and tissue samples are the primary means of gaining this information.
Specific recommendations for harbour seal research in British Columbia include:

1) *Survey randomly selected areas of BC.* Current sampling methods used to count harbour seals appear sound (Olesiuk et al., 1990a). However, to obtain an estimate for the entire province, either the entire coastline must be surveyed, or randomly chosen areas must be surveyed and extrapolated to the entire coastline.

   Surveys should be conducted annually or biannually for several consecutive years. One survey should be scheduled shortly before pupping begins. A second survey should be conducted post-pupping. This strategy will provide information on the number of pups produced over the pupping season and also survival between years. The post-pupping survey can be timed to coincide with the autumn molt. The maximum numbers of animals are hauled-out during this period, increasing the accuracy of the count.

   Aerial surveys are the most efficient. Surveys should be conducted in good weather with calm seas. Photographs can be used to make counts of groups too large to reliably count during the survey. Movement between sites as determined above may be useful to refine population estimates by formulating a method to account for movement out of and between census sites.

2) *Hot-brand pups in designated study areas.* Marking and resighting cohorts of harbour seals will allow survival and birth rates to be calculated. This in turn will

provide information about physical condition, population regulation and the rates of population change. Two or more study areas may be necessary to assess differences in the northern and southern populations. Pups will need to be captured to determine length, weight, and sex.

Jeffries et al. (1993) have developed a successful method for capturing and handling harbour seals at haulouts on sandbars and mudflats. Using a 12-person team, two boats deployed a seine in front of and encircling the haulout and brought the net and any caught seals to shore. Each seal was then placed headfirst into a hoop net until measured and marked. This method may not work in rocky areas, so alternative strategies will need to be devised for these areas (e.g. gill nets, cannon nets). Study area selection must therefore consider the feasibility of capturing seals.

Brands should be numbered and could have different designations for sex (M or F) and year (1-4). This will facilitate sighting by untrained observers (see 3 below). Study duration will likely be 10 years (2 to 4 years of branding, 6 to 10 years of observation). This will provide estimates of fecundity, pup survival, and movement patterns. In addition to incidental sightings, an annual survey should be conducted post-pupping in the study area(s). It is recommended that the study area(s) be of moderate size (<200 pups) to allow for a complete census. An area previously surveyed would be preferred. Multiple areas could be used, but only if funding and manpower allow for complete census of all areas.

Hot-branding has been recommended over other options such as tagging, photo-ID, or electronic ID methods. Tags are not permanent and their readability is variable. Branding gave better results on Steller sea lion pups in Alaska than tagging (Merrick et al., 1996).

3) *Sighting and stranding information.* A considerable amount of information can be gathered through coordinated and incidental observations (see Introduction).

4) *Population monitoring - Disease and parasites.* Blood samples should be drawn from pups captured for branding (see 2 above) and from a random sample of adults. These samples can then be used to screen for disease to determine present and past exposure to disease. Historical disease data can also be used to identify emerging disease agents which may be responsible for future or current outbreaks and ultimately reduce the scope of their impact. Stomach contents and intestinal tracts can be collected from stranded and fishery killed animals to determine parasite loads. This could prove valuable to fishery managers since harbour seals are known to be one of the terminal hosts for nematodes that infest many species of fish, reducing marketability (Scott, 1953).

Diet and Fishery conflicts

The perpetual question is how much salmon are harbour seals eating. This information can be gained from stomach contents, scat analysis, fatty acids (in blood and blubber) or stable isotopes (in hard parts such as bones and vibrissae). These last two techniques are still in the developmental stage, are expensive, and may not provide any more information than what can be gained from stomach and scat analysis. The method that has gained the widest acceptance over the past decade is scat analysis. Much of the refinement of this methodology has been developed at the Pacific Biological Station. Dietary analysis can show what portion of the diet is made up of salmonids and other species. It can also indicate seasonal and annual changes in prey abundance. Marine mammals are excellent samplers of their environment and can reveal much about the relative abundance of species managed by DFO.

5) *Scat collections*. The scatological diet research conducted by Olesiuk et al. (1990b) should be continued and expanded. Approximately 80 scat samples are required per collection to accurately describe and detect changes in diet (Trites et al., unpubl. data). For example, to compare diet differences between summer and winter at one site, 80 scats would have to be collected in summer and another 80 scats collected in the winter.

   One or two sites for both the northern and southern populations should be identified as long term monitoring sites. Samples should be collected at these sites seasonally, every year to identify seasonal changes in diet and relative abundance of prey. Specific collection strategies can be used to maximize the information gathered about species of primary concern. Collecting scats in spring and fall would provide more information on salmon and herring consumption than winter and summer collections (when these species compose a smaller proportion of the diet). Scats should be collected in the census areas (see 2 above) to correlate diet with pupping success and movement patterns.

Harbour seals are perceived by many as causing the declines of salmonid stocks. Dietary information can help to address this issue by demonstrating how little of the average harbour seal diet is composed of salmon. However, this does not address the issue of salmon specialists or problem animals. Some seals do feed on large numbers of returning adults or outgoing smolts in estuaries and rivers. This is a major issue from California to Alaska that needs further research to be adequately addressed.

6.) *Predator control.* Commercial fishermen are probably the most directly affected by harbour seal damage to fishery gear and caught fish. Gillnetters are likely more affected than other gear types. A survey could be formulated and distributed to assess the scope of the problem and receive input on possible solutions.

   Various devices that "scare" seals away may be helpful in reducing seal predation on salmonids in a some areas. Further testing should be conducted on these

acoustic deterrent devices as a means of discouraging predation on salmonid smolts and fry in the spring and adults returning to spawn in summer and fall. These devices have had limited experimental trials, but appear to be the most effective means of those studied (Jurk et al., 1996).

Other deterrents should also be investigated. Optical devices, feeding barriers, and release of smolts directly into estuaries are all possible means to decrease smolt losses from seal predation.

Study Sites

As previously mentioned, at least two long term study sites (one each in the northern and southern parts of the province) are needed for a reasonable assessment of harbour seal population parameters in British Columbia. Using areas that have been previously studied would allow for results to be put in a historical context. Suitable areas include: Lower Skeena River (northern, high density), Queen Charlotte Islands (northern, low density), Comox Harbour (southern, high density), and Southwest Vancouver Island (southern, low density, e.g. Barkley Sound).

References

Barlow, J., R. L. Brownell, Jr., D. P. DeMaster, K. A. Forney, M. S. Lowry, S. Osmek, T. J. Ragan, R. R. Reeves, and R. J. Small. 1995. U.S. pacific marine mammal stock assessments, 1995. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-219. 162 p.

Beach, R. J., A. C. Geiger, S. J. Jeffries, S. D. Treacy, and B. L. Troutman. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980-1982. Third Annual Rep. NOAA, NMFS Grant No. 80-ADB-0012. 316 p.

Berggren, P., and F. Arrhenius. 1995. Densities and seasonal distribution of harbour porpoises (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas. Report of the International Whaling Commission, Special Issue 16: 109-121.

Bigg, M. A. 1969. The harbour seal in British Columbia. Bull. Fish. Res. Board Can. No. 172. 33 p.

Bigg, M. A. 1981. Harbour Seal, *Phoca vitulina* Linnaeus, 1758 and *Phoca largha* Oallas, 1811, p. 1-27 *In* S. H. Ridgeway and R. J. Harrison (ed.) Handbook of marine mammals. Vol. 2. Seals. Academic Press, London, U. K. 359 p.

Boveng, P. 1988. Status of the Pacific harbor seal population on the U. S. west coast. Southwest Fisheries Center, NMFS. Admin. Rept. LJ-88-06. 43 p.

Brown, R. F. 1986. Assessment of pinniped populations in Oregon. Processed Report, NMFS, Northwest and Alaska Fisheries Center, Seattle, WA.

Burg, T. M. 1996. Genetic analysis of eastern Pacific harbour seals (*Phoca vitulina richardsi*) from British Columbia and parts of Alaska using mitochondrial DNA and microsatellites. M. Sc. thesis. University of British Columbia. 77 p.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bull. Fish. Res. Board Can. No. 93. 58 p.

Harvey, J. T. 1987. Population dynamics, annual food consumption, movements and dive behaviors of harbor seals, *Phoca vitulina richardsi*, in Oregon. Ph. D. thesis, Oregon State University. 177 p.

Herder, M. J. 1986. Seasonal movements and hauling site fidelity of harbor seals, *Phoca vitulina richardsi*, tagged at the Russian River, California. MS Thesis. Humboldt State Univ. 52 p.

Huber, H., S. Jeffries, R. Brown, and R. Delong. 1993. Abundance of Harbor seals (*Phoca Vitulina richardsi*) in Washington and Oregon, 1992. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Huber, H. R., S. J. Jeffries, R. F. Brown, and R. L. DeLong. 1996. Harbor seal stocks in Washington and Oregon: evidence from pupping phenology, tagging, and genetics studies. NMML, Seattle, WA.

Jeffries, S. J., R. F. Brown, and J. T. Harvey. 1993. Techniques for capturing, handling and marking harbour seals. Aquat. Mamm. 19:21-25.

Jurk, H., A. W. Trites, C. L. Wilson, G. M. Ellis, and J. K. B. Ford. 1996. Reducing the predation on outmigrating juvenile salmonids caused by harbour seals (*Phoca vitulina*) in the Puntledge River, British Columbia. Report for the Department of Fisheries and Oceans (unpubl.). 28 p.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1996. Hot branding: a technique for long-term marking of pinnipeds. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-68, 21 p.

Olesiuk, P. F. 1993. Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fish. Bull. 91: 491-515.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990a. Recent trends in the abundance of harbour seals, *Phoca vitulina*, in British Columbia. Can. J. Aquat. Sci. 47:992-1003.

Olesiuk, P. F., M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990b. An assessment of feeding habits of harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. Aquat. Sci. No. 1730, 135pp.

Olesiuk, P. F., G. Horonowitsch, G. M. Ellis, T. G. Smith, L. Flostrand, and S. C. Warby. 1995. An assessment of harbour seal (*Phoca vitulina*) predation on outmigrating chum fry (*Onchorhynchys keta*) and coho smolts (*O. kisutch*) in the lower Puntledge River, British Columbia. PSARC Document.

Pitcher, K. W., and D. G. Calkins. 1979. Biology of the harbour seal, *Phoca vitulina vichordsi*, in the Gulf of Alaska. Final report. Outer Continental Shelf Environmental Assessment Program, Research Unit 229, Contract no. 03-5-002-69. 79 p.

Pitcher, K. W., and D. C. McAllister. 1981. Movements and haul-out behaviour of radio-tagged harbour seals, *Phoca vitulina*. Can. Field-Nat. 95: 292-97.

Scheffer, V. B., and J. W. Slipp. 1944. The harbor seal in Washington State. Am. Midl. Nat. 32: 373-416.

Scott, D. M. 1953. Experiments with the harbour seal, *Phoca vitulina*, a definitive host of a marine nematode, *Porrocaecum decipiens*. J. Fish. Res. Board Can. 10: 539-547.

Steller sea lion (*Eumetopias jubatus*)

Steller sea lions range in the eastern North Pacific Ocean from California to Alaska, and are distributed throughout the coastal waters of British Columbia (Figure 1). Bigg (1985) found 5 rookeries, 15 summer haulouts and 29 winter haulouts along the coast. A coastwide survey in the summer of 1987 counted 7,000 Steller sea lions, including 1,200 pups (Bigg as cited in Cowan, 1988). Aerial surveys in 1994 produced a count of 9,277 animals (Hill et al., 1996). The population may be increasing slowly, but insufficient information exists to determine the rate of increase.

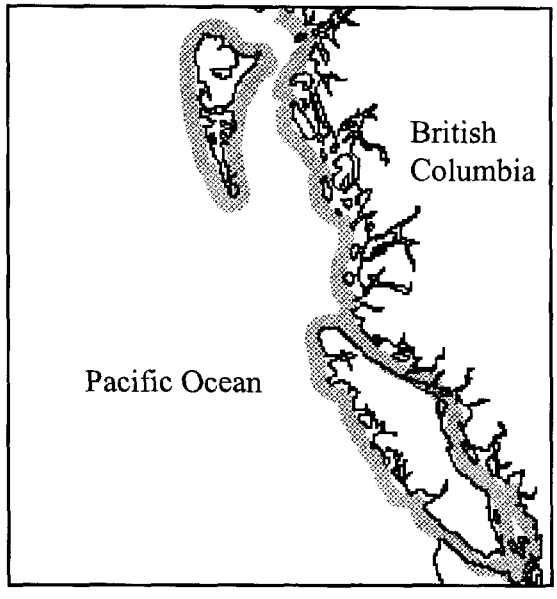

Figure 1. The known distribution of Steller sea lions in British Columbia.

