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Results of the 1986-87 California Sea Lion-Steelhead Trout Predation Control Program at the Hiram M. Chittenden Locks

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RESULTS OF THE 1986-1987 CALIFORNIA SEA LION - STEELHEAD TROUT PREDATION CONTROL PROGRAM AT THE HIRAM M. CHITTENDEN LOCKS

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ABSTRACT

California sea lions, Zalophus californianus, were first observed at the Hiram Chittenden Locks at Seattle, Washington on 6 October 1986 and last sighted on 15 May 1987 for a span of 7.4 months. Sea lions were present near the Locks on 142 out of 151 days (94%) during which coverage was maintained. At least 11 different sea lions were observed in the vicinity of the Locks during the season, based on sightings of individually identifiable animals.

California sea lions were observed to forage on both coho salmon, Oncorhynchus kisutch, and steelhead trout, Salmo gairdneri. Sea lions predated on both net caught fish from tribal gillnets set in the Lake Washington Ship Canal and on free swimming salmon and steelhead in the Locks vicinity. Sea lion predation of steelhead occurred in both the inner and outer portions of the ship canal on free swimming fish. We also observed instances of free swimming steelhead captured by sea lions in other areas of Puget Sound, Elliott Bay and Shilshole Bay.

In an attempt to mitigate an increasing sea lion predation problem a harassment program (6 January - 30 April 1987) was initiated at the Locks using primarily firecrackers. The harassment program reduced the observed predation rates by 67% and contributed to the savings of an estimated 1084 steelhead. The harassment program was not as effective in reducing predation as it was during the previous season (during 1985 and 1986) when predation rates were reduced by 97%. We suspect that if a similar program were conducted next season the overall effectiveness would continue to decline due to habituation by individual sea lions.

Sea lions predated an estimated 2,604 steelhead near the Locks during 1986-1987. This accounted for 43% of the total combined run or 42% of the wild run and 44% of the hatchery run. Predation by sea lions contributed to a 27% shortfall in the escapement of wild fish, which was estimated to be 1,172 fish.

To obtain an overall abundance estimate, sea lions were counted during an aerial survey of Puget Sound during mid-April when peak numbers are present in Puget Sound. We counted 650 sea lions during this survey and noted 18 different haul out sites.

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INTRODUCTION

This report summarizes the 1986-1987 investigations of California sea lion, Zalophus californianus, predation on steelhead trout, Salmo gairdneri, in the Lake Washington Ship Canal and Hiram M. Chittenden Locks (hereafter referred to as Locks) at Seattle, Washington (Figure 1).

The earliest record of California sea lion presence and foraging at the Locks was from December 1970 when an animal was photographed consuming several steelhead (Seattle Times, December 17, 1970). California sea lions first began appearing at the Locks with regularity six to seven years ago according to Locks personnel, Department of Wildlife agents and biologists, and local fishermen (Gearin et al. 1986). Initially, in the early 1980's, only one or two sea lions were observed at the Locks by steelhead anglers and Locks personnel. In the last several years, however, at least three to four sea lions have been observed regularly at the Locks. It also appears that sea lions are arriving earlier in the year (September) and staying later (May) in the last several years.

The months when sea lions are observed at the Locks corresponds to the timing of the winter steelhead run as it passes through the Locks to spawn in the Lake Washington and Lake Sammamish tributaries. The presence of sea lions also overlaps to some degree the run of coho salmon and that of cutthroat trout, Salmo clarki.

Initial action was taken to address the sea lion predation on steelhead in 1984 when firecrackers were used intermittently by Washington Department of Game (WDG) wildlife agents to chase away sea lions. In the spring of 1984,

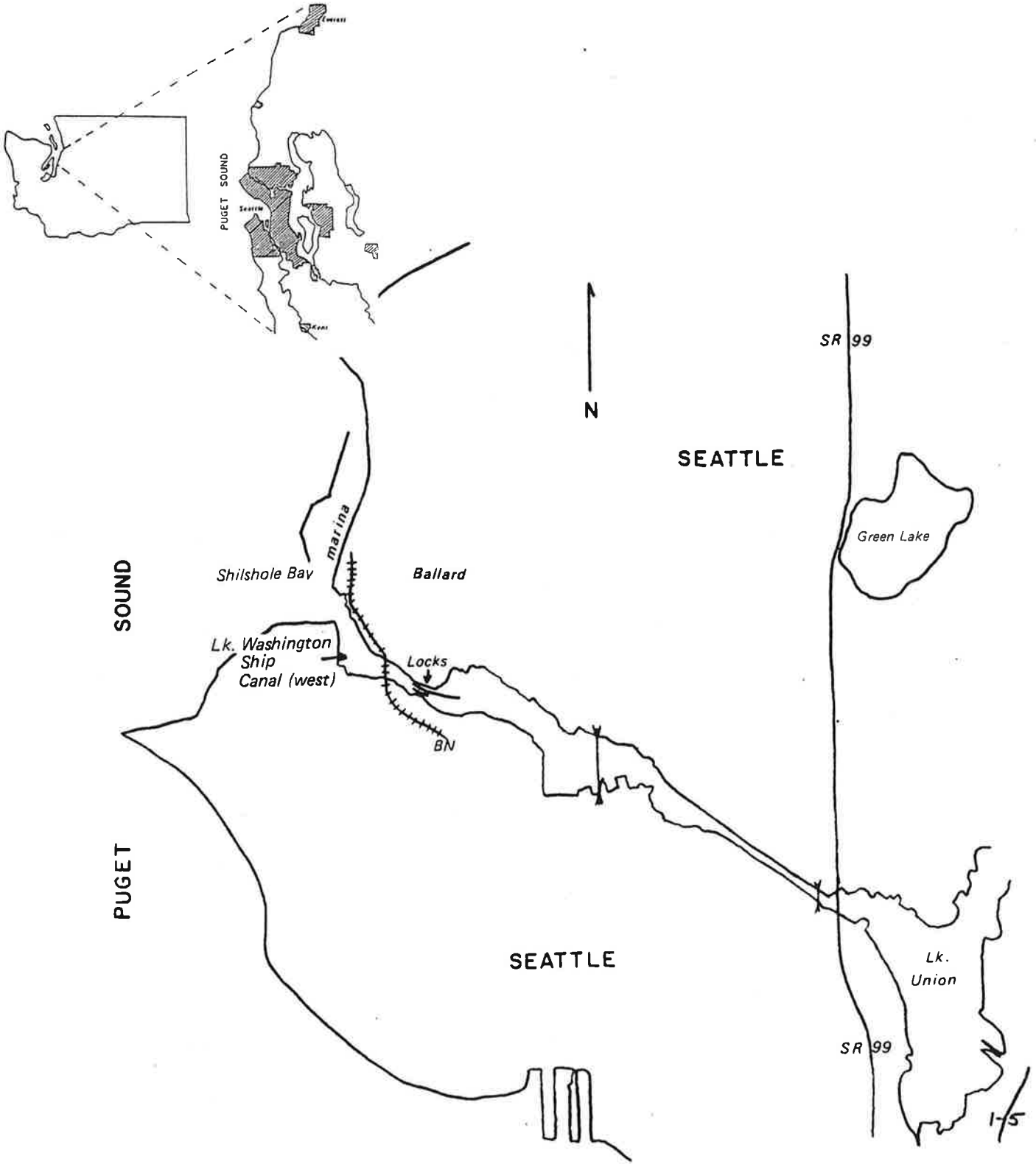

Figure 1 Location of the study area in relation to western Washington, Seattle, Shilshole Bay, Ship Canal and the Chittenden Locks.

fixed acoustic harassment devices (AHD's) were tested at the Locks by WDG biologists with mixed results. The devices worked for only a short time before the sea lions appeared to ignore or habituate to their sound.

In the winter of 1984-85 four sea lions were actively foraging at the Locks and averaged one fish taken every 1.5 hours (Van Doornik 1985). The majority of fish taken were steelhead, however, a few coho salmon were also taken. It became apparent that sea lion predation on wild winter-run steelhead was a serious problem when the 1984-85 spawning escapement in the Lake Washington watershed was estimated to be only 474 fish (Freymond and Foley 1986). Concern was voiced by various user groups, principally sport fishermen, that the sea lions were seriously depleting the steelhead run and also disrupting and competing with sport and tribal fisheries. The winter steelhead run which migrates through the Ship Canal supports several fisheries, including a commercial fishery by the Muckleshoot and Suquamish Tribes plus sport fisheries at the Locks and in the Lake Washington watershed.

In January 1986, a sea lion predation control program was begun at the Locks to reduce the impact of sea lions on the wild steelhead run. Sea lions were "harassed" in the vicinity of the Locks for a period of 3 months using primarily firecrackers and acoustic harassment devices. This program was quite successful and resulted in a 97% reduction in observed predation and saved an estimated 1,803 steelhead (Gearin et al. 1986).

The 1986 study also documented foraging behavior of sea lions and their distribution and abundance in greater Puget Sound. The resulting report (Gearin et al., 1986) provided background information on sea lion fishery interactions and recommendations for future control programs at the Locks.

We decided to continue the predation control program through the 1986-87 season to help assure that minimal escapement needs were met and because a cost analysis estimated that a similar program could result in a cost to benefit ratio of 1 to 4 (Gearin et al. 1986).

The cooperative research effort was undertaken at the Locks in late November 1986 in order to document interactions between California sea lions and steelhead trout as well as to control or lessen sea lion predation. This study was conducted by the National Marine Fisheries Service (Regional Office and National Marine Mammal Laboratory) in cooperation with the Washington Department of Wildlife (formerly Department of Game), the Muckleshoot and Suquamish Tribes and the U.S. Army Corps of Engineers (Seattle District). A list of participants and their affiliations is provided in Appendix Table 1.

Preliminary observations were made at the Locks beginning in early October, however, the bulk of this report is based on 152 days of observation between 22 November 1986 and 30 April 1987. Follow up observations were made through May 1987.

The primary objectives of this program were to save steelhead from predation by California sea lions (to ensure adequate escapement of wild fish) and to conduct experimental studies in order to evaluate and develop effective control measures for future use.

In order to achieve the objectives relating to evaluating and reducing predation we divided the study into four phases:

1: Estimation of Predation Losses (pre-harassment).

2: Predation Control (harassment).

3. Alternative Control Methods Evaluation.

4: Sea Lion Behavior and Biology.

MATERIALS AND METHODS

Study Sites

The primary study site was within the western portion of the Lake Washington Ship Canal, approximately six miles north of downtown Seattle, Washington, at latitude 47°40'N, longitude 122°25'W (Figure 1). The inner and outer bay portion of the Ship Canal is a small extension of Puget Sound and is the primary water route for inbound or outbound vessels between Puget Sound and Lakes Union and Washington.

The Lake Washington Ship Canal is of major biological importance, being the migratory corridor from Puget Sound for major runs of salmonids destined for the Lake Washington and Lake Sammamish watersheds (Figure 2). Three species of salmon including: chinook, Oncorhynchus tshawyscha, coho, Oncorhynchus kisutch, and sockeye, Oncorhynchus nerka, and two species of sea-run trout, (steelhead, Salmo gairdneri, and cutthroat, Salmo clarki), utilize this route for passage between saltwater and freshwater spawning and rearing areas.

The Lake Washington Ship Canal (hereafter referred to as the Ship Canal) and associated Chittenden Locks was completed by the U.S. Army Corps of Engineers in 1917. A new pool and weir fishway (ladder) consisting of 21 weirs was constructed in 1976 to facilitate the upstream migration of the anadromous fish stocks. Vessel passage through the Ship Canal is accomplished using either one of two parallel locking chambers (one small and one large). The small lock is 9.1m (30 ft) in width and 47.7m (150 ft) in length. The large lock is 24.3m (80 ft) in width and 251m (825 ft) in length. Each has an average depth of 15.1m (50 ft) (Figure 3).

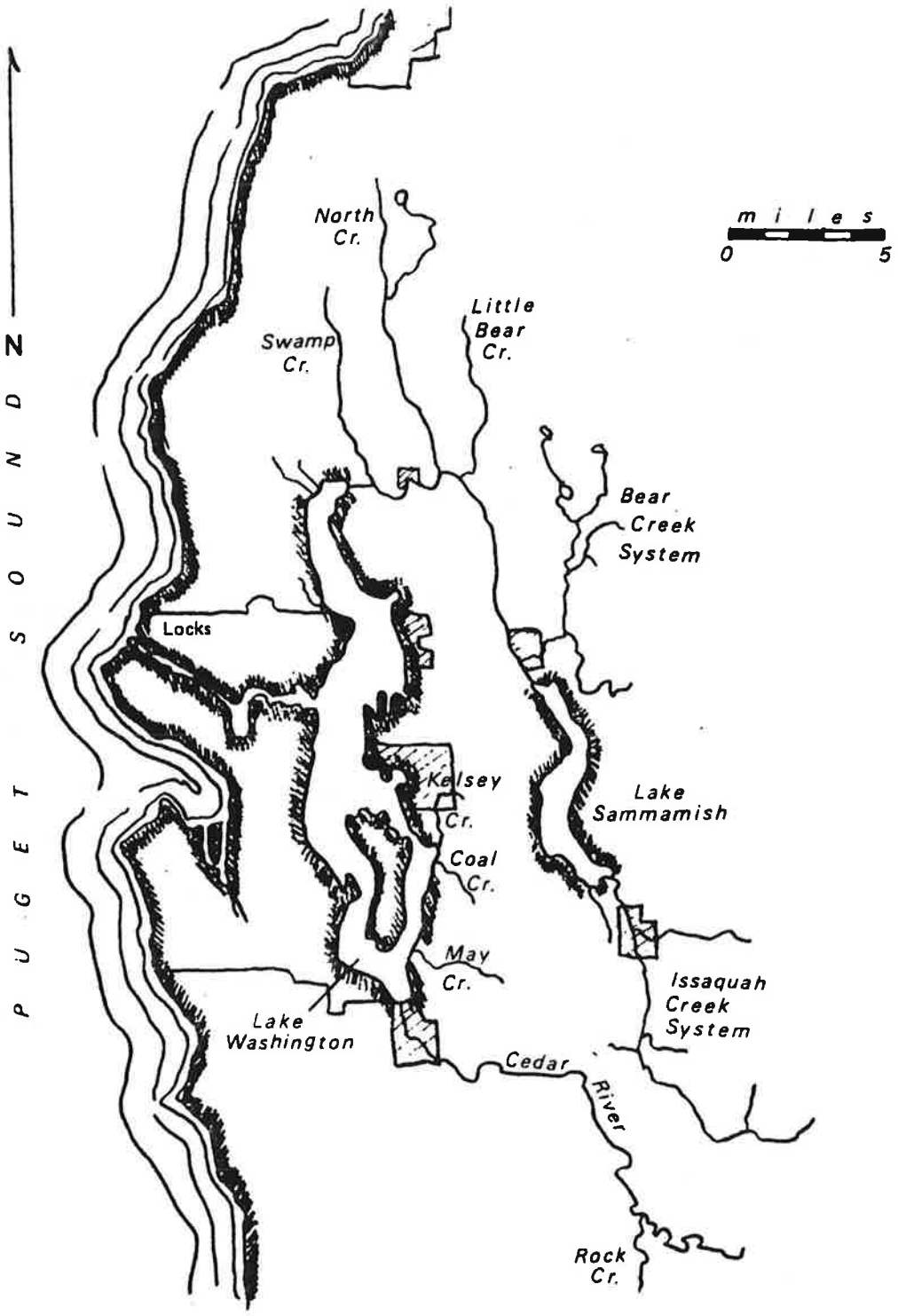

Figure 2 Map of the Lake Washington watershed showing principal spawning streams utilized by winter-run steelhead.

