An Assessment of Pinniped Predation Upon

Fall-run Chinook Salmon

in the Klamath River Estuary, CA, 1998

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ABSTRACT

The Yurok Tribal Fisheries Program conducted an investigation to assess the impacts of pinniped predation upon fall-run chinook (*Oncorhynchus tshawytscha*) in the Klamath River Estuary from 4 August to 14 November 1998. Direct observations of surface feeding events by pinnipeds indicated that approximately 3,077 (2761, 3393) adult (including grilse chinook and coho salmon) salmonids were consumed. Fall-run chinook was the primary species of prey, with an estimated 2,559 fish consumed, which was equivalent to 2.6% of the estimated fall chinook run. An estimated 438 spring-run chinook were consumed during the first three weeks of the study, and an estimated 20 coho salmon (*Oncorhynchus kisutch)* and 60 steelhead (*Oncorhynchus mykiss)* were consumed during the entire study period. An estimated 63 coho salmon and 110 steelhead were consumed during the entire study period. California sea lions (*Zalophus californianus*) were the primary pinniped predator, accounting for 89.8% of the impacts on salmonids. Pacific harbor seals (*Phoca vitulina richardsi*) and Steller sea lions (*Eumetopias jubatus*) were also observed feeding upon salmonids, accounting for approximately 5.3% and 1.2% respectively. Analysis of harbor seal scat collected in the Klamath River Estuary indicated that adult salmonids were present in 13.9% of scats collected during the fall study period, 1.9% of scats collected during the spring period, and were absent from scats collected during the winter period.

INTRODUCTION

The Marine Mammal Protection Act of 1972 dramatically reduced the harvest or taking of seals and sea lions except for those killed by natural causes. With this protection, California sea lion (*Zalophus californianus*) and Pacific harbor seal (*Phoca vitulina richardsi*) populations have increased along the coast of California, Oregon and Washington by an average annual rate of 5-8%. California sea lion populations may now be larger than any historical level (Lowe as cited in NMFS 1997).

Concurrent with this increase in pinniped populations, salmonid populations in the Klamath drainage have decreased. Fall chinook salmon (*Oncorhynchus tshawytscha*) have failed to meet their minimum spawning escapement floor in several of the past years (PFMC 1994). Concern over the continued existence of natural coho salmon (*Oncorhynchus kisutch*) populations in Southern Oregon and Northern California (including the Klamath Basin) has led to their designation as "threatened" under the Endangered Species Act (ESA) in 1997. Similar concern has been expressed for Klamath Basin Steelhead (Oncorhynchus mykiss) populations, in particular the summer run (NMFS 1994). Spring chinook salmon currently represent a small portion of salmon escapement to the Klamath-Trinity Basin, however historically spring chinook are thought to have been the dominant race of salmon within the basin (Hume as cited in Snyder 1931).

Several factors have led to the decline of fisheries resources within the Klamath Basin, including loss and/or degradation of freshwater habitat from poor land and water management practices. Access to major spawning and rearing areas, especially for spring-run chinook salmon, was lost with the construction of dams on the Klamath and Trinity Rivers that lacked provisions for fish passage. Water diversions from the Upper Klamath and Trinity Basins, as well as major tributaries, have resulted in poor water quality and inadequate flows that are unsuitable to sustain healthy salmonid populations. The geomorphology of the river has also been negatively altered as a result of modified hydrological conditions from mainstem dams, especially from the Trinity River Dam (USFWS et al 1999). Other land management factors that have contributed to the degradation of freshwater habitat within the Klamath-Trinity Basin include poor logging and road construction practices, mining, and grazing (KRBFTF 1991).

Uncounted generations of Yurok people have enjoyed the bounty of Klamath River resources, including the harvest of fisheries and marine mammals (Kroeber and Barrett 1960, Leshy 1993). The fisheries resource is an integral component of the Yurok way of life; intertwined with cultural, ceremonial, sustenance and commercial aspects of Yurok existence. It has been estimated that pre-European Indians in the Klamath drainage consumed in excess of 2 million pounds of salmon annually (Hoptowit 1980).

It is recognized that several factors other than pinniped predation led to the decline of Klamath River fisheries resources, however there is concern that the increased abundance of pinniped populations may have a negative effect on the recovery of Yurok fisheries resources. Anecdotal information from tribal fishers indicates that pinniped predation upon migrating adult salmon has substantially increased during recent years. In recognition of this concern, the Yurok Tribe conducted a pilot study in 1997 to assess the impacts that pinniped predation may have upon fall-run chinook in the Lower Klamath River. Methodology consisted predominantly of direct observations during daylight hours, as well as monitoring the abundance of pinniped populations in the Klamath River Estuary and assessment of fishery interactions with pinnipeds in the Lower Klamath River.

STUDY AREA

The Klamath River watershed drains approximately 14,400 square kilometers (km^2) in Oregon and 26,000 km^2 in California (Figure 1). The largest spawning tributaries for anadromous salmonids in the basin include the Trinity River, draining approximately 7,690 km^2, and the Shasta, Scott and Salmon Rivers, each draining approximately 2,070 km^2. The current upper limit of anadromous salmonid migration in the Klamath Basin is Iron Gate Dam at river kilometer (rkm) 306, while Lewiston Dam represents the upper limit of migration in the Trinity River (rkm 179). The study site for this investigation included the lower three kilometers of the Klamath River Estuary (Figure 2).

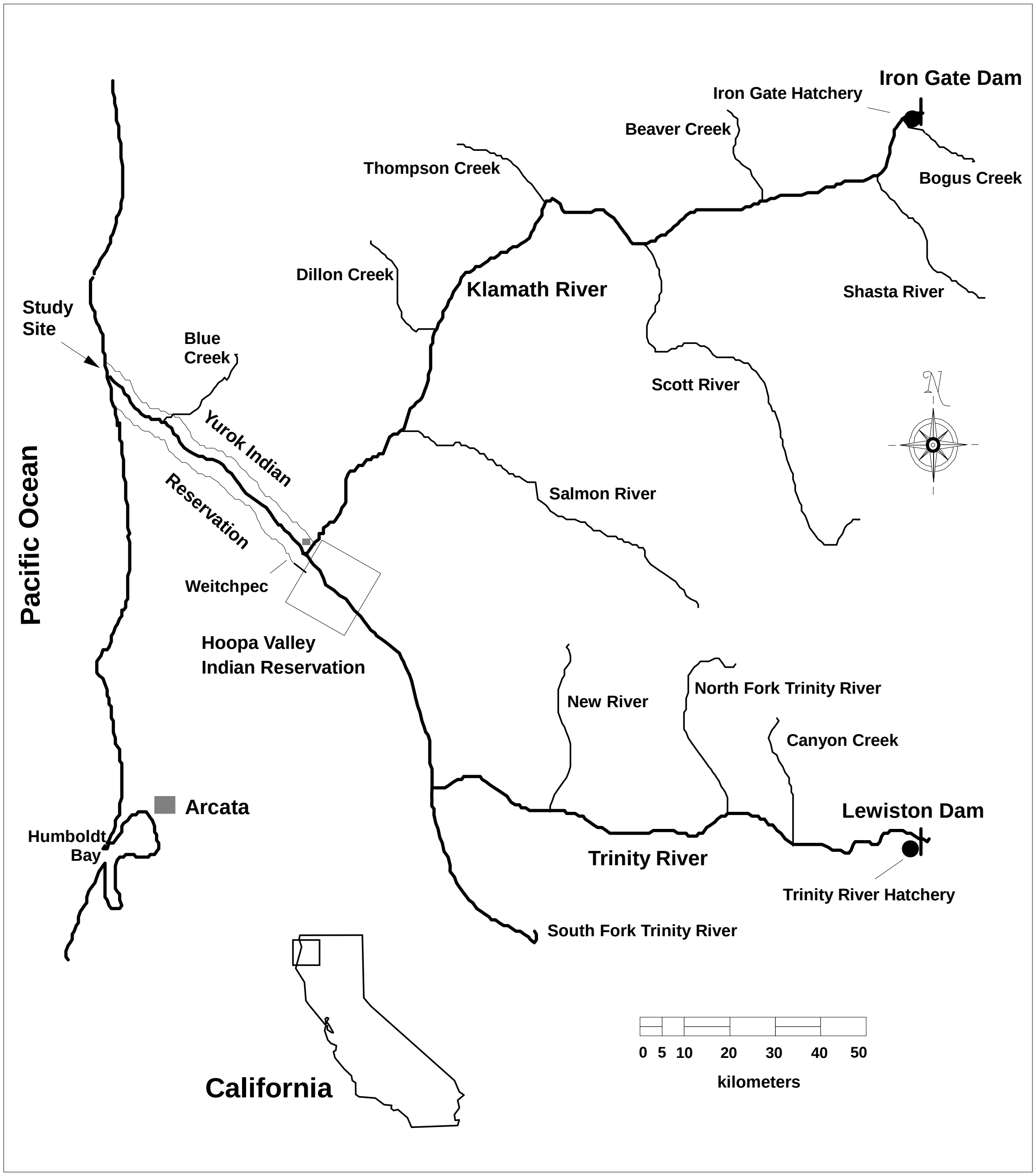


Figure 1. Location of study site and the Klamath River Basin within California.

