months. The peak of the calving season is different among localities: October–January in the South China Sea, April–May in the Yangtze River, November–December and March in western Kyushu, and April–June in the Seto Inland Sea and on the Pacific coast of Japan. Females are thought to calve every 2 years. The lactation period is estimated to be about 7 months, which is short as in other phocoenids.

VI. Interaction with Humans

Because of its nearshore habitat, the finless porpoise tends to be threatened by many human activities. Although there is no fishery that takes finless porpoises directly, incidental catches mainly by gillnets occur throughout its range (Jefferson and Hung, 2004; IWC, 2006). Habitat degradation by land reclamation and deforestation of mangrove areas are also serious problems. It has been suggested that intensive sand dredging is responsible for severe decline of the species in the central-eastern Seto Inland Sea, Japan (Kasuya *et al*., 2002; Shirakihara *et al*., 2007). Moreover, very high levels of toxic contaminants, including organochlorine and butyltin compounds and heavy metals, have been reported in finless porpoises from eastern Asia (Jefferson and Hung, 2004; Ramu *et al*., 2005). In the Yangtze, the combined threats of bycatches, habitat degradation including heavy traffic and construction, and pollution, which in concert caused extinction of the baiji, are also suspected to have contributed to the recent significant decline of the finless porpoise in the river (Wang *et al*., 2005).

The distribution seems to be separated into relatively small local subpopulations by unsuitable habitats of deep water or rocky bottoms. Such local subpopulations are easily depleted, contributing to the decline of genetic diversity of the larger regional metapopulations.

Despite these concerns, our ability to assess the current status and population trends of the species is still very limited, especially for the populations in the Indian Ocean and the southeast Asia.

See also the Following Articles

Baiji ■ Indo-West Pacific Marine Mammals ■ Pollution and Marine Mammals ■ Porpoises, Overview

References

Biodiversity Center (2002). "Survey of Marine Animals (Finless Porpoises)." Biodiversity Center, Ministry of the Environment, Fujiyoshida, Japan, 136pp. [In Japanese].

Gao, A., and Zhou, K. (1995a). Geographical variation of external measurements and three subspecies of *Neophocaena phocaenoides* in Chinese waters. *Act. Ther. Sin.* **15**, 81–92 [In Chinese with English summary].

Gao, A., and Zhou, K. (1995b). Geographical variations of skull among the populations of *Neophocaena* in Chinese waters. *Act. Ther. Sin.* **15**, 161–169 [In Chinese with English summary.].

Gao, A., and Zhou, K. (1995c). Geographic variations of postcranial skeleton among the populations of *Neophocaena* in Chinese waters. *Act. Ther. Sin.* **15**, 246–253 [In Chinese with English summary.].

IWC. (2006). Report of the Scientific Committee, Annex L, Report of the sub-committee on small cetaceans. *J. Cetacean Res. Manage.* **8** (Suppl.), 221–240.

Jefferson, T. A. (2002). Preliminary analysis of geographic variation in cranial morphometrics of the finless porpoise (*Neophocaena phocaenoides*). *Raffles Bull. Zool.* **10**(Suppl.), 3–14.

Jefferson, T. A., and Hung, S. K. (2004). *Neophocaena phocaenoides*. *Mamm. Sp.* **746**, 1–12.

Jefferson, T. A., Robertson, K. M., and Wang, J. Y. (2002). Growth and reproduction of the finless porpoise in southern China. *Raffles Bull. Zool.* **10**(Suppl.), 105–113.

Kasuya, T. (1999). Finless porpoise *Neophocaena phocaenoides* (G. Cuvier, 1829). *In* "Handbook of Marine Mammals" (S. H. Ridgway, and R. Harrison, eds), Vol. 6, pp. 411–442. Academic Press, San Diego.

Kasuya, T., Yamamoto, Y., and Iwatsuki, T. (2002). Abundance decline in the finless porpoise population in the Inland Sea of Japan. *Raffles Bull. Zool.* **10**(Suppl.), 57–65.

