Stark

The Ecology of the Dall Porpoise
(*Phocoenoides dalli*) and Interaction With
Japanese Fisheries in the North Pacific Ocean

by

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THE DOLPHIN'S DEATH

Now, of the ways of dolphins, this wonder too I hear,
For which I do them honor. When there at last draws near
The sickness that shall end them, unpitying, well they know
Their life is done, then coastward from the great deeps they go
And running themselves ashore on the beach yielding sand,
There breathe their last; preferring to meet their doom on land,
In hope some man may find them and (still remembering
Their loving gentleness of heart) may stay to fling
A mound of shingle o'er them, feeling he honors so
The Earth-Shaker's holy messenger; or else the flow
Of the wild-weltering surges may heap their sandy bed;
Lest the creatures of the waters should see their lord lie dead,
Or from some beast that hates them their bodies suffer shame.
So their virtue and their courage abide to the end the same,
Even to death; and they sully not the dolphin's ancient fame.

Oppian, from "Fishing"

In: The Dolphin Smile,
E. Devine & M. Clark,
MacMillan Co.,N.Y., 1967

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INTRODUCTION

The Dall porpoise (Phocoenoides dalli True) is a small, deep-bodied and easily identifiable cetacean found in the northern North Pacific Ocean and adjacent waters including the Gulf of Alaska, Bering Sea, Sea of Okhotsk, and the Sea of Japan.

Although this species is widely distributed a limited attempt was made before the passage of the Marine Mammal Protection Act in 1972 to understand its ecology. Early studies were mostly of a descriptive nature with an emphasis on distribution and color variation (Benson and Groody 1942; Brown and Norris 1956; Nishiwaki 1967) or dealt with morphometrics (Cowan 1944; Scheffer 1949,1953; Wilke et al. 1953). This is in part due to the difficulty of studying this porpoise as well as other cetaceans.

The Dall porpoise is difficult to capture and attempts to bring this animal into a captive environment have not been met with much success. These porpoises, along with other small odontocetes, exhibit what is known as " capture shock" and undergo high mortality rates after capture. To date, only three animals have been documented to survive longer than a month in captivity with the longest surviving 15 months (Ridgway 1966; Walker 1975).

In more recent years a major concern about this species is the number of animals killed incidentally in the Japanese salmon gillnet fishery. This concern led to a Japan-United states Dall porpoise research program in 1978 and the signing of a Protocol agreement to the International North Pacific Fisheries Commission between Canada, Japan, and the United States in April of 1978. This Protocol increased the area where North American salmon and marine mammals are protected and in addition Article 10 of the Protocol stated:

> The Contracting Parties agree that a scientific program is necessary to carry out the provisions of this Convention. The Contracting parties, therefore, agree to establish a program to coordinate their scientific research activities with respect to anadromous species in the Convention area, as well as species of marine mammals caught in the fishing for anadromous species. The Contracting Parties agree to exchange scientists in order to carry out scientific observations with respect to the catches and methods of operation. The Contracting Parties shall establish procedures to facilitate observations.

Also in 1978, a Memorandum of Understanding (MOU) was signed between Japan and the United States in connection with Article 10 of the Protocol. This MOU outlined the research to be conducted by both countries. In 1981 a second MOU was signed and scientists were to meet annually to discuss sufficient methods to determine the status of populations of marine mammals affected by the salmon gillnet fisheries, specifically the Dall porpoise.

As a consequence of the joint Japan-United States research program there has been considerable progress made towards understanding the ecology of the species due, in part, to the dedicated research vessels Hoyomaru No. 12 and Hoyomaru No. 81. Research has been limited to the western North Pacific and waters surrounding Alaska where there are substantial commercial salmon fisheries and pressure to lower the rate of incidental take. Research concerning the prevention of porpoise entanglement in fishing gear was initiated in 1981. (Hatakeyama et al. 1986; Soeda et al. 1986; Ogiwara et al. 1987; Hasegawa et al. 1987). In areas where fishing pressure is absent, from British Columbia to southern California for example, there is a scarcity of information on the ecological and biological aspects of this species.

TAXONOMY

The Dall porpoise belongs to the Order Cetacea, suborder Odontoceti, Family Phocoenidae, genus *Phocoenoides*. The species was first described as *Phocoena dalli* by True in 1885. In 1911, Andrews observed that the skeleton, except for the skull and teeth, was distinct from others in the genus *Phocoena* and he renamed the genus *Phocoenoides*.

In addition, Andrews (1911) described a new species, the True porpoise, and gave it the name *Phocoenoides truei*. Andrews based his description on the attributes of one specimen of which he considered color pattern and five morphological features to be the primary criteria for distinguishing *P. truei* from *P.dalli*. The most obvious feature that separates *P.dalli* from *P.truei* is the length of the white patch on the flanks. *P.truei* has a white flank patch that extends to a position averaging 225 mm posterior to the snout whereas *P.dalli* has a white flank patch extending 550 mm posterior to the snout (Newby 1982).

Subsequently, there have been many views concerning the relationship between the two types as it is unclear if they are colormorphs or represent subspecies. There is geographical separation between the two types with the *truei*-type distributed in Japanese waters and the *dalli*-type distributed throughout the North Pacific. However, there is an area of overlap where mixed schools of both color types are seen.

Wilke et al. (1953) considered the two types as subspecies of P.dalli. Kuroda (1954) regarded the types as subspecies based on Wilke et al (1953) findings of a fetus marked indistinctly like a truei-type taken from a dalli-type female and also from the sighting reports of mixed schools of the dalli-type and the truei-type. Kasuya (1978) questioned the validity of Kuroda's conclusions as it is difficult to determine at the fetal stage what type the fetus will mature into.Kuroda also concluded that the truei-type is a small population that has evolved in Japanese waters as the result of a dominant mutation from the dalli-type distributed in the western North Pacific Ocean. Nishiwaki (1972) also considered the two types as subspecies and designated them as P. dalli dalli and P. dalli truei.

Kasuya and Jones (1984) reported that the dalli-type population in the western North Pacific was segregated by growth and reproductive status and that during the breeding season the majority of the population was segregated from the truei-type. Kasuya and Shiraga (1985) and Miyazaki and Fujise (1985) also reported growth differences between the two types not only in body length, but size at attainment of sexual maturity. However ,they compared the growth differences between the two types using biological data from a study of the truei-type by Kasuya. The data by Kasuya is biased due to the method of sample collecting. Until further studies are conducted on life history parameters of the truei-type accurate comparisons cannot be made concerning growth differences between the two color types.

From a morphometrical skull analysis performed between dalli-type animals from offshore waters and truei-type animals from the coastal area, Miyazaki (1986) showed that even though some measurements overlapped, that it is possible to distinguish the two types on this basis. From dalli and truei types of the same coastal area, it was possible to separate them only on two characteristics. These studies suggest that the amount of interbreeding between the two types might be less frequent then previously thought and due to the suggested genetic isolation as well as geographical segregation, it will be plausible to deal with the two types as subspecies in the future. However, there must be more evidence for genetic isolation before justifing the two types into subspecies.

Studies by Benson and Groody (1942), Cowan (1944), Benson (1946), Kuroda (1954), Tomilin (1967), Kasuya (1978), Morejohn (1979), Newby (1982) advocate the viewpoint that the two types represent one species especially in light of the considerable variation in pigmentation.

Rice and Scheffer (1968) and Houck (1976) are of the view that the two types are color phases indicating that only one species should be recognized.

As evidenced above, there is disagreement concerning the exact taxonomic relationship between the dalli-type and the truei-type. Further investigation of the segregation between the types, primarily during the breeding season, and the life history parameters will help to firmly establish the systematics of the types.

EXTERNAL FORM

Pigmentation

The Dall porpoise has three basic color variations: the *dalli*-type, *truei*-type, and a black variant (Figure 1). The *dalli*-type is slate-gray to black with a white abdominal patch and a white flank patch that originates near the anus and extends to an average of 550 mm posterior to the snout whereas in the *truei*-type the white patch extends to an average of 225 mm posterior to the snout (Newby 1982). Both of these types also have markings on the flukes and fins but these markings are extremely variable between individuals. The black variant is entirely black and is not considered to be a major color morph. There is considerable variation among each color pattern and there are intermediate pigmentation patterns such as a grayish-brown variant (Morejohn et al. 1973).

Pigment intensity seems to be somewhat affected by age as subadult males and females tend to be lighter than adults and the degree of white pigment on the flukes and dorsal fin appears to be more intense in adults (Benson 1946; Scheffer 1949; Morejohn et al. 1973).

Size and Sexual Dimorphism

The maximum size of a dalli-type male recorded to date is 225 cm in length and a weight of 220 kg (Morejohn et al. 1973; Newby 1982) while the limit of a dalli-type female being 222 cm in length and weighing 189 kg (Newby 1982). The maximum reported size for a truei-type male is 220 cm and weighing 164 kg and that for a female truei-type is 205 cm and a weight of 115 kg (Subramanian et al. 1986;Kasuya 1979; Kuzin and Belyaev 1987). The small sample size of the truei-type is most likely responsible for the difference in sizes among the two types and not growth differences.

There are a few slight differences between the sexes. Although the maximum attainable length is about the same for males and females, females tend to be smaller and weigh less as body length is related to body weight. Adult males can be distinguished from females by the pronounced keel of the caudal peduncle region and also in the placement of the genital opening in relation to the anal opening. In males the urogenital opening is farther away from the anal slit than in females which is true for many cetaceans.

Dentition

The dentition of Phocoenoides is very characteristic and unique from other Phocoenidae.They have extremely small, conical shaped teeth that are more numerous on the bottom jaw than on the top. True (1885) gives the dental formula as 23-23/27-27 and these teeth may only be marginally functional as they are poorly rooted and barely protrude above the gums (Tomilin 1967). What appears to compensate for this loss in effectiveness is the presence of what Miller (1929) calls "gum teeth". These dermal papillae emerge between the teeth from the gums and can extend to a point beyond that of the teeth.

The upper jaw has fewer teeth and contains a "dental pad" which has no teeth anterior to it and those that occur lateral to it are very small (Morejohn 1979). The dental pad as well as the gum teeth would appear to greatly assist an animal to grasp fish and cephalopods which comprises P.dalli's diet. The dental pad is a secondary specialization present in many teuthophagous cetaceans and ruminant artiodactyls that have lost most or all of their upper incisors over time (Morejohn 1979) and the gum teeth bear a strong resemblance to the stages in which the Mysticeti might have gone through to form baleen.

