Competition with Fisheries

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I. Introduction

From an ecological perspective, competition is a situation where the simultaneous presence of the two competitors is mutually disadvantageous. This review focuses on biological interactions (also known as trophic interactions), and specifically the competition for food and fishery resources between marine mammals and fisheries, in contrast to operational interactions in which marine mammals damage or become entangled in fishing gear with negative consequences for both the fishery and the animals (Northridge, 1991, for a review).

Interactions due to bycatches in fisheries constitute one of the major threats to marine mammals (see Fisheries, interference with). These two forms of conflict are sometimes difficult to separate because e.g., animals may damage fishing gear in the process of removing fish therewith. A third important marine mammal–fishery interaction concerns anisakid nematodes whose larvae use commercial fish and squid for transmission to marine mammals (see Parasites), but this is not of direct relevance to the current topic.

Competitive interactions between marine mammal populations and fisheries can either be “direct” or “indirect.” In the former case, the two groups share a common prey species whereas in the latter case, e.g., a marine mammal may prey on a species that is also an important component of the diet of a commercial fish species.

Perceived conflicts between marine mammals and humans in pursuit of common sources of food have come increasingly to the fore in recent years. Escalating pressures on shared resources are expected in the future because of both the increasing marine mammal populations and an increasing human population. Reductions in directed takes in response to recognition that several populations of marine mammals were heavily over-exploited in the nineteenth and earlier part of the twentieth century, as well as a widespread change in people’s perceptions of whether marine mammals should still be regarded as renewable resources available for harvest, have meant that several marine mammal populations are currently on the increase, sometimes by as much as 5–10% per annum (Bowen et al., 2006). From the human population perspective, the Food and Agriculture Organization of the United Nations (FAO, 2006) has estimated that over 2.6 billion people worldwide currently rely on fish and shellfish for more than 20% of their animal protein. Marine capture fisheries seem unlikely to much exceed the present global level, so that ability to meet the demands from an increasing human population will be heavily dependent on a continuation of the recent rapid increase in aquaculture production.

Commercial fisheries and marine mammals frequently target the same fish species, so that faced with possible shortages in marine food production in the future, it is likely that the possible impacts of growing marine mammal populations on the sustainable harvest of commercial fisheries will be vigorously questioned. Concerns about the consequences for fisheries of an increasing marine mammal population have already been expressed in southern Africa, e.g., where in 1990, Cape fur seals (Arctocephalus pusillus pusillus) were estimated to consume some 2 million tons of food a year. Considering that this amount was about the same as the annual human catch of fish in the region, and that the fur seal population was anticipated to increase further, the reasons for concerns and potential for conflict are obvious. A second example concerns the Pacific Ocean, where marine mammals are estimated to consume about 150 million tons of food per annum, which is some 3 times the current annual fish harvest by humans.

This chapter first presents a brief summary of some specific examples which address the question of whether marine mammal populations have negatively impacted the potential yields from fisheries through competition. Examples of perceived competitive interactions are included because the evidence is generally inconclusive. Secondly, some examples pertinent to the reverse—whether fisheries negatively impact marine mammals—are summarized.
II. Detrimental Effects of Marine Mammals on Fisheries

A. Pinnipeds (Seals, Sea Lions and Walruses)

In the early 1990s, catastrophic collapses occurred in the cod (Gadus morhua) fisheries on the East coast of Canada. Although several hypotheses have been posited to explain this, the most likely cause was overfishing. Harp seal (Pagophilus groenlandicus) populations off Newfoundland and Labrador increased at an estimated rate of 5% per annum over the 1980s and 1990s and are known to consume a substantial tonnage of juvenile cod. The socio-economic implications of the collapse of the cod fishery were huge, with some 40,000 fishers rendered out of work, and there is an obvious temptation to argue a causal relationship between the failure of the cod population to recover as rapidly as expected after its protection and the increase in harp seal abundance. Although the results of at least one ecosystem modeling study support the hypothesis that the recovery of these cod populations is being retarded to some extent by the increased abundance of harp seals, ecosystem models generally have poor predictive reliability, largely because of data limitations.