Kimura, T., and Hasegawa, Y. (2005). Fossil finless porpoise, *Neophocaena phocaenoides*, from the Seto Inland Sea, Japan. *Bull. Gunma Mus. Nat. Hist.* **9**, 65–72 [In Japanese with English Summary.].

Ramu, K., Kajiwara, N., Tanabe, S., Lam, P. K. S., and Jefferson, T. A. (2005). Polybrominated diphenyl ethers (PBDEs) and organochlorines in small cetaceans from Hong Kong waters: Levels, profiles and distribution. *Mar. Poll. Bull.* **51**, 669–676.

Rice, D. W. (1998). "Marine Mammals of the World." Special publication No. 4, the Society for Marine Mammalogy, Lawrence, KS.

Shirakihara, K., Yoshida, H., Shirakihara, M., and Takemura, A. (1992). A questionnaire survey on the distribution of the finless porpoise, *Neophocaena phocaenoides*, in Japanese waters. *Mar. Mamm. Sci.* **8**, 160–164.

Shirakihara, K., Shirakihara, M., and Yamamoto, Y. (2007). Distribution and abundance of finless porpoise in the Inland Sea of Japan. *Mar. Biol.* **150**, 1025–1032.

Wang, D., Hao, Y., Wang, K., Zhao, Q., Chen, D., Wei, Z., and Zhang, X. (2005). The first Yangtze finless porpoises successfully born in captivity. *Env. Sci. Poll. Res.* **12**, 247–250.

Xia, J., Zheng, J., and Wang, D. (2005). *Ex situ* conservation status of an endangered Yangtze finless porpoise population (*Neophocaena phocaenoides asiaeorientalis*) as measured from microsatellites and mtDNA diversity. *ICES J. Mar. Sci.* **62**, 1711–1716.

Yoshida, H. (2002). Population structure of finless porpoise (*Neophocaena phocaenoides*) in coastal waters of Japan. *Raffles Bull. Zool.* **10**(Suppl.), 35–42.

Zheng, J., Xia, J., He, S., and Wang, D. (2005). Population genetic structure of the Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*): Implications for management and conservation. *Biochem. Gen.* **43**, 307–320.

Fisheries, Interference With

Dagmar Fertl

Marine mammal interactions with fisheries may be characterized as biological (ecological) or operational (IUCN, 1981). This section focuses on operational interactions. "Operational" interactions are those in which marine mammals take fish from fishing operations (depredation), disturb fishing, or damage fishing gear. Interference with fisheries might negatively affect fisheries by resulting in loss of bait, damage to fishing gear, decreased catches, reduced fish weight (in the case of fish farms), or increased time spent during fishing operations. Difficult to assess is hidden damage, i.e., the amount of fish wholly removed from nets without a trace and the catch losses due to the presence of marine mammals.

I. Depredation

Evidence from some fisheries shows that cetaceans, pinnipeds, sirenians, and even the sea otter (*Enhydra lutris*) are attracted to fishing gear and attempt to remove bait and catches during commercial and recreational fisheries. Read (2005) noted that more information is needed about depredation in artisanal fisheries. Marine mammals also feed at mariculture (i.e., fish farm) enclosures and fish aggregated at natural and artificial constraints in river systems, such as falls or fish ladders. Gear likely to have the most interactions with (and interference from) marine mammals are purse seines, trawls, gill nets, traps, and hooks and lines. In fact, baited longlines have been described as "loaded lunchboxes" and shrimp trawlers as "smorgasbords".

Fishing operations concentrate food of interest, decreasing energy expenditure associated with foraging by marine mammals. Nursing females may especially benefit from this feeding technique. Fishing operations may permit marine mammals to select food of higher caloric value. Some food niches, not otherwise available to some marine mammals, may be opened up, making prey easier to access that might be normally more difficult (e.g., because of depth required to dive).