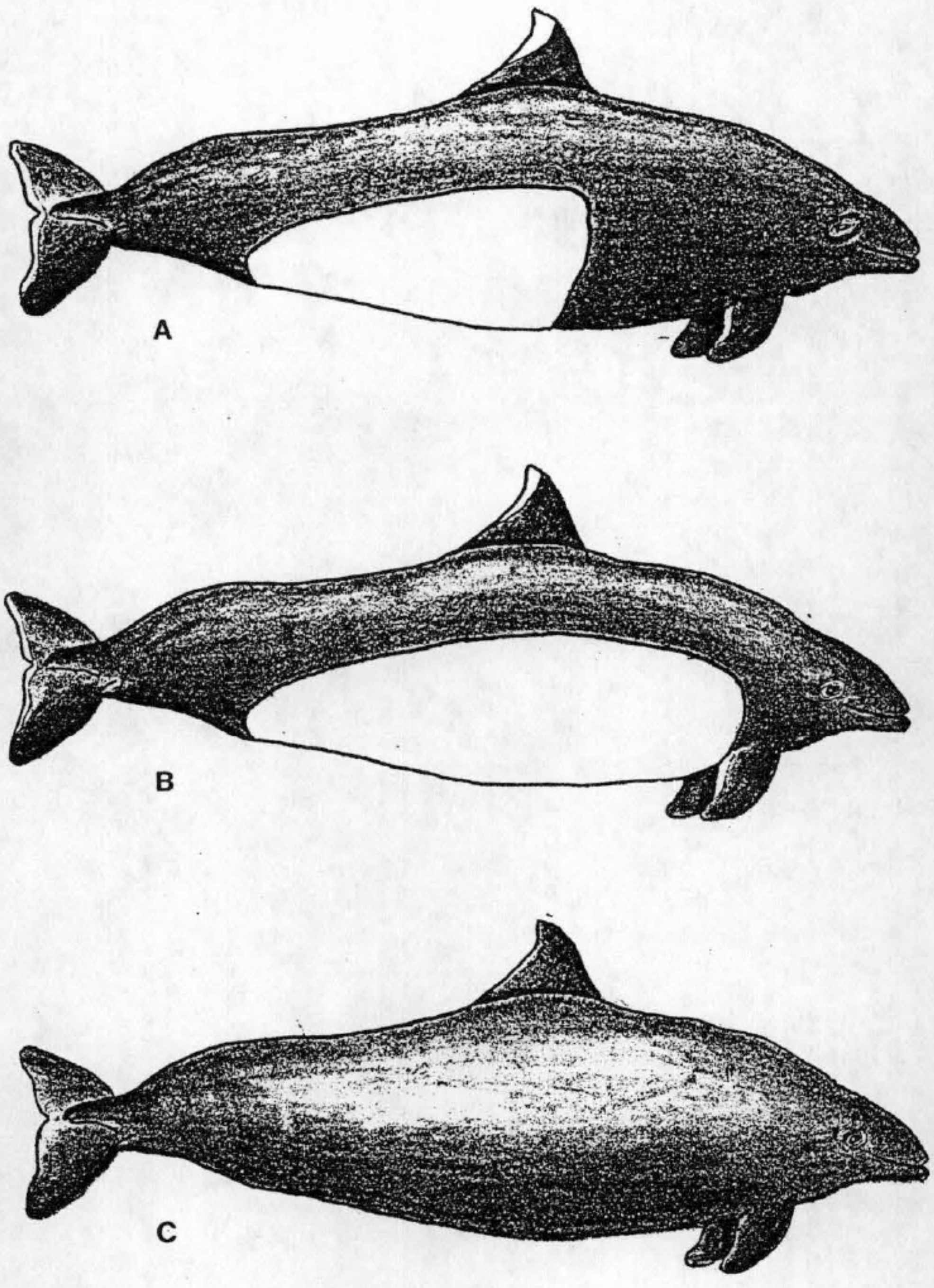

Fig. 1. Three color variations of the Dall porpoise: (A) dalli-type, (B) truei-type, (C) black variant.

DISTRIBUTION

The Dall porpoise is distributed throughout the North Pacific Ocean (Figure 2). In the eastern North Pacific P.dalli ranges as far south as Baja California (28°N) and occurs along the North American coast to the Gulf of Alaska (Leatherwood and Fielding 1974). It occurs as far north as Cape Navarin (62°N) in the Bering Sea (Nishiwaki 1967) and inhabits the central North Pacific across to the Sea of Okhotsk, Sea of Japan, and the Pacific coast of Japan to a southern limit of 35°N (Kasuya 1976).The truei-type has a limited distribution off the Pacific coast of Japan and southern Kuril Islands and about a 200 mile overlap exists into the dalli-type's range. From the geographical distribution of the two color types, Kasuya (1978) suggests there are three stocks in the western North Pacific and adjacent waters: (1) a population off the Pacific coast of Japan composed mostly of truei-type individuals but with a mixture of some dalli-type; (2) a population in the Bering Sea and the offshore waters of the northwestern North Pacific composed of the dalli-type and the southwestern part of the range of this stock overlaps the northeastern range of the Japanese east coast population; (3) a population in the Sea of Japan and Okhotsk Sea composed entirely of the dalli-type.

Winans and Jones (1988) separate the Bering Sea and North Pacific Ocean populations on the basis of electrophoretic analysis. They concluded that the two areas do not contain one interbreeding population but state this result should be verified by further tests. There appears to be no clear stock separation in the eastern North Pacific. Fiscus and Niggol (1965) observed that this porpoise seemed to be distributed evenly along the Pacific coast however Mercer (1978) suggests that there are several stocks along the North American coast.During a workshop on the status of the Dall porpoise it was concluded that in the Bering Sea and near the Aleutian Islands, a separation might occur at 175°E longitude between eastern and western North Pacific stocks (IWC 1978).

This porpoise is characterized as being a pelagic, offshore species but it does occur in protected waters such as straits and channels when they are open at both ends and have strong tidal currents (Cowan 1944; Scheffer 1949). They also occur in inshore waters where the water is deep such as the Monterey Submarine Canyon, the Farallon Islands, and the Channel Islands all off the California coast. Off of North America it is typically found in water deeper than 100 fathoms and within 100 miles from shore over the continental shelf (Yocum 1946; Fiscus and Niggol 1965; Pike and MacAskie 1969; Huber et al. 1980). They are common in deep oceanic water (2500 + meters) and seldom seen in shallow water which might be the reason they are scarce in the eastern and northeastern Bering Sea (Jones et al. 1984).

The Dall porpoise is characteristically a cold water species and it is usually found in water below 18°C (Kasuya and Jones 1984). Miyazaki et al. (1984) gives the temperature range as 5.8-17.1°C for both color types but the truei-type was sighted more often in warmer waters. This agrees with the findings of Yoshioka et al.(1987) and Miyashita and Kasuya (1987a) that most dalli-types were seen in water below 16°C and truei-types were seen in water above 18°C. The southern distributional limit of the species corresponds with the 17°C isotherm (Kasuya 1976).

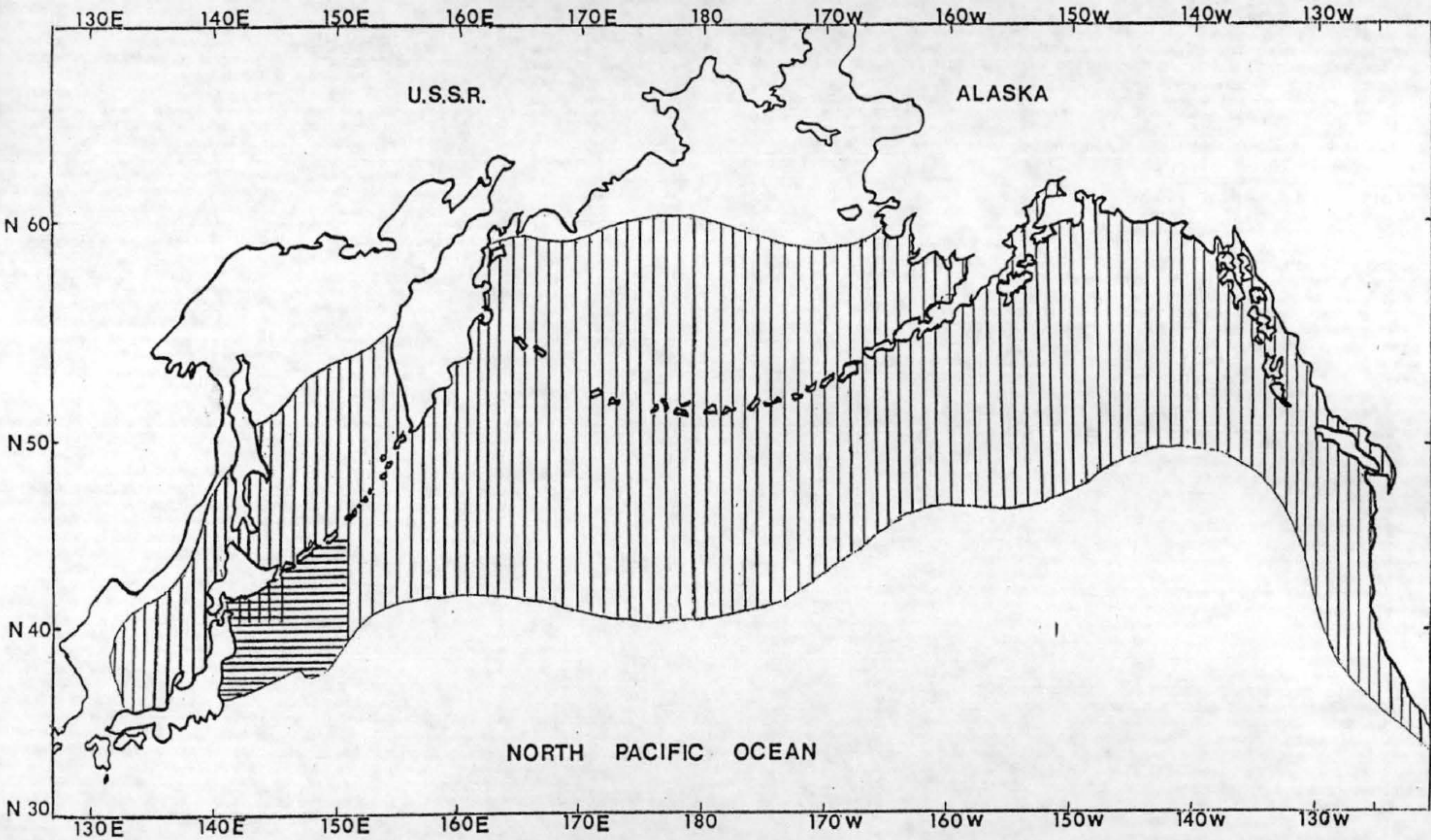

Figure 2. Distribution of the Dall porpoise in the North Pacific Ocean and adjacent waters. Vertical lines indicate distribution of the <u>dalli</u>-type and horizontal lines indicate distribution of the <u>truei</u>-type.

MIGRATION AND SEASONAL MOVEMENTS

There is no clear indication of large scale migrations of P. dalli in the eastern North Pacific. They have been sighted nearly year round from the Gulf of Alaska southward down along the North American coast (Pike and MacAskie 1969; Loeb 1972). However, in southern California waters they appear to move from inshore to offshore areas during summer months (Brown and Norris 1956; Leatherwood and Fielding 1974). Near the Farallon Islands and the Channel Islands off California, they also move offshore in the summer (Yocum 1946; Lustig 1949). These shifts in discrete populations are probably due to the increased availability of the preferred prey species in the fall and winter (Morejohn 1979). Although Morejohn (1979) stated that there does not seem to be any strong seasonal north to south movement of the entire population from one area to another, there is some evidence to suggest that there are north to south migrations in the spring and summer months as large schools were seen moving northward by Scheffer (1950) and Mercer (1978) observed that Dall porpoises in the western Gulf of Alaska move into the Bering Sea in the spring. Also, sightings by Newby (1982) within the central area of distribution for P. dalli indicate that porpoises move northward in the summer as the western subarctic gyre also moves northward. This lends additional support to the idea that oceanographic features may affect distribution.