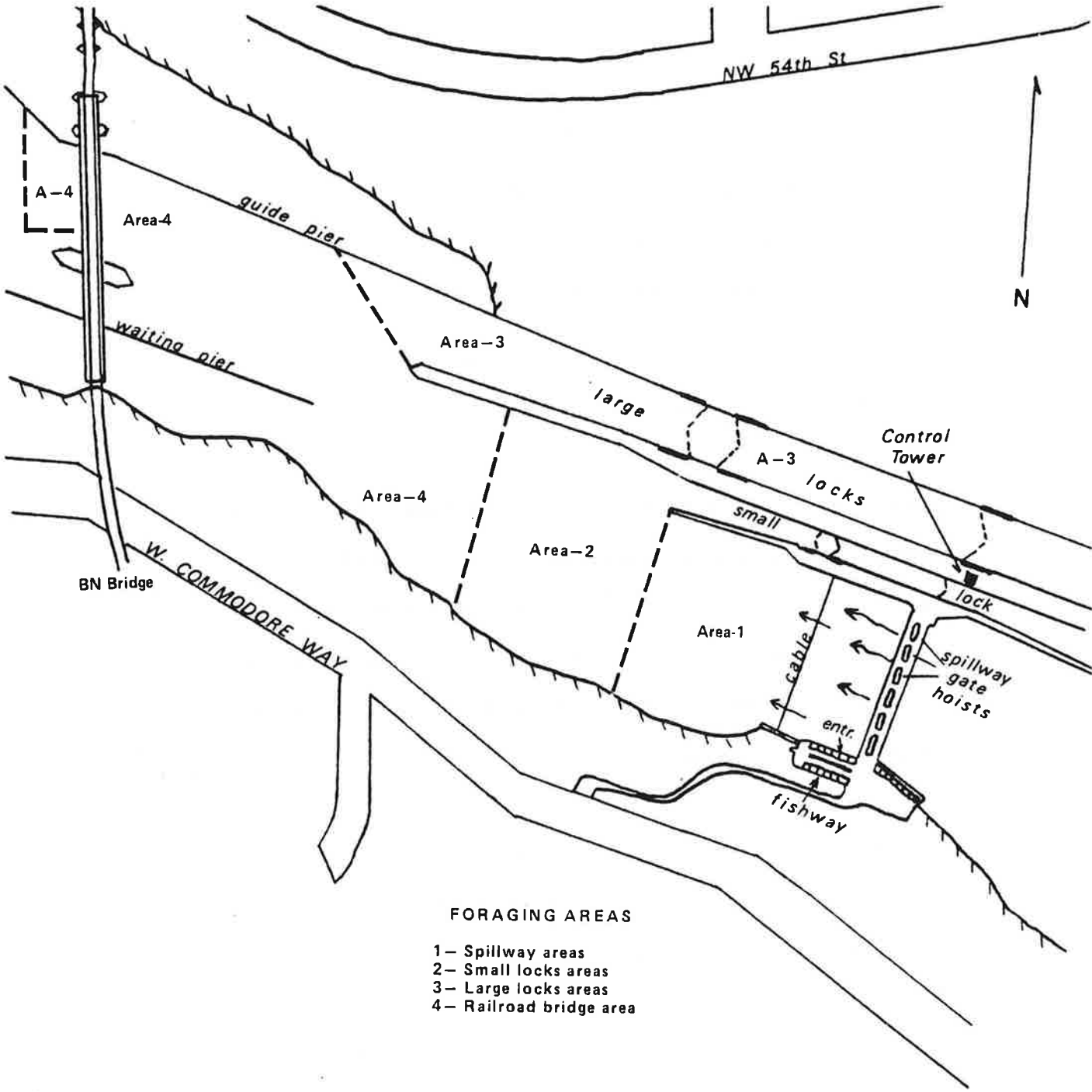

Figure 3 Map of the Chittenden Locks, and spillway dam (Inner Ship Canal Bay).

In addition to the primary study area in the Ship Canal, several other areas are considered important as they related to sea lion distribution and occurrence within the Locks area. In general, these secondary areas included the waters of Puget Sound from the Nisqually River delta northward to Port Susan and Saratoga Passage and westward along the southern Strait of Juan de Fuca to Dungeness Spit (Figure 4). Hood Canal and the inlets south and west of Case Inlet are not included within the study area.

Pre-harassment Phase

The pre-harassment phase of the study was conducted between 22 November 1986 through 5 January 1987. The objectives during this phase were: to assess overall predation losses of steelhead by estimating the daily rate of sea lion predation on steelhead; to estimate total steelhead predation losses over the course of the fish run with no harassment; to obtain information on numbers of sea lions frequenting the Locks and predating steelhead; to attempt to identify individual sea lions involved; and to collect data on feeding behavior of sea lions.

An observer was stationed at the Locks for 8-hour shifts generally from 0700-1500 and 1500-2300. During shifts, observers walked the vicinity of the Locks and observed sea lions and steelhead predation incidents. Data collected included number of sea lions present, identity of individual sea lions (if possible) and location of sea lions. Each predation incident observed was recorded and data collected included time, location and whether the fish was consumed whole, broken apart, or if portions were not eaten.

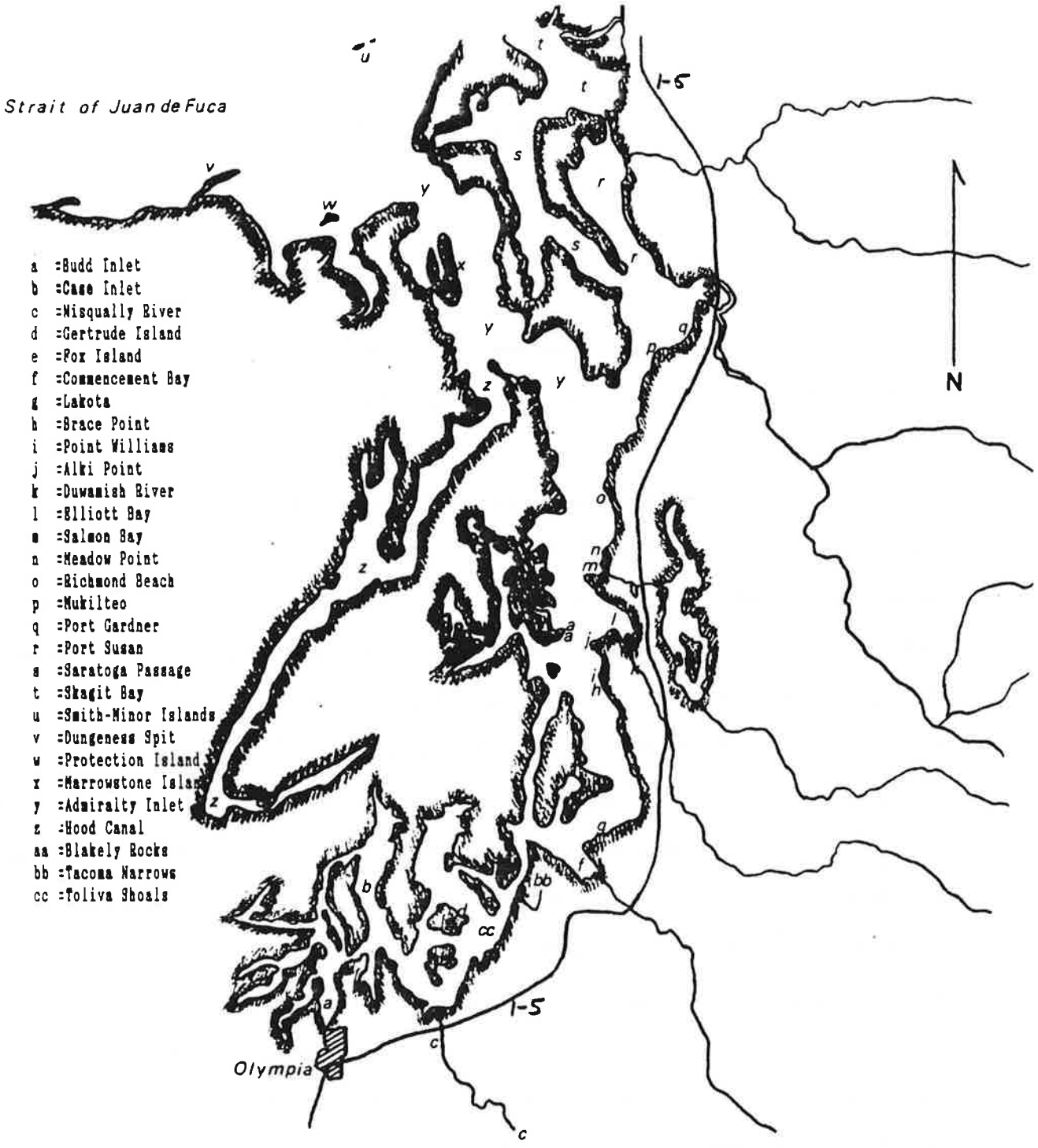

Figure 4 Areas of Puget Sound surveyed by air or boat for abundance and distribution of sea lions.

Harassment Phase

Inner Ship Canal Bay

The harassment phase of the study consisted of observations from the inner and outer Ship Canal Bay areas. The inner Ship Canal Bay is defined as the area from the Burlington Northern Railroad Bridge (BN) east to the spillway dam (Figure 3). The outer Ship Canal Bay study site runs from west of the BN Bridge to the southern end of the Shilshole Marina jetty (Figure 5).

We conducted the harassment phase of the study from 6 January through 30 April 1987. Control of predation was attempted by three methods of sea lion harassment: seal bombs (firecrackers), acoustic harassment devices (AHD's), and by hazing sea lions with a boat. The seal bombs used were purchased from California Seal Control Corporation. These devices are classified as Class C explosives, and are registered as agricultural fireworks by the State of California. Each unit consists of a spiral-wound cardboard tube containing 36 grains of potassium perchlorate and pyro-aluminum flash powder with an 8-second waterproof fuse (Geiger and Jeffries 1986). The units are weighted with sand and when lit and dropped into the water will sink to 3 to 5 m before exploding, causing a flash of light and a slight percussion in the water.

The AHD device was a "Sealchaser" unit designed and built[1] as a method to deter seals and sea lions from damaging fishing gear and fish. The system consists of a sound pulser unit, amplifier and small transducer which is lowered underwater by cable. The AHD produces high intensity (12 to 15 kHz),

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[1]By Cascade Applied Sciences, Philomath, Oregon. Reference to trade names throughout this report does not imply endorsement by the National Marine Fisheries Service, N.O.A.A., or the Washington Dept. of Wildlife.

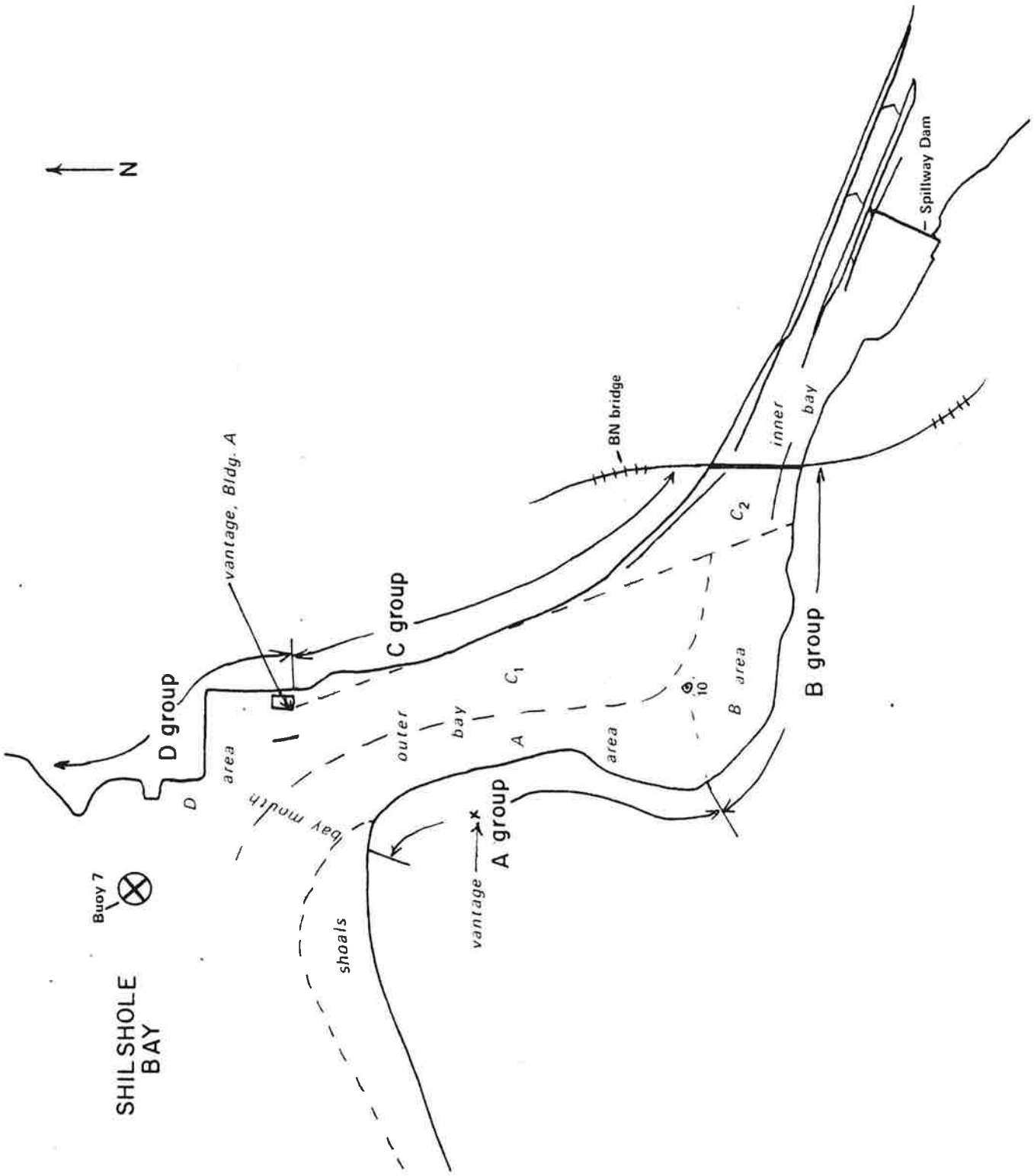

Figure 5 Map of Outer Ship Canal, showing the locations of tribal net groups and sea lion foraging areas.

underwater sounds which are within the normal hearing range of pinnipeds but are inaudible to fish (Mate and Greenlaw 1982). We used one AHD device during this study which was centered near the spillway cable (Figure 3).