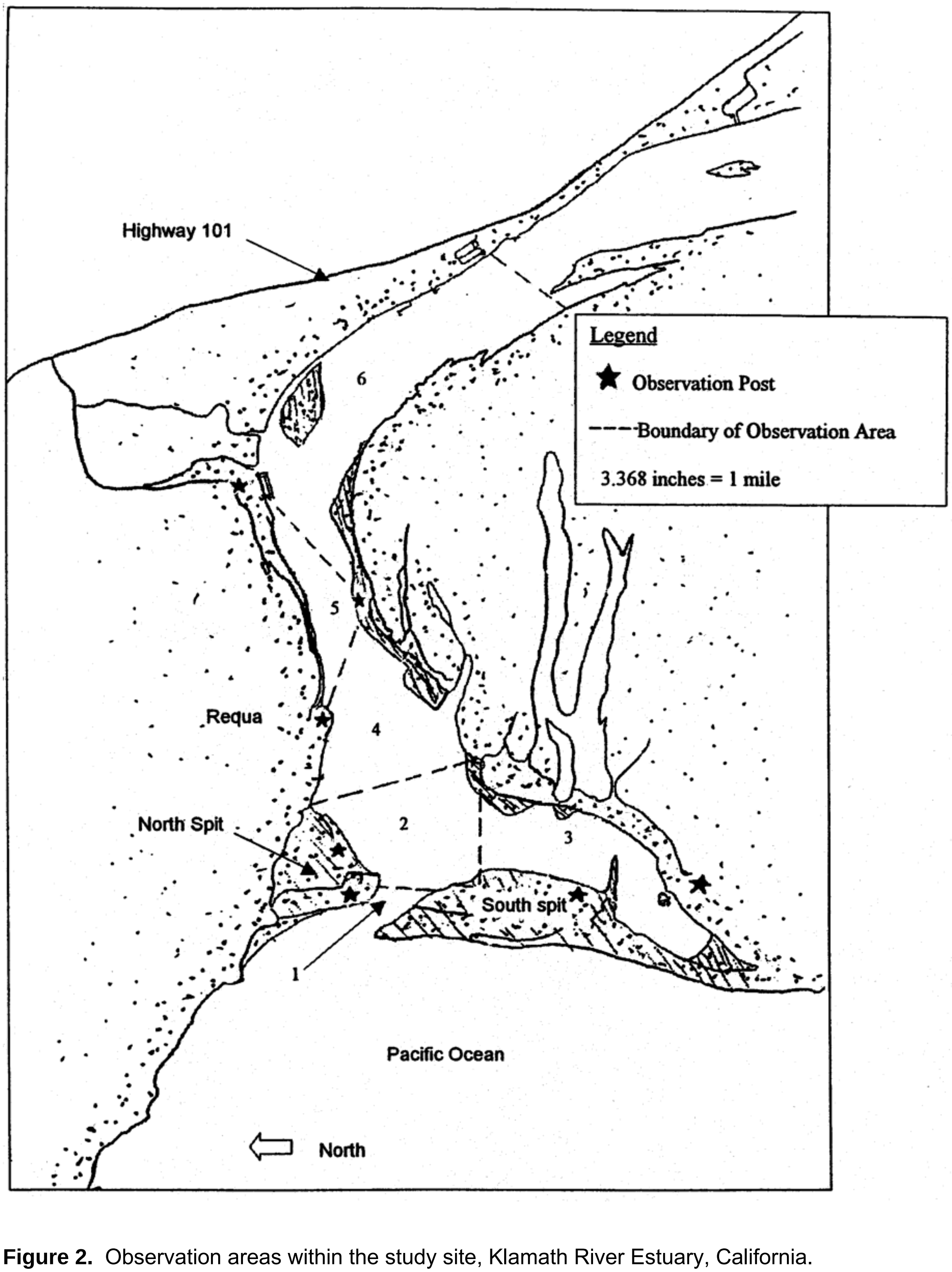


Figure 2. Observation areas within the study site, Klamath River Estuary, California.

METHODS

Assessment of Pinniped Predation on Adult Salmonids

Direct observations were used to record predation events of pinnipeds upon adult salmonids within specified times and areas. The 1997 pilot study indicated that most pinniped predation upon adult salmonids occurred within the lower three kilometers of the Klamath River Estuary, so observations to document feeding bouts were restricted to this area. Observations were conducted from approximately 20 minutes before sunrise until 20 minutes after sunset, between 4 August and 14 November 1998. Binoculars were used to aid in the detection of feeding events as well as identification of predator and prey.

A probability sample survey was conducted to estimate the extent of pinniped predation on adult salmonids in the Klamath River estuary. The survey was limited to predation that occurred during daylight hours in the Fall of 1998, and to adult salmonids that were consumed at the river's surface. For the purposes of this study, no distinction was made between grilse and adult salmonids because of difficulty observers had with estimating size precisely. As used in this report, the term "adult" refers to salmonids approximately 50 cm. and larger.

The lower three kilometers of the estuary were partitioned into six geographic areas (Figure 2). Various markers were used to delineate area boundaries, including landmarks, buoys, painted sticks, logs, and metal posts. Observation areas were defined such that the entire area could be observed from a designated observation post. Observations were usually made from a vantage point elevated at least two meters above the surface of the water, as this enhanced the ability to detect feeding events. Several observation towers were constructed throughout the estuary for this purpose, yet only one, located across the channel from Requa, remained at the completion of the field season. Two towers on the north sand spit were destroyed in early October when the spit shifted during a storm. A tower on the south sand spit was abandoned in late August due to safety and logistical reasons. An alternate observation location was utilized for the remainder of the field season. The elemental sampling unit of the survey was an area-hour of observation (one of the six areas observed for a period of one hour). For each area-hour sampled, the observer recorded the beginning and end times for the observation period; number of adult salmonids consumed during the first and second 30 minutes of the observation period; the species of predator for each feeding bout; whether the prey was free swimming, taken from a net, or from a hook and line (if known); the beginning and end times for each feeding bout; the location of each feeding bout; the maximum number of each pinniped species observed within the observation area at any one time; the maximum number of set gill nets fishing within the observation area at any one time; the maximum number of sport fishermen fishing within the observation area at any one time and the percent visibility within the observation area.

The intent of the survey was to have at least one observer working every daylight hour of every day throughout the fall period, and to increase the number of observers per hour during the peak of the fall-chinook run and as labor conditions otherwise allowed. For each daylight-hour throughout the fall period, areas to be sampled were selected at random, without replacement, from among the six defined areas (sample size for each hour was dependent on the number of observers available). Observers worked shifts consisting of five or six 60-minute observation periods, with 20 minutes scheduled between periods for travel or rest. As the season progressed, shifts overlapped in the middle of the day due to decreasing daylight hours.

The random selection of areas within each daylight hour was done using unequal probability sampling (area-specific probabilities of selection). Unequal selection probability schemes are more efficient than equal probability selection schemes (reduced estimator sampling variance) when these area-specific selection probabilities are proportional to the variable of interest (Särndal et al. 1992, section 3.6.1); here, the expected number of adult salmonid predation events per hour. Because the survey was carried out hourly over the course of several months, we were able to use to our advantage, knowledge we gained concerning changes in the distribution of predation events across the estuary areas by resetting the area-specific selection probabilities to reflect these changes in the distribution of predation impacts (Table 1).

Table 1. Within-hour area selection probabilities $\{p_a\}$ used in 1998 survey (rounded to two decimal digits). Subscript a refers to estuary observation areas 1,2,…,6.

Set	Date-in-effect	p_1	p_2	p_3	p_4	p_5	p_6
1	08/04/1998	0.27	0.32	0.05	0.09	0.14	0.14
2	08/07/1998	0.25	0.28	0.09	0.11	0.12	0.14
3	08/20/1998	0.23	0.23	0.23	0.10	0.10	0.10
4	09/01/1998	0.23	0.19	0.20	0.14	0.14	0.10
5	09/10/1998	0.18	0.18	0.15	0.15	0.23	0.11
6	09/22/1998	0.21	0.18	0.15	0.15	0.20	0.11
7	09/24/1998	0.25	0.18	0.13	0.13	0.19	0.12
8	10/07/1998	0.25	0.17	0.20	0.13	0.13	0.12
9	11/05/1998	0.26	0.18	0.21	0.14	0.13	0.08

Deviations from above mentioned sampling protocol occurred. For example, time periods were occasionally shortened or omitted altogether due to excessive fog or hazardous wave conditions. If an observation period lasted less than 30 minutes or the mean visibility within an observation period was less than 75%, the observation period was omitted.

Estimated Impacts

Sample survey estimators were used to expand observed predation events over unsampled areas, unsampled times (e.g. observer travel time between selected sample areas), and for any occasions of within-site reduced visibility. Estimates were stratified by area-week, by area, by week, and totaled over the respective fall period.

Our notation for a given area-week is as follows:

n = realized sample size for the area-week

i = sampled unit index: 1, 2, …, n

π_i = sample inclusion probability, unit i

y_i = observed number of events (total), unit i

f_i = fraction of sampled area visible, unit i

d_i = observation duration (hours), unit i

x_i = $f_i \times d_i$

X = total daylight hours in week

$\breve{y}_i$ = y_i / π_i

$\breve{x}_i$ = x_i / π_i

The probability that unit i was included in the sample (π_i) depends both on the set of area-specific selection probabilities $\{p_a, a = 1, 2, \ldots, 6\}$ in use at the time, and on the within-hour sample size (number of observers working) at the time. For example, if six observers were working the hour in question $\pi_i = 1$ regardless of the $\{p_a\}$ values. To determine the value of π_i, all possible within-hour area selections for the given within-hour sample size were numerically constructed and the probability of each possible sample calculated given without replacement sampling and the $\{p_a\}$ in effect. The sum of this probability over those samples that contained the y_i-area is, by definition, the unit i inclusion probability π_i (Särndal et al. 1992, section 2.4).

Symbols denoting the specificity of the above quantities on “area” and “week” have been suppressed here for conciseness, but are later introduced when presenting estimators at the higher levels of stratification.

Stratification: Area-Week

For a given area-week, the ratio estimator (Särndal et al. 1992, equation 10.6.2) was used to estimate the number of events per hour (β)

$$\hat{\beta} = \frac{\sum_i \breve{y}_i}{\sum_i \breve{x}_i}, \tag{1}$$

and the total number of events (Y) was estimated as

$$\hat{Y} = X\hat{\beta}. \tag{2}$$

Notice that if: (1) all areas sampled were fully visible, (2) all areas sampled were observed for the full hour, and (3) the $\{\pi_i\}$ were all equal; the $\hat{Y}$ estimator reduces to the average number of events observed per hour in this area times the number of daylight hours in the week.

The following variance estimators were used to quantify the uncertainty of $\hat{\beta}$ and $\hat{Y}$ (Särndal et al. 1992, equation 10.6.3) noting that Poisson sampling (Särndal et al. 1992, section 3.5) applies within an area-week:

$$\hat{V}(\hat{\beta}) = \frac{\sum_i (1-\pi_i)\breve{e}_i^2}{(\sum_i \breve{x}_i)^2} \tag{3}$$

and

$$\hat{V}(\hat{Y}) = X^2\hat{V}(\hat{\beta}) = \sum_i (1-\pi_i)(g_i\breve{e}_i)^2, \tag{4}$$

where $\breve{e}_i$ is the π_i-expanded residual

$$\breve{e}_i = \breve{y}_i - \hat{\beta}\breve{x}_i\,, \tag{5}$$

and

$$g_i = \frac{X}{\sum_i \breve{x}_i}\,. \tag{6}$$

The degrees of freedom associated with $\hat{\beta}$ and $\hat{Y}$ is df = n - 1, and approximate 95% confidence intervals were constructed for each area-week Y as

$$\hat{Y} \pm t_{.975,df}\sqrt{\hat{V}(\hat{Y})}.$$

Stratification: Area

Denote now by $\hat{Y}_{kh}$ the area k, week h estimate (Equation 2) of the previous section. The area-k estimates for the entire fall period were obtained by simple pooling across week (Särndal et al. 1992, equations 7.71 and 7.2.11):

$$\hat{Y}_k = \sum_{weeks}\hat{Y}_{kh} \tag{7}$$

$$\hat{V}(\hat{Y}_k) = \sum_{weeks}\hat{V}(\hat{Y}_{kh}) \tag{8}$$

$$df_k = \sum_{weeks} df_{kh}. \tag{9}$$

Approximate confidence intervals were constructed for each Y_k as

$$\hat{Y}_k \pm t_{.975,df_k}\sqrt{\hat{V}(\hat{Y}_k)}.$$

Stratification: Week

The week-h estimates were also obtained by simply pooling across areas (Särndal et al. 1992, equations 7.71 and 7.2.11):

$$\hat{Y}_h = \sum_{areas} \hat{Y}_{kh} \tag{10}$$

$$\hat{V}(\hat{Y}_h) = \sum_{areas} \hat{V}(\hat{Y}_{kh}) + \widehat{COV}_h \tag{11}$$

$$df_h = \sum_{areas} df_{kh}. \tag{12}$$

Approximate confidence intervals were constructed for each Y_h as

$\hat{Y}_h \pm t_{.975, df_h} \sqrt{\hat{V}(\hat{Y}_h)}$.

