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Cetacean Interactions with Trawls: A Preliminary Review

D. Fertl[1]
Marine Mammal Research Program, Texas A & M University
4700 Avenue U, Galveston, Texas 77551, USA

and

S. Leatherwood[2]
IUCN/SSC Cetacean Specialist Group, c/o Ocean Park Conservation Foundation
Ocean Park, Aberdeen, Hong Kong

Abstract

Cetaceans interact with trawls to an undetermined extent. A preliminary review of global data indicates that individuals of 25 cetacean species (two mysticete, 23 odontocete) have been documented to have died in working trawls or discarded trawling gear. Cetacean interactions with trawls are complex, in part because both fishermen and cetaceans are drawn to areas of high prey density. Furthermore, within such areas, cetaceans are probably often attracted to trawling activities because they make it easier for the animals to exploit a concentrated food source. Individuals of 15 (possibly 16) cetacean species (13 odontocete, and one or even two mysticete) have been reported to feed in association with trawls. Animals follow working nets (feeding on stirred-up organisms or fish gilled in mesh) and also feed on discarded by-catch. Damage to gear as a result of feeding interactions or entanglement has been reported. Such damage results in (1) harm to the animals, (2) creation of negative opinions of cetaceans by fishermen (regardless of whether a cetacean or a shark is, in fact, responsible for the damage in question), and (3) loss of time and money for repair and replacement of gear. The relationships of cetaceans with trawls need to be further studied to determine what effects the trawl fisheries have on the ecology and population status of the whales and dolphins involved.

Key words: behaviour, by-catch, cetacean, feeding, fishery interaciton, mysticete, odontocete, trawl

Introduction

Interactions between various cetacean species and fisheries are geographically widespread and diverse (see reviews in Northridge, 1984, 1991; Currey *et al.*, 1990, 1991). Interactions are potentially harmful to cetaceans (e.g. depletion of fish stocks, direct kills in fisheries, and incidental captures in fishing gear) and to humans (e.g. gear damage and depletion of commercially valuable fish stocks) (Beddington *et al.*, 1985). Incidental catches of cetaceans in nets, especially purse seines, gillnets, and drift nets, are extensive and cause considerable mortality (Bjørge *et al.*, 1991; Perrin *et al.*, 1994). Mortality in trawls has been less frequently reported and all but ignored in evaluations of fisheries impacts, even though many of the causes of catches in trawls are similiar to those associated with gillnet captures.

Many fisheries in the world use trawl nets (Nedelec and Prado, 1990). Trawl nets are towed nets consisting of a cone-shaped net with a cod-end or bag for collecting the target species. Trawls can be bottom, midwater, or surface, and are operated from one, or occasionally two, boats to take various species of fishes, squids and crustaceans. Many national fishing fleets include a broad class of trawlers, ranging from small coastal trawlers to large catcher/processing vessels. To a large degree, net size and type (bottom, midwater, etc.) is dependent on vessel size (i.e. fishing power).

[1] *Current address*: Minerals Management Service, U.S. Dept. of the Interior, 1201 Elmwood Park Blvd, New Orleans, LA 70123

[2] Deceased January 1997

Incidental takes of cetaceans exist in most areas where trawling occurs, for example, the North Sea, Bering Sea, Atlantic Ocean, Gulf of Mexico, Gulf of California, Mediterranean Sea, Indian Ocean, and waters off Australia and New Zealand (Appendix 1). Information on the numbers of animals caught and the causes of by-catches in trawls is not readily accessible (e.g. it is often embedded in the literature on gillnets); this paper compiles and summarizes existing information.

Cetacean catch and composition

Individuals of two mysticete species, 23 odontocete species, and several unidentified cetaceans (including beaked whales) have been documented to have been incidentally caught in trawls (Appendix 1 and 2)[1]. The condition of incidentally caught cetaceans varies. It has been suggested that cetaceans found in nets are rarely alive when caught, and that dead or dying animals are sometimes scooped up as the nets pass (T. Loughlin, National Marine Mammal Lab., Seattle, WA, USA, pers. comm., 1991). There are a number of reports of trawls bringing up dead and decomposed bodies of cetaceans (Scheffer and Slipp, 1948; Testaverde, 1978; Perez and Loughlin, 1991), as well as skulls (Anonymous, 1979; Smith *et al.*, 1989; Lake, MS 1995). Some workers contend that healthy cetaceans should be able to avoid trawl nets easily, since the vessels' forward progress is quite slow (van Utrecht, 1978; Niazi, 1990; T. Loughlin, pers. comm., 1991). This is clearly not the case for pinnipeds that interact with trawls, many of which are caught alive and perish in the nets [e.g. Steller sea lions (*Eumetopias jubatus*) (Alverson, 1992); Cape fur seals (*Arctocephalus pusillus*) (Shaughnessy and Payne, 1979); Hooker's sea lions (*Phocarctos hookeri*) (MAF Fisheries, 1991); northern fur seals (*Callorhinus ursinus*) (Perez and Loughlin, 1991); California sea lions (*Zalophus californianus*) (Miller *et al.*, MS 1983), and New Zealand fur seals (*Arctocephalus forsteri*) (MAF Fisheries, 1991)]. Similarly, most cetaceans caught alive in trawls die, while few can be released alive (Appendix 1). One incident involved a minke whale (*Balaenoptera acutorostrata*) harpooned in Newfoundland that was found with trawl mesh web grown into its rostrum (D. E. Sergeant, Hudson, Quebec, Canada, pers. comm., 1992). It was thought that this whale had been cut out of a trawl net at some point in its life.

Why do cetaceans become caught in trawls? Trawling is an active fishing process; therefore, cetaceans are probably aware of the net and the boat's activity. Engines on trawlers produce a character-istic sound, particularly when changing stages of operation. It has been suggested that some odontocetes are able to acoustically distinguish between stages of trawl operation. Bottlenose dolphins (*Tursiops truncatus*) are sometimes attracted when nets are deployed (e.g. Gunter, 1954) and have been seen approaching shrimp boats to wait for by-catch to be culled (e.g. Norris and Prescott, 1961; Leatherwood, 1975; Delgado-Estrella, MS 1991). Killer whales (*Orcinus orca*) have been observed to do the same with trawlers in the Bering Sea (J. R. Heimlich-Boran, Cambridge, UK, pers. comm., 1991). Gruber (MS 1981) documented various reactions of bottlenose dolphins to operational stages, including following the net as it was being hauled in and, at other times, switching to boats trawling in the vicinity. On the other hand, Fertl (MS 1994) suggested that factors other than just the trawler's operational stage, such as social interactions, may play an important part in dolphin movements around shrimp boats.

A variety of biological factors can influence catches of marine mammals: species distribution, various behavioral traits, sensory capacities, and attention and searching images (Nelson, 1990). Many of the possible causes of cetacean entanglement in gillnets (IWC, 1994) can be applied to catches of cetaceans in trawls; for example, behavior (curiosity, exploration, attention and perception, social patterns, and feeding) of the cetecean appears to be an important consideration. It has been reported that there have been higher catches of cetaceans in trawls at night (Waring *et al.*, 1990; Maigret, 1994; Baird, 1995; Crespo *et al.*, 1997); Maigret (1994) suggests that this is perhaps the time that dolphins (e.g. *Delphinus* spp., and *Stenella* spp.) are moving slowly near the surface and are less alert, while Waring *et al.* (1990) noted that the reason higher catches of *Delphinus* spp. occur at night is not readily apparent, but did seem related to a behavioral phenomenon of the

[1] A northern right whale (*Eubalaena glacialis*) was reported as having been caught in a trawl [the single incident was reported in O'Hara *et al.* (1986), Waring *et al.* (1990) and Kraus (1990)]. Kenney and Kraus (1993) published a correction to this; therefore, this species is not included in the tally.

dolphins. Unfortunately, there is little systematic knowledge of many behavioral processes that cause cetaceans to be vulnerable to incidental takes in fishing gear (IWC, 1994).

Feeding behavior

Marine mammals frequently exploit fisheries for food. California sea lions, bottlenose dolphins, and botos (*Inia geoffrensis*) are known to remove fish from nearshore gillnets (Everitt *et al.*, 1981; Cato and Prochaska, 1976; S. Leatherwood, unpubl. data, respectively); bottlenose dolphins (Cato and Prochaska, 1976; Iversen, MS 1975), rough-toothed dolphins (*Steno bredanensis*) (Iversen, MS 1975), false killer whales (*Pseudorca crassidens*) (Leatherwood *et al.*, 1989), and killer whales (Sivasubramanian, 1964) steal hooked fish; and long-finned pilot whales (*Globicephala melas*) frequent traps to remove the target species, which is the squid *Illex illecebrosus* (Lien, 1994). It appears that some cetacean species, like pinnipeds, are attracted to trawl nets because of the easy food source they represent (e.g. Shaughnessy and Payne, 1979; Beddington *et al.*, 1985).

