An Assessment of Pinniped Predation Upon Fall-run Chinook Salmon in the Klamath River Estuary, CA, 1999

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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 8 August to 15 November 1999. Direct observations of surface feeding events by pinnipeds indicated that approximately 1,804 (1,570 - 2,038) adult (including grilse chinook and coho salmon) salmonids were consumed. Fall-run chinook was the primary species of prey, with an estimated 1,630 fish consumed, which was equivalent to 2.3% of the estimated fall chinook run. An estimated 63 coho (*Oncorhynchus kisutch)* salmon and 110 steelhead (*Oncorhynchus mykiss)* were consumed during the entire study period. California sea lions (*Zalophus californianus*) were the primary pinniped predator, accounting for 93.5% 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. The majority of prey captures (94.4%) were determined to be free-swimming fish that were not taken from recreational or tribal fishers. The remaining captures were taken from gill nets. Night observations indicated minimal pinniped presence or activity in the Klamath River Estuary. Most pinniped predation in the Klamath River Estuary occurred during daylight hours. Relationships linking increased predation with tidal cycle or time of day were indicated in several locations within the study area. Predation increased significantly during incoming low tide in areas 1 and 2, locations that were closest to the confluence with the ocean. Increased predation was noted to coincide with high tide in area 4, located directly upriver from area 2. At the furthest upriver locations, areas 5 and 6, significant relationships were found to exist between increased predation and time of day, with predation peaking during the early afternoon. Analysis of harbor seal scat collected in the Klamath River Estuary indicated that adult salmonids were present in 12.4% of scats collected during the study period. Analysis of California and Steller sea lion scats, collected twice from a sea lion haul out located approximately one mile north of the Klamath River, indicated that adult salmonids were present in 37.9% of scats.

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 began conducting studies 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).

METHODS

Assessment of Pinniped Predation on Adult Salmonids

Direct observations were used to record predation events of pinnipeds upon salmonids within specified times and areas. The 1997 pilot study and 1998 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 focused in this area. Daytime observations were conducted from approximately 20 minutes before sunrise until 20 minutes after sunset, between 8 August and 15 November 1999. Binoculars were used to aid in the detection of feeding events as well as identification of predator and prey. Night observations were conducted during the anticipated peak of the fall chinook run, between 20 August and 23 September 1999, with the aid of night vision equipment.

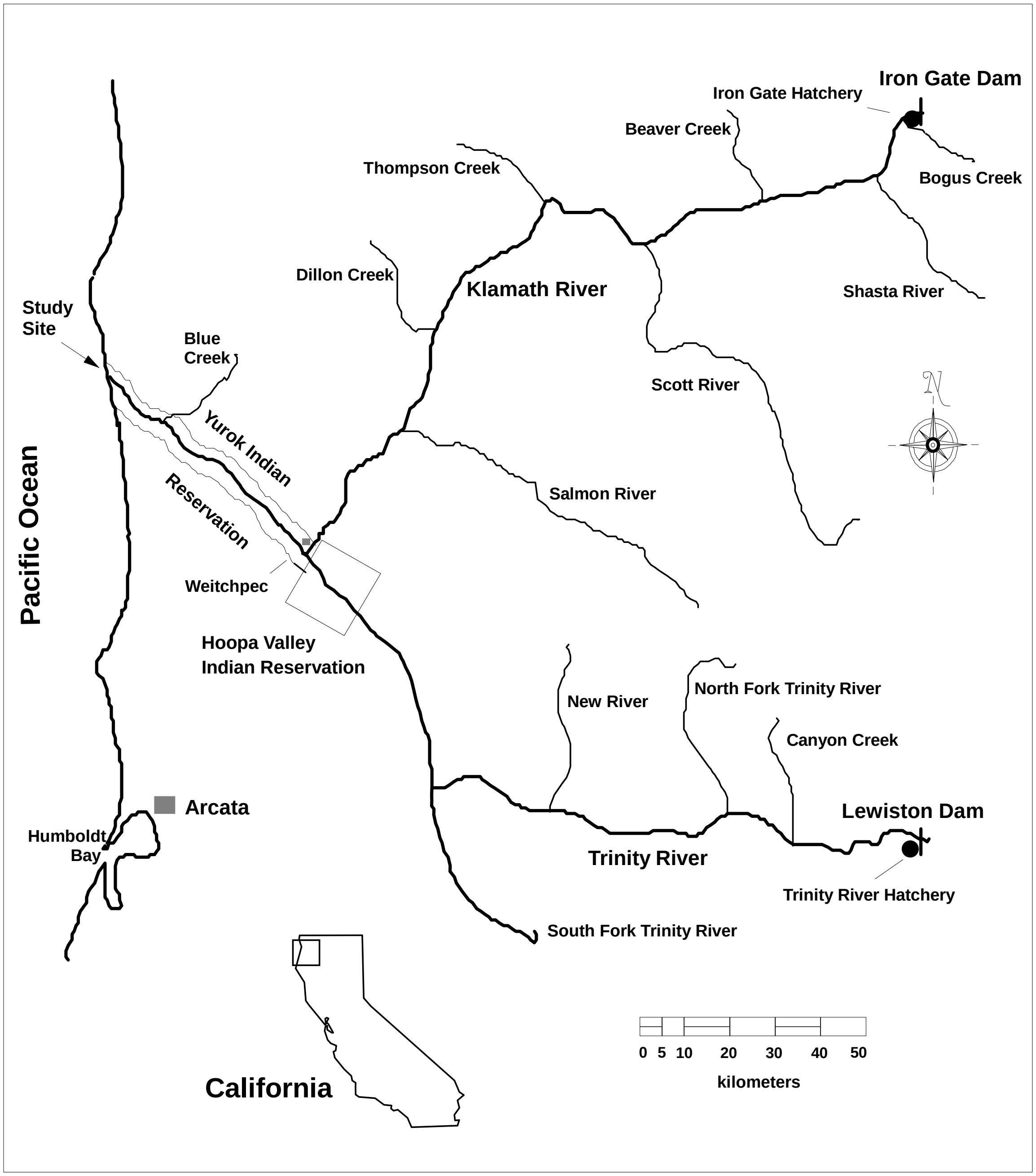


Figure 1. Location of study site and the Klamath River Basin within California.

