COMMITTEE ON THE
STATUS OF ENDANGERED
WILDLIFE IN CANADA

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COMITÉ SUR LE STATUT
DES ESPÈCES MENACÉES
DE DISPARITION AU
CANADA

OTTAWA (ONT.) K1A 0H3
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STATUS REPORT ON THE SPERM WHALE *PHYSETER MACROCEPHALUS* IN CANADA

BY

RANDALL R. REEVES

AND

HAL WHITEHEAD

STATUS ASSIGNED IN 1996
NOT AT RISK

REASON: SPERM WHALES RANGE WIDELY THROUGH THE WORLD'S OCEANS AND ARE FOUND OFF BOTH COASTS OF CANADA. THE WORLD-WIDE POPULATION IS RELATIVELY LARGE DESPITE HISTORIC LARGE REDUCTIONS BY COMMERCIAL WHALING. WHALING FOR THIS SPECIES WAS DISCONTINUED IN 1972 IN CANADA.

OCCURRENCE: ATLANTIC AND PACIFIC OCEANS

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CSEMDC - Un comité de représentants d'organismes fédéraux, provinciaux et privés qui attribue un statut national aux espèces canadiennes en péril.

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STATUS REPORT ON THE SPERM WHALE *PHYSETER MACROCEPHALUS* IN CANADA

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Status of the Sperm Whale, *Physeter macrocephalus*, in Canada

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The Sperm Whale (Physeter macrocephalus) is the largest of the toothed whales. Members of this species are extreme, or distinctive, among cetaceans in many ways which include their large brain size, sexual dimorphism, diving behaviour, social organization, communication system and ecological significance. They occur in all the deeper waters of the world's oceans that are not ice-covered, although females are generally restricted to areas where surface temperatures are warmer than 15°C and depths are greater than 1000m. Sperm Whales range widely with no clear divisions between populations. Sperm Whales were depleted during two massive, world-wide hunts (peaking in approximately the 1840s to the 1860s and the 1950s to the 1970s). The current world population likely numbers a few hundred thousand, but there are considerably fewer Sperm Whales now than there were before whaling. Recovery of the population is slow because of a very low reproductive rate, possibly compounded by the lingering effects of a socially disruptive hunt concentrated on large males. Sperm Whales are found off both the east and west coasts of Canada with particular concentrations at the entrance to the Hudson Strait, on the Scotian Shelf and west of Vancouver Island. Both sexes occur off western Canada, but females only occasionally use the southern most waters off Atlantic Canada. Although no immediate threats to Sperm Whale populations are known, these animals are vulnerable to particular kinds of human disturbance, and populations may be threatened, in the long term, by increasing levels of pollutants in the oceans.

Le cachalot macrocéphale (Physter macrocephalus)est le plus gros des odontocètes. À bien des égards y compris le larges de leur cerveaux, leur dimorphisme sexuel, leur comportement de plongé, leur organisation sociale, leur système de communication, et leur importance écologique; les membres de cette espèce sont extrême ou distinctives parmi les cétacés. Elles habitent toutes les eaux plus profondes des océans du monde oú il n'y a pas une couverture de la glace, bien que les femelles soient généralement limitées aux zones oú les températures aux surfaces sont plus chaud que 15°C et la profondeur est supérieure à 1000m. Les cachalots courent partout les océans et elles n'y ont pas aucunes divisions distinctes entre les populations. Deux mondiaux chasses massives (qui ont gagnées un pointe environs 1840 à 1860 et encore de 1950 à 1970) Les nombres des cachalots sont épuisées par deux massives chasses mondiaux qui ont gagnées un pointe environs 1840 à 1860 et encore de 1950 à 1970. Aujourd'hui, les cachalots sont considérablement moins nombreux que avant la Pêche à la baleine même que la population mondiale du jour est probablement plusieurs centaines de milles. La quérison de la population est lente à cause de une bas taux de la reproduction, et il est possible que l'effet sur le taux soit aussi composé par les effets prolongés de une chasse socialement disruptives qui a concentrée son attention sur les gros males. Au Canada, on rencontre les cachalots dans les zones ouest et est de ces deux bassins océaniques, mais il y a des centres de convergence dans l'entrée du détroit de Hudson, le long de la bordure de la plate-forme né-écossaise, et ouest de l'île Vancouver. Au large de la Colombie-Britannique on peut retrouver les deux sexes, mais les femelles ne pénètrent généralement les eaux nord au large de l'Atlantique de Canada. Quoique on ne connaisse pas aucune menace immédiate contre les populations des cachalots, mais ces baleines sont vulnérables aux quelques genres de dérangements humains et les populations peuvent être menacées, dans le long terme, par les niveaux de polluants croissant dans les océans.

Key Words: Sperm whale, cachalot, *cachalot macrocéphale*, *Physeter macrocephalus*, Cetacea, Odontoceti, conservation status

The Sperm Whale (*Physeter macrocephalus* Linnaeus 1758) is the world's largest living odontocete, or toothed whale (Figure 1). Males grow to a maximum length of 18m and reach weights of nearly 60 metric tons. Females are much smaller, with a maximum length of about 11m and a weight of 24 metric tons (Rice 1989). The Sperm Whale is extreme among mammals in a number of ways in addition to its large size and sexual dimorphism. It has the largest brain on Earth, and the largest geographical separation of adult males from adult females. The aggregate world biomass is among the highest of any wild mammal, and this distinction probably would have been more marked in pre-whaling times. Sperm Whales may dive deeper than any other mammal, although they are rivalled by Elephant Seals (*Mirounga* sp.) and Bottlenose Whales (*Hyperoodon* sp.), and they seem to have one of the most caring of marine mammal societies. The world's Sperm Whale populations were the target of two massive commercial hunts. The first, using open rowed whale-boats and hand-thrown harpoons, lasted from the early 18th Century to the early 20th Century, peaking in the 1840s and 1850s. Modern whalers aboard steam or diesel powered catcher vessels with deck-mounted harpoon guns took hundreds of thousands of Sperm Whales between 1946 to 1978 (Best 1983).