Demonstrating that either a fishery or a marine mammal will be adversely affected as a result of an increase in the removals by one party of a limited resource is not simple. Inferences based on assumptions of a linear relationship between predator and prey abundance are often incorrect because of the complex nonlinear interactions in an ecosystem. For example, off the west coast of South Africa, seals consume almost as much hake as is taken by the commercial fishery (Fig. 1). However, the commercially valuable hake consists of two species, a shallow-water (Merluccius capensis) and a deep-water species (M. paradoxus), with the larger of the shallow-water species eating the smaller individuals of the deep-water species. The results of multispecies models suggest that the net effect of a seal cull would be less hake overall because fewer seals would mean more shallow-water hake, and hence more predation on small deep-water hake (Punt and Butterworth, 1995). This study highlights the complexity of predation, food-fish and fishery interactions and hence the difficulties of demonstrating conclusively that marine mammals are in direct competition with humans for food fish, as may superficially appear to be the case.

B. Whales

Numerous multispecies modeling studies have been employed to investigate the direct and indirect effects of common minke whales (Balaenoptera acutorostrata) on cod, herring (Clupea harengus), and capelin (Mallotus villosus) fisheries in the Greater Barents Sea. Minke whales are abundant in this region and prey on all three species, prompting the question of whether or not fishermen could expect greater catches if the populations of these marine mammals were reduced. The indications of these studies are that there is competition between the whales and the fishers in this region, and that the fisheries are likely to respond linearly to changes in whale abundance. The studies estimate that each minke whale reduces the potential annual catches of both cod and herring by some 5 metric tonnes. Similarly, studies off Iceland suggest that the piscivorous minke, humpback (Megaptera novaengliae), and fin (B. physalus) whales may be having a considerable impact on the region’s cod stock. The cod fishery is of key importance to the Icelandic economy, and the rebuilding of the cod population and catches are recognized as an important economic consideration. It is therefore not surprising that arguments have been put forward that there is a need to reduce whale populations to permit commercial fisheries to increase.

Marine mammals are thought to exert relatively minor influences on systems such as the North Sea and Baltic Sea, whereas they have been identified as potentially serious competitors off, e.g., the northeastern USA, a region that includes important fishery areas such as the Gulf of Maine and Georges Bank. The latter region exemplifies the conflicts that can arise between fishery management plans tasked with rebuilding prey populations and prescriptions, by the USA Marine Mammal Protection Act in this case, to facilitate an increase in the abundance of marine mammal predators.

Figure 1. Schematic showing the complexities of predation, food-fish and fishery interactions as summarized in a minimal realistic model of Cape fur seals and Cape hake interactions off South Africa. Reproduced with permission from Punt (1994).
C. Small Cetaceans

In many areas of the world, coastal fishermen consider dolphins as serious competitors, although retaliation by the fishermen usually has only minor effects on the populations or on their perceived damage. Common dolphins (Delphinus delphis) in the Mediterranean have often been perceived as a threat to the purse-seine and trawl fisheries operating in these waters, and as a result have been deliberately caught in direct retaliation. Declines in this population have been attributed to both direct and incidental catches by the fishery.

The largest hunt designed to reduce the perceived level of competition with fisheries took place in the Black Sea from 1870. In the mid-1900s, tens of thousands of dolphins and porpoises were killed every year as a result of fishing industry claims of competition. Other examples of cetacean kills due to perceived competition include the bombing of belugas (Delphinapterus leucas) from the air by the Quebec government in the 1920s and 1930s, the commissioning by the Icelandic government in 1956 of a US naval vessel to kill killer whales (Orcinus orca), and the use of explosives and firearms by Alaskan fishers in the mid-1980s to eliminate local killer whales.

D. Sea Otters

Sea otters prey on a variety of marine invertebrates such as urchins and abalone. Off southern California, southern sea otters (Enhydra lutris nereis) have been labeled by some as responsible for the decline of the abalone (Haliotis spp.) fishery, but there is little direct evidence to support this notion. The commercial abalone fishery in California was closed in late 1997, and factors such as common coastal fishing, poaching, disease, and changing environmental conditions are all thought to have contributed to the decline of these commercially valuable shellfishes. Although the southern sea otter population is listed as federally threatened, southward movements of otters increased the overlap between otter fishing grounds and abalone fishing areas, and several conflicts exist with commercial and recreational abalone fisheries. Southern sea otters in some areas likely exert a greater impact on red abalone (H. rafinescus) populations than human harvests.