Individuals of at least 15–16 cetacean species (13 odontocete and two, possibly three mysticete) have been documented to feed in association with trawling (Table 1, Appendix 3). Such associations appear to occur in all areas of the world. Individuals exploit food concentrated by trawling operations. This process is best illustrated by the long-standing relationship between bottlenose dolphins and shrimp trawlers, in which the dolphins show readiness to make use of a variety of easily procured food items (e.g. Leatherwood, 1975; Gruber, MS 1981; Corkeron *et al.*, 1990; Fertl, MS 1994).

Animals tend to be attracted to food that is clumped or patchy in distribution (Krebs, 1978). A trawler might well be considered as a mobile patch. By remaining with this moving patch, in which available food is frequently concentrated, dolphins presumably can reduce the proportion of time spent foraging (searching for and consuming food) and possibly increase the quantity and quality of the food they do consume. The less time they spend foraging, the less energy they use. By this logic, trawling may provide an abundance and diversity of food in a small area and permit the cetaceans to select food of higher-than-usual caloric value.

Fishing operations may also open up some food niches not otherwise available to some cetaceans, such as in the Alaskan fishery for sable fish (*Anoplopoma fimbria*) (Matkin *et al.*, 1986). Killer whales are often observed taking sablefish from long lines; these fish otherwise live too deep for killer whales to catch them (Matkin and Saulitis, 1994). There are two reports of humpback whales (*Megaptera novaeangliae*) feeding behind trawl nets (von Ziegesar, 1984 in NMFS, 1991; D.E. Sergeant, pers. comm., 1992). Sergeant suggested that, since humpback whales usually do not dive very deeply, the additional food supply brought up by trawl nets gives the whales a broader feeding resource (D.E. Sergeant, pers. comm., 1992). There is, however, little evidence to demonstrate that, for humpback whales, associating with trawl fisheries is really beneficial.

There is considerable overlap of prey species in the stomachs of cetaceans that have been feeding opportunistically around trawlers and on prey species that are targets of commercial trawl fisheries or in stomachs of target species of the commercial fishery. Analyses of stomach contents of bottlenose dolphins from the Gulf of Mexico (Barros and Odell, 1990) indicated prey composition similar to that of the non-shrimp catches of shrimp boats (Bryan, MS 1980; Pellegrin, 1982). Pellegrin (1982) calculated an overall fish/shrimp ratio (measured in tons) in by-catches of the Gulf of Mexico shrimp fishery of 9.1:1. Stomach contents of pilot whales (*Globicephala* spp.) caught in the North Atlantic mackerel (*Scomber scombrus*) fishery suggested that mackerel may be a major component of the pilot whales' diet, though feeding on Atlantic mackerel may well be an opportunistic phenomenon related only to the fishery (Waring *et al.*, 1990; Overholtz and Waring, 1991). Analysis of stomach contents of trawl-caught Atlantic white-sided dolphins (*Lagenorhynchus acutus*), bottlenose dolphins and common dolphins (*Delphinus* spp.) southwest of Ireland showed that the dolphins were feeding on the target species of the fishery (Couperus, 1997). Couperus also noted that, based on otoliths retrieved from their stomachs, the white-sided dolphins appeared to have had a completely different diet before they arrived in the area and fed in association with trawling activities. The above observations do not necessarily indicate that the cetaceans are scavenging from trawls, but they do show that they are exploiting the same species targeted by the fisheries. Cetaceans could be feeding on fish that are ancillary to the catch (as is the case for bottlenose dolphins feeding in association with the shrimp fishery) or feeding on

TABLE. 1. Worldwide interactions (feeding or bycatch) of cetaceans with trawl nets. • = reports of bycatch; Δ = reports of feeding association; ∗ possible record; × marked as unidentified pilot whale species during feeding associations, it is most likely this species; + marked as *Delphinus delphis* before Heyning and Perrin (1994) on genus *Delphinus*.

Minke whale (*Balaenoptera acutorostrata*)	•		
Fin whale (*Balaenoptera physalus*)	Δ		
Humpback whale (*Megaptera novaeangliae*)	•	Δ	∗
Finless porpoise (*Neophocaena phocaenoides*)	•		
Dall's porpoise (*Phocoenoides dalli*)	•		
Harbor porpoise (*Phocoena phocoena*)	•	Δ	
Vaquita (*Phocoena sinus*)	•		
Sperm whale (*Physeter macrocephalus*)	•		
Commerson's dolphin (*Cephalorhynchus commersonii*)	•		
Heaviside's dolphin (*Cephalorhynchus heavisidii*)	•		
Hector's dolphin (*Cephalorhynchus hectori*)	•	Δ	
Common dolphin (*Delphinus* spp.)+	•	Δ	
Short-finned pilot whale (*Globicephala macrorhynchus*)	•		
Long-finned pilot whale (*Globicephala melas*)	•	Δ	×
Risso's dolphin (*Grampus griseus*)	•		
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	•	Δ	
White-beaked dolphin (*Lagenorhynchus albirostris*)	•		
Peale's dolphin (*Lagenorhynchus australis*)	•		
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	•		
Dusky dolphin (*Lagenorhynchus obscurus*)	•		
Killer whale (*Orcinus orca*)	•	Δ	
Tucuxi (*Sotalia fluviatilis*)	Δ		
Indo-Pacific hump-backed dolphin (*Sousa chinensis*)	Δ		
Striped dolphin (*Stenella coeruleoalba*)	•	Δ	
Atlantic spotted dolphin (*Stenella frontalis*)	•	Δ	
Spinner dolphin (*Stenella longirostris*)	•	Δ	
Bottlenose dolphin (*Tursiops truncatus*)	•	Δ	
Franciscana (*Pontoporia blainvillei*)	•		
Northern bottlenose whale (*Hyperoodon ampullatus*)	Δ		

the fishery target species (such as the association of pilot whales with the Atlantic mackerel fishery in the northeastern United States) (see Appendix 3 for sources). A cetacean could be attracted to nets because of prey caught in the trawl nets, as well as scavengers feeding on fish caught by the nets. One dramatic example of the latter was reported for the Bering Sea, where killer whales pursued Steller sea lions that were waiting to feed on discarded bycatch from a trawler (Branson, 1971).

The bottlenose dolphin is the cetacean species most often documented to feed in association with trawls. Leatherwood (1975) describes three feeding patterns that bottlenose dolphins use when associating with shrimp boats: (1) foraging behind working boats, (2) feeding on trash fish discarded or fallen from the net, and (3) feeding on fish attracted to non-working shrimpers. The vast majority of episodes of cetaceans feeding around trawls involve feeding behind working trawlers (Appendix 3). In such instances, the animals typically follow a vessel and feed on organisms stirred up by the trawl, pick out fish entangled in the net's mesh, or possibly feed on fish that pass through the mesh. It is reasonable to assume that in all three of these circumstances the prey are dead, injured, or disoriented and therefore easier for the dolphins to catch than individuals of the same species that are healthy and actively avoiding capture. Bottlenose dolphins, pilot whales (*Globicephala* spp.), and Indo-Pacific hump-backed dolphins (*Sousa chinensis*) have been observed feeding around the mouth of nets (bottlenose dolphins: Fertl, MS 1994; Delgado-Estrella, MS 1991; Leatherwood, unpubl. data; pilot whales:

Waring *et al.*, 1990; Indo-Pacific hump-backed dolphins: S. Leatherwood, unpubl. data), presumably on fish escaping the net's pathway. In interviews, many Gulf of Mexico shrimpers told one of us that they had witnessed bottlenose dolphins entering trawl nets to feed. Crespo and Corcuera (1990) provided similiar reports of dolphins (unid. species) in Argentine waters moving into and out of trawl net mouths to feed

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Opportunistic feeding by cetaceans in association with fisheries is perhaps best exemplified by cetaceans feeding on discarded bycatch. This behavior has been described for killer whales in the Bering Sea and off the Shetland Islands (Teshima and Ohsumi, 1983; Couperus, 1994, respectively) and bottlenose dolphins in the Gulf of Mexico (e.g. Caldwell and Caldwell, 1972; Leatherwood, 1975; Gruber, MS 1981), southeastern United States (Davis, 1988), and Moreton Bay, Australia (e.g. Corkeron *et al.*, 1990; Wassenberg and Hill, 1990). Typically, the animals have been seen to wait alongside the vessel for bycatch to be discarded. Wassenberg and Hill (1990) calculated that dolphins scavenging behind a trawler can eat about 86% of fish discarded from a single trawl. In observations of bottlenose dolphins feeding on trash fish, the dolphins were found to show preferences for some prey species over others (Shane, MS 1977; Gruber, MS 1981; Corkeron *et al.*, 1990; Wassenberg and Hill, 1990; Fertl, MS 1994).

