Alternative Animal Models for Assessing the Role of Nutrition in the Population Dynamics of Marine Mammals

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Introduction

The past three decades have seen extensive variation in the population dynamics of marine mammals in the North Pacific. California sea lions and northern elephant seals have increased by approximately 600% and 400% respectively, in California and Oregon since the 1970's (Brown, 1997). Contrary to this, populations of northern fur seals, harbor seals and Steller sea lions have suffered enormous declines in Alaska over the same time period (Trites, 1997), as have monk seals in Hawaii (Antonelis and Regan, 1997). A plausible and widely accepted explanation of these different dynamics is that they are caused by differences in nutritional status. It is known that there are physiologic links between nutritional or metabolic status and the reproductive axis, and so it may be that in these wild populations, this could lead to altered population structures and dynamics. While the populations in California have ample food supplies, the primary prey of Alaskan pinnipeds appears to have decreased in abundance, such that sea lions have switched to alternative, and possibly inadequate, sources. Similarly, the Hawaiian monk seal decline may be connected to reduced prey availability and its impact on vulnerable, juvenile animals (Antonelis and Ragen, 1997).

Intensive studies have been underway for over a decade to determine the role of nutrition on the decline in population of the Alaskan Steller sea lion. Steller sea lion populations have dropped by almost 75% since the late 1970's in parallel with a shift in the ocean's composition of fish, most notably an increase in Walleye pollock and a decrease in Pacific herring (Calkins et al., 1999; Trites and Larkin, 1996). Stomach contents of Steller sea lions reflect a shift in dominant prey species from herring to pollock (Merrick and Calkins, 1996; Pitcher, 1981). In a physiologic context, these changes have been accompanied by reduced body size (length and mass), low reproductive weights, high mortalities and poor fur quality for Steller sea lions (Calkins et al., 1998). One hypothesis connecting the above observations is that the sea lions experienced a nutritional deficiency when their dominant prey species shifted from a fatty fish (herring) to a non-fatty fish (pollock).

Although nutritional deficiency is the most likely factor driving the decline of the Steller sea lions and other marine mammals, testing this hypothesis is challenging. The primary obstacle for evaluation of the connection between nutritional status and sea lion well being has been the difficulty in accurately ascertaining nutritional profiles on animals both in captivity and in the wild. Studies at the Vancouver Aquarium Marine Science Center have monitored Steller sea lions fed pollock and herring, and have recorded such parameters as changes in body weight, digestive efficiencies and the heat increment of feeding (Rosen and Trites, 1997; in press). Unfortunately, only a few sea lions can be held in captivity due to their size. Additionally, the lengthy reproductive cycle of sea lions makes it impossible to test the effects of diet on reproductive performance.

In order to examine the role of nutrition on population dynamics in the wild, strict regulation of which prey species and the amount of each consumed is required. Individual sea lions would also have to be followed for many years to monitor reproductive success. At the present time, these research objectives are not technologically feasible and so empirical experiments are only feasible with captive animals.

One solution to this predicament is to use alternative animal species to model nutritional studies of marine mammals. Selective criterion such as the logistics of using one particular animal, the costs involved, and the feasibility of the comparison are critical in choosing an appropriate model.

Animal Models

There are three potential animals that could be used as models to assess the nutritional consequences for marine mammals that eat different types of prey. They include the rat, the mink and the harbor seal.

Rats

The rat is by far the most economic model for nutritional studies. Housing is relatively inexpensive and cages require low maintenance and little space, allowing for a large sample size. Rats are also easy to handle. Other benefits include the short, predictable, five day breeding/estrus cycle and their extensive past use in nutritional, toxicologic and biomedical experimentation. One of the shortcomings is that rats are naturally omnivorous rather than piscivorous. However, rats have been shown to eat fish and maintain healthy growth rates on fish diets (Arnold et al., 1998). In further support of the use of the model, the rat was recently used as a model for harbor seals in two toxicology investigations (Ross et al., 1997; Ross et al., 1996) in which it proved to be a valuable tool.

Mink

Mink are another viable marine mammal model, although the logistics involved in using these animals are more complex than those of the rat. Mink are larger, more expensive aquatic animals making housing and maintenance quite complex. Mink are also more difficult to work with and handle, and have longer breeding cycles, being seasonal breeders (Tauson, et al., 1994), which lengthens the study time if reproductive parameters are to be measured. It is, however, possible to have a moderate sample size using mink, but again the cost involved and the willingness of the farmer to allocate a large number of animals to study can limit samples. Mink are naturally carnivorous, aquatic animals, making comparison between them and other marine mammals slightly more reasonable. Already, they have successfully been used as models for carnivores in general (Tauson et al., 1994) and for nonruminant animals (Urlings, et al., 1993).

Harbor Seals

Harbor seals are another alternative marine mammal model. They require the most extensive housing of the models examined so far, and due to political and ethical issues, only small sample sizes are available. In addition, these animals require training to work with them due to their size, increasing experimental time and expense. One of the greatest drawbacks to the use of harbor seals is the difficulty in breeding the animals and obtaining nutritional effects on reproduction. The breeding cycle of these seals is a full year in length (Bonner, 1999), again lengthening the study time if breeding is successful. The greatest advantage of using harbor seals, however, is that they *are* marine mammals, and are cheaper and easier to work with than Steller sea lions. It is much easier to extrapolate physiologic results to other marine mammals because they have evolved to deal with similar environmental and physiologic variables. Peter Ross and colleagues (Ross et al., 1995) have recently used the harbor seal as a model to examine the effect of ingesting contaminated prey on marine mammal immune suppression. Seals are piscivorous, are found among many other marine mammals, and are the smallest, least aggressive and least expensive of the marine mammals to work with.

Conclusions

Alternative animal models are desirable to assess the role of nutrition on the population dynamics of marine mammals. If an appropriate model could be found, it might be possible to identify population consequences and risks that face sea otters forced to eat fish after depleting local invertebrates, or for sea lions which switch from a fatty fish to a lean fish.

From the arguments raised above, the rat appears to be a feasible model for studying marine mammal nutrition. A preliminary study exploring the effects of nutrition on population dynamics via parameters of growth and reproductive success is feasible. Although mink and harbor seal models are superior in their similarity to other marine mammals, the difficulty and time involved in breeding them is either extremely labor intensive or prohibitive. Again, the regular, five day cycle of the rat and shorter generation time allow for parameters of fertility and offspring viability in response to different diets to be examined in a cost effective and economic way. Additionally, because of the extensive use of rats in other nutritional studies, many signs and symptoms of specific nutritional shortcomings are known and easily detected

If a reliable model can be implemented in the study of marine mammal population dynamics, research can explore aspects of physiology not available when using captive marine mammals or mammals in the wild. Development of a model also has the potential to reduce the number of mammals taken from the wild for scientific study, thereby helping to preserve many threatened species.

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