Relationship between Steller Sea Lion Diets and Fish Distributions in the Eastern North Pacific

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Abstract

Distributions of fish species were compared with diet information for Steller sea lions (*Eumetopias jubatus*) to assess the level of correspondence between potential prey availability and sea lion feeding habits. Fish distributions were compiled as part of the Sea Around Us Project at the UBC Fisheries Centre, and were based on published distributions and habitat preferences (e.g., latitude, depth). Sea lion scat samples were collected during the 1990s from seven geographic regions from Oregon to the western and central Aleutian Islands. The frequencies of occurrence of four prevalent species (walleye pollock, *Theragra chalcogramma*; Pacific herring, *Clupea pallasii*; Pacific cod, *Gadus macrocephalus*; and North Pacific hake, *Merluccius productus*) in the Steller sea lion diet were compared to their distributions in the North Pacific Ocean. The data suggest that Steller sea lion diets broadly reflect the distributions of these major prey species. However, some of the fish species that were regionally predicted to be present in high abundance were not proportionally reflected in the Steller sea lion diet, suggesting that other factors in addition to fish abundance influence their diets.

Introduction

The Steller sea lion population declined by more than 80% in western Alaska between the mid-1970s and the early 1990s (Trites and Larkin 1996, Loughlin 1998, NAS 2003) while the smaller eastern population increased. Accordingly, the western and eastern populations of Steller sea lions were listed as “endangered” and “threatened,” respectively, un-

der the U.S. Endangered Species Act. In an attempt to better understand their role in the ecosystem and the differences between the decreasing western population and the increasing eastern population, considerable research has focused on determining the diet of Steller sea lions (Merrick et al. 1997, Sinclair and Zeppelin 2002).

Comprehensive changes have occurred to the biomass and composition of the marine community off the Alaska coast since the oceanic regime shift of 1976. Increases were noted following the regime shift in the abundances of flatfish, gadids, and salmonids (Hare and Francis 1995, Hollowed et al. 2001, Benson and Trites 2002, Wilderbuer et al. 2002). A small mesh survey around Kodiak Island (1953-1997) also noted increases in groundfish such as cod and pollock, as well as a decline in the abundance of forage species such as capelin and shrimp (Anderson and Piatt 1999). Such changes in the abundances and distributions of key prey species composition may be related to the decline of Steller sea lions in western Alaska.

One of the leading hypotheses for the decline in western Alaska is nutritional stress caused by a shift in ocean climate that favored the abundance of less nutritious fishes over those that had higher fat content (Alverson 1992, Rosen and Trites 2000, Trites and Donnelly 2003, Trites et al. 2006). Like other pinnipeds, Steller sea lions have often been classified as generalist feeders. However, it is not clear whether Steller sea lions merely eat what is available to them, or whether other factors influence which prey they consume. We therefore sought to assess the level of correspondence between prey distribution and sea lion diets.

Methods

Predicted fish distribution maps were obtained from the Sea Around Us Project (Fisheries Centre, University of British Columbia, www.seaaroundus.org) and were based on published distributions and habitat preferences (e.g., latitude, depth) (Watson et al. 2004). These maps represent the expected percent of world distribution of individual fish species and are an indication of relative abundance of each species across the North Pacific Ocean.

Scat samples were collected during the 1990s (Riemer and Brown 1997, Sinclair and Zeppelin 2002, Trites et al. unpubl. data) from seven geographic regions from Oregon to the Central and Western Aleutian Islands (Oregon [OR], British Columbia [BC], Southeast Alaska [SEA], Gulf of Alaska 1 [GOA1], Gulf of Alaska 2 [GOA2], Eastern Aleutian Islands [EAI], and Western Central Aleutian Islands [WCAI]). Frequently occurring species (walleye pollock, *Theragra chalcogramma*; Pacific herring, *Clupea pallasii*; Pacific cod, *Gadus macrocephalus*; and North Pacific hake, *Merluccius productus*) in the Steller sea lion diet were compared to their predicted distributions. The importance of each prey species was deter-

mined by the percent frequency of occurrence (%FO) in scat samples from each region (Croxall 1993).