Leatherwood (1975) suggested that bottlenose dolphins have learned the advantages of following and feeding in conjunction with shrimp boats. Females with calves, in particular, have been observed following shrimp boats, and it has been speculated that the calves learn this foraging behavior by observation and participation (Shane *et al.*, 1986). Studies of other marine mammals, such as sea otters (*Enhydra lutris*) and killer whales, have suggested that youngsters develop feeding skills through imitation of the mother's feeding behaviors (Riedman *et al.*, 1989; Guinet, 1991 and Guinet and Bouvier, 1995). It has been speculated that females with calves may be taking advantage of the concentrated food resource provided by shrimp boats to meet increased energetic needs due to lactation (Fertl, MS 1994; P. Corkeron, Univ. of Sydney, Sydney, Australia, pers. comm., 1993). Lactating mammals have greater energetic needs, and may need to eat greater quantities of food or change to a diet richer in nutrients (Bernard and Hohn, 1989). Caloric consumption by captive, lactating bottlenose dolphins in the six months following parturition increases from 129% to 204% of that of resting dolphins (Ridgway *et al.*, 1992). The association of cetaceans with trawls may well be a strategy to increase the rate of feeding, while decreasing the energy expenditure associated with foraging.

The association of cetaceans with trawls indicates the behavioral flexibility of these animals to capitalize on human activities. This feeding pattern may be beneficial in that it reduces time required to forage, and provides the animals with an easier way to obtain food that is outside their usual foraging depths or otherwise too energetically costly for them to exploit. Associations with working trawlers may be harmful in that it may expose dolphins to greater risk of injury or death. Corkeron *et al.* (1990) noted that bottlenose dolphins spent seemingly "unnecessary" time taking preferred items in shrimp boat by-catches, appearing to place themselves at a greater risk of shark attack; at least one dolphin was known to have been bitten by a shark while following a trawler. There also may be cause for concern that generations of dolphins that have fed largely or exclusively in association with such fisheries may be at disadvantage when these fisheries collapse.

Gear damage during feeding

Many trawl fishermen blame dolphins for holes in their nets (Gunter, 1942, 1944, 1951, 1954; Cadenat, 1957; Ravel, 1963; Reynolds, 1985; Northridge, 1984, 1991; dos Santos and Lacerda, 1987; Bearzi and Notarbartolo di Sciara, 1992; Consiglio *et al.*, 1992; Silvani *et al.*, 1992; Fertl, MS 1994), but such damage may likely be as a result of sharks tearing at the nets (as reported in Shane, MS 1977; Gruber, MS 1981; Delgado-Estrella, MS 1991; Fertl, MS 1994) as from dolphins attempting to pull fish out of the nets. The areas with the most frequent complaints appear to be the Mediterranean and the Gulf of Mexico, and the species most fishermen blame is the bottlenose dolphin (when species was designated). Gulf of Mexico shrimpers insisted that dolphins were "attacking" the nets in response to low fish productivity in the area (Fertl, MS 1994).

Attempts to reduce damage to trawl nets on the Gulf Coast of the United States and the Mediterranean have included the use of firecrackers detonated near the animals and bullets fired into

the water nearby (Gunter, 1944; Cadenat, 1957; Reynolds, 1985; Bearzi and Notarbartolo di Sciara, 1992; Consiglio *et al.*, 1992; Silvani *et al.*, 1992; Fertl, MS 1994). Acoustical deterrents appear to be successful only for a very short time period, if at all (Caldwell and Caldwell, 1972; Consiglio *et al.*, 1992). Non-acoustical methods used by shrimp fishermen include tying ribbons to nets and installing an extra skirt on the net to frighten dolphins away; these methods have met with mixed results. On the coast of the Adriatic and Tyrrhenian seas, there is a story of fishermen putting a fake dolphin in the net — like a scarecrow — to scare dolphins away. The results were apparently good for a few days, but then the dolphins "saw the cheating" and tore the nets with their teeth (L. Marini, Univ. of Rome, Rome, Italy, pers. comm., 1993).

Holes in nets and incidental captures of dolphins can result in loss of fishing time, while the crew disentangles carcasses or live animals, and loss of money while crews fix or replace damaged gear. Dolphins sometimes blunder into a tow or handling line and do minor damage while struggling to free themselves (Leatherwood and Reeves, 1982; Fertl, MS 1994). Netting and rope may be lost in trying to free live or dead cetaceans. In one instance, a net was cut to release a bottlenose dolphin caught in a groundfish trawl (C. Pharr, NMFS, Pascagoula, Mississippi, USA, pers. comm., 1991). In another, a stranded bottlenose dolphin from Mississippi was found lodged in a complete, small trawl net (stranding record SE3983, Southeast U.S. Stranding Network Region). Northridge (1988) reported an incident of a pilot whale (*Globicephala* spp.) that became lodged in a trawl and drowned; the net was subsequently lost.

Distribution of entanglements

It is not surprising that cetaceans and humans that exploit similar food resources have overlapping ranges. Potential cetacean and trawl fishery interactions are likely to occur when spatial and temporal habitat use coincides, for example, Atlantic white-sided dolphins and trawlers both taking migrating mackerel southwest of Ireland (Couperus, 1997) and white-beaked dolphins (*Lagenorhynchus albirostris*) and midwater trawlers taking spawning herring in the North Sea (Northridge, 1988). The frequency with which individuals of a cetacean species are caught accidentally in trawls is a function of the abundance of that species in a fishing area, as well as operational characteristics of the fishery. For abundant species in heavily fished areas, it would be surprising if some animals were not taken in fishing nets. For example, high catch rates in the Northwest Atlantic may be related to the distribution of fishing effort in particular areas of high pilot whale density (Northridge, 1991). Harbor porpoises (*Phocoena phocoena*), generally found near-shore, may be particularly susceptible to incidental captures because inshore areas are often heavily fished (Nelson, 1990). Movements and seasonal changes in distribution of a species will be reflected in seasonal and geographic differences in net catches (it should be noted that in some fisheries, the fishing effort in certain areas may be very different interannually, depending on the market situation, quota regulations, and behavior of fish schools, particularly if they are a pelagic species). Some species' abundance, however, may have little connection to catch rates. For example, the size and behavior of the animal, and net size could determine the possibility of the animal's being caught.

Gear characteristics

Individuals of more cetacean species are caught in mid-water trawls than in bottom trawls. Northridge (1988) discussed several reasons why mid-water gear is more likely to catch cetaceans. First, mid-water nets generally target small pelagic fish species, which are often the same species preyed upon by marine mammals. Second, mid-water gear is generally towed at relatively high speeds. Finally mid-water trawls are generally much larger than most demersal trawls. Niazi (1990) speculated that the smaller size and openings of bottom trawls in Pakistan make them harmless to finless porpoises (*Neophocaena phocaenoides*). Whether he felt the trawl openings were small enough to deter animals from entering the nets is not clear. Pair trawlers tow nets with higher headlines and greater overall dimensions and they tow them faster than single trawlers (Anonymous, 1981; Kuiken *et al.*, 1994); pair trawlers account for about 50% of all cetacean catches in waters off New Zealand, with gillnets and single trawlers making up the remainder (Anonymous, 1981).

Northridge (1988) and Waring *et al.* (1990) speculated that the mouth in many trawl nets permits dolphins to enter and get caught. It is generally thought that some individuals enter the trawl and become trapped when the boat stops hauling and the trawl entrance collapses

("haulback") (Clausen and Andersen, 1988; Northridge, 1988; Waring *et al*., 1990) or when the net is being put out into the water ("shot") (Moreno, 1993), and then the net is relatively shapeless and slow-moving. This is the time when many pinnipeds appear to become caught (e.g. MAF Fisheries, 1991). It is highly probable that many cetaceans trapped during shooting or haulback are alive when caught, but die because the nets are kept in the water for long periods of time before being checked. Bottlenose dolphins in the Gulf of Mexico have been reported with their rostrums caught in the net mesh, perhaps when pulling fish scraps from the nets (Leatherwood and Reeves, 1982; R. Ford, NMFS, Pascagoula, Mississippi, USA, pers. comm., 1991); one bottlenose dolphin in the Gulf of Mexico was caught by its teeth in the net, but was released alive (Fertl, MS 1994). Ironically, there are two separate reports of bottlenose dolphins that were found caught in turtle excluder devices (installed on trawls to allow turtles caught as by-catch to escape from shrimp trawls) (Burn and Scott, 1988; Fertl, MS 1994).