There is only one species of *Physeter*, although the appropriate nomenclature and evolutionary history of the Sperm Whale are matters of debate. Most scientists and organizations (including the International Commission for Zoological Nomenclature and the International Whaling Commission) call the Sperm Whale *Physeter macrocephalus* (Husson and Holthuis 1974; Holthuis 1987; Rice 1989). Schevill (1986; 1987), however, argued that *Physeter catodon* was the proper Linnaean name for the species. The Sperm Whale is generally classified in the suborder Odontoceti, the toothed whales, but molecular evidence has recently been interpreted as suggesting that it is more closely related to the baleen whales (suborder Mysticeti) and therefore that the odontocetes are not monophyletic (Milinkovitch, Guillermo and Meyer 1993).

This review discusses the conservation status of the Sperm Whale, with particular attention to the animals of the North Atlantic and North Pacific.

Distribution and Stock Identity

The Sperm Whale's distribution spans virtually all latitudes between the north and south polar ice caps. It has the widest distribution of any marine mammal except the Killer Whale (*Orcinus orca*) (Rice 1989). The Sperm Whale, generally an animal of deep waters, is particularly abundant off the outer edges of the world's continental and island shelves, in or near upwelling areas, and in deeper basins of seas and gulfs (Townsend 1935; Berzin 1971; Jaquet In press). Females and young animals are generally restricted to tropical and temperate waters whereas mature males are more common at higher latitudes (Rice 1989).

Both tagging experiments carried out with the whaling industry and resightings of individually identified animals indicate that female Sperm Whales have ranges spanning very approximately 1000km, although there is a great deal of variation (Best 1979; Kasuya and Miyashita 1988; Dufault and Whitehead 1995). Mature males have larger ranges, migrating from high-latitude feeding grounds to breed in tropical and subtropical waters (Best 1979). They also make considerable longitudinal migrations (see below).

The delineation of Sperm Whale stocks was a contentious issue at meetings of the Scientific Committee of the International Whaling Commission during the 1970s and early 1980s (e.g. International Whaling Commission 1980). Evidence from different sources was often contradictory. Part of the problem lay in the

very different ranging patterns of males and females, but the weight of evidence suggests that there are no well-defined Sperm Whale stocks--no areas in the ocean which Sperm Whales rarely cross, or even areas which they rarely cross at a particular time of year. For instance female Sperm Whales which visit the Galápagos Islands also use waters off mainland Ecuador, 1000km away, where they mix with females which do not visit the Galápagos (Dufault and Whitehead 1993). In a study of variation in the maternally-inherited mitochondrial DNA of female Sperm Whales, strong group-level similarities among females were found, indicating genetic relatedness within groups, but no geographic structure at any scale: females in different groups in the same area were as likely to share mitochondrial haplotypes as those in different oceans (M. Dillon et al. in prep.). Thus it seems that groups of female Sperm Whales, and individual males, have ranges, but that the population has no other clear geographic structure.

North Atlantic

The overall North Atlantic distribution of adult males extends north to at least 69°N in Denmark Strait and to 71°N west of Jan Mayen and north of Norway (Rice 1989). Sperm Whales are found in the Caribbean Sea, the Gulf of St Lawrence and the Mediterranean Sea (Viale 1977; Rice 1989; see below). In the Atlantic, females and young males rarely move north of the Subpolar Convergence (45-50°N--higher in the east than the west).

Off the east coast of Canada, Sperm Whales have not been reported north of Hudson Strait, although they certainly move into higher latitudes (at least to 64°N) off West Greenland (Kapel 1979; Perkins et al. 1982). The lack of records off the east coast of Baffin Island may be due partly to the whales' offshore distribution and the small amount of research effort there. Large males are common at the eastern entrance to Hudson Strait in late August and September (Mitchell 1974; MacLaren Atlantic Limited 1977; MacLaren Marex Inc. 1979), and some enter Hudson Strait and Ungava Bay (Reeves et al. 1986). Male Sperm Whales are present off, and sometimes on, the continental shelf along the entire east coast of Canada south of Hudson Strait (e.g. Mitchell 1974; 1975; Mitchell and Kozicki 1984; Whitehead, Brennan and Grover 1992; Parsons 1995; Figure 2). They are found with considerable reliability in the northern part of the Gully (44°N, 59°W), a submarine canyon on the edge of the Scotian Shelf (Whitehead, Brennan and Grover 1992). Sperm Whales are found in the Gulf of St. Lawrence, usually only sporadically and in relatively small numbers (Richard Sears, Migan Island Cetacean Study In., St. Lambert, Quebec; personal communication), although one to four Sperm Whales, including one well-known individual, 'Tryphon,' have been seen off Tadoussac in the St Lawrence Estuary quite consistently during the summer months (May-October) between 1991-1995 (R. Michaud, personal communication).

Sperm Whales have stranded in several parts of eastern Canada, throughout the year (Table 1). Dead Sperm Whales are reported in the Gulf of St Lawrence more often than might be expected judging by the infrequency of sightings. For example, between 1982 and 1985 Sperm Whales represented close to 4 percent of the total documented cetacean mortalities in the Gulf (Béland et al. 1987).

The fishery for Sperm Whales off Nova Scotia only took males (Mitchell 1975), and recent studies of living Sperm Whales on and near the Scotian Shelf have focused almost entirely on males (Mullins, Whitehead and Weilgart 1988; Whitehead, Brennan and Grover 1992). Recent strandings off eastern Canada have also been principally of males (Table 1). However, a female stranded in July 1994 in southern Nova Scotia (Table 1), and groups of females have twice been

observed in the Gully: once on 23 June 1990 (Whitehead, Brennan and Grover 1992), and once (tentative identification) on 15 July 1993 (H. Whitehead, unpublished data). Thus, in the Atlantic, the southern limit of the Canadian EEZ appears to coincide approximately with the northern limit of the range of female Sperm Whales (Figure 1).

A male tagged off Nova Scotia (42° 12'N, 65° 07'W; 26 July 1966) was taken by whalers off northwestern Spain (44° 10'N, 11° 20'W; 7 August 1973), some 6000km away (Mitchell 1975). Another male taken in the northern part of Denmark Strait (ca. 65°N, 29° 45'W) in early August 1981 apparently had been wounded the previous August by whalers near the Azores about 3000km to the south (Martin 1982; Sigurjónsson 1985). Several Azorean-type hand harpoons (or harpoon fragments) were found in Sperm Whales killed off northwestern Spain (Aguilar 1985). Thus Sperm Whales move across large parts of the North Atlantic, and the International Whaling Commission has accordingly managed whaling for Sperm Whales in the North Atlantic on the assumption that there is only one population.

