Food Habits of California Sea Lions (Zalophus californianus) and Their Impact On Salmonid Fisheries in Monterey Bay, California

Report Submitted to:

Fishermen’s Alliance of California - Monterey Bay Chapter
885 Abrego Street
Monterey, California 93940

Contract Number: 23-1509-7400

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MLML Technical Publication No. 99-01

3 February 1999
ABSTRACT

In the ocean commercial troll and recreational salmon fishery in Monterey Bay California, California sea lions (Zalophus californianus) will swim near or follow fishing boats and will depredate fish once hooked. The objectives of the study were to determine the percentage of salmon taken by pinnipeds in commercial and recreational fisheries, identify relative importance of prey items seasonally consumed by sea lions, and determine the proportion of salmonids in the sea lion diet on a seasonal basis. From April 1997 through September 1998, 1041 hours of onboard and dockside surveys of the commercial and recreational salmon fisheries were conducted at the three ports in Monterey Bay, California. Sea lions depredated 7.9 % of the fish hooked in the commercial fishery in 1997 and 28.6 % in 1998, 8.4 % (1997) and 18.3 % (1998) of the CPFV fishery, and 15.6 % (1997) and 17.5 % (1998) of the private skiff fishery. Increased depredation rates in both the commercial and recreational salmon fisheries in 1998 were most likely the result of the large El Niño Southern Oscillation event that occurred in 1997-1998 during which a greater number of sea lions were present in central California. Prey hardparts identified in sea lion fecal samples collected in Monterey Bay indicated that schooling fishes were the predominant prey fish species, such as market squid (Loligo opalescens), Pacific sardine (Sardinops caeruleus), northern anchovy (Engraulis mordax), and rockfish (Sebastes sp.). Sea lions consumed similar prey species in the summer and fall 1997, winter 1997-98, and spring 1998 (PSI > 70.0) with market squid and northern anchovy being the dominant prey species. However, prey composition changed significantly during the summer 1998 and fall 1998 (PSI < 46.0) because of the increased importance of sardine and rockfish in the diet and the decreased importance of market squid. This report does not intend to imply that salmonids are not a prey species for pinnipeds in the Monterey Bay region, but highlights the difficulties encountered in establishing the role of salmonids in the pinniped diet when analyzing fecal samples.
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Acknowledgments

We appreciate the students and staff of Moss Landing Marine Laboratories who participated in dockside and onboard surveys, rivermouth observations, scat collection, and aerial surveys. This study could not have been completed without all the help from MLML students and Bird and Mammal lab interns. Thanks to Tomoharu Eguchi, Tony Orr, Tony Alisea, Laird Henkel, Stori Oates, Sarah Wilkin, Greg Cunningham, Jeff Field, Joe Bizarro, Julie Neer, Scott Benson, Denise Greig, and Betsy Lorden who braved the high seas, high flying, and/or the processing of scat. Special thanks to the Bird and Mammal lab interns Sean Lema, Lydia Neilson, Guido Parra, Mimi Reyes, Meisha Key, Sharon Updike, Michelle Garcia, Inger-Marie Laursen, Cina Loarie, and Judd Weiss for the countless hours of dockside and onboard surveys, and scat collection and processing. Scott Davis was instrumental in aerial photography for aerial surveys.

We extend special thanks to the commercial, charter boat, and personal skiff fishers, deckhands, and captains for their cooperation, this research would not have been possible otherwise. Also thanks to the Santa Cruz municipal wharf, United States Coast Guard, California State Parks for allowing us access to pinniped haulouts.

This project was supported by funding from the Fishermen’s Alliance of California - Monterey Bay Chapter. Many thanks to members Russ Colwell, Rich Hughett, and Jack Harrell for their assistance in coordinating many aspects of this project.
INTRODUCTION

California sea lion (*Zalophus californianus*) interact with almost all commercial and recreational fisheries along the California coast causing entanglement and damage to fishing gear and loss of catch (Beeson and Hanan 1996, NMFS 1997). The prey of these pinnipeds has been of interest for years because they have been viewed as competitors with humans for a variety of fish species. Historically, this competition between pinnipeds and fisherman was of limited importance because both fish and pinnipeds were harvested. However, the increasing specialization of the fishing industry during the twentieth century coupled with the changing attitudes toward pinnipeds have intensified this competition (Harwood and Croxall 1988). Since the passage of the Marine Mammal Protection Act (MMPA) in 1972, populations of California sea lions have increased along the West Coast (NMFS 1997). This increase in pinniped populations has resulted in an increase in the number of reports of pinnipeds interacting with fishing boats and depredating the catch in salmonid fisheries along the West Coast in recent years (Beeson and Hanan 1996, NMFS 1997).

California sea lions occur from the offshore islands of Mexico north to Vancouver Island, British Columbia. The California sea lion population has increased dramatically this century with an average annual rate of increase of greater than 5% since the passage of the MMPA in the early-1970s. Recent population estimates range between 161,066 and 181,355 individuals in 1994 (Barlow et al. 1995). California sea lions give birth from late May through late June each year, and mating occurs in July at breeding rookeries in southern California and western Baja California (NMFS 1997). Following the breeding season, most adult and subadult males migrate northward to central and northern California, Oregon, Washington, and British Columbia (Beeson and Hanan 1996, NMFS 1997). In the spring, most adult and subadult males migrate south to the breeding rookeries. Females and young animals either remain on or near the breeding grounds throughout the year with some animals moving southward (King 1983).