The population of Steller sea lions in the Aleutian Islands and Gulf of Alaska has declined by over 70% since the mid 70's (Trites and Larkin, 1996). The species was declared endangered in the Aleutians and Gulf of Alaska in 1997 by the U.S. They are listed as threatened with extinction in southeast Alaska.

Since 1989 the population decline has slowed in the eastern Aleutians and western Gulf of Alaska. Increases have occurred in the smaller populations of southeast Alaska and northern British Columbia (Trites and Larkin, 1996). The reasons for the decline in Alaska is not known and the future of the populations of Steller sea lions in the eastern North Pacific Ocean is uncertain.

Steller sea lions breeding on the coast of British Columbia represent about 5% of the world population and are believed to reside in the province year-round (Malouf, 1986). The population may increase in the winter months as animals from the rookery at Forrester Island, Alaska move south at the end of the breeding season (Cowan, 1988). The number summering in British Columbia is not known.

Diet

The diet of Steller sea lions has not been extensively studied in British Columbia. However, the diet of sea lions present at the Forrester Island rookery and haul-outs along the Alaska-BC border have been examined using scat analysis. The results of this study do give an idea of what Steller sea lions in British Columbia may be eating. Gadids were the most common prey type present in scat samples (Trites and Money, unpubl. data). Small schooling species (particularly herring and sandlance), demersal species, and salmon species were the next most common in descending order. Salmon were more

often present in scats collected in the summer than in the winter and the same was true for demersal prey types.

The diet of Steller sea lions appears to change with season (Trites, Calkins, and Money, unpubl. data). Winter samples contained greater proportions of gadids and cephalopods (39.8% and 9.7%, compared to 25.9% and 2.2% for summer, respectively) , while summer samples had greater numbers of salmon (20.5%) and small schooling species (24.9%) than winter samples (6.7% and 18.3%, respectively). Bigg et al. (1990) recorded Steller sea lions catching and eating fall run prespawning salmon in Cowichan Bay. Other areas where this occurs have not been reported.

Sea lion-fishery interactions

Steller sea lions were regarded as a nuisance by the fishing industry and were hunted heavily from 1913 to 1965 to reduce their numbers in British Columbia. Several breeding colonies were destroyed and have not been reoccupied (Cowan, 1988).
In Alaska, Steller sea lions have been incidentally caught in trawl nets and have been blamed for damaging fishing gear and caught fish (Loughlin and Nelson, 1986). Data is currently not available on Steller sea lion interactions with fisheries in British Columbia.

Research Needs:

The main emphasis of Steller sea lion research in British Columbia has centered around their impact on salmon. Given the rates of decline of the populations in Alaska, greater knowledge of their abundance and distribution is needed.

Abundance and Distribution

Steller sea lion surveys are currently made sporadically, with the goal of covering portions of the northern BC coastline, especially rookery sites. Particular attention needs to be paid to the northern breeding population. Consideration should be given to surveying randomly selected areas every 1 - 2 years.

Data should also be gathered on the survival rates and birth rates of Steller sea lions in British Columbia. This will allow for estimation of the parameters necessary to monitor the status of the population in British Columbia. Currently the only means of gathering this information is by shooting a random sample of individuals, or by marking (e.g. branding) a known cohort. Consideration should be given to branding Steller sea lion pups and putting effort into resighting individuals in subsequent years.

Significant die-offs and population declines of sea lions have been reported at various times in California and Alaska. Typically, government agencies have been at a loss to explain these declines to the public because insufficient historic information was available. Die-offs caused by disease, man-made toxins, or dinoflagellates can be distinguished if samples from the dead and dying are compared to archived samples. Blood and tissue samples are the primary means of gaining this information.

Specific recommendations for Steller sea lion research in British Columbia include:

1) *Survey randomly selected areas of BC.* Current sampling methods used in the U. S. to count Steller sea lions have been published (Sease et al., 1993), but differ slightly from those used in Canada. Ideally, estimates should be obtained for the entire province by surveying the entire coastline, or by surveying randomly chosen areas and extrapolating to the entire coastline.

   Surveys should be conducted annually or biannually for several consecutive years. One survey should be scheduled shortly after pupping ends. A second survey should be conducted in late fall/early spring. This strategy will provide information on the number of pups produced over the pupping season and also the number and dispersal of animals from the rookery. The late fall/early spring survey will help identify winter feeding areas and haulouts that are important for this species. It will also allow for estimates of the number of animals migrating into the province from other areas and/or the number emigrating out of the province. This may be important for determining management strategies for trans-boundary stocks with neighboring US states.

   Aerial surveys are the most efficient. Surveys should be conducted in good weather with calm seas. Photographs can be used to make counts of groups too large to reliably count during the survey. Movement between sites as determined above may be useful to refine population estimates by formulating a method to account for movement out of and between census sites.

2) *Hot-brand pups in designated study areas.* Marking and resighting cohorts of Steller sea lions will allow survival and birth rates to be calculated. This in turn will provide information about physical condition, population regulation and the rates of population change. Two of more rookeries may need to be used as study sites to determine if significant differences exist between northern and southern populations. Pups will need to be captured to determine length, weight, and sex.

   Merrick et al. (1996) have developed a successful method for capturing and branding Steller sea lion pups at rookeries. Using a 3-person team, two people can hand-restrain the pup while the third applies the brand. The selection of brands and branding iron and forge construction are detailed in Merrick et al. (1996). The Alaskan Department of Fish and Game also is experienced, having branded large numbers of anesthetized pups in southeast Alaska in 1994 and 1995.

   Brands should be numbered and could have different designations for sex (M or F) and year (1-4). This will facilitate sighting by untrained observers (see 3 below). Study duration will likely be 10 years (2 to 4 years of branding, 6 to 10 years of observation). This will provide estimates of fecundity, pup survival, and movement patterns. In addition to incidental sightings, an annual survey should be conducted post-pupping in the study area(s). It is recommended that the study

area(s) be of moderate size (<200 pups) to allow for a complete census. An area previously surveyed would be preferred. Multiple areas could be used, but only if funding and manpower allow for complete census of all areas.

Hot-branding has been recommended over other options such as tagging, photo-ID, or electronic ID methods. Tags are not permanent and their readability is variable. Branding gave better results on Steller sea lion pups in Alaska than tagging (Merrick et al., 1996).

3) *Sighting and stranding information.* A considerable amount of information can be gathered through coordinated and incidental observations (see Introduction).

4) *Population monitoring - Disease and parasites.* Blood samples should be drawn from pups captured for branding (see 2 above) and from a random sample of adults. These samples can then be used to screen for disease to determine present and past exposure to disease. Historical disease data can also be used to identify emerging disease agents which may be responsible for future or current outbreaks and ultimately reduce the scope of their impact.

Diet and Fishery conflicts

The amount of salmon present in the diet of Steller sea lions is of concern to fishery managers, fishermen, and conservationists alike. This information can be gained from stomach contents, scat analysis, fatty acids (in blood and blubber) or stable isotopes (in hard parts such as bones and vibrissae). These last two techniques are still in the developmental stage, are expensive, and may not provide any more information than what can be gained from stomach and scat analysis. The method that has gained the widest acceptance over the past decade is scat analysis. Much of the refinement of this methodology has been developed at the Pacific Biological Station. Dietary analysis can show what portion of the diet is made up of salmonids and other species. It can also indicate seasonal and annual changes in prey abundance. Marine mammals are excellent samplers of their environment and can reveal much about the relative abundance of species managed by DFO.

5) *Scat collections.* The scatological diet research conducted by Olesiuk et al (1990) on harbour seals should be continued and expanded to include Steller sea lions. Approximately 80 scat samples are required per collection to accurately describe and detect changes in diet (Trites et al., unpubl. data). For example, to compare diet differences between summer and winter at one site, 80 scats would have to be collected in summer and another 80 scats collected in the winter.

One or two sites for both the northern and southern parts of the province should be identified as long term monitoring sites. Samples should be collected at these sites seasonally, every year to identify seasonal changes in diet and relative abundance of prey. Specific collection strategies can be used to maximize the information gathered about species of primary concern. Collecting scats in spring

and fall would provide more information on salmon and herring consumption than winter and summer collections (when these species compose a smaller proportion of the diet). Scats should be collected in the census areas (see 2 above) to correlate diet with pupping success and movement patterns.

Steller sea lions in conjunction with California sea lions and harbour seals are perceived by many as causing the declines of salmonid stocks. Dietary information can help to address this issue by demonstrating how much of the average Steller sea lion diet is composed of salmon. However, this does not address the issue of salmon specialists or problem animals. Some sea lions do feed on large numbers of returning adults or outgoing smolts in estuaries and rivers. This is a major issue from California to Alaska that needs further research to be adequately addressed.

6.) *Predator control.* Commercial fishermen are probably the most directly affected by sea lion damage to fishery gear and caught fish. Gillnetters are likely more affected than other gear types. A survey could be formulated and distributed to assess the scope of the problem and receive input on possible solutions.

Various devices that "scare" sea lions away may be helpful in reducing predation on salmonids in some areas. Further testing should be conducted on these acoustic deterrent devices as a means of discouraging predation on salmonid smolts and fry in the spring and adults returning to spawn in summer and fall. These devices have had limited experimental trials on harbour seals, but appear to be the most effective means of those studied (Jurk et al., 1996).

Other deterrents should also be investigated. Optical devices, feeding barriers, and release of smolts directly into estuaries are all possible means to decrease smolt losses from seal predation.

Study Sites

As previously mentioned, at least two long term study sites (one each in the northern and southern parts of the province) are needed for a reasonable assessment of Steller sea lion population parameters in British Columbia. Using areas that have been previously studied would allow for results to be put in a historical context. Suitable rookery sites include: the Scott Islands (northern tip of Vancouver Island), Cape St. James (southern tip of Queen Charlotte Islands) and North Danger Rocks (in the Hecate Strait). Suitable haulout sites for the late fall/early spring collections include: Race Rocks (southern Vancouver Island) in addition to the previously mentioned rookery sites.

References

Bigg, M. A., G. M. Ellis, P. Cottrell, and L. Millette. 1990. Predation by harbour seals and sea lions in Comox Harbour and Cowichan Bay, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1769. 31p.

Bigg, M. A. 1985. Status of the Steller Sea Lion (*Eumetopias jubatus*) and California Sea Lion (*Zalophus californianus*) in British Columbia. Can. Spec. Pub. Fish. Aquat. Sci. 77. 20p.

Cowan, I. M. 1987. The marine mammals of British Columbia, their status and distribution, p. 95-104 *In* R. J. Fox (ed.) The Wildlife of Northern British Columbia - Past, Present and Future. Spatsizi Association for Biological Research, Smithers, B.C. 159 p.

Hill, P.S., D. P. DeMaster, and R. J. Small. Alaska Marine Mammal Stock Assessments 1996. National Marine Mammal Laboratory,Alaska Fisheries Science Center. 155p.

Jurk, H., A. W. Trites, C. L. Wilson, G. M. Ellis, and J. K. B. Ford. 1996. Reducing the predation on outmigrating juvenile salmonids caused by harbour seals (*Phoca vitulina*) in the Puntledge River, British Columbia. Report for the Department of Fisheries and Oceans (unpubl.). 28 p.

Loughlin, T. R., and R. Nelson, Jr. 1986. Incidental mortality of northern sea lions in Shelikof Strait, Alaska. Mar. Mam. Sci. 2(1):14-33.

Malouf, A. 1986. Seals and sealing in Canada. Report of the Royal Commission, 3. 679p.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1996. Hot branding: a technique for long-term marking of pinnipeds. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-68, 21 p.

Olesiuk, P. F., M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990. An assessment of feeding habits of harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. Aquat. Sci. No. 1730, 135pp.

Sease, J. L., J. P. Lewis, D. C. McAllister, R. L. Merrick, and S. M. Mello. 1993. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992. U. S. Dept. Comm., NOAA Tech. Memo. NMFS-AFSC-17. 57p.

Trites, A. W., and P. A. Larkin. 1996. Changes in the abundance of Steller sea lions (*Eumetopias jubatus*) in Alaska from 1956 to 1992: how many were there? Aquatic Mam. 22(3):153-166.

