The Role of Pinnipeds in the Ecosystem

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Abstract

The proximate role played by seals and sea lions is obvious: they are predators and consumers of fish and invertebrates. Less intuitive is their ultimate role (dynamic and structural) within the ecosystem. The limited information available suggests that some pinnipeds perform a dynamic role by transferring nutrients and energy, or by regulating the abundance of other species. Others may play a structural role by influencing the physical complexity of their environment; or they may synthesize the marine environment and serve as indicators of ecosystem change. Field observations suggest the ultimate role that pinnipeds fill is species specific and a function of the type of habitat and ecosystem they occupy. Their functional and structural roles appear to be most evident in simple short-chained food webs, and are least obvious and tractable in complex long-chained food webs due perhaps to high variability in the recruitment of fish or nonlinear interactions and responses of predators and prey. The impact of historic removals of whales, sea otters and seals are consistent with these observations. Many of these removals produced unexpected changes in other components of the ecosystem. Better insights into the role that pinnipeds play and the effect of removing them will come as better data on diets and predator-prey functional responses are included in ecosystem models.

Introduction

What role do pinnipeds play in the ecosystem? Are they at all-important to the ecosystem or is the ecosystem more important to them? These questions are not easily answered, but are important to those concerned with fisheries, marine mammals, and the health of the marine environment.

At the root of the problem are 34 species of seals and sea lions, one of which is now extinct (King 1983; Jefferson *et al.* 1993). They occupy a variety of habitats and ecosystems from the Arctic to the Antarctic. Some live in fresh water, others in marine shelf areas, or areas of open ocean and deep water. Their diets are specialized and may consist primarily of krill, fish or even warm bodied animals. They are the top predators.

As a top predator, their role within the ecosystem is self defined: they are consumers. Some may even say they consume too much. But is this role of consumer useful to overall ecosystem function and do seals and sea lions fulfill any others? These are the question I explore.

I begin with a brief overview of marine ecosystems and the roles that different organisms play in it. I then consider how top predators such as seals and sea lions have influenced and continue to influence their environment. I discuss a few examples of marine ecosystems that were affected by the removal of marine mammals. Finally, I give a brief overview of the insights being gleaned from ecosystem models and present my conclusions.

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Ecosystems and Ecosystem Roles

Ecosystems are dynamic systems where physical, chemical and biological processes interplay (Mann and Lazier 1991). There are basically two types of marine ecosystems: deep sea and shelf areas (Laevastu *et al.* 1996). Shelves are dominated by zooplankton, benthos, fish and mammals. In contrast, the deep sea ecosystem is dominated by these same groups with the exception that the benthos are replaced by squids.

Ecosystems are typically depicted as a series of interconnected organisms placed at various trophic levels (Paine 1980; Laevastu *et al.* 1996). They consist of both short- and long-chained food webs and may be controlled or regulated from above — top-down or below — bottom-up (Hunter and Price 1992). Each of the organisms in a food web can fill one or more proximate roles within the ecosystem (Figure 1). An organism can be a decomposer, a filterer, a grazer, a scavenger, a host, a prey or a predator, to name a few of the possible roles. In addition, regardless of the proximate role played by an organism, it ultimately plays at least one of two basic roles within an ecosystem: either dynamic and/or structural. They may play a dynamic role by transferring nutrients and energy or by regulating abundance of other species (*e.g.*, Laws 1977; Gwiazda 1990; Radchenko 1992); or they may play a structural role, as in the case of sponges, coral and kelp, by providing physical complexity to the environment (*e.g.*, Barthel 1995; Roberts 1995).

Roles Played by Top Predators

Pinnipeds can and have influenced the dynamics and structure of ecosystems in a number of ways. On an evolutionary time scale, for example, escape from predation likely determined the life history characteristics of a number of organisms alive today (*e.g.*, Siniff and Stone 1985; Warwick 1989). On an annual or seasonal time scale, predation can affect the growth and reproduction of prey and the abundance of other predators (*e.g.*, Laws 1977; Bester and Laycock 1985; Hempel 1985; NRC 1996). Pinnipeds can also influence the benthic fauna and community structure, and contribute to the recycling of nutrients (*e.g.*, Barthel 1995; Roberts 1995; Wallace and Webster 1996). Pinnipeds may also be home to a number of different species of parasites (*e.g.*, Myers 1970; McClelland 1980; Grenfell and Gulland 1996).