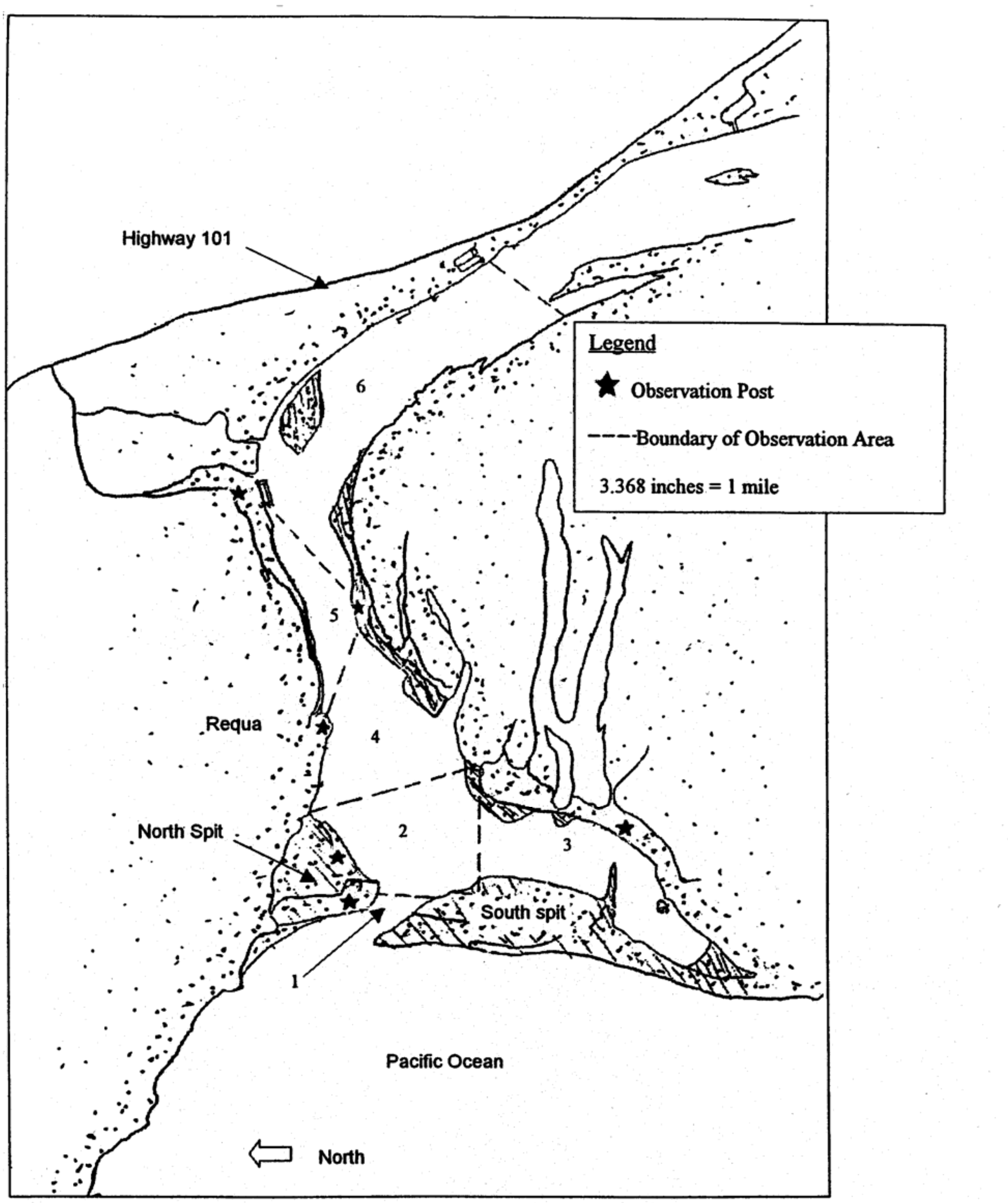


Figure 2. Observation areas within the study site, Klamath River Estuary, California.

Daytime Observations

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 1999, 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 late October when the spit shifted during a storm. 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).

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.

Table 1. Within-hour area selection probabilities $\{p_a\}$ used in 1999 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	08/08/1999	0.20	0.20	0.15	0.15	0.20	0.10
2	08/13/1999	0.20	0.22	0.15	0.15	0.18	0.10
3	08/18/1999	0.19	0.30	0.13	0.15	0.13	0.10
4	08/26/1999	0.19	0.25	0.14	0.16	0.15	0.11
5	08/27/1999	0.14	0.25	0.16	0.16	0.14	0.15
6	09/01/1999	0.13	0.33	0.17	0.12	0.15	0.10
7	09/09/1999	0.16	0.25	0.19	0.10	0.20	0.10
8	09/19/1999	0.12	0.22	0.12	0.21	0.21	0.12
9	09/23/1999	0.21	0.18	0.20	0.13	0.14	0.14
10	09/30/1999	0.30	0.17	0.17	0.12	0.12	0.12
11	10/14/1999	0.28	0.16	0.16	0.12	0.12	0.16
12	10/21/1999	0.31	0.14	0.15	0.11	0.11	0.18
13	11/04/1999	0.33	0.14	0.15	0.11	0.11	0.16

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

$\breve{y}_i = y_i / \pi_i$

$\breve{x}_i = x_i / \pi_i$

The probability that unit i was included in the sample (π_i) depends both on the set of area-specific selection probabilities $\{p_a, a = 1, 2, . . . , 6\}$ 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):

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

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

$$df_h = \sum_{areas} df_{kh}. \quad (12)$$

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.

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

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:

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

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

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

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 74 of the 1,356 selected units (5.5%). 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 af 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 during the weeks beginning 8 August, 26 September, 3 October, and 24 October through the end of the study 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.

Tissue and 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 water with fine meshed nets. Collected tissue samples were covered in 70% alcohol and stored in labeled vials for future genetic analysis and species identification. Genetic analysis performed at the Bodega Bay Marine Lab, involved two PCR based single-tube procedures that distinguish between chinook, coho, and steelhead. Scale samples were mounted and pressed for future species identification.

Pinniped feeding event footage was collected in the estuary with a Sony DCR-TRV310 digital video camera. The camera was utilized in the field several days per week, often during the daytime/nighttime comparison observation shift. The camera was mounted on a tripod prior to the start of observations. If a feeding event commenced in the estuary, the observer would attempt video capture of the event for later editing and identification. The video footage was edited on a Pentium III Processor with an IEEE 1394 FireWire and software from Digital Origin (MotoDV and PhotoDV), and Adobe (Premier 5.1LE and Photoshop 5.0L). Individual video frames were saved in Photoshop (photo-editing software) if the footage contained prey with potentially identifiable characteristics. Each frame was magnified, as much as possible without losing detail, and imported into Premier (movie-editing software). The still frames were extended in length, so as to last approximately 15 seconds, and saved as "movie clips". The "movie clips" were then pieced together into a longer "movie" and saved on a VHS videocassette. The video was then viewed on a large screen television to facilitate prey identification.

Coded wire tags (CWTs) recovered from chinook salmon in the Yurok Tribal net fishery indicated that spring chinook had moved out of the estuary prior to the commencement of the field season. All chinook salmon consumed by pinnipeds during the study were assumed to be fall-run.

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) after enumeration by various agencies and volunteer groups (CDFG 2001). The proportion of the fall chinook run lost to pinniped predation during 1999 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 estimated the 1999 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 15 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.

Night Observations

Nighttime observations were conducted two to three times per week, beginning from 40 minutes to two hours following sunset. For each night that observations were conducted, a corresponding day shift was conducted in the same area(s), at approximately equivalent stages of the tidal cycle. Night observations were conducted as a pilot study to qualitatively assess predation during hours of darkness, therefore a sampling regime was not followed that would allow estimation of total predation impacts during periods of darkness. In order to maximize the efficiency of detecting predation events, night observations were primarily focused area 2, located directly inside the mouth of the river (Figure 2). This location is where the majority of daytime feeding events occurred during previous years. Ten night observation shifts were focused in area 2, with observers periodically walking to the river mouth to check the surf for pinniped presence.

A 1x monocular night vision scope was utilized to facilitate nighttime observations. Nighttime observers usually worked in pairs, alternating approximately every 10 minutes between making observations and recording data, to alleviate strained vision associated with looking through the scope for extended periods of time. Due to limited field of vision when using the night scope, methodology necessitated that the observer continuously scan the entire area from boundary to boundary, focusing on a specific position if a sight or sound indicated the potential presence of a pinniped. Recorded data included; beginning and end times for the observation period; time sampled; area sampled; visibility; maximum number of pinnipeds present (identified to lowest level of taxa); maximum number of nets fishing the area; and descriptive data regarding observed behaviors. Occasionally only one person conducted night observations. In these instances, the observer would rest for approximately ten minutes between each observation period. Night shifts were cut short when hazardous conditions or persistent fog arose.

On two occasions, attempts were made to sample each of the six observation areas in the estuary in one night. The areas were sampled sequentially with the initial area and sampling direction selected at random. Each area was sampled for 60 minutes. Poor visibility prevented the completion of one of these surveys. The identical sampling scheme was followed in the daytime at equivalent points in the tidal cycle. Two upriver excursions were spent collecting qualitative data on pinniped distribution and behavior. Shortly after dark, a crew slowly boated upriver from Klamath Glen to Blue Creek, scanning the area for pinniped presence and activity. Observations were conducted at frequently fished tribal fishing areas at Klamath Glen, focusing on pinniped activity associated with gill nets. This survey methodology was attempted twice, each time ending prematurely due to poor visibility. Corresponding daytime shifts were not conducted with the qualitative upriver sampling excursions.

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) ÷ (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 and 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

Pinniped abundance data was collected from shore during observations. 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.

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.

Fishery Interactions

While monitoring the recreational fishery in the lower river, the California Department of Fish and Game asked the following question of every fifth angler they interviewed: “Did you have any interactions with seals or sea lions while fishing today?” Tribal fishers were not asked this question because gill net fishing does not require the fisher’s attention to be focused on the net at all times.

Pinniped 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.

Scat samples were processed by thawing and 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 1,259 hours of daylight observations, 328 surface feeding bouts upon adult salmonids were observed (Table 3). The quantity of time sampled represents 16.6% of the potential daylight time available among the 6 areas during the course of the study. There were an estimated 1,804 impacts (± 234) upon adult salmonids during the study period (Figure 3). More than 85% of the feeding events observed in the 1999 study took place during the first 6 weeks of the 14-week study period (Figure 4).