Feeding in association with fisheries is likely a learned behavior, with increasingly more individual marine mammals seeking out fishing gear for an easy meal. Very often, acoustic aspects of the fishing activity (e.g., cavitation noise from changes in the propeller speed of ship engines) act as a "dinner bell." As noted by Königson *et al.* (2006), an earlier foraging experience could encourage individuals to return to feeding grounds that were previously successful. It has been suggested that this type of feeding behavior is also passed from generation to generation by observation and participation (Fertl and Leatherwood, 1997).

Marine mammals may cause abrasions and wounds to fish during unsuccessful capture attempts or while "playing" with fish during fishing operations, even when they are satiated. It is not known how the number of injured fish relates to the total number killed. Marine mammals may take portions of fish or the entire fish, rendering them nonmarketable. Most estimates of loss vary between <1% and 8% of the total catch. There are exceptions, such as in some longline and salmon gill net fisheries. Various species of cetaceans (e.g., killer whale [*Orcinus orca*], false killer whale [*Pseudorca crassidens*], sperm whale [*Physeter macrocephalus*], pilot whale [*Globicephala* spp.]) and pinnipeds (e.g., South American sea lion [*Otaria flavescens*] and California sea lion [*Zalophus californianus*]) depredate longline-caught fish (Gilman *et al.*, 2006). Flesh may be torn from hooked fishes or fish may be removed completely (often leaving only the head or lips) as lines are hauled back to the fishing vessel. Estimates of lost catch per attack by killer whales on longlines off Alaska range from 25% to 100%; of the catch (Yano and Dahleim, 1995), while world-wide catch rate reductions of only 1–3% are reported for sperm whales with longline fisheries (Sigler *et al*., 2008). Depredation rates may be related to a variety of factors, including low availability of fish in the area at the time or presence of particular individual marine mammals causing problems. Longline fishermen off Alaska report that sperm whale depredation is more common when fishery offal (discarded heads and internal organs) is unavailable (Sigler *et al.*, 2008).

II. Disturbance

When the mere presence (i.e., attendance) of a marine mammal(s) can cause catches to be reduced and time wasted, fishing operations are disturbed. Cetaceans and pinnipeds may disturb fishing activity by causing fish shoals to disperse or sound (dive rapidly); and thus escape being trapped by the net. Marine mammals might also cause a large decrease in prey abundance in a fishing area; e.g., during acoustic surveys of Spanish sardine (*Sardinella aurita*) in Venezuela, Fréon and Misund (1999) observed that fish disappeared when dolphins arrived in the area. In the case of fish farms, predators may attack and harass fish through the pen walls, thus stressing, scarring, and wounding the fish and resulting in lower product quality through reduced value or reduced fish weight.

Disturbance of fishing activities even occurs in dolphin–human fishing cooperatives, such as one in Brazil, with "bad" dolphins (*ruim* in Portuguese) occasionally interfering with the fishing by dispersing fish and damaging nets and netted fish (Pryor *et al.*, 1990).

Once a marine mammal has located fishing gear, fishermen might have to move to another site or the marine mammal would continue to take substantial amounts of the catch. This disturbance results in cost to the fishermen because they have to move and relocate to fish.

Fishing operations may be impeded in other ways. Seals may be caught in the fish pump (used to remove fish from the net) and die. Fishing operations may be disrupted if live seals are brought abroad in nets or otherwise make their way onto fishing boats, especially if they manage to get below deck. Crew injuries may result from direct interactions with seals, including people being bitten and nylon burns or cut fingers from tug-of-wars between a fisherman and a seal.

III. Gear Damage

When a marine mammal attempts to remove fishery catches entangled in a net's mesh or hooked on a line, holes may be torn or hooks removed. Marine mammals may become incidentally entangled during these encounters; netting and rope may be lost in trying to free live or dead animals. Damaged gear may not fish as efficiently, and a loss of catch may result. The visible gear damage such as holes and tears in the nets is only a small part of the total economic losses. Indirect expenses include costs for new material, time for repairing fishing gear and reduction in gear durability, increased time and fuel consumption due to emptying the gear more often should also be considered. Further, repairs may be costly, and the time spent repairing fishing gear may be significant in a seasonal fishery where most of the catch is taken in a period of a few weeks. Additionally, animals become injured, with fish hooks in their mouths or dorsal fin disfigurements that occur during the struggle by the animal to free itself (Baird and Gorgone, 2005).