There are a number of examples where pinnipeds have affected their ecosystems in these ways. A case in point is the growth and reproduction of prey. In Quebec, Canada, for example, there are a number of fresh water lakes that are home to land-locked harbor seals. Studies have found that the trout in these lakes attain smaller sizes and spawn at younger ages compared to adjacent lakes without seals (Power and Gregoire 1978).

Another case in point is the ability of pinnipeds to affect the abundance of prey which are in turn the predators of other species. In British Columbia for example, the annual diet of harbor seals in Georgia Strait contains about 4% salmon and 43% hake (Olesiuk 1993). Countrary to popular opinion, the harbor seals may be benefiting salmon because they affect the abundance of hake, a species of fish which is one of the largest predators of salmon smolts.

Another way that pinnipeds can affect their ecosystem is by influencing the benthic fauna and community structure. Walrus do this when they turnover the bottom substrate in their search for clams and other bivalves (Fay 1981). They contribute to the turnover of nutrients (Oliver *et al.* 1983, 1985; Fukuyama and Oliver 1985). Similarly, the excrement of pinnipeds, such as from the one million fur seals in the Bering Sea or the 3 million harp seals off of Newfoundland contributes to the turnover and recycling of nutrients.

Finally, pinnipeds act as a host to parasites as in the case of gray seals in the Atlantic Ocean (Myers 1970; McClelland 1980). These parasites pass through a number of life stages and hosts that include copepods, fish and seals.

Up until now I have mentioned only two ultimate ecosystem roles: structural and dynamic. There is in fact a third and very important role that pinnipeds play: indicators of change. Top predators such as seals and sea lions can indicate environmental changes and degradation. As top predators in the marine ecosystem, changes in their abundance, behaviors and health can serve as important indicators of change (*e.g.*, Bengtson and Laws 1985; Croxall *et al.* 1988; Sahrhage 1988; Bengtson 1988; Trillmich and Ono 1991). Thus their ultimate value in our eyes may be to synthesize the marine environment and serve as our early warning sign when things have gone amiss.

Removing Top Predators

We cannot say with certainty what would happen if seals and sea lions were removed from their ecosystems. We don't know how the California marine ecosystem might change if the sea lions, fur seals and harbor seals were removed. But we can make a few educated guesses.

In theory, removing the predators should lead to increased numbers of prey. These prey may have major predatory impacts on other components of the ecosystem, or they may become a newly available prey for other species. Regardless of which scenario might get played out, it seems reasonable to predict that the ecosystem will ultimately lose diversity, physical complexity, productivity and resilience.

Further insight into what might really happen if the seals and sea lions were removed can be gained through removal experiments and ecosystem models. While no removal experiment has ever been conducted with the intent of answering this question, a number of mass removals of marine mammals have occurred over time (Parsons 1992). Some examples include whaling in the Antarctic Ocean and Bering Sea, the hunting of sea otters in the north Pacific, and the culling of harbor seals in Alaska.

Earlier this century commercial whaling systematically removed right whales, humpback whales, blue whales, fin whales, sei whales and minke whales from the Antarctic and north Pacific Oceans. Over 84% of the whale biomass was removed from the Antarctic system leaving an estimated 150 million tons of krill to go uneaten each year (Knox 1994). Other krill-eating predators responded to this huge amount of available krill. Species such as crab eater seals, Antarctic fur seals, leopard seals, and penguins began to increase; moving the Antarctic marine ecosystem to new equilibrium levels

(Beddington and May 1982). These species directly benefited from the removal of whales and may now be hindering the recovery of whale stocks (Knox 1994; Clapham and Brownell 1996).

A similar scenario may have played out in the north Pacific where commercial whaling also freed up millions of tons of copepods and euphasids (NRC 1996). However, unlike the Antarctic scenario, this new food source was consumed by fish, not pinnipeds. One of the direct beneficiaries may have been pollock, a species of fish which now dominates in the Gulf of Alaska and Bering Sea. Unfortunately for seals and sea lions, pollock is a poor quality food fish and may be part of the reason that populations of Steller sea lions, northern fur seals and harbor seals have declined in the north Pacific.