The $\widehat{COV}_h$ term in Equation (11) is due to sampling without replacement during within-hour area selection (Särndal et al. 1992, p.45). No covariance is induced across hours due to the independence of area selection across hours. Denote by t = 1, 2,…,T the respective sample hour blocks within week-h, and by S_t the set of selected areas for sampling during hour t.

$$\widehat{COV}_h = \sum_{t=1}^{T} \sum_{\substack{i,j \in S_t \\ i \neq j}} (1 - \frac{\pi_i \pi_j}{\pi_{ij}})(g_i \breve{e}_i)(g_j \breve{e}_j) \tag{13}$$

Derived from (Särndal et al. 1992, equation 7.2.11), π_i is the probability that both unit i and unit j were included in the sample. Here again, π_i depends both on the set of area-specific selection probabilities $\{p_i\}$ in use at the time, and on the within-hour sample size (number of observers working) at the time. The value of π_{ij} was determined numerically, as before, by forming all possible within-hour area selections for the given within-hour size and the probability of each possible sample calculated given without replacement sampling and the $\{p_i\}$ in effect. The sum of this probability over those samples that contained both the y_i-area and the y_j -area is, by definition, the unit i and j inclusion probability π_i (Särndal et al. 1992, section 2.4).

Fall Total

The survey estimated totals were obtained by pooling the week-stratified estimates:

$$\hat{Y}_{total} = \sum_{weeks} \hat{Y}_h \qquad (14)$$

$$\hat{V}(\hat{Y}_{total}) = \sum_{weeks} \hat{V}(\hat{Y}_h) \qquad (15)$$

$$df_{total} = \sum_{weeks} df_h . \qquad (16)$$

Approximate confidence intervals were constructed for Y_{total} as

$$\hat{Y}_{total} \pm t_{.975, df_{total}} \sqrt{\hat{V}(\hat{Y}_{total})}.$$

Sampling Protocol Departures

Field samplers did not always adhere to the sampling protocol described above. For various reasons, samplers would occasionally not go to the area selected for sampling but would go to another area instead, or were not otherwise available to observe the selected unit. This occurred in 155 of the 1,459 selected units (10.6%). The potential effect of these protocol departures on the estimators is two-fold: (1) sample size is a random rather than fixed variable which may increase the variance of the point estimators; and (2) more importantly, if observers tended to shy away from sampling certain units because predation events there were relatively numerous (or relatively few), this may bias the point estimators.

We responded to these potential concerns as follows. First, none of the “volunteered” data (observations recorded from non-selected units) was included in any of the estimates. Second, because the realized sample size was within 10% of its nominal value, any increase in point estimator variance due to the sample size being somewhat random was expected to be relatively minor, and thus no adjustment was made to the variance estimators presented above. Third, the potential for selection bias as described above would have been more of a concern had the estimates not been stratified by area-week. But having done so, the estimators remain essentially unbiased under the much less demanding assumption that within an area-week all selected units were equally likely not to be sampled-"data missing at random" (Särndal et al. 1992, equation 15.6.2); an assumption we felt comfortable with.

Species Composition of Salmonid Prey

Chinook salmon, coho salmon, steelhead, and cutthroat trout were the anadromous salmonid species present in the estuary during the study period. Seining investigations conducted in the estuary during the 1980's by the U.S. Fish and Wildlife Service determined that chinook salmon was the most abundant salmonid species present in the estuary from August through October. However, the proportion of chinook versus other species fluctuates annually, and it is unknown whether pinnipeds have a preference for, or are more efficient predators of one salmonid species over another.

The species composition of salmonids consumed by pinnipeds during the study was estimated by averaging the proportion of each species harvested per week within the recreational and tribal net fisheries in the Lower Klamath River. Only the tribal fishery was used to represent species composition after the week ending 19 September because the quantity of fish caught in the recreational fishery was negligible. This estimate assumed no sampling bias associated with these fisheries, no preference by pinnipeds for particular salmonid species, and that pinnipeds were equally efficient at capturing each salmonid species.

Scale samples were collected opportunistically from feeding bouts occurring in the estuary. Working from a jet boat, Tribal staff would rush to the location of an ongoing feeding bout and skim the waters with fine meshed nets. Scale samples were mounted and pressed onto cards by tribal staff. Species identifications were assigned by a Humboldt State University student. Three independent classifications were made for each sample. For the purpose of determining reliability of identifications, 90 known species scale samples (consisting of coho, chinook, and steelhead) were classified by the same individual.

Coded wire tags (CWTs) recovered from chinook salmon in the Yurok Tribal net fishery indicate that substantial numbers of spring chinook were present in the estuary during the first three weeks of August. The proportion of spring versus fall chinook consumed by pinnipeds was estimated based upon the proportion of spring versus fall chinook CWTs recovered in the tribal fishery, after making appropriate expansions for hatchery production multipliers and accounting for the natural production of each race.

Estimated Impact to the Spawning Escapement

The abundance of fall chinook to the Klamath River Basin is reported annually by the California Department of Fish and Game (CDFG 2001) after enumeration by various agencies and volunteer groups. The proportion of the fall chinook run lost to pinniped predation during 1998 was estimated by summing the estimated river run and the estimated impacts to fall chinook from pinniped predation and dividing this quantity into the estimated pinniped impacts to fall chinook.

The California Department of Fish and Game (CDFG) estimated the 1998 coho salmon escapement to the Trinity River (above the Willow Creek weir) using a mark and recapture methodology, Hoopa Valley and Yurok Tribal fishery programs estimated tribal coho harvest, and returns to Iron Gate Hatchery were enumerated by CDFG. Coho escapement to the rest of the Klamath-Trinity Basin was not estimated, however it is thought to be substantially less than escapements above the Willow Creek weir and to Iron Gate Hatchery. This investigation ended on 14 November, which is prior to the end of the coho run, however catch per unit effort in the Yurok Tribal fishery indicates that the majority of the run has entered the river by this time (Yurok Tribe data files). A crude estimate of the proportion of the coho run lost to pinniped predation was determined by dividing the estimated pinniped predation by the sum of estimated coho river run (above Willow Creek weir and at Iron Gate Hatchery) and estimated predation to coho salmon.

Tidal Influence

The tidal stage was determined for the middle of each observation period, using the following formula that standardized the tidal stage on a scale of –1 to 1:

A = middle of the observation period
B = time of most recent high or low tide
C = time of next high or low tide
D = time of nearest low tide (which equals B or C)
Tidal Stage = $(A - D) \div (B - C)$

Using this formula, values of one and negative one represent high tides, while zero represents a low tide. The distance of a value from zero represents its relative distance from low tide. Negative numbers represent an outgoing tide while positive numbers represent an incoming tide.

The relationship between tidal stage and the number of feeding bouts was assessed within each area by looking at scatter plots and conducting a chi-square test of independence. Observation periods with visibility below 75% or duration less than 30 minutes were excluded. Observation periods with visibility between 75 and 100% and/or duration between 30 and 60 minutes were expanded to represent a full hour of observations at 100% visibility. For the Chi-square analysis, tidal stage was categorized as high or low (absolute value of tidal stage ≥ 0.5 and < 0.5 respectively). The number of feeding impacts for each 60-minute observation period was categorized as being less than two impacts or two or more impacts.

Diurnal Influence

Observation areas were assessed for relationships between time of day and presence of feeding impacts by performing chi-square analysis. Bar charts depicting the area specific hourly rate of feeding impacts for each daylight quarter were created as visual aids.

Daylight quarters were determined for each day by summing the quantity of daylight minutes, (20 minutes before sunrise until 20 minutes after sunset), and dividing the sum into four equal quarters to represent early morning (quarter 1); late morning (quarter 2); early afternoon (quarter 3); and late afternoon / evening (quarter 4). The assignment of each observation period to a quarter of the day was dependent upon the time of the middle of the observation period. Observation periods with visibility below 75% or duration less than 30 minutes were excluded. Observation periods with visibility between 75 and 100% and/or duration between 30 and 60 minutes were expanded to represent a full hour of observations at 100% visibility. For chi-square analysis, time of day was categorized by daylight quarter and feeding events were categorized by presence or absence.

Pinniped Abundance

The abundance of pinnipeds was monitored by boat and from land. During each observation period, the maximum number of individuals, per species, was recorded for the sampled area. These counts were expanded to account for visibility less than 100%. The maximum hourly occurrence of each species, per area, was determined on a weekly basis.

Approximately once a week, boat surveys were conducted during the high and low tidal cycles. Beginning at the upriver boundary of the study area (area 6; Figure 2), Yurok staff would slowly cruise through each observation area recording species composition and distribution. Each boat survey culminated with a shore count of the mouth and surf zone (area 1), as conditions were often hazardous at the mouth for boat traffic.

Although sea lions do not haul-out in the estuary, there is a site located approximately one mile north of the Klamath River which is utilized as a haul-out by California and Steller sea lions. During the study period, at low tide, an individual hiked to this site approximately once a week to enumerate pinnipeds hauled out. Between November 1996 and January 1998, The Yurok Tribe conducted regular counts of this haul-out area from a single observation point. Portions of the haul-out were obstructed from view due to the character of the terrain at the cove, resulting in occasional underestimation of the sea lion populations. In August 1998, sampling was resumed and new observation points were located where the entire haul-out could be viewed by dividing it into three sections that could be counted in their entirety from different observation points. The Tribe continues to survey this site approximately once each month.

Harbor Seal Scat Collection, Processing, and Analysis

Scat samples were collected from harbor seal haul-out sites in the Klamath River Estuary. Attempts were made several days each week in the early morning hours. A target number of 50 scat samples per week was established. As the study progressed, the scarcity of scat at haul-out sites led to additional attempts by staff to opportunistically collect scat. Individual scats were placed in plastic bags, labeled with date and location, and frozen for later processing.

Thawed scat samples were processed by rinsing through a series of nested sieves (2.0 mm, 1.0 mm and 0.71 mm). Prey hard parts were recovered from the sieves and placed in labeled vials containing 70% alcohol. After soaking for at least one week, the samples were dried in a food dehydrator and stored in labeled vials for future identification.

Prey hard parts were examined by Pacific IDentifications Inc. (Victoria, British Columbia), a private company that specializes in the identification of hard parts. Identification and enumeration of prey items was accomplished using the all structures available methodology and a comparative skeletal collection. Size estimates of prey were determined using comparative specimens of known size. Salmonids were classified into three categories; smolt, small-sized adults (or jacks), and full-sized adults (Table 2). Frequency of occurrence (% FO) and minimum number of individuals (MNI) were determined to the lowest taxonomic level for each prey taxa. Frequency of occurrence was determined by dividing the sum of all scats containing identifiable prey remains of a particular prey taxa by the sum of all scats containing any identifiable prey remains. Minimum number of individuals was determined by summing from all scat samples, the minimum number of individuals enumerated for particular prey taxa.

