Effects of Body Condition on Resting Metabolism in Captive and Free-ranging Steller Sea Lions (*Eumetopias jubatus*)

Lisa A. Hoopes[1]*
Lorrie D. Rea[2]
David A.S. Rosen[3]
Graham A.J. Worthy[4]

[1]Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843 USA; [2]Alaska Department of Fish and Game, Anchorage, AK 99518 USA; [3]Marine Mammal Research Unit, University of British Columbia, Vancouver, BC, Canada; [4]Department of Biology, University of Central Florida, Orlando, FL 32816 USA

Introduction

Steller sea lions (*Eumetopias jubatus*) are the largest of the short-haired otariids and range from California to Japan and Russia, with the majority of the world's population located in Alaska. The western Alaskan Steller sea lion population has continuously declined over the past 3 decades to about 10% of peak population levels and this species is now listed as threatened in their eastern Alaskan range, and endangered in their western range (Merrick et al., 1987; Loughlin, 1998). A number of proximate and ultimate factors have been suggested as the mechanism of decline, but reduced juvenile survival and nutritional stress are the leading but unconfirmed hypotheses attributed to this decline (York, 1994; Merrick and Loughlin, 1997; Calkins et al. 1998).

Nutritional stress may occur through changes in prey quality, density and/or distribution, and implies that energetic demands on the animal (e.g., locomotion, thermal balance, reproduction, molting, and/or growth) are not being met by energy input. Some animals are able to compensate for limited food intake by limiting their energy expenditures, with the most common physiologic response being a lowering of resting metabolic rate (RMR), known as metabolic depression. Metabolic depression has been documented in captive Steller sea lions fed a low-energy diet of pollock and squid for 12-14 days (Rosen and Trites, 1999, 2000) and this reduction in RMR (15-24%) was nearly comparable to the 30% reduction in RMR seen in fasting sea lions. (Rosen and Trites, 2002). Given the evidence of metabolic depression in captive sea lions, the objectives of this study were to compare RMR from animals in the eastern and western Alaskan populations to discern whether there is any evidence of nutritional stress.

Methods

Oxygen consumption data were collected from captive Steller sea lions held at the Vancouver Aquarium, Vancouver, BC and from free-ranging Steller sea lions captured from western and eastern Alaskan stocks.

Vancouver

Oxygen consumption rates were measured for both pups (n=4, 58-60 kg) and sub-adult (n=5, 97-156 kg) Steller sea lions in water. Open flow respirometry was used to measure oxygen consumption rates of animals held in a temperature-controlled seawater-filled swim flume as described by Rosen and Trites (1999, 2002). The swim flume was equipped with a 120-liter lexan respirometry dome, under which the sea lions could surface to breathe. Air was drawn through the dome at a constant rate (range 140-200 l min-1) and oxygen and carbon dioxide concentrations within a desiccated sample of air were determined by a fuel cell analyzer (FC-1B, Sable Systems, Nevada, USA) and an infrared gas analyzer (CA-2A, Sable Systems, Nevada, USA), respectively. RMR was determined at three water temperatures (2, 4, 8 °C) on post-absorptive animals held in the flume between 20-25 min.

All sub-adult sea lions began the study in a state of reduced body condition after being subjected to a sub-maintenance diet of varying length (9 days or 31 days) as part of a separate study (see Kumagai et al. 2003; Rosen unpublished data). Sub-adult sea lions were fed throughout the duration of the current study (31-34 days) to achieve pre-fasting body mass levels. Deuterium oxide dilution was used to assess body condition (expressed as % total body fat, TBF) at the start and end of each trial. Body condition manipulations were not undertaken with sea lion pups.

Alaska

Oxygen consumption rates were also measured from free-ranging animals (aged 5, 8, 17, and 20 mo) captured from the western stock in Prince William Sound (PWS, n=23) and from the eastern stock in Southeast Alaska (SE, n=23). Open flow respirometry was used to measure oxygen consumption of animals held in a 1,022-l chamber consisting of a lexan lid which fitted into a trough on a wooden base. Seawater was used to fill the trough to ensure that the chamber was airtight. Air was drawn through the chamber at a constant rate (range 150-230 L min^{-1}) and fans were mounted in the corners of the lid to ensure air mixing. Oxygen and carbon dioxide concentrations were measured using the Sable System analyzers as described above. RMR was determined at ambient air temperatures (mean range -6 to 3°C) on post-anesthetized animals held in the chamber for 30-120 min.