Proportionally sized circles, representing the %FO, were plotted for comparison with fish distributions in respective regions. Percentages of both diet and distribution data were arcsine transformed to satisfy the assumptions for statistical analysis.

Results and discussion

The data suggest that there is a relationship between fish distributions and Steller sea lion diets (Figs. 1 and 2). For example, in the northern part of the sea lion's range, walleye pollock has a high relative abundance and is an important part of the sea lion diet (Fig. 1A). Although not statistically significant ($r = 0.63$, $P > 0.05$), the correlation is positive and consistent with the relationship found for the other prey species. In the southern part of the sea lion range (e.g., Oregon), the predicted relative abundance of walleye pollock is lower and North Pacific hake is predominant both in relative abundance and in the sea lion diet ($r = 0.74$, $P = 0.05$) (Figs. 1A, 1D, and 2). A similar pattern can be seen with Pacific herring ($r = 0.80$, $P = 0.03$), arrowtooth flounder ($r = 0.83$, $P = 0.02$), and, to a lesser extent, Pacific cod ($r = 0.28$, $P > 0.05$), where the frequency of occurrence of the prey species in the diet of Steller sea lions is higher in regions that also have high predicted relative fish abundance (Figs. 1B, 1C, and 2).

While the relationship between relative fish abundances and Steller sea lion diets seems strong, it is not as straightforward as Figs. 1 and 2 might suggest. For example, in the Gulf of Alaska the biomass of arrowtooth flounder (Turnock et al. 2001) is estimated to be approximately six times the biomass of walleye pollock (Dorn et al. 2001). However, pollock is two to eight times more prominent in the Steller sea lion diet (%FO) than arrowtooth flounder (Sinclair and Zeppelin 2002) (Tables 1 and 2). Atka mackerel is also 35 times more prominent than rockfish in the diet of Steller sea lions in the Aleutian Islands region (Sinclair and Zeppelin 2002) despite the fact that both have a similar biomass estimate (Lowe et al. 2002, Spencer and Ianelli 2002) (Tables 1 and 2). Although not statistically significant, Atka mackerel ($r = –0.18$, $P > 0.05$) and Pacific ocean perch/Rockfish ($r = –0.29$, $P > 0.05$) show a weak negative correlation between the percent of world distribution and percent frequency of occurrence in Steller sea lion diet (Fig. 3).

Many factors likely influence the prey that sea lions choose to eat. These include the presence of spines, and the vertical and horizontal distribution of prey in the water column. Such factors may account for some of the apparent discrepancies between diets and relative prey abundances. For example, arrowtooth flounder may make up a large portion of the relative biomass, but may be harder for sea lions to locate and capture because they tend to be solitary and not school in easily