Table 2. Age classification and corresponding lengths used by Pacific IDentifications to enumerate salmonid prey remains identified from pinniped scats.

Age Class	Length (cm)
Smolt	≤ 29.4
Small-sized Adult (or jack)	29.5 – 59.4
Full-sized Adult	≥ 59.5

RESULTS

Assessment of Pinniped Predation on Adult Salmonids

Estimated Impacts

During 1,358 hours of direct observations, 483 surface feeding bouts upon adult salmonids were observed (Table 3). The quantity of time sampled represents 17.2% of the potential daylight time available among the 6 areas during the course of this study. There were an estimated 3,077 impacts (± 316) upon adult salmonids during the study period (Table 3, Figure 3).

Table 3. Summary of hours observed, salmonid predations observed, salmonid predations estimated, and associated variance and 95% confidence intervals by area and for the entire study area.

Area	Hours Observed	Salmonid Predations Observed	Salmonid Predations Estimated	Variance	95% Confidence Interval
1	303	110	519	3,586	(401, 637)
2	271	134	752	7,537	(581, 923)
3	209	61	487	3,242	(375, 600)
4	207	60	347	3,072	(238, 456)
5	199	77	601	9,414	(410, 792)
6	169	41	371	4,309	(241, 500)
All	1358	483	3077	26,000	(2760, 3393)

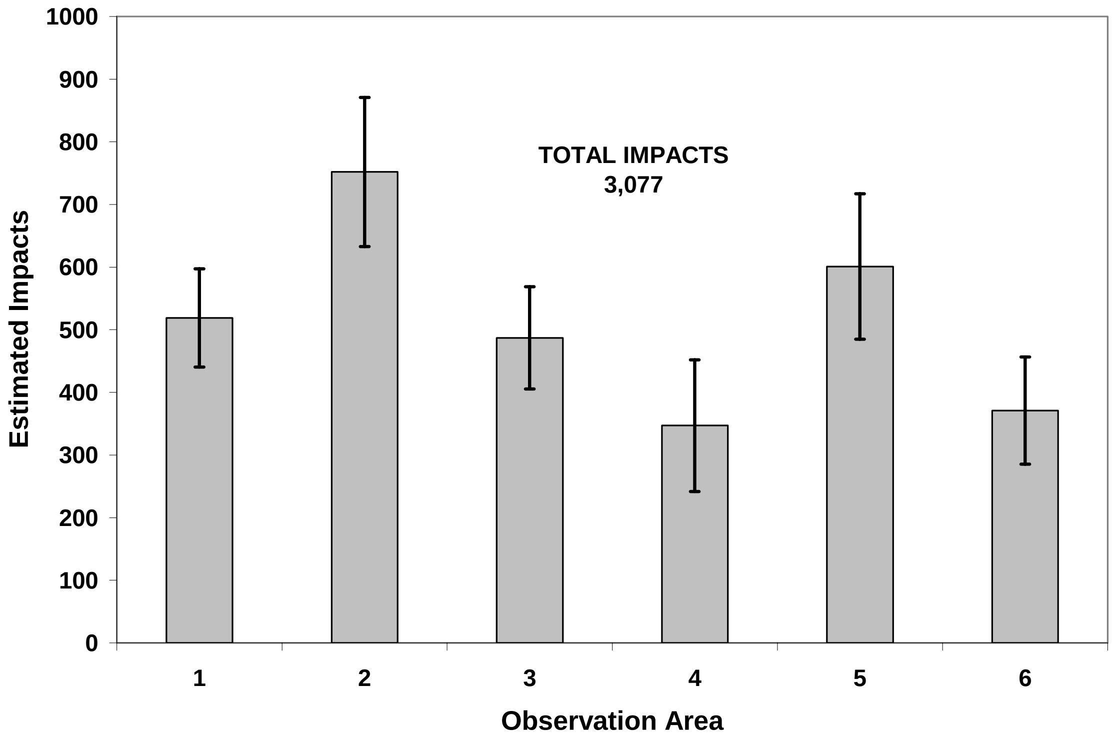


Figure 3. Estimated pinniped predation impacts upon adult salmonids and 95% confidence intervals, by observation area, in the Klamath River Estuary, 4 August-14 November 1998.

Species Composition of Salmonid Prey

Assuming species composition similar to that of the tribal and non-tribal estuary fisheries, chinook salmon were the primary salmonid species consumed during the study period, with an estimated 2,997 impacts (97.4%). Based upon coded wire tags recovered from the Yurok Tribal fishery, approximately 438 of these were spring-run chinook that were consumed during the first 3 weeks of August. Impacts to steelhead trout and coho salmon were minimal relative to chinook, with 60 (1.9%) and 20 (0.6%) impacts respectively (Figure 4).

A total of 39 salmonid scale samples were collected during feeding bouts, 37 of which contained scales in a condition that was adequate for determining species identities. Twenty-three of the samples were identified as chinook (62.2%), 9 were identified as steelhead (24.3%), and 5 were identified as coho (13.5%). The margin of error for the identification of known scales was greater than 20%, therefore the results from scales collected during feeding bouts were considered inadequate for determining the composition of prey species.

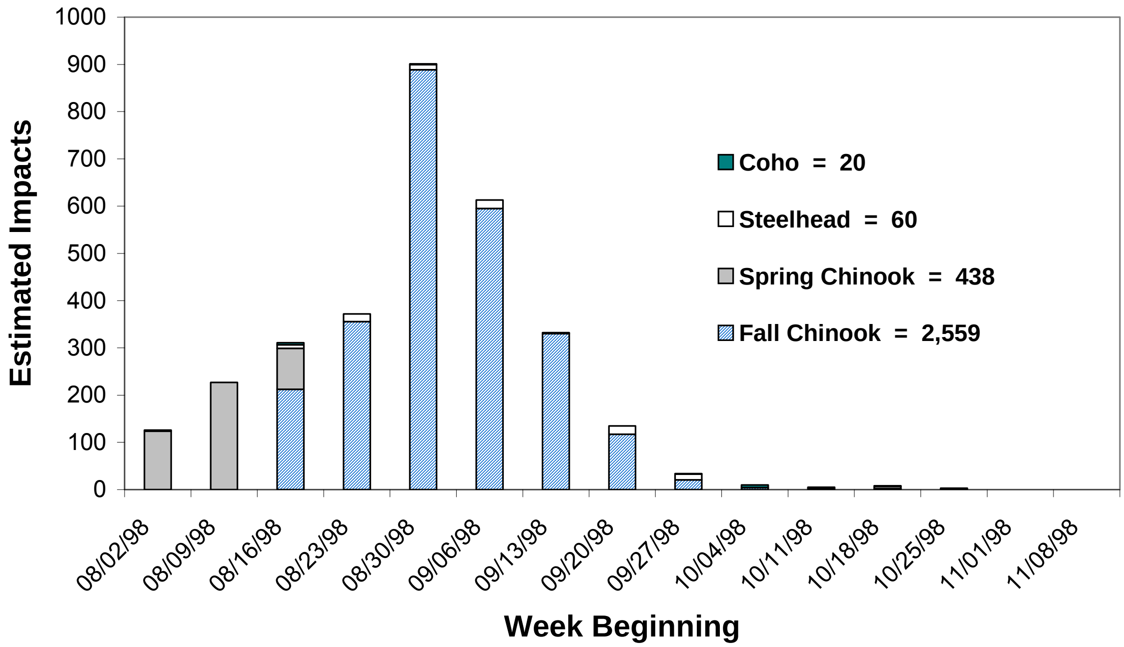


Figure 4. Estimated species composition of adult salmonids (including grilse chinook) consumed by pinnipeds in the Klamath River Estuary, 4 August-14 November 1998. Estimates based upon average species composition of tribal and non-tribal estuary fisheries.

Estimated Impact to the Spawning Escapement

The 1998 fall chinook run to the Klamath-Trinity Basin was estimated to be 95,210 salmon. Assuming that 2,559 fall chinook were consumed by pinnipeds during the study period, the impact rate to the river fall chinook run was estimated to be 2.6% (Table 4). Based on methods previously described, the estimated minimum escapement of coho salmon to the Klamath-Trinity Basin during 1998 was 10,891 salmon. Assuming that 20 coho salmon were consumed during the study period, the impact rate to the coho run was estimated to be 0.2% (Table 4).

Table 4. Estimated minimum pinniped predation rates upon fall chinook and coho salmon runs to the Klamath River, 1998.

Prey Species	Estimated Run Size (Excluding Pinniped Predation)	Estimated Pinniped Predation Impacts	Estimated Pinniped Predation Impact Rate
Fall Chinook	95,210	2,559	2.6%
Coho	10,891	20	0.2%

Species Composition of Pinniped Predators

Three species of pinnipeds were observed feeding upon adult salmonids during the study period; California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina richardsi*), and Steller sea lions (*Eumetopias jubatus*). California sea lions were responsible for 89.8% of the estimated impacts to adult salmonids, while Pacific harbor seals and Steller sea lions were responsible for 6.3% and 3.8% respectively (Figure 5). It should be noted that these estimates are based on direct observations, which revealed that feeding events by California sea lions are much easier to recognize than the more discrete feeding events of Pacific harbor seals. The presence of Steller Sea Lions in the estuary is rare relative to the other two species.