Behavior and social structure

Cetacean social structure may play a significant role in incidental capture potential. Incidental catches of pilot whales (*Globicephala* spp.), very social cetaceans, often involve multiple animals (G. Waring, NMFS, Woods Hole, Massachusetts, USA, pers. comm. 1991). Cetaceans that forage in dense groups, such as common dolphins (*Delphinus* spp.) and pilot whales (*Globicephala* spp.), often become victims of trawls (Waring *et al* ., 1990). Where cetaceans feed in the water column also affects how frequently they are caught. For example, the frequent feeding at mid-water depths may account for the large number of cetaceans (e.g. pilot whales, *Globicephala* spp., common dolphins, *Delphinus* spp., and harbor porpoise) trapped in mid-water trawls.

It appears that of all cetaceans captured, a disproportionate number are young animals (Teshima and Ohsumi, 1983; Corkeron *et al*., 1990; Niazi, 1990; Vidal, MS 1990; V. Cockcroft, Port Elizabeth Museum, Humewood, South Africa, pers. comm., 1992). Most of the common dolphins (*Delphinus* spp.) killed in squid (*Loligo*) and Atlantic mackerel fisheries are likely sexually immature (Waring *et al*., MS 1990). Vidal (MS 1990) suggested that because vaquita (*Phocoena sinus*) calves move too slowly they become trapped in trawls. It is also probable that young cetaceans are caught because of their inexperience with fishing gear (Nelson, 1990). Young animals may learn safe movements around nets by watching conspecifics. Phocoenids have a shorter dependency period and shorter lifespan than delphinids (Gaskin, 1984; Perrin and Reilly, 1984), and thus, have less opportunity to learn from their mothers or conspecifics. Tyack (1986) reviewed the importance of a long period of parental care as it relates to the importance of social learning in odontocetes. It is also probable that younger animals are not as attentive as adults to the dangers that nets pose, and become caught accidentally, panic, and are unable to free themselves. Young cetaceans may also be greater "risk takers" than adults (Nelson, 1990), as is true in most animal species (Fagen, 1981).

Lack of attention (also discussed in IWC, 1994, for gillnet captures) may be another reason for incidental takes. Mature cetaceans, as well as young and inexperienced individuals, may become "careless" around nets. Attention to social activity, such as play, may distract individuals. Trawl fishermen insist that dolphins do not get caught in their nets because they are too fast and too smart (Davis, 1988; Moreno, 1993; Fertl, MS 1994). Bottlenose dolphins sometimes drown when they are caught around the tail stock in the hanging line of the trawl (Fertl, MS 1994). We have witnessed several episodes of bottlenose dolphins playing with lines while nets were being pulled.

Additional considerations

Discarded or lost gear. Entanglement in discarded gear is an often over-looked, but important, problem. Trawl fisheries are major activities in the North Pacific Ocean, with 5 500 km of nets in use (Uchida, 1985). When proportions of litter were studied on southeastern Alaska beaches, 76–85% by weight consisted of trawl-web fragments (Low *et al*., 1985). There are many reports of marine mammals becoming entangled in trawl webbing (O'Hara *et al*., 1986), but few data on the numbers of entangled animals that die. Fowler (1982) has shown that entanglement in trawl net fragments could account for about a 5% mortality rate of northern fur seals a year. These fragments may act as ghost nets, not unlike fragments of monofilament gillnet. It is probable that some of these fragments may have food organisms in them. One sperm whale (*Physeter macrocephalus*) stranded in Oregon was reported to have had approximately one liter of tightly packed trawl nets in its stomach (Mate, 1985). De-

spite the link between frequency of entanglement and resultant death, there seems little doubt that this, and perhaps other kinds of operational interaction arising from the increased trawling in the Bering Sea, is a major factor in determining the otherwise inexplicable decline of the northern fur seal (Beverton, 1985) and Steller sea lion (Alverson, 1992).

Ecological/Resource Depletion. There has been some concern that trawling may disperse and alter distributional features of prey species for some cetaceans and other marine mammals. Biomass of epifaunal organisms has dropped dramatically in some areas due to trawling, and changed the dominant species of fish caught (Sainsbury, 1988 in Hutchings, 1990). The Steller sea lion has already experienced a population collapse, reputedly from the vast overfishing in its habitat (Alverson, 1992). Populations of these sea lions are suggested to be in danger because of a nutritional deficiency resulting from the absence of fatty fishes in their diet (Alverson, 1992). Similar impacts may gravely endanger cetaceans in areas of heavy trawl-fishing, such as the Bering Sea, Mediterranean Sea, and Gulf of Mexico. It has been thought that shrimp trawling operations have a net beneficial effect for bottlenose dolphins, providing more easily captured food (Wang *et al.*, 1994); however, while trawling (of any type) may open up new feeding niches, it probably destroys others. As noted earlier in this paper, bottlenose dolphins may currently be taking advantage of the easily concentrated food resource that shrimp boats provide, but future generations may be disadvantaged by shifts, or even severe declines, in prey species. Trawl fisheries not only affect takes of target species, but also the food web. For example, high-seas trawl fisheries off Patagonia take hake (*Merluccius hubbsi*) as one of their targets. Hake is a predator of anchovy, the main prey item of dusky dolphins *(Lagenorhynchus obscurus*) (Crespo *et al.*, 1997). Unbalancing of the marine ecosystem may cause shifts that initially seem beneficial to the dolphins, but may soon or ultimately prove detrimental to all participants in the system.

Concluding Remarks

Intensive trawling occurs in many areas of the world, with resulting incidental catches of cetaceans. However, considering the intensive trawl fisheries that exist in some areas, it appears that comparatively smaller numbers of cetaceans are caught by trawls in contrast to other fishing gear such as purse seines (Coe *et al.*, 1985; Bjørge *et al.*, 1991) and gillnets (Leatherwood, 1994; Perrin *et al.*, 1994).

Cetacean distribution, social structure, and behavior are important biological factors that interact with characteristics of trawl nets to cause entanglements. Cetacean feeding habits may be important in many of the incidental captures. In fact, common dolphins (*Delphinus* spp.) in New Zealand (Anonymous, 1982) and bottlenose dolphins in the Gulf of Mexico (Leatherwood, 1975) feed on fish attracted to non-working trawlers; when boats are anchored at night, their lights often attract fish and other animals to feed. Trawlers may make it easier for individuals, especially juveniles, old individuals, or mothers with calves, to capture food that is otherwise difficult (in volume) for them to catch.

As also reported by the IWC (1994): entanglements may occur where the target species are prey or potential prey for cetaceans; the fish caught are not prey species but cetaceans are attracted to the nets because other potential prey are associated with the net; the target and incidental species are seeking similar prey; or the cetaceans and fisheries occur in the same vicinity for reasons related to physiography and biological productivity. In general, the behavior of cetaceans near nets is poorly understood. Several additional causes for these bycatches may be an individual's inattention or inexperience, and patterns of social interactions.

In summary, the evidence summarized in this report, while preliminary, suggests that fishing trawls can represent a significant source of cetacean mortality and that inadequate attention has been paid to this problem to date. Existing data do not permit us to determine the relative incidence of such mortalities among the different trawl types: sample sizes are too small, and many areas have no observer coverage. However, it seems likely that the greatest potential for conflict exists with mid-water and surface trawls operating in areas of high cetacean density, notably where both fishermen and cetaceans target the same prey.

It can probably be taken for granted that, as with gillnet fisheries, the number of cetacean mortalities reported by trawl fishermen underrepresents the

true situation. Fear of prosecution or other legal sanctions (and absence of observers) probably results in many or most incidentally killed animals being discarded. Because an assessment of this problem is not possible without directed research, we recommend that an observer program be established to collect information on the frequency of cetacean mortality among the various types of trawling operations. Observer data would also permit an assessment of the extent to which mortality rates differ by area and by target fish species. Inevitably, this research must be conducted in concert with studies to address broader biological and management questions relating to abundance, population structure, and seasonal movements of the cetacean species concerned.

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APPENDIX 1. Individual cetaceans documented to have been incidentally caught in trawl nets in various areas of the world.