However the equator does not act as a barrier to Sperm Whale movements, so that distinguishing North Atlantic versus South Atlantic populations is artificial. A young male tagged off Mauritania, West Africa, in late November one year was killed west of Cape Town, South Africa, in March somewhat more than four years later (Ivashin 1967). This animal had moved between an area near the Tropic of Cancer to an area far south of the Tropic of Capricorn.

North Pacific

Sperm Whales are found throughout the North Pacific, including the deeper waters of the Bering Sea, the South China Sea, the East China Sea, the Sea of Japan, the Sea of Okhotsk, the Gulf of Alaska and the Gulf of California (Rice 1989). Females and young males generally do not move north of the Transitional Domain, just north of the Subarctic Boundary (ca. 42°N in most of the North Pacific) [Rice 1989]. Berzin and Rovnin (1966) gave the northern boundary for the summer range of females and young males in the eastern North Pacific as the southern Gulf of Alaska, approximately in the latitude of 50-51°N. The occasional occurrence of females as far north as the Aleutian Islands may be explained by exceptional incursions of warm water into high latitudes (Pike and MacAskie 1969).

Sperm Whales are present in the deep waters off the west coast of Canada (Figure 1), and strandings have been reported at a low, but quite steady, rate (Table 1). The whaling grounds for Sperm Whales off Vancouver Island were in the open ocean up to 200 nautical miles (370km) from shore. Large concentrations, including herds of 50-150 animals, were encountered there from late spring through early autumn (Pike and MacAskie 1969). Sperm Whales are observed occasionally in Hecate Strait, Dixon Entrance, Queen Charlotte Sound, and the broader inside waterways north of Vancouver Island (Pike and MacAskie 1969; H. Patterson, pers. comm.).

Ninety percent of the Sperm Whales taken in British Columbia were males averaging 11.6-14.0m long, and most of them were sexually mature (Pike and MacAskie 1969). This strong bias in the catch could have been at least partially due to legal restrictions, including requirements that only whales 35ft (10.7m) or longer be hunted and that females accompanied by calves not be taken. However, females and young are present in the deep waters off Vancouver Island (Pike and MacAskie 1969) and, in some years, the Queen Charlotte Islands (Reeves et al. 1985).

Tagged Sperm Whales have crossed much of the North Pacific, as well as from

the North Pacific to the South Pacific (Kasuya and Miyashita 1988). Despite this, there has been considerable inconclusive debate as to whether the Sperm Whales in the North Pacific constitute one, two, three or more stocks (e.g. Rice 1974; Bannister and Mitchell 1980; International Whaling Commission 1980; Kasuya and Miyashita 1988; Donovan 1991).

Exploitation and Protection

North Atlantic

Sperm Whales were hunted by American and European whalers on many grounds throughout the North Atlantic, beginning in the early 1700s (Starbuck 1878). The 18th and 19th Century hunting grounds of the American whaling fleet included the Labrador and Newfoundland coasts, the Gulf of St. Lawrence, and the Grand Banks.

Modern whaling began in the 1860s. Although rorquals were the principal targets of most modern whaling operations in the North Atlantic, substantial catches of Sperm Whales (100 or more per year) were made in Iceland (mid-1950s to 1982), Madeira (to 1981), the Azores (to 1987), and Spain (early 1950s to 1980), and moderate but regular catches were made in Norway, the Faroe Islands, Portugal, and Canada (Jonsgård 1977). Small numbers of Sperm Whales continued to be taken in the Lesser Antilles as recently as the 1980s (Price 1985; Reeves 1988).

Whalers in Newfoundland and Labrador caught from 0 to 53 Sperm Whales per year (mean 6/yr) from 1904 to 1970 (Mitchell 1974). Sperm Whales did not become major targets of shore whaling in Nova Scotia until 1970, when 25 were taken (Mitchell 1974). From 1964, when operations began at Blandford, through 1972, when commercial whaling in Canada stopped, the total Nova Scotian catch of Sperm Whales was 109 males and no females (Mitchell 1975). Sperm Whales generally were taken at Blandford only when Fin Whales (*Balaenoptera physalus*) and Sei Whales (*Balaenoptera borealis*) were unavailable, due either to their absence on the grounds or to the fact that quotas had been filled (Mitchell 1975).

There was no Sperm Whale catch limit in the North Atlantic until 1977, when the International Whaling Commission set a quota of 685 whales per year (Sigurjónsson 1988). In 1980 the quota was reduced to 273, divided by bilateral agreement between Spain (173) and Iceland (100) and in 1981 it was further reduced to 130 (Iceland only; Spain ceased whaling). The Sperm Whales in the North Atlantic were classified as a protected stock beginning in 1982. Catching at Madeira and the Azores was unaffected by the regulations because Portugal was not a member of the International Whaling Commission.

Currently (1996) we are unaware of any directed catch of Sperm Whales in the North Atlantic.

North Pacific

The American and European pelagic whaling fleets began visiting Sperm Whale grounds in the Pacific Ocean in the late 1700s (Starbuck 1878). Thereafter, tens of thousands of Sperm Whales were taken in the North Pacific by the American, French, and British fleets (du Pasquier 1982; Best 1983; Webb 1988). The open-boat fishery in the North Pacific was especially intense between about 1825 and 1845 (Tillman and Breiwick 1983).

Modern whaling was introduced to the North Pacific in the last decade of the 1800s, and floating factories and shore stations proliferated during the early decades of the 20th Century (Ohsumi 1980). A list of reported Sperm Whale catches throughout the North Pacific from 1910 to 1976 totals more than a quarter

million, of which nearly 60 percent were taken between 1963 and 1976 (Ohsumi 1980). Large post-war catches were made from shore stations in Japan and the Kuril Islands and by Japanese and Soviet floating factories that operated all over the North Pacific (Ohsumi 1980; Kasuya 1991).