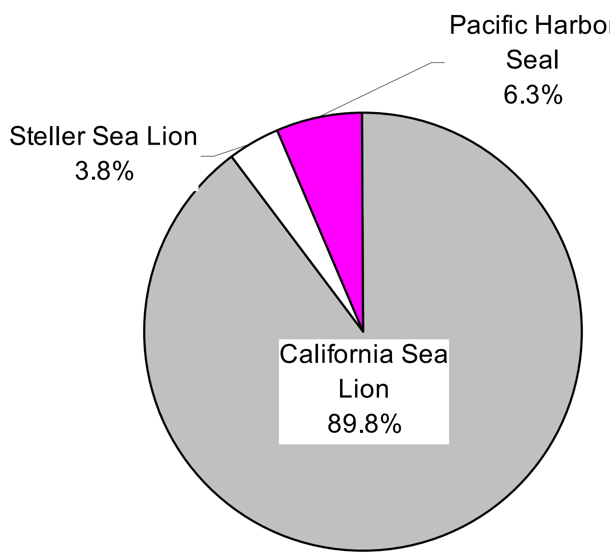
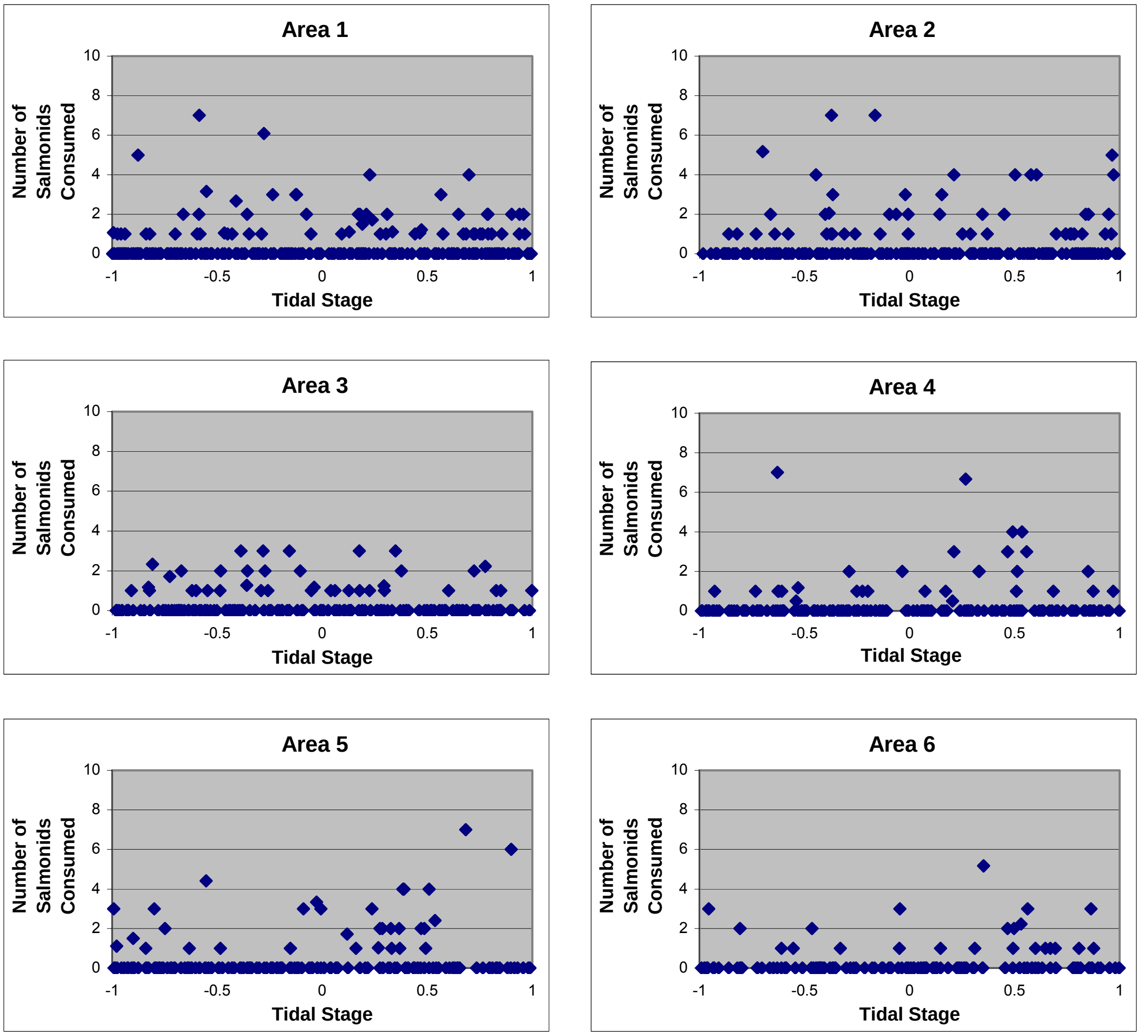


Figure 5. Percent predation by pinnipeds upon adult salmonids in the Klamath River Estuary, 1998.

Tidal Influence

Scatter plots indicate little relationship between tidal stage and frequency of feeding events (Figures 6-11). Chi-square analysis supports the conclusion that frequency of feeding events was independent of tidal stage (Table 5).



Figures 6-11. Relationship, by area, between tidal stage and number of salmonids consumed during observation periods in the Klamath River Estuary, 4 August-14 November 1998. Observation periods with visibility between 75 and 100% and/or duration between 30 and 60 minutes were expanded to represent 60-minute periods with 100% visibility. Observation periods under 30 minutes or with visibility below 75% were excluded. High tidal stage is represented by "-1" and "1", while low tidal stage is represented by "0".

Table 5. Results of chi-square analysis to test the null hypothesis (H_o) that the quantity of feeding events during an observation period was independent of tidal stage in the Klamath River Estuary, 1998. Tidal stage was classified into 2 categories (low vs. high) and feeding impacts per observation period were classified into 2 categories (less than two and two or more).

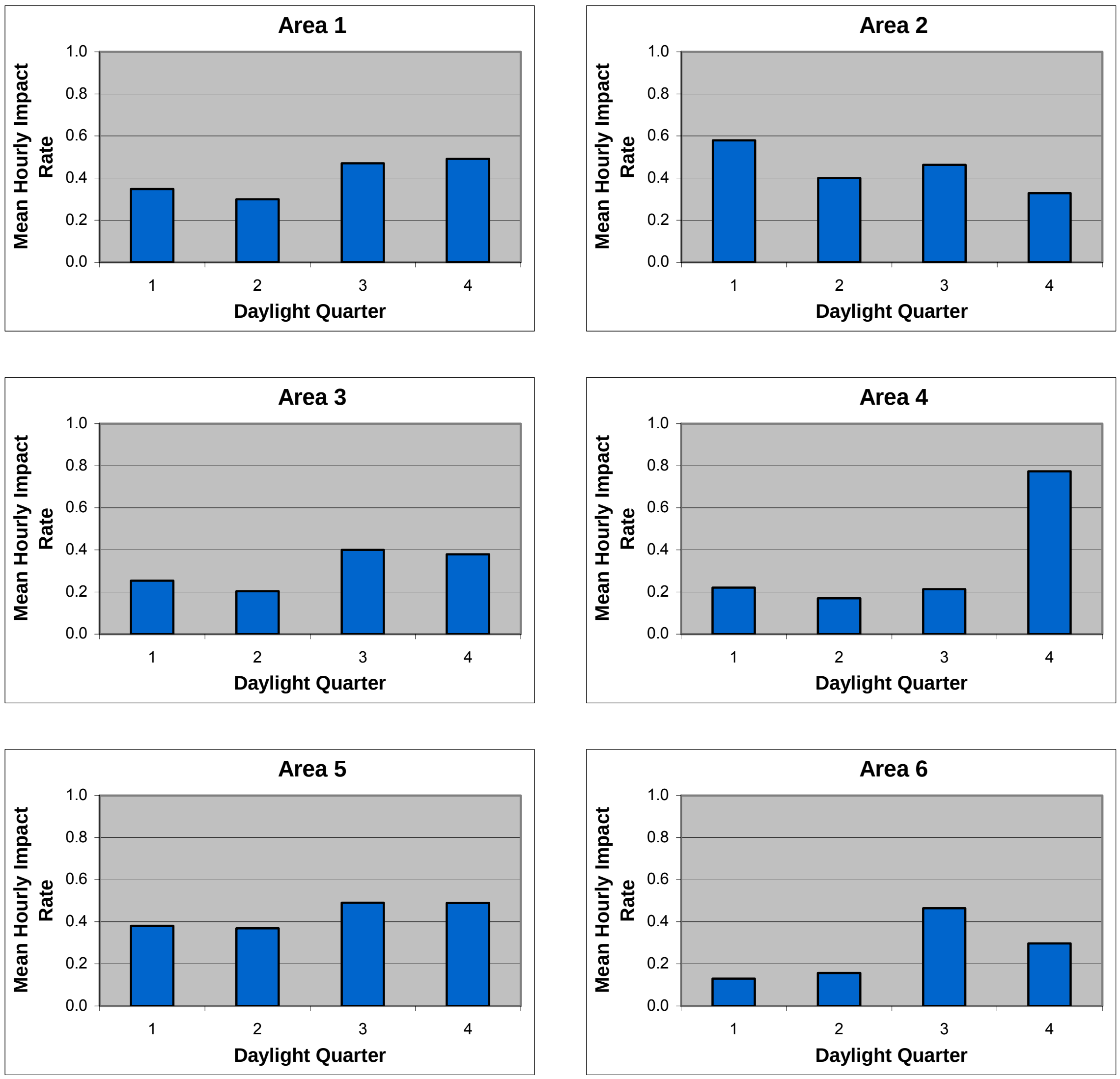
Area Tested	Result	Chi-Square Value	P-Value
1	Do not Reject H_o	0.119	0.730
2	Do not Reject H_o	1.532	0.216
3	Do not Reject H_o	3.051	0.081
4	Do not Reject H_o	0.676	0.411
5	Do not Reject H_o	0.548	0.459
6	Do not Reject H_o	0.033	0.855

Diurnal Influence

There was no relationship between time of day and number of feeding events in areas 1,2,3, and 5 (Figures 12-14, 16). Chi-square analysis supported that the presence of feeding events was not dependent on the time of day in these areas (Table 6). Increased predation did occur during the last quarter of the day in area 4 (Figure 15) and this was supported by chi-square analysis ($p = 0.03$, Table 6). Predation rates slightly increased in the early afternoon (quarter 3) in area 6 (Figure 17), however the presence of feeding events was not significantly dependent upon the time of day in this area ($p = 0.30$, Table 6).

Table 6. Results of chi-square analysis to test the null hypothesis (H_o) that the presence of feeding events during an observation period was independent of time of day in the Klamath River Estuary, 1998. Time of day was classified into 4 categories (early morning, late morning, early afternoon, late afternoon / evening) and feeding events were categorized by presence or absence.