There are numerous examples of marine mammals (particularly pinnipeds) damaging fishing gear; there are more reports of damage to static gear (e.g., fish traps, gill nets, longlines) than moving gear (e.g., trawls, purse seines). Gear damage may also result from accidental collision with fishing gear. For example, humpback whales (*Megaptera novaeangliae*) in Newfoundland in the 1970s caused several hundred thousand dollars of damage annually as a result of colliding with cod traps while feeding on capelin (*Mallosus villosus*).

Cetaceans and pinnipeds are often blamed for damage to gear or catches that should actually sometimes be attributed to other predators. For example, bottlenose dolphins (*Tursiops truncatus*) often are blamed for damage to trawl and gill nets when sharks are often the real culprits. Killer whales and sharks are both known to feed on longline catches off Brazil (Dalla Rossa and Secchi, 2007). Although South African fur seals (*Arctocephalus australis*) are blamed for taking lobsters from traps, clear evidence shows that octopus are to be blamed (Wickens. 1996). Birds may also be seen taking bait off hooks as they are cast into the water during line fishing.

A. Pinniped Interference with Fisheries

Seals, sea lions, and fur seals take caught fish from nets, hooks, trawls, seines (Fig. 1), or traps, and attack fish that are being raised

Figure 1 *A gray seal* (Halichoerus grypus) *raiding a gillnet with caught herring* (Clupea *spp.*) *in the northern Baltic Sea. About 200 herring were set on the net, and 20 min later the net was empty. Photo by Sara Königson.*

in aquaculture pens. Pinnipeds may also be attracted by discarded bycatch; e.g., Nitta and Henderson (1993) observed a Hawaiian monk seal (*Monachus schauinslandi*) feeding on discarded fish. The impact of pinnipeds on fisheries is of particular concern through depredation and gear damage during gill netting on the west coasts of North America, Japan, Britain, Scandinavia, and Chile; through depredation, net damage, and disturbance at fish farms on the west coast of North America, Chile, and the United Kingdom (Nash *et al.*, 2000), and depredation from trawls, depredation and gear loss from hand lines (Meÿer *et al.*, 1992), and disturbance of purse seining in South Africa (Wickens, 1995). Estimates of the consumption by seals from fishing operations in South Africa show it to be a minimal percentage of fishery catches and a small proportion of the total predation by seals (Meÿer *et al.*, 1992). Preliminary calculations of overall economic losses resulting from these seals' interference show this to be small (0.3%) in comparison with the wholesale value of the catches.

Some pinnipeds converge on areas where anadromous fish stocks aggregate or where the movements of fish are constrained naturally or artificially (bottleneck or "choke points" where salmonids aggregate in response to human-made structures or natural river physiography, such as fish ladders or below falls, respectively). Seals may be attracted to a farm by escaped fish and oil slicks from feed, or increased wild fish outside the pens. The most thoroughly studied pinniped/salmonid conflict is California sea lion predation on winter steelhead (*Oncorhynchus mykiss*) at Washington State's Ballard Locks. The severe decline in salmon is considered primarily a direct result of human activities (Fraker and Mate, 1999); however, much concern has been voiced that the expanding populations of seals and sea lions may be causing a further decline (or impeding the recovery) of various salmon runs in the Pacific Northwest.