The general strategy employed for chasing sea lions from the Locks was to use seal bombs in conjunction with the AHD device. This was accomplished either from shore or by using a small boat to chase sea lions from the spillway dam area into outer Ship Canal Bay or Shilshole Bay.

We maintained an average of 16 hours of observer coverage per day during the harassment phase. Coverage was not maintained during the hours between 2300-0700 because observed predation rates were very low during this time frame. Background lighting allowed observers to record fish kills during darkness.

During all shifts any sea lion observed below the Locks was chased out immediately by first throwing several seal bombs. The AHD on the cable was then turned on. The AHD was left on for 20 to 30 minutes following the sighting. We tossed seal bombs from the walkway crossing the spillway dam and also off the finger piers adjacent to the small and large locks (Figure 3). When the boat was available we used it as a platform from which to throw seal bombs. Using the boat was in most cases preferred because it often enabled the observer to chase the sea lion(s) well out of the spillway dam vicinity. During the harassment phase we collected data on the number of sea lions present each day and steelhead predation observed. Data collected included time, location, method of consumption and identity of the predator.

Outer Ship Canal

During the harassment phase our activities in the outer Ship Canal (west of the BN bridge; Figure 5) included periodic boat and seal bomb harassment of animals into Puget Sound.

Boat harassment usually occurred when animals could not be chased out of the inner bay solely by shore based methods. The specific technique of boat and seal bomb harassment was the same as that used in the inner bay area, with the exception that the animals were generally chased out of the bay and into the open waters of Puget Sound. The [western] [outer] limit for harassment was typically near red buoy #7, about 100 m west of the Ship Canal mouth (Figure 5).

Observers recorded pertinent information on the behavior and number of animals being herded through the outer Ship Canal. In 1987 a concerted effort was made to gather specific data on the behavior of sea lions in the outer Ship Canal as it related to the presence or absence of set tribal gill nets.

Virtually the entire bay west of the BN bridge was observed during surveys on 14 days in January. Half of these surveys were essentially dawn-to-dusk. Most of the observations were made from Building A (Figure 5), but at times concurrent observations were made from above the bay on Sheridan Avenue West. When observations were made from Sheridan Avenue, biologists were also making concurrent observations of sea lion activity at the Locks, the inner and outer bays and the outer bay mouth. At these times accurate counts were made of the total number of sea lions active in the bay, as well as the total number of fish killed. Outer bay sea lion behavioral observations were aided by use of binoculars (10x).

Data gathered as part of the outer bay observations included weather conditions, tidal stage, number and location of set gill nets, the number of sea lions actively foraging in the area, the time and location of fish kills (both from nets and free swimming fish) whether the sea lions were harassed, whether tribal fishermen were tending (collecting fish from) their nets, and the number and location of sea lions rafted beyond the outer bay mouth. Incidental observations included the reaction of foraging sea lions to harassment by our crews or tribal fishermen, interactions between foraging sea lions and the manner in which steelhead were captured and consumed. Data were recorded in a running documentary fashion in waterproof field notebooks.

Tribal gill nets were generally set in the same locations from one fishing day to the next. We assigned the nets into four location groupings relative to our principal observation point. Net Group A included those set from the point of land on the south shore at the narrowest point of the bay mouth on around (into) the bay to the southwesterly-most point of the bay (Figure 5). The Group B nets were those from the aforementioned point easterly along the south shore to beneath the BN bridge. Group C nets were those on the north shore beneath the BN bridge that were visible from Building A, and west to Building A. Group D nets were those set from Building A north to Anthony's Home Port Restaurant.

Tidal data for Puget Sound from the National Ocean Survey of NOAA, as published locally by Elliott Sales Corp. (Dot's Fishing Guide), were used in this study.

Observations in the outer bay began before dawn and terminated after dusk on most of the days sampled. When sea lions could not be seen because of darkness their presence was often revealed by audible exhalations or

thrashing of fish. In this manner we documented nighttime presence in the outer bay, as well as confirmed nocturnal steelhead takes, but we were unable to quantify the overall number of steelhead taken through periods of darkness.

Crepuscular observations also served to document the amount of time that sea lions could forage effectively, as well as be seen by researchers, prior to or after official times of sunrise and sunset.

Estimating Predation Losses

Total losses of steelhead by sea lion predation were estimated for the inner and outer Ship Canal Bay areas during the course of the study from 22 November to 30 April.

The season length was set at 160 days although a few fish which were early or late arrivals may have extended this length by 10-20 days. Rates of predation were determined by actual observations of steelhead kills by sea lions in the inner and outer Ship Canal area. Since rates varied significantly depending on: time of day, gillnetting activity, whether or not harassment was employed, and location (inner and outer bay), these rates of predation were stratified and combined to obtain a total estimate of losses. Predation rates were derived by determining the numbers of fish killed per hour and using the pooled mean of hourly rates to compute a 24 hour "daily kill rate." We divided all sample observations into either daylight or darkness hours and computed the 24-hour rate by combining these 2 periods. Darkness was defined as the period known as "civil twilight" which is the time prior to actual sunrise or after sunset when stars are still visible or first visible in the sky. Civil twilight varies according to season but averages 34 minutes before sunrise and 34 minutes after sunset. Actual times of sunrise and sunset were taken from standard tide tables from 1986 and 1987.

We included the use of civil twilight to define darkness because our observations indicated that sea lions can still capture steelhead successfully during this period.

Predation rates for the inner Ship Canal were determined for 6 separate periods including: preharassment with nets in (1) and out (2), harassment with nets in (3) and out (4), and during the time of captures (5) and when harassment was halted for 1 week in March (6).

We conducted statistical analysis on the data for predation rates in the inner bay to obtain confidence limits on our estimated fish losses and to compare differences between periods. Confidence intervals were determined for the total estimated fish losses in the inner bay area using two methods; the t-interval based on the parametric t-distribution and the W-interval, a non-parametric analogue derived from the Wilcoxon statistic. We made comparisons of the six predation rate periods to determine if significant differences existed. The Mann-Whitney test was utilized (Zar, 1984) to evaluate differences in mean hourly predation rates between periods.

Alternative Control Methods

Several studies were conducted to evaluate the potential of using alternative predation control methods.

Taste Aversion

We attempted to condition taste aversion to steelhead in California sea lions at the Locks in late December 1986 and early January 1987.

Initially, steelhead which were freshly killed, were tethered with approximately 25 cm of 15 pound test monofilament nylon which was attached to 2 m of 250 pound test monofilament. The heavy monofilament was then attached

to approximately 50 m of one-fourth inch polyethylene rope. Fish were presented to sea lions in the water below the spillway gates to determine if sea lions would feed on the tethered fish.

Freshly killed steelhead were then prepared by placing gelatin capsules with 100 g of lithium chloride (LiCl) into the body cavity through an incision in the belly. The incision was closed with sutures of dental floss. This amount of LiCl approximated a dosage rate of 0.4 to 0.6 g/kg of sea lion body weight which was found to be effective in conditioning taste aversions in captive sea lions (Kuljis 1986). The LiCl treated fish were then tethered and presented to sea lions in the water below the spillway gates.

Capture and Translocation

Capture attempts were made at the Locks on 3 days in late January to evaluate capture and translocation of sea lions. A gillnet of number 36 nylon twine (110 m long and 15 m deep with 33 cm mesh) was set by gillnet vessel in the channel in front of the spillway as sea lions were foraging near the fish ladder. Several boats with divers were standing by in the vicinity to assist in the net and sea lion recovery.

Captured animals were to be translocated and released off the California coast within the breeding range of the species.

Tactile Harassment

Tests were conducted using rubber buckshot to evaluate the potential of using non-lethal rubber projectiles as a harassment technique. Rubber buckshot[2] fired from a 12-gauge shotgun was test fired at Calligan Lake to evaluate the accuracy, force and ricochet potential of the projectiles.

[2]Made by Fiocchi of Italy

Rubber buckshot was fired from distances of between 7 to 25 m at a stationary target of white paper and the number of pellets and spread pattern from each shot was determined. Rubber buckshot was also fired from various angles into the water to evaluate the number of pellets and impact potential of ricochets. Rubber buckshot was subsequently fired at a dead sea lion from various distances to evaluate the potential for penetration of the hide.

Adult Steelhead Counts

Counts of steelhead in the fishway viewing chamber were made on a daily basis. Due to variable water turbidity, counts should be considered only as an index for actual steelhead passage. The data are presented in Appendix Table 2. Additional notes were made on steelhead schools observed in the Ship Canal and their reaction to the presence of sea lions.

Sea Lion Behavior and Biology

Periodic surveys were conducted in the vicinity of Shilshole Bay to obtain information about the abundance and distribution of sea lions potentially using the Ship Canal area. Because sea lions had been observed in the vicinity near Meadow Point and Duwamish Head in previous years (Figure 6), we routinely surveyed the following areas by boat: Meadow Point, Shilshole Bay, the Ship Canal, West Point, Four Mile Rock, Elliott Bay, the Duwamish waterways (East and West channels) and Duwamish Head. We counted sea lions seen during these surveys, and noted their behavior, i.e., rafting, foraging, transiting, etc.

One aerial survey, flown in a DeHavilland Beaver, was conducted on 17 April 1987 to obtain information on the abundance and distribution of sea lions in Puget Sound. Surveys were flown between 135 and 200 m of altitude

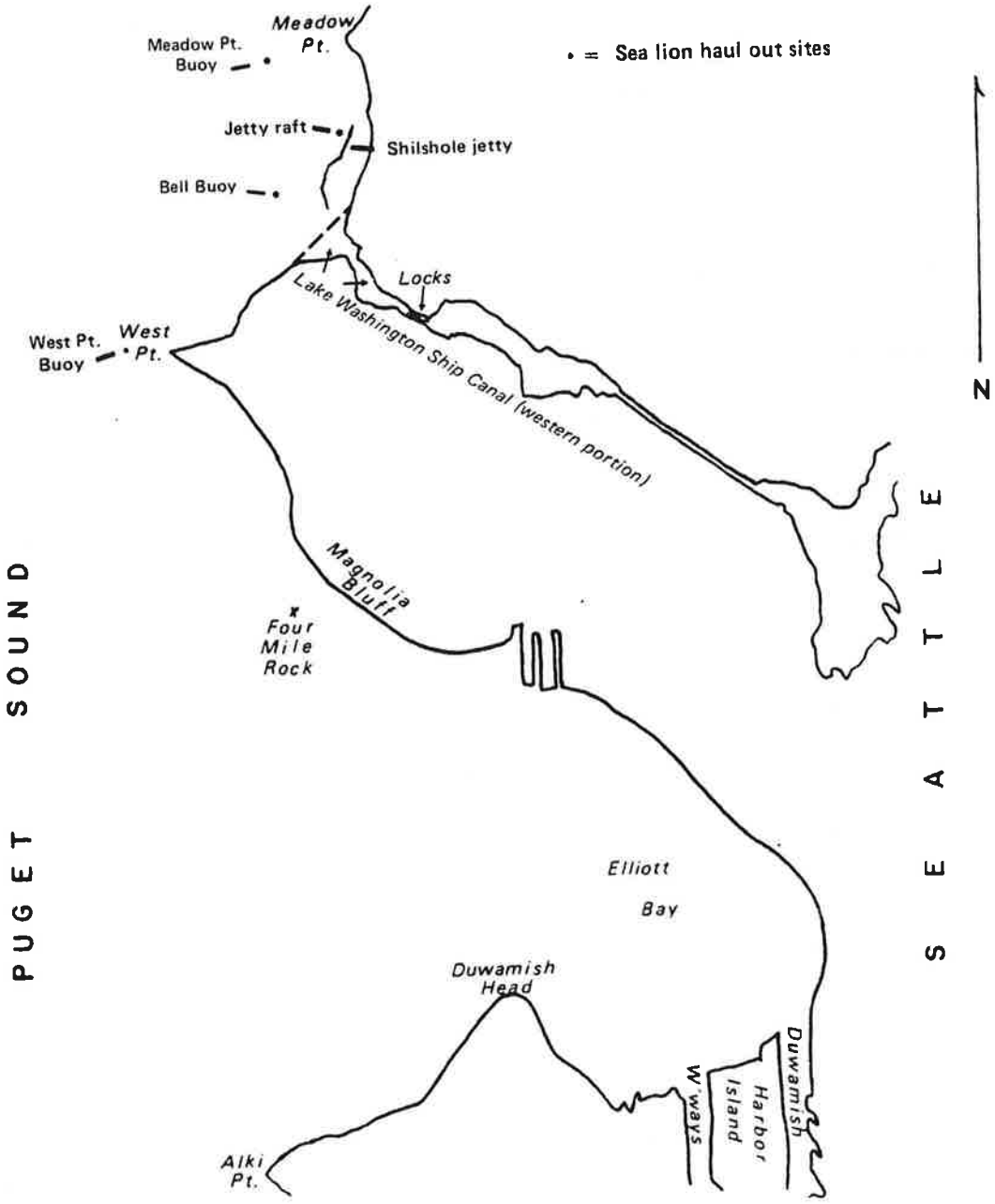

Figure 6 Geographic areas near Shilshole Bay surveyed by boat for sea lions. Known haul out sites are noted.

between 90 and 130 mph. Photographs of major sea lion centers of abundance (where 25 or more animals are observed) were taken. The photographic slides were then projected onto a sheet of white paper, where the images were counted to obtain a total estimate of sea lion numbers.

We continued to monitor weekly for sea lions at the Locks until the end of May 1987 in order to determine departure dates.

Food Habits

The food habits of sea lions in Puget Sound were evaluated by analyzing scat (fecal) and spewing (vomitus) samples collected from haul out sites at Everett and Shilshole Bay and by actual observation of foraging sea lions. Collections at Shilshole Bay were made from the flat barge buoy off the west side of Shilshole jetty. Collections from Everett were made at the sunken barges off the southwest side of the Everett jetty. Samples were collected between 3 February and 4 May 1987, with 48 scats or spewings collected from Everett and 71 collected from Shilshole Bay.

Scats and spewings were placed in plastic bags with liquid detergent and water for 24 to 48 hours to soften and break down fecal components. The contents were then poured into a plastic beaker and rinsed through a series of four nested straining sieves with openings 4.75, 1.4, 1.0, and 0.5 mm, respectively. Bony, chitonous and cartilaginous hard parts were then retrieved from the sieves and sorted into identifiable prey categories. Prey taxa were determined by identification of saggital otoliths (fish ear bones) characteristic fish vertebrae or other bony parts. The otolith and fish skeletal reference collection at the National Marine Mammal Laboratory was

used to compare material for identification. Published keys were also used to identify otoliths (Morrow 1979). Common and scientific names of fishes used follow the American Fisheries Society list (Fourth Edition, 1980).