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, during the 1998 and 1999 studies.

Area	Year	Hours Observed	Salmonid Predations Observed	Salmonid Predations Estimated	Variance	95% Confidence Interval
1	1998	303	110	519	3586	(401, 637)
	1999	**271**	**62**	**297**	**1598**	**(218, 375)**
2	1998	271	134	752	7537	(581, 923)
	1999	**262**	**132**	**532**	**3679**	**(413, 651)**
3	1998	209	61	487	3242	(375, 600)
	1999	**207**	**44**	**272**	**1720**	**(190, 353)**
4	1998	207	60	347	3072	(238, 456)
	1999	**188**	**31**	**200**	**2810**	**(95, 305)**
5	1998	199	77	601	9414	(410, 792)
	1999	**179**	**32**	**268**	**3454**	**(152, 384)**
6	1998	169	41	371	4309	(241, 500)
	1999	**152**	**27**	**236**	**1877**	**(150, 321)**
All	1998	1358	483	3077	26,000	(2760, 3393)
	1999	**1259**	**328**	**1804**	**14,231**	**(1570, 2038)**

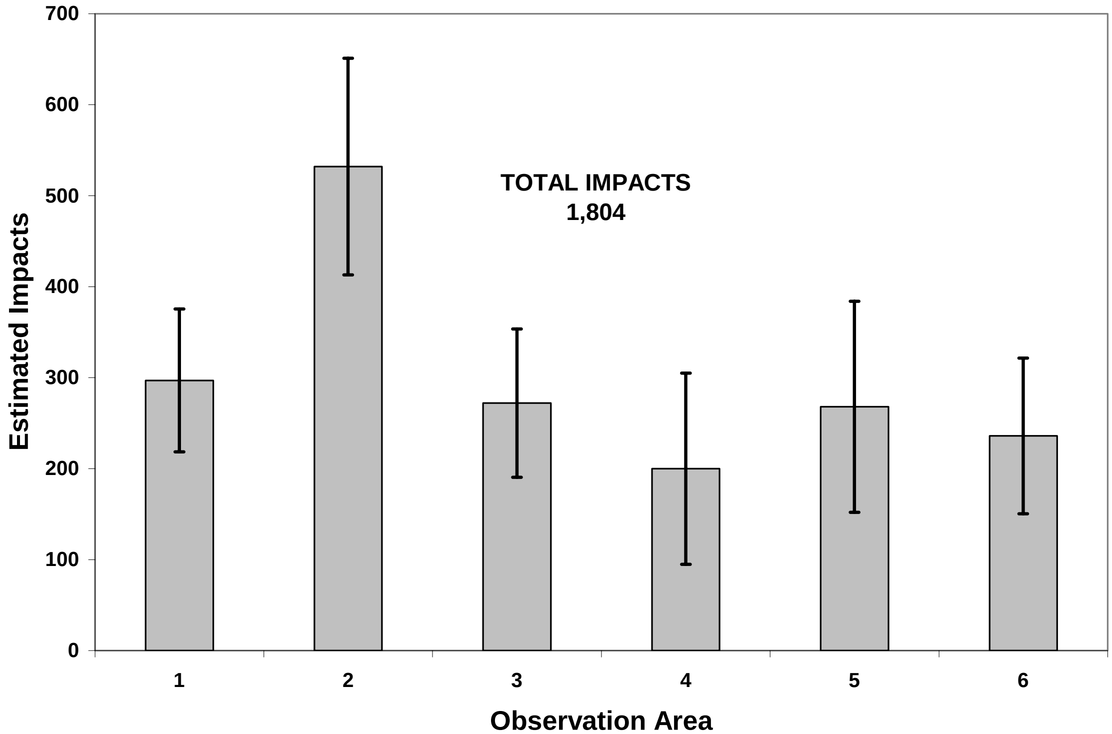


Figure 3. Estimated pinniped predation impacts upon adult salmonids and 95% confidence intervals, by observation area, in the Klamath River Estuary, 8 August – 15 November 1999.

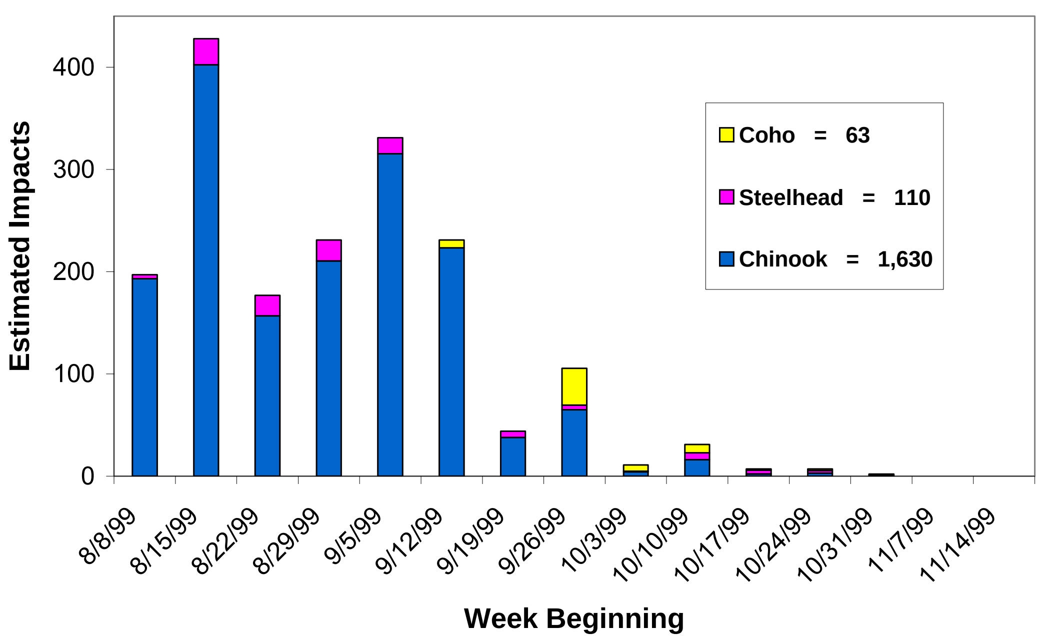


Figure 4. Estimated species composition of adult salmonids (including grilse chinook) consumed by pinnipeds in the Klamath River Estuary, 8 August – 15 November 1999. Estimates based upon average species composition of tribal and non-tribal estuary fisheries.

During 55 hours of night observations there were no observed feeding bouts in the area of observation. On one occasion, there appeared to be a sea lion feeding near the border of the observation area, however, the distance and visibility made it impossible to say with certainty if indeed it was inside the observation area and if the prey was an adult salmonid. The prolonged splashing activity associated with the event resembled sea lion predation events upon adult salmonids observed during daylight hours. During 53 hours of equivalent daytime observations (same days and areas), 61 feeding bouts were observed.

Species Composition of Salmonid Prey

Assuming species composition similar to that of the tribal and non-tribal estuary fisheries, fall-run chinook salmon was the primary salmonid species consumed during the study period, with an estimated 1,630 impacts. Impacts to steelhead and coho salmon were minimal relative to chinook, with 110 and 63 impacts respectively (Figure 4). The majority of estimated impacts upon coho occurred between late September and early October.

Eleven tissue samples were collected from feeding bouts in the Estuary between 14 August and 18 September 1999. Using genetic analysis, all were identified as chinook salmon.

Forty-eight attempts were made to capture feeding events on video. The majority of the footage was not useful. The highest quality still frames containing prey capture were extracted from ten feeding events. Video editing failed to enhance the images to a level of quality in which species differentiation was possible.

Estimated Impact to the Spawning Escapement

The 1999 fall chinook run to the Klamath-Trinity Basin was estimated to be 70,190 salmon. Assuming that 1,630 fall chinook were consumed by pinnipeds during the study period, the impact rate to the river fall chinook run was estimated to be 2.3% (Table 4). Based on methods previously described, the estimated minimum escapement of coho salmon to the Klamath-Trinity Basin during 1999 was 5,398 salmon. Assuming that 63 coho salmon were consumed during the study period, the impact rate to the coho run was estimated to be 1.2% (Table 4).

