Steller Sea Lion Feeding Habits in the Russian Far East, 2000-2003

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Abstract

During the breeding seasons of 2000-2003 we collected 1,724 scats from seven rookeries and eighteen haul-outs on the Kamchatka Peninsula and in the Kuril Islands, Okhotsk Sea, and Commander Islands to analyze the diet of Steller sea lions (*Eumetopias jubatus*) in the Russian Far-East. The most frequently encountered prey items in all scats combined were Atka mackerel (*Pleurogrammus monopterygius*), walleye pollock (*Theragra chalcogramma*), salmon (*Oncorhynchus* sp.), sculpins (Cottidae), cephalopods, Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasii*), Northern smoothtongue (*Leuroglossus stilbius*), snailfish (Liparidae), and Pacific cod (*Gadus macrocephalus*).

Spatial differences were analyzed by comparing frequency of occurrence (FO) values on a site-by-site basis for each year and all years combined. Breeding-season collection sites were grouped into seven geographic regions based on FO similarities using cluster analysis. Diet diversity was calculated for each of these geographic regions. No significant relationship was found between diet diversity and population trend ($P = 0.886$). Significant differences in diet composition were found between geographic regions ($P < 0.001$ for all regions). Significant seasonal differences were also detected at two haul-outs on the Kamchatka Peninsula from which an additional 93 scats were collected during the fall molt ($P < 0.001$ for both locations).

Introduction

The Steller sea lion (*Eumetopias jubatus*) ranges along the continental shelf of the Pacific Ocean from the Kuril Islands and Okhotsk Sea, across the Bering Sea and the Gulf of Alaska, and south along the coast of North America to California. The Steller sea lion population in the United States was listed under the U.S. Endangered Species Act as threatened in 1990. The Steller sea lion was listed in the Russian Red Book as an endangered species in 1994. Based on genetic studies, population dynamics, and morphological studies, the Steller sea lion population was divided into two separate stocks by the National Marine Fisheries Service (NMFS 1995, Bickham et al. 1996). The eastern stock (east of 144°W) appears to be stable or increasing (Calkins et al. 1999), while the Alaska population of the western stock has declined 80-90% over the last 20-30 years (NMFS 1995). In 1997, the western stock in Alaska was classified as "endangered" under the U.S. Endangered Species Act (U.S. Federal Register 62:24345-24355). The Steller sea lion population of the Kuril Islands, Okhotsk Sea, and Bering Sea in Russia is part of the western stock and has also been unstable for the last three decades (Perlov 1977, Burkanov et al. 1991, Loughlin et al. 1992, Burkanov 2000).

Though the cause for the Steller sea lion decline in Alaska has not yet been determined, one of the leading hypotheses is nutritional stress or food limitation as a result of changes in the quantity and/or quality of certain prey items (Calkins and Goodwin 1988; NMFS 1995, 2001). Studies that have been conducted in North American waters to describe the diet of Steller sea lions (Imler and Sarber 1947, Mathisen et al. 1962, Fiscus and Baines 1966, Pitcher 1981, Merrick and Calkins 1996, Merrick et al. 1997, Riemer and Brown 1997, Sinclair and Zeppelin 2002, etc.) allow for spatial and temporal analyses of prey utilization in these areas over time, and a significant relationship between diet diversity and rate of population change has been described (Merrick et al. 1997). Information on the diet of Steller sea lions in Russian waters, however, is intermittent and sparse (Belkin 1966, Panina 1966, Perlov 1975). The primary purpose of this study was to describe the recent diet of Steller sea lions in Russian waters. The data presented here have been used to explore a preliminary relationship between diet diversity and population trends in the Russian Far-East; however, additional scat collections through 2005 and population surveys through 2006 are being performed in order to perform a more comprehensive analysis.