In the ocean commercial troll and recreational salmon fishery, sea lions will swim near or follow fishing boats and will depredate fish once hooked. To date, several studies have been conducted in the Monterey Bay region. Briggs and Davis (1972) reported depredation rates (number of salmon taken by sea lions above and below the surface of the water relative to the total angler landings) by California sea lions of 4.1% for all the salmon hooked during the 1969...
commercial and sport salmon season, Miller et al. (1983) reported rates of 3.0 % for the commercial salmon fishery, and Beeson and Hanan (1996) found rates of 15 % for the commercial fishery in 1995. Miller et al. (1983) reported depredation rates of 5.2 % for the CPFV salmonid fishery in Monterey Bay in 1980 and approximately 1.4 % for the personal skiff fishery. According to Beeson and Hanan (1996), Monterey Bay and San Francisco dominated the recreational ocean salmon landings in 1995 and experienced the greatest degree of sea lion predation with depredation rates of 10.5 % of the legal catch for the 1995 recreational fishery season (CPFV and private skiff combined).

Pinniped food habit studies provide information on seasonal prey selection, feeding locations, and prey availability. There is little doubt that pinnipeds are feeding on salmonids, and there is a growing concern about the increasing rate of pinniped interaction with recreational and commercial salmon fisheries. California sea lions are opportunistic feeders, whose diets consist primarily of prey that are seasonally and locally abundant (Fiscus and Baines 1966, Fiscus 1979, Jones 1981, Bailey and Ainley 1982, Hawes 1983, Antonelis et al. 1984, Lowry et al. 1986, Nicholson 1986, Lowry and Folk 1987, Lowry et al. 1990, Lowry et al. 1991, Hanson 1993). Sea lions prey heavily on schooling prey, such as market squid (Loligo opalescens), northern anchovy (Engraulis mordax), rockfish (Sebastes sp.), jack mackerel (Trachurus symmetricus) and Pacific hake (Merluccius productus; Lowry et al. 1990).

The objectives of the study were to: (1) determine the percentage of salmon taken by pinnipeds in commercial, Commercial Passenger Fishing Vessels (CPFV), and private skiffs salmon fisheries in Monterey Bay, CA; (2) identify and determine the relative importance of prey items seasonally consumed by California sea lions in Monterey Bay, California; and (3) determine the proportion of salmonids in the California sea lion diet on a seasonal basis in the Monterey Bay region.

METHODS

Fishery Interactions

Field observations were conducted onboard boats and dockside at the three major ports in the Monterey Bay region: Santa Cruz, Moss Landing, and Monterey (Fig. 1). Salmon fishing operations included the commercial troll fishery, and the recreational fishery, consisting of
CPFVs and private skiffs. The commercial troll fishery included both day-trip boats and multiple-day trip boats. This study included fishing areas from Pt. Sur north to and including the entire Monterey Bay, and north along the coast to Año Nuevo Island. Sampling days and ports were randomly selected, but onboard surveys were limited by crew cooperation and space availability.

Dockside surveys were conducted in order to achieve a higher sampling effort than only onboard observations. Onboard surveys were conducted to test the reliability of the dockside surveys, and to ensure that investigators fully understood the nature of the interaction. Small biases have been observed using this method of combining onboard and dockside surveys, but were attributed to choices of random samples in areas where interaction was more prevalent (Miller et al. 1983).

Sampling was stratified by month with an equal number of dockside and onboard surveys being conducted on a monthly basis. The 1997 commercial salmon season was May 1-31, June 23-July 18, and the month of September, whereas the 1998 commercial season was May 1 - 31, and June 15 - September 30. Sampling dates for the dockside and onboard surveys of the commercial fishery were randomly selected from all possible days during both seasons. The sampling period was a four-hour period in the mid to late afternoon with the intent of sampling the majority of boats returning to a given port. The 1998 recreational salmon season was March 15 - September 30. For the charter boats, which run virtually every day but have a greater number of overall boats and overall passengers on the weekends, two-thirds of the sampling dates were randomly selected from possible weekend dates and one-third of the sampling dates were randomly selected from all possible weekday dates. The sampling period for CPFVs was a 2-3 hour period in the early afternoon in an effort to sample every boat out of a given port on the survey date. In the private skiff fishery the preponderance of activity is on the weekends, therefore, approximately three-quarters of the sampling dates were on weekends, and one-quarter of the sampling dates were weekdays. The survey period was 2 hours in the late morning and early afternoon when the majority of fisherman typically return to a given port.

Information collected dockside included port of call, sea state, swell height, and weather conditions, number of fish landed, number of fish taken by pinnipeds at the surface, species of marine mammal involved in the take, number of marine mammals involved in the take, number
of takes below the surface, number of fish released, number of released fish taken by marine mammals, fishing locations, time of takes, number of boats in the area of the takes. Onboard surveys included all of the same information collected dockside, and the standard length of all fish landed, and any marine mammal bite and scratch marks on each fish. The field data were collected at three different ports in the region, but fisherman from all three ports typically fish wherever fish are being caught, therefore, the data were pooled.

