Assessing the Role of Nutritional Stress in the Decline of Wild Populations: A Steller Case of Scientific Sleuthing

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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 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 when dealing with large, wild animals.

There are essentially three fundamental questions that need to be addressed to resolve whether a population is nutritionally stressed (Table 1). These can be generalized as concerns of: 1) food intake (i.e., prey identity, quantity, and foraging location), 2) food quality (i.e., energetic and specific nutritional components), and 3) the ultimate impact of diet on the individual and the population (i.e., energy budgets, overall health, life history parameters). All three questions require a combination of field and captive studies to be properly addressed.

Since 1995, we have been studying whether the decline of Steller sea lions in the North Pacific Ocean has been caused by nutritional stress. We feel our research approach may provide an appropriate template for others addressing similar issues with other species. The following is an overview of some of the research we are actively undertaking to address the aforementioned 3 questions that are fundamental to evaluating the role of nutritional stress in wild populations.

Food Intake

The cornerstone of evaluating the effect of diet on a population is obtaining accurate information on the prey consumed. Data on the quantity and type of food are critical, including geographic and temporal variation in foraging patterns. As seen with Steller sea lions, it is important to have information of both present and historic diets.

A number of techniques are available, which provide data on the quantity and/or type of prey consumed over a number of time scales. Listed roughly from short to long-term diet indicators, these include: direct observation, stomach temperature telemetry, stomach content and scat analyses, and fatty acid and stable isotope profiles. Many of these techniques have been widely used, but poorly validated. Studies with captive animals allow researchers to evaluate both the accuracy and precision of such estimates through experimental diet manipulations, and to perfect novel techniques and equipment prior to the expense and effort of collecting data in the field. For example, identification of non-digested fish parts has historically been used to determine diets in Steller sea lions. Experimental feeding trials with captive sea lions allow researchers to quantify the effects of feeding regimes and activity patterns on otolith collection, and to develop alternate diet identification markers.

Quality of Prey Items

For the purposes of discussion, the quality of food items can be divided into their energetic and elemental contents. The latter includes the vitamin, mineral, and essential fatty acid composition of the prey. Protein, fat, carbohydrate, and water content of prey are important as individual components, as well as for determining the energy density of prey. Prey can be sampled (and archived) on an appropriate geographic and temporal basis, and the appropriate analyses run in a laboratory without the need for experimental animals.

A prominent distinction between potential Steller sea lion prey items are differences in gross energy density (primarily a result of differences in lipid content). For example, energetic differences in energy density suggest a sea lion would have to consume approximately 55% (range: 35 to 120%) more pollock than herring (two key prey species) to achieve the same gross energy intake. The considerable range in this estimate highlights the effect of variability in gross energy density on food consumption estimates.

While the gross energy content of prey items can be determined independently, the estimation of net energy (the energy that is biologically available to the animal) requires studying captive animals under controlled conditions. To calculate the net energy of prey items it is necessary to estimate digestive efficiency, urinary energy, and heat increment of feeding. The importance of incorporating these factors is apparent from our studies of Steller sea lions which suggest they would have to consume an average of about 75% (range 35 to 130%) more pollock than herring to maintain a similar net energy intake (even without the additional costs of consuming larger meal sizes) (Rosen and Trites, 1997, 2000, in press).

Effect of Inadequate Nutrition

Changes in the Energy Budget

Inadequate nutrition frequently affects body size and/or composition. To determine whether Steller sea lions in the wild are nutritionally stressed researchers routinely record a series of morphologic measurements to compare animals between sites and years. While some of these measures offer absolute comparisons (e.g., mass, length) they are also used to calculate a variety of multi-parameter ‘condition indices.’ As the ‘condition’ of marine mammals is often defined as the relative extent of the hypodermal blubber layer, researchers also use a number of measures that directly estimate the extent of this lipid reserve. These indices can only be developed and evaluated with appropriate longitudinal data from animals with a known nutritional profile.

Changes in food supply can result in changes in animal behavioral. Researchers have constructed activity budgets of wild Steller sea lions, using either direct observation or telemetric data collection. The goal is to discern behavioral differences that may indicate or contribute to nutritional stress. These data includes nursing times, foraging trip length, dive profiles, foraging effort, etc. (Milette, 1999)

It is difficult to translate these behavioral differences into energetic currency. Measuring individual bioenergetic parameters on captive animals helps to estimate the energetic consequences of changes in observed activity budgets. This information can be assimilated through a responsive bioenergetic model that estimates the energetic outcome of changes in behavior, generates novel hypotheses of how changes in one parameter may effect others, and highlights critical parameters that need further research (Winship, 2000).

It is also critical to remember that animals can adapt to changes in energetic input through a suite of behavioral and physiologic adjustments. For example, when faced with decreases in energy intake, animals can display either a foraging response (increased energy expenditure due to increased foraging effort) or metabolic depression (decreased energetic expenditures to limit tissue loss). Experimental studies with captive Steller sea lions have helped to understand what determines which strategy is employed, and the extent to which they can compensate for decreases in energy intake (Rosen and Trites, 1999b).