Results and Discussion

In water, RMR ranged from 33.3 to 56.7 MJ/day for sub-adult animals (109-158 kg, 2.9-4.6 times predicted for an adult animal) and from 20.0 to 26.6 MJ/day for pups (57-59 kg, 3.3-4.3 times predicted) at 2°C. RMR, generally decreased with increasing water temperature, but the relationship was not statistically significant. Sub-adult animals experienced dramatic changes in body mass (9-17%) over the course of the trial that corresponded with changes in body condition (0.2-12.5% TBF). The response of RMR to changing body condition varied. As body mass and TBF recovered during the trial, the smallest sub-adult sea lion exhibited a 49% decline in RMR at 2°C and a 40% decline at 4 and 8°C. However, a larger animal, which exhibited a 9% increase in body mass over the course of the trial, showed little change in RMR at all temperatures. In this latter case, percentage TBF change over the duration of the trial was negligible. Reduced body condition had a noticeable impact on RMR in juvenile sea lions at colder water temperatures. The results of the present study suggest that young sea lions would be subject to even greater thermoregulatory demands if their body condition were reduced.

With a 6ºC increase in water temperature, sub-adult sea lions decreased RMR by 0-23% when at their poorest body condition. At the end of the trial when pre-fasting body mass had been regained, this same increase in temperature generally produced a smaller decrease in RMR (2-17%).

In air, mean RMR ranged from 16.4 to 21.0 MJ/day in free-ranging pups (47-106 kg) and from 20.2 to 28.3 MJ/day in yearlings (115-159 kg.). These values represent 1.8-2.8 times the predicted mammalian value. Despite slight differences in age, within each age class, animals from western and eastern regions were similar in body mass and blubber depth. Mass-specific RMR was significantly higher for both pups and juveniles captured in PWS (mean ambient temperature -6°C) compared to animals of similar age from SE (mean 3ºC). This 9ºC difference in air temperature corresponds to a 28% greater RMR in PWS pups over SE pups, and a 40.1% increase in RMR in PWS yearlings over SE yearlings. These differences in mass-specific RMR may be due to slight differences in age (and thus growth rate), but given the similarities in mass between SSL's from both regions, these differences are more likely a result of differences in ambient temperature. This suggests that animals from PWS may be operating below their lower critical temperature. At this point in our study there is no evidence of metabolic depression in western stock animals.

Acknowledgments

Thanks a million to the trainers and technicians at the Vancouver Aquarium and the crews of the P/V Stimson and P/V Medeia for assistance with data collection and sea lion handling. Financial assistance was provided by the North Pacific Universities Marine Mammal Research Consortium, Alaska Department of Fish and Game and the University of Central Florida.

Literature Cited

Calkins, D.G., E.F. Becker, and K.W. Pitcher. 1998. Reduced body size of female Steller sea lions from a declining population in the Gulf of Alaska. Mar. Mammal Sci. 14:232-244.

Kumagai, S., D.A.S. Rosen, and A.W. Trites. 2003. Seasonal differences in body composition and energy intake balance in response to low energy intake in Steller sea lions (*Eumetopias jubatus*). 15th Biennial Conference on the Biology of Marine Mammals. December 14-19, 2003, Greensboro, NC.

Loughlin, T.R. 1998. The Steller sea lion: A declining species. Biosphere Conserv. 1:91-98.

Merrick, R.L., T.R. Loughlin, and D.G. Calkins. 1987. Decline in the abundance of the northern sea lion (*Eumetopias jubatus*) in Alaska, 1956-86. Fish. Bull. 85:351-365.

Merrick, R.L. and T.R. Loughlin. 1997. Foraging behavior of adult female and young-of-the-year Steller sea lions in Alaskan waters. Can. J. Zool. 75:776-786.

Rosen, D.A.S. and A.W. Trites. 1999. 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. Cost of transport in Steller sea lions, *Eumetopias jubatus*. Mar. Mammal Sci. 18:513-524.

York, A. 1994. The population dynamics of Northern sea lions, 1975-1985. Mar. Mammal Sci. 10:38-51.