A surface take or a definite take was defined as the loss of a hooked salmon when the depredation was observed and the species and number of marine mammals involved in the depredation could be determined. Additionally, a surface take was recorded when a fish was hooked and then the action of the line indicated that a fish was no longer hooked, and a pinniped surfaced immediately with a fish in its mouth. A take below the surface or a probable take, was defined as when a fish was hooked followed by a heavy tug of the line, and sea lions were in the immediate area, but no sign of depredation was witnessed. Two types of takes were designated because takes below the surface were not witnessed, and other predators including sharks, also take fish from lines or the fish may have escaped. The sighting of a pinniped consuming a salmon at the surface was noted but not logged as a take because the fish may have been taken from the line of another boat, or a weakened fish released earlier in the day.

The total catch was defined as the total number of fish hooked, which included all legal fish, depredated fish, and undersize fish. The legal catch only included fish legally landed by the anglers. Mean percentage of fish taken by sea lions relative to the total catch for the commercial, CPFV, and personal skiff fishery were compared using a two-sample t-test when sea lions were present versus when the majority of sea lions were on their southern breeding rookeries. Presence and absence, or low number of sea lions was determined using aerial and ground count data.

Food Habits

Information on prey composition and temporal changes in the diet of pinnipeds in the Monterey Bay region were obtained through the examination and identification of prey hardparts found in fecal samples. Only fresh fecal samples were collected biweekly at sites used exclusively by California sea lions. Samples were categorized as being collected in the summer (May, June, July), autumn (August, September, October), winter (November, December,
January), or spring (February, March, April). Sufficiency of the number of samples for each season was evaluated by plotting cumulative numbers of prey taxa against randomly chosen fecal samples.

Scat samples were collected using hand-trowels, spoons, tweezers, and sponges. Water bottles were used to wash between rocky crevices to ensure the collection of all hardparts. Each sample was then placed in a zip-lock storage bag and labeled with the date and location. Samples were frozen and stored for later analysis. Scat samples were processed by thawing the samples and allowing them to soak in soap and water until soft. The sample and water were then placed in an enclosed elutriator, which operates on the principal that the soluble and flocculent components of the scat can be separated from the potentially identifiable undigested elements by differences in their densities (Bigg and Olesiuk 1990). The remaining solution was poured into a 0.5 mm mesh sieve and all prey hardparts were removed using forceps. Fish hardparts were placed dry in vials, cephalopod hardparts were placed in vials with a 50% isopropyl alcohol solution.

All identifiable prey hard parts, including numerous skeletal bones, otoliths, cartilaginous parts, eye lenses, teeth, and cephalopod beaks were separated from each sample. Otoliths and beaks were used to preliminarily identify prey species, and all other hardparts were saved for later analysis. Otoliths and beaks were identified and enumerated using illustrations and pictures (Morrow 1979, Wolfe 1982, Clarke 1986, Canon 1987, and Harvey et al. in press), and a reference collection at Moss Landing Marine Laboratories (Harvey 1987). Otoliths and cephalopod beaks were counted and the greatest number of right or left otoliths, and upper or lower beaks were used to determine a minimum number of individuals (MNI).

The percentage number of prey occurrences (%N) was calculated for each prey species and averaged for a seasonal value. Prey species composition and abundance were compared for each season using a percentage similarity index (PSI, Silver 1975):

$$\text{PSI} = \sum \text{minimum } P_{1i} P_{2i}$$

where $P_{1i}$ and $P_{2i}$ are the relative abundances of species $i$ from seasons “1” and “2”, respectively. The index ranges from zero, no similarity, to 1.00, identical species composition. The percent similarity index significance level was arbitrarily set at 0.65 (Oxman 1995, Trumble 1995).
RESULTS

Fishery Interactions

From April 1997 through September 1998, 1041 hours of onboard and dockside surveys of the commercial and recreational salmon fisheries were conducted at the three ports in Monterey Bay, California. From April 20 through September 30 1997, a total of 337 hours of onboard and dockside surveys were conducted with 144 hours in the commercial fishery, 103 hours in CPFVs fishery, and 90 hours for the skiff fishery. Onboard and dockside hours surveyed for the commercial, CPFV, and skiff fishery were 44 hours and 100 hours, 32 hours and 71 hours, and 23 hours and 67 hours, respectively. From March 15 through September 30 1998, 704 hours of onboard and dockside surveys were conducted with 370 hours in the commercial fishery, 270 hours in the CPFV fishery, and 64 hours in the private skiff fishery. In an effort to increase the onboard survey sample size effort was concentrated in the commercial and CPFV fisheries. Onboard and dockside surveys of the commercial, and CPFV fishery were 214 hours and 156 hours, 175 hours and 95 hours, respectively. In the 1998 private skiff fishery, 64 hours of dockside surveys were conducted (Table 1).