Most bioenergetic parameters are measured one at a time. However, documenting and understanding the interactions between bioenergetic parameters is important for a realistic interpretation of the energetic consequences of changes in energy intake. For example, we have examined the interaction between the heat increment of feeding and thermoregulation in Steller sea lions to determine whether the heat increment of feeding is lost as heat or whether it can be used to offset thermoregulatory costs (Rosen and Trites, 1999a).

Changes in Overall Health

A variety of biological samples can be obtained from wild animals to determine their nutritional status. Tissue and blood samples provide information on toxic loads (PCBs, metals), and to screen for disease and pathogens. Blood samples can also used to look for biochemical indicators of nutritional stress (e.g., blood urea nitrogen and ketone body concentrations, and free radical buffering capacity).

Studies with captive animals are necessary to validate these measures. Researchers have used controlled feeding experiments (short-term fasts and longer-term reduced food intake) to determine the range of blood metabolite concentrations in sea lions undergoing a known level of nutritional stress (Rea et al., in press). Diet shift studies have provided information on the effect of different prey types on oxidative stress and vitamin deficiencies. Feeding manipulation studies can not only provide a framework for interpreting values obtained from wild animals, but studies using supplemented diets can directly test competing hypotheses regarding the proximate cause of any observed deficiencies.

Consequences to Life History

Nutritional stress caused by inadequate diet can impact populations by altering life history parameters, such as reproductive and survival rates. Counts and surveys of wild populations are critical to evaluate this. Unfortunately, studies with large captive animals are necessarily excluded from empirical tests of this hypothesis due to logistic and ethical constraints.

However, studies with captive animals can still provide data on the ultimate effect of changes in diet on life history parameters. For example, longitudinal blood samples can provide comparative data for interpreting blood hormone concentrations from wild sea lions. Appropriate alternate animal models can also be used to perform the types of empirical experiments examining the impact of diet changes on life history traits that are impractical with sea lions.

Summary

Problems concerning populations of wild animals must ultimately be addressed by field data. However, the flexibility and control inherent in empirical studies conducted in the laboratory make them critical to testing specific hypotheses and verifying measurements and techniques to be used with wild animals. Creativity and care in experimental design and application provide invaluable research tools. The framework outlined in Table 1 is providing a structured approach to evaluate whether the decline of Steller sea lions has been caused by nutritional stress. The aim is to gather data that will ultimately be used to aid in the recovery of wild sea lion populations.

Literature Cited

Milette, L.L. 1999. Behaviour of lactating Steller sea lions (*Eumetopias jubatus*) during the breeding season: A comparison between a declining and stable population in Alaska. M.Sc. thesis, University of British Columbia, Vancouver, Canada.

Rea, L.D., D.A.S. Rosen, and A.W. Trites. (in press). Rapid metabolic adaptation to fasting in Steller sea lion pups. Can. J. Zool.

Rosen, D.A.S. and A.W. Trites. 1997. Heat increment of feeding in Steller sea lions, *Eumetopias jubatus*. Comp. Biochem. Physiol. 118A: 877-881.

Rosen, D.A.S. and A.W. Trites. 1999a. Hold the hot sauce: heat increment of feeding does not contribute to thermoneutrality in Steller sea lions. *In* 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Hawaii, 28 Nov - 3 Dec, 1999. pp. 163.

Rosen, D.A.S. and A.W. Trites. 1999b. Metabolic effects of low-energy diet on Steller sea lions, *Eumetopias jubatus*. Physiol. Biochem. Zool. 72: 723-731.

Rosen, D.A.S. and A.W. Trites. 2000. Digestive efficiency and dry-matter digestibility of Steller sea lions fed herring, pollock, squid, and salmon. Can. J. Zool. 78: 234-239.

Rosen, D.A.S. and A.W. Trites. (in press). Pollock and the decline of Steller sea lions: testing the junk food hypothesis. Can. J. Zool.

Winship, A.J. 2000. Growth and bioenergetic models for Steller sea lions (*Eumetopias jubatus*) in Alaska. M.Sc. thesis, University of British Columbia, Vancouver.

Table 1. Outline of the type of data that can be collected from animals in the wild and in the laboratory to evaluate the potential impact of diet on overall population health. The list was compiled to investigate the nutritional stress hypothesis in relation to Steller sea lion population declines, but can be readily adapted to other species.

Question of interest	Field data	Laboratory data
Food intake		
What are they eating? How much are they eating? Where are they eating?	- scat and stomach samples - fatty acids, stable isotopes - telemetry data	- validating techniques
Quality of prey	- survey and archive prey	
Net energy from prey		- digestive efficiency - heat increment of feeding -urinary energy loss
Nutritional components		- vitamins - minerals - essential fatty acids
Effect of inadequate nutrition		
Changes in energy budget	- morphologic measurements - field energetic rates - activity budgets	- bioenergetic parameters - energetic adaptations - body condition indices
Changes in overall health	- blood biochemistry - tissue samples - disease panels	- validate blood biochemistry - supplementation studies - toxin analyses
Consequences to life history	- population numbers - survival rates - reproductive rates	- alternate animal models - reproductive hormones