California Sea Lion (*Zalophus californianus*)

California sea lions historically ranged from California to British Columbia, but were severely culled at their breeding sites (in California and Mexico) earlier this century. Since their protection in 1972 in the U.S., migrating males have begun to return to British Columbia. In 1984, 4,496 animals were counted at 10 haulout sights in British Columbia located on the southwest coast of Vancouver Island and the southern portion of the Strait of Georgia (Figure 1, Bigg, 1985). One sighting was made in Queen Charlotte Sound of approximately 20 animals in 1983 (NMFS, unpubl. data), and other sporadic sightings of individual animals have been made in the Gulf of Alaska.

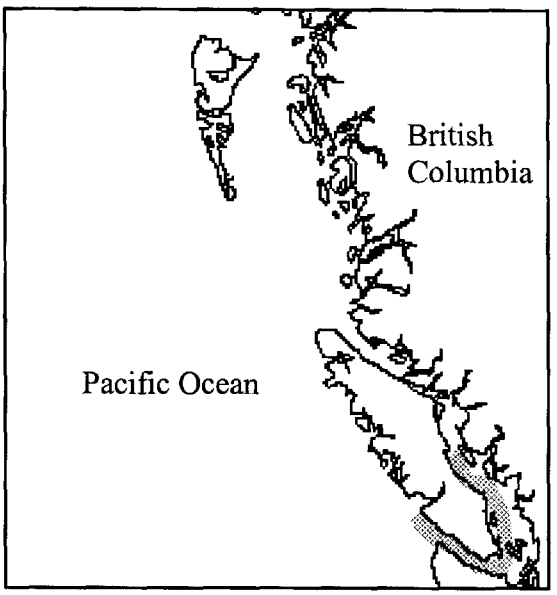

Figure 1. The known distribution of California sea lions in British Columbia.

California sea lions seasonally arrive in British Columbia in October and depart by the end of May (Cowan, 1987). The majority of animals sighted in the province appear to be males. They breed and give birth on rookeries in California and Mexico.

Diet

Lowry et al. (1990) examined California sea lion diets at San Clemente Island, California, from September 1981 through September 1986 using fecal samples (i.e., scats). They identified seven main types of prey: northern anchovy *Engraulis mordax*, jack mackerel *Trachurus symmetricus*, pelagic red crab *Pleuroncodes planipes*, Pacific whiting *Merluccius productus*, rockfishes, *Sebastes* spp., market squid *Loligo opalescens*, and blacksmith *Chromis punctipinnis*. In British Columbia, California sea lions have been observed hunting and eating salmon in Cowichan Bay (Bigg et al., 1990).

Sea lion-fishery interactions

Data is not available on California sea lion interactions with fisheries in British Columbia. However, dead animals with gunshot wounds are commonly reported during the spring herring fisheries. In the U.S., California sea lions are incidentally killed in set and drift gillnet fisheries (Barlow et al., 1994). Similarly, sea lions have been observed entangled in monofilament gillnetting at rookeries and haulouts in California (Stewart and Yochem, 1987) and animals with gunshot wounds have been found on shore (Barocchi et al., 1993).

Research Needs

Abundance, Distribution and Population Status

Annual or biannual surveys of the California sea lion population in southern British Columbia should be conducted. These surveys could easily be included in the surveys for harbour seals as outlined in that species report. Bigg (1985) found that a February sampling date maximized the number of California sea lions present in the province.

Diet

Collection and analysis of scats can be a powerful tool for understanding pinniped diet composition. The scatological diet research conducted by Olesiuk et al (1990) on harbour seals should be expanded and applied to California sea lions. Approximately 80 scat samples are required per collection to accurately describe and detect changes in diet (Trites et al., unpubl. data). One or two haulout sites should be identified as long term monitoring sites. Samples should be collected at these sites every year when California sea lions are present to identify changes in diet and relative abundance of prey.

References

Barlow, J., R. W. Baird, J. E. Heyning, K. Wynne, A. M. Manville II, L. F. Lowry, D. Hanan, J. Sease, and V. N. Burkanov. 1994. A review of cetacean and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. Report of the International Whaling Commission (Special Issue 15):405-425.

Barocchi, M., L. E. Morgan, and K. D. Hanni. 1993. Frequency of fishery interactions among live stranded pinnipeds in central and northern California (abstract). Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, Tx., November 11-15, 1993.

Bigg, M. A., G. M. Ellis, P. Cottrell, and L. Millette. 1990. Predation by harbour seals and sea lions in Comox Harbour and Cowichan Bay, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1769. 31p.

Bigg, M. A. 1985. Status of the Steller Sea Lion (*Eumetopias jubatus*) and California Sea Lion (*Zalophus californianus*) in British Columbia. Can. Spec. Pub. Fish. Aquat. Sci. 77. 20p.

Cowan, I. M. 1987. The marine mammals of British Columbia, their status and distribution, p. 95-104 *In* R. J. Fox (ed.) The Wildlife of Northern British Columbia - Past, Present and Future. Spatsizi Association for Biological Research, Smithers, B.C. 159 p.

Lowry M S., C. W. Oliver, C. Macky, and J. B. Wexler. 1990. Food habits of California

sea lions, *Zalophus californianus* at San Clemente Island, California, USA, 1981-1986. Fishery Bulletin 88(3):509-522.

Olesiuk, P. F., M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990. An assessment of feeding habits of harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. Aquat. Sci. No. 1730, 135pp.

Stewart, B. S., and P. K. Yochem. 1987. Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel Islands, California, 1978-1986. Marine Pollution Bulletin 18:336-339.

Incidental Pinniped Species

Northern elephant seals (*Mirounga angustirostris)* have been sighted in the waters off British Columbia from March through October. Sightings are rare and generally limited to the westcoast of Vancouver Island and Queen Charlotte Sound, though there is one uncomfirmed report of an animal in the Strait of Georgia (NMFS, unpubl. data). Only one haul-out site (Race Rocks) has been identified at the southern tip of Vancouver Island (Baird, unpubl. data).

Northern fur seals (*Callorhinus ursinus*) are found primarily in BC waters from February to July with 88% of sightings occurring during this period (NMFS, unpubl. data). These animals conduct an annual migration from summer breeding grounds on the Pribolof Islands in the Bering Sea to winter feeding grounds off the coasts of Oregon and California (Trites and Bigg, 1996). Northern fur seals have been sighted off the coast of British Columbia west of Vancouver Island and the Queen Charlotte Islands, with a few reports from Queen Charlotte Sound (NMFS, unpubl. data). They were studied extensively by Canadian researchers between 1958 and 1972 (Lander, 1980).

References

Trites, A. W., and M. A. Bigg. 1996. Physical growth of northern fur seals (*Callorhinus ursinus*): seasonal Fluctuations and migratory influences. J. Zool. Lond. 238:459-482.

Lander, R. H. 1980. Summary of northern fur seal data and collection procedures. 2: Eastern Pacific pelagic data of the United States and Canada (excluding fur seal sighted). NOAA Tech. Memo. NMFS F/NWC-4.

Harbour Porpoise (*Phocoena phocoena*)

Harbour porpoise occur in the eastern Pacific Ocean from the Bering Strait, Alaska to central California. They are often seen in bays, estuaries, and occasionally ascending freshwater streams (Leatherwood and Reeves, 1983). Harbour porpoise are known to occur year-round in BC coastal waters (Baird and Guenther, 1995). Very little is known about the biology and status of harbour porpoise in British Columbia.

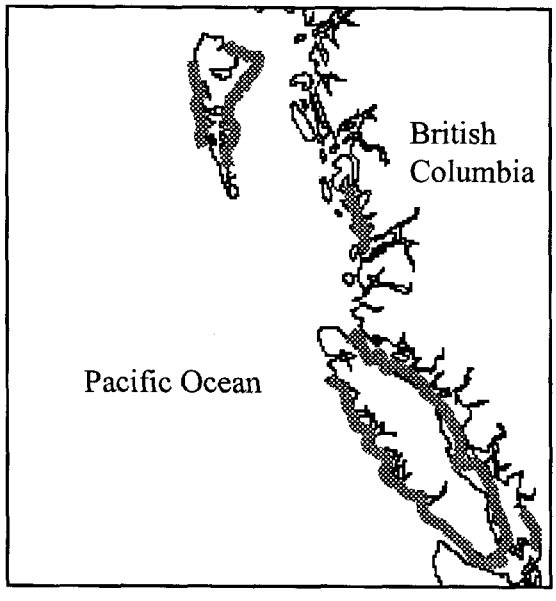

Figure 1. The known distribution of harbour porpoise in British Columbia.

The life history of harbour porpoise on the Atlantic coast has been more extensively studied than for the Pacific coast populations. Read and Hohn (1995) examined 239 animals killed in gill-net fisheries in the Gulf of Maine. The oldest animal was 17 years old with average longevity estimated at 12 years (Read and Hohn, 1995). The reproductive cycle was estimated from changes in the proportion of lactating females killed in the fisheries. Reproduction appears to be annual and seasonal with parturition, conception, and ovulation occurring from June to early July. Calf survival was estimated to be 92% in summer dropping to 71% by early fall (Read and Hohn, 1995).

The limited amount of life history data available for the Pacific suggests that there may be significant variation between the Atlantic and Pacific populations. Female harbour porpoise in California were estimated to be on a two-year calving cycle, possibly due to resource limitations (food availability) (Hohn and Brownell, 1990). In British Columbia, calving is thought to occur from May through September or possibly earlier in the spring (Baird and Guenther, 1995).

Diet

Very little information is available on the diet of Pacific harbour porpoise. Diet information for Pacific harbour porpoise was obtained from stomach contents of incidentally caught animals in the Makah set-net fishery in Washington State from May to September, 1988-1990. Pacific herring was the top prey item, followed by smelt, and squid (Gearin et al., 1994). Prey length varied by species: herring 12-18cm (2 to 3 years old), smelt 6-10.5 cm (juveniles), and market squid 6-10cm (most were probably 12 months old). Adult porpoise fed primarily on herring, with few feeding on smelt. Juveniles fed mostly on smelt (over 60%), but also ate herring. Adult chinook salmon stomachs from the same fishery were predominantly full of herring (93.1%), followed by

smelt (18.1%), and market squid (12.5%) (Gearin et al., 1994). This suggests that the harbour porpoise and chinook salmon were feeding on the same resource.

Abundance, Distribution and Population Status

Harbour porpoise groups typically number less than 10 individuals. In Oregon and Washington waters, distribution varied by depth with 79% occurring at depths < 50 fathoms (91 m) and rare sightings at depths greater than 200 m (Green et al., 1992). Harbour porpoise that inhabit the waters surrounding the San Juan Islands were found more often at depths greater than 91 m. This suggests that distribution may be dependent on factors other than water depth. In the summer of 1991, 65% of all sightings occurred in waters shallower than 37 m along the Oregon/Washington coast (Calambokidis et al., 1992). In Glacier Bay, Alaska, Taylor and Dawson (1984) observed an increase in porpoise density from 1.7 animals/km. sq. during summer to 5.9 in fall and group size increased from 1 in July to greater than 3 in February. The authors concluded that changes in group size and density were related to prey availability and feeding strategies.

Based on DNA evidence two clades are thought to exist on the Pacific coast of North America. One clade inhabits California and Washington (no data were available for Oregon) and the other extends from California to Alaska (Rosel, 1992). The two clades are not geographically distinct. Further genetic testing of the same data mentioned above along with additional samples, found significant genetic differences for 4 of the 6 pair-wise comparisons between the four areas investigated: California, Washington, British Columbia, and Alaska (Rosel et al. 1995). These results demonstrate that harbour porpoise along the Pacific coast of North America are not migratory, and that movement is sufficiently restricted to evolve genetic differences. This is consistent with low movement suggested by genetic analysis of harbor porpoise specimens from the North Atlantic.

Evidence from discriminant analysis of organochlorine pollutant residue (OPR) also suggests that harbour porpoise movements along the Pacific coast of the United States may be limited. Calambokidis and Barlow (1991) found that the state from which the animal was collected could be accurately predicted for 86% of the samples using OPR ratio comparisons with known concentrations for coastal waters. Although it is difficult to determine the true stock structure of harbour porpoise populations in the northeast Pacific, from a management standpoint, it would be prudent to assume that regional populations exist and that they should be managed independently (Rosel et al. 1995). The use of productivity and population parameter estimates from either Washington or Alaskan waters for the British Columbia harbour porpoise population is not recommended without further study.

The net maximum growth rate for harbour porpoise populations has been estimated at 9.4% (Barlow and Hanan, 1995). This may be an unrealistic estimate as no cetacean population has been shown to grow at such a high rate. Money (unpubl.) estimated a maximum net productivity rate of 2.54%. This rate is based on a mathematical survival model incorporating the most recent estimates of life history parameters for the species.

Model parameters used for this estimate included annual calf production for females over the age of 3 (50% producing calves at age 3 and age 10), no calf production after age 10, longevity of 14 years (maximum expected life span), and mortality from 35 to 5% depending on age class.