In the commercial fishery in 1997, 253 boats were surveyed dockside accounting for 17,580 hooked salmon. And in 1998, 286 boats were surveyed dockside accounting for 15,446 hooked salmon (Table 2). The mean percentage of takes based on dockside surveys were significantly greater in 1998 (mean=31.58%, SD=16.05) than in 1997 (mean=12.07, SD=16.33; t-test: P=0.000). A significantly greater mean percentage of takes occurred in 1997 (mean present=26.65, SD=16.42, mean absent=5.82, SD=11.67, t-test: P=0.000) and 1998 (mean present=33.14, SD=15.18, mean absent=28.28, SD=17.37, t-test: 0.015) when sea lions were present versus when they were absent or in low numbers. Sea lion presence and absence or low number was based on ground and aerial count data. In 1997, sea lions were present April, May, August, and September and absent or in low numbers in June and July. In 1998, sea lions were present in March-June 20, August, September and absent or in low numbers in June 21 - June 30, and July. The percentage of pinniped takes relative to the total catch were high early in the season in both May 1997 (20.5 %) and May 1998 (32.2 %). The decline in the percentage of takes was later and less severe in 1998, with 22.8 % in June dropping to only 17.9 % in July, compared to 1997 with 0.9 % for June and 3.2 % in July (Fig. 2). Late in the season in both 1997
and 1998, surveys were conducted but little to no fishing effort was present. The percentage of
below surface takes in 1997 (5.6 %) and 1998 (27.9 %) were greater than the surface takes in
1997 (2.3 %) and 1998 (0.6 %).

In the CPFV fishery in 1997, 139 boats were surveyed dockside accounting for 5168
hooked salmon. And in 1998, 182 boats were surveyed dockside accounting for 4692 hooked
salmon (Table 3). The mean percentage of takes for dockside surveys were significantly greater
in 1998 (mean=20.56%, SD=17.40) than in 1997 (mean=9.77%, SD=14.30; t-test: P=0.000). A
significantly greater mean percentage of takes relative to the total catch occurred in 1997 (t-test:
P=0.027) and 1998 (t-test: 0.001) when sea lions were present versus when they were absent or
in low numbers. Again the decline in the percentage of takes relative to the total catch was later
and less severe in 1998, with 23.8 % in June dropping to 7.0 % in July, compared to 1997 with
2.7 % for June and 10.7% in July. Late in both 1997 and 1998, surveys were conducted but little
to no salmon fishing effort was present because most boats targeted albacore tuna. Surface takes
in 1997 (4.8 %) and 1998 (6.5 %) were not greatly different than below the surface takes in 1997
(3.6 %) and 1998 (11.7 %; Fig. 3).

In the private skiff fishery in 1997, 725 boats were surveyed dockside accounting for 2926 hooked salmon. And in 1998, 530 boats were surveyed dockside accounting for 1564
hooked salmon (Table 4). The mean percentage of takes relative to the total catch for dockside
surveys were significantly greater in 1997 (mean=10.62%, SD=21.20) than in 1998
(mean=8.36%, SD=19.04; t-test: P=0.048). Again a significantly greater mean percentage of
takes relative to the total catch occurred in 1997 (t-test: P=0.000) and 1998 (t-test: 0.050) when
sea lions were present versus when they were absent or in low numbers. And the decline in the
percentage of takes was later in 1998, with 24.5 % in June dropping to 8.6 % in July, compared
to 1997 with 3.3 % for June and 5.8 % in July. Late in both 1997 and 1998, surveys were being
conducted but little to no salmon fishing effort was present because the remaining boats targeted
albacore tuna. Surface takes in 1997 (10.3%) and 1998 (6.3 %) were not greatly different than
below surface takes in 1997 (5.2 %) and 1998 (11.1 %; Fig. 4).

In 1997, 4 onboard commercial surveys, 4 onboard CPFV surveys, and 5 onboard private
skiff surveys were conducted. And in 1998, 22 onboard surveys were conducted in both the
commercial and CPFV fishery (Table 5). There were no significant differences in the mean
The percentage of fish taken by pinnipeds for onboard and dockside surveys in the commercial, CPFV, and private skiff fisheries for 1997 (commercial, t-test: P=0.402; CPFV, t-test: P=0.329; skiff, t-test: P=0.959) and 1998 (commercial, t-test: P=0.453; CPFV, t-test: P=0.646; Fig. 5). The lack of significance was marginal in 1997, therefore, sample sizes were increased and concentrated in the commercial and CPFV fisheries for 1998.

Food Habits

Sixty-five scat collections from California sea lions yielded 503 samples, of which 69.4% (349) contained identifiable prey hardparts. Twenty-five taxa were identified to species, 1 to genus, and 3 to family. Of the 4,876 prey occurrences, 59.1% (2882) were cephalopods and 40.9% (1994) were fishes. Market squid (*L. opalescens*) was the predominant cephalopod prey species (58.0%), and octopus (*Octopus* sp.) was the other cephalopod species consumed (1.1%). Schooling fishes were the predominant prey fish species, such as Pacific sardine (*Sardinops caeruleus*; 16.3%), northern anchovy (*Engraulis mordax*; 7.7%), rockfish (*Sebastes* sp.; 6.1%), and Pacific hake (*Merluccius productus*; 5.0%; Fig. 6).

Cumulative species curves indicated that approximately 43 fecal samples were required to adequately assess prey consumed by California sea lions (Fig. 7). Because 133 fecal samples were collected in the summer and fall 1997, 81 in winter 1997-98, 125 in spring 1998, 85 in summer 1998, and 79 in fall 1998, we assumed an adequate number of samples were collected for comparing prey species number and composition among seasons. Fecal sample collection began in the late summer of 1997, yielding an inadequate number of samples for the season, therefore samples were pooled with the fall 1997 data.