Table 4. Estimated minimum pinniped predation rates upon fall chinook and coho salmon runs to the Klamath River, 1999.

Prey Species	Estimated Run Size (Excluding Pinniped Predation)	Estimated Pinniped Predation Impacts	Estimated Pinniped Predation Impact Rate
Fall Chinook	70,190	1,630	2.3%
Coho	5,398	63	1.2%

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*), and Steller sea lions (*Eumetopias jubatus*). California sea lions were responsible for 93.5% of the estimated impacts to adult salmonids, while Pacific harbor seals and Steller sea lions were responsible for 5.3% and 1.2% 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.

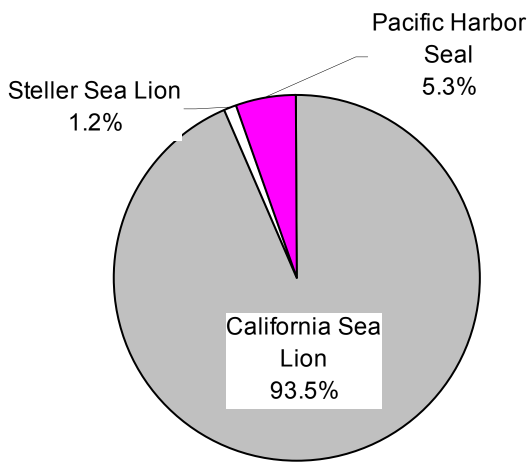


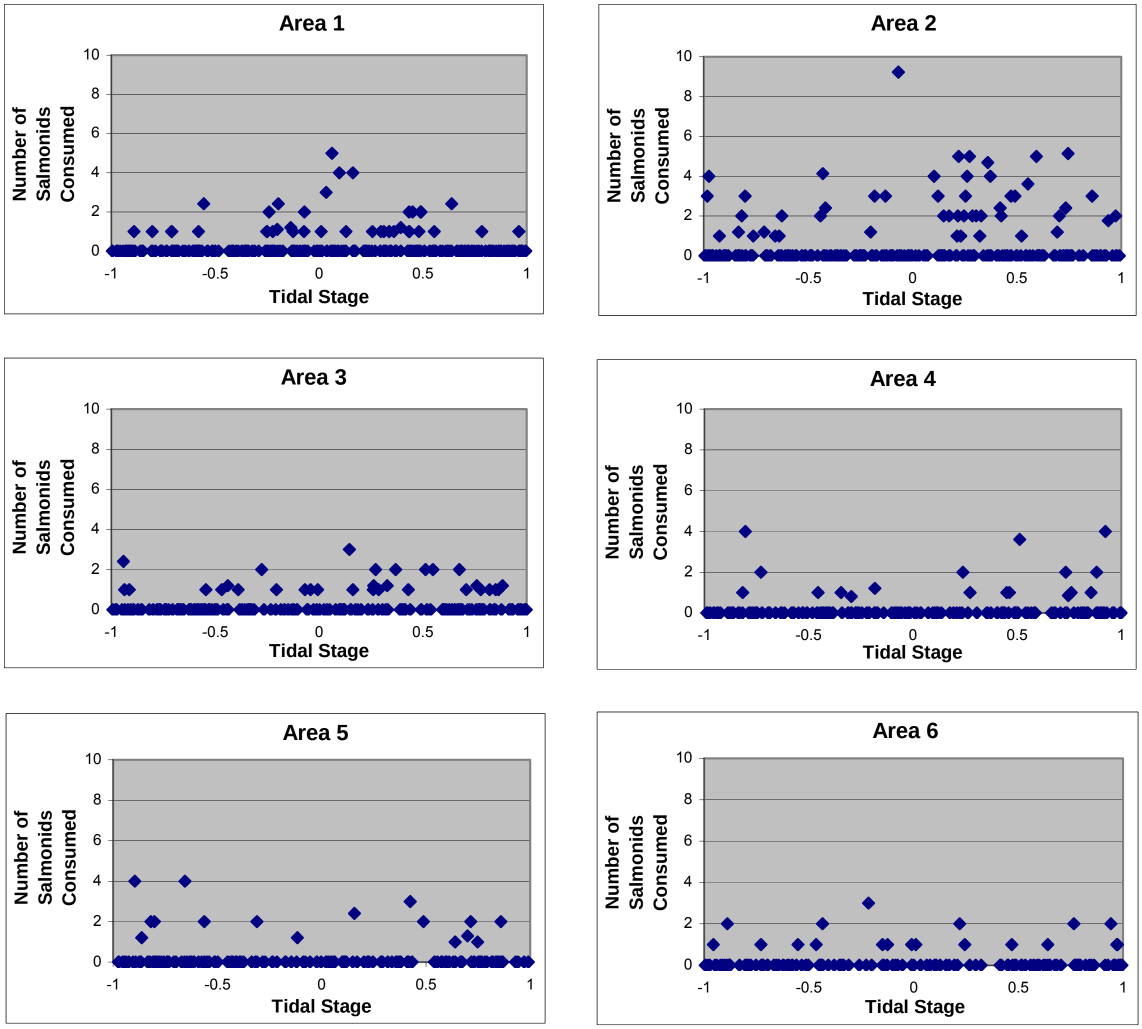
Figure 5. Percent predation by pinnipeds upon adult salmonids in the Klamath River Estuary, 1999.

Tidal Influence

Scatter plots were created to depict the relationship between tidal stage and frequency of feeding events (Figures 6-11). Areas 1 and 2 experienced increased frequency of feeding events during low tide (Figures 6-7), especially while the tide was incoming. Chi-square analysis supported these findings of significant dependence (area 1, p=0.009; area 2, p=0.022) (Table 5). A scatter plot of area 4 indicated increased frequency of feeding events during high tide. Results of chi-square analysis supported this significant dependence (p=0.046).

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, 1999. Tidal stage was classified into two categories (low vs. high) and feeding impacts per observation period were classified into two categories (less than two and two or more).

Area Tested	Result	Chi-Square Value	P-Value
1	Reject H_o	6.826	**0.009**
2	Reject H_o	5.256	**0.022**
3	Do Not Reject H_o	0.233	0.629
4	Reject H_o	3.972	**0.046**
5	Do Not Reject H_o	0.277	0.599
6	Do Not Reject H_o	0.232	0.630



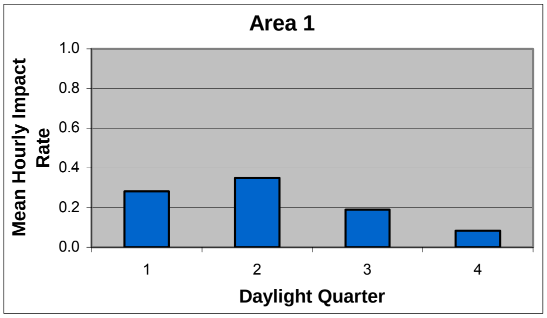
Figures 6-11. Relationship, by area, between tidal stage and number of salmonids consumed during observation periods in the Klamath River Estuary, 8 August – 15 November 1999. Observation periods with visibility between 75 and 100%, and/or duration between 30 and 60 minutes were expanded to represent 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”.

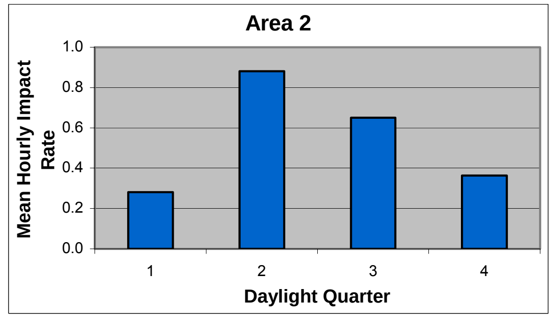
Diurnal Influence

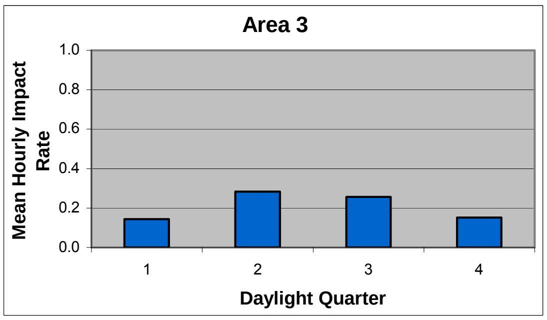
Bar charts depicting mean hourly rate of salmonid impacts during each quarter of daylight time show an increased frequency of predation during late morning (quarter 2) in areas 1-3 (Figures 12-14). Chi-square analysis to determine if a relationship existed between time of day and presence of feeding events was statistically significant at $\alpha = 0.10$ for areas 1 ($p = 0.063$) and 2 ($p = 0.082$; Table 6). Areas 4-6 tended towards increased rates of predation during quarter 3, early afternoon (Figures 15-17). Chi-square analysis supported the hypothesis that a statistically significant relationship existed between time of day and presence of feeding events in areas 5 ($p = 0.007$) and 6 ($p = 0.043$) at the significance level $\alpha = 0.05$ (Table 6). Chi-square analysis tested for presence or absence of predation only, and did not account for multiple feeding events in any given observation period. The bar charts represent frequency and therefore are influenced by multiple feeding events in any given observation period.