Population estimates for British Columbia are not available. Cowan (1988) suggested that the population in the province may be decreasing. A variety of factors may be contributing to this decline. Incidental mortality from entanglement in fishing gear (particularly salmon gillnets) (Everitt et al., 1980) and increasing pollutant levels in the preferred nearshore habitat (Muir and Norstrom, 1990) are the two factors which have received the greatest attention. Stacey et al. (1990) estimated that 43-59 individuals are killed annually in BC waters through incidental mortality. This was considered to most likely be an underestimation. The eastern Canadian population has been listed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but insufficient information was available to assess the western Canadian population (Gaskin, 1992).

Research Needs:

The harbour porpoise population in the waters of British Columbia appears to be decreasing (Cowan, 1988). The extent of this decrease and the current status of the British Columbia population are unknown. Possible causes of this decrease include entanglement in fishing gear, sensitivity to pollutants, and a reduction in the quantity and/or quality of prey. Basic population information is needed to assess the extent of the population decrease and the abundance and distribution of harbour porpoise in British Columbia. Areas important to harbour porpoise (calving, breeding, and feeding areas) need to be identified.

Current knowledge for the province is mostly derived from reports of incidental sightings and strandings. Harbour porpoise are shy and secretive animals that tend to avoid motorized watercraft (even low-flying aircraft) and are difficult to approach (Watson and Gaskin, 1983). Their spouts are rarely visible and their coloration and size make them difficult to see in the water. These characteristics make harbour porpoise difficult animals to study in the field. Initial studies will need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for harbour porpoise research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine areas frequented by harbour porpoise and identify possible research areas. Methods are described in the Introduction to this volume.

2.) *Abundance estimates.* Total abundance estimates for one or more limited areas should be conducted using non-motorized craft (i.e., kayak) or land-based observation in conjunction with the methods outlined in (3) below. Watson and

Gaskin (1983) found that observations from a kayak were superior both in quantity and quality to a motorboat. Video recording and photographs may also prove useful for counting groups of animals.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted annually or biannually for several consecutive years following the basic methodology described in the introduction of this volume. Hiby and Hammond (1989) recommended line-transect surveys over strip-transect surveys since the greater ability to correct for missed animals produced more accurate estimates. Line-transect coastal surveys should utilize zig-zag tracklines from shore to the 200m isobath. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather conditions.

References

Baird, R. W. and T. J. Guenther. 1995. Account of harbour porpoise (*Phocoena phocoena*) strandings and bycatches along the coast of British Columbia. Report of the International Whaling Commission (Special Issue 16):159-168.

Barlow, J. and D. Hanan. 1995. An assessment of the 1994 status of harbor porpoise in California. Report of the International Whaling Commission (Special Issue 16):123-140.

Berggren, P., and F. Arrhenius. 1995. Densities and seasonal distribution of harbour porpoises (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas. Report of the International Whaling Commission, Special Issue 16: 109-121.

Calambokidis, J., J. and J. Barlow. 1991. Chlorinated hydrocarbon concentrations and their use for describing population discreteness in harbor porpoise from Washington, Oregon, and California. Pages 101-110. *In* J. E. Reynolds III and D. K. Odell (editors), Proceedings of the Second Marine Mammal Stranding Workshop: 3-5 December 1987. Miami, FL. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 98.

Calambokidis, J., J. R. Evenson, J. C. Cubbage, P. J. Gearin, and S. D. Osmek. 1992. Harbor porpoise distribution and abundance off Oregon and Washington from aerial surveys in 1991. Contract report available through NMFS, AFSC, National Marine Mammal Laboratory. Seattle, WA. 44 p.

Cowan, I. M. 1988. The marine mammals of British Columbia, their status and distribution. Pages 95-104. *In* R. J. Fox (editor) The Wildlife of Northern British Columbia - Past, Present and Future. Spatsizi Association for Biological Research, Smithers, BC. 159 p.

Everitt, R. D., C. H. Fiscus, and R. L. DeLong. 1980. Northern Puget Sound marine

mammals. USEPA, Interagency Energy/Environment R & D Program Report. EPA-600/7-80-139. 134 p.

Gaskin, D. E. 1992. Status of the harbour porpoise, *Phocoena phocoena*, in Canada. Can. Field-Nat. 106(1):36-54.

Gearin, P. J., S. R. Melin, R. L. DeLong, H. Kajimura, and M. A. Johnson. 1994. Harbor porpoise interactions with a chinook salmon set-net fishery in Washington state. Reports of the International Whaling Commission (Special Issue 15):427-438.

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnel, and K. C. Balcomb. 1992. Cetacean distribution and abundance of Oregon and Washington, 1989-1990. Pages 1-100, *In* Brueggeman, J. (editor), Oregon and Washington marine mammal and seabird surveys. Final Rep. OCS Study MMS 91-0093. 100 p.

Hiby, A. R. and Hammond, P. S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. Report of the International Whaling Commission (Special Issue 2):47-80.

Hohn, A. A. and R. L. Brownell, Jr. 1990. Harbor porpoise in central Californian waters: life history and incidental catches. Paper SC/42/SM47 presented at 42nd Meeting of the Scientific Committee, International Whaling Commission, Nordwijk, Holland.

Leatherwood, S. and R. R. Reeves. 1983. Whales and dolphins. Sierra Club Handbook, San Francisco, CA. 302 p.

Muir, D. C. G. and R. J. Norstrom. 1990. Marine mammals as indicators of environmental contamination by PCBs and dioxins/furans. Paper presented at the 17th Annual Aquatic Toxicity Workshop, Vancouver, November, 1990.

Read, A. J. and A. A. Hohn. 1995. Life in the fast lane: the life history of harbor porpoises from the Gulf of Maine. Mar. Mam. Sci. 11(4):423-440.

Rosel, P. E. 1992. Genetic population structure and systematic relationships of some small cetaceans inferred from mitochondrial DNA sequence variation. Ph. D. dissertation, University of California, San Diego. 191 p.

Rosel, P. A., A. Dizon, and M. Haygood. 1995. Variability of the mitochondrial control region in populations of harbour porpoise, *Phocoena phocoena*, on inter-oceanic and regional scales. Can. J. Fish. Aquat. Sci. 52:1210-1219.

Stacey, P. J., R. W. Baird, and D. A. Duffus. 1990. A preliminary evaluation of incidental mortality of small cetaceans, primarily Dall's porpoise (*Phocoenoides dalli*), harbour porpoise (*Phocoena phocoena*) and Pacific white-sided dolphins

(*Lagenorhynchus obliquidens*), in inshore fisheries in British Columbia, Canada. Paper SC/42/SM20 presented at 42nd Meeting of the Scientific Committee, International Whaling Commission, Nordwijk, Holland.

Taylor, B. L. and P. K. Dawson. 1984. Seasonal changes in density and behavior of harbor porpoise (*Phocoena phocoena*) affecting census methodology in Glacier Bay National Park, Alaska. Report of the International Whaling Commission 34:479-483.

Watson, A. P. and D. E. Gaskin. 1983. Observations on the ventilation cycle of the harbour porpoise *Phocoena phocoena* in coastal waters of the Bay of Fundy. Can. J. Zool. 61:126-132.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise are common across the entire North Pacific Ocean. They occur from Alaska to Baja, California on the westcoast of North America and are among the most energetic and common bow-riding small cetaceans. Dall's porpoise have been sighted throughout the coastal and deep oceanic waters of British Columbia in groups of from one up to several hundred animals (NMFS, unpubl. data). Very little is known about the biology and status of Dall's porpoise in British Columbia.

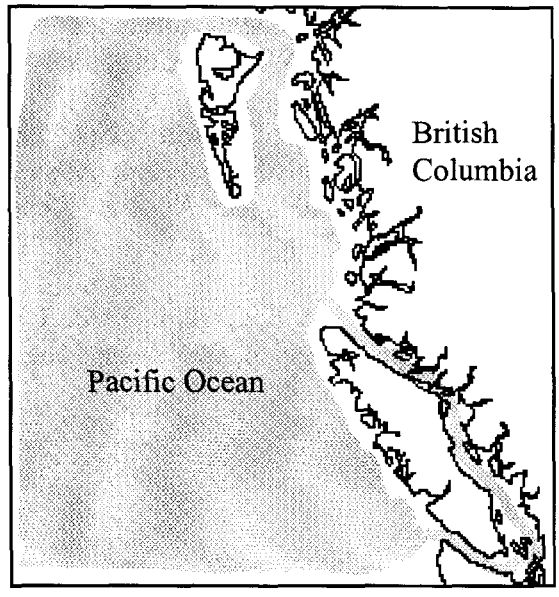

Figure 1. The known distribution of Dall's porpoise in British Columbia.

Life history information for this species in the eastern North Pacific Ocean is very sparse and limited to a few documented specimens obtained through incidental catch. From these specimens, Jefferson (1988) estimated that calving occurs from early spring to early fall with a peak from June to August. A population estimate for British Columbia is not currently available.

Using data from the western North Pacific Ocean, Gaskin et al. (1981) estimated the average age of first birth in Dall's porpoise to be 7.257 years. A four year old pregnant female was recorded by Kasuya (1978). Gestation period has been estimated at 11 months (Gaskin et al., 1981). A distinct mating season may not exist with mating and births occurring year round (Morejohn, 1979).

Diet

No information is available on the diet of Dall's porpoise in British Columbia. Since these animals are commonly caught in salmon drift gillnet and high seas squid gillnet fisheries their diet is likely to consist of squid and prey pursued by salmon (Turnock et al., 1995). Leatherwood and Reeves (1983) concluded that Dall's porpoises eat squid, crustaceans, and both pelagic and deep-water benthic fish species.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of Dall's porpoise in British Columbia. Areas important to Dall's porpoise (calving, breeding, and feeding areas) need to be identified. Current knowledge for the province is solely from reports of incidental sightings. Dall's porpoise are attracted to fast moving vessels. They create a distinctive and clearly visible "rooster-tail" of spray off their

rostrum when moving at high speed. Their distinctive coloration makes them one of the easiest small cetaceans to identify in the field.

The distinctive characteristics of Dall's porpoise make them a good species for sighting studies using volunteer observers. Shipboard and/or aerial surveys are needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution and will form the basis further.

Specific recommendations for Dall's porpoise research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine areas frequented by Dall's porpoise and future research needs. Methods are described in the Introduction to this volume.

2) *Abundance estimates.* Total abundance estimates for one or more limited areas should be conducted using aerial surveys and land-based observation in conjunction with the methods outlined in (3) below. Shipboard surveys are not recommended for this species since their attraction to moving ships would positively bias the counts. Video recording and photographs may also prove useful for counting large groups of animals.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted following the basic methodology described in the Introduction of this volume. Hiby and Hammond (1989) recommended line-transect surveys over strip-transect surveys since the greater ability to correct for missed animals produced more accurate estimates. Line-transect surveys should utilize zig-zag tracklines from shore to the 1000m isobath. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather conditions.

References

Gaskin, D. E., G. J. D. Smith, A. P. Watson, W. Y. Yasui, and D. B. Yurick. 1981. Reproduction in the porpoises (*Phocoenidae*): implications for management. Report of the International Whaling Commission (Special Issue 6): 135-148.

Hiby, A. R. and Hammond, P. S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. Report of the International Whaling Commission (Special Issue 2): 47-80.

Jefferson, T. A. 1990. Status of the Dall's porpoise, *Phocoenoides dalli*, in Canada. Can.-Field Nat. 104: 112-116.

Kasuya, T. 1978. The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. Scientific Reports of the Whales Research Institute, Tokyo 28: 74-106.

Leatherwood, S. and R. R. Reeves. 1983. Whales and dolphins. Sierra Club Handbook, San Francisco, CA. 302 p.

Morejohn, G. V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. p. 45-83. *In* H. E. Winn and B. L. Olla (eds.) Behavior of Marine Mammals: Current Perspectives in Research. Volume 3: Cetaceans. Plenum Press, New York. 438 p.

Turnock, B. J., S. T. Buckland, and G. C. Boucher. 1995. Population abundance of Dall's porpoise (*Phocoenoides dalli*) in the western North Pacific Ocean. Report of the International Whaling Commission (Special Issue 16): 381-397.

Killer Whale (*Orcinus orca*)

Killer whales are one of the most frequently encountered cetaceans and inhabit all of the oceans and seas of the world. In British Columbia, killer whales occur along the entire coast and are also often sighted in offshore waters (Ford et al., 1994). Killer whales often travel in groups of up to 60 animals called pods. Three types of pods are currently recognized; "resident", "transient" and "offshore", based on genetic, behavioural, and ecological differences (Ford et al., 1994). Resident whales frequent the same areas throughout the year. The movements of transients and offshores are unpredictable, though seasonal trends in conjunction with prey abundance have occasionally been observed.