Shore-based whaling for Sperm Whales off western North America has a long history. Sperm Whales were prominent in the catches of stations on Vancouver Island and the Queen Charlotte Islands (Pike and MacAskie 1969; minimum of 5,937 taken from 1919 through 1967), Kodiak and the Aleutian Islands (Reeves et al. 1985), Washington State (Scheffer and Slipp 1948), and California (Rice 1974). Shore whaling ended on the Canadian west coast in 1967 and on the west coast of the United States in 1971 (Ohsumi 1980).

A North Pacific Working Group was established by the International Whaling Commission in 1951 and a Sperm Whale Subcommittee of the Scientific Committee of the International Whaling Commission in 1962. Based largely on the work of these groups, the Commission began setting Sperm Whale quotas for pelagic whaling in the North Pacific in 1971. The quota was subdivided by sex beginning in 1973. In 1975 North Pacific catch limits were 6000 males and 4000 females (International Whaling Commission 1977), and, in 1981, 890 males and 0 females (International Whaling Commission 1982a). The Japanese officially stopped catching Sperm Whales in the North Pacific in 1988.

Worldwide

A worldwide ban on commercial whaling was agreed by the International Whaling Commission in 1982 and took effect in 1985. By the end of the 1980s the few remaining major shore-based whaling operations involving a catch of Sperm Whales (Iceland, the Azores, Madeira and Japan) had ceased. The Sperm Whale has been in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 1985. Trade in products, most importantly sperm oil, teeth, and ambergris (a waxy substance found in the large intestine of the Sperm Whale) is therefore illegal in most countries (but not Japan and Norway, both of which entered reservations against the Appendix I listing). Since 1981, importation of sperm oil and other Sperm Whale products (teeth excepted) has been prohibited by the European Union, and this has meant the closing of a formerly important market (Klinowska 1991). The importation of marine mammal products has been banned in the United States since 1972.

The only place in the world where a catch of Sperm Whales is known to continue is at Lamalera, Lembata (Loblem on world maps) Indonesia, where a few animals are taken per year by primitive methods (Barnes 1991).

Population Sizes and Trends

All available estimates of Sperm Whale population sizes are problematic. To obtain unbiased population estimates, visual counts from ships or aircraft must be corrected to account for their dives which generally last at least 30min (Papastavrou, Smith and Whitehead 1989; Watkins et al. 1993). Reliable corrections for Sperm Whale dives are not available, and estimates from visual counts are presented uncorrected. However, because failing to correct for diving behaviour always results in a negative bias in population estimates, several well-conducted visual surveys provide useful minimum density estimates for particular ocean areas (e.g. Christensen, Haug and Oien 1992; Wade and Gerrodette 1993; Davis et al. 1995). Acoustic surveys of Sperm Whales, in which a count is made of the number of vocalizations or vocalizing animals heard through towed hydrophones, have been attempted (e.g. Leaper, Chappell and Gordon 1992; Davis

et al. 1995), but the methodology behind such censuses need further development. In two cases mark-recapture estimates of the number of animals visiting a restricted study area have been made using individual photographic identifications (Whitehead, Waters and Lyrholm 1992; Childerhouse, Dawson and Slooten 1995). However the wide ranging behaviour of this species, and the lack of any clear stock divisions means that none of these estimates refer to a discrete population.

During the 1970s and early 1980s considerable effort was put into trying to determine the status of Sperm Whale populations using data obtained during whaling, principally catch per unit effort statistics and changes in length and age distributions. There are many problems with these estimates, including the lack of clear stock divisions and the differences in distribution and ranging behaviour of the different segments of the population, with the result that none of these estimates of the sizes of Sperm Whale populations are credible (Cooke 1986).

A fundamental problem when trying to assess the status of Sperm Whale populations is determining the effects of the open-boat hunt, which principally took place in the 19th Century (Gambell 1983). Using analyses of whalers' logbooks, Whitehead (1995) estimated that Pacific Sperm Whale populations may have been reduced to about 10 to 30% of their pre-whaling size by 1860. Only slight recovery was probably achieved by 1946, when modern whaling for Sperm Whales became intense. As Sperm Whaling started earlier in the Atlantic (see above), the Atlantic populations may have been more seriously affected than those in the Pacific (Whitehead 1995).

It is generally agreed that modern commercial whaling made further substantial reductions in the populations of adult male Sperm Whales in all oceans (Gosho, Rice and Breiwick 1984). Populations of adult females were also reduced, but less severely in most cases (Gosho, Rice and Breiwick 1984).

In the North Atlantic, catch-effort series from Spain indicate that the hunted population of males was reduced by approximately 80% between 1905 and 1981; that of females by about 50% (Gosho, Rice and Breiwick 1984). Data from Iceland and the Azores, used in a length-specific model, indicate similar but less extreme declines in those areas during the same time-interval (Gosho, Rice and Breiwick 1984: Table 5).

Models of North Pacific Sperm Whale populations suggest pre-whaling numbers of a few hundred thousand, with modern whaling depleting male numbers by about 36% and females by 14% (Gosho, Rice and Breiwick 1984). However, as noted above, these estimates have little credibility. There is an additional problem in that the Soviets, who were important exploiters of North Pacific Sperm Whales, seriously misreported catches (Yablokov 1994). This was not public knowledge when the status of North Pacific Sperm Whale populations was examined in the late 1970s and early 1980s.

Estimates of Sperm Whale numbers from surveys and photoidentifications suggest a few thousand individuals inhabiting relatively small parts of the world's oceans (e.g. Christensen, Haug and Oien 1992; Whitehead, Waters and Lyrholm 1992; Wade and Gerrodette 1993). Thus, as Sperm Whales continue to be sighted over deep waters throughout the world, it seems likely that there are more than one hundred thousand alive to-day. The relationship between their abundance now, and that in 1700, before substantial whaling began, is unknown, although males are probably depleted to a greater extent than females.

Habitat

Although Sperm Whales can be found over any deep water, they are most abundant near the edges of continental shelves, large islands and offshore banks and over submarine trenches and canyons where vertical mixing of water masses creates zones of high biological productivity (Berzin 1971; Gulland 1974; Jaquet In press). Females are rarely found in waters less than 1000m deep (H. Whitehead unpublished data). Males, although also primarily deep water animals, are in some ocean areas regularly found in waters of 200 to 1000m (Caldwell, Caldwell and Rice 1966). A prime example of relatively shallow water habitat of male Sperm Whales is on the Scotian Shelf where they were caught, and are seen, in water depths of 40 to 200m (Mitchell 1975; Whitehead, Brennan and Grover 1992). In addition to their stricter habitat requirements for depth, female Sperm Whales are also generally restricted to waters with surface temperatures warmer than about 15°C (Rice 1989).