In the western North Pacific seasonal movements are well documented and the dalli-type individuals of the Sea of Japan and the Okhotsk Sea stock have a north/south migration. In the summer months the majority of the population moves north from the Sea of Japan into the Okhotsk Sea and then moves back south in the winter (Kasuya 1982; Miyashita and Kasuya 1987a). Miyashita and Kasuya (1987a) surmise that a part of this stock migrates in the spring through the Tsugaru Strait to the Pacific coast of Japan and stays there through summer while the truei-types are slightly north and offshore and when the truei-types arrive, the dalli-type move south.

The truei-type population off the Pacific coast of Japan (35°N-45°N) have a northeast to southwest movement. They move southwest during late fall through winter possibly due to their preferred prey, Pacific mackerel, moving west in response to cooler water temperatures (Kuzin and Belyaev 1984). Some move as far south as Choshi (35°N & 140°E) in the winter and in the summer the majority of the population stays off the east coast of Hokkaido and the southern Kuril Islands (Kasuya 1982).

The Bering Sea and offshore northwestern North Pacific population display a north/south migration as they move north from early spring to early fall (Ohsumi 1975).

ABUNDANCE

There have been few abundance evaluations for the Dall porpoise throughout its distribution, particularly in the eastern North Pacific Ocean. In the Gulf of Alaska the population is estimated to contain between 152,280 and 246,899 porpoises (Bouchet 1983) and Hall (1979) estimated the population in Prince William Sound by using shipboard and aerial surveys to be 7,300 in the summer and 6,800 in the fall. The Dall porpoise is the dominant cetacean found in Prince William Sound (U.S.Fish & Wildlife Service 1978) and the Aleutian Islands form a high density area (Wahl 1979).

The Bering Sea population has been estimated by Bouchet (1983) to include between 86,091 and 122,327 porpoises and Kato's (1987) estimate for this area is between 213,000 and 468,000 porpoises. This disparity betweeen the two estimates does not necessarily indicate an increase in the population but reflects different methodologies for calculating abundance figures.

The truei-type population contains 125,000 according to Kato (1987) and between 56,000 and 90,000 according to Miyashita and Kasuya (1987a).

Ohsumi and Takagi (1979) estimated between 5 and 10 million porpoises extending over the entire range of *P. dalli*. However, these figures were based upon data from

Japanese research vessels using the sighting method for large whales. Kato (1987) estimated the total abundance to be from 2.26 to 2.73 million porpoises based upon sightings when the visibility was good (0-3 on the Beaufort scale).

Abundance estimates can be affected by the tendency of P. dalli to ride a vessel's bow, stern, and side waves. If porpoises approach a vessel and move into a transect area this will result in an overestimation of abundance. An underestimation of abundance can result when surveying an area that contains schools with calves as these individuals tend to avoid vessels (Kasuya and Jones 1984). To help solve this problem Turnock (1987) calculated a correction factor for population estimates that takes into account the response to vessels. However, the response differs by area, sex, and age so a correction factor will need to be calculated for each area to determine abundance accurately.

DIET

The diet of the Dall porpoise is at least partially determined by geographic area and oceanic features. Throughout its distribution the diet consists of fish and squid but in Japanese waters and the western North Pacific where deep water occurs, there is a decrease in prey diversity. In the shallower water of the eastern North Pacific there is a large variety of prey in the diet (Table 1).

Off British Columbia and Washington squid and herring (*Clupea harengus pallasi*) are frequent prey (Pike and MacAskie 1969) while off of Oregon and northern California waters the most abundant prey are *Merluccius productus* (Pacific hake), squid, and *Trachurus symmetricus* (jack mackerel) (Fiscus and Niggol 1965).

Porpoises in Monterey Bay have a variety of prey items in their diet with *Merluccius productus*, *Loligo opalescens* (squid), juvenile rockfish (*Sebastes* spp.), *Engraulis mordax* (northern anchovy), and *Clupea harengus pallasi* being the dominant items year round. From October through April other species of fish and squid appear in the diet in small quantities (Loeb 1982) and these species are listed in Table 1. Dall porpoises in southern California have been spotted circling schools of anchovies (*Engraulis mordax*) and sauries (*Cololabis saira*) presumably to feed on them (Brown and

Table 1. Location and species account of prey items in the diet of the Dall porpoise (*Phocoenoides dalli*) detected from stomach contents.

	California	Oregon to the Gulf of Alaska	North Pacific Ocean and Bering Sea	Japan	Reference *
Alosa sapidissima, American shad		■			9
Ammodytes sp., sandlance			■		8
Anguilliformes, eels	■				6
Anoplopoma fimbria, sablefish	■	■			6,9
Bathylagus stilbius, California smoothtongue	■				6
Citharichthys sordidus, Pacific sanddab	■				6
Clupea harengus pallasi, Pacific herring	■	■	–		5,6
Cololabis saira, Pacific saury	■			■	6,11
Diaphus sp., lanternfish				■	3
Engraulis mordax, northern anchovy	■				6
Laemonema longipes, cod				■	3
Laemonema morsum, gadid				■	2
Lampanyctus regalis, pinpoint lampfish	■				6
Lampanyctus sp., lanternfish				■	3
Liparis sp., snailfish	■				6
Macrouridae, rattail	■				6
Mallotus villosus, capelin		■			1,7,9
Merluccius productus, Pacific hake	■	■			4,6
Myctophidae, lanternfish				■	2
Notoscopelus sp., lanternfish				■	2,3
Otophidium taylori, cusk eel	■				6
Paralepis sp., Sudidae				■	2
Peprilus simillimus, Pacific pompano	■				6
Pleuronectidae, flatfish		■			7,9
Protomyctophum thompsoni, lanternfish			■		8
Sardinops sagax, Pacific sardine				■	11
Scomber japonicus, Pacific mackerel				■	11
Sebastes sp, rockfish(juvenile)	■	■			6,9
Spirinchus starksi, night smelt	■				6
Tarletonbeania crenularis, blue lanternfish	■				6
Tarletonbeania taylori, lanternfish				■	2,3
Thaleichthys pacificus, eulachon		■			7,9
Theragra chalcogramma, walleye pollock			■		8
Trachurus symmetricus, jack mackerel	■	■			4
Zoarcidae, eelpout	■				6
Abraliopsis sp., squid	■				6
Gonatidae		■	■	■	2,7,9,10
Gonatus sp., squid	■	■	■		6
Loligo opalescens, squid	■	■			6,9,10
Octopus bimaculatus, octopus	■				6
Ommastrephes sloani pacificus, squid				■	2,3
Onychoteuthis banksii, squid				■	11
Onychoteuthis borealijaponicus, squid	■	■	■		6,7,9,10
Watasenia scintillans, squid				■	3

* References: (1) Scheffer 1953 (2) Wilke et al. 1953 (3) Wilke & Nicholson 1958 (4) Norris & Prescott 1961 (5) Pike & MacAskie 1969 (6) Loeb 1972 (7) Kajimura et al. 1980 (8) Crawford 1981 (9) Stroud 1981 (10) Fiscus 1982 (11) Kuzin and Belyaev 1987

Norris 1956; Norris and Prescott 1961).

Pacific hake occurs from the Gulf of Alaska to the Gulf of California (Fiscus 1979) but Scheffer (1953) examined two animals in the Gulf of Alaska that contained only capelin (Mallotus villosus) in their stomachs. Porpoises in the Bering Sea feed on squid almost exclusively.

Wilke et al. (1953) and Wilke and Nicholson (1958) found that in Japanese waters the most frequent prey is squid (Ommastrephes sloani pacificus and Watasenia scintillans) and myctophids (lanternfish). Kuzin and Belyaev (1987) found that Pacific mackerel (Scomber japonicus) as well as squid are significant prey items in the diet of Dall porpoises off the Pacific coast of Hokkaido. Crawford (1981) examined stomach contents from porpoises taken in the high seas salmon fishery in the North Pacific and found that Protomyctophum thompsoni, Paralepis sp., Notoscopelus sp., squid and other species of lanternfish are frequent prey items. Crawford (1981) also noticed an absence of salmon in the diet even though their distributions overlap.

Subramanian et al.(1986) attempted to determine feeding grounds for porpoises off Japan and in the northwestern Pacific by using organochlorines (PCB/DDE) as tracers. The amount of chemicals accumulated in porpoise tissues is dependent upon geographic location of prey items. Subramanian et al. concluded that individuals in the Bering

Sea and North Pacific have separate feeding grounds and porpoises off Japan also have a distinct feeding ground.

The diet of the Dall porpoise appears to consist mostly of small, soft-bodied, nonspinous, fish and squid that are easily ingested and digested. Many of their prey items that are considered to be deep water species exhibit vertical migrations at night when the porpoises are thought to feed. This would suggest that they do not have to dive deep to feed, however, other prey showing no diel migrations such as deep-sea smelts, zoarchids, and macrourids all live in water over 100 fathoms. This indicates that they are capable of diving to substantial depths although no maximum depth has ever been recorded. Their blood chemistry also suggests that they are capable of diving in deep water as Dall porpoises have a high total blood volume (143 ml/kg) and a high hematocrit (57%) (Ridgway & Johnson 1966).

PREDATORS

The only natural predator of the Dall porpoise known is the killer whale (Orcinus orca). There have been several reports of killer whale attacks on this porpoise with most of the predation occurring in waters off Alaska, British Columbia and Washington (Rice 1968; Pike and MacAskie 1969;

Barr and Barr 1972; Bigg and Wolman 1975). Sharks are not commonly accepted as a predator of the Dall porpoise but attacks probably do occur infrequently.

PARASITES

There are several helminth parasites associated with the Dall porpoise listed in Table 2. The extent of mortality caused by these parasites is not known.

TABLE 2. Helminth parasites of the Dall porpoise.

SPECIES	LOCATION	SOURCE
Trematoda		
Campula oblonga	hepatopancreatic ducts, bile ducts	Dailey 1971, Conlogue et al. 1985
Nasitrema dalli	nasal sinuses	Dailey 1971
Cestoda		
Phyllobothrium sp.	blubber	Dailey & Brownell 1972 (per. comm. with W.J. Houck)
Nematoda		
Pharurus dalli	nasal sinuses	Dailey 1971
Halocercus dalli	lungs	Conlogue et al. 1985
Halocercus kirbyi	lungs	Dailey & Brownell 1972
Anisakis simplex	stomach	Dailey 1971
Crassicauda sp.	mammary glands	Conlogue et al. 1985
Placentonema sp.	mammary glands	Ridgway 1966
Stenurus sp.	head sinus	Norris & Prescott 1961

BEHAVIOR

Vessel response

The propensity of the Dall porpoise to ride bow, stern, or side waves in certain areas creates biases in some life history parameters. Samples taken from inshore waters are obtained by hand-held harpoons which depends upon animals being attracted to the bow wave. However, mature and juvenile porpoises have a greater tendency to avoid vessels than subadult ones (Loeb 1972; Morejohn 1979; Kasuya and Ogi 1987). As a result, subadult age classes are overrepresented which may affect school structure and life history data.