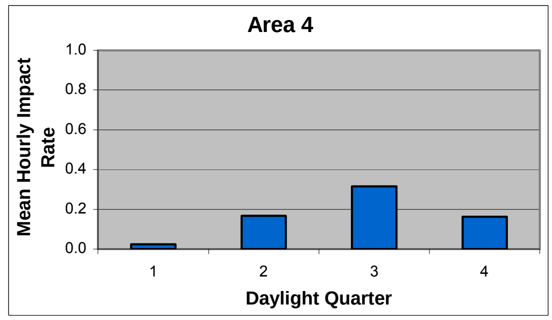
Table 6. Results of chi-square analysis to test the null hypothesis (H_o) that the presence of feeding events during an observation period was independent of time of day in the Klamath River Estuary, 1999. Time of day was classified into 4 categories (early morning, late morning, early afternoon, and late afternoon/evening) and feeding events were categorized by presence or absence.

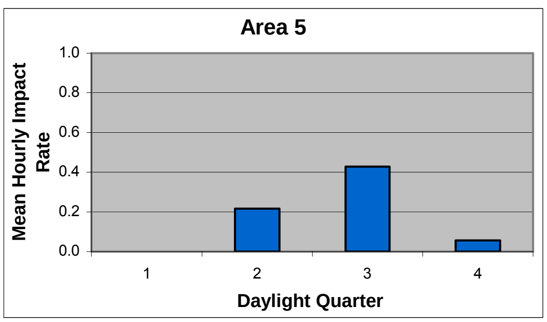
Area Tested	Result	Chi-Square Value	P-Value
1	Reject H_o	7.305	**0.063**
2	Reject H_o	6.698	**0.082**
3	Do Not Reject H_o	1.787	0.618
4	Do Not Reject H_o	5.736	0.459
5	Reject H_o	16.023	**0.007**
6	Reject H_o	8.172	**0.043**

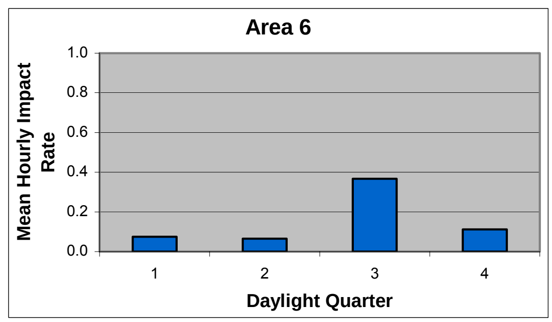








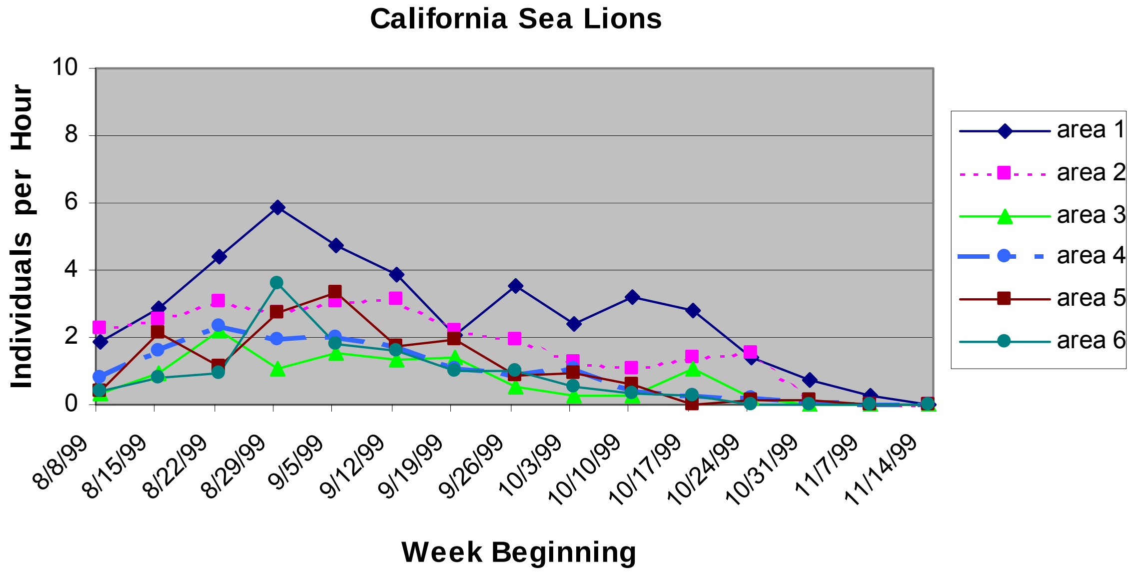


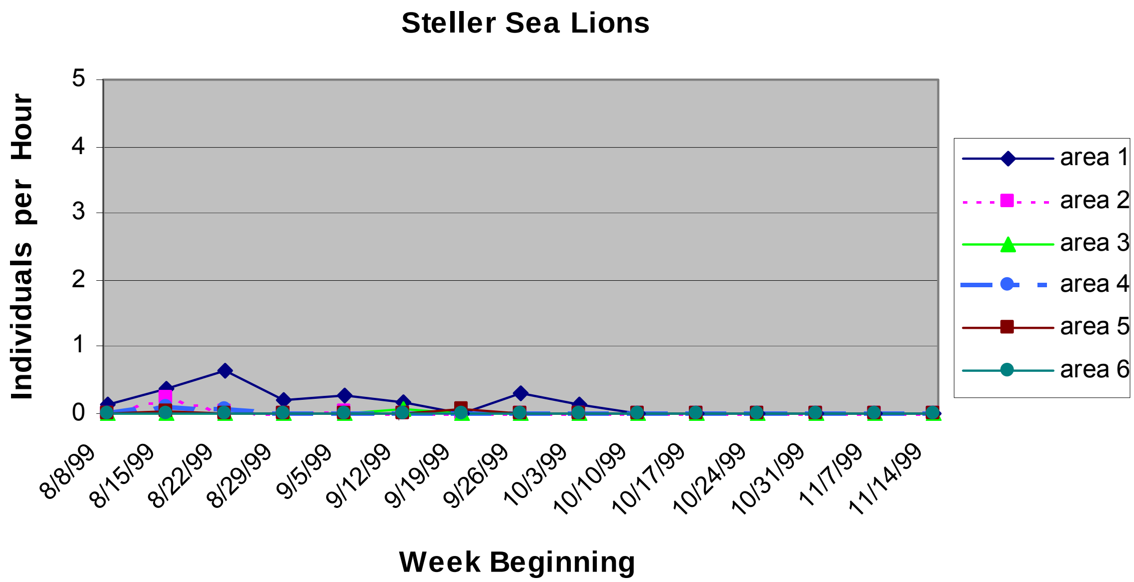


Figures 12-17. Mean hourly rate of salmonid impacts, by area, for each quarter of daylight, 8 August – 15 November 1999. Daylight quarters represent early morning (quarter 1), late morning (quarter 2), early afternoon (quarter 3), and late afternoon / evening (quarter 4). Observation periods with visibility 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 all pinniped species were most abundant in area 1 throughout most of the study period (Figures 18-20). Steller sea lion abundance was significantly lower than both other pinniped species. They were rarely observed anywhere other than areas 1 and 2, and were absent in the estuary subsequent to the week of 3 October (Figure 19). Harbor seal abundance increased following the week of 19 September (Figure 20), at which time California Sea Lion abundance began to decline (Figure 18).