III. Detrimental Effects of Fisheries on Marine Mammal Populations

A. Pinnipeds

The western Alaska population of Steller sea lions (Eumetopias jubatus) declined by 75% between 1976 and 1990, with subsequent continuing declines of the western stock resulting in its listing in 1997 as an endangered species under the US Endangered Species Act. Several groups have argued that this decline is due in part to the large fishery harvest of walleye pollock (Theragra chalcogramma), simultaneously a key source of food for sea lions and the most important US commercial fishery. There is considerable evidence to suggest that nutritional stress played a role in reducing both the recruitment and the reproductive rates of Steller sea lions (DeMaster and Atkinson, 2002). Measures to reduce the perceived competition between sea lions and fisheries for ground fish stocks include the establishment of “buffer” (no-trawl) areas to include important locations where the sea lions breed, feed, and rest, as well as specifying a pollock harvest which is more evenly distributed over the remaining areas and spread throughout the year. However, the results of modeling studies indicate that the observed sea lion population decline cannot be explained solely through trophic interactions, and rather is more likely linked to inadequate recruitment and shifts in environmental conditions which lead to changes in the favored complex of species (DeMaster and Atkinson, 2002; Cornick et al., 2006; Fay and Punt, 2006). Moreover, studies such as Trites et al. (1999) highlight the difficulties of predicting the direction and magnitude of a change in an ecosystem arising from a reduction in predation or fishing pressure. They posit that, paradoxically, Steller sea lion and northern fur seal (Callorhinus ursinus) populations might realize greater benefits if adult pollock and large flatfish were more heavily fished. This competitive release effect may result because, e.g., pollock are cannibalistic and hence decreased adult pollock abundance as a result of heavier fishing may result in increased numbers of juvenile pollock available to marine mammals.

B. Whales

Competition effects are difficult to quantify, but it has been proposed by Whitehead and Carscadden (1985) that the collapse of the eastern Canadian capelin fishery in the 1970s had a negative effect on fin whales. They suggest that a shortage of capelin might have allowed humpback whales to out-compete fin whales because the latter rely principally on capelin as a prey source.

If competitive predation between a marine mammal and fishery occurs, it implies that the marine mammal population is limited by food availability and hence it should be possible to demonstrate a response of some vital population parameters to a change in food availability. Past probable population increases of several krill-eating marine mammals, such as minke whales, crabeater seals, and fur seals, have been attributed by some investigators to a likely large increase in the availability of krill (Euphausia superba) in Antarctic waters (Mori and Butterworth, 2006). Following the substantial reduction through overexploitation of large whale populations during the early twentieth century, some 50–150 million tons of “surplus” krill is argued to have become available annually to other predators. This “krill surplus” hypothesis (Laws, 1977) is yet to be universally accepted, and questions remain concerning potential corroborative evidence, e.g., whether trends in the mean age at maturity of minke whales and crabeater seals (Lobodon carcinophaga) are fully consistent with the changes in food availability that the hypothesis suggests.

Trites et al. (1999) suggested that marine mammal populations can be quickly reduced through reductions in prey abundance but show a generally slow recovery when abundant food becomes available.