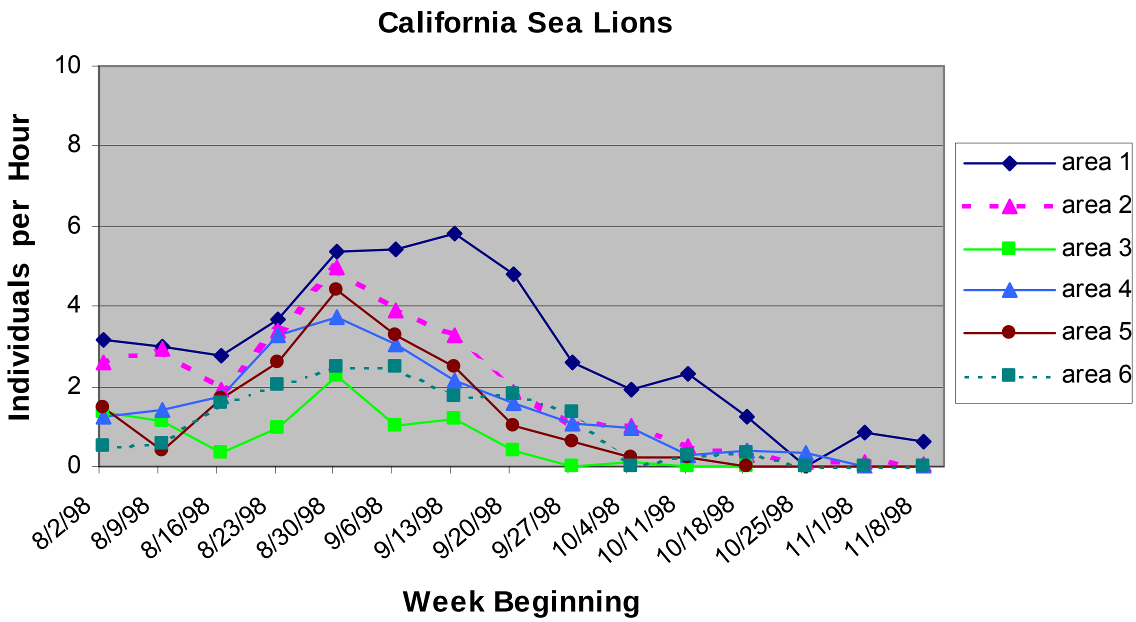
Area Tested	Result	Chi-Square Value	P-Value
1	Do Not Reject H_o	1.201	0.753
2	Do Not Reject H_o	1.380	0.710
3	Do Not Reject H_o	3.362	0.339
4	Reject H_o	8.446	**0.038**
5	Do Not Reject H_o	0.398	0.941
6	Do Not Reject H_o	3.688	0.297

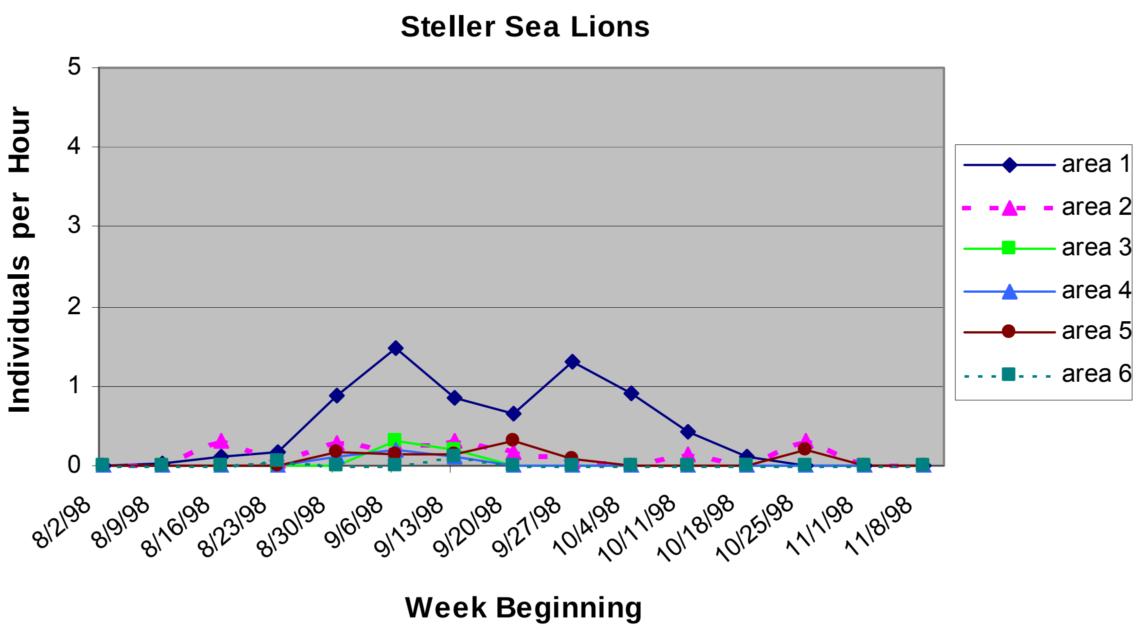


Figures 12-17. Mean hourly rate of salmonid impacts, by area, for each quarter of daylight, 4 August- 14 November 1998. Daylight quarters represent early morning (quarter 1), late morning (quarter 2), early afternoon (quarter 3), and late afternoon / evening (quarter 4). Observation periods with visibility between 75 and 100%, and/or duration between 30 and 60 minutes were expanded to represent 60-minute periods with 100% visibility. Observation periods under 30 minutes or with visibility below 75% were excluded.

Pinniped Abundance

Estimated maximum hourly occurrence of each pinniped species indicated that California and Steller sea lions were most abundant in area 1 throughout most of the study period (Figures 18-19).





Figures 18-19. Estimated maximum hourly occurrence of California and Steller sea lions, by area, 4 August -14 November 1998.

California sea lion abundance peaked in early September in all areas except area 1, which reached a plateau throughout most of September (Figure 18). Steller sea lion abundance was substantially lower than both other pinniped species, most often observed in area 1 from late August through early October (Figure 19). Pacific harbor seal abundance increased through the months of October and November (Figure 20), corresponding with decreased occurrence of sea lions (Figures 18-19). Large numbers of harbor seals were observed congregating in the shallow sandy banks in the northern portion of area 2 and the southern portion of area 4 (Figures 2, 20).

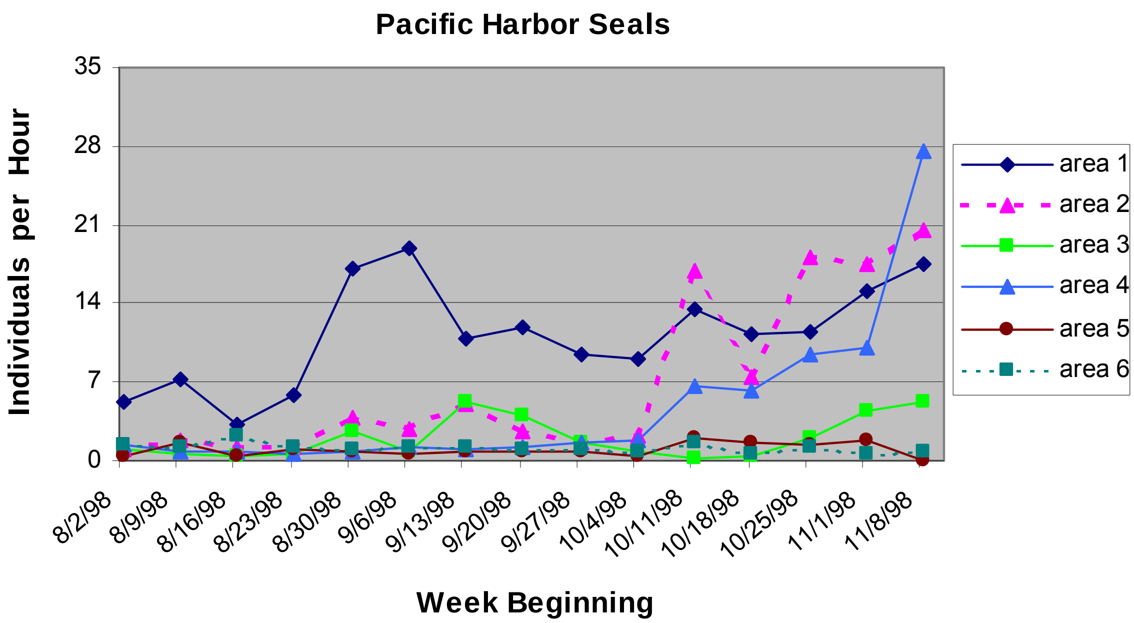


Figure 20. Estimated maximum hourly occurrence of Pacific harbor seals, by area, 4 August - 14 November 1998.

Boat surveys conducted approximately once per week, during high and low tidal cycles, revealed general pinniped usage trends in the estuary. The population of California sea lions followed an increasing trend throughout August, peaking in early September before decreasing throughout the remainder of the study. California sea lion counts were generally greater during high tide (Figure 21). Steller sea lions were rarely seen in the estuary at either high or low tide. The abundance of harbor seals increased throughout the study period. Following the decline of California sea lions in mid September, harbor seal abundance substantially increased throughout the remainder of the study, becoming much greater than the abundance of California sea lions.

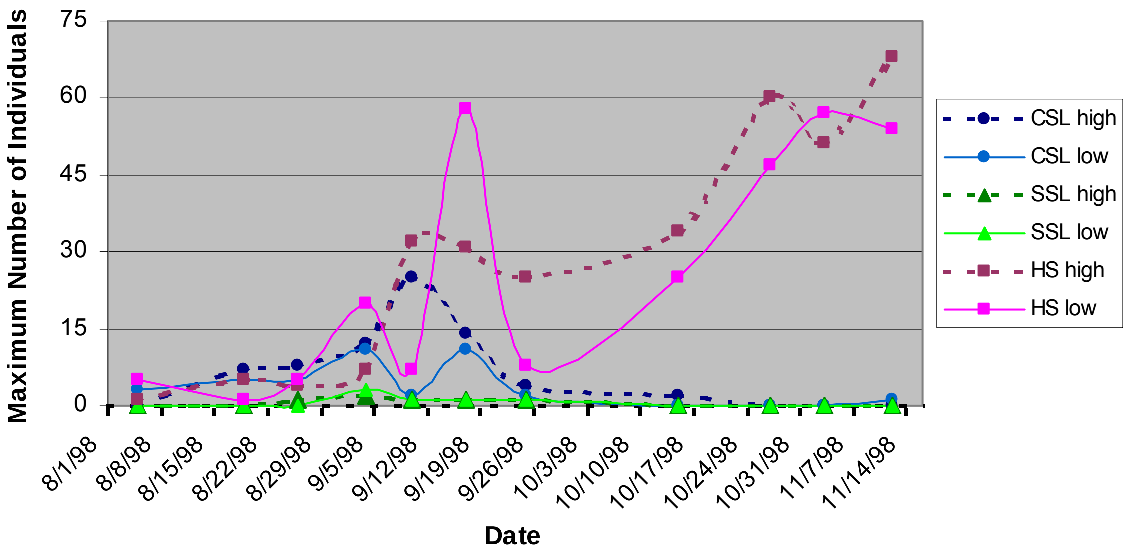


Figure 21. High and low tide comparison of pinniped abundance counts in the Klamath River Estuary, 5 August - 12 November 1998.

Abundance counts at Klamath Cove, a known haul-out location near the Klamath River Estuary indicate California sea lions, and to a lesser extent Steller sea lions, are utilizing the haul-out regularly during the fall chinook and coho runs. California sea lion abundance ranged from 46 to 226 individuals during the study period, peaking in early September. Steller sea lion counts fluctuated between 6 and 41 individuals during that time. Seasonal fluctuations can be noted as California sea lion populations drop throughout spring, becoming virtually absent in June and July. Steller sea lions displayed an increase in population throughout the winter before decreasing in the spring (Figure 22).

