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What Is It about Food? Examining Possible Mechanisms with Captive Steller Sea Lions

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Overview

Changes in the quality or quantity of food can have a dramatic effect on the population status of wild animals. Unfortunately, it is difficult to assess (or define) whether nutritional stress is a contributing factor to the decline of any particular species. The "nutritional quality" of a diet to an animal is a complex matter to assess given the range of components that can influence its value. The effects of different diets on animal health are equally complex, and are particularly difficult to assess in large, wild animals.

Research by the North Pacific Universities Marine Mammal Research Consortium with captive Steller sea lions is evaluating the possible mechanisms by which dietary changes might adversely affect the nutritional or health status of individual animals, and ultimately the population as a whole. The research investigates the three potential proximate mechanisms by which changes in diet might impact Steller sea lions: a decrease in energy intake, a decrease in the intake of some essential element, and the over-consumption of an element detrimental to sea lion health.

Energy Intake

To examine the hypothesis that population changes are the result of decreases in relative energy intake, our research evaluates both the potential energetic value of prey items (energy intake), and the energy requirements of sea lions (energy output).

The first step in determining potential limitations in energy intake is to quantify sea lion diet. Although analysis of fish remains in scat samples is an accepted technique for diet determination, we have been developing correction factors for these diet reconstructions, and quantifying the time period that these samples represent. We are also participating in a study to test the efficacy of fatty acid signatures to identify prey intake over longer time periods.

Experiments to determine the heat increment of feeding (HIF) and fecal energy loss (FE) enable us to calculate the net (biologically useful) energy value of common prey. These studies are necessary to accurately convert between energetic demand and food consumption estimates. The results suggest that sea lions would have to consume substantially more pollock (35-80%) and squid (107-145%) to achieve the same energy intake of a herring diet (Rosen and Trites 1999, 2000a,b). The differences can be further magnified by the need to ingest larger meals of low-energy prey, which further decreases digestive efficiency (Rosen and Trites 1997). The significant range of these estimates results primarily from variation in prey energy content. Proximate composition analyses of common prey items have revealed that the gross energy content of potential prey items changes temporally, geographically, and by age/sex class (C. Azano, U.B.C., unpubl. data).

Ad libitum feeding trials are used to investigate potential controls and limitations in food intake, particularly in younger animals given the allometries between body mass, energetic needs, and digestive capacity. In several studies, young sea lions did not increase their food intake sufficiently on (short-term) low energy diets to maintain energy intake and body mass (Rosen and Trites 1999, 2000a). We suspect that physical or chemical satiation may be limiting the sea lions' capacity for energetic compensation through increased food intake. Studies continue into the factors limiting food and energy intake, including satiation and feeding opportunities.

A computer model of Steller sea lion bioenergetics has helped to understand the relationship between energy intake and expenditures. The model integrates diet information with empirically derived data on the costs of particular parameters of the sea lion's energy budget (Winship et al. 2002). Experiments with captive sea lions have provided data on the costs (including variation and interaction) associated with standard metabolism, swimming, foraging, and thermoregulation. These studies have also been instrumental in testing and developing techniques for measuring energy expenditure in wild sea lions (e.g., heart rate).

Metabolic studies with fasted or food-restricted sea lions have documented the degree to which bioenergetic adaptations (e.g., metabolic depression, changes in activity) can compensate for decreased energy intake. When fasted or on a low-energy diet, the sea lions displayed a decrease in metabolism proportional to changes in body mass (Rosen and Trites, in press), typical of a "fasting response." While this metabolic depression was significant (<30%), it was not sufficient to preclude loss of body mass. In contrast, the sea lions exhibited a "foraging response," characterized by increased activity and no metabolic depression, during food restriction trials. We are investigating further the criteria that trigger these alternate energetic strategies.

Intake of Essential or Detrimental Elements

One aspect of the nutritional stress hypothesis suggests that sea lion health is being negatively affected because sea lion diet does not provide adequate levels of unspecified essential elements. An alternate hypothesis proposes that the diet is providing too much of an element that is detrimental to sea lion health. We have begun to investigate both of these possibilities by evaluating the composition of key prey items, and by documenting the effect of different prey items on animal health. Both avenues are key to the investigation: chemical analyses of prey can help suggest which physiological effects to monitor, and vice versa.

Given that a major difference between potential prey items is their lipid content, we have been specifically investigating the effects of a low-fat diet on sea lion condition and health. Initial results suggest that when sea lions are maintained on isocaloric pollock and herring diets for 6 weeks, they display similar changes in body mass. However, body lipid stores decrease faster when sea lions are on a (low fat) pollock-only diet, although additional factors (e.g., season, gender) may control body lipid levels.

Numerous chemical analyses can be performed on prey samples. We have concentrated our efforts on those elements we feel are most likely to impact Steller sea lions, including essential fatty acids and key vitamin complexes. The impact of these prey items has primarily been investigated through blood samples taken from sea lions while they were on different diets. For example, we are currently investigating whether a diet high in gadid species results in hematological abnormalities, as demonstrated with other mammals.

Given the constraints of studying long-lived species, we have used an alternate mammalian model to document the long-term effects of different diets on key life history parameters. Initial experiments have used rats on normal and lipid-enhanced pollock and herring based diets. Results confirm the need for increased pollock intake, but also suggest that increased intake of pollock oil may negatively impact certain life history parameters (e.g., low birth weights) (C. Donnelly, U.B.C., unpubl. data).

Initial Conclusions

- The gross energy content of specific prey items can vary widely. Our experiments have affirmed that accurate calculations of the net energy of these prey items are essential to determining their biological energy value and for accurate estimates of prey requirements.

- Ingested food mass may be limiting the degree to which sea lions, particularly younger animals, can compensate for lower energy-density prey by increasing food intake. The frequency of feeding opportunities may also limit total food intake.

- Steller sea lions can alter their energy budgets to compensate for decreased energy intake, but the extent and duration of this ability is limited. There is also a clear differentiation between a physiological “foraging” response and a “fasting” response.
- There are preliminary indications that the nutritional quality of particular prey may be negatively impacting Steller sea lion health. Initial results from sea lion and alternate models suggest both short-term (hematological changes, lipid stores) and long-term (reproductive success) effects.
- In evaluating the link between diet changes and sea lion population declines, it is imperative to evaluate whether potential energetic or nutritional deficiencies incurred by an individual ultimately impact the life history parameters of the population.

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