General Biology

Reproduction

Females begin to ovulate (and usually conceive for the first time) at seven to 13 years of age when they are 8.3-9.2m long (Rice 1989). Intervals between births are usually about four to six years, although older females have much reduced reproductive rates (Best, Canham and Macleod 1984). Following a gestation period of about 15 to 16 months, a single 4m calf is born (Best, Canham and Macleod 1984). In most areas there is a peak calving season of about three months during the spring (Best, Canham and Macleod 1984). Lactation seems to last about 2 years although the duration varies, and estimates are complicated by both allosuckling--suckling by females other than the mother--and occasional suckling of older (up to 13yr) juveniles (Best, Canham and Macleod 1984; Gordon 1987b).

Sexual maturity in males is gradual, beginning at about seven to 11yr of age and a length of 8.7 to 10.3m (Rice 1989). The relative size of the testes, and density of spermatozoa, increase during the male's late 20s (Rice 1989). These physiological changes are consistent with what is known about breeding strategies in male Sperm Whales. Males in their late teens and early twenties are largely segregated from females by latitude. On the prime breeding grounds they would probably generally be outcompeted by older, and much larger, males, so it pays them to remain at high latitudes, investing in growth rather than seeking mating opportunities (Whitehead 1994). However, there is some overlap in distribution, and young sexually mature males will attend females whom they encounter, and may obtain some mating opportunities (Best, Canham and Macleod 1984; Whitehead, Brennan and Grover 1992). Large males, in their late twenties and older, migrate back to low latitudes to breed (Best 1979). The duration, frequency and timing of such migrations are unknown.

While on the breeding grounds the large males rove between groups of females spending a few hours or so with each (Whitehead 1993). The large males do fight each other, but rarely (Best 1979; Kato 1984; Clarke, R. and Paliza 1988; Whitehead 1993). Watkins et al. (1993) suggested that males on a breeding ground may establish dominance hierarchies. This, together with synchronized oestrus among grouped females (Best and Butterworth 1980), may account for the indications of paternal relatedness among grouped females shown by genetic analysis (K.R. Richard et al. submitted m/s). Mating itself has not been convincingly described.

Population Structure and Social Behaviour

The fundamental element of the social structure of the Sperm Whale is the matrilineal family unit: about 12 genetically related females and their offspring who are permanent companions (Best 1979; Whitehead, Waters and Lyrholm 1991; K.R. Richard et al., submitted manuscript). Most, if not all, females seem to spend their lives with their female relatives. The number of individuals in a family unit is highly variable (Whitehead, Waters and Lyrholm 1991). The units may travel with other units for periods of days as coordinated groups of about 20-25 animals (Whitehead, Waters and Lyrholm 1991).

Within groups, it is usually difficult to distinguish particular family units, so that most descriptions of social behaviour are at the level of the group. Calves accompany different adult members of their group during their mothers' dives, and groups containing calves have more staggered dives than those without, suggesting active babysitting (Gordon 1987b; Whitehead In press-a). This form of alloparental care would be in addition to allosuckling (see above), and might be the most important function of the family units and groups (Best 1979; Whitehead In press-a). Sperm Whale calves are vulnerable to predators, such as Killer Whales, but can be successfully defended by coordinated actions of members of their group (Arnbom et al. 1987; Jefferson, Stacey and Baird 1991).

The cohesive nature of the female society is also shown by the structured ranks, about 500m long and arranged perpendicular to the direction of movement, that groups may form while foraging (Whitehead 1989), and social gatherings at the surface. For periods of several hours, members of a group may remain at or close to the surface, lying close to one another, often almost motionless (Whitehead and Weilgart 1991). Distinctive behaviour, such as rolling and touching, and vocalizations, such as codas (see below), are characteristic of such social periods (Whitehead and Weilgart 1991).

The age at which males leave the family units seems to be highly variable but may average about six years (Best 1979; K.R. Richard et al. submitted manuscript). After dispersal the males are found in bachelor schools with other males of about their own age (Best 1979). As the males age, they generally live in smaller schools and at higher latitudes (Best 1979).

The structure of schools of young bachelors has been little studied. However, by the time males reach the age of about 20yr, bachelor schools seem to consist of little more than loose aggregations of similar-sized whales, probably in the same area because of food concentrations (Whitehead, Brennan and Grover 1992; Childerhouse, Dawson and Slooten 1995). Such males rarely cluster close together. While an underlying social structure may exist, and is perhaps indicated by multiple strandings of males of about this age (e.g. Table 1), there is little sign of it over the spatial and temporal scales used in recent boat-based studies of living animals (Whitehead, Brennan and Grover 1992; Childerhouse, Dawson and Slooten 1995). The largest males appear essentially solitary, and some evidence suggests that they avoid one another on the breeding grounds (Whitehead 1993).

Aggregations of 50 to as many as several hundred Sperm Whales are sometimes encountered (Caldwell, Caldwell and Rice 1966; Whitehead and Weilgart 1990). These are temporary gatherings, probably formed in response to clumped prey.

Diving

A typical Sperm Whale dive cycle consists of a dive to roughly 400m below the surface for about 40min followed by breathing at the surface for about 8min, with the whale maintaining a speed of approximately 4km/hr throughout (Gordon

1987a; Papastavrou, Smith and Whitehead 1989; Whitehead, Brennan and Grover 1992; Watkins et al. 1993). However there is considerable variation. The longest timed dive was well over two hours (Watkins, Moore and Tyack 1985), and the discovery of a fresh bottom-dwelling shark in the stomach of a Sperm Whale captured in over 3195m of water, as well as other data, suggests that the species is capable of dives of several kilometres (Clarke, M. R. 1976).