We identified some fish taxa by examining vertebral characters or characteristics of other diagnostic bony parts. This methodology allowed us to identify and determine percent occurrences of salmonids, herring, Clupea harengus, hake, Merluccius productus, and spiny dogfish, Squalus acanthias, from scats or spewings which may not have contained otoliths. Identifying prey from vertebrae represents a significant improvement over past methodology because many cartilaginous fishes do not have otoliths and also because otoliths can be degraded or completely broken down in the digestive process.

Prey remains in scat and spewing samples were quantified by two means: percent occurrence (frequency) and numerically as numbers and percentages of identifiable otoliths. Frequency of occurrence was determined for each prey species or prey category as a percentage of occurrence in the total samples examined. A numerical value was determined by counting identifiable otoliths. This value was expressed as a percentage of the total identifiable otoliths from the total samples.

RESULTS

Sea Lion Occurrence: Preharassment

Sea lions were first observed during the 1986-87 season at the Locks on 6 October 1986 and last sighted on 15 May 1987 (Appendix Table 3). These observations indicate that sea lions were present at the Locks for a period of at least 7.4 months.

During the preharassment phase of the study from 22 November 1986 to 5 January 1987, sea lions were present at the Locks during 31 of 36 days

(86%). The presence and number of sea lions in the inner bay during this period appears to be affected by the tribal gillnet fishery in the outer bay. For example, during days when the tribes were gillnetting in the outer bay, sea lions were observed at the Locks on 13 out of the 17 (76%) of the days. When the tribes were not gillnetting, sea lions were observed at the Locks on 21 out of 22 (95%) days.

Numbers of individual sea lions observed simultaneously at the Locks ranged from zero to seven animals during the pre-harassment study (Table 1). The numbers of individuals at the Locks also appeared to be related to the presence or absence of tribal gillnets in the outer bay. The mean number of sea lions at the Locks for netting days was 2.29 and for non-netting days was 3.13 (Table 1) (not significantly different at 0.10 level, t-test).

The mean number of sea lions which occurred in the inner bay was greater this year (3.13) than for a similar period last year (2.65). These data may indicate an increasing trend in numbers of sea lions from 1985-86 to 1986-87.

Sea Lion Occurrence: Harassment Phase

Sea lions were observed in the inner bay area during 111 (96%) of these days and were absent on only 4 days. During the previous year's study in 1985-86, sea lions were observed at the Locks on 60 out of the 80 days (72%) during harassment. These data indicate increased presence of sea lions at the Locks from 1985-86 to 1986-87.

The mean number of sea lions which occurred at the Locks during the harassment period was 2.68 per day when nets were not present in the outer bay, which was significantly greater than the 2.15 when nets were present, (t-test, $p = 0.064$) (Tables 2 and 3). The mean number of sea lions present

Table 1.--Maximum daily counts of sea lions at the inner Ship Canal during preharassment, with nets in and out, 22 November 1986 - 5 January 1987.

Date	Count With Nets In	Count With Nets Out
11/22/86	-	1
11/26/87	3	-
11/27/86	-	2
11/28/86	3	-
12/01/86	0	-
12/02/86	0	-
12/03/86	0	-
12/04/86	0	-
12/05/86	-	1
12/06/86	-	0
12/08/86	1	-
12/09/86	1	-
12/10/86	2	-
12/11/86	-	3
12/12/86	-	3
12/13/86	-	7
12/14/86	-	5
12/15/86	5	-
12/16/86	3	-
12/17/86	3	-
12/19/86	-	3
12/20/86	-	4
12/21/86	-	3
12/23/86	4	4
12/24/86	-	4
12/25/86	-	4
12/26/86	-	4
12/27/86	-	2
12/28/86	-	2
12/29/86	4	-
12/30/86	3	4
12/31/86	-	3
01/02/87	-	4
01/03/86	-	4
01/04/86	4	2
01/05/86	3	-
	39	69
	Mean Number = 2.29	Mean Number = 3.13

Table 2.--Maximum daily counts of sea lions at the inner Ship Canal during harassment with nets in Outer Bay, January 6-February 10, 1987 and during period of no harassment in March.

Date	Number
January 6	3
January 7	3
January 8	2
January 12	2
January 13	1
January 14	2
January 15	2
January 16	4
January 17	1
January 29	3
January 30	2
February 9	2
February 10	1
	28

Mean number = 2.15

Maximum Sea Lion Counts When Harassment Halted

Date	Number
March 25	7
March 26	7
March 27	6
March 28	7
March 29	6
March 30	8
	41

Mean number = 6.83

Table 3.--Maximum daily counts of sea lions at the Inner Ship Canal during harassment with no nets, 6 January-30 April 1987.

January Day	Number	February Day	Number	March Day	Number	April Number
6	-	1	3	1	6	3
7	-	2	6	2	3	2
8	-	3	2	3	4	3
9	3	4	1	4	3	4
10	3	5	0	5	2	3
11	2	6	3	6	5	2
12	-	7	2	7	5	5
13	-	8	2	8	3	5
14	-	9	-	9	3	3
15	-	10	-	10	4	3
16	-	11	2	11	3	4
17	-	12	2	12	2	3
18	5	13	1	13	4	2
19	2	14	1	14	3	4
20	3	15	2	15	0	3
21	2	16	2	16	2	0
22	2	17	3	17	2	2
23	2	18	1	18	2	2
24	2	19	2	19	3	2
25	2	20	2	20	3	3
26	2	21	2	21	3	3
27	3	22	2	22	2	3
28	3	23	2	23	2	2
29	-	24	2	24	2	2
30	-	25	2	25	-	2
31	1	26	2	26	-	2
	22	27	2	27	-	2
		28	2	28	-	2
			53	29	-	1
				30	-	0
				31	1	-
					87	77

	Number	Days	Mean
January	22	8	2.75
February	53	26	2.00
March	87	25	3.48
April	77	30	2.56
Total	239	89	2.68

varied by month and was highest in March (3.48) which corresponded with increasing numbers in the greater Shilshole Bay area. The mean number per day (2.68) was 3 times greater this season than for last season (0.78) during the harassment period. These observations may indicate that the harassment program was less effective this season than last in terms of keeping individuals away from the Locks and also may indicate that more individuals utilized the Locks vicinity this season.

Sea Lion Abundance

Data regarding sea lion counts were analyzed for four different periods; preharassment with nets in (PNET1) preharassment with nets out (PNET2), harassment with nets in (HNET1) and harassment with nets out (HNET2). Statistical tests used were the Mann-Whitney two-sample rank test and two-sample t-tests. Based on the results of these tests, the only 2 periods which were significantly different were HNET1 and HNET2, $p = 0.064$ when using the t-test.

A one way analysis of varience (ANOVA test) was conducted on the HNET2 data by month (January through April). Counts for March were significantly greater than for the other three months and the counts for April were significantly greater than for February ($F = 6.41$ so $p < 0.99$). No significant differences were found between the January and February or the January and April counts. These analyses indicate that significantly greater numbers of sea lions occur at the Locks in March which corresponds to the timing of an increase of animals in the Shilshole Bay area.

Sea Lion Identification

The identifying characteristics of individual sea lions were recorded on 5 x 8 inch ID cards. Information recorded included color, pelage type, whisker color, distinctive scars, marks, and wounds, approximate size, and daily presence or absence (Appendix 4). Eleven sea lions which had distinctive characters were subsequently identified throughout the season (Table 4). Eight out of the 11 animals identified at the Locks were observed on more than 1 day during the season. There is extreme variability in the ease by which individual animals can be identified, however, due to the distinctiveness of their marks, size, and color. Some animals have very indistinct marks which can only be seen under optimal conditions such as the proper lighting, swimming speed, and orientation. It is likely therefore that many of these animals could have been present on any given day and not identified. At least 2 of the sea lions which were present at the Locks this season (numbers 1 and 2) were known to have been there the previous season in 1985-86. In addition, it is likely that at least 2 other animals (numbers 3 and 8) were present during the previous season as their marks conform closely with 2 animals observed in April of 1986 at the Locks. All of the California sea lions which occur at the Locks and in Puget Sound are males.

Total Sea Lion Estimate

We could not obtain an estimate of the total number of sea lions which visited the area of the Locks because of the difficulty in identifying individuals. We know that at least 11 individuals visited the Locks during the 1986-87 season and potentially another 10 to 15 which could not be identified. A haul out and rafting site near Shilshole jetty was

Table 4. California sea lions identified at the Locks (Inner Ship Canal) during the 1986-87 season.

Number	Name	First Record	Last Record	Days Sighted
1	Humpback	21 November 1986	13 April 1987	57
2	Scar	22 November 1986	11 May 1987	63
3	Thrasher	22 November 1986	23 April 1987	68
4	Pox	2 January 1987	30 January 1987	3
5	Speedy	5 December 1987	5 December 1987	3
6	Blue Eye	26 December 1986	6 April 1987	4
7	Knothead	7 April 1987	7 April 1987	1
8	Left Flank	29 March 1987	21 April 1987	3
9	No Name	5 March 1987	6 March 1987	2
10	Three Spot	29 March 1987	29 March 1987	1
11	Spud	30 March 1987	30 March 1987	1

consistently used by from 7 to 135 sea lions from 22 March until mid-May. This location was about 1 km from the Locks and was therefore within easy access to the Locks. The potential for larger numbers of sea lions to enter the Ship Canal and discover the Locks area is great due to the proximity of this haul out - rafting site. A reliable estimate of the number of individual sea lions which utilize the Locks area can not be made until a proportion of the animals are marked with easily identifiable tags or marks.

Sea Lion Behavior

The behavior of sea lions which occur at the Locks can be broadly divided into two general categories; foraging and non-foraging. Foraging

behavior involved the pursuit, capture, killing and consumption of prey. Non-foraging behavior involved either surface resting, grooming, or interactions with other sea lions, birds, or seals.

A foraging sea lion's behavior was characterized by continuous movement. The movements consisted of a series of shallow dives averaging one to three minutes in duration, followed by a short (10 to 60 second) period of resting at the surface before resuming the dive. The short "rest" time following a feeding dive was different from the "normal" resting observed when sea lions were not foraging. Normal resting behavior of sea lions often involved prolonged periods (>5 mins.) of stationary aquatic rafting. Rafting is characterized by the sea lions lying on their back or side with a flipper raised out of the water. Rafting often involves several animals floating and resting together in close contact. The short rest periods between foraging were characterized by slow swimming on the surface during which the animal was in its normal swimming posture (ventral surface submerged, flippers not exposed). We estimated that the sea lions at the Locks spent 95% or more of their time actively foraging as opposed to rafting or interacting with other animals.

Foraging Locations

Inner Ship Canal Bay

Sea lions foraged for steelhead in several areas of the inner Ship Canal including: both locks, near the Burlington Northern railroad bridge, and near the fishway (Figure 3). The primary foraging area during the pre-harassment study was within the safety cable area near the fishway entrances (in Area 1, Figure 3). Seventy-two percent of all observed fish takes were caught within the cable area adjacent to the fishway entrances. The next

areas of importance were the small locks area which accounted for 12.5% and near the railroad bridge (3.1%). The percentages of fish caught in these locations changed considerably during the harassment phase of the study when sea lions began foraging further out away from the spillway area (Table 5).

Individual sea lions appeared to have specific foraging areas within the Locks area. Generally when more than one sea lion was present, they would spread out within the area and forage in what appeared to be individual feeding territories. For example, if five animals were present, two would forage near the fishway, one each in the small and large locks, and one by the railroad bridge. It was not unusual to observe sea lions together for short periods of time, however, they did not appear to forage cooperatively or remain together for extended periods. On several occasions, active displacement of one sea lion by another from a foraging area was observed. It appeared that the largest sea lions obtained the most preferred or optimal foraging sites and actively excluded other smaller animals from remaining. For example, of the three sea lions which could be readily identified, the largest (number 3) foraged on the north side of the spillway area and excluded the next largest (number 1) from foraging in this area. Sea lion 1 foraged on the south side of the spillway area near the fishway and was observed to exclude other smaller animals from this area. The next largest sea lion (number 2), swam in a large circle in and outside of the spillway area in a pattern which crossed through both number 1 and number 3 sea lion's territories. It appeared that number 2 was permitted access to these areas as a transient, however, if he captured a fish within these areas a struggle would often ensue upon which he lost his fish and was chased out.

Table 5.--Locations of sea lion steelhead captures near the Locks during preharassment and harassment phases 1986-1987.

Location	Preharassment Number	%	Harassment Number	%	Total	%
1	115	72.0	162	39.0	277	48.8
2	20	12.5	51	12.3	71	12.5
3	8	5.0	79	19.0	87	15.3
4	5	3.1	65	15.7	70	12.3
5	4	2.5	23	5.5	27	4.8
6	1	.6	18	4.3	19	3.3
62	0	0	4	1.0	4	.7
64	0	0	9	2.2	9	1.6
65	7	4.3	4	1.0	4	.7
	160	100	415	100	568	100

Location Codes - See Figure 3
1-Spillway area
2-Small Locks
3-Large Locks
4-Bridge Area
5-Outer Bay
6-Unknown
62-Unknown, First seen by small locks
64-Unknown, First seen by bridge area
65-Unknown, First seen in outer bay

Sea lions were often observed fighting over and attempting to steal fish from other sea lions in most areas of the inner bay. On days when sea lions 1 and 3 were not present or arrived later in the day, these foraging locations were taken by other animals. These two large sea lions, however, quickly regained possession of these foraging locations shortly after they arrived. On some days, both number 1 and 3 sea lions ranged over a larger foraging area and did not appear to actively defend the spillway locations. On these days (when fish may have been scarce) they tended to circle in and out of the small

and large locks and back through the spillway area thereby scanning a larger area for prey. These observations are noteworthy because they are the first records that indicate Zalophus may establish and defend foraging territories.

Outer Ship Canal Bay

In the outer Ship Canal sea lions were observed to depredate steelhead from the set gillnets and also to predate free swimming fish when the nets were not set. When the gillnets were set in the outer bay, sea lions continuously scanned the nets for fish from the railroad bridge out to the south entrance of Shilshole Marina (Figure 5). When the nets were not set in the outer bay, most sea lions returned to the inner bay to forage near the Locks and spillway, however, some animals remained in the outer bay and successfully caught fish. The breakdown of percentages of fish caught in different locations during netting and non-netting periods is provided in Figure 7.