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
			Bering Sea and Aleutian Islands		
1	Minke whale	1973–88	2 (decomp.)	0	Perez and Loughlin (1991)
2	Minke whale	1989	1	N/A	NMFS (1995)
3	Harbor porpoise	1973–88	4 (3 dead, 1 decomp.)	0	Perez & Loughlin (1991)
4	Dall's porpoise	1973–88	13 (11 dead, 2 decomp.)	0	Perez & Loughlin (1991)
5	Dall's porpoise	1989	1	N/A	NMFS (1995)
6	Dall's porpoise	1990	6	N/A	NMFS (1995)
7	Dall's porpoise	1991	1	N/A	NMFS (1995)
8	Dall's porpoise	1992	5	N/A	NMFS (1995)
9	Dall's porpoise	1993	4	N/A	NMFS (1995)
10	Risso's dolphin	1973–88	1 (decomp.)	0	Perez and Loughlin (1991)
11	Killer whale	1982	1 calf	1 calf	Teshima and Ohsumi (1983)
12	Killer whale	1973–88	4 (1 dead, 1 alive, 2 decomp.)	N/A	Perez and Loughlin (1991)
13	Killer whale	1991	1	0	NMFS (1995); Matkin and Saulitis (1994)
14	Killer whale	1992	1	N/A	NMFS (1995)
15	Killer whale	1993	1	N/A	NMFS (1995)
16	Unid. cetacean	1973–88	25 (7 dead, 18 decomp.)	0	Perez and Loughlin (1991)
17	Unid. cetacean	1990	1	N/A	NMFS (1995)
18	Unid. cetacean	1991	1	N/A	NMFS (1995)
19	Unid. cetacean	1992	1	N/A	NMFS (1995)
20	Unid. cetacean	1993	1	N/A	NMFS (1995)
			British Columbia		
21	Dall's porpoise	1990	1	0	Baird *et al*. (MS 1991)
			Gulf of Alaska		
22	Dall's porpoise	1973–88	2 (1 dead, 1 alive)	N/A	Perez and Loughlin (1991)
23	Dall's porpoise	1993	1	N/A	NMFS (1995)
24	Killer whale	1973–88	1 dead	0	Perez and Loughlin (1991)
25	Unid. cetacean	1973–88	2 dead	0	Perez and Loughlin (1991)
			Alaska		
26	Harbor porpoise	1941	1 (dredged by trawler)	0	Scheffer and Slipp (1948)
27	Harbor porpoise	1986–88	3	N/A	Barlow *et al*. (1994)
28	Dall's porpoise	1986–88	20	N/A	Barlow *et al*. (1994)
29	Dall's porpoise	1989	1	N/A	Barlow *et al*. (1994)
30	Pacific white-sided dolphin	N/A	3	N/A	Barlow *et al*. (1994)
31	Killer whale	1986–88	2	N/A	Barlow *et al*. (1994)
32	Unid. cetacean	N/A	18	N/A	Barlow *et al*. (1994)
			West Coast of United States		
33	Dall's porpoise	1973–88	9 (8 dead, 1 alive)	N/A	Perez and Loughlin (1991)
34	Dall's porpoise	1989	1	N/A	NMFS (1995)
35	Dall's porpoise	1990	3	N/A	NMFS (1995)
36	Dall's porpoise	1992	1	N/A	NMFS (1995)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
37	Harbor porpoise	N/A	# not given	N/A	Leatherwood and Reeves (1986)
38	Pacific white-sided dolphin	1973–88	3 (dead)	0	Perez and Loughlin (1991)
39	Pacific white-sided dolphin	1990	8	N/A	NMFS (1995)
40	Unid. cetacean	1973–88	10 (9 dead, 1 alive)	N/A	Perez and Loughlin (1991)
41	Unid. cetacean	1990	2	N/A	NMFS (1995)
			Gulf of California		
42	Vaquita	1961	1	N/A	Norris & Prescott (1961)
43	Vaquita	1984	# not given	N/A	Vidal (MS 1990)
44	Vaquita	1985	2	N/A	Vidal (MS 1990)
45	Vaquita	1990	2	N/A	Vidal (MS 1990)
46	Vaquita	N/A	1	1	G. Silber, pers. comm. (1993)
			Gulf of Mexico		
47	Short-finned pilot whale	N/A	# not given	N/A	NMFS (1995)
48	Risso's dolphin	N/A	# not given	N/A	NMFS (1995)
49	Atlantic spotted dolphin	1985	2	N/A	R. Ford, pers. comm. (1991)
50	Atlantic spotted dolphin	1988	2	N/A	R. Ford, pers. comm. (1991)
51	Bottlenose dolphin	N/A	small numbers	N/A	Gunter (1942)
52	Bottlenose dolphin	1976	1	N/A	Prescott *et al*. (1980)
53	Bottlenose dolphin	1988	2	N/A	Burn & Scott (1988)
54	Bottlenose dolphin	N/A	# not given	N/A	Reynolds (1985)
55	Bottlenose dolphin	1978–79	1	1	Gruber (MS 1981)
56	Bottlenose dolphin	N/A	small numbers	N/A	Leatherwood and Reeves (1982)
57	Bottlenose dolphin	1987	1	1	C. Pharr, pers. comm. (1991)
58	Bottlenose dolphin	N/A	small numbers	3	Fertl (MS 1994)
			Southeastern United States		
59	Bottlenose dolphin	N/A	1	N/A	Wang *et al*. (1994)
60	Bottlenose dolphin	N/A	small numbers	N/A	Reynolds (1985)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
			Northeastern United Atates/Atlantic Ocean		
61	Humpback whale	1986	2 (1 alive, 1 dead)	N/A	O'Hara *et al.* (1986)
62	Harbor porpoise	1977	1 (decomp.)	0	Testaverde (1978)
63	Harbor porpoise	1982	1	N/A	O'Hara *et al.* (1986)
64	Common dolphin	1977–83	8	N/A	Waring *et al.* (1990)
65	Common dolphin	1983	1 (alive)	N/A	O'Hara *et al.* (1986)
66	Common dolphin	1984	3	N/A	Waring *et al.* (1990)
67	Common dolphin	1985	66	N/A	Waring *et al.* (1990)
68	Common dolphin	1986	76	N/A	Waring *et al.* (1990)
69	Common dolphin	1987	19	N/A	Waring *et al.* (1990)
70	Common dolphin	1988	31	N/A	Waring *et al.* (1990)
71	Common dolphin	1989	4	0	Overholtz and Waring (1991)
72	Common dolphin	1990	11	N/A	NMFS (1995)
73	Common dolphin	1991	2	N/A	NMFS (1995)
74	Common dolphin	1992	3	0	Gerrior *et al.* (1994)
75	Common dolphin	1993	6	N/A	NMFS (1995)
76	Pilot whale	1977–83	35	N/A	Waring *et al.* (1990)
77	Pilot whale	1984	2	N/A	Waring *et al.* (1990)
78	Pilot whale	1985	47	N/A	Waring *et al.* (1990)
79	Pilot whale	1986	20	2	Waring *et al.* (1990)
80	Pilot whale	1987	26	1	Waring *et al.* (1990)
81	Pilot whale	1988	142	3	Waring *et al.* (1990)
82	Pilot whale	1989	5	0	Overholtz and Waring (1991)
83	Pilot whale	1990	1	N/A	NMFS (1995)
84	Pilot whale	1990	107	N/A	Young *et al.* (1993)
85	Pilot whale	1991	13	N/A	Young *et al.* (1993)
86	Pilot whale	1992	12	N/A	NMFS (1995)
87	Risso's dolphin	1985	1	N/A	Waring *et al.* (1990)
88	Risso's dolphin	1986	1	N/A	Waring *et al.* (1990)
89	Risso's dolphin	1987	1	N/A	Waring *et al.* (1990)
90	Risso's dolphin	1992	1	0	Gerrior *et al.* (1994)
91	Atlantic white-sided dolphin	1990	4	N/A	Young *et al.* (1993)
92	Atlantic white-sided dolphin	1990	10	N/A	NMFS (1995)
93	Atlantic white-sided dolphin	1991	1	N/A	Young *et al.* (1993)
94	Atlantic white-sided dolphin	1991	7	N/A	NMFS (1995)
95	Striped dolphin	1991	2	N/A	NMFS (1995)
96	Bottlenose dolphin	1977–83	2	N/A	Waring *et al.* (1990)
97	Bottlenose dolphin	1984	1	N/A	Waring *et al.* (1990)
98	Bottlenose dolphin	1985	3	N/A	Waring *et al.* (1990)
99	Bottlenose dolphin	1988	2	N/A	Waring *et al.* (1990)
100	Bottlenose dolphin	1991	1	N/A	NMFS (1995)
101	Bottlenose dolphin	1992	4	N/A	Gerrior *et al.* (1994)
102	Bottlenose dolphin	1993	17	N/A	NMFS (1995)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
103	Unid. dolphin	1977–83	3	N/A	Waring *et al*. (1990)
104	Unid. dolphin	1985	1	N/A	Waring *et al*. (1990)
105	Unid. dolphin	1988	1	N/A	Waring *et al*. (1990)
106	Unid. dolphin	1992	4 (1 alive,1 dead)	N/A	Gerrior *et al*. (1994)
107	Unid. baleen whale	1977–83	1	1	Waring *et al*. (1990)
108	Unid. cetacean	1992	3 (1 alive?)	N/A (1 alive?)	Gerrior *et al*. (1994)
			Northwest Atlantic		
109	Risso's dolphin	N/A	a few captures	N/A	O'Hara *et al*. (1986)
110	Atlantic white-sided dolphin	1978–85	3	N/A	O'Hara *et al*. (1986)
			Argentine Waters		
111	Commerson's dolphin	N/A	tens of individ/yr	N/A	Scialabba (MS 1989)
112	Commerson's dolphin	N/A	# not given	N/A	Crespo and Corcuera (1990)
113	Commerson's dolphin	N/A	2	N/A	Goodall *et al*. (1988)
114	Commerson's dolphin	N/A	# not given	N/A	Goodall *et al*. (1990)
115	Common dolphin	N/A	# not given	N/A	Crespo and Corcuera (1990)
116	Long-finned pilot whale	N/A	1	N/A	Goodall *et al*. (1988)
117	Peale's dolphin	N/A	# not given	N/A	Crespo and Corcuera (1990); Goodall *et al*. (1990)
118	Dusky dolphin	N/A	3	N/A	Scialabba (MS 1989)
119	Dusky dolphin	N/A	# not given	N/A	Crespo and Corcuera (1990)
120	Dusky dolphin	1989	1	N/A	Crespo *et al*. (1994)