Feeding

Sperm Whales prey mainly on mesopelagic and bathypelagic cephalopods of more than 55 species from 36 genera (Kawakami 1980). Most of these squid are quite small, weighing a few hundred grams (Clarke, M. R., Martins and Pascoe 1993). However, they do take much larger animals at times including the Giant Squid (*Architeuthis* sp.) which can approach the size of the Sperm Whales themselves (Fiscus and Rice 1974). Large males prey on larger species of cephalopod and on larger individuals of a given species than do females and younger males (Best 1979; Clarke, M. R. 1980; Best, Canham and Macleod 1984). A variety of large demersal and mesopelagic fishes is also taken, especially by adult males in high latitudes, for example in Denmark Strait (Kawakami 1980; Martin and Clarke 1986). Items occasionally found in Sperm Whale stomachs include large crustaceans, parts of seals, stones, and man-made flotsam and jetsam (Rice 1989). However, there is no evidence that Sperm Whales prey on mammals regularly. Most stomachs examined from Sperm Whales taken off Vancouver Island during late spring, summer, and fall contained food, mainly squid (*Moroteuthis robusta* and *Gonatus* sp.), Ragfish (*Acrotus willoughbyi*) and Rockfish (*Sebastodes* sp.) [Pike and MacAskie 1969].

Clarke et al. (1993) suggested that the cephalopod prey of Sperm Whales fall into two main classes. Smaller, neutrally buoyant, luminous animals without much musculature are easily detected visually and captured; whereas larger, faster, non-luminescent animals must be actively chased using sonar (see below).

Sperm Whales apparently feed at all times of day, year-round (Rice 1989). Lockyer (1981) developed an energy budget for Sperm Whales. She concluded, judging mainly from an analysis of stomach capacities and assuming a diet of squid providing 800kcal/kg, that Sperm Whales weighing less than 15 metric tons consume about 3 percent of their body mass daily. This rate probably increases to about 3.5 percent for the 30 to 50 ton males.

Acoustics

The principal vocalization of the Sperm Whale is a loud (source level 171dB re 1μPa), broad-band (ca. 0.1 to 20kHz) click (Worthington and Schevill 1957; Backus and Schevill 1966; Watkins 1980; Weilgart 1990; Goold and Jones 1995). These clicks are used in a number of ways.

During deep foraging dives, the clicks are heard in long trains with inter-click-intervals of about 0.8s for males and 0.5s for females (Mullins, Whitehead and Weilgart 1988; Whitehead and Weilgart 1990; Goold and Jones 1995). Most authors (e.g. Norris and Harvey 1972; Gordon 1987a; Weilgart 1990; Goold and Jones 1995) believe that these clicks are a form of echolocation, allowing the whales to detect prey at ranges of several hundred metres.

During social periods Sperm Whales produce codas, consisting of from two to about 20 clicks arranged into a patterned series (Watkins and Schevill 1977). Codas are often heard as exchanges, and they seem to function as communication (Watkins and Schevill 1977; Weilgart and Whitehead 1993).

Other click-based vocalizations include creaks (click trains with high

repetition rates) heard during both foraging and social periods (Gordon 1987a; Whitehead and Weilgart 1991), and slow clicks: loud, reverberant clicks with an inter-click interval of about 6s heard principally from mature males on the breeding grounds (Weilgart and Whitehead 1988). A few, much quieter, non-click vocalizations are occasionally recorded from Sperm Whales (Gordon 1987a).

Limiting Factors

Mortality

Estimates of total natural mortality rates for Sperm Whales vary between 0.05 and 0.09 per year (Rice 1989). Young Sperm Whales are preyed upon by Killer Whales and possibly by large sharks (Best, Canham and Macleod 1984; Arnbom et al. 1987), but adult Sperm Whales probably experience almost no natural predation (Jefferson, Stacey and Baird 1991). Lambertsen (in International Whaling Commission 1987) suggested that nematodes can inflict penetrating ulcers in the stomachs of Sperm Whales, in rare instances possibly causing death.

Sperm Whales strand, singly or multiply (up to 72 animals), alive or dead throughout the world from time to time (Rice 1989; Table 1). The causes of the strandings are generally unclear.

During 1988 and 1989 at least 32 dead male Sperm Whales were discovered in northern Europe, about as many as the total reported from the area during the previous 100 years (Christensen 1990). In late 1994, another 20 Sperm Whales were found dead in and around the North Sea. It is not clear what caused these deaths, although pollutants might have contributed to the rash of deaths in what is one of the more polluted parts of the world's oceans (Joiris 1995)). In general Sperm Whales have pollutant loads somewhere between those of the often highly contaminated inshore odontocetes, and the much less affected baleen whales (Aguilar 1983).

Some mortality is caused by entanglement in gillnets (Di Natale and Mangano 1985; Cousteau and Paccalet 1988; Leatherwood and Reeves 1989). Ingestion of marine debris such as plastic buckets and netting could pose serious health risks to individuals (International Whaling Commission 1987). Sperm Whales may be killed or injured by collisions with ships. A severely injured, but living, Sperm whale observed south of Nova Scotia on 10 May 1994, in position 42°12'N 65°21'W (J. Conway, Department of Fisheries and Oceans, pers. comm.), was likely hit by a ship.

Disturbance

Sperm Whales seem to be particularly sensitive to acoustic disturbances within the frequency range of their own clicks. They consistently interrupted their sound production in the presence of underwater pulses made by pingers or submarine sonar (Watkins and Schevill 1975; Watkins, Moore and Tyack 1985), and deserted an area of abundance after the onset of seismic testing using air guns (Davis et al. 1995:244-249). Sperm Whales sometimes react to close approaches (<200m) of a survey vessel by abrupt dives (Davis et al. 1995:232-233). High-speed whalewatching vessels affected the behaviour of male Sperm Whales off Kaikoura, New Zealand, especially when the boats were not handled cautiously (Gordon et al. 1992).

Climatic/Oceanographic Factors

Off the Galápagos Islands, Sperm Whales have greatly reduced feeding success when sea temperatures are warmer than average, as in El Niño years (Whitehead, Papastavrou and Smith 1989). In such conditions, their residence

periods near the Islands are shorter, and their movements more directed (Whitehead In press-b). If these effects are general, then global warming could have a serious impact on Sperm Whale populations.

Residual Effects of Whaling

We do not know how populations of Sperm Whales have been affected by past whaling. However there is concern that the effects may persist longer than would normally be expected for an exploited population.