Methods

During the breeding seasons of 2000-2003 (May through August) we collected 1,728 scats from seven rookeries and nineteen haul-outs on the Kamchatka Peninsula and in the Kuril Islands, Okhotsk Sea, and Com-

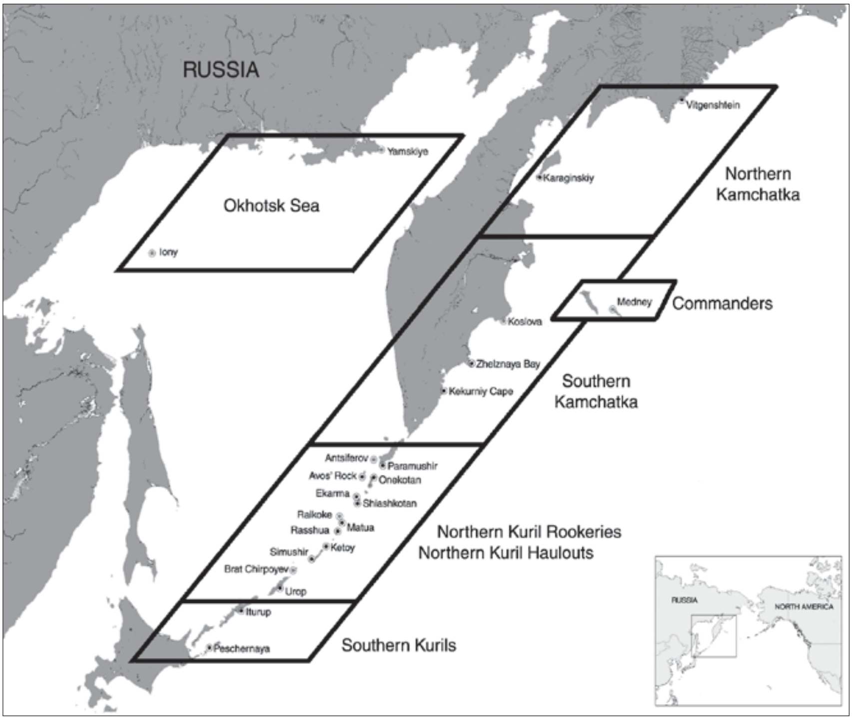

Figure 1. Scat collection sites and geographic regions of diet similarity.

mander Islands (Fig. 1). An additional 93 scats were collected from two of these haul-outs in the fall during molt (Table 1). Scats were collected opportunistically when rookeries and haul-outs were disturbed for other research purposes.

Population counts were performed on rookeries and haul-outs from both land and sea. Land-based counts were performed from an elevated vantage point whenever possible. The few boat-based counts that were performed were only done at haul-outs and only when weather conditions would not allow landing a skiff on the rocks. Field camps were also placed on five of the rookeries and one rookery was monitored via remote video system. At these locations, regular counts were performed throughout the breeding season.

Each scat was placed in a plastic zip-loc bag and processed in the field onboard the support vessel. The plastic bags were filled with water and a mild dishwashing detergent and allowed to soak for 12-24 hours while being agitated by the movement of the vessel. The resulting slurry was rinsed through a series of three nested mesh sieves (VWR Scientific,

Table 1. Total number of scats collected in the Russian Far-East from 2000 to 2003 by year, location, and season.

	2000	2001	2002		2003	
Location	Breed	Breed	Breed	Molt	Breed	Location total
Antsiferov	25	33	70	–	121	249
Avos Rock	–	9	20	–	–	29
Brat Chirpoyev	54	29	32	–	68	183
Ekarma	–	5	–	–	–	5
Iony	–	97	59	–	–	156
Iturup	–	18	–	–	–	18
Karaginsky	–	–	21	21	–	42
Kekurniy	–	12	68	–	16	96
Ketoy	–	28	–	–	–	28
Kozlov	–	9	74	72	–	155
Matua	–	12	–	–	27	39
Medny	–	12	–	–	–	12
Onekotan/KYP	–	39	30	–	–	69
Paramushir	–	40	–	–	–	40
Peshchernaya	–	32	–	–	78	110
Rasshua	–	10	–	–	–	10
Raykoke	–	42	14	–	58	114
Shiashkotan	–	33	40	–	103	176
Simushir	–	38	19	–	45	102
Urop	–	–	–	–	50	50
Vitgenshteyn	–	–	21	–	–	21
Yamskiye	–	16	44	–	–	60
Zheleznaya	–	–	53	–	–	53
Season total	79	518	565	93	566	1,821

#18, #25, and #35 U.S. Standard Size). Solid fecal material was gently wiped with a soft brush and rinsed with water until it passed through the sieves. The remaining undigested elements were frozen and brought back to either the Alaska SeaLife Center (Seward, Alaska) or the National Marine Mammal Lab (Seattle, Washington) where they were then dried, placed into vials, and shipped to Pacific IDentifications (Victoria, British Columbia) for analysis.