121	Franciscana	N/A	2	N/A	Goodall *et al*. (1988)
122	Franciscana	N/A	rare event	N/A	Crespo and Corcuera (1990)
123	Franciscana	N/A	# not given	N/A	Perez Macri and Crespo (1989)
124	Bottlenose dolphin	N/A	1	N/A	Goodall *et al*. (1988)
125	Unid. dolphin	N/A	5 in one trawl	N/A	Crespo and Corcuera (1990); Crespo *et al*. (1994)
			Northeast Atlantic		
126	Harbor porpoise	1980–81	28	N/A	Andersen and Clausen (MS 1983)
127	Harbor porpoise	–	3	N/A	Anonymous (1988b)
128	Harbor porpoise	1973–87	21	N/A	Lindstedt and Lindstedt (1989)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
129	Harbor porpoise	1986–89	4	N/A	Kinze (1994)
130	Common dolphin	1971–81	15	N/A	Duguy and Hussenot (1982)
131	Common dolphin	1971–76	1	N/A	Duguy (1977)
132	Long-finned pilot whale	1971–76	1	N/A	Duguy (1977)
133	Long-finned pilot whale	1971–81	3	N/A	Duguy and Hussenot (1982)
134	Long-finned pilot whale	–	possible 1 record	N/A	Northridge (1988)
135	Risso's dolphin	–	occasionally caught	N/A	Northridge (1984)
136	Striped dolphin	–	occasionally caught	N/A	Northridge (1984)
137	Striped dolphin	1971–76	1	N/A	Duguy (1977)
138	Bottlenose dolphin	1971–76	2	N/A	Duguy (1977)
139	Bottlenose dolphin	1977–81	3	N/A	Duguy and Hussenot (1982)
140	Bottlenose dolphin	–	1	N/A	Anonymous (1988b)
			Baltic Sea		
141	Harbor porpoise	1952	1	N/A	Ropelewski (1957)
142	Harbor porpoise	N/A	2	N/A	Skora *et al.* (1988)
143	Harbor porpoise	1987/90	1	N/A	Benke *et al.* (1991)
			North Sea		
144	Harbor porpoise	–	several tens/yr	N/A	Currey *et al.* (1990)
145	Harbor porpoise	1963–82	18	N/A	Gaskin (1984)
146	Harbor porpoise	1987–88	7	N/A	Anonymous (1989a)
147	Harbor porpoise	–	few	N/A	Mitchell (1975)
148	Harbor porpoise	1992	137	N/A	Moreno (1993)
149	Harbor porpoise	–	regularly caught	N/A	Reijnders and Lankester (1990)
150	Common dolphin	–	regularly caught	N/A	Reijnders and Lankester (1990)
151	Pilot whale	–	regularly caught	N/A	Reijnders and Lankester (1990)
152	Pilot whale	1994	3(dead) in 1 haul	0	N. Lowry, pers. comm. (1994)
153	Risso's dolphin	–	not given	N/A	Reijnders and Lankester (1990)
154	White-beaked dolphin	–	few	N/A	Leatherwood and Reeves (1983)
155	White-beaked dolphin	1958	1	N/A	van Bree and Nijssen (1964)
156	Bottlenose dolphin	–	# not given	N/A	Currey *et al.* (1990)
157	Bottlenose dolphin	–	few	N/A	Mitchell (1975)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
			Mid-Atlantic Bight		
158	Bottlenose dolphin	N/A	3 in 8 years	N/A	Northridge (1991)
			Scotland		
159	Harbor porpoise	1988–89	20+	N/A	Northridge (1991)
			Britain		
160	Harbor porpoise	N/A	# not given	N/A	Northridge (1991)
161	Harbor porpoise	N/A	1	N/A	Northridge (1988)
162	Harbor porpoise	1989	2	N/A	Anonymous (1990c)
163	Common dolphin	1982	5 (3 alive, 2 dead)	3	Pascoe (1986)
164	Common dolphin	N/A	# not given	N/A	Couperus (1994)
165	Pilot whale	1986	towed in trawl	N/A	Northridge (1988)
166	Long-finned pilot whale	N/A	# not given	N/A	Couperus (1994)
167	Atlantic white-sided dolphin	N/A	# not given	N/A	Couperus (1994)
168	White-beaked dolphin	1986, 1987	# not given	N/A	Northridge (1988)
169	White-beaked dolphin	N/A	# not given	N/A	Couperus (1994)
170	Unid. porpoise	N/A	entangled at least 6, one drowned in net	N/A	Northridge (1988)
171	Unid. porpoise	N/A	3	N/A	Northridge (1988)
172	Unid. whale	1986	1	N/A	Northridge (1988)
			Eastern Central Atlantic		
173	Common dolphin	N/A	# not given	N/A	Scialabba (MS 1989)
174	Bottlenose dolphin	N/A	# not given	N/A	Scialabba (MS 1989)
			Bay of Biscay		
175	Long-finned pilot whale	N/A	# not given	N/A	Gerrior *et al*. (1994)
			Mediterranean		
176	Common dolphin	N/A	1	N/A	Di Natale (1983)
177	Common dolphin	N/A	not given	N/A	Di Natale (1989)
178	Striped dolphin	N/A	not given	N/A	Di Natale (1989)
179	Bottlenose dolphin	N/A	3	N/A	Duguy and Hussenot (1982)
180	Bottlenose dolphin	N/A	incidental catches said to be high, although some dolphins reported to be freed	N/A	Currey *et al*. (1990)
181	Bottlenose dolphin	N/A	not given	N/A	Di Natale (1989)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
182	Bottlenose dolphin	N/A	1	N/A	Silvani *et al*. (1992)
183	Sperm whale	N/A	3	N/A	Di Natale and Mangano (1983)
184	Sperm whale	N/A	1	N/A	Di Natale (1989)
			Portugal		
185	Harbor porpoise	1977–91	1	N/A	Sequeira and Ferreira (1994)
186	Common dolphin	1977–91	18	N/A	Sequeira and Ferreira (1994)
			Central Cantabrian Sea		
187	Harbor porpoise	1977–91	1	N/A	Nores *et al*. (1992)
188	Common dolphin	1977–91	1	N/A	Nores *et al*. (1992)
189	Long-finned pilot whale	1977–91	1	N/A	Nores *et al*. (1992)
			Northwest Africa		
190	Common dolphin	N/A	# not given	N/A	Northridge (1984)
191	Common dolphin	N/A	large numbers	N/A	Currey *et al*. (1990)
192	Common dolphin	1980	'6-22' dolphins per haul' at night for one trawler. 12 trawlers in area also caught dolphins, exact number unknown. An estimated minimum of 500–1 000 common dolphins and *Stenella* spp. are caught per year.	N/A	Maigret (1994)
			South and Southwest Africa		
193	Heaviside's dolphin	1978–79	2	N/A	Anonymous (1979)
194	Heaviside's dolphin	1978–79	small numbers	N/A	Northridge (1984)
195	Heaviside's dolphin	1977	1	N/A	P. Best, pers. comm. (1992)
196	Heaviside's dolphin	1990	1	N/A	P. Best, pers. comm. (1992)
197	Common dolphin	N/A	small numbers	N/A	Northridge (1984)
198	Common dolphin	1983	5	N/A	P. Best, pers. comm. (1992)
199	Common dolphin	N/A	2 young	N/A	V. Cockcroft, pers. comm. (1992)
200	Risso's dolphin	1986	1	N/A	P. Best, pers. comm. (1992)
201	Dusky dolphin	N/A	small numbers	N/A	Northridge (1984)
202	Dusky dolphin	1988	4	N/A	P. Best, pers. comm. (1992)
203	Dusky dolphin	1989	6	N/A	P. Best, pers. comm. (1992)
204	Dusky dolphin	1990	1	N/A	P. Best, pers. comm. (1992)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
			East Africa		
205	Unid. dolphin	N/A	large number	N/A	Currey *et al*. (1991)
			Pakisan		
206	Finless porpoise	1989	2 young	N/A	Niazi (1990)
			India (Gulf of Mannar)		
207	Bottlenose dolphin	1980–82	3	0	Pillai & Kasinathan (1987)
			Thailand		
208	Spinner dolphin	1970–71	10	N/A	Perrin *et al*. (1989)
			China (Hong Kong)		
209	Finless porpoise	1987	1	0	T. Jefferson, pers. comm (1995)
			New Zealand		
210	Hector's dolphin	1970's	7	N/A	Baker (1978)
211	Hector's dolphin	N/A	occasionally	N/A	Anonymous (1981); Scialabba (MS 1989); Slooten and Dawson (1988)
212	Hector's dolphin	1988	5	N/A	Anonymous (1990b)
213	Common dolphin	N/A	a few	N/A	Mitchell (1975)
214	Common dolphin	1978	10	4	Anonymous (1981)
215	Common dolphin	1979	23	2	Anonymous (1981)
216	Common dolphin	N/A	occasionally	N/A	Slooten and Dawson (1988)
217	Common dolphin	1980	1	N/A	Anonymous (1982)
218	Common dolphin	since April 1986	2	N/A	Anonymous (1988a)
219	Common dolphin	1987	1	N/A	Anonymous (1989b)
220	Common dolphin	1988	1	N/A	Anonymous (1990b)
221	Common dolphin	1989	2 (adult+calf)	N/A	Anonymous (1990b)
222	Common dolphin	1989–90, 1993–94	69	N/A	Baird (1995)
223	Common dolphin	1990	34–35	N/A	Anonymous (1991b)
224	Common dolphin	1995	21	N/A	R. Mattlin, pers. comm. (1995)
225	Pilot whale	N/A	1	N/A	R. Mattlin, pers. comm. (1995)
226	Dusky dolphin	1986–88	2	N/A	Anonymous (1988a)
227	Dusky dolphin	1988	1	N/A	Anonymous (1988a)