Percent similarity indices indicated that sea lions consumed similar prey species in the summer and fall 1997, winter 1997-98, and spring 1998 (PSI > 70.0; Fig. 6, Table 2) with market squid and northern anchovy being the dominant prey species. However, prey composition changed significantly during the summer 1998 and fall 1998 (PSI < 46.0; Fig. 6, Table 2) because of the increased importance of sardine and rockfish in the diet and the decreased importance of market squid.
DISCUSSION

The growing awareness that human activity can have direct and indirect effects on the marine environment are reflected in such legislation as the MMPA and the Endangered Species Act. Managers of marine resources are directed through such legislation to consider the health and stability of the ecosystem in developing management practices. Management of marine mammals must take into account their numerical and functional relationships with other components of the marine ecosystem. Furthermore, to effectively manage fish populations and to regulate the influence of fishing activities on marine mammal populations and vice versa, an understanding of the trophic ecology of marine mammals is necessary.

Fishery Interactions

The conflict between pinnipeds and fisheries is well documented in California (Briggs and Davis 1972, Fiscus 1979, Ainley et al. 1982, Herder 1983, Miller et al. 1983, Hanan et al. 1989, Beeson and Hanan 1996, NMFS 1997). California sea lions are the primary pinniped species involved in depredating ocean commercial and recreational salmon fisheries (Miller et al. 1983, Hanan et al. 1989, Beeson and Hanan 1996). To date, several studies have been conducted in the Monterey Bay region. In comparing present results with past studies it is imperative to distinguish between the percentage of salmon taken by pinnipeds relative to the total number of angler landings or legal catch versus the number of pinniped takes relative to the total number of fish hooked or total catch. The former presents inflated percentages by not including undersize and depredated fish in calculating the percentage of takes, while the latter includes all fish that are hooked in the calculation and assumes all fish, regardless of size, have an equal probability of being depredated.

Depredation rates by pinnipeds in the commercial salmon fishery have increased dramatically in the last several decades, up to a 67% increase in the depredation of the legal catch since the 1970’s and 1980’s. Briggs and Davis (1972) reported depredation rates by California sea lions of 4.1% for all the salmon hooked during the 1969 commercial and sport salmon season, Miller et al. (1983) reported depredation rates of 3.0% for the legal catch in the commercial salmon fishery, and Beeson and Hanan (1996) found depredation rates of 15% of the legal catch in the commercial fishery in 1995. The present study found depredation rates of
7.9 % for the total commercial catch or 11.5 % of the legal catch in 1997, and 28.6% of the total commercial catch or 71.1% of the legal catch in 1998. The greatest depredation rates occurred in the spring of each year corresponding with the southern migration of sea lions to their breeding grounds in the Channel Islands. The 1997 depredation rates dropped significantly following a high in May (20.5 %). However in 1998, the southern migration appeared to have been delayed with high depredation rates occurring in May (32.2 %), June (22.8 %), and July (17.9 %). Briggs and Davis (1972), Miller et al. (1983), and Beeson and Hanan (1996) found similar results with the greatest number of salmon being depredated in the spring in the commercial and recreational salmon fisheries. Depredation rates were greater in June and July in all three fisheries in 1998, but the commercial fishery had the highest sustained depredation rates. Commercial fisheries also have a greater proportion of below surface takes as a result of the large amount of trolling gear used and the time required to pull the gear. It was not uncommon on onboard surveys for fishers to take up to 10 minutes to pull a hooked fish, allowing ample time for sea lion takes. Less gear and perhaps different types of gear that can be pulled faster may reduce the high below the surface and overall depredation rates.

Depredation rates of the legal catch by pinnipeds on the CPFV salmon fishery have experienced up to a 21 % increase since 1983, and close to 16 % since 1995. Miller et al. (1983) reported depredation rates of 5.2 % for the CPFV legal catch in Monterey Bay, and Beeson and Hanan (1996) reported depredation rates of 10.5 % of the legal catch for the 1995 recreational fishery season (CPFV and private skiff combined). The present study found depredation rates of 8.4 % of the total catch or 13.7 % of the legal catch in 1997, and 18.3 % of the total catch or 26.3 % of the legal catch in 1998. Again, the greatest depredation rates of the total catch occurred in the spring of both years coinciding with the male sea lion southward migration. Peaks in depredation rates occurred in May (20.6 %) of 1997, and later in May (22.7 %) and June (23.8 %) 1998. Later in 1997, depredation rates of the total catch were high in August (28.3 %), concurrent with greater abundance of animals returning to the region on the male sea lion northward migration. Surface and below surface takes occurred in approximately equal proportions resulting from the ability to pull hooked fish quickly with rod and reel fishing gear.

In the personal skiff portion of the recreational salmon fishery, depredation rates of the legal catch have increased over 29 % since 1983 and over 20 % since 1995. Miller et al. (1983)
reported depredation rates of 1.4 % for the private skiff legal salmonid catch in Monterey Bay, and Beeson and Hanan (1996) reported depredation rates of 10.5 % of the legal catch for the 1995 recreational fishery season (CPFV and private skiff combined). We found depredation rates of 15.6 % of the total catch or 27.7 % of the legal catch in 1997, and 17.5 % of the total catch or 31.0 % of the legal catch. Again, the greatest depredation rates occurred in the spring of both years, May (22.2 %) in 1997 and April (20.6 %), May (24.4 %), and June (24.5 %) 1998, coinciding with the male sea lion southward spring migration.