The relative importance of each prey item was calculated using simple frequency of occurrences (FO). Scats that were empty and remains that could not be identified with certainty to at least the family level were not included in the analysis.

Spatial differences were analyzed by comparing FO values on a site-by-site basis for each year and all years combined. Identified prey items were grouped into seven categories: (1) gadids; (2) salmon; (3) forage fish; (4) flatfish; (5) hexagrammids; (6) cephalopods; and (7) other prey (Merrick et al. 1997). If a scat contained more than one species from a particular category, it was scored as having a single occurrence of that individual category. The relative importance of each of these categories was calculated using split-sample frequency of occurrence (SSFO) (Merrick et al. 1997). Breeding-season collection sites were grouped into geographic regions based on these SSFO values using an agglomerative hierarchical cluster analysis (Sinclair and Zeppelin 2002). A diet diversity index (DDI) was calculated for each rookery and for each region using the SSFOs and Shannon's index of diversity (Ludwig and Reynolds 1988). The population trends estimated from 2000-2004 for each of these regions were compared to the corresponding DDI.

Seasonal differences were analyzed for the two haul-outs for which scats were collected in both summer and fall.

Results

A total of 83 different prey items were identified (50 to species) in the 1,633 scats that contained identifiable remains. The ten most frequently encountered prey items in all scats combined were Atka mackerel (*Pleurogrammus monopterygius*), walleye pollock (*Theragra chalcogramma*), salmon (*Oncorhynchus* sp.), sculpins (Cottidae), cephalopods, Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasii*), northern smoothtongue (*Leuroglossus stilbius*), snailfish (Liparidae), and Pacific cod (*Gadus macrocephalus*).

Plotting the results of the cluster analysis by geographic location resulted in seven distinct geographic areas of prey similarity: Northern Kamchatka Peninsula, Southern Kamchatka Peninsula; Commander Islands; Northern Kuril Island rookeries; Northern Kuril Island haul-outs; Southern Kuril Islands; and the Northern Sea of Okhotsk (Fig. 1). The Commander Islands may have been identified as a separate cluster due to the small sample size from that site ($n = 12$). Chi-square was used to test the hypothesis that there was no difference between the diets of each cluster ($\chi^2 = 2476.914$, $P < 0.001$). Diet composition for each region is given in Table 2.

There was not a significant relationship between diet diversity and rookery population trends ($R^2 = 4.56 \times 10^{-3}$, $P = 0.886$) or population trends by cluster ($R^2 = 0.0616$, $P = 0.591$) (Fig. 2). For example, the South-

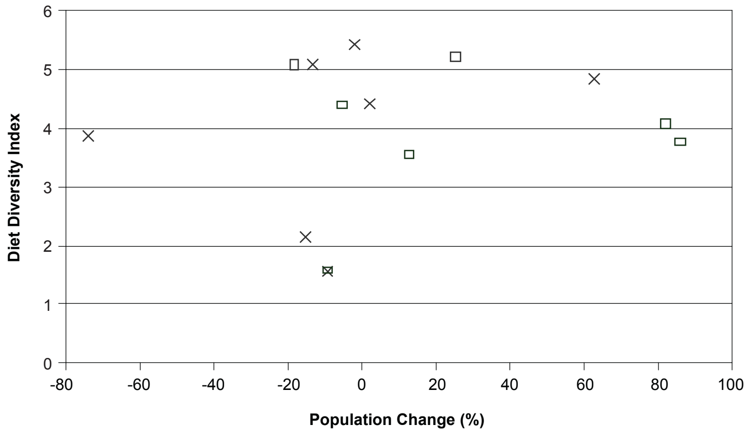

Figure 2. Rate of population change versus diet diversity index. X represents clusters and square represents individual rookeries.

ern Kuril Islands had the highest level of diet diversity (DDI = 5.44), but had a relatively stable population trend, whereas the Southern Kamchatka Peninsula had the second highest level of diet diversity (DDI = 5.07) but also the second highest level of population decline.

The ten most common prey items consumed by Steller sea lions in the Russian Far East were similar to those consumed by the western stock in Alaska waters (Sinclair and Zeppelin 2002); however, the proportions consumed were significantly different ($\chi^2 = 20.727$, $P = 0.014$). The primary contributor to this result is the significantly higher occurrence of sculpins (FO = 26%). Differences in the proportion of other prey items consumed were not significant at the 5% level ($\chi^2 = 10.950$, $P = 0.205$).