Figures 18-19. Estimated maximum hourly occurrence of California and Steller sea lions, by area, 8 August – 15 November 1999.

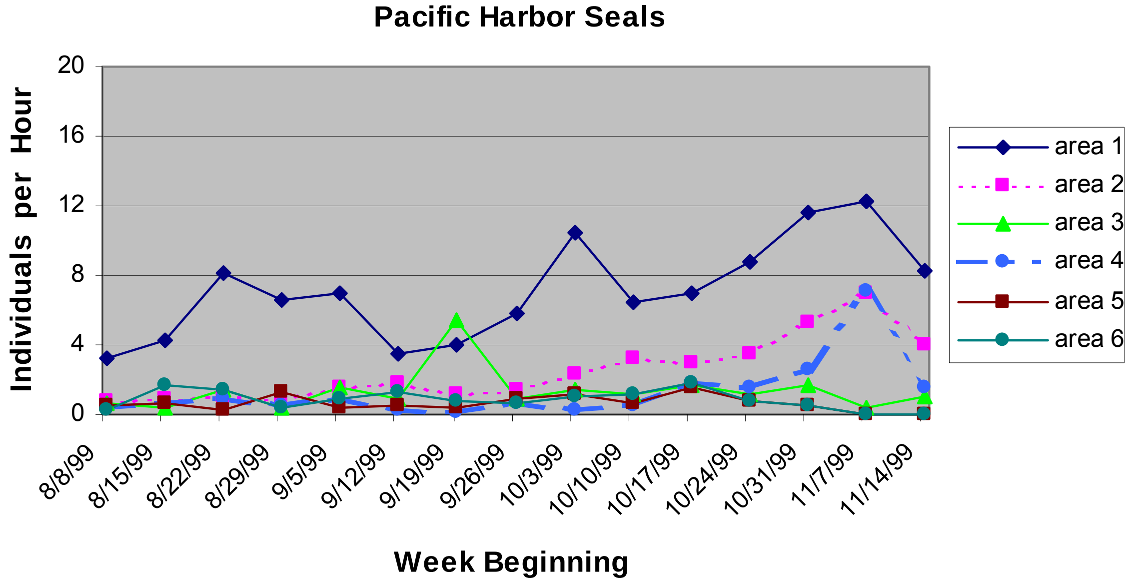


Figure 20. Estimated maximum hourly occurrence of Pacific harbor seals, by area, 8 August – 15 November 1999.

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 period of time when fall-run chinook enter the Klamath River Estuary. California sea lion abundance counts taken during the 1999 study were significantly smaller than those from the 1998 study. Abundance ranged from 41 to 106 individuals during the 1999 study period, peaking in late August, compared to the 1998 range of 46 to 226 individuals, peaking in early September. Steller sea lion counts fluctuated between 3 and 43 individuals during the 1999 study, which is comparable with the 6 to 41 individuals enumerated during the 1998 study. Seasonal fluctuations can be noted as California sea lion abundance declines throughout the 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 21).

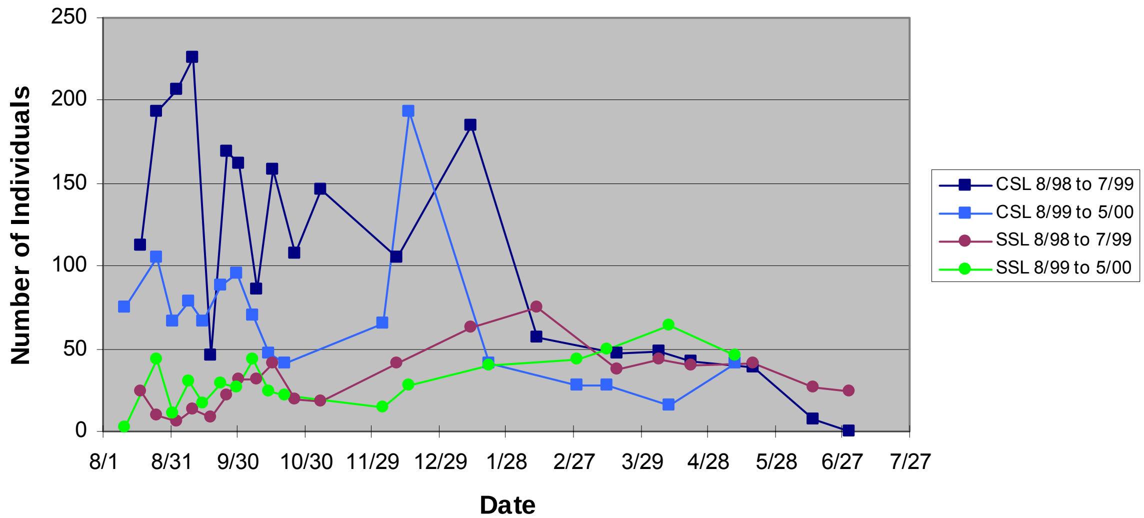


Figure 21. Comparison of California and Steller sea lion abundance counts at Klamath Cove haul-out, August 1998 – May 2000

Fishery Interactions

The results of a question that California Department of Fish and Game asked fishers while monitoring the 1999 estuary fishery, indicates that the drop-off rate in the estuary due to pinniped predation was approximately 4.7%. Given that 5.5% of the recreational harvest occurred in the estuary during 1999 (CDFG 2001), the drop-off rate for the entire basin, due solely to pinniped predation, was estimated at 0.3%.

Pinniped Scat Analysis

Harbor Seal Scat

A total of 91 harbor seal scats were collected from various haul-out locations on the south spit of the Klamath River Estuary on 13 collection days between 7 September and 9 November 1999. Identifiable prey remains were contained in 90 samples (98.9%). Five prey items were identified to species, with 24 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 1083.

The most frequently occurring prey items identified in these samples were righteye flounder (Family Pleuronectidae; 53.9%), smelt (Family Osmeridae; 39.3%), Pacific lamprey (*Lampetra tridentata*; 32.6%), sanddab species (*Citharichthys* spp.; 21.3%), and salmonid species (*Oncorhynchus* spp.; 12.4%)(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=89) collected at haul-out sites located in the Klamath River Estuary, Autumn 1999.

COMMON NAME	SCIENTIFIC NAME	% FO	MNI
Righteye flounder	Family Pleuronectidae	53.9	295
Smelt	Family Osmeridae	39.3	428
Pacific lamprey	*Lampetra tridentata*	32.6	99
Sanddab species	*Citharichthys* spp.	21.3	110
Salmonid adult	*Oncorhynchus* spp.	12.4	11
Sculpin	Family Cottidae	11.2	27
Cod / haddock	Family Gadidae	7.9	10
Dover sole	*Microstomus pacificus*	7.9	19
Snailfish	Family Cyclopteridae	7.9	9
Flatfish	Order Pleuronectiformes	6.7	15
Octopus species	*Octopus* spp.	6.7	8
Skate	Family Rajidae	6.7	6
Poacher	Family Agonidae	5.6	5
Hagfish species	*Eptatretus* spp.	4.5	4
Large-tooth flounder	Family Paralichthyidae	4.5	4
Greenling	Family Hexagrammidae	3.4	5
Lamprey species	*Lampetra* spp.	3.4	3
Rex sole	*Glyptocephalus zachirus*	3.4	4
Salmoniformes	Order Salmoniformes	3.4	3
Herring	Family Clupeidae	2.2	2
Squid	Order Teuthida	2.2	2
Unidentified fish		2.2	3
Hake species	*Merluccius* spp.	1.1	1
Ophidiiformes	Order Ophidiiformes	1.1	1
Pacific halibut	*Hippoglossus stenolepis*	1.1	1
Pacific tomcod	*Microgadus proximus*	1.1	1
Perciformes	Order Perciformes	1.1	1
Sablefish	Family Anoplopomatidae	1.1	1
Scorpaeniformes	Order Scorpaeniformes	1.1	1
Surfperch	Family Embiotocidae	1.1	4

Adult salmonids were identified from 11 scat samples collected between 19 September and 13 October 1999, to yield a FO of 12.4%. Eleven individuals were enumerated, of which 2 were estimated to be full sized adults and 9 small-sized adults or jacks (Tables 2, 8). Six salmonid otoliths were recovered. Two small adult/jack sized individuals and one of unestimated size (not smolt) were identified to order level Salmoniformes. It is likely these fish were salmonid species but due to poor bone condition or the lack of specific prey remains necessary for identification at the lower taxonomic level, could only be confidently identified to the higher taxonomic level. No salmonid smolts were identified.