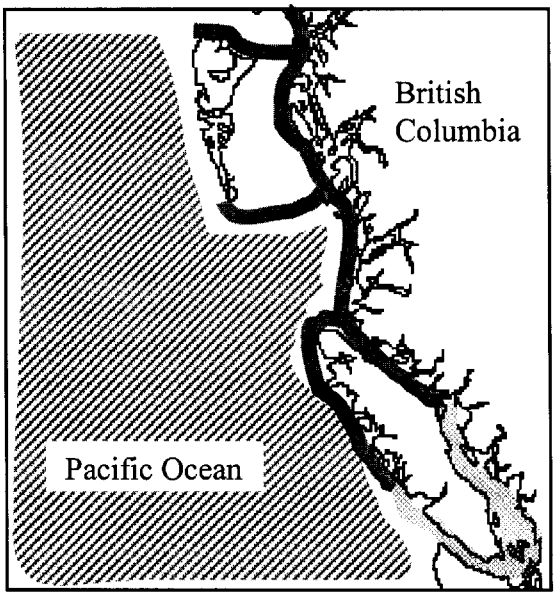

Figure 1. The known distribution of killer whales in British Columbia.
- Northern Residents
- Southern Residents
- Unknown (presumed offshore and transients))

The "resident" killer whale population has been subdivided into northern and southern groups based on geographic range, genetics, and similarities of underwater communication sounds called "dialects" (Ford and Fisher, 1982). As of 1993, at least 305 resident whales and 170 transients had been identified in coastal waters. The true size of the transient and offshore populations is not known.

Killer whales reach reproductive maturity at an average of 14 or 15 years. The gestation period has been estimated at 16 to 17 months based on pregnant females held in aquaria (Ford et al., 1994). Calf mortality in the first year may be quite high (over 40%) though the reasons for this are not known. Females produce 4 to 6 surviving offspring over a 20 to 25 year period and then no longer breed. Females may live for up to 80 years, though the average longevity is estimated at 50 years (Olesiuk et al., 1990). Males lives are probably shorter, though some live to at least 40 years of age.

Diet

The diets of transient and resident whales in British Columbia are very different and foraging strategies have been implicated in the separation of the two groups (Bigg et al., 1990). Transients feed mainly on marine mammals (seals, porpoise, and sea lions), while residents consume mostly fish. The diet of offshore killer whales is not known, though they are suspected of being piscivorous due to their commonalities (frequent vocalization and use of echolocation) with resident whales (Ford et al., 1994).

Fishery Interactions

Killer whales have been known to scavenge on longline fishery catches in the Bering Sea (Yano and Dahlheim, 1995). Interactions with aquaculture facilities, sport-fishing boats, and commercial fishing vessels have also been known to occur. The impact and regularity of these interactions in the waters of British Columbia are not known.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of "offshore" and "transient" killer whales in British Columbia. Shipboard and/or aerial surveys will be needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for killer whale research in British Columbia include:

1) *Abundance estimates*. Photographic identification should continue to be used to estimate the abundance of residents, transients, and offshore killer whales. However, consideration should be given to estimating overall abundance using aerial surveys. Aerial surveys in conjunction with water and land-based observations will provide useful information about distribution (see 3 below).

2) *Survey randomly selected areas of BC*. Aerial surveys should be conducted following the basic methodology described in the Introduction of this volume. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather.

3) *Determine ranges for "offshore" and "transient" killer whales*. Radio-tagging or other long-range tracking methodologies could be used to determine the movements and ranges of the "transient and "offshore" killer whales. This information in conjunction with 1) and 2) above and sighting information on "residents" will allow for the estimation of the size of the "transient" and "offshore" populations (total number of whales minus "residents" equals number of "transients" and "offshores"). The impacts of non-resident whales on other marine mammals and fisheries can then be assessed based on food preferences, etc.

References

Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford, and K. C. Balcomb. 1990. Social organization and genealogy of resident killer whales in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission (Special Issue 12):383-405.

Ford, J. K. B., and H. D. Fisher. 1982. Killer whale (*Orcinus orca*) dialects as an

indicator of stocks in British Columbia. Report of the International Whaling Commission 32:671-679.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. Killer whales: The natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. UBC Press, Vancouver, BC, Canada. 102 p.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission (Special Issue 12):209-43.

Yano, K. and Dahlheim, M. E. 1995. Killer whale, Orcinus orca, depredation on longline catches of bottomfish in the southeastern Bering Sea and adjacent waters. U S National Marine Fisheries Service Fishery Bulletin 93(2). 1995. 355-372.

Pacific White-Sided Dolphin (*Lagenorhynchus obliquidens*)

Pacific white-sided dolphins are likely the most abundant cetacean in the inshore and nearshore waters of British Columbia (Figure 1). There has been a dramatic increase in sightings in provincial coastal waters since the mid-1980's due to the migration rather than an increase in the resident population (Heise, 1996). Pacific white-sided dolphins are among the most acrobatic of the Delphinids and are seen in groups of up to 1,000 individuals. They are attracted to vessels and are avid bow-riders.

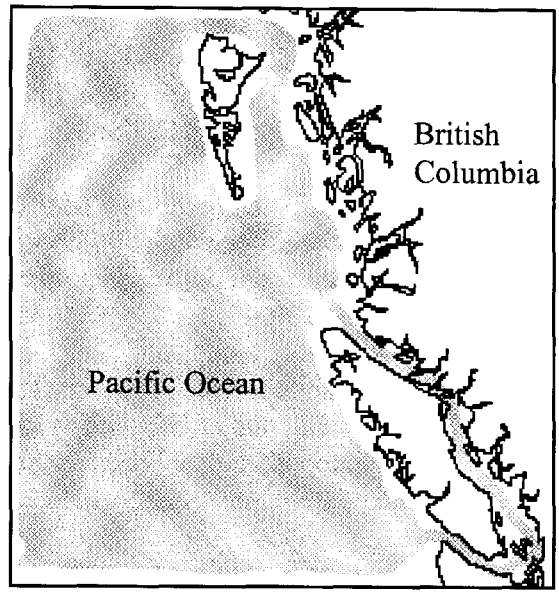

Figure 1. The known distribution of Pacific white-sided dolphin in British Columbia.

Age at sexual maturity for males and females has been estimated at 7 to 8 years with a 21.4% annual pregnancy rate for sexually mature females (Heise, 1996). Calving peaks in June through August with an average calving interval of 4.67 years and a gestation period of approximately one year (Heise, 1996). Following birth, calves nurse for at least six months. After calves are weaned, females appear to enter a resting period, lasting about 38 months, prior to the next pregnancy (Heise, 1996). Longevity has been estimated at 37 years for females.

Diet

Pacific white-sided dolphins in British Columbia are opportunistic predators and are known to feed on at least 13 different prey species. Salmon are an important diet component from June through November representing an estimated 30 to 60% of the diet during this period (Heise, 1996). The majority of salmon consumed were small (< 25 cm) though larger fish (> 50 cm) were taken occasionally.

Herring is the most important year-round prey for these animals in British Columbia occurring in 59% of samples (Heise, 1996). Cod, shrimp, and capelin were also consumed (6%, 3%, and 1% of the diet, respectively)

Fishery Interactions

An assessment of the impact of fishery interactions in British Columbia is currently not available for this species.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of Pacific white-sided dolphins in British Columbia. Areas important to Pacific white-sided dolphins (calving, breeding, and feeding areas) need to be identified. Current knowledge for the province is solely from reports of incidental sightings. Pacific white-sided dolphins are attracted to fast moving vessels. Their distinctive coloration makes them one of the easiest small cetaceans to identify in the field. These characteristics make Pacific white-sided dolphins an almost ideal species for a sighting study using volunteer observers. Shipboard and/or aerial surveys will also be needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for Pacific white-sided dolphins research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine areas frequented by Pacific white-sided dolphins and identify possible research areas. Methods are described in the Introduction to this volume.

2.) *Abundance estimates.* Total abundance estimates for one or more limited areas should be conducted using aerial surveys and land-based observation in conjunction with the methods outlined below (3). Shipboard surveys are not recommended for this species since their attraction to moving ships would positively bias the counts. Video recording and photographs may also prove useful for counting large groups of animals.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted following the basic methodology described in the Introduction of this volume. Hiby and Hammond (1989) recommended line-transect surveys over strip-transect surveys since the greater ability to correct for missed animals produced more accurate estimates. Line-transect surveys should utilize zig-zag tracklines from shore to the 1000m isobath. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather.

References

Heise, K. A. 1996. Life history parameters of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and its diet and occurrence in the coastal waters of British Columbia. M. Sc. Thesis, University of British Columbia. 95 p.

Hiby, A. R. and Hammond, P. S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. Report of the International Whaling Commission (Special Issue 2):47-80.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The Northern Right Whale Dolphin occurs in temperate waters throughout the North Pacific Ocean ranging from Alaska to Baja, California in the eastern Pacific. The majority of sightings and strandings in British Columbia have been recorded from the southern parts of the province (Baird and Stacey, 1991; NMFS, unpubl. data; Figure 1). They have been sighted in groups of from 1 to 200 individuals with an average group size of 24. Inshore sightings are rare with the vast majority of encounters occurring in offshore waters.

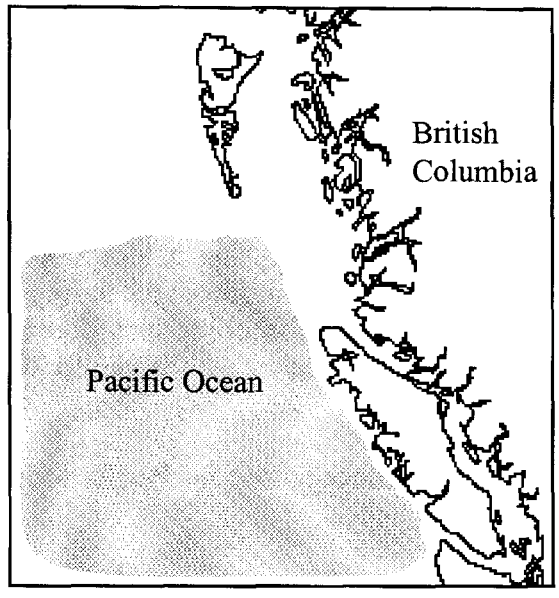

Figure 1. The known distribution of Northern Right Whale Dolphin in British Columbia.

Ferrero and Walker (1993) estimated female reproductive status from Northern Right Whale Dolphins taken in Japanese squid driftnets in the central North Pacific Ocean. Sixteen percent were pregnant, 3% were pregnant and lactating, 33% were post partum, 24% were lactating (no recent pregnancy), 10% were resting (neither pregnant not lactating), and 14% were of unknown condition. The gestation period was approximately 12 months. Estimates of the average age at sexual maturation were 10 years for males and females. Calving appeared to peak in July and August with a minimum calving interval of 2 years.

Barlow et al. (1995) suggested that Northern Right Whale Dolphins moved from California in winter to Oregon and Washington in late spring and summer. Records from sightings and strandings in the waters off British Columbia do not support this theory (Baird and Stacey, 1991; NMFS unpubl. data). Northern Right Whale Dolphins have been seen from February through November in BC. The lack of sightings in January and December is possibly due to a lack of effort during these months. The peak of sightings and strandings occur from July through October, but this probably reflects effort and not necessarily dolphin abundance.

Current populations trends for Northern Right Whale Dolphins in the Pacific Ocean are currently unknown. No estimates of the size of the population in the waters off British Columbia have been made.

Diet

Northern Right Whale Dolphins feed on a variety of fish and cephalopods (Clarke, 1986). Their diet in Canadian waters has not been determined.

Fishery Interactions

An assessment of the impact of fishery interactions in British Columbia is currently not available for this species.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of Risso's dolphins in British Columbia. Areas important to northern right whale dolphins (calving, breeding, and feeding areas) need to be identified. Current knowledge for the province is solely from reports of incidental sightings. Shipboard and/or aerial surveys will be needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for northern right whale dolphins research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine areas frequented by northern right whale dolphins and identify possible research areas. Methods are described in the Introduction to this volume.

2.) *Abundance estimates.* Total abundance estimates for one or more limited areas should be conducted using aerial surveys and land-based observation in conjunction with the methods outlined below (3). Video recording and photographs may also prove useful for counting large groups of animals.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted following the basic methodology described in the Introduction of this volume. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather.