Vessel response is also affected by time of day and surface water temperature. Morejohn (1979) noticed a tendency for animals not to approach a ship during midday in California waters whereas Kasuya and Jones (1984) noticed in the northwestern North Pacific that wave riding occurred most frequently during midday and that the number of individuals that rode the bow or side wave increased as the surface water temperature also increased.

The speed and geographic location of a vessel have some influence whether a porpoise will ride a vessel's wave. A speed of at least 9 knots is essential to attract a porpoise (Leatherwood et al. 1982). In the Johnstone Strait (British Columbia) Dall porpoises never ride bow waves and they will seldom ride a ship's wave between 175°N and 155°N (Jefferson 1987; Yoshioka et al. 1987). In Japanese waters, Prince William Sound and other eastern North Pacific waters, this porpoise has a strong tendency to ride a ship's wave (Withrow et al. 1985).

Swimming

The Dall porpoise is considered to be one of the fastest swimming small odontocetes. It can sustain speeds of 15-20 knots and overtake a vessel at 32 knots (Ridgway and Johnson 1966).

Bouchet et al. (1984) and Jefferson (1987) identified several behaviors associated with swimming:

1) slow roll--This is the most common behavior observed. A porpoise creates a slight disturbance at the surface then arches its back exposing the dorsal fin and dorsal part of the caudal peduncle then submerges slowly. Jefferson noted that while slow rolling porpoises traveled at an average speed of 5.1 km/hr. Loeb (1972) and Morejohn (1979) interpret this behavior as resting or sleeping since it occurs frequently in daylight when they are less active but in the Johnstone Strait (B.C.) porpoises also slow roll when leisurely traveling and deep diving.

2) rooster tail--This is the second most commonly observed behavior. A fast swimming porpoise surfaces quickly creating a V-shaped spray called a "rooster tail" then exhales loudly and submerges. High-speed photography indicates that exhalation actually begins before the blowhole is at the surface and inhalaton continues inside an air cavity under the surface caused by the porpoise's head. This behavior is known only to the Dall porpoise and both Jefferson and Morejohn (1979) suggest that this may be associated with play behavior.

3) fast swimming--This is when a porpoise is swimming at a rapid pace just below the water surface. The animal breathes loudly and creates a smaller splash at the surface than a rooster tail.

4) surface splash--This was described by Bouchet et al. when splashes over a short distance were accompanied by sharp changes of direction at or just below the water surface. This behavior occurred when there was several to many porpoises (up to 20) and is thought to be related to feeding.

Group structure

Best (1979) stated that the term "school" can only be applied when the behavior of the animals in a unit offers some evidence for a degree of social cohesion. Therefore, I will use the term "group" as not much is known concerning the social structure of the Dall porpoise.

This porpoise usually travels in small groups but Pike and MacAskie (1969) have reported schools of up to 100 animals in the inshore waters of British Columbia in spring and fall months. Sightings of large schools have generally been in areas of high porpoise concentration such as the Aleutian Islands and Gulf of Alaska. The most common group size throughout P. dalli's distribution is two (Kasuya and Jones 1984; Jefferson 1987). Group size remains relatively constant throughout the year and time of day but groups that comprise calves and adults tend to be slightly larger as would be expected (Jefferson 1987). Table 3 gives the range and mean group size of P. dalli in various locations.

Group formation in the western North Pacific is to some degree related to color pattern as Kasuya (1978) suggested. The proportion of groups with mixed color types to the total number of groups containing either color type is lower than would be expected if no segregation occurred among the two color patterns.

The Dall porpoise is seldom seen in the presence of other cetaceans. The higher surface water temperature preference of other cetaceans in the North Pacific Ocean is partly responsible for this segregation. The southern range of P. dalli overlaps with Lissodelphis borealis (northern right whale dolphin) and Lagenorhynchus obliquidens (Pacific white-sided dolphin) but few of these species have been seen with a Dall porpoise. Loeb (1972) reports an incident where a group of Dall porpoises which were riding a boat's bow wave left when two groups of L. obliquidens approached the boat. The Dall porpoise and Orcinus orca (killer whale) are sporadically seen together in the northern North Pacific and peacefully co-exist in the Johnstone Strait (Jefferson 1987).

There is little known concerning the age and sex composition of Dall porpoise groups. There have been groups described consisting entirely of adult, immature, and male individuals but the sample size is small so no conclusions based on this data can be made at this time. There is some evidence to suggest that sexual segregation of immature animals may occur in the Subarctic Convergence Zone as the ratio of males/females is higher in this area (Kasuya and Shiraga 1985). Also, in the western North Pacific the ratio of immature females/males is higher and peaks in March (Kasuya 1978).

Table 3. The mean group size of Dall porpoises from several locations.

area	GROUP SIZE range	mean	source
Prince William Sound	1-11	2.6	Withrow et al. 1985
Johnstone Strait, B.C.	----	2.6	Jefferson 1987
Monterey Bay, CA.	2-50	---	Loeb 1972
Bering Sea & North Pacific Ocean	1-16	3.8 5.5	Miyazaki et al. 1984
northwestern North Pacific	1-14	3.5-3.8	Kasuya & Jones 1984
Japan	----	6.7	Miyashita & Kasuya 1987a

BIOLOGICAL PARAMETERS

Sex ratio

The ratio of adult males to females does not significantly differ from 1:1. However, in the northern North Pacific there appears to be a higher proportion of immature males than females (Yoshioka et al. 1987). This agrees with the findings of Jones et al.(1984) that the ratio of immature males to females north of 56°N was .86 and this ratio dropped to .38 in adult porpoises.

Age

The age of *P. dalli*, as well as other mammals, is determined by counting the stainable growth layers in the tooth cemental layer. It is assumed that one growth layer is equal to one year. It is difficult to age this species due to the small size of their teeth and the readability of layers may decrease with increasing age (Newby 1982). The oldest male and female Dall porpoise had 22 and 19 growth layers respectively (Newby 1982). Kasuya and Shiraga (1984) obtained samples from the western North Pacific by harpooning and found the ages ranged from 1 to 17 layers although the majority of porpoises are less than 10 with fewer individuals in the older age classes.

Sexual maturity

Male:

The age at attainment of sexual maturity for males is determined when 50% of the males in a population are sexually mature. According to Kasuya (1978) and Kasuya and Shiraga (1984) this age is 7.9 years and 4-6 years respectively. The samples in both of these studies were obtained by harpooning and since there is a difference in harpoonability after a certain age, it is difficult to accurately estimate when 50% of the males were mature. Newby (1982) estimated the males to be sexually mature at 5.67 years and Miyazaki (1987) at 4.4 years (Table 4). All of these estimates are for porpoises found in the northwestern North Pacific, Bering Sea, and the Pacific coast of Japan. There are no estimates for males in the eastern North Pacific.

There is a strong correlation between body length and attainment of sexual maturity in males. Onset of sexual maturity is dependent upon length and not age. The length at which 50% of the males were mature ranged from 182.6 - 195.7 cm (Table 4).

Female:

The age at attainment of sexual maturity for females is

Table 4. Selected life history parameters of the Dall porpoise (*Phocoenoides dalli*).

	AREA		
PARAMETER	Northwestern North Pacific & Bering Sea (mothership fishery)	Northwestern North Pacific(land-based fishery)	Pacific coast of Japan(harpoon sample)
length at birth(cm)	94.85	----	100
length at sexual maturity: (cm) male	182.6	185.5	195.7
female	170.3	175.5	186.5
age at sexual maturity: (yr) male	5.7	4.4	7.9
female	3.3	3.4	6.8
maturity rate(%): male	30.6	17.4	18.5
female	57.7	28.8	34.8
age at first birth(yr)	5.1	5.2	----
postnatal sex ratio (% female)	61.8	63.5	53.8
pregnancy rate(%)	95.3	78.3	----
gestation (months)	11.4	----	11.4
lactation (months)	1.6-4.0	----	.71-1.09
resting (months)	.5	----	.24-6.5
mean calving interval (months)	13.5-15.9	----	12.35-19
SOURCE	Newby 1982	Miyazaki 1987	Kasuya 1978

determined by the presence of one corpora albicans in the ovaries. This age is in close agreement between Newby and Miyazakis' samples (3.3 and 3.4 years) but differ from Kasuya's finding that females are sexually mature at 6.8 years. This older age might be attributed to two factors: the biases associated with harpooning or an indication that the females off Japan mature at a later age (or length).

The lengths at which females attain sexual maturity are shown in Table 4. In Yoshioka's (1986) sample, the lengths at onset of maturity ranged from 169-189 cm. It seems reasonable to assume that sexual maturity is also dependent upon length in females.

Pregnancy rate

Northern cetaceans generally have a higher birth rate than southern species and the Dall porpoise has a high pregnancy rate compared with other odontocetes from all areas. Newby and Jones et al. (1984) both found extremely high pregnancy rates of 95.3% and 95% respectively.

Length at birth

The length at birth has been estimated to be 94.85 cm

(Newby), 99.7 cm (Kasuya),and 97 cm (Jones et al. 1984). Newby determined the mean length by including all fetuses and neonates to adjust the frequency difference between the two categories so this is perhaps the reason for a smaller length at birth.

Calving

Gestation:

The length of gestation appears to be short for this species. Kasuya (1978) estimated the gestation interval for the Pacific coast of Japan population to be 11.4 months. Jones et al.(1984) suggest that if ovulation occurs approximately 40 days after parturition then the gestation interval would be about 10.7 months. Regardless of the difference between these two values, they still indicate a gestation length shorter than one year.

Lactation:

The lactation interval is approximately 1.6-4.0 months and .71-1.09 months according to Newby and Kasuya respectively (Table 4). However, limited sampling during the time when lactation occurs makes it difficult to obtain an accurate estimate of the lactation period. For the Dall porpoise to have an annual reproductive cycle, which they are thought to possess, the lactation period would have to be short-not more than two months.

Resting:

The resting interval between weaning and gestation ranges from .5 month (Newby) to .24-6.5 months (Kasuya). As seen from the high pregnancy rate, most of the sexually mature females become pregnant annually and only a small proportion are termed resting females. Resting females are those that are sexually mature but are not pregnant or lactating. These are usually females in the older age classes.

Calving interval:

The total of the above estimates gives a mean calving interval of 13.5-15.9 months (Newby) and 12.35-19 months (Kasuya). If a gestation length of 10.7 is correct, then the calving interval would be about 11.65-12.8 months using the minimum time value for each step. The high birth rate (95%), high gross annual reproductive rate (.25-.41 in the U.S. FCZ), and occurence of ovulation about 40 after parturition, all indicate that an annual reproductive cycle for most of the sexually mature females occurs (Jones et al. 1984).

Newby hypothesized that delayed implantation occurs for the Dall porpoise because "If conception takes place one to two months after parturition or lactation there would have to be delayed implantation due to the effects of suppression by gonadotrophic hormones on follicle development". In Newby's study the peak calving occurred in late June so "It is reasonable for amenorrhic suppression to last until August 15-30. During this interval the follicles are developing towards ovulation". Newby stated that further evidence to support this idea is that males are going into a rut at the peak parturition time (Newby 1982; Ridgway & Green 1967). This would ensure that births occur at the same time every year and this strategy is common among pinnipeds but not known to cetaceans. The male rhythmic cycle is evidence for annual reproduction and additional information, the sampling of females during conception and directly after, is needed to support Newby's hypothesis.