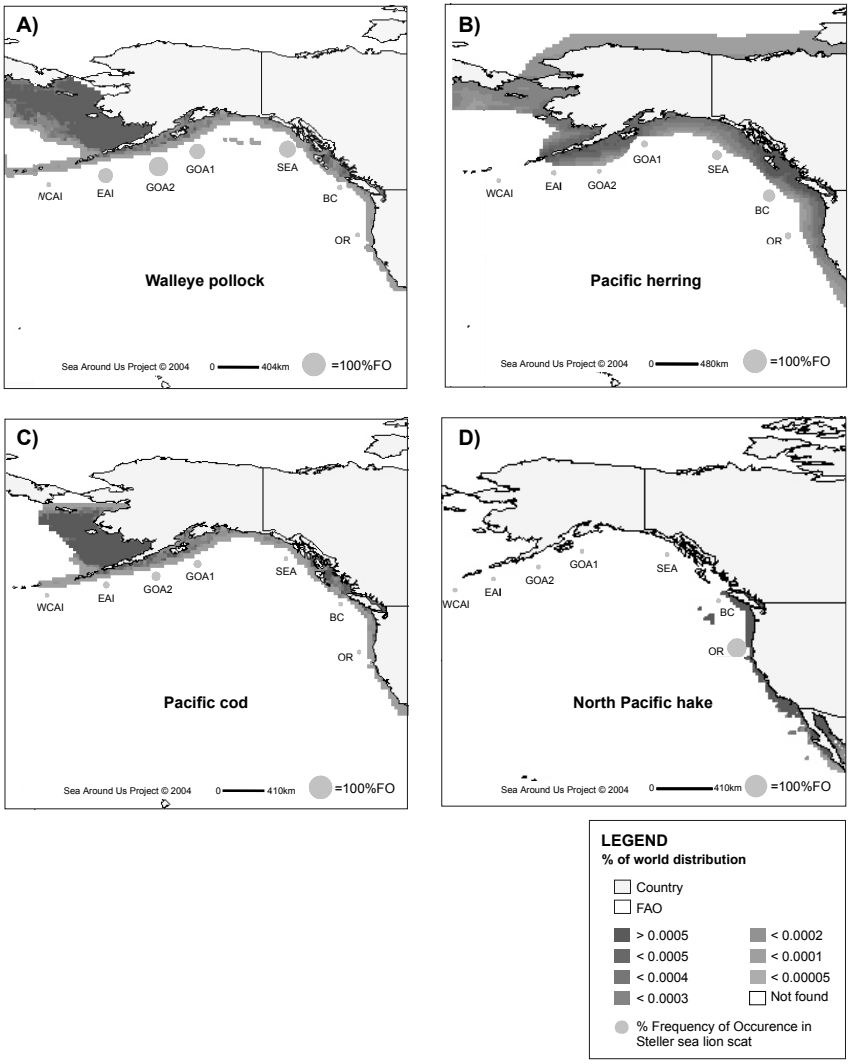

Figure 1. Predicted distribution and relative abundance of four species of fish in the eastern North Pacific (Watson et al. 2004). Grayscale shading indicates relative abundance of each species. Proportionally sized circles, plotted in respective regions, represent the percent frequencies of occurrence (%FO) of fish species in scat samples from Steller sea lions during the 1990s (from Riemer and Brown 1997, Sinclair and Zeppelin 2002, and Trites et al. unpubl. data). Regions, from left to right, are Western Central Aleutian Islands (WCAI), Eastern Aleutian Islands (EAI), Gulf of Alaska 2 (GOA2), Gulf of Alaska 1 (GOA1), Southeast Alaska (SEA), British Columbia (BC), and Oregon (OR).

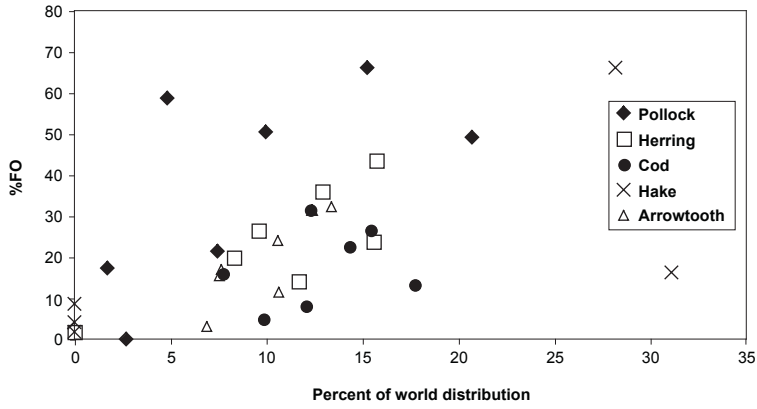

Figure 2. Relationship between percent frequency of occurrence in the diet of Steller sea lions in the 1990s and percent of world distribution for five prominent prey species in the North Pacific Ocean. Statistically significant positive correlations occur between world distribution and frequency of occurrence for herring, hake, and arrowtooth flounder. Correlations for pollock and cod were positive but not significant.