Another species which can significantly affect the coastal marine ecosystem is the sea otter (Van Blaricom and Estes 1988; Estes and Duggins 1995). Sea otters were hunted to near extinction before the turn of the century. The loss of this species resulted in underwater barrens because urchin populations grew unchecked and removed all of the fleshy algae. The removal of urchins by otters allows kelp to grow and increases overall marine productivity. The kelp provides habitat for fish and invertebrates, changes water motion and can affect the recruitment process and onshore erosion. Thus a top predator such as sea otters can change the state of an ecosystem and the way it functions.

The third example is from the Copper River Delta in Alaska which supported a salmon fishery and a razor clam fishery. Harbor seals were culled here in the 1960s to reduce predation on salmon. However the immediate result of culling the seals was not an increase in numbers of salmon caught, but a decrease and failure of the razor clam fishery (Ray Baxtor—deceased, and Craig Matkin, Homer, Alaska, pers. comm.). It turns out that the seals ate primarily Starry Flounder which fed on the razor clams. Without the seals, the predatory Starry flounders grew unchecked.

These three examples of predator removals resulted in marked and noticeable changes in the ecosystem. But there are other cases of mass removals that did not appear to have major tractable impacts, such as when sea lions, fur seals and elephant seals were hunted to near extinction (Roppel 1984; Le Boeuf and Laws 1994). The lack of tractable impacts in these cases might be due to the complexity of their food webs and the type of marine ecosystem these species inhabited (i.e. whether shelf or deep water).

The three examples where impacts were noted were all short-chained food webs where the predator was a major competitor or controlled the abundance of another predator that influenced the benthic fauna. No apparent impacts were noted when pinnipeds were removed from systems containing complex and long chained food webs. The effect of removing pinnipeds from complex food webs might be masked by the high natural variability in the recruitment of fish. Similarly, interactions and responses of predators and prey in complex food webs are likely nonlinear and not tractable to the point that cause and effect can be determined.

Ecosystem Models
The second way we might gain some insight into the effect of removing predators is with mathematical ecosystem models. Unfortunately most of the models constructed to date are unable yet to properly address this issue. They have typically assumed pinnipeds are static consumers that sit at the top of the food chain and remove fish and energy from the system (*e.g.*, Laevastu and Favorite 1981; *c.f.*, McClaren and Smith 1985). They also tend to ignore prey switching and predator-prey functional responses because of a general lack of information on these and other items concerning the diets, distribution and foraging behaviors of pinnipeds in the ecosystem (*e.g.*, Christensen and Pauly 1992).

What these models have shown to date is that the mammals don't have a major impact on fish populations and that fish are far more important predators of other fish than are the mammals (*e.g.*, Trites *et al.* 1997). These conclusions may change as more information is gathered on functional responses and foraging ecology.

Conclusions
What conclusions can be drawn about the role that the 33 existing species of pinnipeds play in the ecosystem? Do they in fact have a role other than consumer?

The evidence is that they do indeed play a number of different roles. Depending upon the species and the ecosystem in question, pinnipeds are capable of altering the structure and dynamics of their systems. Their roles appear to be specific to each species of pinniped and seem to be most noticeable in simple short-chained food webs. Their role is least obvious and tractable in complex long-chained food webs presumably because recruitment of fish is highly variable, and interaction and responses of predators and prey are not necessarily linear. It is difficult if not impossible to demonstrate their significance convincingly. Better insights into the role that pinnipeds play and the effect of removing them will come as better data on diets and predator-prey functional responses are included in ecosystem models (*c.f.*, DeMaster and Sisson 1992).

It is not easy to determine the roles that seals and sea lions play in the ecosystem. There is clearly so much more to be learned about pinnipeds and ecosystems. It is nevertheless an important and interesting question to pose because of the perceived conflict between marine mammals and fisheries. But it does seem an audacious and presumptuous question, and one that should also be asked of humans. What is our role in the marine ecosystem, and is it a useful role? Now *that* is something to think about.

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Figure 1. A simplified depiction of the Bering Sea food web: (1) ice algae; (2) phytoplankton; (3) copepods; (4) mysids and euphausids; (5) medusae; (6) hyperid amphipods; (7) sea birds; (8,9) pelagic fishes; (10) walrus; (11) seals; (12) basket stars; (13) ascideans; (14) shrimps; (15) filter-feeding bivalves; (16) sand dollars; (17) sea stars; (18) crabs; (19) bottom feeding fishes; (20) polychaetes; (21) predatory gastropods; (22) deposit feeding bivalves (McConnaughey and McRoy 1976).