Increased depredation rates in both the commercial and recreational salmon fisheries in 1998 were most likely the result of the large El Niño Southern Oscillation event that occurred in 1997-1998. The 1997-98 El Niño event was one of remarkably large anomalies in physical and biological conditions in the coastal waters off California resulting in above average seasonal norms in sea surface temperatures and large displacements in the distribution of many fish species (Lynn et al. 1998). A combination of factors during a large El Niño events contribute to increased depredation of salmon catches. These factors include a decrease in sea lion prey populations, a shift in sea lion prey composition, an increasing number of sea lions in the region, a decrease in the number of salmon being landed, and a decrease in fishing effort by commercial and recreational salmon fishers. Commercial gill net fishers report that pinniped depredation is more intense during El Niño events (Beeson and Hanan 1996). This increased intensity in depredation by pinnipeds may be indicative of decreased foraging success resulting from shifts in prey availability and abundance. Food habit data indicated a significant shift in sea lion diet from market squid and northern anchovy to Pacific sardine and rockfish. Additionally, the commercial squid and herring fisheries were virtually nonexistent from the fall of 1997 through the summer of 1998. It is, therefore, reasonable to assume that sea lions were probably stressed with the lack and change in prey items, and would find a netted halibut or a hooked salmon an attractive and easy meal. Sea lion numbers along the central coast increased during the 1983 and 1992 El Niño events due to the enhancement of the normal northward migration resulting from poor food availability in the Southern California Bight (Sydeman and Allen 1997). Sea lion pup mortality was extremely high in May and June 1998, presumably because schooling prey fish were less abundant in the Southern California Bight (Lowry, pers. comm. September 1998). During the winter of 1997-98, abnormally high water temperatures associated with El Niño
conditions caused a drastic decline in squid abundance in southern California waters (CalCOFI 1998). Aerial survey data on sea lion abundance along the central California coast was not of sufficient duration to detect an increase in abundance from before to after El Niño conditions occurred. However, given the lack of schooling prey and declines in commercial fisheries in southern California, it is reasonable to assume that greater numbers of animals moved northward to the central coast during the 1997-98 El Niño event.

Commercial and recreational landings in number of salmon and fishery effort were down in 1998 versus 1997, presumably as a result of El Niño conditions. Dockside surveys indicated the catch per unit of effort (CPU) of the legal salmon catch declined in all three salmon fisheries in 1998. The commercial salmon fishery experienced a precipitous decline in the CPU from 47.7 fish per boat in 1997 to 21.7 fish per boat in 1998. The recreational salmon fishery CPU also declined with the CPFVs' dropping from 22.7 fish per boat in 1997 to 18.2 fish per boat in 1998, and private skiffs went from 2.3 fish per boat to 1.7 fish per boat in 1998. Fishery effort is based on the number of salmon boats sampled per hour (bph) dockside. In the commercial fishery, the fishery effort declined from 2.5 bph in 1997 to 1.8 bph in 1998. The recreational fishery also declined in fishery effort from 1997 to 1998, with CPFV declining from 2.0 bph to 1.9 bph and private skiffs declining from 10.8 bph to 8.3 bph.

Limitations encountered in this study may affect the depredation rates reported for the commercial and recreational salmon fisheries in Monterey Bay. The lack of direct validation for information received on dockside surveys had unknown impacts on depredation rate estimates. Data collection began in late April of 1997, missing approximately 5 weeks of the recreational season, which may underestimate the overall depredation rates for the season because of the high interaction typically occurring in the spring. Additionally, commercial and private skiff salmon boats bypass the sampling docks with unknown impacts on depredation rates. Commercial boats would bypass the sampling dock if the catch was sold to a private dealer, the catch was kept by the fisher, or if no fish were landed. Private skiffs that docked in slips in the harbor would bypass the boat launching dock. The sample size for onboard surveys for both the commercial and recreational fishery in 1997 were low making it difficult to validate the findings on the dockside surveys. Boat surveys were limited by crew cooperation, therefore, not all fishing styles and locations were sampled with unknown impacts on depredation rates. Boat surveys were also
limited to day trips because multiple day trip boats often fished outside the study area during the course of a trip.

**Food Habits**

Pinniped food habit studies provide information on seasonal prey selection, feeding locations, and prey availability. There is little doubt that pinnipeds are feeding on salmonids, and there is a growing concern about the declining stocks of salmonids in the Pacific Northwest. But determining the impact of pinniped foraging on these depressed stocks is difficult. Pinnipeds are opportunistic predators switching prey species depending on the availability of fish (Fiscus and Baines 1966, Fiscus 1979, Jones 1981, Bailey and Ainley 1982, Hawes 1983, Antonelis et al. 1984, Lowry et al. 1986, Nicholson 1986, Lowry and Folk 1987, Lowry et al. 1990, Lowry et al. 1991, Hanson 1993), such as salmon, when they are abundant (Briggs and Davis 1972, Miller et al. 1983, Hanan et al. 1989, Beeson and Haran 1996, and NMFS 1997).