References

Baird, R. W., and P. J. Stacey. 1991. Status of Northern Right Whale Dolphin, *Lissodelphis boralis*, in Canada. Canadian Field-Naturalist 105(2): 243-250.

Barlow, J., R. L. Brownell, Jr., D. P. DeMaster, K. A. Forney, M. S. Lowry, S. Osmek, T. J. Ragan, R. R. Reeves, and R. J. Small. 1995. U.S. pacific marine mammal stock assessments, 1995. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-219. 162 p.

Clarke, M. R. 1986. Cephalopods in the diet of odontocetes. Pages 281-321, *In* M. M. Bryden and R. Harrison (eds.), Research on Dolphins. Clarendon Press, Oxford.

Ferrero R C., and W. A.Walker. 1993. Growth and reproduction of the northern right whale dolphin, Lissodelphis borealis, in the offshore waters of the North Pacific Ocean. Canadian Journal of Zoology 71(12): 2335-2344.

Risso's Dolphin (*Grampus griseus*)

Risso's dolphins have a worldwide distribution and occur in tropical and warm-temperate seas. They are found in the eastern North Pacific Ocean from the Gulf of Alaska (Braham, 1983) to south of Baja, California (Mangels and Gerrodette, 1994). They have been recorded year-round in the waters off British Columbia (Figure 1).

Sightings and strandings of Risso's dolphins in British Columbia have occurred near the Queen Charlotte Islands, in the Strait of Georgia and off the westcoast of Vancouver Island (Baird and Stacey, 1991; NMFS, unpubl. data). Groups sighted in BC waters numbered between 1 and 200 (mean = 15). An abundance estimate for British Columbia is not available and population trends have not been determined.

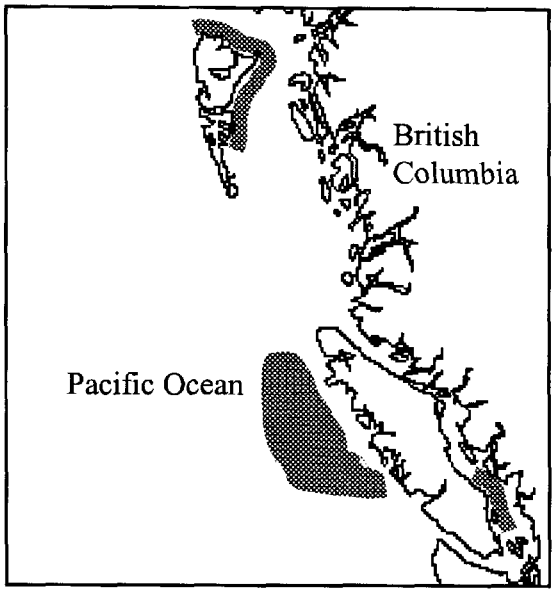

Figure 1. The known distribution of Risso's dolphins in British Columbia.

There is only a limited information available on the basic biology of Risso's dolphin. The gestation period is estimated to last for 13 to 14 months with a gross population reproductive rate of 6 to 7% (Kasuya, 1985). Calving season, calving interval and age at sexual maturity are not known. Kasuya and Izumisawa (1981) found 4 pregnant females (carrying fetuses) of 13 females collected in the Western North Pacific Ocean. Kruse (1987) has suggested that groups of Risso's dolphins may have a reasonably cohesive social structure.

Diet

Diet consists almost exclusively of squid (Mitchell, 1975). Fish may also be incidentally consumed.

Fishery Interactions

Risso's dolphins are susceptible to incidental mortality from drift gillnets (used for shark and swordfish) and squid purse seine fisheries. An assessment of the impact of fishery interactions in British Columbia is currently not available for this species.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of Risso's dolphins in British Columbia. Areas important to Risso's dolphins (calving, breeding, and feeding areas) need to be identified. Current knowledge for the province is

solely from reports of incidental sightings. Shipboard and/or aerial surveys will be needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for Risso's dolphins research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine areas frequented by Risso's dolphins and identify possible research areas. Methods are described in the Introduction to this volume.

2.) *Abundance estimates.* Total abundance estimates for one or more limited areas should be conducted using aerial surveys and land-based observation in conjunction with the methods outlined below (3). Video recording and photographs may also prove useful for counting large groups of animals.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted following the basic methodology described in the Introduction of this volume. Hiby and Hammond (1989) recommended line-transect surveys over strip-transect surveys since the greater ability to correct for missed animals produced more accurate estimates. Line-transect surveys should utilize zig-zag tracklines from shore to the 1000m isobath. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather.

References

Braham, H. W. 1983. Northern records of Risso's Dolphin, *Grampus griseus*, in the Northeast Pacific. Canadian Field-Naturalist 97(1): 89-90.

Baird, R. W., and P. J. Stacey. 1991. Status of Risso's Dolphin, *Grampus griseus*, in Canada. Canadian Field-Naturalist 105(2): 233-242.

Kasuya, T. 1985. Fishery-dolphin conflict in the Iki Island area of Japan. Pages 253-272, *In* J. R. Beddington, R. J. H. Beverton, and D. M. Lavigne (eds.), Marine Mammals and Fisheries. George Allen and Unwin Ltd., London.

Kasuya, T. and Y. Izumisawa. 1981. The fishery-dolphin conflict in the Iki Islands, Japan area. Report to the Marine Mammal Commission. 31 p.

Kruse, S. 1987. *Abstract.* Behavior of Risso's dolphins in Monterey Bay, California. Page 39, *In* Abstracts of the Seventh Biennial Conference on the Biology of Marine Mammals, December 5-9, 1987, Miami, Florida.

Mangels, K.F., and Gerrodette, T. 1994. Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA ships *McArthur* and *David Starr Jordan* July 28 - November 6, 1993. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-211.

Mitchell, E. 1975. Porpoise, dolphin and small whale fisheries of the world - status and problems. IUCN Monograph No. 3. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland.

Incidental Dolphin Species

False killer whales (*Pseudorca crassidens*) are uncommon in British Columbia waters and are probably at the northern limit of their range. Three strandings were reported along the British Columbia coast from 1987 to 1990 and a single animal was sighted on several occasions in Barkley Sound (Stacey and Baird, 1991).

Short-finned pilot whales (*Globicephala macrorhynchus*) are rare in the waters off British Columbia (Baird and Stacey, 1993). Twenty records of strandings and sightings were recorded from 1954 to 1989. Six animals were caught in an experimental driftnet fishery for flying squid (*Ommastrephes batrami*), but this fishery has been discontinued. No other fishery interactions have been reported for this species.

Striped dolphins (*Stenella coeruleoalba*) are rarely sighted in the waters off southern British Columbia and this is likely the northern limit of their range. Baird et al. (1993) reported 10 recorded strandings and 1 sighting off the Pacific coast of Canada from 1948 to 1987 with 6 strandings occurring between 1972 and 1987. No sightings have been reported for Oregon and Washington waters, though strandings have occurred in both states.

References

Baird, R. W., and P. J. Stacey. 1993. Sightings, strandings and incidental catches of short-finned pilot whales, *Globicephala macrorhynchus*, off the British Columbia coast. Report of the International Whaling Commission (Special Issue 14):475-479.

Baird, R. W., P. J. Stacey, and H. Whitehead. 1993. Status of the Striped Dolphin (*Stenella coeruleoalba*), in Canada. Can. Field-Nat. 107(4):455-465.

Stacey, P. J., and R. W. Baird. 1991. Status of the false killer whale, *Pseudorca crassidens*, in Canada. Can. Field-Nat. 105(2):189-197.

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is one of the most widely distributed of any marine mammal species occurring on both sides of the equator and in all of the major oceans of the world. In the eastern North Pacific, sperm whales are found from the equator to the Pribilof Islands (Omura 1955). The shallow continental shelf apparently bars their movement into the north-eastern Bering Sea and Arctic Ocean (Rice 1989).

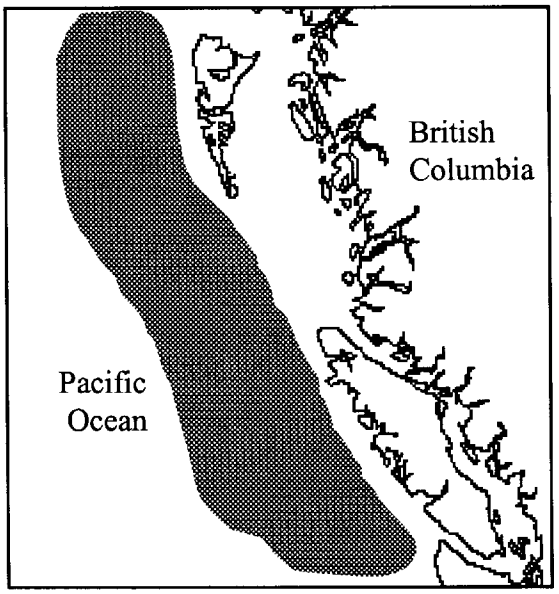

Figure 1. The known distribution of sperm whales in British Columbia.

Sperm whales are generally distributed south of 40°N during the winter months (Gosho et al., 1984). Males move north in the summer to feed, while females and young sperm whales remain in tropical and temperate waters year-round. Data from commercial whaling revealed that in past years a great deal of east-west movement occurred between the Eastern and Western North Pacific, with little evidence of north-south movement in the Eastern North Pacific. The seasonal movement of sperm whales in the Eastern North Pacific is still unclear at this time.

Sperm whales have a very low recruitment rate, about 0.05 calves/female/year, as indicated by rates of observation of calves (Whitehead et al., 1997). Best et al. (1981) estimated the recruitment rate at 0.14 calves/female/year (1 calf per 7 years after sexual maturity).

Current (1991) estimates of whale abundance in California coastal waters include 1,256 sperm whales (CV=0.55) (Barlow, 1994). Current and historic estimates for the abundance of sperm whales in the North Pacific are considered unreliable. Therefore, caution should be exercised in interpreting published estimates of abundance. The abundance of sperm whales in the North Pacific was reported to be 1,260,000 prior to exploitation, which by the late 1970s was estimated to have been reduced to 930,000 whales (Rice 1989). Further, recent information indicates that these estimates are positively biased.

Gestation period is about 14-15 months (Best et al., 1981) with the peak calving period in July and August. Suckling may occur for up to 4 years. Sexual maturity in females is attained at an average age of 18 years (Best et al., 1981).

A considerable amount of data on sperm whales was collected by the commercial whaling fleet during the first half of this century. These data include information on

morphometrics, reproduction and seasonal movements of sperm whales in the offshore waters of British Columbia. Analysis of these data is currently underway and results are not yet available (Trites, pers. comm.).

Diet

Sperm whales feed primarily on medium-sized to large-sized squids, but may also feed on large sharks, skates, and fishes (Gosho et al. 1984).

Fishery Interactions

Sperm whales were commercially harvested in the offshore waters of British Columbia during the early to mid 1900's. Since that time, sperm whales have been incidentally caught in offshore drift gillnet fisheries and possibly damaged by collisions with ships (Barlow et al., 1995). An assessment of the impact of fishery interactions in British Columbia is currently not available for this species.

Research Needs:

Basic population information is needed to estimate the abundance and distribution of sperm whales in the waters of British Columbia. Areas important to sperm whales (feeding areas) need to be identified. Current knowledge for the province is solely from reports of incidental sightings. Shipboard and/or aerial surveys will be needed to estimate the population of these animals in offshore waters. Initial studies need to focus on assessing abundance and distribution. Based on the results of these initial studies further research can be proposed.

Specific recommendations for sperm whale research in British Columbia include:

1) *Sighting and stranding information.* Sighting and stranding information can be used to determine offshore areas frequented by sperm whales and identify possible research areas. Methods are described in the Introduction to this volume.

2.) *Abundance estimates and correction factors.* Total abundance estimates for one or more limited areas should be conducted using aerial surveys in conjunction with the methods outlined below (3). Due to the long submersion times recorded for this species during deep dives, correction factors need to be calculated to estimate group sizes and animals missed while submerged. Using correction factors from other areas may be misleading, since prey type, feeding depth and other factors may affect dive duration. Direct observations of individually identifiable whales need to be made to determine dive times. Methodology will need to be developed and repetitive observations conducted. Video recording may prove useful for observing large groups of animals over time.

3) *Survey randomly selected areas of BC.* Aerial surveys should be conducted

following the basic methodology described in the Introduction of this volume. Surveys should be made on clear days with little wind to insure maximum detection. Consecutive surveys should be conducted in similar weather.