Calving time:

Little is known about calving in the eastern North Pacific due to limited sampling in this area. Parturition is thought to occur from May-June (Loeb 1972). A near term fetus was found in southern California waters in April (Ridgway 1966) suggesting that parturition may occur earlier in the eastern North Pacific than in other areas. In Prince

William Sound during August 10% of all porpoises sighted are calves which gives a parturition time of June-July (Bouchet et al. 1984). Withrow et al.(1985) sighted calves in this area as early as June 19.The peak calving in the Johnstone Strait appears to be in July when there is a high proportion of calves in the area (Jefferson 1987).

In the northwestern North Pacific the majority of calves are sighted from August 26-30 and parturition is probably from mid June-mid August with a peak in mid July (Kasuya & Jones 1984). The peak calving time in this area coincides with the end of the salmon gillnet fishing season in July.

Off of Japan the peak parturition time is in late July-early August and the mating season occurs from mid August-late October with a peak on September 17 (Kasuya 1978).

Calving grounds:

There are only two known calving grounds in the eastern North Pacific (Figure 3). One is in the Johnstone Strait since there is such a high number of calves in this area during the summer (Jefferson 1987). The other is an area between 140°W & 150°W in the Gulf of Alaska when calves are seen in abundance from early August to early October (Yoshioka et al. 1987).

In the northwestern North Pacific there are also two

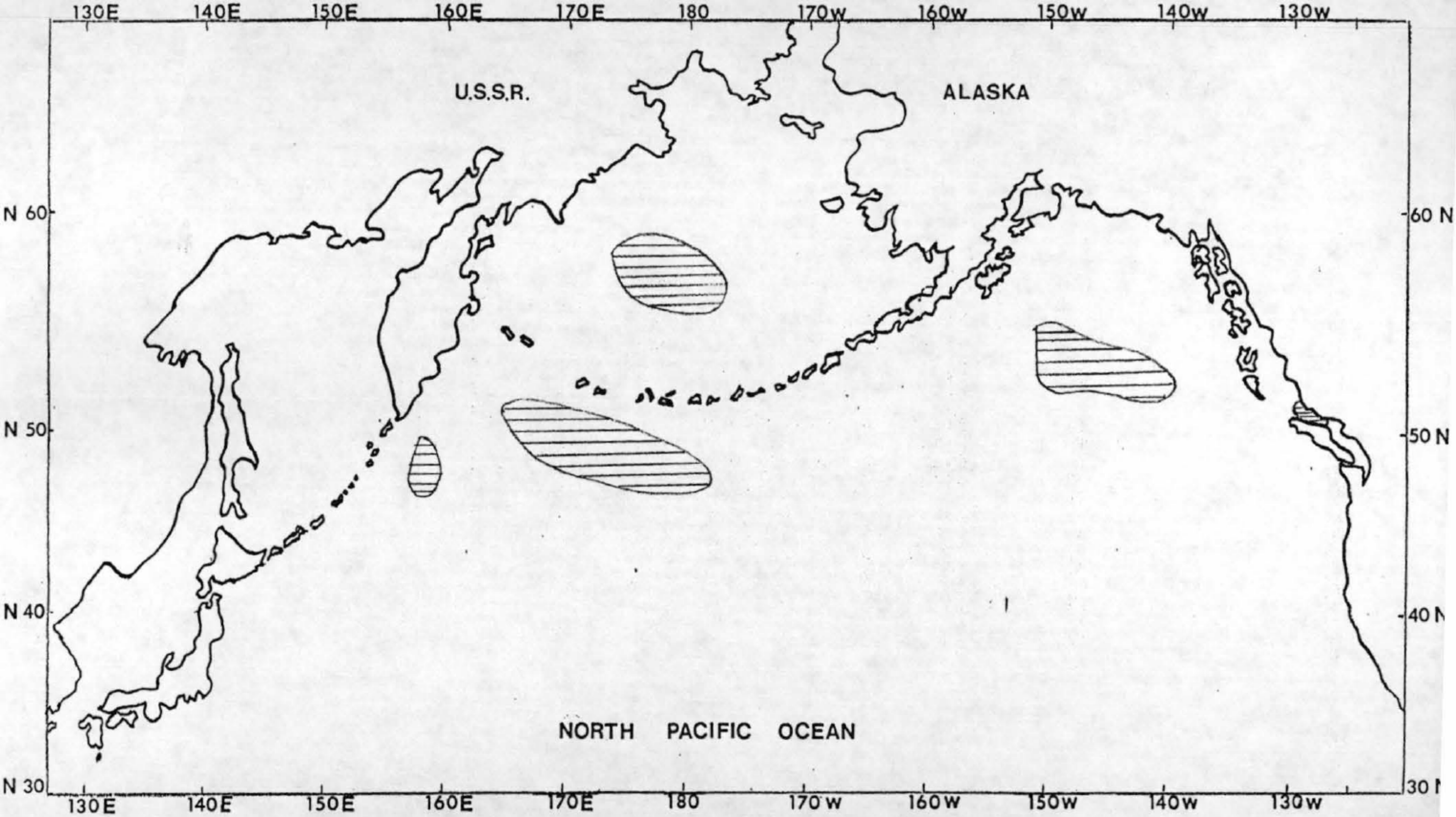

Figure 3. Known calving grounds of the Dall porpoise (Phocoenoides dalli) in the North Pacific Ocean.

calving grounds (Figure 3). One is between 45°N & 49°N and west of 160°E. The second area is east of 165°E to 178°W and north of 45°N (Kasuya & Ogi 1987).

There is a calving ground in the Bering Sea separate from those in the North Pacific. There is a high proportion of calves seen in this area, especially at 58°N, during August and September (Kasuya & Ogi 1987). It appears as though Dall porpoises are concentrating in the northern North Pacific and Bering Sea for calving and breeding purposes.

The Fisheries

There are currently three Japanese fisheries affecting the Dall porpoise: a coastal harpoon fishery, a land-based salmon gillnet fishery, and a high seas mothership salmon gillnet fishery.

The harpoon fishery

The harpoon fishery operates off the east coast of Japan from January 21-31 to early April (Kasuya 1982). The porpoises in this fishery are actively hunted and taken to fish markets where there are sold as food. The majority of the porpoises are the truei-type and biased towards the smaller size classes perhaps due to the difference in harpoonability after a certain age (Kasuya 1978). In 1978 (Kasuya) the estimated catch was approximately 6,000 porpoises but in 1982 the reported catch increased to about 13,000 porpoises (Fisheries Agency of Japan 1983).

The land-based fishery

The land-based salmon gillnet fishery operates south and to the west of the mothership salmon gillnet fishery (Figure 4). The fishing season opens on May 1 and closes on

July 31. The porpoises in this fishery, as well as the mothership fishery, are taken accidentally when they become entangled in the gillnets used during salmon fishing and either drown or suffocate. The majority of the porpoises entangled are the dalli-type.

The land-based fishery operates differently from the mothership fishery. The vessels are smaller, they operate independently rather than as a fleet, and the gillnets are spaced 6 km apart.

The high seas mothership salmon gillnet fishery

The mothership fishery operates in the western North Pacific Ocean and Bering Sea (Figure 4). The peak exploitation for this porpoise was in the late 30's and 40's when the Japanese had developed an extensive salmon gillnet fishery (Kasuya 1978). In 1952 fishing operations began under restrictions imposed by the International Convention for the High Seas Fisheries of the North Pacific Ocean (INPFC). One restriction was that the Japanese were not to fish for salmon east of 175°W because most of the salmon in this area were of North American origin. An agreement to the INPFC in 1978 moved the abstention line from 175°W to 175°E with an exception of an area in the Bering Sea excluded from the United States Fishery Conservation Zone (U.S. FCZ). In

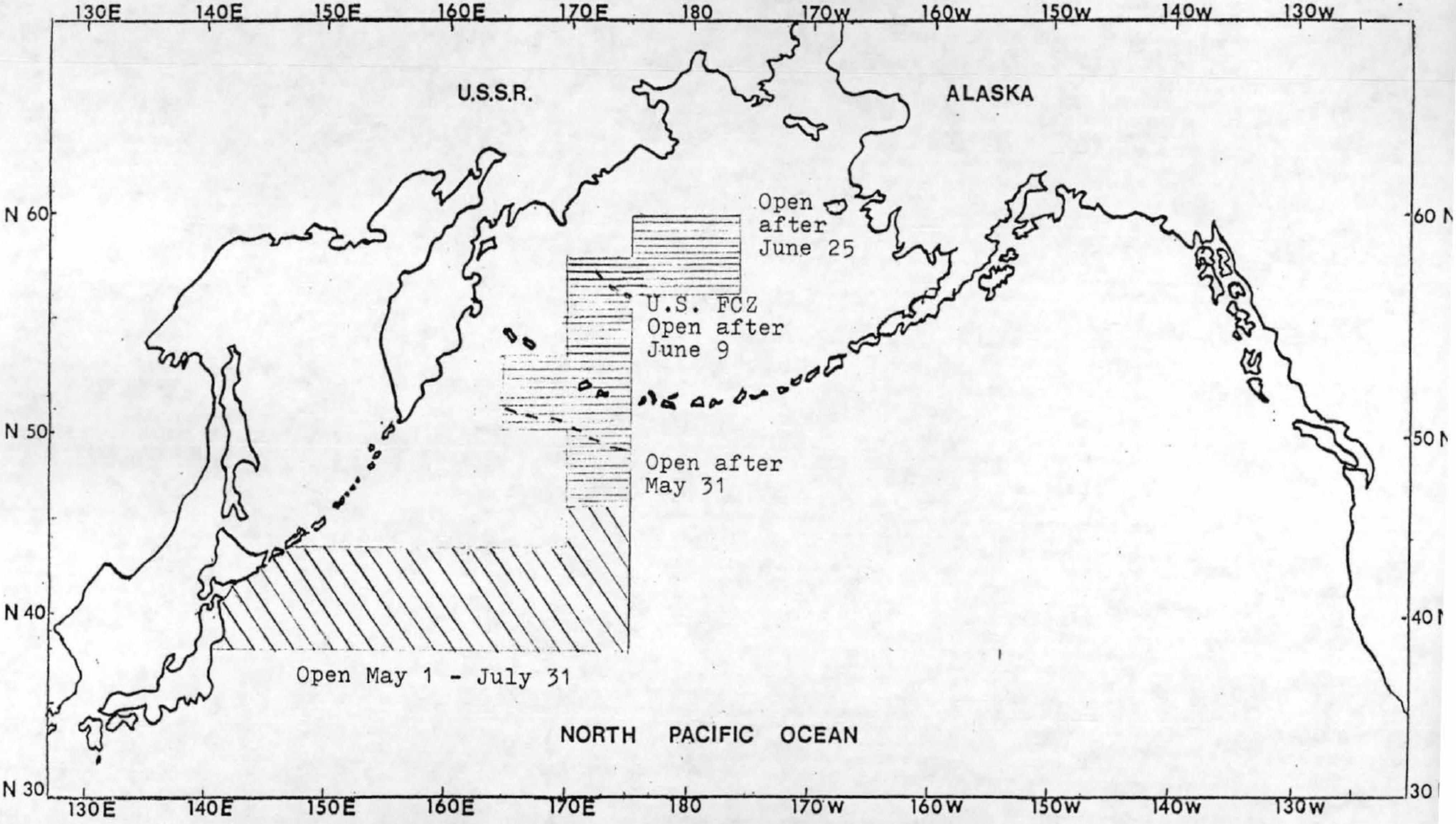

Figure 4. Location of the mothership salmon gillnet fishery (horizontal lines) and the land-based salmon gillnet fishery (slanted lines) with dates of area openings.

return for ceasing activities in this area, the Japanese fleet is allowed to fish for salmon in 70,000 square miles inside the U.S. FCZ.