Salmonid remains were identified from scats collected during the weeks beginning 19 September through 16 October 1999. Salmonid FO, calculated weekly over the course of the study, ranged from 0% to 66.7%, peaking the week of 3 October. It should be noted that the sample size during that week was only 3 scats. Weekly MNI peaked the week of 19 September, with 7 individuals enumerated (Table 8).

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, and frequency of adult salmonids occurring in scats (% FO), Autumn 1999.

Week Beginning	Estimated Harbor Seal Predation from Direct Observations	Number of Scat	Number of Scat Containing Adult Salmonids	MNI Adult Salmonids	% FO Adult
08 Aug	10	0	0	0	0
15 Aug	26	0	0	0	0
22 Aug	0	0	0	0	0
29 Aug	0	0	0	0	0
05 Sept	7	3	0	0	0
12 Sept	0	7	0	0	0
19 Sept	0	32	7	7	21.9
26 Sept	23	0	0	0	0
03 Oct	4	3	2	2	66.7
10 Oct	7	14	2	2	14.3
17 Oct	7	0	0	0	0
24 Oct	7	8	0	0	0
31 Oct	2	3	0	0	0
07 Nov	0	20	0	0	0
Total	**93**	**90**	**11**	**n/a**	**11**

Sea Lion Scat

A total of 29 California and Steller sea lion scats were collected on two occasions (23 September and 7 October 1999) from the sea lion haul-out located north of the Klamath River at Klamath Cove. Every sample contained identifiable prey remains. Five prey items were identified to species, with 19 other prey items identified to genus, family, order, or class level. Cumulative MNI for these scat samples was 166.

The most frequently occurring prey items identified in these samples were salmonid species (*Oncorhynchus spp*; 44.8%), North Pacific hake (*Merluccius productus*; 24.1%), Pacific saury (*Cololabis saira*; 24.1%), rockfish (Family Sebastidae; 24.1), and smelt (Family Osmeridae; 24.1%)(Table 9).

Adult salmonids were identified from eleven samples to yield a MNI of 11 and FO of 37.9%. Eleven individuals were enumerated, of which 4 were estimated to be full sized adults and 7 small-sized adults or jacks (Table 2). Four otoliths were recovered from 3 of these samples. Additionally, two salmonid smolts were enumerated, yielding a FO of 6.9% (Table 9). Three small adult/jack sized individuals were identified to order level Salmoniformes. It is likely these fish were salmonid species but due to poor bone condition or the lack of specific prey remains necessary for identification at the lower taxonomic level, could only be confidently identified to the higher taxonomic level.

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Table 9. Percent frequency of occurrence (% FO) and minimum number of individuals (MNI) of prey items identified from sea lion scats (California and Steller; n=29) collected at Klamath Cove haul-out, Autumn 1999.

PREY ITEM	SCIENTIFIC NAME	% FO	MNI
Salmonid species	*Oncorhynchus* spp.	44.8	13
Salmonid adult		37.9	11
Salmonid smolt		6.9	2
North Pacific hake	*Merluccius productus*	24.1	7
Pacific saury	*Cololabis saira*	24.1	31
Rockfish	FamilySebastidae	24.1	10
Smelt	Family Osmeridae	24.1	12
Sculpin	Family Cottidae	20.7	9
Skate	Family Rajidae	20.7	6
Squid	Order Teuthida	17.2	26
Righteye flounder	Family Pleuronectidae	13.8	7
Salmoniformes	Order Salmoniformes	13.8	4
Hagfish species	*Eptatretus* spp.	10.3	3
Snailfish	Family Cyclopteridae	10.3	5
Unidentified fish		10.3	3
Cod / haddock	Family Gadidae	6.9	2
Lamprey	Family Petromyzontidae	6.9	2
Sanddab species	*Citharichthys* spp.	6.9	17
Agnatha	Class Agnatha	3.4	1
Cephalopod	Class Cephalopoda	3.4	1
Flatfish	Order Pleuronectiformes	3.4	1
Gadiformes	Order Gadiformes	3.4	1
Pacific tomcod	*Microgadus proximus*	3.4	1
Rajiformes	Order Rajiformes	3.4	1
River lamprey	*Lampetra ayresii*	3.4	1
Scorpaeniformes	Order Scorpaeniformes	3.4	1
Starry flounder	*Platichthys stellatus*	3.4	1

DISCUSSION

Predation Impacts

The investigations into pinniped predation upon adult salmonids in the Klamath River Estuary in 1999 indicate that fewer salmonids were consumed during the 1999 study than during the 1998 and 1997 studies. Estimates from this study indicate that 1,804 adult salmonids were consumed during the entire study period, as compared to 3,077 during the 1998 study and 10,105 during the 1997 pilot study. The estimated 1999 impact rate upon adult fall-run chinook was 2.3%, down from the estimates of 2.6% in 1998, and 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 and 1999 studies, 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 and 1998 studies, California sea lions remained the primary predator, accounting for 93.5% of estimated impacts (87% in 1997, 89.8% in 1998). 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 recent investigation (including the 1997 and 1998 studies) 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 5.3% (95) of the total estimated impacts, which equates to approximately 0.1% (83) of the fall chinook run. While the estimated numbers of harbor seal impacts were higher in 1998 and 1997, the corresponding percent of impacts attributed to harbor seals upon adult salmonids remains comparable (9% in 1997 and 6.3% in 1998). The impact of harbor seal predation upon adult fall-run chinook remains considerably lower than that of California sea lions, exhibiting a decreasing trend over the past three years. 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. During the 1999 study, the increase of harbor seal abundance in the estuary, which began approximately September 19, coincided with the decrease of California sea lion abundance in the estuary (Figures 18 and 20).

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 (94.4%) were determined to be free-swimming fish that were not taken from recreational or tribal fishers. The remaining captures were taken from gill nets. It is possible that the quantity of fish taken from nets 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. The composition of free swimming and net caught prey from this study is comparable to the 1998 study. There were no observed captures from recreational fishers using hook and line, however California Department of Fish and Game reported that when asked the following question: "Did you have any interactions with seals or sea lions while fishing today?", 4.7% of the recreational fishers reported that indeed they had an interaction with a marine mammal. This was substantially less than the 22.6% of the recreational fishermen in 1997 that responded that they had salmon damaged or lost to marine mammals while they were on their hook. This decrease may be related to the apparent overall reduction in pinniped predation since 1997.

Several relationships were indicated, linking increased predation with tidal cycle or time of day. Predation increased significantly during incoming low tide in areas 1 and 2, locations that were closest to the confluence with the ocean (Figure 2) and that contained the highest estimated predation associated with gill nets. Although not as significant, increased predation also occurred during the late morning hours in areas 1-3. During the 1998 study, these relationships did not exist. Increased predation was noted to coincide with high tide in area 4, located directly upriver from area 2 (Figure 2). This area also had notably less total predation impacts than any of the other areas. Increased predation and time of day was found to be significant at the furthest upriver locations, areas 5 and 6, with predation peaking during the early afternoon. Given that areas 1-3, those closest to the ocean (Figure 2), had increased predation during the late morning hours and areas 5 and 6, study areas furthest from the ocean, had increased predation in the early afternoon, it seems possible that most fish (and pinnipeds) entered the river during the late morning and then migrated further upriver in the early afternoon. A similar corollary was seen with tidal influence, with significantly increased predation occurring in areas 1 and 2, those closest to the ocean, during low tidal stages, and increased predation occurring in area 4, further upstream from the ocean, during the high tidal stage.

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.

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. Genetic analysis was utilized during this study to aid in determination of prey species composition. Between mid-August and mid-September, eleven tissue samples were collected during feeding events in the estuary. All samples were identified as chinook salmon. Although the sample size was low, this evidence helps substantiate chinook salmon as the primary prey species during this study. While genetic analysis proved to be a useful tool for determining species composition of prey, obtaining adequate sample sizes was difficult. If this study is conducted in the future, it is recommended that a crew with jet boat be designated for the sole purpose of obtaining scale/tissue samples from feeding events.