Catching and Consuming Prey

The majority of steelhead captures occurred under water out of view of the observer. Captures were first noted when the fish was brought alive to the surface in the jaws of a sea lion. When a fish was brought to the surface, the sea lion re-oriented the fish in its mouth, grabbing it by the head from above. The sea lion would kill it by shaking it several times with quick lateral movements of the head, as it was held in its jaws. Violent thrashing almost always resulted in beheading the fish, followed by swallowing of the head. After the fish was killed, it would be consumed either whole or broken into chunks. Although large fish (> than an estimated weight of 4.5 kg, or 10 lbs) were observed to be eaten whole, they were more likely to be

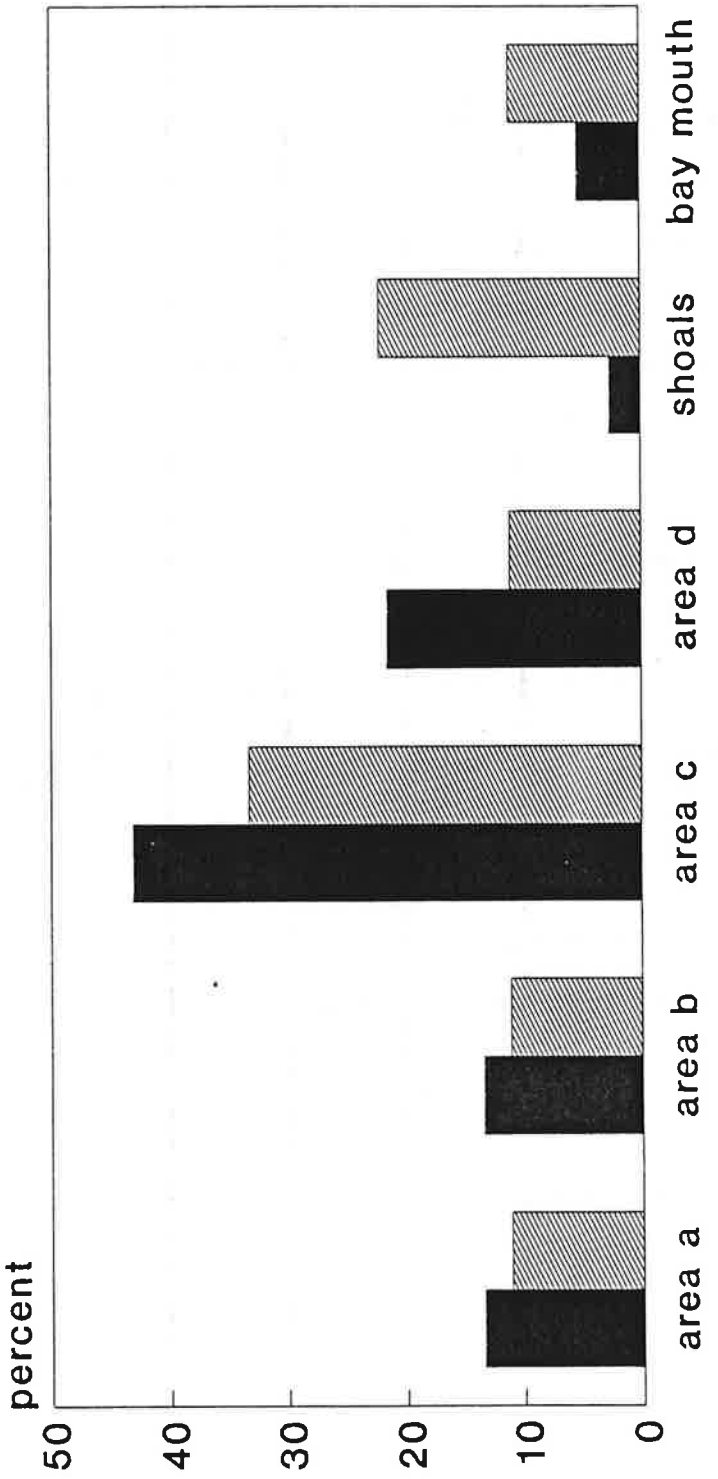

Figure 7 Locations of steelhead kills in Outer Ship Canal during tribal netting and non-netting periods.

broken apart for eating. Only 9.6% of the total fish observed eaten, however, were eaten whole. The remainder (90.4%) were broken apart and consumed. When fish were broken apart, in most cases the head was eaten first. At this stage, the fish was either broken further apart or swallowed as it was. Fish which were broken apart were eaten from the head toward the tail by a continuing series of violent shakes by the sea lion. Generally, when the fish was about two thirds to one half it's initial length, the remainder would be swallowed.

All fish observed eaten whole were swallowed head first. When a fish was about to be swallowed, the sea lion would align the fish vertically in its mouth and raise slightly out of the water to force the fish further into its esophagus. The sea lion would then roll under water with its mouth open, forcing the fish further in by the pressure of the water. After a fish was swallowed, the sea lion quickly returned to its specific feeding area and resumed foraging.

There appears to be a great deal of variability in the amount of fish actually consumed by individual sea lions. Sea lion 3, for example, appeared to waste a large proportion of the fish he captured, and number 1 appeared to consume nearly all of what he captured. An unusual aspect of sea lion fish consumption was the propensity for eating the head of caught fish while discarding the seemingly more palatable flesh. Sea lions were not observed to simply "rip the bellies" from fish and eat only the roe as is frequently suggested by untrained observers.

Individual Consumption Rates

Rates of steelhead predation were not equal for each sea lion. Individual predation rates are probably related to time spent at the Locks,

individual ability, and foraging location. In general, the individuals who spent the longest period of time foraging near the fishway were the most successful at catching fish.

We reported earlier in this report that sea lions at the Locks appeared to set up and defend foraging territories. Based on our observations, it appears that the most preferred foraging territories are in area 1 which encompasses 3 territories (Figure 3). During the preharassment period, 72% of all observed fish takes above the BN bridge occurred in this area.

Coincidentally, this area was utilized by the three largest and most successful (and dominant) sea lions in terms of foraging success. Foraging success was measured by calculating predation rates (fish taken per hour) of known identifiable sea lions. The most successful predator at the Locks was sea lion 3 who averaged 0.91 fish taken per hour of foraging time during the preharassment period for an 8-hour average of 7.3 fish. In terms of the fish kills by known individuals, number 3 accounted for 75 (40%) of all the known (189) kills throughout the study. Sea lion number 1 was the second most successful predator at the Locks and averaged 0.61 fish taken per hour or 4.9 in 8 hours during preharassment. Of the predation by known sea lions at the Locks, number 1 was observed to consume 54 (28%) of the fish taken. Number 2 accounted for 57 (30%) of fish kills by known individuals. The rate of predation for number 2 was not calculated because he was not present during enough days of the preharassment period.

Maximum Consumption Rates

The maximum number of fish which were observed taken by individual sea lions during any 8-hour period were 9 fish by sea lion 3 and 8 fish by number 1. These numbers are, however, considerably less than last season when

number 1 was observed to average 12 fish taken over 8 hours during a seven day period prior to harassment. We suspect that increased competition between sea lion 1 and 3 who foraged relatively close together during the season, accounted for the reduced rates observed in 1986-87.

Time of Predation

One of the most important factors related to the rate of predation at the Locks appears to be the amount of ambient light. Sea lions are not as successful at capturing free swimming fish during hours of darkness as during daylight. Only 11 out of 578 observed fish kills (1.9%) were taken when it was dark over the course of the study. These observations correspond closely with those from the 1985-86 study which also indicate that very few fish were taken when it was dark.

The distribution of fish kills by hour during days when there were no commercial nets in the water (Figure 8) clearly indicates that most predation occurs when light levels are high. The data in figure 8 are unimodal with the majority of kills occurring during mid-day hours. This appears to indicate that sea lion foraging efficiency on steelhead is greatest when there is maximum light in the water column and is much lower a few hours after dawn and before the onset of darkness.

We have observed sea lions foraging on steelhead at night from the gill nets in the outer Ship Canal, however, we were unable to measure the nighttime rate of predation during this season.

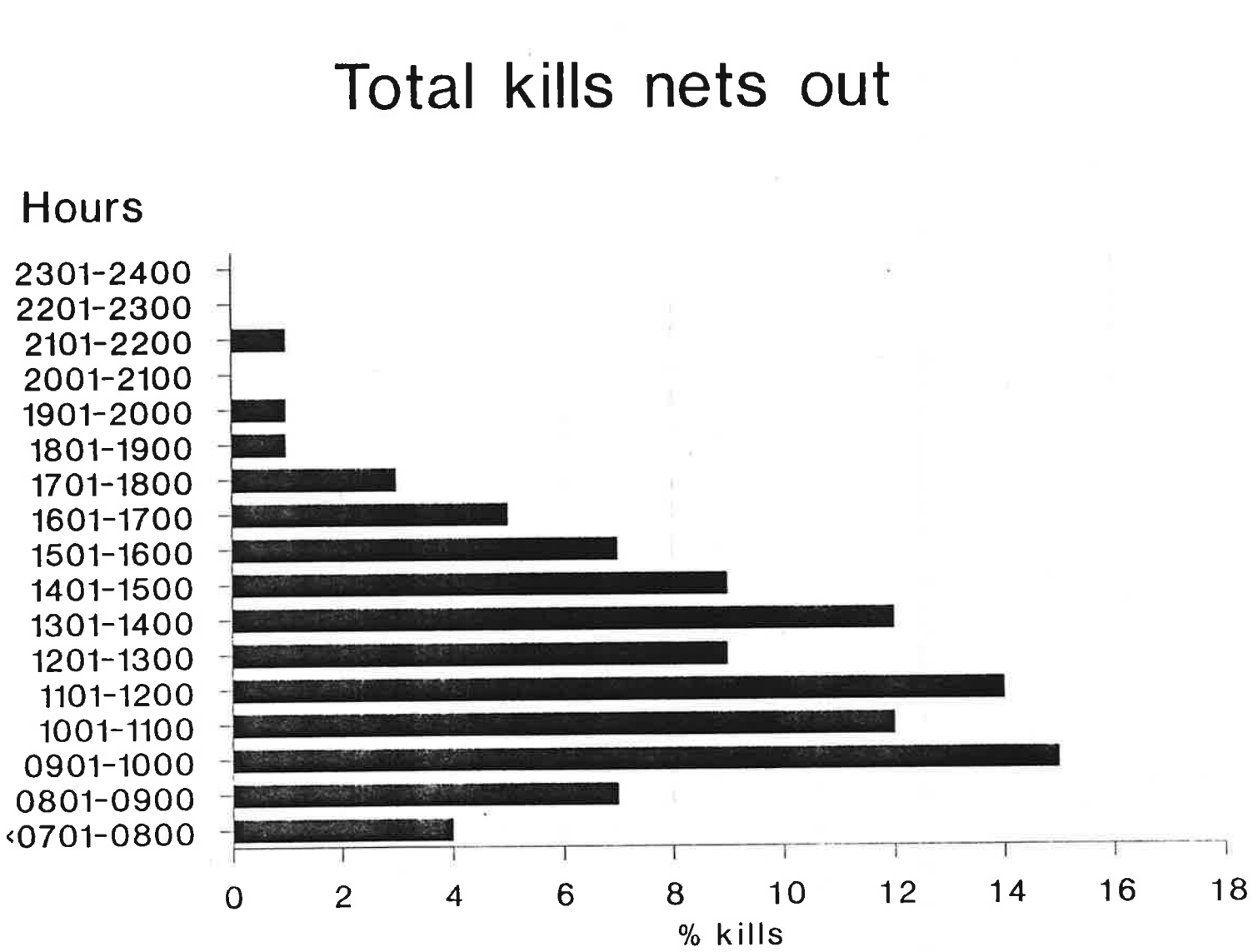

Figure 8 Percent of steelhead kills by sea lions during various hours of the day at the Chittenden Locks 1986-87.

Predation Rates and Steelhead Losses

Inner Ship Canal Bay

Predation rates for the inner Ship Canal (Locks area) were determined for six separate periods during the study.

(Preharassment-Nets In). Predation rates were determined for the preharassment period when gillnets were set in the outer bay. A daily predation rate was derived by determining hourly rates for daylight and darkness hours observed and adding them together. The 24-hour predation rate for this period was 3.15 fish per day (Table 6). No fish were observed taken during darkness hours during this period.

(Preharassment-Nets out). Predation rates were determined for this time period based on 93 hours of observation over 22 days during the time prior to harassment when nets were not set in the outer bay. The 24-hour predation rate for this period was 15.3 fish per day (Table 7). No fish were observed taken by sea lions during darkness hours during this period.

(Harassment-Nets In). Rates of predation were determined for the period of time when gillnets were set in the outer bay during the harassment phase of the study. The 24-hour predation rate was 2.31 fish per day (Table 8).

(Harassment Nets Out). Predation rates for the harassment period when gillnets were not set in the outer bay were determined to be 5.0 fish per day (Table 9).

(Capture Period). Predation rates were determined for a period of 7 days from 20-26 January during which captures of sea lions were attempted. These data were considered separately because harassment during this time was intermittent. The predation rate for this time period was 4.20 fish per day (Table 10).

Table 6.--Inner Bay preharassment steelhead kill rates, with nets in (26 November 1986 - 5 January 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
11/26/86	4.50	3	0	0
11/28/86	6.00	0	0	0
12/01/86	2.75	0	.50	0
12/02/86	5.00	0	0	0
12/03/86	2.00	0	0	0
12/04/86	3.00	0	.50	0
12/08/86	6.00	0	.50	0
12/09/86	4.25	1	0	0
12/10/86	3.50	2	0	0
12/15/86	5.00	5	1.00	0
12/16/86	3.37	0	.38	0
12/17/86	2.00	3	.38	0
12/23/86	3.00	0	0	0
12/29/86	5.50	2	0	0
12/30/86	2.00	1	0	0
01/04/87	5.00	3	6.50	0
01/05/87	9.50	4	6.50	0
	72.99	24	15.26	0

Daylight predation rate = 24/72.99 = .3288121 x 9.5970588* = 3.15

Darkness predation rate = 0/15.26 = 0

24 hour predation rate = 3.15 + 0 = 3.15 fish per day

* Indicates the average number of actual daylight hours per day for this period.

Table 7.--Inner Bay preharassment steelhead kill rates, with nets out (22 November 1986 - 4 January 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
11/22/86	1.50	1	0	0
11/27/86	0.75	2	0	0
12/05/86	5.00	0	0	0
12/06/86	.25	0	.50	0
12/11/86	6.50	5	0	0
12/12/86	8.00	11	0	0
12/13/86	0.50	1	0	0
12/14/86	3.16	7	0	0
12/19/86	6.50	13	0	0
12/20/86	7.00	19	0	0
12/21/86	3.00	14	0	0
12/23/86	2.33	3	0	0
12/24/86	4.00	12	0	0
12/25/86	0.50	0	0	0
12/26/86	6.00	19	0	0
12/27/86	1.00	1	0	0
12/28/86	0.25	0	0	0
12/30/86	2.00	0	0	0
12/31/86	5.50	3	0	0
01/02/87	6.75	9	0	0
01/03/87	9.50	16	6.50	0
01/04/87	4.50	1	.50	0
	85.49	137	7.5	0

Daylight predation rate = 137/85.49 = 1.6025266 x 9.538* = 15.3

Darkness predation rate = 0/7.5 = 0

24 hour predation rate = 15.3 + 0 = 15.3 fish per day

* Indicates the average number of actual daylight hours per day during period.