Figure 2 *Sperm whale* (Physeter macrocephalus) *near a longline vessel in the Gulf of Alaska. Photo by Heather Vukelic, SEASWAP, permit number 473-170-01.*

B. Cetacean Interference with Fisheries

The following is not meant to serve as a comprehensive list, but illustrates some of the better known cetacean–fishery interactions. Bottlenose dolphins and "blackfish" (e.g., killer whales, false killer whales, pilot whales) are notorious fish stealers, and there are widespread reports of catch and gear damage by these species. Cetaceans may feed directly on a fishery's target species, such as killer whales and sperm whales feeding on sablefish (black cod, *Anoplopoma fimbria*) in the North Pacific longline fishery (Yano and Dahlheim, 1995). Interactions between sperm whales and killer whales with longline fisheries (Fig. 2) also have been well documented in the Southern Ocean (in particular, South Georgia, the Kerguelen Islands, and Southern Chile). Such interactions include entanglement in gear, following vessels for days, and observed feeding off gear. Killer whales also feed in association with bottom set fisheries off eastern Russia, interfere with the tuna fishery in the Strait of Gibraltar, and even take salmon off lines in recreational fisheries. Zollett and Read (2006) documented depredation by bottlenose dolphins in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Long-finned pilot whales (*Globicephala melas*) in Newfoundland frequent traps to remove the target species squid. Bottlenose dolphins in Belize have been observed retrieving fish from local, homemade fish traps. Even baleen whales are known to interact with fisheries, following boats and taking fish from nets; an example is fin whales (*Balaenoptera physalus*) off Archipelago Campano feeding in association with trawls and encircling nets (Mussi *et al.*, 1999). Cetaceans also prey on fish confined in mariculture (i.e., fish farm) enclosures (Kemper *et al.*, 2003; Díaz López, 2006).

Cetaceans may also feed on fish that are ancillary to the catch, as in the case of bottlenose dolphins feeding on bycatch from trawl fisheries for shrimp and prawn (Fertl and Leatherwood, 1997). Whales and dolphins may interfere with traps or pots (Fig. 3), such as bottlenose dolphins in the Indian River Lagoon in Florida interacting with the crab pot fishery, apparently to steal bait fish (Noke and Odell, 2002).

C. Sirenian Interference with Fisheries

Fishermen in Jamaica and Sierra Leone have complained about damage caused to gill nets by "net robbing" West Indian and West

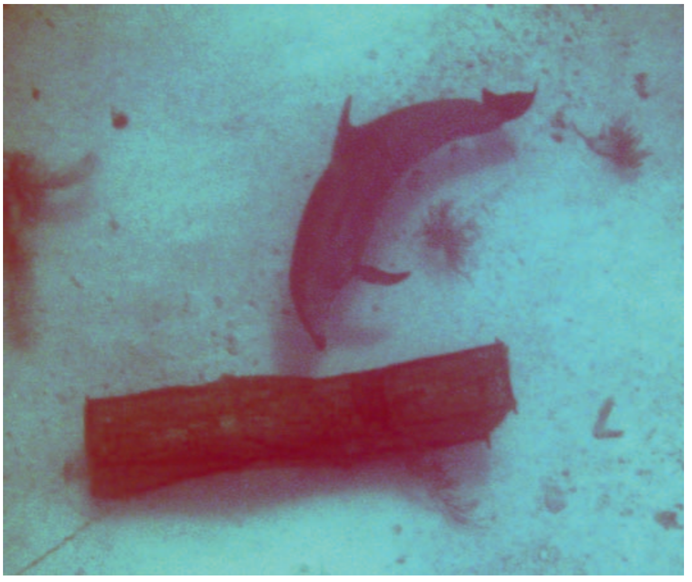

Figure 3 *Bottlenose dolphin* (Tursiops truncatus) *investigating fish trap utilized by the Haitian fishermen, in 70 ft of water at the Northwest Point of Navassa National Wildlife Refuge. The trap is an Antillean Z-trap constructed of meshed/woven bamboo (3–4 cm mesh size) with wooden cross supports and corners and opposing funnel entrances. Photo by Amy V. Uhrin, NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina.*

African manatees (*Trichechus manatus* and *T. senegalensis*) (Powell, 1978, Reeves *et al.*, 1988). Manatees have been described as stripping the flesh off fish entangled in gill nets and leaving the bones. Fishermen in Puerto Rico have noticed manatees circling gill nets, picking out fish.