At its peak after 1952, the mothership fishery contained 16 motherships and 460 catcherboats (Table 5). However, since 1978 the fishery has been reduced to 4 motherships each with 6 scout boats and 37 catcherboats for a total of 172 boats in the fishery. Due to the reduction in the size of the fleet, the fishing effort since 1978 has been less than 3.2 million tans. Most of the fishing (>60%) occurs within the U.S. FCZ (Jones et al. 1984).

The mothership fishery begins one month after the start of the land-based fishery. The fleet operates between 170° and 175°E from June 1 to June 9. On June 10 the fleet is allowed to enter the U.S. FCZ. After June 25 the fleet is allowed to move north of 56°N in the Bering Sea outside the U.S. FCZ. The fishing season ends when quotas for either salmon or marine mammals have been reached. If quotas are not reached then fishing ends on July 31.

In 1981 the National Marine Fisheries Service issued a three year permit to the Federation of Japan Salmon Fisheries Cooperative Association to take up to 5,500 Dall poprpoises incidentally within the U.S. FCZ. This permit was extended until June 9, 1987 with the understanding that research would be continued on the incidental take of Dall

Table 5. The Japanese high seas mothership fleet size and fishing effort from 1952-1986.

Year	Number of motherships	Number of catcherboats	Millions of tans fished
1952	3	57	0.5
1953	3	105	1.3
1954	7	205	3.3
1955	12	347	7.0
1956	14	447	9.3
1957	14	405	6.6
1958	15	432	8.6
1959	16	460	7.1
1960	12	410	6.5
1961	12	410	5.0
1962	11	369	5.8
1963	11	369	6.0
1964	11	369	7.5
1965	11	369	6.1
1966	11	369	5.2
1967	11	369	5.2
1968	11	369	5.9
1969	11	369	6.2
1970	11	369	6.0
1971	11	369	5.8
1972	10	332	5.9
1973	10	332	5.9
1974	10	332	5.4
1975	10	332	5.7
1976	10	332	5.9
1977	6	245	4.0
1978	4	172	2.7
1979	4	172	2.8
1980	4	172	3.2
1981	4	172	2.9
1982	4	172	2.9
1983	4	172	3.0
1984	4	172	---
1985	4	172	2.3
1986	4	172	1.9

Table modified from Newby (1982).Other data sources: Jones et al. (1984), Fisheries Agency of Japan (1986 & 1987).

porpoises. On June 10, 1987 a new permit went into effect and states:

> The (new) regulation provides for a general permit to be issued under the Marine Mammal Protection Act allowing an aggregate taking during the three year permit period of no more than 789 Dall porpoises in the Bering Sea and 5,250 in the North Pacific Ocean, of which no more than 448 may be taken in the Bering Sea and no more than 2,494 may be taken from the North Pacific Ocean in any single calendar year. (from the Federal Register 1987)

To ensure that these quotas are not being exceeded, a monitoring program was established in 1981. There is one Japanese observer in each fleet to monitor all salmon gillnet operations throughout the season and U.S. observers are on two different vessels when fishing is conducted in the U.S. FCZ. The U.S. observers spend up to 6 days on a catcherboat and 3 days on the mothership. About 7% of all gillnet operations within the FCZ are monitored and only about 2% outside the FCZ (Jones et al. 1984).

The gillnets consist of a 121 mm and 130 mm stretch mesh monofilament line. Each net is 330 tans which is set in three sections loosely connected and extends from the surface to 6-8 m in depth. The catcherboats position themselves about 9.3 km apart in the same compass orientation in parallel rows. Each boat sets one net per day and the nets are set at dusk and retrieved at dawn.

INCIDENTAL TAKE

There are discrepencies between the reported and estimated incidental take of Dall porpoises. This is due to two reasons: not all porpoises are returned to the motherships and many porpoises fall out of the nets and sink during retrieval. Besides porpoises falling out of the nets, a small portion are released alive and these are also counted in incidental take rates. The wide range of values for both the mothership and land-based fisheries reflect the difference in methodologies for calculating the take rate as well as trends in the fisheries and oceanic features.

The reported incidental take

The reported incidental take of Dall porpoises by the mothership gillnet fishery have ranged from a low of 499 in 1978 to a high of 3,688 in 1982 (Jones et al. 1984) (Table 6). Since 1982 the incidental rates have been decreasing and reached a low in 1986. The low take in 1986 corresponds to a shorter fishing season and a lower catch rate due to modified fishing gears.

The catch rates are based on the number of porpoises caught per net (300 tans) and have ranged from an average of

Table 6. The reported and estimated incidental take of Dall porpoises in the Japanese fisheries.

INCIDENTAL TAKE

YEAR	MOTHERSHIP FISHERY	LAND-BASED FISHERY	SALMON RESEARCH VESSELS	SOURCE
		REPORTED		
1978	499	303	27	5
1979	683	127	20	5
1980	999	139	56	5
1981	1,354	699	25	5
1982	3,688	1,644	50	5
1983	2,986	1,291	31	5
1984	----	----	--	
1985	2,747	781	38	6
1986	1,856	404	22	7
		ESTIMATED		
1964	19,700			2
1965	10-20,000	---		1
1980	8,970-11,851	---		4
1981	2,812	2,961		3,5
1982	5,903	6,099		5
1983	3,573	----		5

Source: (1) Mizue & Yoshida 1965 (2) Mizue et al. 1966 (3) Jones & Bouchet 1981 (4) Newby 1982 (5) Jones et al. 1984 (6) Fisheries Agency of Japan 1986 (7) Fisheries Agency of Japan 1987.

.29 in 1981 to .39 in 1985 (Jones & Bouchet 1981; Fisheries Agency of Japan 1986). The catch rates have not had any large fluctuations in the past years, at least since 1980, which indicates that the same number of porpoises are being caught with the same amount of fishing effort each year. In 1986, 77% of the mothership fleet was equipped with modified gears to reduce net entanglement and the catch rate (.31) was slightly lower than in previous years (Fisheries Agency of Japan 1987).

The reported incidental take by the land-based fishery have ranged from 127 in 1979 to 1,644 in 1982 (Jones et al. 1984). The catch rates for this fishery have also been steadily decreasing since 1982. The reported incidental take for the land-based fishery have consistently been less than those for the mothership fishery. This may be attributed to the fishing season commencing earlier than the mothership fishery and also to the different fishing locality. Dall porpoises are generally aggregating in the northern areas of the mothership fishery as reflected in the higher entanglement rates in these areas (Ito 1986).

A minor source of incidental take comes from Japanese salmon research vessels (Table 6). The values have ranged from 20 in 1979 to 56 in 1980 (Jones et al. 1984). The majority of all mortality occurs within the U.S. FCZ, 71% to 88% according to Newby (1982) and the Fisheries Agency of Japan (1987) respectively.

The estimated incidental take

The estimated incidental take values are higher than reported values for the reasons listed above (Table 6). In 1964 the number of tans fished was over twice what it is presently and the estimated incidental take was 19,700 (Mizue & Yoshida 1965). Since 1978 when the mothership fishery was reduced to 4 motherships, the highest take (8,970-11,851) occurred in 1980 (Newby 1982) and the lowest (2,812) was in 1981 (Jones & Bouchet 1981).

The land-based fishery has taken an estimated 2,961 porpoises in 1981 to 6,099 in 1982 (Jones et al. 1984). The data for this fishery is limited so comparisons over the years cannot be made accurately. However, the incidental take rates for the land-based fishery have generally followed the same trends as the mothership fishery. Years in which the take rates for the motherships have been high or low have corresponded to the same patterns in the land-based fishery.

Entanglement in the gillnets

Dall porpoises have a tendency to entangle in the upper and central portions of the gillnet. The upper part of the net accounts for 44% and 68% of all entanglements according to Ogiwara et al. (1987) and Jones et al. (1984) respectively and the central portion is responsible for 44% and 23% of entanglements. The former researchers found the percentages that became entangled in the upper and middle portions were approximately the same. Few porpoises are entangling in the portion of the gillnet that is set the deepest.

There is not a clear correlation between entanglement rate and horizontal distribution of the gillnet. It does appear though that porpoises entangle more frequently in the end portions of the net.

Dall porpoises become entangled in the gillnets by their tail flukes (33%) and by complex entanglement (31%) most often. They also become caught in the nets by their pectoral fins and mouths (Ogiwara et al. 1987).

MODIFIED GEAR TO REDUCE INCIDENTAL TAKE

The high entanglement rate in the salmon gillnets leads to the question as to whether or not the Dall porpoise can detect the monofilament gillnets. The two main factors involved in order for porpoises to be able to detect the nets by echolocation are the nets target strength and the frequency and intensity of echolocation pulses. It has been determined that the Dall porpoise emits pulse trains that are well suited for echolocation. These porpoises have short, narrow band, constant frequency single or double pulses with a peak energy between 120-160 kHz (Awbrey et al. 1979). Awbrey estimated the upper threshold of hearing to be about 170-200 kHz. This is almost the same range as the bottlenose dolphin (*Tursiops truncatus*) and the harbor porpoise (*Phocoena phocoena*).

To determine if Dall porpoises can detect the nets, an experiment using threads of different sizes and colors was conducted using a trained captive beluga (*Delphinapterus leucas*) because the auditory frequency range of a beluga is close to that of a Dall porpoise. The results indicated that as the diameter of the thread increased, the recognition time became shorter. The recognition time was also shorter with nets colored red, black, white, blue, colorless respectively (Soeda et al. 1986). The threads used in the salmon gillnet fishery are as small as .4 mm and are colorless.

According to Awbrey it is questionable whether Dall porpoises can detect the gillnets due to the low target strength of the nets (-50 dB, Hatakeyama et al. 1986) and the low level of resounding echoes. The higher the target strength, the easier it is to detect an object. Also, the Dall porpoise produces high frequency sounds and a reciprocal relationship occurs between the frequency and the size of the object refelecting the sound.

To reduce entanglement in the gillnets two methods have been proposed. One is to attach sound generators to the nets which emit supersonic pulses to alert the porpoises to the location of the nets and the other is to attach objects to the nets to increase the net target strength.

In 1983 the Vice Secretary in charge of fisheries at NOAA determined that the modified gear which offered the most practical and effective solution to reduce the incidental take was nets which contained air tube threads. The research began on this gear in 1981 and three air tube threads are woven into the central portion of the net to increase the net target strength from -50 dB to about -46 dB (Table 7). In 1986 approximately 77% of the Japanese fishing fleet was equipped with this gear and the incidental take decreased by 20% (Ogiwara et al. 1987). However, if factors such as the sea conditions, weather, and time are removed then the air tube thread decreases the take by 31% which is considered to be an effective method for reducing incidental take. The air tube thread decreased the CPUE slightly and had almost no reduction in the catch of salmon (Table 7).