The 2002 summer and fall diets of sea lions on Koslova Cape, a rookery on the Kamchatka Peninsula, were significantly different ($\chi^2 = 340.797$, $P < 0.001$). During the breeding season, the three primary prey items were walleye pollock, Atka mackerel, and sculpins. In the fall, Pacific sand fish (*Trichodon trichodon*) and salmon were the dominant prey items. Poachers (Agonidae), pricklebacks (Stichaeidae), and Arctic lampreys (*Lampetra japonica*) occurred in high numbers during the fall but did not occur during the breeding season.

The 2002 summer and fall diets of sea lions on Karaginsky Island, a haul-out on the Kamchatka Peninsula, were also significantly different ($\chi^2 = 529.939$, $P < 0.001$). During the fall, the sea lions switched from a diet of primarily sculpins and sand lance to one consisting almost entirely of salmon and skates (*Raja* sp.).

Table 2. Frequency of occurrence of prey items found in sea lion scat collected in the Russian Far-East during 2000-2003.

	Frequency of occurrence (%)						
Prey item	Russian range $n = 1633$	Northern Kamchatka $n = 42$	Southern Kamchatka $n = 226$	N. Kuril haul-outs $n = 524$	N. Kuril rookeries $n = 503$	Southern Kurils $n = 125$	Sea of Okhotsk $n = 201$
Anchovy sp.	4.2	0.0	0.0	0.2	0.0	50.4	2.0
Atka mackerel	65.7	4.8	69.5	98.1	58.8	27.2	0.5
Capelin	6.6	38.1	35.0	0.0	2.2	0.0	0.5
Cephalopods	14.2	4.8	6.6	8.2	20.9	21.6	14.9
Flatfish sp.	3.4	16.7	11.5	0.4	1.6	5.6	2.5
Greenling sp.	3.1	7.1	7.5	2.9	3.8	8.8	0.0
Gunnel sp.	2.1	4.8	0.4	1.7	0.2	12.8	1.5
Herring	9.2	0.0	0.9	0.2	2.0	0.8	67.7
Lampfish sp.	1.6	0.0	2.2	0.8	2.8	0.0	1.0
Lumpsucker sp.	2.4	2.4	1.3	2.1	3.6	0.8	0.5
N. smoothtongue	7.1	0.0	0.0	1.3	20.9	0.0	2.0
Other gadids	2.1	42.9	1.3	0.4	0.2	6.4	1.0
Pacific cod	6.9	2.4	11.5	1.3	4.4	41.6	1.5
Pollock	32.4	23.8	62.4	6.5	38.4	14.4	65.2
Polychaete worms	10.1	9.5	15.0	7.3	7.2	4.0	16.9
Prickelback sp.	2.8	2.4	0.0	3.2	1.0	12.0	0.5
Salmon sp.	29.9	0.0	14.6	10.7	60.4	5.6	41.8
Sand lance	10.6	95.2	31.4	1.9	2.4	29.6	0.5
Sandfish	2.2	2.4	8.8	1.7	0.6	0.8	0.0
Sculpin sp.	25.7	92.9	53.1	8.6	10.1	76.8	25.4
Skate sp.	3.0	0.0	12.4	0.6	1.4	6.4	1.5
Smelt sp.	0.9	0.0	5.3	0.0	0.0	2.4	0.0
Snailfish sp.	7.1	11.9	7.1	9.5	2.6	8.8	4.0
Stickleback sp.	3.4	14.3	17.7	0.2	1.6	0.0	0.0

Commander Islands are not shown (100% Atka mackerel, 33% polychaete worms, $n = 12$).

Discussion

Plotting the results of the cluster analysis by geographic location resulted in distinct groups of contiguous sites. This pattern is likely to be mainly an artifact of fish distribution due to latitude and season. The effect of normal geographic fish distribution is most evident by the distinctly different diets of sea lions in the northern- and southern-most clusters. Anchovies, most likely Japanese anchovy (*Engraulis japonicus*), occur only in the Southern Kurils cluster where they are the second most frequently occurring prey item (50.4%). The northern range of this species is the southern Sakhalin Islands, the Sea of Japan, and the Pacific coasts of Japan (Whitehead et al. 1988), which explains its occurrence in scat collected in the southern Kuril Islands only. A conglomerate of "other" gadids, such as Arctic cod (*Boreogadus saida*) and saffron cod (*Eleginus gracilis*), but not Pacific cod or walleye pollock, are the third most commonly occurring prey items in the Northern Kamchatka cluster (42.9%). Arctic cod have a more northern distribution and saffron cod are more likely to be found in the shallow coastal waters of the mainland (Cohen et al. 1990) rather than the deep waters surrounding the offshore islands of the Kuril chain.