D. Sea Otter Interference with Fisheries

When a sea otter investigates a lobster pot, Dungeness crab trap, or live-fish trap, the individual itself can become trapped and die (Newby, 1975).

E. Toward Solutions

In response to presumed or real interference with fishing operations, fishermen use various means to deter marine mammals in an attempt to safeguard their catches and gear. Lethal methods have been attempted, including shooting at or killing the marine mammal with a variety of objects and methods, sometimes involving poison. Sometimes these practices are illegal. Seals have been persecuted much more intensely than cetaceans. Lethal methods have not been found to be a consistently effective means of keeping pinnipeds from interacting with fishing operations. The idea is that if problems are caused by a few rogue seals, then removal of these animals should eliminate the problem. However, this method removes individuals that are then often replaced by others.

A diversity of nonlethal methods has been attempted (Werner *et al.*, 2006). At the most basic level, fishermen throw stones or bait to distract the predator. Other methods used include firing gunshots (nonlethal and lethal), using explosives (such as firecrackers and seal bombs), acoustic deterrent devices (ADDs), gear modifications, gear switching, physical barriers (nets), vessel chase (hazing), tactile harassment (e.g., rubber bullets), visual signals, and taste aversion (baiting fish using a chemical to induce vomiting).

The most commonly used deterrents are ADDs that have been widely used to attempt to reduce depredation on fish. These include pingers, acoustic harassment devices (AHDs), passive acoustic devices, predator sounds, and banging pipes. Marine mammals are difficult to deter by acoustic methods, and the acoustic signal of the AHDs over time can be a "dinner bell" effect, alerting animals to the presence of a fish pen or trap. New high-intensity AHDs appear to be more effective but have a greater potential for causing hearing damage, as well as affecting nontarget species. In some cases, a problem may be eased by changing the location of the fishing effort.

The most successful mitigation measures appear to be changes to fishing gears or fishing methods where a particular change may reduce or exclude problems, thereby resulting in a permanent solution. Implementation of anti-predator cages around fish farms, physical barriers at the entrance of fish ladders, and the change to synthetic twine in gill nets are some examples. Other measures include exclusion devices in nets to mitigate bycatch (Suuronen *et al.*, 2006). The Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) is testing changes to the longline fishery, such as circle hauls that minimize engine cycling (which as noted earlier, appears to attract whales), and changing the time of year the fishermen deploy their gear.

Capture and relocation of "problem" pinnipeds has proven ineffective, with the animals returning to the problem area. California sea lions have been captured at the Ballard Locks and placed in temporary captivity and released after the steelhead run. This proved ineffective in the long term, as did permanent captivity, which eliminates the "problem" sea lions without having to kill them but is limited by the availability of facilities that can hold the sea lions and the costs involved in capturing and holding the animals.

Past efforts have been unsuccessful in finding effective, long-term, nonlethal approaches to eliminating or reducing marine mammal–fishery conflicts. Some nonlethal deterrence measures appear to be effective initially or effective on "new" animals but become ineffective over time or when used on "new" animals in the presence of "repeat" animals that do not react to deterrence. Further research on the development of new technologies and techniques is needed.

See Also the Following Articles

Competition with Fisheries ■ Feeding Strategies and Tactics ■ Incidental Catches ■ Management ■ Noises, Effects of ■ Parasites.

References

Baird, R. W., and Gorgone, A. M. (2005). False killer whale dorsal fin disfigurements as a possible indicator of long-line fishery interactions in Hawaiian waters. *Pac. Sci.* **59**, 593–601.

Dalla Rossa, L., and Secchi, E. R. (2007). Killer whale (*Orcinus orca*) interactions with the tuna and swordfish longline fishery off southern and south-eastern Brazil: A comparison with shark interactions. *J. Mar. Biol. Assoc. UK* **87**, 135–140.