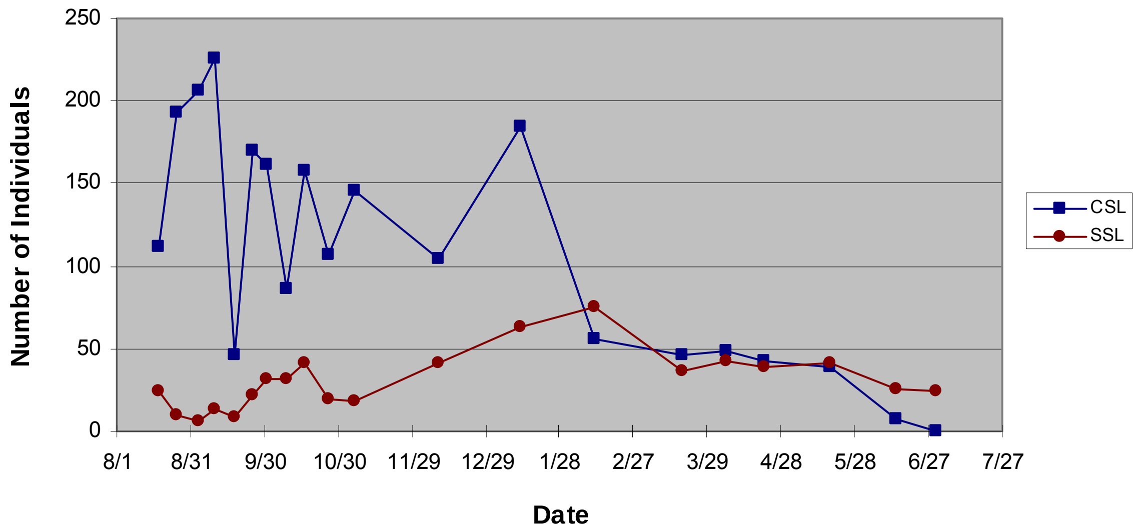


Figure 22. Comparison of California and Steller sea lion abundance counts at Klamath Cove haul-out, August 1998 - June 1999.

Harbor Seal Scat Analysis

A total of 399 harbor seal scats were collected from various haul-out locations on the south spit of the Klamath River Estuary between April 1998 and March 1999, Identifiable prey remains were contained in 390 (97.7%) of the samples. For the purpose of seasonal diet comparison, the year was divided into three time periods based upon historical anadromous fish run timing; Autumn, to coincide with fall-run chinook and coho as well as the pinniped predation study period, from August through November; Spring, to coincide with spring-run chinook from April through July; and Winter to coincide with winter-run steelhead from December through March.

During the Autumn period, a total of 252 harbor seal scats were collected, all containing identifiable prey remains. Twelve prey items were identified to species, with 35 additional prey items identified to genus, family, order, or class level. Scat samples collected during this study period yielded a cumulative minimum number of individuals (MNI) of 2367.

The most frequently occurring prey items (FO) identified in these samples were smelt (Family Osmeridae; 56.3%), righteye flounder (Family Pleuronectidae; 33.7%), lamprey species (*Lampetra* spp.*;* 16.7%), sanddab species (*Citharichthys* spp.*;* 15.1%), and salmonid species (*Oncorhynchus* spp.*; 14.3*%) (Table 7).

Table 7. Percent frequency of occurrence (%FO) and minimum number of individuals (MNI) of prey items identified from Pacific harbor seal scats (n = 252) collected at haul-out sites located in the Klamath River Estuary, Autumn 1998.

COMMON NAME	SCIENTIFIC NAME	% FO	MNI
Smelt	Family Osmeridae	56.3	1158
Righteye flounder	Family Pleuronectidae	33.7	238
Lamprey species	*Lampetra* spp.	16.7	56
Sanddab species	*Citharichthys* spp.	15.1	215
Salmonid species	*Oncorhynchus* spp.	14.3	40
Salmonid adult		13.9	37
Salmonid smolt		0.8	3
North Pacific hake	*Merluccius productus*	13.1	38
Flatfish	Order Pleuronectiformes	10.3	46
Cephalopod	Class Cephalopoda	9.9	47
Sculpin	Family Cottidae	6.7	86
Skate	Family Rajidae	6.3	16
Pacific lamprey	*Lampetra tridentata*	5.6	33
Herring species	*Clupea* spp.	4.4	43
Surf smelt	*Hypomesus pretiosus*	4.4	135
Snailfish	Family Cyclopteridae	4.0	17
Large-tooth flounder	Family Paralichthyidae	3.6	55
Hagfish species	*Eptatretus* spp.	3.2	8
Rockfish species	*Sebastes* spp.	3.2	8
Agnatha	Class Agnatha	2.8	7
Cod / haddock	Family Gadidae	2.4	6
Dover sole	*Microstomus pacificus*	2.4	12
Scorpaeniformes	Order Scorpaeniformes	2.4	6
Unidentified fish		2.4	7
Ophidiiformes	Order Ophidiiformes	2.0	9
Rex sole	*Glyptocephalus zachirus*	2.0	14
Gaddiformes	Order Gadiformes	1.6	4
Pacific tomcod	*Microgadus proximus*	1.6	5
Clingfish	Family Gobiesocidae	1.2	4
Greenling species	*Hexagrammos* spp.	1.2	6
Herring	Family Clupeidae	1.2	3
Octopus species	*Octopus* spp.	1.2	13
Poacher	Family Agonidae	1.2	3
Salmoniformes	Order Salmoniformes	1.2	3
Hagfish	Family Myxinidae	0.8	2
Pacific herring	*Clupea pallasi*	0.8	5
Pacific sanddab	*Citharichthys sordidus*	0.8	2
Clupeiformes	Order Clupeiformes	0.4	1
cusk-eel	Family Ophidiidae	0.4	2
Gobiesociformes	Order Gobiesociformes	0.4	1
Gunnel	Family Pholidae	0.4	1
Irish lord species	*Hemilepidotus* spp.	0.4	1
Kelp greenling	*Hexagrammos decagrammus*	0.4	3
Pacific halibut	*Hippoglossus stenolepis*	0.4	1
Pacific staghorn sculpin	*Leptocottus armatus*	0.4	1
Perciformes	Order Perciformes	0.4	1
Rockfish	Family Sebastidae	0.4	1
Slender sole	*Lyopsetta exilis*	0.4	2
Surfperch	Family Embiotocidae	0.4	1
Wolf-eel	*Anarrhichthys ocellatus*	0.4	1

Adult salmonids were identified from 35 scat samples collected between 1 September and 17 October, to yield a FO of 13.9%. Thirty-seven individuals were enumerated, of which 13 were estimated to be full sized adults and 24 small-sized adults or jacks (Table 2). Five salmonid otoliths were recovered. Two full sized adults and one small sized adult/jack were identified to order level Salmoniformes. It is likely these fish were salmonid species but due to poor bone condition could only be confidently identified to the higher taxonomic level. Three salmonid smolts were also identified (Tables 7,8).

Salmonid remains were identified from scats collected during the weeks beginning 30 August through 17 October 1998. Salmonid FO, calculated weekly over the course of the study, ranged from 0% to 34.8%, peaking the week of 13 September. Weekly MNI peaked the week of 30 August, coinciding with peak estimated Pacific harbor seal predation. Prior to the week of 30 August, very few scats were collected and none contained salmonid remains. This was the trend continuing for the weeks prior to 18 October through the end of the study.

Table 8. Weekly summary of estimated predation due to Pacific harbor seals, scat sample size, number of scats containing adult salmonid remains, minimum number of adult salmonids (MNI) enumerated from scats, frequency of adult salmonids occurring in scats (%FO), and minimum number of salmonid smolts (MNI) enumerated from scats, Autumn 1998.

Week Beginning	Estimated Harbor Seal Predation from Direct Observations	Number of Scat	Number of Scat Containing Adult Salmonids	MNI Adult Salmonids	% FO Adult	MNI Smolt
02 Aug	19	5	0	0	0	0
09 Aug	24	1	0	0	0	0
16 Aug	24	0	0	0	0	0
23 Aug	3	0	0	0	0	0
30 Aug	50	60	15	17	25.0	2
06 Sept	30	15	1	1	6.7	0
13 Sept	19	23	8	8	34.8	0
20 Sept	7	56	5	5	8.9	1
27 Sept	7	35	3	3	8.6	0
04 Oct	0	19	1	1	5.3	0
11 Oct	0	26	2	2	7.7	0
18 Oct	8	0	0	0	0	0
25 Oct	3	2	0	0	0	0
01 Nov	0	7	0	0	0	0
08 Nov	0	3	0	0	0	0
Total	**194**	**252**	**35**	**37**	**n/a**	**3**

One hundred and ten scats were collected between April and July 1998, 105 (95.5%) contained identifiable prey remains. Ten prey items were identified to species with 28 other prey items identified to genus, family, order, or class level. The most frequently occurring prey items were North Pacific hake (*Merluccius productus*; 56.2%), righteye flounder (Family Pleuronectidae; 21.9%), lamprey species (*Lampetra* spp.; 19.0%), smelt (Family Osmeridae; 19.0%), and cod/haddock (Family Gadidae; 14.3%). Adult salmonids were identified in two scats, yielding a FO of 1.9%. Three salmonid smolts were identified, resulting in a FO of 2.9% (Table 9).

Between December 1998 and March 1999, 37 scats were collected, of which 33 (89.1%) contained identifiable prey remains. Two prey species plus 24 other prey taxon were identified. The most commonly occurring prey items were righteye flounder (Family Pleuronectidae; 30.3%), smelt (Family Osmeridae; 30.3%), poacher (Family Agonidae; 24.2%), sculpin (Family Cottidae; 24.2%), and snailfish (Family Cyclopteridae; 24.2%). No salmonids were identified from the samples (Table 10).

Table 9. Percent frequency of occurrence (%FO) and minimum number of individuals (MNI) of prey items identified from Pacific harbor seal scats (n = 105) collected at haul-out sites located in the Klamath River Estuary, Spring 1998.

COMMON NAME	SCIENTIFIC NAME	% FO	MNI
North Pacific hake	*Merluccius productus*	56.2	75
Righteye flounder	Family Pleuronectidae	21.9	91
Lamprey species	*Lampetra* spp.	19.0	22
Smelt	Family Osmeridae	19.0	34
Cod / haddock	Family Gadidae	14.3	48
Pacific lamprey	*Lampetra tridentata*	12.4	29
Herring species	*Clupea* spp.	11.4	16
Pacific tomcod	*Microgadus proximus*	10.5	23
Sanddab species	*Citharichthys* spp.	8.6	24
Unidentified fish		8.6	9
Rex sole	*Glyptocephalus zachirus*	5.7	16
Sculpin	Family Cottidae	5.7	9
Snailfish	Family Cyclopteridae	5.7	7
Flatfish	Order Pleuronectiformes	4.8	5
Octopus species	*Octopus* spp.	4.8	14
Cephalopod	Class Cephalopoda	3.8	6
Salmonid species	*Oncorhynchus* spp.	3.8	5
Salmonid adult		1.9	2
Salmonid smolt		2.9	3
Gadiformes	OrderGadiformes	2.9	3
Hake species	*Merluccius* spp.	2.9	3
Prickleback	Family Stichaeidae	2.9	4
Skate	Family Rajidae	2.9	3
Surfperch	Family Embiotocidae	2.9	3
Hagfish	Family Myxinidae	1.9	2
Ophidiiformes	Order Ophidiiformes	1.9	2
Agnatha	Class Agnatha	1.0	1
Californian anchovy	*Engraulis mordax*	1.0	1
Clupeiformes	Order Clupeiformes	1.0	1
Dover sole	*Microstomus pacificus*	1.0	1
Herring / shad	Family Clupeidae	1.0	1
Large-tooth flounder	Family Paralichthyidae	1.0	2
Longfin smelt	*Spirinchus thaleichthys*	1.0	6
Midshipman species	*Porichthys* spp.	1.0	1
Pacific cod	*Gadus macrocephalus*	1.0	1
Pacific sand sole	*Psettichthys melanostictus*	1.0	1
Perciformes	Order Perciformes	1.0	1
Poacher	Family Agonidae	1.0	1
Rock sole	*Lepidopsetta bilineata*	1.0	1
Rockfish species	*Sebastes* spp.	1.0	1
Squid	Order Teuthida	1.0	1

Table 10. Percent frequency of occurrence (%FO) and minimum number of individuals (MNI) of prey items identified from Pacific harbor seal scats (n = 33) collected at haul-out sites located in the Klamath River Estuary, Winter 1998.