California sea lions using the Monterey Bay region in 1997-98 consumed a variety of prey species, consisting primarily of fish and cephalopods species as indicated by the presence of cephalopod in 59.1% of scats and fish in 40.9% of scats. Sea lions were opportunistic predators feeding on a variety of prey species, primarily schooling prey such as squid, sardines, anchovy, and rockfish. Twenty-five taxa were consumed by sea lions and identified to species, 1 to genus, and 3 to family. At San Miquel Island, Antonelis et al. (1984) found sea lions preying upon 15 species of fish and 6 species of cephalopod, Hawes (1983) found sea lions on San Nicholas Island consumed 15 species of fish and 7 species of cephalopods, Nicholson (1986) reported sea lions on the Coast Guard jetty in Monterey consumed 6 species of fish and 1 species of cephalopod, and Lowry et al. (1990) found that California sea lions on San Clemente Island consumed 44 species of fishes and 5 species of cephalopods.

The prevalence of squid in the sea lion diet early in the study, summer and fall of 1997, is not surprising since market squid dominated the commercial fishery landings in the Monterey Bay region at that time of year. However, squid remained dominant in the sea lion diet through spring 1998, while commercial landing stopped abruptly in the end of September of 1997 until the present time a result of the 1997-98 El Niño event (CalCOFI 1998, Bob Leos pers. comm. January 1999). The El Niño event in 1991-92 also resulted in below average yields of
commercially harvested market squid (CDF&G 1992). The presence of market squid in the diet of California sea lions through the spring of 1998 indicates the availability of the prey to sea lions, despite the low commercial harvest.

Pacific sardines were an increasingly important prey item found in scat samples during all seasons, becoming the dominant prey item in the summer and fall of 1998. Sardine populations have rebounded as indicated by the rebuilding of the sardine fishery, which in 1997 reported the greatest total landings since the reopening of the directed fishery in 1986 (CalCOFI 1998). Sardines schools occur up to 300 miles offshore, moving inshore to spawn in late winter through early summer (Love 1991). Sardine egg distribution differed sharply in 1997 with a broad offshore extension compared to a narrow, northward, near-shore pattern in 1998 (Lynn et al. 1998). The increase in dominance of sardines in the sea lion diet from 1997 to 1998 was concurrent with the seasonal spawning movement of sardines, and more importantly, the apparent concentrating effect on sardines in the central California coast region as a result of oceanographic patterns during the 1997-98 El Niño event.

Northern anchovies occurred in approximately equal numbers throughout the study period. However, the decrease in the presence of market squid in the summer and fall of 1998 increased the relative importance of anchovies. Anchovies are an important commercial species in the Monterey Bay, ranking third highest in commercial landings in 1997, behind sardine and squid.

Rockfish occurred in increasingly larger numbers throughout the study, becoming one of the predominant prey items in the summer and fall of 1998. This increased importance of rockfish in the sea lion diet coincides with their increased abundance in the summer as aggregations of juvenile rockfish move into shallow water (Loeb et al. 1996). The estimated standard lengths of rockfish indicate that most of the rockfish consumed by sea lions were juvenile. While reported commercial rockfish catches encompass an extensive array of fish species, and inter-annual variability exists in the composition of this array, the overall commercial catch in 1997 was high. In contrast, Lynn et al. (1998) recorded the lowest pelagic-young-of-the-year rockfish catch rate in the history of the survey in their May 1998 survey. This remarkable decline in young-of-the-year rockfish does not effect the occurrence of rockfish in the
sea lion diet, but may do so when this size-class reaches the juvenile stage, apparently preferred by sea lion.

There are numerous limitations and potential biases associated with the use of fecal samples in the investigation of pinniped food habits described in the literature (Pitcher 1980, Hawes 1983, DaSilva and Neilson 1985, Harvey 1989, Cottrell et al. 1996). The differential recovery rates of fish hard parts varies with prey species. The preliminary analysis of fecal samples presented in this study only includes the use of fish otoliths and cephalopod beaks to determine the relative importance of prey items in the sea lion diet. The frequency and number of individual prey have been reported as at least two times greater for most prey taxa when prey structures in addition to otoliths were identified (Browne, pers. comm. October 1998). Large fishes are typically underestimated because they are less likely to be consumed whole, and their otoliths may not appear in fecal samples (Pitcher 1980). Harvey (1989) noted in captive feeding experiments that recovery rates of otoliths from fecal samples varied greatly among prey species and individual seals. Additionally, fishes with small, or less robust, otoliths tended to have lower recovery rates due to the increased probability of complete digestion. The difficulty in describing the role of salmonids in pinniped food habits is compounded by their large body size and comparatively small otolith size.

Cephalopod beaks are often retained in the stomach and regurgitated en masse after accumulation, rather than being passed through the intestinal tract (Pitcher 1980). Therefore, cephalopod beaks can be substantially underestimated in fecal samples, biasing estimates of number, biomass, and relative importance. In this study, the relative importance of squid in the diet on a seasonal basis would not be significantly affected by the loss of squid beaks during regurgitation, although squid may have dominated the diet from the summer of 1997 through spring 1998 to a greater extent than indicated by fecal samples.