Díaz López, B. (2006). Bottlenose dolphin (*Tursiops truncatus*) predation on a marine fin fish farm: Some underwater observations. *Aquat. Mamm.* **32**, 305–310.

Fertl, D., and Leatherwood, S. (1997). Cetacean interactions with trawls: A preliminary review. *J. Northw. Atl. Fish. Sci.* **22**, 219–248.

Fraker, M. A., and Mate, B. R. (1999). Seals, sea lions, and salmon in the Pacific Northwest. *In* "Conservation and Management of Marine Mammals" (J. R. Twiss, Jr., and R. R. Reeves, eds), pp. 156–178. Smithsonian Institution Press, Washington, D.C.

Fréon, P., and Misund, O. A. (1999). "Dynamics of Pelagic Fish Distribution and Behaviour: Effects on Fisheries and Stock Assessment." Fishing News Books, Oxford.
Gilman, E., Brothers, N., McPherson, G., and Dalzell, P. (2006). Review of cetacean interactions with longline gear. *J. Cet. Res. Manag.* **8**, 215–223.
IUCN (1981). Report of IUCN workshop on marine mammal/fishery interactions, La Jolla, California, 30 March–2 April 1981. International Union for the Conservation of Nature and Natural Resources, Gland.
Kemper, C. M., *et al*. (8 authors) (2003). Aquaculture and marine mammals: Co-existence or conflict? *In* "Marine Mammals: Fisheries, Tourism and Management Issues" (N. Gales, M. Hindell, and R. Kirkwood, eds), pp. 208–225. CSIRO Publishing, Melbourne.
Königson, S. J., Lundström, K. E., Hemmingsson, M. M. B., Lunneryd, S. G., and Westerberg, H. (2006). Feeding preferences of harbour seals (*Phoca vitulina*) specialised in raiding fishing gear. *Aquat. Mamm.* **32**, 152–156.
Meÿer, M. A., Kotze, P. G. H., and Brill, G. W. (1992). Consumption of catch and interference with linefishing by South African (Cape) fur seals *Arctocephalus pusillus pusillus*. *South Afr. J. Mar. Sci.* **12**, 835–842.
Mussi, B., Miragliuolo, A., Monzini, E., Diaz Lopez, B., and Battaglia, M. (1999). Fin whale (*Balaenoptera physalus*) feeding ground in the coastal waters of Ischia (Archipelago Campano). *Eur. Res. Cet.* **13**, 330–335.
Nash, C. E., Iwamoto, R. N., and Mahnken, C. V. W. (2000). Aquaculture risk management and marine mammal interactions in the Pacific Northwest. *Aquaculture* **183**, 307–323.
Newby, T. C. (1975). A sea otter (*Enhydra lutris*) food dive record. *Murrelet* **56**, 7.
Nitta, E. T., and Henderson, J. R. (1993). A review of interactions between Hawaii's fisheries and protected species. *Mar. Fish. Rev.* **55**, 83–92.
Noke, W. D., and Odell, D. K. (2002). Interactions between the Indian River Lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncatus*. *Mar. Mamm. Sci.* **18**, 819–832.
Powell, J. A., Jr. (1978). Evidence of carnivory in manatees (*Trichechus manatus*). *J. Mammal.* **59**, 442.
Pryor, K., Lindbergh, J., Lindbergh, S., and Milano, R. (1990). A dolphin–human fishing cooperative in Brazil. *Mar. Mamm. Sci.* **6**, 77–82.
Read, A. J. (2005). Bycatch and depredation. *In* "Marine Mammal Research: Conservation Beyond Crisis" (J. E. Reynolds, III, W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen, eds), pp. 4–17. Johns Hopkins University Press, Baltimore.
Reeves, R. R., Tuboku-Metzger, D., and Kapindi, R. A. (1988). Distribution and exploitation of manatees in Sierra Leone. *Oryx* **22**, 75–84.
Sigler, M. F., Lunsford, C. R., Straley, J. M., and Liddle, J. B. (2008). Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. *Mar. Mamm. Sci.*24, 16–27.
Suuronen, P., Siira, A., Kauppinen, T., Riikonen, R., Lehtonen, E., and Harjunpää, H. (2006). Reduction of seal-induced catch and gear damage by modification of trap-net design: Design principles for a seal-safe trap-net. *Fisheries* **79**, 129–138.
Werner, T., Kraus, S., Read, A., and Zollett, E. (2006). Fishing techniques to reduce the bycatch of threatened marine animals. *Mar. Tech. Soc. J.* **40**, 50–68.
Wickens, P. A. (1995). "A Review of Operational Interactions between Pinnipeds and Fisheries." FAO Fisheries Technical Paper, No. 346.
Wickens, P. A. (1996). Fur seals and lobster fishing in South Africa. *Aquat. Conserv.: Mar. Freshw. Ecosys.* **6**, 179–186.
Yano, K., and Dahlheim, M. E. (1995). Killer whale, *Orcinus orca*, depredation on longline catches of bottomfish in the southeastern Bering Sea and adjacent waters. *Fish. Bull.* **93**, 355–372.
Zollett, E. A., and Read, A. J. (2006). Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. *Fish. Bull.* **104**, 343–349.