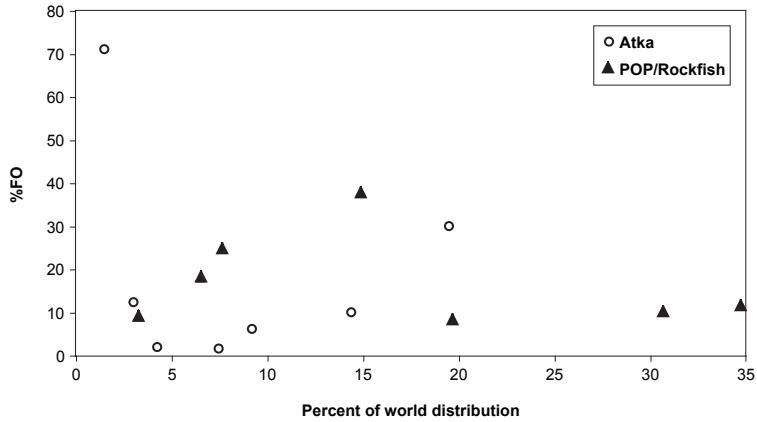

Figure 3. Percent frequency of occurrence versus percent of world distribution for two Steller sea lion prey species (Atka mackerel and Pacific ocean perch). Neither of the relationships were statistically significant.

Table 1. Percent frequency of occurrence (%FO) for prominent prey species in Steller sea lion scat.

		%FO[a]						
Region	N[b]	Walleye pollock	Pacific herring	Pacific cod	N. Pacific hake	Arrow-tooth flounder	Atka mackerel	Rockfish
WCAI	1,370	8.85	0.1[c]	7.62	0.1[c]	0.29	89.61	2.51
EAI	889	57.25	11.59	14.75	0.1[c]	3.93	25.32	4.02
GOA2	929	83.56	5.93	27.40	0.1[c]	8.49	3.12	3.13
GOA1	574	59.43	16.21	20.03	0.50	27.18	1.22	2.07
SEA	1,438	73.02	34.56	2.02	2.23	16.48	0.14	17.59
BC	1,077	13.28	47.45	5.29	7.80	28.51	0.09	37.60
OR	256	0	19.92	0.75	83.60	7.03	4.67	9.77

[a]Percentages were arcsine transformed prior to statistical analysis.
[b]Number of scat samples containing identifiable prey used to calculate annual average of percent frequency of occurrence (%FO).
[c]Species present but <1 (Sinclair and Zeppelin 2002).

Table 2. Percent of world distribution for prominent prey species in Steller sea lion scat.

	% of World distribution[a]						
Region	Walleye pollock	Pacific herring	Pacific cod	N. Pacific hake	Arrow-tooth flounder	Atka mackerel	POP/ rockfish
WCAI	0.09	0	1.81	0	1.44	0.06	0.33
EAI	12.50	2.08	6.12	0	3.40	11.09	32.45
GOA2	6.91	4.10	4.52	0	1.77	6.14	26.03
GOA1	2.99	7.22	7.08	0	4.60	2.53	11.34
SEA	0.71	5.00	4.36	0	3.38	0.54	1.78
BC	1.68	7.34	9.25	26.69	5.37	1.66	6.61
OR	0.22	2.77	2.93	22.30	1.73	0.27	1.30

[a]Proportions of world distribution were summed by region for each fish species. Percentages were arcsine transformed prior to statistical analysis.

exploitable densities for much of the year. Similarly, not all fish may be equally available to sea lions if they occur at depths or in areas that are difficult for sea lions to access. Thus, to fully understand the association between Steller sea lion feeding habits and their prey, consideration needs to be given to factors other than the simple distribution of prey species.

The available data suggest that the diets of Steller sea lions broadly reflect the distributions of their major prey species. However, discrepancies suggest that other factors such as nutritional value, relative foraging costs, prey preference, etc., should also be considered to better understand the feeding habits of Steller sea lions. Nonetheless, given the general relationship between fish distributions and Steller sea lion diets, factors that affect fish assemblages (such as climatic change) may also have implications for sea lion populations. Additional analysis is therefore required to achieve a better understanding of Steller sea lion diet and how it is related to the distribution of their prey throughout their range. An analysis at finer spatial and temporal scales, incorporating seasonal or monthly sea lion diet data and fish abundance data would further help to elucidate factors that affect Steller sea lion feeding habits. Consideration should also be given to the different depth ranges that adults and juvenile fish species inhabit, and how it relates to the ability of sea lions to successfully forage.

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