COMMON NAME	SCIENTIFIC NAME	% FO	MNI
Righteye flounder	Family Pleuronectidae	30.3	23
Smelt	Family Osmeridae	30.3	72
Poacher	Family Agonidae	24.2	11
Sculpin	Family Cottidae	24.2	30
Snailfish	Family Cyclopteridae	24.2	17
Skate	Family Rajidae	15.2	5
Sanddab species	*Citharichthys* spp.	12.1	34
Unidentified fish		12.1	4
Irish lord species	*Hemilepidotus* spp.	9.1	4
Lamprey species	*Lampetra* spp.	9.1	4
Rockfish	Family Sebastidae	9.1	3
Cod / haddock	Family Gadidae	6.1	2
Large-tooth flounder	Paralichthyidae	6.1	2
Pacific lamprey	*Lampetra tridentata*	6.1	4
Cartilaginous fish	Class Chondrichthyes	3.0	1
Cephalopod	Class Cephalopoda	3.0	1
Flatfish	Order Pleuronectiformes	3.0	1
Greenling	Family Hexagrammidae	3.0	1
Hagfish	Family Myxinidae	3.0	1
Hagfish species	*Eptatretus* spp.	3.0	1
Herring	Family Clupeidae	3.0	1
Kelp greenling	*Hexagrammos decagrammus*	3.0	1
North Pacific hake	*Merluccius productus*	3.0	1
Octopus species	*Octopus* spp.	3.0	1
Polychaete worm	Class Polychaeta	3.0	1
Scorpaeniformes	Order Scorpaeniformes	3.0	1

DISCUSSION

Predation Impacts

The investigations into pinniped predation upon adult salmonids in the Klamath River Estuary in 1998 indicate that fewer salmonids were consumed during the 1998 study than during the 1997 pilot study. Estimates from this study indicate that 3,077 adult salmonids were consumed during the entire study period, as compared to 10,105 during the 1997 pilot study. The estimated 1998 impact rate upon adult fall-run chinook was 2.6%, down from the estimate of 8.8% in 1997. However, it is worth noting that the 1997 pilot study did not have a statistically rigorous sampling design, so unlike the 1998 study, the level of confidence in the 1997 impact estimate is unknown. Ocean conditions during the 1997 study were drastically different from the 1998 and 1999 studies. August through October 1997 represented the strongest El Niño conditions during these months since 1950. Hillemeier (1999) speculated that poor ocean feeding conditions associated with El Niño may have led to increased numbers of California sea lions entering the Klamath River in search of prey, coinciding with the fall chinook run.

As in the 1997 study, California sea lions remained the primary predator, accounting for nearly 90% of estimated impacts (87% in 1997). Results from investigations into the feeding habits of pinnipeds in the Lower Klamath River conducted 10 to 20 years prior to this study indicated vastly different results. Sea lions were markedly absent from the Klamath River during the time of year when these investigations were conducted (Bowlby, 1981.) Bowlby speculated that sea lions primarily came to the Klamath River between March and June to feed upon Pacific Lamprey (*Lampetra tridentatus*) that were migrating upriver. While monitoring pinniped fishery interactions during the fall of 1980, Herder (1983) noted that all predation impacts were attributable to harbor seals, none to sea lions. Similarly, while investigating harbor seal predation upon seined and released salmonids in the Klamath River from 1984 to 1988, Stanley and Shaffer (1995) made no mention of sea lion predation during their study. The contrasting results between this study (including the 1997 pilot study) and previous investigations indicate that temporal utilization of the Klamath River Estuary by sea lions has increased dramatically over the last two decades. Simultaneously, the impact of sea lions upon migrating adult salmonids during the fall season has also increased.

The estimated impact upon adult salmonids attributable to Pacific harbor seals, was substantially less than California sea lions; approximately 6.3% (195) of the total estimated impacts, which equates to approximately 0.2% (160) of the fall chinook run. While the estimated number of impacts was higher in 1997, the corresponding percent of impacts attributed to harbor seals upon adult salmonids remains comparable (9% in 1997). Past studies conducted in the Klamath River indicated that harbor seals were the primary pinniped predator of adult salmonids

(Bowlby 1981, Herder 1983, Stanley and Shaffer 1995), however given the differences in methodology; there is no comparable harbor seal predation rate. Hillemeier (1999) speculated that the presence of California sea lions foraging in the estuary might have decreased predation by harbor seals. Bigg (1990) noted that vigorous sea lion activity in the main foraging area in Cowichan Bay appeared to discourage harbor seals from feeding there.

While conducting observations, observers attempted to discern if prey was captured from a net, hook and line, or open areas where fishing activity was not present. The majority of prey captures (93.9%) were determined to be free-swimming fish that were not taken from recreational or tribal fishers. The remaining captures were taken from gill nets or recreation fishermen's gear. It is possible that this quantity was underestimated. At times, sea lions were observed taking salmon from a gill net and swimming to a different location within the estuary to feed. Observers attempted to accurately classify prey captures, yet given the large size of observation areas, it is possible that some prey captures were mistakenly classified as free swimming when indeed they were taken from a gill net or a recreational fishermen's gear.

One major assumption of this study was that all feeding events upon adult salmonids could be seen at the surface of the water. California and Steller sea lion feeding events were conspicuous during this study, due to the thrashing about of the fish on the surface of the water. Similar observations were previously noted by Bigg (1990) and Hanson (1993), and the observation of surface feeding events for the purpose of quantifying pinniped predation on adult salmonids is considered a good technique at sites where salmonid foraging occurs, such as river mouths (NMFS 1997). However harbor seal predation during this study may have been underestimated due to the inconspicuous nature of harbor seal predation relative to California and Steller sea lions. As Hanson noted (1993), pursuit of prey may be obvious, but prey capture is often subtle, quick, and quiet, lacking the visible events of thrashing on the surface or birds in attendance. Given the fairly large size of observation areas used in this study, it is possible that some pursuits and subsequent feeding events by harbor seals were not detected.

Another assumption was that pinniped predation occurred only during daylight hours. While pinniped predation is thought to be minimal at night, pinnipeds have been observed at night both taking salmon from gill nets in the Klamath River, as well as occasionally eating salmon where gill nets were absent. Pinnipeds have also been observed eating salmon at night in other rivers, however it was thought that artificial illumination might have enhanced the opportunity for predation (Scordino and Pfeifer 1993).

The species composition of adult salmonids consumed during this study was assumed to be the same as the average weekly species composition of the tribal and recreational fisheries. This assumes no preference of pinnipeds for one salmonid species over another, and that there is no differential efficiency of ability to catch different salmonid species. This also assumes that any species bias within these fisheries is proportionally the same for pinnipeds consuming salmonids. The U.S. Fish and Wildlife Service conducted seining operations in the Klamath River during the months of July through September, 1986 – 1989. The results indicated that 86% (81 to 95% range) of the adult salmonids present in the estuary were chinook salmon. Bigg (1990) noticed that the primary species consumed during a given period of time in Comox Harbor and Cowichan Bay was the most abundant salmon species present. Given the USFWS results and Bigg's observation, Hillemeier (1999) speculated that the species composition of recreational and tribal fisheries might be a fairly accurate representation of the species composition of salmonids preyed upon by pinnipeds. Scale samples were also collected during feeding events in the estuary for the purpose of determining species composition. The resulting species identifications indicated that chinook salmon was the primary prey species, however, upon classification of known salmonid scales (chinook, coho and steelhead), over 20% of the scale samples were misidentified. The margin of error was too great to consider the results with any certainty. While the use of scale analysis could prove to be a useful tool for determining composition of prey species, genetic analysis would likely yield a more accurate result in determining prey identification.

Harbor seal scat analysis

Harbor seals haul-out along the sand spit that separates the Klamath River Estuary from the ocean. Scat was collected from these haul-out sites before, during and after this study. Sample size goals were not determined for scat collection prior to and following the fall chinook study period. Attempts to collect a minimum of 50 scat samples per week during the 15 week fall chinook study period was only achieved during two weeks (Table 8). The minimum number of samples was rarely obtained because of the sporadic and minimal use of haul-out sites during the study period. The sporadic use of haul-out sites may have been the result of Tribal and sport fishery activities, such as people camping at known haul-out locations and boat activity, discouraging the harbor seals from utilizing the spit as a haul-out location. The scarcity of harbor seals and scat at haul-out sites prompted additional opportunistic collection attempts. Very few scats were collected during the first and last four weeks of the study period.

Analysis of harbor seal scat collected in the Klamath River Estuary indicated that adult salmonids were present in 13.9% of scats collected during the study period. Scats containing salmonid remains were collected during the weeks of 30 August through 17 October 1998. Frequency of occurrence ranged from 5.3% to 34.8% during the weeks when salmonid remains were identified from scats. The largest weekly MNI (17) and scat sample size (n=60) occurred the week of 30 August 1998. This was the same week during which peak estimated predation in the estuary attributed to harbor seals, California sea lions, and combined pinniped species occurred. Nearly all the fish harvested in the tribal fishery through 3 October 1998 were chinook salmon.

The tribal fishery consists primarily of gill netting. Mesh size of the gill nets varies, however the typical size used is 7.25 inches, which is selective for large fish. Therefore, while the net fishery may indicate relative species composition of salmonids in the estuary at a given time, it likely underestimates the proportion of smaller species, such as coho salmon listed as “Threatened” under the Endangered Species Act and steelhead. During this study, coho salmon were harvested in the tribal fishery between 26 September and 17 October 1998. The Tribal fishery harvest ratio of coho to all salmonids was greatest the week of 4 October 1998, with 58% of the harvest consisting of coho salmon. One salmonid was identified from 19 scats during that week. It may be useful to further assess the prey composition of harbor seal scat in the future, especially during the time period that coho salmon are in the estuary. However, such efforts would be of limited value unless the species of the salmonid prey could be identified. It is recommended that if scat is collected in the future, that genetic analysis be used to identify the species of salmonid prey. The utility of such information would also be substantially increased by the ability to make a quantitative estimate regarding the number of salmonids consumed by harbor seals.

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