References

Barlow, J. 1994. Abundance of Large Whales in California Coastal Waters: A Comparison of Ship Surveys in 1979-80 and in 1991. Report of the International Whaling Commission 44: 399-406.

Barlow, J., R. L. Brownell, Jr., D. P. DeMaster, K. A. Forney, M. S. Lowry, S. Osmek, T. J. Ragan, R. R. Reeves, and R. J. Small. 1995. U.S. pacific marine mammal stock assessments, 1995. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-219. 162 p.

Best, P. B., P. A. S. Canham, and N. MacLeod. 1981. Patterns of reproduction in sperm whales, *Physeter macrocephalus*. Report of the International Whaling Commission (Special Issue 6): 51-79.

Gosho, M. E., D. W. Rice, and J. M. Breiwick. 1984. The sperm whale, *Physeter macrocephalus*. Mar. Fish. Rev. 46(4):54-64.

Omura, H. 1955. Whales in the northern part of the North Pacific. Nor. Hvalfangst-Tidende 44(6):323-345.

Rice, D. W. 1989. Sperm whale, *Physeter macrocephalus*. Pp. 177-233, *In* S. H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals. vol 4. River Dolphins and the Larger Toothed Whales. Academic Press, New York.

Whitehead, H., J. Christal, and S. Dufault. 1997. Past and distant whaling and the rapid decline of sperm whales off the Galapagos Islands. Conservation Biology 11(6): 1387-1396.

Incidental Toothed Whale Species

Beaked whales (family Ziphiidae) were commonly sighted by commercial whaling vessels in the mid-1900's (Pike and MacAskie, 1969). Since that time approximately 40 sightings and strandings have been recorded along the British Columbia coast (Willis and Baird, 1998). These records are distributed throughout provincial waters. Little is known about these species in Canada or elsewhere in the world. Estimates of abundance and information on fishery interactions is not available.

References

Pike, G. C., and I. B. MacAskie. 1969. Marine mammals of British Columbia. Fish. Res. Board Can. Bull. 171. 54p.

Willis, P. M., and R. W. Baird. 1998. Sightings and strandings of beaked whales on the west coast of Canada. Aquatic Mammals 24 (in press).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a worldwide distribution and is known to be migratory. The northern Pacific populations travel from tropical and temperate wintering grounds to the westcoast of the United States and Canada. Relatively distinct populations are thought to exist in the northern and southern hemispheres. It is suspected that the northern Pacific population is made up of four sub-populations which mix infrequently (Baker et al., 1986).

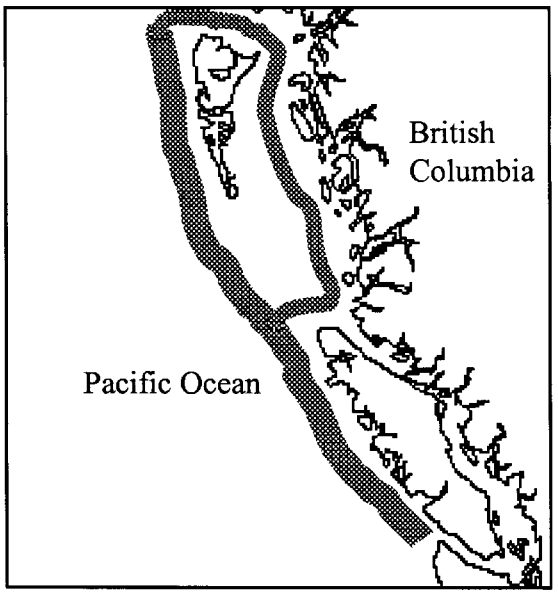

Figure 1. The known distribution of humpback whales in British Columbia.

At least two of these sub-populations are known to occur off the westcoast of Canada in the summer and fall (Figure 1). The population which overwinters off the coast of Central America and Mexico migrates to southern British Columbia in the summer (Steiger et al., 1991). The population inhabiting the Hawaiian Islands in winter and spring also migrates to northern British Columbia in the summer (Baker et al., 1990; Perry et al., 1990). Movement between a population in Japan and southern British Columbia has also been reported (Darling et al., 1996).

One explanation for the occurrence of these distinct populations is maternally directed site fidelity. Whales return to feeding areas where their mothers first brought them as calves (Baker et al., 1987). Several feeding humpbacks have been documented in British Columbia (Darling and McSweeney, 1985). The existence of feeding areas along the British Columbia coast has not, however, been adequately investigated. Humpback whales are regularly sighted along the British Columbia coast, though it is not known how long individual whales stay in these areas.

The age of sexual maturity for humpback whales has been estimated at 9 years (Johnson and Wolman, 1984). Calving generally lasts approximately 11 months and occurs in the wintering areas from January to March following a gestation period of 12 months. The female reproductive cycle is, therefore, about 2 years in duration.

Diet

Humpback whale diets in the northern Pacific consist primarily of herring, capelin, and krill. It is believed that the whales prefer krill and only consume the other food types incidentally to capturing krill or when their preferred food is not available. They may also consume young groundfish incidentally.

Humpback whales have been observed actively feeding in BC waters (Ford, pers. comm.). In BC, they have been observed feeding mostly on euphausiids, but also sand lance, herring, and crab zoae.

Abundance, Distribution and Population Status

The North Pacific population of humpback whales was estimated at 15,000 to 20,000 individuals prior to extensive catches by commercial whalers (Rice, 1978). By 1967, fewer than 1,200 animals may have remained (Johnson and Wolman, 1984). Barlow (1994) estimated the population to be greater than 3,000 individuals by 1991. Green et al. (1992) found humpback whales to be the second most abundant large whale in Oregon and Washington waters. Perry et al. (1990) suggested a minimum population estimate of 1,140 humpback whales for the North Pacific. Though a reliable current population estimate does not exist, the population is thought to be increasing (DeMaster, 1995).

Humpback whales have been sighted in BC waters throughout the year, but are more commonly seen from April through November with the peak number of sightings occurring in July and August (Ford, pers. comm., NMFS, unpubl. data). They are seen in both southern and northern BC waters in groups of 1 to 10, with the majority of the sightings from the waters surrounding the Queen Charlotte Islands (Ford, pers. comm., Figure 1). An estimate of the number of whales entering BC waters is not available, though approximately 300 individuals have been identified over the past 15 years (Ford, pers. comm.).

Whale-Human Interactions

Over the last 10 to 20 years, whale watching has become a major source of income on the westcoast of Canada. The impact of this activity on the animals involved is a topic of current research and debate. The limited geographic scope of whale watching (predominantly in Georgia Strait and Vancouver Island) currently limits the impact. The possible expansion of this growing industry throughout the province does present a need for continued research on its impacts.

Whales are incidentally killed in fishery operations. This appears to be a rare occurrence. Statistics for incidental whale kills in British Columbia are not currently available.

Research Needs:

Although a considerable amount of information on humpback whale distribution in British Columbia exists, it has not been gathered into a single database. The creation of one repository for all sighting and stranding information in the province would be helpful and increase the accessibility of the information.

Abundance and distribution

1) *British Columbia humpback whale catalogue.* Create a photographic catalogue of

the flukes of humpback whales occurring on the British Columbia coast. Several collections of photographs of humpback whales exist in the province and could be combined into a single registry. Individual humpback whales can be identified using photographs of the underside of the flukes. Distinctive markings on the flukes and the pattern of irregularities on the trailing edge of the flukes are discernible between individuals. Photographic catalogues are available for previously identified individual humpback whales in the U.S. and Japan. Comparison of the B.C. catalogue with other catalogues may allow researchers to determine the whales wintering grounds, migration patterns, etc.

The identification of individuals can also be used to formulate population estimates. Using techniques developed for mark/recapture studies, estimates of population size can be calculated. This information can also be used to determine movement patterns along the coast and length of residence in B.C. waters.

2) *Sighting and stranding information.* Information on humpback whales can be gathered through the sighting and stranding network described in the Introduction of this volume. This information will not be useful for identification of individuals, but will give an indication of distribution of the species throughout the province.

Diet

A better understanding of where and what humpback whales are eating in BC waters is essential to protecting necessary habitat and food resources for these magnificent creatures. Including important humpback whale prey species and the impact of humpback whales as predators in fishery management decisions will allow for more realistic scenarios to be formulated and evaluated.

3) Using observer data, determine the extent to which whales are feeding in BC waters. If feeding areas are located, conduct a fishery survey to determine the types of prey frequenting these areas. Prey identification can also be accomplished by extended periods of observation of surface feeding whales (e.g., prey seen leaping from water to escape capture). Prey identification will allow for management of prey species.

References

Baker, C. S., L. M. Herman, A. Perry, W. S. Lawton, J. M. Straley, A. A. Wolman, G. D. Kaufman, H. E. Winn, J. D. Hall, J. M. Reinke, and J. Ostman. 1986. Migratory movement and population structure of humpback whales (*Megaptera novaeangliae*) in the central and eastern North Pacific. Mar. Ecol. Prog. Ser. 31:105-119.

Baker, C. S., A. Perry, and L. M. Herman. 1987. Reproductive histories of female humpback whales (*Megaptera novaeangliae*) in the North Pacific. Mar. Ecol. Prog. Ser. 41:103-114.

Baker, C. S., S. R. Palumbi, R. H. Lambertson, M. T. Weinrich, J. Calambokidis, and S. J. O'Brien. 1990. Influence of seasonal migration on geographic distribution of mitochondrial DNA haplotypes in humpback whales. Nature 344:238-240.

Barlow, J. 1994. Recent information on the status of large whales in California waters. NOAA Tech. Memo. NMFS-SWFSC-203. 27 p.

Berggren, P., and F. Arrhenius. 1995. Densities and seasonal distribution of harbour porpoises (*Phocoena phocoena*) in the Swedish Skagerrak, Kattegat and Baltic Seas. Report of the International Whaling Commission, Special Issue 16: 109-121.

Darling, J. D., and D. J. McSweeney. 1985. Observation on the migrations of North Pacific humpback whales (*Megaptera novaeangliae*). Can. J. Zool. 63:308-314.

Darling, J. D., J. Calambokidis, K. C. Balcomb, P. Bloedel, K. Flynn, A. Mochizuki, K. Mori, F. Sato, and M. Yamaguchi. 1996. Movement of a humpback whale (*Megaptera novaeangliae*) from Japan to British Columbia and return. Mar. Mammal Sci. 12(2):281-287.

DeMaster, D. P. 1995. Minutes from the 4-5 and 11 January 1995 meeting of the AlaskaScientific Review Group, Anchorage, Alaska. 27 pp. + appendices.

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Chapter 1, *In*: J. J. Brueggeman (ed.) Oregon and Washington Marine Mammal and Seabird Surveys. Minerals Management Service Contract Report 14-12-0001 -30426.

Johnson J. H., and A. A. Wolman. 1984. The humpback whale, *Megaptera novaeangliae*. Mar. Fish. Rev. 46:30-37.

Perry, A., C. S. Baker, and L. M. Holman. 1990. Population characteristics of individually identified humpback whales in the central and eastern North Pacific: A summary and critique. Rep. Int. Whal. Comm. (Special Issue 12):307-317.

Rice, D. W. 1978. The humpback whale in the North Pacific: distribution, exploitation, and numbers. Appendix 4. Pp.29-44, *In* K. S. Norris and R. R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. Nat. Tech. Info. Serv. PB-280-794. Springfield, VA.

Steiger, G. H., J. Calambokidis, R. Sears, K. C. Balcomb, and J. C. Cubbage. 1991. Movement of humpback whales between California and Costa Rica. Mar. Mammal Sci. 7:306-310.

Gray Whale (*Eschrichtius robustus*)

The gray whale is currently only found in the North Pacific (Rice et al. 1984). The majority of animals in the Eastern North Pacific stock spend the summer feeding in the inshore water off Alaska (Rice and Wolman 1971). Gray whales have been reported feeding in waters off of British Columbia and have been sighted in provincial coastal waters from March through October (NMFS, unpubl. data; Figure 1).

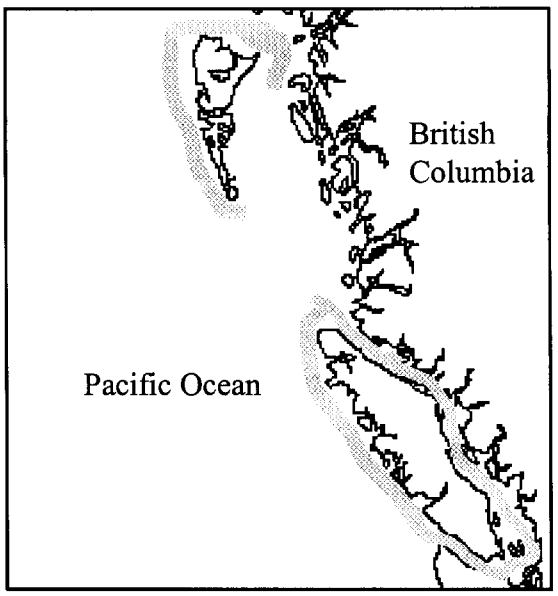

Figure 1. The known distribution of gray whales in British Columbia.