In 1986 a new type of gear was implemented. Multifilament threads were woven into the central portion on the nets of eight catcherboats. The relection of the multifilament thread is about 10 dB higher than that of a standard gillnet (Table 7). There was a slight decrease in the salmon catch (Table 8). This gear reduced the incidental take by 28% and showed better results than the air tube thread so an increase in the amount of catcherboats equipped with this gear should be tested in the future.

Another experiment was conducted by also attaching objects to the nets. Vinyl string, blister sheet plastic, and rope were attached to gillnets for a total of 13 operations (Table 9). The objects all had a higher target strength than a standard gillnet. A total of five Dall porpoises were entangled and two of these were in the standard net and the other three were caught in the nets with the rope attached. The rope had the lowest target strength out of all the objects placed on the nets (Hasegawa et al. 1987).

There are presently three types of sound generators

Table 7. Effectiveness and cost of modified gear on reducing the incidental take of Dall porpoises.

GEAR TYPE	REFLECTION (dB)	% TAKE REDUCED FROM STANDARD GILLNET	# OF VESSELS WITH GEAR (81% fleet equipped)	COST ($) TO EQUIP 100% OF FLEET
Standard gillnet	-50	---	32	12,817
Air tube thread	-47 to -46	20	123	269,152
Multifilament thread	-40	28	8	269,152
Sound generators:*				
simple type	----	19	4	2,175,181
porpoise-like type	----	26	4	2,354,849
20-50 kHz type	----	29	1	3,410,470
				8,478,804

* Sound generators were attached to nets which contained the air tube thread. Data from Ogiwara et al. (1987).

Table 8. Effect of modified gear on the catch per unit effort (CPUE) of Dall porpoises and salmon.

GEAR TYPE	CPUE Dall porpoises (porpoise/set)	salmon (fish/set)
Standard gillnet	.388	538
Air tube thread	.309	535
Multifilament thread	.279	519
Sound generators:*		
simple type	.316	527
porpoise-like type	.287	529
20-50 kHz type	.235	478

* Sound generators were attached to nets containing air tube thread. Data from Ogiwara et al. (1987).

Table 9. Effectiveness of reflectors attached to gillnets during 13 fishing operations to reduce incidental take of Dall porpoises.

Reflector		Reflection (dB)	# of porpoises entangled
Standard gillnet:			
	max.	-50	2
Vinyl string:			
	min.	-45 to -42	
	max.	-21 to -21	0
Blister plastic:			
	min.	-48 to -38	
	max.	-12 to -11	0
Rope:			
	min.	-51 to -43	
	max.	-38 to -29	3
		Total	5

Data from Hasegawa et al. (1987).

that have been designed and tested to reduce mortality. There is a simple-type generator which emits a 145 kHz repeated pulse, and a porpoise-like generator which also emits a pulse of 145 kHz but does so with changes in the pulse interval. The testing of these two types was intiated in 1983. The third generator emits a pulse between 20-50 kHz and has only been tested since 1985.

A test of the 20-50 kHz type was conducted by attaching the generators to the net at three positions during 32 operations. A total of eight Dall porpoises were entangled and seven became caught in the side of the net not having the generators attached so it appears as though the porpoises have to be facing the generators for them to be effective (Hatakeyama 1987).

An experiment using all three types was conducted aboard Japanese catcherboats during the 1986 fishing season. A total of five boats were equipped with the sound generators (Table 7). The generators were attached to nets which had air tube thread also attached so results are multiplied. The most effective generator was the 20-50 kHz type which reduced the incidental take by 29% compared to boats which included the standard gillnets (Ogiwara et al. 1987) and the catch per unit effort (CPUE) was the lowest with this generator (Table 8). The salmon catch was slightly lower for the vessels which contained nets with the generators than for those without, especially the 20-50 kHz type. Hatakeyama et al. (1987) suggests guidelines for designing sound generators for future use as Dall porpoise auditory sensitivity is best between 20-75 kHz and severly reduced at 143 kHz. These guidelines are as follows:

1. the frequency of the emitted sound waves should be lower than 100 kHz
2. using wider pulse widths should be more effective
3. in order to intimidate Dall porpoises, the sound pressure of the generated sound waves should be between 122 and 130 dB at the location of the porpoise. This pressure is about 70 dB higher than the auditory threshold.

DISCUSSION AND CONCLUSION

The Dall porpoise is an abundant species in the North Pacific Ocean affected by Japanese fishing operations, principally the high seas mothership salmon gillnet fishery and the land-based salmon gillnet fishery. Questions that need to be examined to find satisfactory solutions for the preservation of this species and the continuation of Japanese fishing operations inside the U.S. FCZ are: how many porpoise stocks and individuals are in the northern North Pacific, is the method for determining Dall porpoise quotas adequate, and is the monitoring program effective for enforcing the set quotas? But perhaps the most significant issue which needs to be answered is are the Japanese fisheries having a deleterious affect on Dall porpoise populations and if so, are the current modified gears sufficient to reduce the incidental take.

It is not known just how many Dall porpoise stocks there are throughout the species' entire distribution. There are three stocks occurring in the western North Pacific (Kasuya 1978) and even though there is not a clear separation of porpoises in the eastern North Pacific, subpopulations most likely occur. There is also no clear segregation of stocks in the northern North Pacific where the Japanese salmon gillnets operate. The population in this area could be representative of a single population which has segregation occuring among the immature and male porpoises. Surveys from June to September indicate a high proportion of pregnant or lactating females with calves in the area south of the Aleutian Islands (Kasuya & Jones 1984).

There have been two electrophoretic studies which have dealt with the problem of Dall porpoise stock identity. Winans and Jones (1988) concluded that the porpoises from the Bering Sea and the North Pacific Ocean are not one interbreeding population. They also estimated the genetic variation to be above average which may reflect a large, stable population size. Their findings agree with those of Numachi et al. (1984) who also found that Dall porpoises have high genetic variablity which may be attributed to a large population and gene pool. They considered that a very large population is necessary to maintain such a high genetic variability and although Dall porpoises have several independent populations, the genetic differentiation between populations is much smaller than for other animals. The low amount of differentiation is thought to be related to the scale of genetic intermingling between populations.

There are biases associated with estimations of abundance. Many calculations are determined by strip transect methodology which may result in either under or over estimations of abundance. The Dall porpoise is attracted to vessels in most areas and this response could lead to porpoises moving into the transect area and causing the population to be overestimated. Many surveys are conducted from June to July when calving occurs. It has been shown that mothers with calves tend to avoid vessels which leads to abundance underestimations. Recently, there has been a study to determine a correction factor to compensate for this porpoise's response to vessels which will greatly increase the accuracy of abundance estimates (Turnock 1987). However, a correction factor will need to be calculated for each area to be estimated as the vessel response differs from one area to another. Combining data from Kato (1987) and Miyashita and Kasuya (1987a), the best estimates of abundance for the Dall porpoise throughout its entire distribution range from 2,295,000 to 2,728,000 animals. The Bering Sea population is estimated to contain 213,000 to 468,000 porpoises and the western and central North Pacific is estimated to contain 935,700 to 1,009,500 porpoises.

The reported mortality for Dall porpoises taken incidentally by the mothership gillnet fishery in the Bering Sea and northwestern North Pacific Ocean is approximately between 1,850 to 3,000 porpoises annually. However, the reported mortality is considerably lower than the estimated mortality because not all porpoises are returned by catcherboats to the motherships and many porpoises fall out of the nets during retrieval.

Dall porpoises exhibit seasonal movements and move north during the summer months. The population in the northwestern North Pacific, especially pregnant and lactating females with calves, are aggregating in the northern areas south of the Aleutian Islands for breeding and calving purposes. The Bering Sea population is focused in the southern Bering Sea during the summer months so that both of these populations are assembling in the Japanese mothership gillnet fishing areas when the peak calving takes place. The incidental take rate increases as the fishing season progresses and reaches a peak from mid to late July and the take of calves also increases at this time.

The Japanese mothership salmon gillnet fishery and the land-based fishery are the major sources of Dall porpoise incidental take. A small number of porpoises are taken by salmon research vessels and an unknown number by the Japanese squid fishery. The squid fishery also uses gillnets and exists in the Dall porpoise's range. It operates from June to December in the North Pacific south of the mothership fishery (Figure 5). This fishery has no monitoring program or regulations on the take of Dall porpoises so it is not known exactly how many are taken

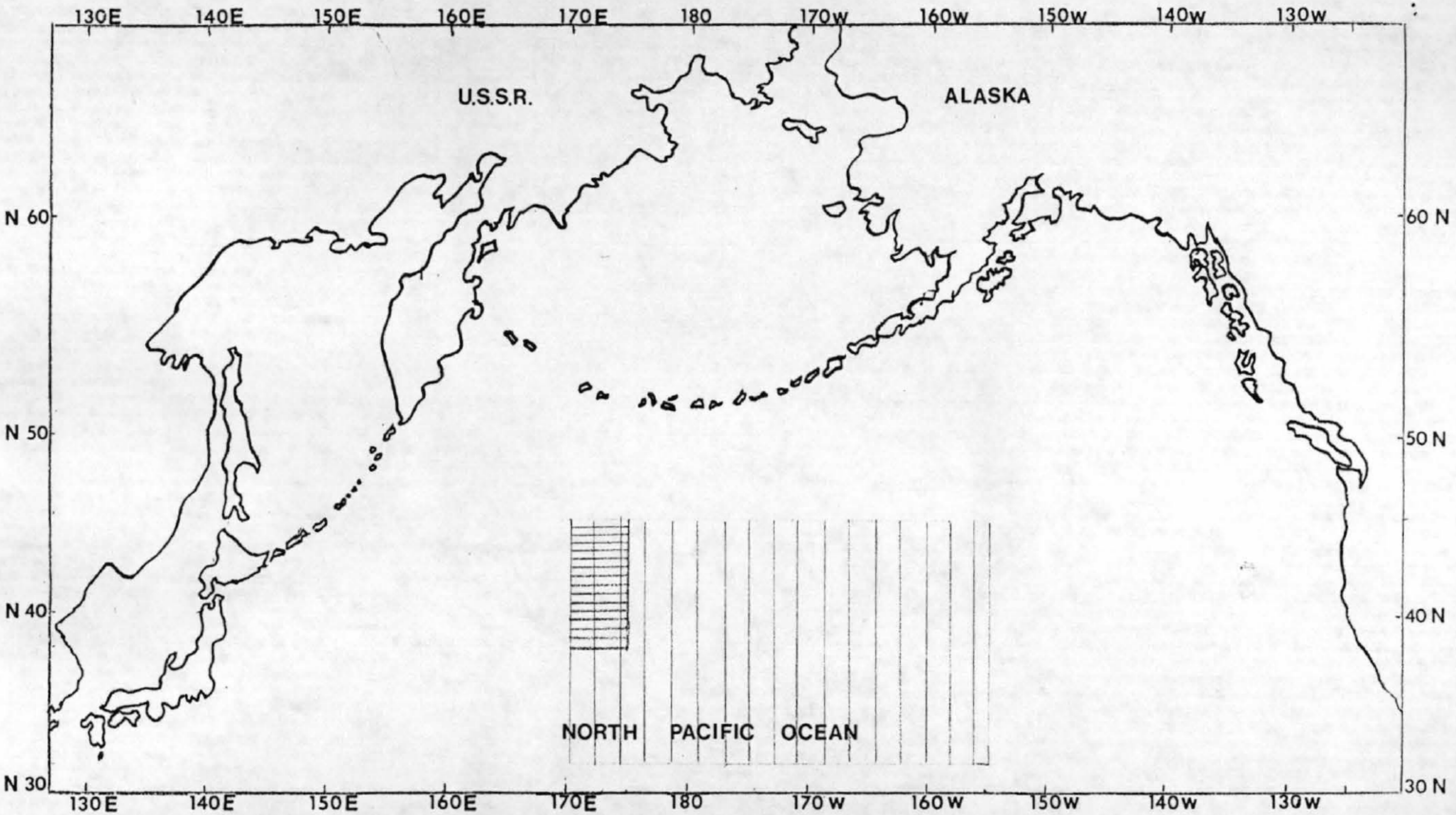

Figure 5. The area of the Japanese squid gillnet fishery (vertical lines). The horizontal lines indicate the area of overlap between the squid fishery and the land-based salmon gillnet fishery.

incidentally each year. Therefore, the incidentally killed porpoises in this fishery are not included in the quota regulations.