No.	Species	Time Period	No. Entangled	No. Released Alive	Source(s)
228	Dusky dolphin	N/A	occasionally	N/A	Slooten and Dawson (1988)
229	Killer whale	1979	1	N/A	Anonymous (1981)
230	Bottlenose dolphin	N/A	100's	N/A	Mitchell (1975)
231	Bottlenose dolphin	N/A	1	N/A	R. Mattlin, pers. comm. (1995)
232	Unid. dolphin	N/A	low numbers	N/A	R. Mattlin, pers. comm. (1995)
233	Unid. beaked whale	1979	1	N/A	Anonymous (1981)
			Australia		
234	Bottlenose dolphin	N/A	2 juveniles	N/A	Corkeron *et al*. (1990)
235	Bottlenose dolphin	1989	1	N/A	Anonymous (1991a)
236	Unid. dolphin	1988	3	N/A	Anonymous (1990a)
237	Unid. dolphin	1990	1	N/A	Anonymous (1991a)

Sources for personal communications

P. Best, Whale Unit c/o South African Museum, P. O. Box 61, Cape Town 8000, South Africa
V. Cockcroft, Port Elizabeth Museum, P. O. Box 13147, Humewood 6013 South Africa
R. Ford, National Marine Fisheries Service, P. O. Drawer 1207, Pascagoula, MS 39568, USA
T. Jefferson, Ocean Park Conservation Foundation, Ocean Park Aquarium, Aberdeen, Hong Kong
N. Lowry, Danish Institute for Fisheries Technology and Aquaculture, The North Sea Centre, P. O. Box 59, DK-9850 Hirtshals, Denmark
R. Mattlin, MAF Fisheries, Greta Point, P. O. Box 297, Wellington, New Zealand
C. Pharr, National Marine Fisheries Service, P. O. Drawer 1207, Pascagoula, MS 39568, USA
G. Silber, Marine Mammal Commission, 1825 Connecticut Avenue, NW, Washington, DC 20009, USA

APPENDIX 2. Cetacean species for which there are reports of incidental catches in trawl nets (Record numbers correspond to entries in Appendix 1.)

Species	Record Number(s)
Minke whale (*Balaenoptera acutorostrata*)	1, 2
Humpback whale (*Megaptera novaeangliae*)	61
Finless porpoise (*Neophocaena phocaenoides*)	206, 209
Dall's porpoise (*Phocoenoides dalli*)	4–9, 21–23, 28–29, 33–36
Harbor porpoise (*Phocoena phocoena*)	3, 26–27, 37, 62–63, 126–129, 141–149, 159–162, 185, 187
Vaquita (*Phocoena sinus*)	42–46
Sperm whale (*Physeter macrocephalus*)	183–184
Commerson's dolphin (*Cephalorhynchus commersonii*)	111–114
Heaviside's dolphin (*Cephalorhynchus heavisidii*)	193–196
Hector's dolphin (*Cephalorhynchus hectori*)	210–212
Common dolphin (*Delphinus* spp.)	64–75, 115, 130–131, 150, 163–164, 173, 176–177, 186, 188, 190–192,197–199, 213–224
Short-finned pilot whale (*Globicephala macrorhynchus*)	47
Long-finned pilot whale (*Globicephala melas*)	116, 132–134, 166, 175, 189
Unidentified pilot whale species (*Globicephala* spp.)	76–86, 151–152, 165, 225
Risso's dolphin (*Grampus griseus*)	10, 48, 87–90, 109, 135, 153, 200
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	91–94, 110, 167
White-beaked dolphin (*Lagenorhynchus albirostris*)	154–155, 168–169
Peale's dolphin (*Lagenorhynchus australis*)	117
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	30, 38–39
Dusky dolphin (*Lagenorhynchus obscurus*)	118–120, 201–204, 226–228
Killer whale (*Orcinus orca*)	11-15, 24, 31, 229
Striped dolphin (*Stenella coeruleoalba*)	95, 136–137, 178
Atlantic spotted dolphin (*Stenella frontalis*)	49–50
Spinner dolphin (*Stenella longirostris*)	208
Bottlenose dolphin (*Tursiops truncatus*)	51–60, 96–102, 124, 138–140, 156–158, 174, 179–182, 207, 230–231, 234–235
Franciscana (*Pontoporia blainvillei*)	121–123
Unid. cetacean species	16–20, 25, 32, 40–41, 108
Unidentified baleen whale	107
Unididentified dolphin species	103-106, 125, 205, 232, 236–237
Unidentified beaked whale	233
Unidentified porpoise	170–171
Unidentified whale	172

APPENDIX 3. Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Bering Sea	
Killer whale	Seen following nets when trawling began.	Teshima and Ohsumi (1983)
Killer whale	Seemed attracted to winching sounds. Positioned themselves along the sides of trawlers to feed on trash fish, and offal. Jostled for positions while feeding was also noted.	J. Heimlich-Boran, pers. comm. (1991)
	West Coast of United States	
Common dolphin	Feed on specimens that had escaped from the net. The fish were disabled and floating belly up.	Edwards (1960)
	Gulf of California	
Bottlenose dolphin	Seen associated with shrimpers. Observed to feed on trash fish. Dolphins attracted to engines shutting down, signifying culling.	Norris & Prescott (1961)
Bottlenose dolphin	Observed feeding in mudboil behind shrimpers.	Leatherwood (1975)
Bottlenose dolphin	Habitually followed trawlers with net down (19% of sightings).	Wells *et al*. (1981)
	Gulf of Mexico	
Bottlenose dolphin	Observed following trawlers. Shrimp found in stomach. Believed to damage nets.	Gunter (1942)
Bottlenose dolphin	Reported to damage nets. Could be made to move with rifle shots.	Gunter (1944)
Bottlenose dolphin	Second-hand report from E.A. McIlhnenny of whole shrimp in stomachs.	Gunter (1951)
Bottlenose dolphin	Reported to distinguish changes of boat operation.	Gunter (1954)
Bottlenose dolphin	Observed to feed on trash fish off northeast coast of Florida, and to feed on catfish while operating shrimp boats were nearby.	Caldwell and Caldwell (1972)
Bottlenose dolphin	Seen following trawling boats; spent more time socializing near boats than eating discarded fish.	Hogan (MS 1975)
Bottlenose dolphin	Categorized behaviors related to shrimp boats as: foraging behind working shrimp boats, feeding on trash fish, and feeding on fish attracted to nonworking shrimpers	Leatherwood (1975)