The timing of local fish runs and scat collection efforts may also have influenced the results of the cluster analysis. The majority of the breeding season scat collections occurred in late June and early July. By this time, offshore salmon schools may have already passed through the southern Kuril chain but not yet reached the near-coastal waters of the Kamchatka Peninsula. During the summer, salmon occurred in only 14.6% of scats in the Southern Kamchatka cluster. However, in the fall the FO of salmon increased to 58.7%.

The diet of sea lions in the Russian Far-East is similar to that of sea lions in the western stock in Alaska (Sinclair and Zeppelin 2002). Like in the Aleutian Islands, Atka mackerel, walleye pollock, and salmon are the most commonly consumed prey items. The most noticeable difference in diet between the two populations is the abundance of sculpins consumed by the sea lions in Russia. Sculpins were found in one quarter of all scats collected and are among the top three most predominant prey items in half of the diet clusters (Table 2). Unfortunately, little is know regarding the nutritional value of this family. Eighteen species of sculpins were identified in the scat, but published nutritional values are available for only a few of these species. However, some species, such as yellow Irish lord (*Hemilepidotus jordani*), have a higher percent lipid value than salmon and energetic densities similar to salmon, adult pollock, and Pacific cod (Logerwell and Schaufler 2005).

Merrick et al. (1997) found that as diet diversity in Alaska decreased, the rate of population decline increased, and suggested that sea lions need a variety of prey as a buffer against major changes in any single prey item; thus a population with a higher diet diversity index would be better prepared in the event of a crash of any given prey species than a population that relied primarily on only one or two prey items. Although Merrick et al. (1997) used diet data from the early 1990s, which may not reflect the oceanographic conditions or prey availability during the years of this study (1999-2003), the diet diversity index is based only on the number of prey groups consumed and does not take into consideration which specific prey items or groups these are or the nutritional quality of those prey items. Therefore, the diet diversity hypothesis as presented by Merrick et al. (1997) should be applicable regardless of the availability of specific prey items, oceanographic conditions, or geographic region. However, this trend was not found in Russian waters, wherein some of the areas with the highest levels of diet diversity also had the highest levels of population decline.

While the availability of alternate food sources may be important, calculating diet diversity based on scat content only provides an index of what a particular population happened to be consuming at the time of scat collection, and does not necessarily represent everything that is available for consumption. Populations that are feeding primarily on one or two species (i.e., "low diet diversity") may be doing so because of a high abundance of those species, not because of a reliance on those species. The absence of other species in the scat does not necessarily indicate the absence of other prey items available for the sea lions to consume in the event that their primary prey item is diminished. The opposite may apply to populations with high diet diversity. While the consumption of many different prey items may indicate the availability of many different prey items, it may also indicate the lack of a primary or abundant food source. The sea lions in these regions may be consuming lower proportions of multiple prey items in an effort to compensate for the lack of an abundant primary prey item.

The current method for calculating Steller sea lion diet diversity indexes may not accurately describe diet diversity in a way that can be used to make inferences to foraging behavior, foraging success, prey availability, and population trends. Using split-sample frequencies of occurrence and presence vs. absence of a limited number of broad prey categories, a collection of scats that contains the remains of only three prey species could have the same diet diversity index as a collection that contains 35 different prey species. Little can be said about the foraging success of these two populations without considering the individual species and nutritional quality of the prey consumed, amounts of each prey item consumed (rather than using presence/absence), and actual prey availability.

Instead of relying on simple frequency of occurrence and diet diversity index, a comprehensive Diet Quality Index should be developed that incorporates size and minimum number of prey individuals consumed, digestive correction factors like those described by Tollit et al. (2004), and the nutritional quality of each prey species. Population structure should be considered before average caloric intake and diet quality can be compared between sites, as different age classes, sexes, and reproductive statuses may have different energy requirements. In addition to describing the prey consumed by sea lions, it is important to determine the prey available for consumption in any given area before an accurate assessment of foraging success can be made.

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