The whales migrate near shore along the coast of North America from Alaska to the central California coast (Rice and Wolman 1971) starting in October or November. The Eastern North Pacific stock winters mainly along the westcoast of Baja California. Pregnant females gather in shallow, nearly landlocked lagoons and bays where the calves are born from early January to mid-February (Rice et al. 1981). The northbound migration along the westcoast of North America begins in mid-February and continues through June with cows and newborn calves migrating northward most commonly between March and June (Rice et al. 1981).

Gray whales migrating along the central California coast were systematically counted by shore-based observers through the entire 1995-96 southbound migration (Hobbs et al. 1996). The preliminary abundance estimate resulting from the 1995-96 census is 22,571 whales. Annual rate of increase for Gray whales has been calculated at 2.5% from 1967-1980 (Reilly, 1981).

Diet

Gray whales feed on benthic fauna in near shore areas including shrimp and amphipods (Weitkamp et al., 1992). They create pits when feeding by scooping benthic sediment in to their mouths and sifting out prey through their baleen plates.

Fishery Interactions

Gray whales entangled in fishing gear have been found along the westcoast of North America. In 1994, two gray whale mortalities related to fisheries were reported in British Columbia (Guenther et al. 1995). Data regarding the level of gray whale mortality related to commercial fisheries in Canadian waters, though thought to be small, are not readily available. However, the large stock size and observed rate of increase over the

past 20 years makes it unlikely that unreported mortalities from Canadian fisheries would be a significant source of mortality.

Research Needs:

Although a considerable amount of information on gray whale distribution in British Columbia exists, it has not been gathered into a single database. The creation of one repository for all sighting and stranding information in the province would be helpful and increase the accessibility of the information for researchers and conservationists.

Specific recommendations for gray whales research in British Columbia include:

Abundance and distribution

1) *British Columbia gray whale catalogue.* Create a photographic catalogue of the dorsal ridges and flukes of gray whales occurring on the British Columbia coast. Several collections of photographs of gray whales exist in the province and could be combined into a single registry. Individual gray whales can be identified using photographs of the markings and shape of the dorsal ridge and/or flukes. Distinctive markings on the dorsal ridge and the pattern of irregularities on the trailing edge of the flukes are discernible between individuals. Photographic catalogues are available for previously identified individual gray whales in the U.S. Comparison of the B.C. catalogue with other catalogues may allow researchers to better determine the whales wintering grounds, migration patterns, etc.

   The identification of individuals can also be used to formulate population estimates. Using techniques developed for mark/recapture studies, estimates of population size can be calculated. This information can also be used to determine movement patterns along the coast and length of residence in B.C. waters.

2) *Sighting and stranding information.* Information on gray whales can be gathered through the sighting and stranding network described in the Introduction of this volume. This information will not be useful for identification of individuals, but will give an indication of distribution of the species throughout the province.

Diet

A better understanding of where and what gray whales are eating in B.C. waters is essential to protecting necessary habitat and food resources. Including important gray whale prey species and the impact of gray whales as predators in fishery management decisions will allow for more realistic scenarios to be formulated and evaluated.

3) Using observer data, determine the extent to which gray whales are feeding in B.C. waters. If feeding areas are located, conduct a fishery and benthic survey

(near the feeding pits) to determine the types of prey frequenting these areas. Prey identification will allow for management of prey species.

References

Guenther, T. J., R. W. Baird, R. L. Bates, P. M. Willis, R. L. Hahn, and S. G. Wischniowski. 1995. Strandings and fishing gear entanglements of cetaceans of the westcoast of Canada in 1994. Unpubl. doc. submitted to the International Whaling Commission (SC/47/O6). 7pp.

Hobbs, R. C., D. J. Rugh, J. M. Waite, J. M. Breiwick, and D. P. DeMaster. 1996. Preliminary estimate of the abundance of gray whales in the 1995/96 southbound migration. Unpubl. doc. submitted to the International Whaling Commission (SC/48/AS9). 11 pp.

Reilly, S. B. 1981. Observed and maximum rates of increase in gray whales, *Eschrichtius robustus*. Reports of the International Whaling Commission (Special Issue 6):389-399.

Rice, D. W., and A. A. Wolman. 1971. The life history and ecology of the gray whale, *Eschrichtius robustus*. Am. Soc. Mammal. Spe. Publ. 3. 142 pp.

Rice, D. W., A. A. Wolman, and H. W. Braham. 1984. The gray whale, *Eschrichtius robustus*. Mar. Fish. Rev. 46(4):7-14.

Rice, D. W., A. A. Wolman, D. E. Withrow, and L. A. Fleischer. 1981. Gray whales on the winter grounds in Baja, California. Reports of the International Whaling Commission. 31:477-493.

Weitkamp L A., R. A. Wissmar, C. A. Simenstad, K. L. Fresh, and J. G. Odell. 1992. Gray whale foraging on Ghost Shrimp (*Callianassa californiensis*) in littoral sand flats of Puget Sound, USA. Canadian Journal of Zoology 70(12):2275-2280.

Minke Whale (*Balaenoptera acutorostrata*)

Minke whales inhabit both hemispheres and all the major oceans and are the most abundant baleen whale. In the eastern North Pacific, minke whales occur from Alaska to near the equator (Leatherwood et al. 1982). In British Columbia, minke whales have been sighted in both inshore and offshore waters throughout the province (Figure 1) during all months of the year (NMFS, unpubl. data).

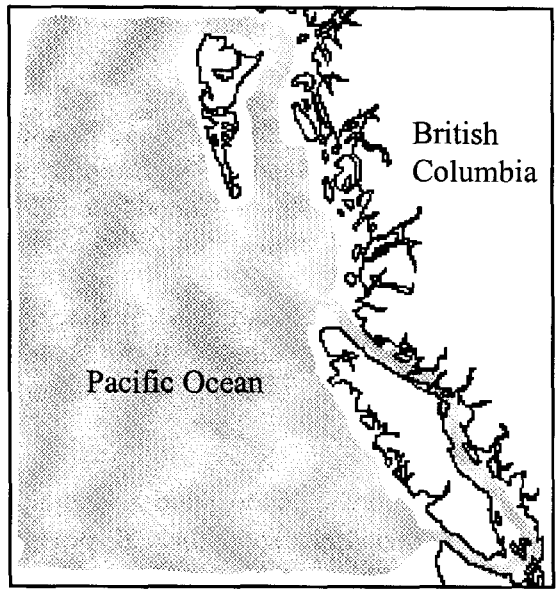

Figure 1. The known distribution of minke whales in British Columbia.

The International Whaling Commission (IWC) recognizes 3 stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea, one in the rest of the western North Pacific, and one in the "remainder" of the Pacific (Donovan 1991). The "remainder" stock designation reflects the lack of exploitation in the eastern Pacific and does not indicate that only one population exists in this area (Donovan 1991).

Minke whales are relatively abundant in the inshore waters of Alaska (Mizroch 1992), but are not considered common in any other part of the Eastern Pacific (Leatherwood et al. 1982). Minke whales are believed to be migratory in the northern parts of their range, but appear to establish home ranges in the inland waters of Washington and along central California (Dorsey et al. 1990). The behaviour of the "resident" minke whales from California to Washington appears to be distinct from migratory whales inhabiting Alaska. The behaviour of minke whales in British Columbia is currently not known.

Diet

In the Atlantic Ocean, minke whales include a larger proportion of fish in their diet than any other baleen whale (Katona et al., 1993). Herring, capelin, cod, pollock, salmon, mackerel, and sand lance are eaten along with some squid, krill, and copepods. The diet of minke whales frequenting British Columbia waters is not known.

Fishery Interactions

Minke whales in Newfoundland have occasionally become entangled in fishing gear (Katona et al., 1993). The fact that they prey on several commercially important species increases the likelihood for significant fishery interactions. The extent of interaction between fishermen and minke whales in British Columbia is not known.

Research Needs:

Information on Minke whale distribution in British Columbia is very limited.

Abundance and distribution

1) *British Columbia minke whale catalogue.* Create a photographic catalogue of the dorsal fins and backs of minke whales occurring on the British Columbia coast. Several collections of photographs of minke whales exist in the U.S. and Japan. Comparison of the B.C. catalogue with other catalogues may allow researchers to determine the whales wintering grounds, migration patterns, etc.

   The identification of individuals can also be used to formulate population estimates. Using techniques developed for mark/recapture studies, estimates of population size can be calculated. This information can also be used to determine movement patterns along the coast and length of residence in B.C. waters.

2) *Sighting and stranding information.* Information on minke whales can be gathered through the sighting and stranding network described in the Introduction of this volume. This information will not be useful for identification of individuals, but will give an indication of distribution of the species throughout the province.

Diet

A better understanding of where and what minke whales are eating in BC waters is essential to protecting necessary habitat. Including important minke whale prey species and the impact of minke whales as predators in fishery management decisions will allow for more realistic scenarios to be formulated and evaluated.

3) Using observer data, determine the extent to which minke whales are feeding in BC waters. If feeding areas are located, conduct a fishery survey to determine the types of prey frequenting these areas. Prey identification can also be accomplished by extended periods of observation of surface feeding whales (e.g., prey seen leaping from water to escape capture). Prey identification will allow for management of prey species.

References

Donovan, G. P. 1991. A review of IWC stock boundaries. Reports of the International Whaling Commission (Special Issue 13):39-68.

Dorsey, E. M., S. J. Stern, A. R. Hoelzel, and J. Jacobsen. 1990. Minke whale (*Balaenoptera acutorostrata*) from the westcoast of North America: individual recognition and small scale site fidelity. Reports of the International Whaling Commission (Special Issue 12):357-368.

Katona, S. V., V. Rough, and D. T. Richardson. 1993. A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland. Smithsonian Institution Press, Washington. 316pp.

Leatherwood, S., R. R. Reeves, W. F. Perrin, and W. E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: A guide to their identification. U.S. Dep. Commer., NOAA Tech.

Mizroch, S. A. 1992. Distribution of minke whales in the North Pacific based on sightings and catch data. Unpubl. doc. submitted to the International Whaling Commission. (SC/43/Mi36). 37 pp.

Incidental Baleen Whale Species

Fin whales (*Balaenoptera physalus*) were reported to be the fourth most abundant large whale in the waters off Washington and Oregon (Green et al., 1992). The population of the eastern Pacific stock was estimated in 1973 between 8,520 and 10,970 animals. Population estimates are not available for British Columbia though fin whales have been sighted off the westcoasts of Vancouver Island and the Queen Charlotte Islands and in Queen Charlotte Sound (NMFS, unpubl. data). Fin whales migrate between summer and winter feeding grounds (the locations of the wintering grounds are not known) and may be in transit when sighted in British Columbia waters.

Northern right whales (*Eubalaena glacialis*) are extremely rare in the North Pacific Ocean with an estimated total post-whaling population of 100-200 animals (Wada, 1973). There is no current information on these animals in British Columbia waters. There are two unconfirmed sightings off the British Columbia coast, one in 1973 and 1985, respectively (NMFS, unpubl. data). These are the only records of right whales in this area since the end of commercial whaling.

Sei whales (*Balaenoptera borealis*) are relatively abundant from May to August in the offshore waters of British Columbia, as estimated by Japanese sighting and catch data up to 1972 (Horwood, 1987). Sei whales undergo annual migrations from their wintering grounds in the tropics and sub-tropics to the temperate and polar regions in the summer. These migrations bring them into British Columbia waters, but it is not known if sei whales reside for long periods (weeks or months) or are passing through on their annual migration. Current estimates of abundance and distribution of sei whales in the waters off British Columbia are not available. Incidental catches by fishermen (especially in pelagic purse seines) and collisions with ships are not considered a significant cause of mortality for sei whales in the North Pacific (Horwood, 1987).

References

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, and K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Chapter 1, *In*: J. J. Brueggeman (ed.) Oregon and Washington Marine Mammal and Seabird Surveys. Minerals Management Service Contract Report 14-12-0001 -30426.

Horwood, J. 1987. The Sie Whale: Population biology, ecology and management. Croom Helm, New York. 375 p.

Wada, S. 1973. The ninth memorandum on the stock assessment of whales in the North Pacific. Report of the International Whaling Commission 23:164-169.