C. Small Cetaceans

Dolphin populations that have restricted or localized coastal distributions may be particularly susceptible to competition with fishers for limited food resources. Prey depletion is considered of primary or secondary importance in causing habitat degradation and loss of at least four small cetacean species in the Mediterranean and Black Seas (Notarbartolo di Sciara et al., 2002). Prey depletion is the most likely proximate cause of declines in short-beaked common dolphins in the Mediterranean, with observed malnutrition in other marine mammals, such as bottlenose dolphins, also being attributed to overfishing of their prey stocks and intensive trawling (Bearzi et al., 2003). Reduced prey availability due to fishing may also play a more indirect role in compromising animal health, which is suggested to have led to the large die-off of Mediterranean striped dolphins in 1990–1992 (Aguilar, 2000). As stocks of some preferred fish species are depleted, such as sardines and anchovies in the Mediterranean, dolphins are depopulated, there is a concern that fishing will refocus on other small pelagic fish that are simultaneously the prey of common dolphins and important in meeting the growing demands of the aquaculture industry (Bearzi et al., 2003).
D. Sea Otters

Recent declines—in excess of 50% since the mid-1980s—in northern sea otter (Enhydra lutris kenyoni) populations in Alaska have recently led to its listing as “Threatened.” Although the reasons for this decline are still subject to considerable debate, one hypothesis suggests the declines are indirectly linked to competition with fisheries (Doroff et al., 2003). As discussed above, fishing is argued to be one of the factors contributing to the decline of pinniped populations (harbor seals Phoca vitulina and Steller sea lions) in some of Alaska’s Aleutian Islands. Killer whales preferentially feed on pinnipeds in this region, but as a result of the decline in pinnipeds, they have switched to sea otters as prey. Estes et al. (1998) argued that reduced populations of fish prey responsible for providing high caloric and nutritive value to pinnipeds, may impact not only directly on pinniped populations but also indirectly on killer whale and sea otter populations.

E. Sirensians (Dugongs and Manatees)

Although direct kills and incidental capture in fishery gear are problems, these mammals feed mostly on vascular aquatic plants so that there is no direct competition with humans for a shared food resource.

IV. Assessing the Competitive Effects

Commercial fishermen in many parts of the world perceive marine mammals as serious competitors for a scarce resource, whereas others argue that marine mammals are being used simply as scapegoats for failed fisheries management policies. Scientific evidence is therefore increasingly being sought to settle these disputes, but it is becoming increasingly appreciated that the scientific methodologies required to address them are complex, time consuming, data hungry, and beset with difficulties.

Initial attempts to quantify the impact of consumption by marine mammals on fish catches used a simple approach. They took account of the fact that, particularly for pinnipeds, the sizes of fish eaten tend to be smaller than are taken by commercial fisheries (Beddington et al., 1985). Thus 1 ton of a commercially desired fish species eaten by seals say, does not translate exactly into 1 ton less in the allowable catch for fishers. This is because although a fish eaten by a seal would have grown larger by the time it became vulnerable to fishing, it might also have died before reaching the size as a result of other sources of natural mortality.

It is now acknowledged that such computations, which essentially treated marine mammals as the equivalent of another fishing fleet, are likely to be inadequate because of oversimplification. There are three complicating factors which need to be addressed in performing more realistic computations, while still accepting that both data and computing power limitations necessarily restrict the degree of complexity that is viable to incorporate in multispecies models. The first concerns how many of the large number of interacting species in any ecosystem need to be considered. Secondly, do age-structure effects need to be taken into account? One instance where this can become important is when one species that predates on the small juveniles of a second, finds itself the prey of the larger adults of that same species. For example, whiting Merlangius merlangus feeds extensively on the youngest (0+ and 1+) age classes of the commercially valuable cod, in turn an important predator on the smaller individuals of whiting. Finally, the customary modeling assumption that species interactions occur homogeneously over space may well be sufficiently flawed to invalidate results. Moreover, the distribution of seal breeding and resting sites does not necessarily reflect their feeding distributions. Modern animal tagging technology has demonstrated, e.g., that gray seals (Halichoerus Grypus) and southern elephant seals (Mirounga Leonina) may travel hundreds of kilometers to a preferred feeding site.

However, with the development of several recent models (Koen-Alonso and Yodzis, 2005; Boyd et al., 2006) as well as generalized multispecies modeling tools such as Ecosim and Ecospace (Walters et al., 1997), groundwork is being laid to provide a more reliable basis for scientific evaluation of these competitive effects (Plagányi, 2007, for a review).