The social organization and segregation of the sexes of this species has led to a consideration of the possibility that a reduction in the ratio of socially mature males to females, caused by selective whaling for bulls, could result in a decrease in the rate of conception of females (e.g. Mitchell 1977; International Whaling Commission 1980; May and Beddington 1980; Whitehead 1987). There is evidence that this happened in the southeast Pacific (Clarke, R., Aguayo and Paliza 1980). A particularly low calving rate off the Galápagos Islands during the past ten years may be related to the small number of mature males in the area (Whitehead 1990). The Galápagos are close to the Peruvian whaling grounds where males were especially heavily hunted in the 1970's and early 1980's (Ramirez 1989).

Special Significance of the Species

A crude guess at the total amount of cephalopods consumed annually by the world Sperm Whale population is 110-320 million metric tons (Clarke, M. R. 1977), roughly comparable with the total world-wide catch of all marine species. A high proportion of the Sperm Whale's diet consists of ammoniacal squid that are unacceptable as human food. Moreover, the direct harvesting by humans of most of the Sperm Whale's prey species is probably impractical. As primarily a mesopelagic macroteuthophage, the Sperm Whale probably has little direct competition for food resources from other marine mammals or humans. Its closest cetacean competitors are ziphiid whales that feed in the same depth zones but generally prey on smaller squids (Rice 1989). Non-cetacean potential competitors for food are Elephant Seals (*Mirounga* sp.) and some of the larger squids (e.g. *Dosidicus gigas*) that are themselves preyed upon by Sperm Whales.

Although the meat of Sperm Whales is not considered palatable in much of the world (Berzin 1971), it is eaten in parts of Japan (Freeman 1988), eastern Indonesia (Barnes 1991), and the Lesser Antilles (Price 1985), despite warnings that it may contain unsafe amounts of organic mercury (Beary 1979). Other valuable products obtained from Sperm Whales include: spermaceti, a waxy substance from the whale's head that has been widely used to make candles and cosmetics (e.g. cold creams); sperm oil, used as a temperature- and pressure-resistant lubricant and industrial wax; ambergris, a concretion formed in the large intestine of the Sperm Whale, used as a fixative in perfumes; and ivory teeth, used for carving (Berzin 1971). Sperm oil was generally more valuable than that obtained from mysticete whales because of its alcohol content; the alcohols were used for manufacturing many kinds of detergent (Bailey, Carter and Swain 1952). Sperm Whale liver is rich in vitamin A (Bailey, Carter and Swain 1952). Synthetic or natural substitutes are now available for most Sperm Whale products.

Since 1988, watching living Sperm Whales has become an important activity in a few parts of the world. The most successful operation is in Kaikoura, New Zealand, but whale-watch tours primarily directed at Sperm Whales are also run regularly from Dominica (West Indies), Andenes in Norway, the Azores and Japan

(Hoyt 1995). In other parts of the world, including the Galápagos and Antarctica, Sperm Whales are among the attractions of more general nature-tourism operations. A number of other sites with deep water close to shore, including Sri Lanka and some Caribbean islands, have considerable potential for the development of whale-watching based on Sperm Whales (Hoyt 1995). Canada, with its broad continental shelves keeping the Sperm Whales generally away from the coasts, appears to have little potential for whale-watching based principally on Sperm Whales. However, in the last few years the Sperm Whales appearing off Tadoussac, Quebec (see above) have been an attractive but sporadic target of the local whale watching tour operators, who focus mainly on rorquals (Michaud, personal communication).

The Sperm Whale is a creature of extremes. It has the largest brain on Earth and (probably) the most powerful natural sonar system, as well as the greatest geographical separation of the sexes. In their sexual dimorphism, dispersion, biomass, diving ability, and longevity Sperm Whales are at, or close to, the maxima of all mammals. No animal on Earth is much like the Sperm Whale anatomically or ecologically, and its unusual social system is only paralleled closely among the elephants (Weilgart, Whitehead and Payne In press). Combinations of these and other attributes have given the Sperm Whale particular significance in a range of areas of human activity, including aboriginal cultures [such as the New Zealand Maoris (M. Donoghue, personal communication.)], commerce (Starbuck 1878)) and literature (Melville 1851).

Evaluation

Sperm Whale populations were likely well below pre-whaling levels in 1946 when modern whaling for them became especially intense, were reduced substantially between 1950 and 1980 (see above), and can only recover very slowly (see below). Thus the current world population is certainly much smaller than it was before the start of whaling in 1710. However, recent population estimates and sighting rates in different ocean areas suggest a world population of more than 100 000 (see above).

Whatever the current level, it will not rise fast. The most recent estimates of Sperm Whale population parameters by the Scientific Committee of the International Whaling Commission (International Whaling Commission 1982b) suggest a maximal rate of increase of about 0.9% per year. Residual effects of whaling (see above), and other factors, may slow even this low rate, leading to very long recovery times.

The lack of any clear stock structure means that the effects of human disturbance, whether from whaling or pollution or other sources, will not be contained within a clearly defined subset of the aggregate population. However, this attribute also promotes resilience at smaller spatial scales: if Sperm Whales are removed from an area, but the world population is healthy, then it is likely that recolonization will take place before too long.

Probably the greatest current threat to Sperm Whale populations is chemical pollution. If toxic loads continue to accumulate in their prey, so that levels in individual animals rise, and this affects reproduction, mortality or social behaviour, then a putative population increase of less than 1% per year could easily become a population decrease. Acoustic pollution could be an additional detrimental factor.

A second area of threat to Sperm Whale populations is the possibility of breakdown in the current international framework for the management and protection of whale populations (through the International Whaling Commission)

and resultant wide-spread unregulated whaling.

Considering the enormous range of the species, its aggregate numerical abundance, and its virtually complete protection from commercial exploitation at present, the Sperm Whale is not endangered. Although vulnerable (principally because of its very slow potential rate of increase which could easily be reversed) and threatened by pollution and other factors, the threats are probably not sufficiently immediate or clear that a COSEWIC designation would be appropriate or useful at this time. If large-scale commercial whaling should resume, or trends of increased pollutant levels or mortality become apparent, then the status of the Sperm Whale should be re-evaluated by COSEWIC.

Canada would improve the prospects of the Sperm Whale, as well as other marine life, by any actions which reduce marine pollution or support international agreements regulating the exploitation of marine resources, such as the International Whaling Commission.