Table 8.--Inner Bay harassment steelhead kill rates, with nets in (6 January - 2 February 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
01/06/87	9.08	0	2.50	0
01/07/87	8.25	1	5.50	0
01/08/87	7.25	1	.75	0
01/09/87	3.33	1	0	0
01/12/87	4.66	2	1.34	0
01/13/87	8.50	0	2.34	0
01/14/87	8.66	2	3.34	1
01/15/87	7.75	2	1.98	0
01/16/87	5.75	2	0	0
01/29/87	5.00	2	2.25	0
02/30/87	4.00	1	0	0
02/09/87	4.44	0	4.81	0
02/10/87	4.75	0	0	0
	81.72	14	24.81	1

Daylight predation rate = 14/81.72 = .1713166 x 10.14* = 1.74

Darkness predation rate = 1/24.81 = .0403063 x 14.22* = .573

24 hour predation rate = 1.74 + .573 = 2.31 fish per day

* Indicates the average number of actual daylight and darkness hours over the period.

Table 9.--Inner Bay harassment steelhead kill rates, with nets out (9 January - 30 April 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
01/09/87	5.44	1	4.13	0
01/10/87	7.91	0	4.50	2
01/11/87	8.50	0	4.50	0
01/12/87	4.50	1	.50	0
01/16/87	2.25	1	2.20	0
01/17/87	8.84	0	5.50	0
01/18/87	9.00	7	6.25	1
01/19/87	9.92	11	.33	0
01/27/87	10.00	11	1.50	0
01/28/87	9.17	2	4.50	1
01/29/87	2.50	2	0	0
01/30/87	4.60	4	1.40	0
01/31/87	8.10	4	2.90	0
02/01/87	10.47	4	5.53	0
02/02/87	10.10	7	4.90	0
02/03/87	8.60	6	5.40	0
02/04/87	10.50	3	5.22	1
02/05/87	9.67	1	1.25	0
02/06/87	9.67	3	4.75	1
02/07/87	10.26	2	4.42	0
02/08/87	10.50	1	3.42	0
02/09/87	5.00	2	0	0
02/10/87	5.86	1	4.89	0
02/11/87	7.56	2	3.39	0
02/12/87	8.74	2	1.64	0
02/13/87	10.86	3	2.31	0
02/14/87	10.42	0	3.75	0
02/15/87	9.83	0	.75	0
02/16/87	9.75	1	4.75	0
02/17/87	7.00	2	5.00	0
02/18/87	8.00	2	4.16	0
02/19/87	10.33	2	1.00	0
02/20/87	9.80	2	3.87	0
02/21/87	10.55	5	4.62	0
02/22/87	10.86	3	1.14	0
02/23/87	11.13	13	4.37	0
02/24/87	10.13	0	4.37	0
02/25/87	10.00	3	2.75	0
02/26/87	5.50	0	0	0
02/27/87	8.00	2	0	0
02/28/87	10.08	2	2.50	0
03/01/87	10.54	7	3.69	0
03/02/87	10.73	6	4.52	0

Table 9.--Continued

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
03/03/87	10.43	7	4.57	0
03/04/87	11.00	2	3.50	1
03/05/87	11.00	5	.50	0
03/06/87	11.18	5	2.72	0
03/07/87	11.50	11	4.00	0
03/08/87	11.50	5	4.50	0
03/09/87	11.50	5	4.50	0
03/10/87	11.00	6	4.25	0
03/11/87	10.00	4	3.50	0
03/12/87	11.65	11	1.85	0
03/13/87	8.00	10	0	0
03/14/87	11.40	4	4.35	0
03/15/87	11.40	3	4.35	0
03/16/87	11.40	10	4.02	0
03/17/87	7.67	3	0	0
03/18/87	8.00	2	0	0
03/19/87	9.25	2	0	0
03/20/87	11.00	4	0	0
03/21/87	11.65	4	2.10	0
03/22/87	10.07	3	4.10	0
03/23/87	7.90	4	3.10	0
03/24/87	10.57	2	1.60	0
03/31/87	11.95	7	0	0
04/01/87	12.11	2	.67	0
04/02/87	8.25	1	0	0
04/03/87	11.26	0	.41	0
04/04/87	11.67	7	0	0
04/05/87	11.25	1	.25	0
04/06/87	11.33	3	.25	0
04/07/87	11.05	2	0	0
04/08/87	7.50	6	0	0
04/09/87	5.94	2	0	0
04/10/87	8.00	3	0	0
04/11/87	13.00	5	0	0
04/12/87	12.25	2	0	0
04/13/87	12.16	6	0	0
04/14/87	10.50	2	0	0
04/15/87	10.25	1	0	0
04/16/87	1.25	0	0	0
04/17/87	10.50	7	0	0
04/18/87	8.65	5	0	0
04/19/87	10.58	3	0	0
04/20/87	12.67	6	.5	0
04/21/87	12.30	4	.5	0

Table 9.--Continued

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
04/22/87	9.33	8	0	0
04/23/24	13.50	2	0	0
04/24/87	6.87	0	0	0
04/25/87	10.50	1	0	0
04/26/87	12.12	2	0	0
04/27/87	9.03	0	0	0
04/28/87	11.00	1	0	0
04/29/87	11.00	4	0	0
04/30/24	13.75	0	2.25	0
	921.76	336	198.91	7

Daylight predation rate = 336/921.76 = .36452 x 12.62990* = 4.60

Darkness predation rate = 7/198.91 = .0351917 x 11.37* = .40

24 hour estimated predation rate = 4.60 + .40 = 5.0 fish per day

* Indicates the average number of actual daylight or darkness hours during the period.

Table 10.--Inner Bay steelhead kill rates during period of capture attempts with nets in and out (January 20-26 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
01/20/87	7.50	0	0	0
01/21/87	7.75	0	.5	0
01/22/87	6.75	0	0	0
01/23/87	9.33	5	4.67	1
01/24/87	8.75	2	6.0	0
01/25/87	10.00	0	4.59	0
01/26/87	8.5	12	0	0
	58.58	19	15.76	1

Daylight predation rate = 19/58.58 = .3243427 x 10.26* = 3.33

Darkness predation rate = 1/15.76 = .0634517 x 13.74* = .872

24 hour predation rate = 3.33 + .87 = 4.20 fish per day

* The average number of actual daylight and darkness hours over the period.

(March Non-Harassment Period). Harassment of sea lions was halted during a six day period from 25-30 March in order to evaluate the effectiveness of the harassment program. Predation rates and numbers of sea lions during this period were compared to data from a week before and after to evaluate thether they were significantly different. The predation rate during this period was 9.24 fish per day (Table 11).

(Total Inner Bay Losses). The total number of steelhead lost to sea lion predation in the inner Ship Canal was estimated by multiplying the dix daily predation rates by the number of days within that time frame and then addtion them together. It was estimated that 1,000 steelhead were predated by sea lions in the inner bay for the 160 day period (Table 12). Confidence

Table 11.--Inner Bay non-harassment steelhead kill rates, with nets in (March 25 - 30 1987)

Date	Observed Hours-Light	Kills	Observed Hours-Dark	Kills
03/25/87	8.00	4	0	0
03/26/87	9.92	2	.17	0
03/27/87	8.00	5	0	0
03/28/87	9.97	11	0	0
03/29/87	10.00	13	0	0
03/30/87	10.00	3	0	0
	55.89	38	.17	0

Daylight predation rate = 38/55.89 = .6799069 x 13.59* = 9.24

Darkness predation rate = 0/.17 = 0

24 hour predation rate = 9.24 + 0 = 9.24 fish per day

* 13.59 = The average number of daylight hours during this period.

Table 12.--Predation rates during daylight and darkness at the Chittenden Locks, Inner Bay area and Estimated Total Seasonal Fish Losses 1986-1987.

Period	Predation Rates Light	Dark	Total	X Days	Fish Lost
P Net 1	3.15	0	3.15	21.5	68
P Net 2	15.30	0	15.30	23.5	360
H Net 1	1.74	.573	2.31	8.5	20
H Net 2	4.60	.400	5.00	93.5	468
Capture	3.33	.872	4.20	7	29
No-Harr	9.24	0	9.24	6	55
				160	1000

intervals were determined for the total estimated fish losses in the inner Ship Canal area using two methods; the t-interval based on the parametric t-distribution and the W-interval, a non-parametric analogue derived from the Wilcoxon statistic. The 95% confidence intervals for the t-interval were 619-1319 fish lost and 563-1239 fish lost for the W-interval.

Predation Rate Comparison - Preharassment to Harassment

The observed fish losses due to sea lion predation were considerably lower during the harassment phase than during the preharassment phase. The 24-hour rate when nets were out dropped from 15.3 fish per day during the preharassment period to 5.0 fish per day once harassment began. This resulted in a 67% reduction in observed predation rates. The 24-hour rates for periods when nets were set in the outer bay also dropped considerably once harassment began. The rates dropped about 48% from 3.15 fish per day to 1.74 from preharassment to harassment.

Although the harassment program resulted in a 67% reduction in observed predation rates during this season it was considerably less effective than last season when the rates dropped about 97% (Gearin et al. 1986). Overall then, the harassment program was about 30% less effective this season than last in reducing predation. We suspect that if a similar harassment program were conducted during 1987-88 it would become increasingly less effective due to apparent rapid habituation by sea lions.

We made comparisons of the six predation rate periods to determine if significant differences existed. The Mann-Whitney test was utilized to evaluate differences in mean hourly predation rates between periods. The results of these tests revealed some significant differences. For example, there was a significant difference ($p = 0.005$) between the two periods

during preharassment when nets were in (PNET1) and out (PNET2) of the water. Mean hourly predation rates were about five times greater in the inner bay when gillnets were not set in the outer bay. There was also a significant difference ($p = 0.0007$) between the predation rates before and during harassment (a 67% decline) when the nets were out of the water. There was also a significant difference ($p = 0.051$) in predation rates between the period during harassment when nets were in and out of the water.

There was no significant difference between rates during netting either before or during harassment which indicates that net presence is the critical factor influencing inner bay predation rates regardless of whether harassment is utilized or not. We compared predation rates using the Mann-Whitney test of the period in late March when harassment was halted for six days. The observed predation rate increased about 54% when harassment was halted. There was a significant difference ($p = 0.053$) between the harassment period when nets were not set and this 6 day period when no harassment was utilized. We compared rates both 6 days before and after this period and found no differences in rates from 6 days before but significant differences at $p = 0.065$ for the 6 day period after harassment was halted. We can draw three major conclusions based on these statistical tests:

1. Rates of predation were significantly less during the harassment period as long as nets were not set in the outer bay.
2. If nets were set in the outer bay, there were no significant differences in predation rates in the inner bay during preharassment or harassment.

3. When harassment was halted for a six day period in March the predation rates increased dramatically and were significantly greater than during the harassment period as a whole.

Predation Rates - Outer Ship Canal

We made observations of sea lions taking steelhead in the outer Ship Canal Bay on 14 days in January, 1987 (Table 13). Most "kills" recorded while nets were in were caught fish depredated from the gillnets but a small proportion were probably free swimming fish. Steelhead losses when nets were set occurred an average of 2.16 times per hour, versus 0.68 times per hour when nets were not set (Table 14).

Data in Table 14 were adjusted to account for the fact that the sea lions were effective at capturing steelhead during all hours of daylight, not simply those which we surveyed. (They also were seen taking fish from set nets during hours of darkness, but we did not have adequate data to quantify their overall nighttime success). The adjusted daylight predation rate based on surveys during hours of daylight was 2.32 steelhead per hour when nets were present versus 0.72 fish per hour when nets were absent.

The mean steelhead predation rate was significantly different during netting and non-netting periods. The rate was 3.24 times higher during periods of netting than when nets were absent. The 95% confidence intervals for the estimated mean predation rate during netting and non-netting periods do not overlap (0.18-1.16 versus 1.31-2.92), indicating that the means are significantly different (Table 15).

Table 13. Observer coverage, total daily survey hours, maximum daily sea lion count, and number of steelhead killed per day, Outer Ship Canal Bay, January 7 - 30, 1987.

Date	Survey Period Start	End	Total Hours	Maximum # of Lions	# of Steelhead Killed
01/07/86	0811	0902	0.85	3	1
01/07/86	1226	1645	4.32	3	12
01/08/86	0640	1718	10.63	3	17
01/09/86	0612	1327	7.25	3	17
01/11/86	0645	1647	10.03	5	2
01/12/86	0740	1715	9.58	4	26
01/13/86	1530	1620	0.83	3	1
01/15/86	1055	1125	0.50	0	1
01/15/86	1615	1700	0.75	6	1
01/16/86	0600	1030	4.50	5	5
01/22/86	0745	1700	9.25	5	24
01/23/86	0830	1215	3.75	5	0
01/27/86	1025	1615	5.83	4	10
01/28/86	1048	1620	5.53	4	7
01/29/86	0620	1705	10.75	3	16
01/30/86	0600	1721	11.35	5	10
		Total	95.70	Mean 4.14	150
				n 14	

Table 14. Steelhead takes, kill rates, and surveys hours, Outer Ship Canal Bay, 1987.

Date Observed	Absolute No. of S'head Takes	Survey Hours On Date	Takes Per Survey Hour	Surveyed Net-Hours	Surveyed Non-net Hours	"Non-net" Kills Observed	"Net" Kills
01/07/87	13	5.17	2.51	5.17	0.00	0	13
01/08/87	17	10.63	1.60	10.63	0.00	0	17
01/09/87	17	7.25	2.34	4.80	2.45	0	15
01/10/87						0	0
01/11/87	2	10.03	0.20	0.00	10.03	2	0
01/12/87	26	9.58	2.71	5.75	3.83	2	24
01/13/87	1	0.83	1.20	0.83	0.00	0	1
01/14/87						0	0
01/15/87	2	1.25	1.60	1.25	0.00	0	2
01/16/87	5	4.50	1.11	4.50	0.00	0	5
01/17/87						0	0
01/18/87						0	0
01/19/87						0	0
01/20/87						0	0
01/21/87						0	0
01/22/87	24	9.25	2.59	9.25	0.00	0	24
01/23/87	0	3.75	0.00	2.75	1.00	0	0
01/24/87						0	0
01/25/87						0	0
01/26/87						0	0
01/27/87	10	5.83	1.72	0.00	5.83	10	0
01/28/87	7	5.53	1.27	0.00	5.53	7	0
01/29/87	16	10.75	1.49	6.08	4.67	2	14
01/30/87	10	11.35	0.88	6.50	4.85	1	9
		Totals		57.51	38.19	26	124

Takes per surveyed netted hour: 2.16

Takes per surveyed non-netted hour: 0.68 (1:3.166)

Note: these factors vary slightly from those in Table 15 which are based on daylight hours only.

Table 15. 1987 outer Ship Canal Bay kill and gear-hour statistics for calculation of kill rate variances and limits (all survey dates).