V. Considering the Influence of Fish and Krill Harvesting on the Ecosystem

The adoption of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) was a watershed in international fishing agreements in that it was the first to acknowledge the importance of maintaining the ecological relationships between harvested, dependent, and related populations of marine resources. Krill is the primary food source of a number of marine mammal species, and concern has been expressed that the rapidly expanding krill fishery might negatively impact or retard the recovery of previously over-exploited populations such as the large baleen whales of the Southern Hemisphere. Thomson et al. (2000) calculated, within a modeling procedure, the level of krill fishing intensity that would reduce krill availability, and hence the population of a predator to a particular level. Moreover, research is currently in progress regarding the subdivision of the precautionary catch limit for krill among 15 small-scale management units (SSMUs) in the Scotia Sea, to reduce the potential impact of fishing on land-breeding predators.

In general, initiatives such as these pursued under CCAMLR recognize the need to balance the needs of predators with the socioeconomic pressures underlying fishery harvests and represent a realistic step forward in resolving some of the management quandaries resulting from competition for limited marine resources.

VI. Food Web Competition

Trites et al. (1997) and Kaschner et al. (2001) assessed the competition between fisheries and marine mammals for prey and primary production in the Pacific and North Atlantic Oceans respectively, concluding that marine mammals in these areas collectively consume about 3 times as much food as humans harvest. Kaschner (2004) presented similar arguments based on a global analysis of catch and food consumption by marine mammals and fisheries. In the Northern Hemisphere, the greatest overlaps occur with pinnipeds and dolphins and porpoises, whereas in the Southern Hemisphere overlaps between baleen whales and large toothed whales are the most substantial. The dietary overlap between the prey items of marine mammals and fisheries is however less than the foregoing might seem to suggest, because specialized feeding habits mean, e.g., that some of the targeted prey are either unfit for human consumption or are not currently viable for commercial harvest.

Trites and others argue that whilst direct competition between fisheries and marine mammals for prey appears limited, indirect competition for primary production may be a cause for concern. Such so-called food web competition may occur if there is overlap between the trophic flows supporting the two groups (see Fig. 2). Evidence in support of food web competition between marine mammals and fisheries
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is provided by a negative correlation between estimates of primary production required to support fisheries catches and to support the number of marine mammals estimated in the different FAO Statistical Areas in the Pacific Ocean.

VII. Additional Indirect Interactions

There are a number of additional instances, as summarized in Plagányi and Butterworth (2005), where fishing has impacted (or is likely to directly impact) marine mammals by damaging critical habitats upon which they depend, by altering the structure of ecosystems or by otherwise altering marine mammal population dynamics and/or population parameters. For example, trawling may have important effects on the fish populations upon which both fisheries and marine mammals depend. Fisheries-generated habitat destruction may impact most heavily on species such as the gray whale *Eschrichtius robustus*, which feeds primarily on benthic organisms such as amphipods, and the walrus which feeds on molluscs and other bottom-dwelling invertebrates. Other destructive fishing practices such as the use of explosives or cyanide in coral areas may seriously damage the habitat, with consequent repercussions for fish and dependent marine mammal populations.

Noise pollution from fishing vessels has been implicated in affecting marine mammals negatively both by interfering with the sensitive echolocation systems of toothed cetaceans and thereby indirectly reducing their foraging efficiency and by routing marine mammals away from preferred feeding areas (Roussel, 2002).

Fishing changes the overall size distribution of fish, and such changes over time may either increase the competitive overlap between fishes and marine mammals or may prove positive for marine mammals with a preference for smaller fish. However, a shift to preying on smaller fish may have negative effects on the bioenergetics of some species.

Several cetacean and pinniped species are known to feed in association with trawlers, as the resulting disturbance may bring prey species higher in the water column where they are easier targets for marine mammals, or alternatively trawlers might beneficially concentrate food (Fertl and Leatherwood, 1997). Although discards associated with trawling provide ready forage for several species (including dolphins and seals), the advantages of opening new feeding niches for marine mammals are likely offset by other negative impacts of trawlers and alterations in marine mammal foraging strategies.

Fishing may play yet another indirect role in increasing the mortality rates of a marine mammal species by forcing animals to either increase their foraging time or to forage further afield in areas where they are