Fishing Industry, Effects Of

Simon Northridge

The fishing industry probably represents the single area of human activity that has the most profound effects on marine mammals. These effects can be categorized broadly as "operational effects" and "biological effects." Operational effects include the accidental capture of marine mammals in fishing gear, a problem that has brought about the extinction of one cetacean species in recent years, and threatens several other populations too. Although accidental capture usually results in the death of the animal concerned, there are also instances where marine mammals are injured or affected in some way during fishing operations so that their survival probability or reproductive potential is compromised. Not all operational interactions have a negative effect on marine mammals. In some cases the effect of the fishing operations may be positive for the marine mammal where, e.g., they feed on discarded fish or take fish that have been caught before these can be retrieved onto the fishing vessel. In a few cases there are even mutually beneficial collaborative efforts between fishermen and marine mammals, with marine mammals assisting in fish capture and being rewarded with a portion of the catch.

Biological effects encompass all the consequences of the large-scale removal of animal biomass from the marine ecosystem through fishing activities, including, although not limited to, possible competition for resources between fisheries and marine mammals. Competitive interactions can be direct or indirect. Direct competition occurs where the mammal and the fishery are both taking the same kind of fish. Indirect competition includes situations where the fishery and the marine mammal population are taking two different types of fish, but where the removal of one of these fish influences the availability of the other through some competitive or predatory link. Indirect interactions need not be competitive, and sometimes the effect of the fishing industry may be to increase the abundance of marine mammal prey items through indirect ecological interactions. Sometimes fisheries may physically alter a habitat and so change the composition and abundance of the fish community to the detriment or advantage of marine mammals and other predators.

Operational effects cover interactions between fisheries and marine mammals that relate to the mechanical process of fishing. Several fisheries have well-documented problems with unwanted entrapment of marine mammals. In some cases the numbers of animals involved are large enough to seriously endanger the marine mammal populations concerned; in one case (baiji, *Lipotes vexillifer*) a species has been driven to extinction, largely due to fishery interactions, while it is feared the same fate awaits the vaquita (*Phocoena sinus*). Examples considered cover gill net fisheries, pelagic trawls, and purse seine fisheries.

Gill nets are a widely used fishing gear with a long history of use in many parts of the world. Their use has become more widespread since the 1950s or 1960s with the introduction of nylon as a netting material during the 1950s. They represent a fuel-efficient means of fishing and, when set on the seabed, provide a fishing method that can be used to exploit areas of rough ground that cannot be fished easily by towed gear. When used in surface waters, they are usually left to drift with the wind and tide and are effective in targeting