A certificate of inclusion is required for any vessel that takes marine mammals incidentally during fishing operations inside the U.S. FCZ. The Administrative Law Judge (ALJ) must on the basis of the "best scientific evidence available", make a determination of the optimum sustainable population (OSP) and show that the populations of the species will not be adversely affected by the proposed taking in the concerned areas before issuing a general permit.

On June 10, 1987 a new general permit became effective in which quotas were established for the incidental take of Dall porpoises by the Japanese high seas salmon gillnet fishery. The permit states that no more than 789 Dall porpoises may be taken in the Bering Sea and no more than 5,250 in the North Pacific Ocean in a total of three years. The conditions of the permit were outlined as follows: the cost of U.S. observer coverage of the mothership fleets must be borne by the Government of Japan, a report must be furnished prior to June 9, 1988 as to the extent of the Japanese high seas gillnet fishery prior to 1952, and the quotas stated alone must be reduced proportionally in the event that the Soviet Union reduces Japanese salmon quotas for 1988 or 1989 in either area by more than 10% from the 1987 salmon quota (Federal Register 1987).

The ALJ determined that Dall porpoise stocks in the Bering Sea and North Pacific Ocean are above the minimum levels of their optimum sustainable population and that the present quotas will maintain each stock above the minimum level of its OSP during the duration of the permit. However, I feel that the present quotas allow a greater number of porpoises to be taken in both areas than is reasonable to ensure the populations do not fall below their minimum OSP level. Calculations for determining the OSP are based on reported catch rates and the estimated incidental take is much higher than the reported values (Table 6). And until abundance estimates are more accurate and an adequate monitoring program established, I believe that these factors combined should result in more conservative quotas.

The U.S. observer monitoring program implemented in 1981 is insufficient for determining accurate incidental catch rates. Only a very small number of fishing operations are monitored and some catcherboats go entirely unobserved for the whole fishing season. No more than 7% of all fishing operations are monitored by eight observers inside the U.S. FCZ, where 71-88% of all Dall porpoise mortality occurs (Jones et al. 1984; Ito 1986).

The Japanese gillnet fisheries clearly have an impact on the Dall porpoise but whether or not they are having a detrimental effect on the population size is not distinct. I do believe, however, that presently all Dall porpoise populations are stable. The catch rates have remained fairly constant over the years which could be an indication that the number of porpoises have also remained constant. The abundance estimates, although they are not strong evidence, and the high genetic variability give further support in my opinion that the populations are not decreasing significantly.

I do firmly believe that while the number of individuals are not decreasing, the Dall porpoise is displaying a response to the mortality imposed by the Japanese fisheries or is perhaps responding to heavy mortality in the past when the mothership fishery was at its peak with 16 motherships. There are several factors which suggest that this species is responding to prolonged mortality. The Dall porpoise has a high birth rate compared to other odontocetes (95.5 %, Newby 1982) and an annual reproductive cycle. The gross annual reproductive rate is also high in the U.S. FCZ compared with other odontocetes (.25-.41). This value is calculated from the annual birth rate, the proportion of females in the population, and the proportion of sexually mature females(Jones et al. 1984). The low age at first reproduction (3.3 years) and a high instantaneous growth rate (14.8%) (Newby 1982) combined with the above biological parameters indicate that these factors are a response to fishing pressures either presently or in the past. Unfortunately, there is little life history data in the eastern North Pacific to compare the above parameters to those of porpoises from the northwestern North Pacific to determine if the eastern stock, where no fishing pressure exists, have high reproductive rates as well.

Net entanglement arises from two primary factors: the time of day the gillnets are set and the target strength of the nets. The nets are set at dusk and retrieved at dawn. This porpoise is most active at night and most likely feeding during the time the nets are allowed to drift. Entanglement may occur from a simple case of inattention because the porpoises are distracted when feeding. This problem is enhanced by the inability to detect the nets due to the low target strength (about -50 dB).

The modified fishing gears which offer the most practical solution to decrease the incidental take of Dall porpoises are air tube thread and multifilament thread which are woven into the center of the gillnets to improve the net target strength. The gillnets used by the Japanese fisheries are small, some line is as narrow as .5 mm, and even though Dall porpoises have good echolocation abilities, the net target strength is too low to be perceived by this method.

The passive methods are feasible since they are not too expensive, they are easy to maintain, they are easy for the fishermen to employ, and they do not decrease the salmon catch.

The results with the multifilament thread have been slightly better than those nets with the air tube thread attached. The incidental take is reduced by 28% and 20% respectively.

Another method attempted to reduce net entanglement has been attaching sound generators which emit supersonic pulses to the nets. Three types of generators have been designed: a 145 kHz type which emits repeated simple pulses, a 145 kHz type which emits porpoise-like pulses, and a 20-50 kHz type. The latter sound generator decreases the salmon catch by about 60 fish/set but this is the most effective in reducing net entanglement of the three generator types. The reason this generator is the most effective of the three is probably due to Dall porpoise hearing being the most sensitive to pulses under 75 kHz (Awbrey et al. 1979).

Disadvantages to using the sound generators are that they are costly, require more work to maintain than the passive methods, are more time consuming to employ since the nets must be retrieved more carefully. Also, the results have shown that the generators are not that effective in reducing net entanglement. Possibly not enough generators are attached to the nets as high frequencies attenuate rapidly in water and it appears that porpoises must be facing the generator to notice the sound. It would be interesting to attach sound generators to the nets which emit 10-20 kHz pulses and also generators which emit sounds of other odontocetes, especially *Orcinus orca*, to compare the results with the present generators.

Even though Dall porpoise populations appear to be stable, continuing the research on modified gears to reduce the incidental take is worthwhile as is learning more about this species in the eastern North Pacific. Taking samples from a larger area and in months after September would reduce some of the biases associated with the current data and greatly help to understand the ecology of this species.

CONTINUING AND FUTURE RESEARCH

The Dall porpoise is one of the most abundant cetaceans in the North Pacific Ocean, however, the known ecology of this species is lacking and the need for further research is evident. The following is a list of suggestions for continuing and future research needs that I feel would be beneficial to the overall understanding and conservation of this porpoise:

1. The taxonomic relationship between the *dalli*-type and the *truei*-type Dall porpoises needs to be resolved. To settle this, studies should be continued to determine if there are differences other than color between the two types which would then enable the types to be classified as subspecies. Also, until the taxonomy is resolved, the scientific names should be consistent in the literature. Perhaps at the next workshop or meeting on the Dall porpoise, a nomenclatorial system can be established for accomplishing this goal.

2. Determining accurate abundance estimates should be designated as a high priority research need. The reason for this is apparent. The incidental take quotas are determined by using current abundance estimates which are likely biased in the fishing areas due to the bow riding behavior of this species. This could result in an overestimation of the optimum sustainable population allowing more porpoises to be taken in the Japanese salmon gillnet fishery, which may or may not have a detrimental effect on the populations in the fishing areas.

More precise abundance estimates would allow the impact of the Japanese fisheries on the Dall porpoise to be evaluated by comparing estimates in successive years to ascertain if the population is declining, increasing, or stable.

The determination of correction factors in the calculation of abundance estimates to compensate for bow riding behavior and sighting visibility began in 1987 and should be continued until a correction factor is found for all areas.

3. Year round sampling or sampling after August would be beneficial to determine accurate periods of lactation, resting, and the total calving interval. At present, many porpoises are collected from entanglement in gillnets during the fishing season which is restricted from June to July. Segregation appears to occur among immature and male porpoises during the present collecting interval which creates biases in biological data, therefore, sampling year round would negate these biases.

4. More effort should be accorded to social structure and stock segregation. Little is known concerning the group structure of the Dall porpoise and areas such as the Johnstone Strait in British Columbia where these porpoises can be observed from land are ideal for learning more on this subject. Groups and individual porpoises could be

observed and photographed and then evaluated to determine if groups change members often or if they are cohesive units. Electrophoretic studies could possibly determine if members of the same group are related. These types of studies have been conducted in the past to determine stock differentiation and more should be continued in the future.

It would be worthwhile to know how many Dall porpoise stocks there are in the northern North Pacific and Bering Sea to discover how many stocks are affected by the Japanese fisheries.

5. There have not been experiments to tag Dall porpoises in the past and some effort should be made to do so. The seasonal movements in the eastern North Pacific are not well documented and it would be advantageous to know if there is emmigration or immigration from one population to another. One method which might be attempted to follow porpoise movements is by identifying parasites or diatoms on the skin film as certain of these species are indicative of specific areas.

6. The fact that there is little known about this species in the eastern North Pacific should be remedied. There have been no major attempts to determine stock segregation or

biological parameters in this area. It would be very interesting to compare life history data, especially pregnancy rates, gross annual reproductive rates, and the total calving interval, between porpoises in the eastern North Pacific and those occuring in the fishing areas to discover if the Japanese fisheries are having an impact on Dall porpoise populations.

7. A greater attempt to return all incidentally killed Dall porpoises to the motherships should be intiated as well as reporting all the porpoises which are taken in the nets. This would lead to more precise catch rates and assist evaluations on the effectiveness of the modified fishing gears.

8. The effectiveness of the marine mammal monitoring program should be assessed and possibly reorganized. If there is not sufficient funds to employ more observers than perhaps a new system should be established. Only a small proportion of the fishing operations are actually monitored and some catcherboats go totally unmonitored for the entire fishing season. Regulations under the general permit isssued by the National Marine Fisheries Service should give control to the observers to decide in what area and which catcherboats to monitor.

9. Observers should monitor several operations of the squid fishery to determine if the incidental take of Dall porpoises is sufficient to warrant regulations concerning marine mammals as this fishery is increasing in size as well as area.

10. The testing of modified gears to reduce incidental take should continue with more emphasis on passive methods as these are less costly and easier to maintain. Equipping more catcherboats with multifilament thread and comparing the effectiveness of the former with the air tube thread would also be valuable. Continuing studies on the present types of sound generators is worthwhile as well as designing new types of sound devices which would alert porpoises to the location of the nets. Studies using sound generators of lower frequencies (10-20 kHz) might be beneficial as well as generators emitting sounds of other species of odontocetes.

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