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Table 1. Known strandings of Sperm Whales on Canadian coasts, including dead animals discovered at sea, during 1987 to 1995 (Q.C.I.=Queen Charlotte Islands; P.E.I.= Prince Edward Island).

Date	Position	No.	Length (m)	Sex	Comments
Newfoundland/Labrador					
11/06/87	Red Harbour, Placentia Bay	1	15	♂	Dead
08/07/87	Penguin Island West, South Coast	1	13	♂	Dead
01/03/89	Conception Harbor, Conception Bay	1	?	?	
30/09/90	Black Tickle, Labrador	4	?	?	Entered harbour, driven out
15/01/91	Port aux Choix, West Coast	1	?	?	Dead
06/03/95	Lord's Cove, Burin Peninsula	1	15	♂	Dead
Nova Scotia					
06/10/90	Sable Island	2	?	♂	Dead
			13.8	♂	Dead
25/04/91	Isle Petitgras, Cape Breaton Island	2	14.5	♂	Dead
			11.6	♂	
??/01/92	Sable Island	3	?	♂	Dead
??/07/94	Cherry Hill, S. Shore, N.S.	1	9.8	♀	Dead
??/12/94	River John, N. Coast, N.S.	1	?	?	Dead
Prince Edward Island					
13/12/88	Near Nail Pond, N.W., P.E.I.	1	12.8	?	Dead, may have beached alive
01/10/89	Covehead Harbour, N., P.E.I.	6			Live stranding:
			13.6	♂	died on site, 5 pulled to open water: 1 died and sank
05/10/89	Malpeque Bay, N., P.E.I.	1	11.4	♂	Dead, probably from Covehead stranding, 45km away
06/10/89	N.W. of Malpeque	1	?	?	Dead, at sea, probably from Covehead stranding
19/12/91	North Rustico, N., P.E.I.	1	?	♂	
20/12/91	Brackley Beach, N., P.E.I.	1	12.1	♂	Dead
23/12/91	Brackley Beach	1	13.1	♂	Dead

Table 1 continued.

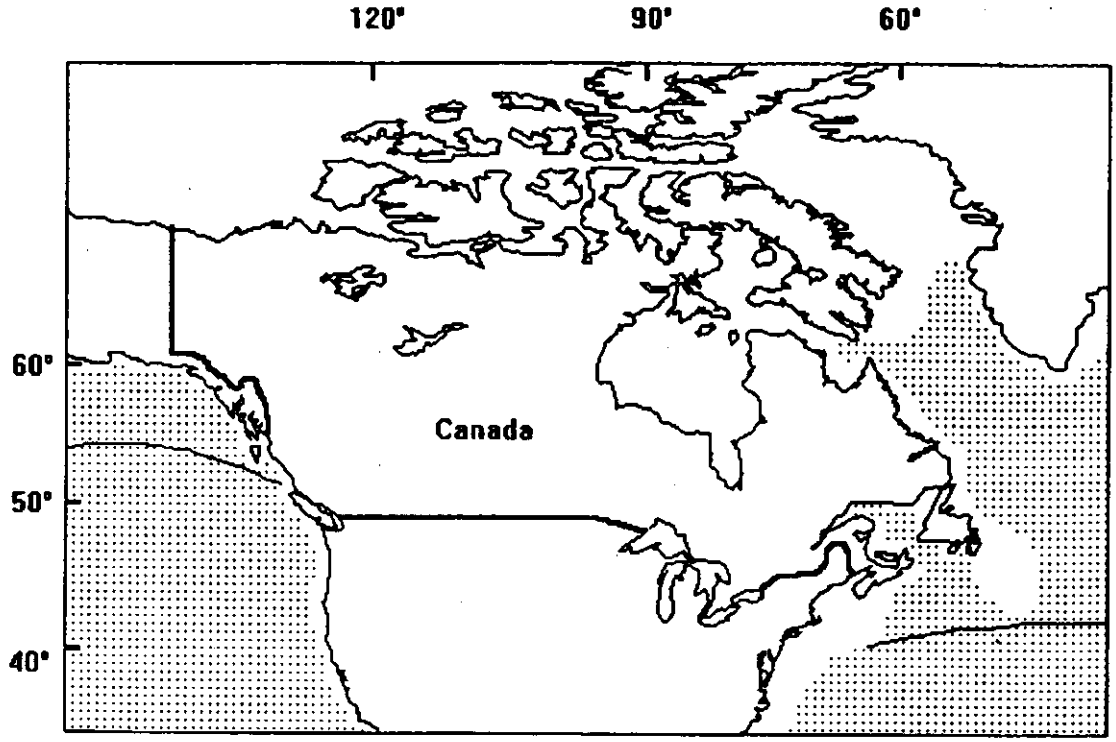
Date	Position	No.	Length (m)	Sex	Comments
New Brunswick					
No strandings since 1987, although some dead animals from Covehead, P.E.I. strandings washed ashore in northern New Brunswick.					
Quebec					
13/06/92	Port Meunier, Anticosti Island	1	13.5	♂	Dead
24/06/93	Sheldrake 50°15'N, 64°54'W	1	10.7	♂	Dead
British Columbia					
26/06/88	Goose Island 51°58'N, 128°26'W	1	?	?	Dead
06/12/88	Rose Pit, Queen Charlotte Islands 54°10',131°40'	1	?	?	Dead
17/11/90	98nm W of Tofino 49°04'N, 128°27'W	1	?	♂?	Dead
07/12/90	Tsusiat Falls 48°42'N, 124°56'W	1	12.5	♂?	Dead
22/05/91	Benson Pt, Nootka Island, 49°47'N, 126°53'W	1	5.5	♀	Dead
02/11/92	Graham Island 53°23'N, 133°11'W	1	~10	♂	Dead
15/01/93	White Point, Graham Island	1	?	?	Dead
01/02/94	Hecate Strait	1	?	?	Dead

Captions for Figures

Figure 1. Sperm Whale, *Physeter macrocephalus*, redrawn from a sketch by T. Ritchie in Watson (1981).

Figure 2. Approximate distribution of Sperm Whales in waters near Canada. The approximate northern limit for females is shown by a solid line in both the North Pacific and North Atlantic.

18 m


120°
90°
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50°
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Canada