Date	Netted?	Netted Survey Hours	Kills	Kills per Hour	Non-net Surveys Hours	Kills	Kills per Hour
01/07/86	Y	5.17	13				
01/08/86	Y	9.73	17	1.75			
01/09/86	Y	3.78	15	3.97	2.21	2	0.90
01/11/86	N				9.33	2	0.21
01/12/86	Y	5.75	24	4.17	3.83	2	0.52
01/13/86	Y	0.83	1	1.20			
01/15/86	Y	1.25	2	1.60			
01/16/86	Y	3.25	5	1.54			
01/22/86	Y	9.25	24	2.59			
01/23/86	Y	2.75	0	0.00	1.00	0	0.00
01/27/86	N				5.83	10	1.72
01/28/86	N				5.53	7	1.27
01/29/86	Y	6.33	14	2.21	3.75	2	0.53
01/30/86	Y	5.33	9	1.69	4.85	1	0.21
			n:	11		n:	8
			sample var.:	1.428		sample var.:	0.347
			mean:	2.112*		mean:	0.670*
			95% CI:	1.31-2.92		95% CI:	0.18-1.16

* vary slightly from Table 14 due to rounding error; kills and net-hours are the same.

Steelhead Losses-Outer Ship Canal Bay

The day lengths plus hours nets were set and absent were used to estimate the number of steelhead taken daily by sea lions in the outer bay based upon the January sample. We recognize the problems in estimating a full season fish loss based upon a limited mid-season sample, but did so because these were the only data available to evaluate the potential importance of outer bay predation to management of this run. An estimated

626 steelhead were killed by sea lions during periods of netting (38 days), and 978 during periods when nets were absent (108 days). Winter-run steelhead returning to the Lake Washington system were sampled for scales in the tribal net fishery (during landings) and in the Chittenden Locks fishway. Scale collection data from 1987 and past years were used to determine the hatchery and wild proportions of the returning run on a bi-weekly basis (Table 16). We could not collect significant numbers of steelhead from the fishway after the first week in February thus, scale data from earlier years were used for the period following statistical week 7. The "hatchery fraction" and "wild fraction" are based on the scale data. Of the estimated 1,604 steelhead taken by sea lions in the outer bay from 1 December 1986 through 25 April 1987, an estimated 807 were of hatchery origin, and 797 were wild (Appendix 5).

Total Steelhead Losses (Inner and Outer Bays)

The total number of fish which were lost to sea lions during the season for both the inner and outer Ship Canal Bays was estimated to be 2,604 fish (1,000 Inner Bay and 1,604 Outer Bay). The total run size was estimated to be 6,018 fish of which 2,969 were wild and 3,049 were hatchery. The sea lions, therefore, accounted for taking 43.2% of the entire run or 42% of the wild stock and 44% of the hatchery stock.

Fish Savings

It was estimated that the harassment program contributed to a savings of 1,084 steelhead of both hatchery and wild origin during the season of which about 531 were wild. This estimate was derived by taking the difference in

Table 16. Sample sizes and scale data results used to estimate total losses of hatchery and wild steelhead to sea lion predation in the Lake Washington Ship Canal 1987.

Statistical Week	Date	Hatchery Fraction	Wild Fraction	Sample Size (Fish)	Hatchery Fraction	Wild Fraction	Sample Size (Years)	Sample Size (Fish)
49	(12/1-6)	.750	.250	4				
50	(7-13)	1.000	0.000	32				
51	(14-20)	.750	.250	28				
52	(21-27)	.775	.225					
53/1	(28-1/3)	.800	.200	15				
2	(1/4-10)	.656	.344	64				
3	(11-17)	.833	.167	18				
4	(18-24)	.613	.387					
5	(25-31)	.393	.607	28				
6	(2/1-7)	.343	.657					
7	(8-14)	.293	.707	41				
8	(15-21)				.483	.517	*	(0)
9	(22-28)				.672	.328	4	101
10	(3/1-7)				.404	.596	*	(0)
11	(8-14)				.136	.864	1	22
13	(22-28)				.257	.743	*	(0)
14	(3/29-4/4)				0.000	1.000		(0)
15	(5-11)				0.000	1.000		(0)
16	(12-18)				0.000	1.000		(0)
17	(19-25)				0.000	1.000		(0)
18	(4/26-5/2)				0.000	1.000		(0)

* Interpolated values based on 100% wild component by 1 April.

observed fish kills from the preharassment to the harassment period and multiplying the number of days within each time period respectively. For example, during the period when nets were not set in the outer bay the rates dropped from 15.3 to 5.0 fish per day for an average savings of 10.3 fish per day. Since 10.3 fish per day were saved for 93.5 days during the harassment period then we estimate that 963 fish were saved during this time (Table 9).

An additional 7 fish were estimated to be saved during an 8.5 day period during harassment when gill nets were set in the outer bay and 114 were saved during the capture period and when harassment was halted in March.

Estimated Losses Without Harassment

We estimated the number of steelhead which would have been predated by sea lions if no harassment would have been used for the entire season. This estimate was derived by extrapolating from the observed rates of the preharassment period. We estimated that 2,084 fish would have been lost from 6 January to 30 April had no harassment been utilized. The wild run would have been about 60% under the escapement goal had no harassment been employed (see escapement).

Sport and Tribal Harvest

The combined sport and tribal catch was 2,244 fish including 1,469 by the tribes and 775 by the sport fishery. The combined total accounted for 1,701 hatchery and 543 wild fish.

Wild Steelhead Escapement

The 1986-87 wild steelhead escapement was estimated to be 1,172 fish. This figure is about 27% short of the agreed goal of 1,600 fish. The Deparment of Wildlife and Muckleshoot and Suquamish tribes set the 1,600 figure in the early 1980's as the minimum number of fish required to ensure survival of the wild run year class. If no harassment had been utilized at the Locks this season, an additional 531 wild fish would have been lost which would have resulted in a 60% shortfall in escapement.

Alternative Control Methods

Capture Attempts

Attempts were made to capture sea lions at the Locks using a nylon twine gillnet which was deployed in front of the spillway dam. Animals captured in this manner were to be transported to California to evaluate whether relocation of sea lions would reduce steelhead predation at the Locks. The net was first deployed on 20 January at 1015 hrs when one sea lion was feeding in front of the spillway. When the net was set, several firecrackers were thrown behind the animal to push it towards the net. The animal escaped after several minutes, apparently going under the net which was not quite long enough to reach the bottom. The net was then pulled and no further attempts were made that day. The net was then modified to increase the depth.

On 21 January another attempt was made to capture a sea lion with the modified net. The net was deployed at 1150 hrs as one sea lion was foraging near the spillway. The animal escaped within several minutes apparently going under the net or along the side. No further attempts were made on the 21st because the animals did not return to the spillway area.

One more attempt was made to capture sea lions on 26 January. The net was deployed at 0915 hrs as an animal was feeding near the spillway. The animal was chased into the net with firecrackers and actually hit the net but did not become entangled. The animal then scanned the net, moving alongside checking for an exit, and after several minutes leaped over the corkline and escaped. No further attempts were made to capture sea lions at the Locks during 1987 due to prohibitive costs and negative publicity. We conclude

that net captures at the Ballard Locks are probably not an effective method for capturing sea lions in this area primarily due to the extreme costs involved in mobilizing personnel and equipment.

Ballistics Tests

Using a 12-gauge shotgun we fired 5 test shots at Calligan Lake from ranges of 7 to 25 m at a white paper target in order to evaluate accuracy and spread pattern. Another 6 shots were fired at varying angles off the water with a wooden cabin in the background to evaluate ricochet potential. The 5 shots at the target indicated that the spread pattern of the rubber pellets (17 per round) were too wide to be effective at distances exceeding 15 m. Shots fired from distances of 7 to 13 m, however, exhibited tight spread patterns which would probably be effective to sting sea lions.

The six shots fired to deflect off the water indicated that at most angles except for straight down that some ricochet did occur. Most ricochets were noted on shots fired from water level in a small boat from distances of 9 to 13 m against the wooden cabin backdrop.

We later fired 10 rounds at varying angles and distances at a dead sea lion on a beach on Whidbey Island to evaluate force of impact and penetration. These tests indicated that penetration did not occur unless fired at distances of less than 3 m and even then was only superficial and did not penetrate into the blubber or muscle layers.

We conclude based on these tests that rubber buckshot could probably be used safely and effectively at the Locks or the Ship Canal area to chase away sea lions if fired at angles of 25° or greater and from distances of between 5 to 15 m.

Although extensive tests were not conducted to evaluate the potential of injury to sea lions from rubber buckshot, we believe that there is only a slight chance of injury or penetration of the hide if fired from ranges of greater than 5 m.

We have not tested the ballistic parameters of rubber bullets, however, the Game Stinger, a 12 gauge rubber bullet shows promise as a non-lethal, and low injury potential product. Game Stingers have been tested on walrus (Odobenus rosmarus), California sea lions, and bears (Ursus sp.), with good results and are not known to ricochet off the water (Butler, pers comm.).[3]

Taste Aversion Conditioning

Sea lions readily took freshly killed steelhead tethered in the current below the spillways. In most cases they brought the fish to the surface and ingested the fish almost immediately, but if the sea lion broke the monofilament tether so that some remained hanging from the fishes head the sea lion appeared to reject the fish, surfacing with nothing. Fish treated with lithium chloride (LiCl) were deployed between 24 December and 2 January (Table 17). Four animals were successfully treated and were observed eating the entire treated fish at the surface of the water. A fifth animal may have received treatment but may have avoided the capsules containing the LiCl as he tore the fish into pieces and ingested the chunks. The primary predators known as Humpback and Thrasher were treated on 28 December. Within an hour following treatment both animals were downstream of their normal foraging areas. They spent longer than normal periods at the surface and exhibited what appeared to be labored breathing. The only evidence of the animals

[3]Mr. Butler, Mountain Scent Research, Box 545, Stevensville, MT. Pers. Commun. Mar, 1987.

Table 17. Steelhead predated by known California sea lions prior to, during and after taste aversion treatments (*) with dead steelhead containing lithium chloride, Chittenden Locks, 1986-1987.

Date	Hours	Fishery	Animal identity			
			Thrasher	Humpback	Pox	Unknown
19 Dec	6.5	Nets out		8		5
20 Dec	7.0	Nets out	7	8		4
21 Dec	3.0	Nets out	6	5		
22 Dec	No Effort					
23 Dec	2.3	Nets in (out at 1130 hr)				3
24 Dec	4.0	Nets out (LiCl)	2			10
25 Dec	(No Effort)					
26 Dec		Nets out	9			10*
27 Dec	2.0	Nets out	1			
28 Dec	4.0	Nets out	1*	1*		*
29 Dec		Nets in at 1338	1			1
30 Dec	2.0	Nets in	1			
31 Dec	5.5	Nets out	1	1		1
1 Jan						
2 Jan	6.8	Nets out	p a	p a	1	6
3 Jan	9.5	Nets out	3	3		10
4 Jan	4.5	Nets in 1130 hr.	p	3	1	
5 Jan		Nets in	1	2		1
6 Jan	Begin harassment					

* Animal treated with LiCl

a Treated fish presented to this animal but it would not take fish

becoming sick occurred when several gulls circled over one of the animals which had just surfaced and picked at the surface of the water. Both animals had returned to their foraging areas within 2 hours after treatment and exhibited normal diving behavior. Both animals were observed to predate one fish during the afternoon of the day of treatment.

Subsequent efforts to get the two identifiable animals to take an additional treated fish failed. Thrasher's behavior around the treated fish could not be observed as his foraging area was in turbulent water. Humpback was observed to swim past the tethered fish several times, and each time he surfaced near the fish he looked away from the fish, without diverting from his apparent intended course. It was unclear whether the conditioned aversion was only to dead steelhead on a tether or whether a partial taste aversion to steelhead had been achieved. Numbers of fish taken by Thrasher and Humpback declined following treatment (Table 17), but both animals resumed active predation 5 days after their first and only treatment. During the period when Humpback and Thrasher were not predating significant numbers of fish following their first treatment with LiCl they remained in their foraging areas and actively dove. Their diving activity in proximity to the entrance of the fish ladder precluded fish from entering the fish ladder.

Experimental studies in captivity have shown that individual animals have to be treated at least twice in order to condition a lasting taste aversion (Kuljis 1986). We were unable, however, to get treated animals to take a second treated fish. Had we been successful in conditioning a lasting taste aversion, the sea lions still may have continued to dive and swim near the entrance of the fish ladder. Under that condition we would not have, therefore, expected to see steelhead enter and pass the fish ladder. Yet it is probable that a sea lion which had a complete taste aversion to steelhead might abandon its accustomed foraging area around the Locks and return to Puget Sound where it would feed on the normally preferred diet of bottom fish and squid.

Costs of the 1986-87 Control Program

The direct costs of the 1986-87 program were determined and a cost: benefit ratio was derived based on the dollar value of fishery-caught and predated steelhead. The costs (Table 18) reported here do not include administrative costs or salaries of personnel who participated in the capture attempts.

Table 19 illustrates the manner in which we estimated the number of steelhead saved by our harassment program in 1986-87. It is simply a subtraction of the estimated losses with harassment from the estimated losses assuming no harassment. The 1986-87 project saved an estimated 1,085 steelhead (both races combined). The cost:benefit ratio was derived by determining the total value of both sport and commercially caught steelhead (Table 19). The total cost for the 1986-87 program was $45,910 and the total value of fishery-caught fish was $58,677, thus the cost to benefit ratio was .78 to 1. The C:B ratio has fallen dramatically since the 1985-86 season when it was at least 1 to 4 (Gearin et al. 1986). It is clear that there can be no justification for present expenditures to save fish for the commercial fishery. At the same time, the cost of effective control is nearing the sport value of the fish saved (assuming only half of the fish saved are available to the sport fishery).

Table 18. Costs of the 1986-87 Control Program

Salaries and Overhead

	Time (mos)	Cost ($)
Area Fishery Biologist	3.36[a]	11,853
WDW Marine Mammal Biologist	0.75	2,646
Lead Field Biologist	9.00	15,660
Technical Aides	7.73	11,869
Typist	1.00	1,209
	Total:	$43,237

Equipment

Item	Cost ($)
Seal bombs (10 cases; 6480 pieces)	2,266
Raingear	60
Notebooks	15
Photographic film and mailers	25
Gas, oil, and boat maintenance	307
	2,673

Costs Summary

Salaries & Overhead	Contributor	% of total Project Costs
$23,743	WDW	51.7
16,869	NMFS	36.7
2,626	Tribes	5.7
Equipment		
$ 2,673	WDW	5.8
Total $45,910[b]		99.9

[a] There was no requirement for any of this time prior to 1985 and the onset of the marine mammal problem. Resolution of the problem would free up this time for application to other WDW program areas.

[b] These figures do not include the salaries and overhead value of time contributed by Army Corps of Engineers staff, other NMFS staff, other WDW staff, and outside veterinary expertise called in to assist in the capture attempts and taste aversion experiment.

Table 19. Estimated number of steelhead saved by the 86-87 control program.