The use of video equipment for prey identification proved ineffective and posed several logistical problems. While many attempts were made to utilize the camera in the field during observations, the distance from shore to the location of many feeding events, often times close to ½ mile, increased the difficulty of catching the unpredictable events on film. Focusing on a sporadically moving object was also quite challenging. The camera contains both an optical zoom lens (20x) and a digital zoom lens (370x). For purposes of clarity, only the optical zoom was utilized as pixelation begins after 20x when using the digital zoom lens. For a study area as large as the Klamath River Estuary, it is not recommended that a video camera be used for identification of prey species, however video identification may be useful in smaller areas.

Night Impacts

Night observations were employed to assess whether or not pinniped predation was occurring in the Lower Klamath River at night. The majority of these observations were conducted during the estimated peak of the fall chinook run, in the lower estuary directly adjoining the mouth of the river (Area 2). This location was the site where daytime feeding events were most frequent. For comparison, night observations were coupled with a corresponding day observation. In trying to minimize confounding factors between day and night conditions, the daytime observations were conducted at the same location, prior to the night observation and at relatively equivalent stages of the tidal cycle. No predation impacts were recorded at night in the area of observation. By comparison, 61 impacts were recorded during equivalent day sampling, suggesting that pinnipeds were not utilizing this area at night as a foraging location. On one occasion, a feeding bout was observed near the boundary of areas 2 and 3. The observer could not ascertain whether the event occurred inside the area of observation, nor whether the prey was salmonid. Due to the nature of the feeding bout, the observer was confident that the predator was a sea lion. Overall abundance of pinnipeds in the estuary diminished significantly at night and on many occasions not a single pinniped was detected all night. This finding validates a primary assumption of this study; that most pinniped predation in the Klamath River Estuary occurs during daylight hours.

There were several logistical factors encountered at night that were not of consideration during the day. The obvious advantage that daytime luminescence provides while conducting observations becomes more comprehensible when compared with observations conducted at night. With the night vision scope, any ambient light, whether from fog, bonfires, light fixtures or any other source occluded visibility with a blinding force. The nighttime range of peripheral visibility was significantly diminished due to dependence on observing through a single eyepiece with no magnification as compared to observations in the day utilizing 12x50 binoculars and the naked eye. A 2x lens was available for use with the night scope but only served to increase distortion in the field of view by providing a grainy texture. The combination of low visibility, lack of magnification, and monocular vision tended to leave the observer with a somewhat ambiguous perception of depth. It was extremely difficult to say with confidence that there were no animals in the farthest portions of observation areas. Some light fog in the day may cause negligible effects to visibility, whereas at night, visibility was drastically depleted.

Anecdotal information from tribal fisherman suggests that when the salmon are running, pinnipeds occasionally travel upriver at night and forage in their nets. On two occasions qualitative sampling was attempted upriver in these locations. Visibility was extremely poor due to fog, and these sampling excursions were terminated after only several hours. Although the observers could not see the area of observation, they did hear pinnipeds surfacing and breathing in their immediate vicinity. Several fishers reported sightings of pinnipeds while they tended their nets. Further observations upriver are recommended to assess the magnitude of nighttime foraging.

Fishery Interactions

Klamath River fall chinook are extensively managed relative to many other fish populations along the west coast. Involved in this process is the modeling of this population to assess its population dynamics, as well as to predict and manage for its abundance each year. Often ocean fisheries from the Columbia River to south of San Francisco, as well as river tribal and recreational fisheries, are constrained to meet the spawning escapement objectives of this stock.

A parameter used in the modeling of this stock is termed the “drop-off” rate, which refers to fish that die as a result of the execution of a fishery but are not included as part of that fishery’s harvest. A primary cause of drop-off in the river fisheries is considered to be loss of fish being harvested to marine mammal predation (KRTT 1986). Another source is fish that escape from fishing gear, e.g. shaking off a fisher’s hook or escaping from a gill net and later dying from the experience. In the tribal net fishery, on a reservation wide basis (including Yurok and Hoopa Valley reservations), this drop-off rate is assumed to be 8% each year.

The drop-off rate currently used while modeling Klamath River fall chinook is 2% for the entire Klamath-Trinity Basin recreational harvest (KRTT 1986). The results of a question that California Department of Fish and Game asked fishers, while monitoring the 1999 estuary fishery, indicates that the drop-off rate in the estuary due to pinniped predation was approximately 4.7%. Given that 5.5% of the recreational harvest occurred in the estuary during 1999 (CDFG 2001), the drop-off rate for the entire basin, due solely to pinniped predation, was estimated at 0.3%. This drop-off rate was substantially less than that calculated from the results of a question asked of recreational fishers during 1997. The 1997 survey indicated that 22.6% of the estuary recreational fishers had a salmon on their gear lost or damaged due to a pinniped interaction. This resulted in an estimated drop-off rate due to pinniped interactions for the entire Klamath Basin recreational fishery of 6.2%. This differences in these drop-off rates is likely due to two factors: 1) the apparent reduced pinniped predation in the estuary during 1999 relative to 1997, and 2) a larger proportion of the Klamath Basin recreational harvest occurred in the estuary during 1997 relative to 1999, 27.6% vs. 5.5% respectively.

Pinniped Scat

Harbor Seal Scat

Attempts were made to collect a minimum of 50 scat samples per week from sites where harbor seals hauled out along the sand spit that separates the Klamath River from the ocean. Similar to the 1998 study, this 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. While a similar amount of effort went into scat collection during the 1998 and 1999 studies, only 93 were collected during this study year, as compared to 252 during the 1998 study.

Analysis of harbor seal scat collected in the Klamath River Estuary indicated that adult salmonids were present in 12.4% of scats collected during the study period. This is comparable to the 13.9% collected during the 1998 study. Scats containing salmonid remains were collected between 19 September and 13 October 1999. Frequency of occurrence ranged from 14.3% to 66.7% during the weeks when salmonid remains were identified from scats. It should be noted that weekly sample sizes were small, therefore limiting the utility of these estimates. The largest weekly MNI (7) occurred the week of 19 September 1999, the week with the largest sample size (n=32). The FO was 21.9% and only 4 predation events were recorded during direct observations. During the week of 3 October 1999, only 3 scats were collected on 2 different days. Two of those scats contained salmonid remains. Nearly all the fish harvested in the tribal fishery up until 26 September 1999 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 30 September and 23 October 1999. The Tribal fishery harvest ratio of coho to all salmonids was greatest the week of 3 October 1999, with 64% of the harvest consisting of coho salmon. Two salmonids were identified from 3 scats during this same time period. 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.

Sea Lion Scat

Sea lions do not haul out inside the Klamath River Estuary. The nearest haul-out is located approximately one mile north of the mouth of the Klamath River, at Klamath Cove. The beach area is utilized by California and Steller sea lions, with harbor seals hauling-out to a lesser degree on the boulders offshore. Large rocks and boulders characterize the intertidal area, rising up to steep cliffs that limit accessibility. Logistical details were resolved and sea lion scats were collected experimentally on two occasions. Although the sample size was small (n=29) and the collection dates (23 September and 7 October 1999) followed the peak of the chinook run, salmonids were the most frequently occurring prey item, appearing in 13 scats to yield a FO of 44.8%. Eleven of the enumerated individuals were adults (FO = 37.9%) and 2 were smolts (FO = 6.9%). Additionally, 4 adult fish were identified to order level Salmoniformes. It is likely that these fish were salmonids as well, but due to the deteriorated condition of the prey remains or lack of certain prey remains necessary for more specific identification, they could not be confidently identified to a lower taxonomic level. In the four days leading up to each of the scat collections, observations of sea lion predation in the estuary were low. Four predation events were observed prior to the 23 September scat collection on 19 September, and none were observed during the four days prior to the 7 October scat collection.

Given the relatively high FO of salmonids in these 29 scat samples, it seems that further investigation is warranted regarding the diet of sea lions hauled out at Klamath Cove, especially during the time of year that coho salmon are entering the Klamath River (late September through mid-November). As with harbor seal scat investigations, the utility of this information would be enhanced by identification of the prey to species (perhaps by genetic analysis) and by quantifying the number of salmonids consumed by the sea lions hauled out at Klamath Cove. Another area worthy of investigation is the movement of sea lions that utilize Klamath Cove. How long do sea lions reside at Klamath Cove? What proportion of the sea lions at Klamath Cove feed in the Klamath River vs. the ocean?

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