APPENDIX 3. (continued). Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Gulf of Mexico	
Bottlenose dolphin	Observed feeding behind shrimp boats that had moved from sounds to marsh in Mississippi.	Leatherwood and Platter (1975)
Bottlenose dolphin	Dolphins' activities completely dominated by shrimp boats.	Shane (MS 1977)
Bottlenose dolphin	Detailed accounts of dolphin behaviors around shrimp boats. Mother/calf pairs fed behind shrimp boats; feeding as early as 0545 and continued past 2200; following boat seemed preferable to eating trash fish. Late spring to early fall, most dolphins observed feeding in association with shrimp boats.	Gruber (MS 1981)
Bottlenose dolphin	Fed in association with shrimp boats in Mobile Bay, Alabama.	Goodwin (MS 1985)
Bottlenose dolphin	Associated with shrimp boats in Galveston Bay, Texas.	Henningsen (MS 1991)
Bottlenose dolphin	Detailed accounts of dolphin behaviors around shrimp boats in Campeche Bay. Dolphins responded to motor changes associated with changes in boat operation. Observed feeding almost exclusively on bycatch. Observations of feeding at night near working shrimp boats.	Delgado-Estrella (MS 1991)
Bottlenose dolphin	Group of 7 young dolphins followed groundfish trawl in Gulf of Mexico.	C. Pharr, NMFS, pers. comm. (1991)
Bottlenose dolphin	Detailed accounts of dolphin behaviors around shrimp boats. Movements of dolphins did not appear to be linked to changes in shrimp boat stages. Speculated that females with calves may be taking advantage of concentrated food resource provided by shrimp boats to meet increased energetic needs due to lactation.	Fertl (MS 1994)
Atlantic spotted dolphin	Observed feeding in association with shrimp boats.	Delgado-Estrella (MS 1991)
Atlantic spotted dolphin	Followed large otter trawl to surface as it was hauled in. Dolphins milled around the filled cod-end of the net until it was actually brought on board.	Caldwell (1955)
Atlantic spotted dolphin	Mixed herd with bottlenose dolphins "biting the bag of the trawl" and were seen in front of the bag.	C. Rogers, pers. comm. (1991)

APPENDIX 3. (continued). Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Belize	
Bottlenose dolphin	Observed feeding in association with trawls.	K. Dudzinski, pers. comm. (1992)
	Brazil	
Tucuxi	On at least 4 occasions, groups of up to 5 individuals observed close were to shrimp boats. No information is available on apparent association.	Barros and Teixeira (1994)
	Argentina	
Unidentifed dolphins	Observed coming into and out of the mouth of the net, catching fish.	Crespo and Corcuera (1990)
	Southeastern United States (North Carolina)	
Bottlenose dolphin	Observed feeding on discarded bycatch.	Davis (1988)
Bottlenose dolphin	Observed following working trawlers.	G. Rountree, pers. comm. (1993)
	Northeast United States	
Pilot whale	Active pursuit and opportunistic feeding in and around mouth of net during haulback.	Waring *et al*. (1990)
	Scotian Shelf	
Fin whale	"Feeding aft of codend."	Can. Fed. Dept. Fish. and Oceans, unpubl. data
Minke whale	"Followed trawl at haulback."	Can. Fed. Dept. Fish. and Oceans, unpubl. data
Common dolphin	"Followed trawl at haulback."	Can. Fed. Dept. Fish. and Oceans, unpubl. data
Pilot whale	Following codend; following codend at haulback; feeding off fish at haulback of trawl; and variations thereof.	Can. Fed. Dept. Fish. and Oceans, unpubl. data
Northern bottlenose whale	15 records of "followed trawl during haulback".	Can. Fed. Dept. Fish. and Oceans, unpubl. data
	North Sea	
Harbor porpoise	Observed following the trawls, catching fish squeezed out through the meshes.	Clausen and Andersen (1988)

APPENDIX 3. (continued). Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Northeast Atlantic (Celtic Sea)	
Atlantic white-sided dolphin	Scavenged on discards	A.S. Couperus, pers. comm (1994)
Pilot whale	Scavenged on catch pumped on board.	A.S. Couperus, pers. comm. (1994)
Killer whale	Feeding on fish that slipped through the meshes or fell overboard, when the net was being hauled or shot.	Couperus (1994)
Bottlenose dolphin	30–40 dolphins scavenging behind a freezer trawler during hauling	A. S. Couperus, pers. comm. (1995)
	Mediterranean Region	
Bottlenose dolphin	Suspected to feed on fish in trawl.	Di Natale (1989)
Bottlenose dolphin	Associated with shrimp boats.	Bearzi and Notarbartolo di Sciara (1992)
Bottlenose dolphin	Reported to harrass trawlers.	Northridge (1984)
Bottlenose dolphin	Feed in association with trawlers.	Goffman *et al*. (1995)
Common dolphin	Feed in association with trawlers.	Goffman *et al*. (1995)
Striped dolphin	Feed in association with trawlers.	Goffman *et al*. (1995)
	West Africa	
Unidentifed dolphin	Feeding at night on fish attracted to non-working trawler.	Fulton (1976)
	South Africa	
Common dolphin	Suspected to feed in association with trawls	V. Cockcroft, pers. comm. (1991)
	Western Sri Lanka	
Bottlenose dolphin	Fed in mudline behind trawler.	Leatherwood *et al*. (1984)

APPENDIX 3. (continued). Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Southeast Malaysia	
Bottlenose dolphin	Fed around trawl net when it was reeled in in the evening. Fed on fish dropping from the nets or discarded over the side, and occasionally rammed their rostrums into the net, causing the net contents to spill.	Abel and Leatherwood (1985)
Spinner dolphin	Fed around trawl net when it was reeled in the evening.	Abel and Leatherwood (1985)
	India (Gulf of Mannar)	
Bottlenose dolphin	Reported following cod-end of net.	Pillai and Kasinathan (1987)
	China (Hong Kong)	
Indo-Pacific hump-backed dolphin	Follow behind trawlers (shrimp and midwater fishes), sometimes for long periods.	S. Leatherwood, unpubl. data; T. Jefferson, unpubl. data
	New Zealand	
Common dolphin	Seen feeding on "meatballing clupeids" beneath the hulls of trawlers and along the trawl warps.	Anonymous (1982)
Comon dolphin	Attracted to vessels and may take advantage of herding effect of a trawl net on fish, specifically, fish swimming ahead of the trawl mouth.	Baird (1995)
Hector's dolphin	Occasionally followed trawlers, possibly feeding on fish stirred up, but not caught by trawl gear.	Slooten and Dawson (1988)
	Australia (Moreton Bay)	
Bottlenose dolphin	Reported feeding behind trawlers; feeding intensively on trash fish. Fish preferences observed. Refused floating fish. Dominance hierarchies inter- and intra-species observed. Fed in mixed groups with humpbacked dolphins.	Corkeron *et al*. (1990)
Bottlenose dolphin	Fed on discarded bycatch. Dolphins estimated to eat about 86% of fish discarded from single trawl. Dolphins scavenged only fish and cephalopods, and not crustaceans or echinoderms. Large floating fish (25–65 g) were eaten by dolphins.	Wassenberg and Hill (1990)

APPENDIX 3. (continued). Accounts of cetaceans feeding in association with trawls, reported geographically.

Species	Interaction	Source(s)
	Australia (Moreton Bay)	
Bottlenose dolphin	Attempted to establish a feeding station by feeding dolphins with discards from stationary trawler. Leading the animals with the trawler was not successful for a variety of speculated reasons.	Green and Corkeron (1991)
Indo-Pacific Hump-backed dolphin	Reported to feed in mixed groups with bottlenose dolphins behind trawlers. Would generally remain farther from stern of trawler. Did not gain access to preferred food items.	Corkeron (1990)

Sources of personal communication and unpublished data:

Canadian Federal Department of Fisheries and Oceans, P. O. Box 550, Station M, Halifax, Nova Scotia B3J 2S7

V. Cockcroft, Port Elizabeth Museum, P. O. Box 13147, Humewood 6013 South Africa

A.S. Couperus, Netherlands Insitute for Fisheries Research (RIVO-DLO), P. O. Box 68, 1970 AB Ijmuiden, The Netherlands

K. Dudzinski, Marine Mammal Research Program, Texas A & M University, 4700 Avenue U, Galveston, TX 77551, USA

J. Heimlich-Boran, 7 Victoria St., Cambridge CB1 1JP, UK

T. Jefferson, Ocean Park Conservation Foundation, Ocean Park, Aberdeen, Hong Kong

C. Pharr, National Marine Fisheries Service, P. O. Drawer 1201, Pascagoula, MS 39568, USA

C. Rogers, National Marine Fisheries Service, P. O. Drawer 1201, Pascagoula, MS 39568, USA

G. Rountree, Cetacean Watch Project, 138 S. Colony Circle, Wilmington, NC 28409, USA