This report does not intend to imply that salmonids are not a prey species for pinnipeds in the Monterey Bay region, but highlights the difficulties encountered in establishing the role of salmonids in the pinniped diet when analyzing fecal samples. Salmon otoliths do not occur in large numbers in fecal samples, but occur regularly and may represent a larger portion of the biomass consumed. Furthermore, salmon are regularly taken by sea lions in the commercial and recreational fisheries. Therefore, salmon may be an important component in the sea lion diet.
Pinniped Abundance

Since the passage of the MMPA in 1972, populations of California sea lions and Pacific harbor seals (*Phoca vitulina richardsi*) have experienced an average annual rate of increase of greater than 5% along the West Coast (NMFS 1997). Seasonal and within season distribution and abundance of California sea lions and Pacific harbor seals at haul-out sites (areas where pinnipeds come ashore to rest) along the California coast is essential in the assessment and evaluation of their potential impact on declining salmonid populations and fisheries. Pinniped census flights were conducted once a month from May 1997 through September of 1998 using a single engine, high wing plane (Cessna 172) going approximately 80 knots at an altitude of 600 m (the legal altitude within the Monterey Bay National Marine Sanctuary) from Pt. Sur north to Ano Nuevo Island. General trends corresponded with other coast-wide surveys indicating that many adult male, subadult, and juvenile sea lions migrate northward from breeding grounds on the Channel Islands and islands in northern Baja to central and northern California. Peak abundances of animals occurred in the Monterey Bay region as early as the beginning of August and lasted through November. In the spring, peak abundance counts occurred in April through June corresponding to the southward sea lion migration as they return to their breeding grounds.

Pinniped Predation on San Lorenzo River

The San Lorenzo River is a major river drainage flowing into the Monterey Bay and is home to the largest stock of steelhead (*Oncorhynchus mykiss*) in the region. The annual winter upstream spawning migration of steelhead coincides with peak abundances of Pacific harbor seals hauling out on rocks in the river lagoon (Harvey and Weise 1997). Scars attributed to predation attempts by harbor seals and California sea lions have increased from 15 % in 1991-92 to greater than 50 % per year in 1995-96 and 1996-97. Foraging behavior was monitored for 205 hours at the mouth of the San Lorenzo River in January through March 1998. No predation events were observed, but 22 foraging behaviors were recorded on 21 % of the observation days. The Monterey Salmon & Trout Project trapped migrating steelhead at the Felton Diversion Dam in 1998 recording pinniped scarring on 18.8 % of the fish in January, 28.9 % in March, and 38 % in April.
LITERATURE CITED


Table 1. Allocation of survey effort in hours for the recreational and commercial salmon fishery in 1997 and 1998 in Monterey Bay, California

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<tr>
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<th>Commercial Fishery</th>
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<td>270</td>
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Table 2. Monthly catch statistics and estimates of the number and percentage of salmon depredated by pinnipeds in the commercial salmon fishery during dockside surveys in 1997-98

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<tr>
<th></th>
<th>Number boats sampled</th>
<th>Total number fish hooked</th>
<th>Number legal fish landed</th>
<th>Number undersize fish</th>
<th>Number fish taken at surface</th>
<th>Number fish taken below surface</th>
<th>Percentage Takes</th>
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Total % of legal catch lost: 20.5, 0.9, 3.2, 1.3, 22.8, 17.9, 28.6

Total % of total catch lost: 27.3, 1.3, 5.1, 11.5, 79.0, 54.9, 49.4
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Table 4. Monthly catch statistics and estimates of the number and percentage of salmon depredated by pinnipeds in the private skiff salmon fishery during dockside surveys in 1997-98

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<td>Number legal fish landed</td>
<td>Number undersize fish</td>
<td>Number fish taken at surface</td>
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Table 5. Seasonal composition of prey species composition from California sea lion fecal samples collected during 1997 and 1998 in Monterey Bay, California based on percent similarity index (PSI). Dashes (-) indicate redundant comparisons.

<table>
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<td>77.3</td>
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<td>*</td>
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Figure 1. Pinniped haulout sites and scat collection sites within the study region. Counts of sea lions and scat collection were conducted in 1997 and 1998.
Figure 2. Percentage of pinniped takes relative to the total number of salmon hooked in the commercial fishery based on dockside surveys in 1997 and 1998 in Monterey Bay, California. Sample size (n) is listed for each month.
Figure 3. Percentage of pinniped takes relative to the total number of salmon hooked in the CPFV salmon fishery based on dockside surveys in 1997 and 1998 in Monterey Bay, California. Sample size (n) is listed for each month.
Figure 4. Percentage of pinniped takes relative to the total number of salmon hooked in the private skiff salmon fishery based on dockside surveys in 1997 and 1998 in Monterey Bay, California. Sample size (n) is listed for each month.
Figure 5. Comparison of dockside and onboard surveys for the percentage of pinniped takes relative to the total number of salmon hooked for the commercial, CPFV, and personal skiff fisheries in Monterey Bay, California in 1997 and 1998. Sample size (n) is listed for each month.
samples collected in Monterey Bay, California in 1997 and 1998.

Figure 6: Comparison among seasons using percentage number of prey species identified in California sea lion fecal
Figure 7. Cumulative number of prey species per fecal sample collected during spring (February, March, April) 1998 in Monterey Bay, California.