	Period	# Days	Kills/d	Total Kills
	H Net 1	8.5	2.31	20
January thru April	H Net 2	93.5	5.00	468
Predation Losses	Capture	7.0	4.21	29
with harassment	No-Harr	6.0	9.24	55
				572
January thru April	H Net 1	8.5	3.15	27
Predation Losses	H Net 2	93.5	15.30	1,431
with harassment	Capture	7.0	15.30	107
	No-Harr	6.0	15.30	92
				1,657

January through April savings = 1,657 - 572 = 1,085

A commercially-caught steelhead was worth an average of $14.16 during the 1985-86 season (Bill Taylor, WDW, pers. comm.)[4]. The value in 1986-87 was not appreciably different. The value of a sport-caught steelhead is about $94 (Gearin et al. 1986). Based on these values, the following cost:benefit ratios can be calculated.

Cost:Benefits:	# fish saved	Commercial value	Sport value	C:B ratios
Total 1986-1987 Cost: $45,910	1085	$7,682[a]	$50,995[a]	0.78:1

[a] Assumes the 1085 are apportioned equally to each fishery.

[4]Bill Taylor, WDW, Oly, WA. Pers. Commun, May, 1986.

Sea Lion Behavior and Biology

Locks - Ship Canal Vicinity

The region near the Locks-Ship Canal area was surveyed frequently by boat throughout the season to record the distribution, numbers of and behavior of sea lions in this vicinity. The numbers of sea lions in this area ranged from 1 to 12 in December, January and February, and then increased dramatically in mid-March (Table 20). The numbers of sea lions from mid-March to early May in this area ranged from 4 to 137 animals with a mean of 44 per day (Table 20).

Sea lions utilize at least five haul out sites in this area including; two buoys at West Point and Meadow Point, the Shilshole Bay bell buoy, the Shilshole jetty barge raft and the S.H. buoy between West Point and Skiff Point (Bainbridge Island).

Sea lions were observed foraging at Shilshole Bay on small unidentifiable prey, possibly herring and squid. Some free swimming steelhead were also observed taken in this area over the shoals at the mouth of the Ship Canal.

Elliott Bay and Vicinity

Three boat surveys were conducted in Elliott Bay and on the east and west channels of the Duwamish waterway. The maximum number observed was 12. Sea lions were observed off Duwamish Head, the east and west channels of the Duwamish Waterway and along the shore of Elliott Bay. No haul out sites were observed in this area. Sea lions did not congregate in the Elliott Bay vicinity in large numbers in 1986-87 as they did during the previous season in 1985-86 when more than 180 were observed there (Gearin et al. 1986).

Table 20. Surveys and censuses of sea lions in the vicinity of the Chittenden Locks, 4 December 1986 - 28 May 1987.

Date	West Pt.	Shilshole	Meadow Pt.	Ship Canal[a]	Total
12/4/86	-	1	0	3	4
12/8/86	0	1	1	1	3
12/9/86	0	0	0	2	2
12/10/86	-	1	0	1	2
12/11/86	-	-	-	3	3
12/13/86	-	-	-	7	7
12/15/86	-	4	-	6	10
12/23/86	-	-	-	6	6
12/24/86	-	1	0	4	5
1/7/87	1	1	0	6	8
1/11/87	-	1	0	4	5
1/12/87	-	1	0	5	6
1/15/87	-	2	0	10	12
1/16/87	0	2	1	4	7
1/17/87	-	2	0	2	4
1/22/87	-	1	1	5	7
1/23/87	0	0	1	6	7
1/24/87	4	0	0	7	11
1/25/87	-	1	-	4	5
1/30/87	0	0	0	3	3
2/3/87	0	0	0	1	1
2/5/87	0	1	1	2	4
2/6/87	-	0	1	1	2
2/7/87	0	1	1	1	3
2/8/87	1	1	0	1	3
2/9/87	0	1	0	1	2
2/10/87	-	0	3	1	4
2/12/87	0	1	1	1	3
2/14/87	0	1	0	1	2
2/15/87	0	1	0	1	2
2/20/87	0	2	-	2	4
2/21/87	0	1	0	1	2
2/25/87	0	2	0	2	4
2/26/87	-	2	0	0	2
2/28/87	2	3	1	0	6
3/1/87	1	1	0	2	4
3/6/87	0	2	0	1	3
3/10/87	-	0	-	4	4
3/15/87	0	0	0	5	5
3/22/87	2	9	0	3	14
3/24/87	0	7	1	2	10
3/25/87	-	13	1	5	19
3/26/87	0	3	1	6	10
3/28/87	0	11	0	5	16

Table 20.--Continued

Date	West Pt.	Shilshole	Meadow Pt.	Ship Canal	Total
3/29/87	3	50	1	4	58
3/30/87	-	70	1	6	77
3/31/87	-	84	1	10	95
4/1/87	-	57	0	2	59
4/2/87	-	33	14	18	65
4/3/87	-	23	0	2	25
4/4/87	1	33	2	0	36
4/5/87	-	32	3	0	35
4/6/87	10	29	1	2	42
4/7/87	-	18	0	2	20
4/9/87	-	10	1	2	13
4/12/87	2	1	0	1	4
4/13/87	1	10	1	2	14
*4/17/87	2	70	1	1	74
4/18/87	1	39	1	2	43
4/19/87	1	133	1	2	137
4/20/87	1	50	7	2	60
4/21/87	-	38	0	1	39
4/23/87	-	24	1	1	26
4/24/87	1	11	45	3	60
4/26/87	-	14	0	0	14
4/27/87	5	48	43	0	96
4/28/87	3	48	0	1	52
5/4/87	3	37	0	1	41
5/5/87	-	52	1	2	55
5/24/87	0	5	0	0	5
5/28/87	0	1	0	0	1

	Max. Count	Mean Count
December	10	4.66
January	12	6.81
February	6	2.93
March	95	26.20
April	137	45.70
May	55	25.50

* Aerial survey
A dash line indicates site was not surveyed.

[a] Includes the area from the spillway dam west to the entrance of the Ship Canal.

Everett and Vicinity

Sea lion aggregations have been observed in Port Gardner, Everett from December through May since at least 1979 (Everitt et al., 1979, 1980; Gearin et al. 1986). Three boat and three aerial surveys were conducted near Everett in 1987 to record numbers of animals and to collect scat. The sea lions used numerous buoys, barges, and log rafts as haul out sites. The boat and aerial censuses conducted in 1987 indicate that peak sea lions counts for this year were in mid-April when at least 376 were counted (Table 21).

Lakes and Rivers

Sea lions were known to have passed through the Locks on numerous occasions during the season. In late February 1987, we began receiving reports of sea lions in Lake Union and Lake Washington. These reports persisted through the month of April and indicated that at least two to three sea lions were in the lakes. One Zalophus was observed on 9 April in Lake Washington near the NOAA complex by the senior author. Sea lions were sighted frequently in Lake Union and the fresh water side of the Ship Canal by personnel of the Locks and this project. We have individually witnessed sea lions swimming back and forth from the fresh to salt water sides of the Locks several times during this season. Although we have not witnessed sea lions feeding in the upper Lakes, several unconfirmed reports indicate that they may be feeding near the tributaries which flow into Lake Washington. Our observations indicate that a few sea lions appear to spend considerable time in the fresh water side of the Ship Canal and the upper lakes.

Table 21.--Boat and aerial censuses of California sea lions near Everett, Washington during 1987.

	Land	Water	Total
27 February	2	94	96
*20 March	9	203	212
27 March	3	299	302
*17 April	277	99	376
*8 May	1	41	42
19 May	66	0	66

* Aerial surveys

Observations on the distribution of Zalophus indicate that they are found throughout the inland and coastal waters of Washington State and also in many of the fresh water lakes and rivers. Although a few animals may remain here year round, the majority are present from early October until the end of May.

Aerial Survey

An aerial survey was flown on 17 April 1987 in Puget Sound, the Strait of Juan de Fuca and the outer Washington coast to record distribution and abundance of California sea lions (Figure 5).

A total of 650 Zalophus were observed in Puget Sound at 30 different locations, including 18 separate haul out sites (Table 22). An additional 50 Zalophus were observed at Race Rocks, B.C. in the north central Strait of Juan de Fuca and 33 were sighted at 2 locations along the outer Washington coast (Table 22).

Table 22.--Counts of California sea lions from an aerial survey of Puget Sound, April 17, 1987. Strait of Juan de Fuca and outer coast counts are included.

Location	Hauled Out	Water	Total
Nisqually Buoy	1	-	1
Fox Island-Acoustic Range	1	1	2
Fox Island-Barge Buoy	3	-	3
Toliva Shoals Buoy	1	-	1
Yellow Buoy	1	-	1
Lakota Raft	10	23	33
Saltwater Park	-	2	2
Three Tree Point Buoy	1	2	3
Elliott Bay-Pier 65	-	1	1
Four Mile Rock	-	1	1
West Point Buoy	1	-	1
S.H. Buoy	1	-	1
Shilshole Bay	-	11	11
Shilshole Bell Buoy	1	-	1
Shilshole Jetty Raft	21	37	58
Meadow Point Buoy	1	-	1
Richmond Beach	-	8	8
Edmonds Wreck Raft	2	82	84
Meadowdale	-	6	6
So. Picnic Point	-	48	48
No. Picnic Point	-	4	4
Everett Log Rafts	274	18	292
Log Buoy	1	-	1
Jetty	-	47	47
Yellow Buoy	1	1	2
Black Buoy	1	10	11
Port Susan	-	23	23
Camano Head	-	1	1
Clinton	-	1	1
Possession Point Buoy	1	-	1
TOTAL	323	327	650
Race Rocks	36	14	50
Carrol Island	30	-	30
Giants Graveyard		3	3
TOTAL	66	17	83

The total of 650 is about 36% less than the 1,015 Zalophus counted the previous year in April 1986 in Puget Sound. We are not convinced, however, that overall Zalophus numbers in Puget Sound were significantly less this year than last for several reasons; animals were more dispersed in 1987 than in 1986 when 734 Zalophus were observed in one group near Everett. The oil rig Sedco 708 which appeared to attract sea lions as a haul out and rafting site was removed in 1987. Sea lions were much less dispersed in area in 1986 and were observed at only 11 locations as opposed to 30 in 1987. The chance of seeing smaller groups of Zalophus is less if they are more spread out. The 1987 survey was also flown later in the year by 16 days which may have affected their overall distribution and numbers.

Haul Out Sites

Puget Sound

Sea lions were observed hauled out at 18 different locations during the 1987 survey as opposed to 4 locations in 1986 (Table 22). All of the locations at which sea lions were observed hauled out in Puget Sound are on man made objects which were either stationary (channel buoys, barges, barge buoys, rafts) or temporary (log booms, barge buoys). The largest single haul out group observed was on log rafts anchored off the Everett jetty where 274 Zalophus were counted. Other locations where more than 20 Zalophus were observed hauled out were on the Everett barges and the Shilshole barge raft off Shilshole jetty.

Outer Coast and Strait of Juan de Fuca

Race Rocks, a group of about six small islets close to Victoria, B.C., is a haul out site used consistently by California and northern sea lions,

Eumetopias jubatus. Numbers of Zalophus which utilize Race Rocks varies by season. Race Rocks appears to be used primarily as a staging-resting or a stopover site during sea lion movements north or south to or from California.

Carroll Island, which is located on the outer Washington coast, is used as a haul out-resting site by Zalophus as they move north or south along the coast during their seasonal migration. Numerous other coastal islets and rocks are utilized by Zalophus for the same purposes including Sea Lion Rock, Split and Willoby Rock, and Tatoosh Island.

Sea Lion Food Habits in Puget Sound

1986 Amended Food Habits

In 1986 we reported on the food habits of sea lions based on analysis of scat and spewing samples collected primarily from Port Gardner, near Everett Washington (Gearin et al. 1986). In this report, we will amend Table 4.17 presented in Gearin et al. 1986 and also summarize our findings for the 1987 season. We have amended the 1986 information because of improvements in methodology incorporated in 1987 which enables us to identify previously unrecorded prey by utilizing vertebral characteristics to denote prey. Prior to 1987, prey were identified solely by identification of fish otoliths, cephalopod beaks, or from the mouth parts of Pacific lamprey, Lampetra tridentatus. The corrected table from the 1986 samples contains 2 major additions including spiny dogfish shark and salmonids (Table 23). In addition, the frequency of occurrence of some prey species such as herring and Pacific whiting (hake) increased. We were not able to differentiate between which salmonid species were taken in 1986 or 1987, however, they were most likely steelhead or blackmouth (chinook) salmon which are both prevalent during the times when scats were collected.

Table 23. Amendment to table 4.17 from Gearin et al 1986. Prey items recovered in California sea lion scats and spewings in 1986.

Name	Frequency Occurrence (%)	# of otoliths	% of total
Pacific whiting (hake) *Merluccius productus*	88	173	65.0
Pacific herring *Clupea harengus*	26	43	16.2
Spiny dogfish *Squalus acanthius*	8	---	----
Miscellaneous codfishes *Gadidae sp.*	6	37	14.0
Miscellaneous salmonids *Salmonidae sp.*	5	0	0
Walleye pollock *Theragra chalcogramma*	5	11	4.1
Pacific cod *Gadus macrocephalus*	2	2	.7
Octopus *Octopus sp.*	1	---	----
Pacific lamprey *Lampetra tridentatus*	1	---	----
		266	100

The 1986 report concluded that gadid fishes, such as hake, walleye pollock, Theragra chalcogramma, and Pacific cod, Gadus macrocephalus, were the most important prey from the Port Gardner vicinity. We believe that this conclusion is still valid for this region during late April. The importance of hake in the diet of sea lions in this region is further strengthened by the new analysis which indicated that hake occurred in 88% of the total samples.

The percent occurrence of herring in the 1986 samples also increased significantly using the new methodology from 12 to 26 percent (Table 23). The major finding from using the new methodology was the occurrence of salmonids, and dogfish shark remains in the samples which were not previously recorded as prey of sea lions based on scat samples from Puget Sound.

1987 Food Habits

We collected 119 samples (114 scat and 5 spewings) during 1987 of which 48 were from Everett-Port Gardner and 71 were from the Shilshole Bay vicinity. The collections were made on 9 separate days, between 3 February and 4 May 1987 (Table 24). The analysis of the scat and spewing contents collected during 1987 led to the identification of nine prey taxa from the samples. In terms of frequency of occurrence in the total samples, 4 taxa were predominant including hake (78.9%), herring (42%), dogfish shark (22.6%) and salmonids (17.6%) (Table 25). In terms of numerical importance based on percentages of identifiable otoliths, hake and herring ranked 1 and 2 respectively (Table 26). Only 4 salmonid otoliths were recovered in the samples, yet salmonid vertebrae or bone was recovered in 17.6% of the total. In the past, we would have grossly underestimated the frequency of occurrence of salmonids and also dogfish shark (which have no otoliths) from the samples since otolith identification was the primary method of identifying and enumerating prey. The analysis of the samples from the two regions revealed some differences in prey utilization between the two areas. Salmonids and dogfish shark remains were more prevalent in the samples from Shilshole (Table 25). Hake and herring were more prevalent in the Everett samples.

Table 24. Sea lion scat and spewing samples collected at Everett and Shilshole Bay during 1987.

Date	Number Everett	Number Shilshole	Total
3 February	0	1	1
27 February	20	0	20
24 March	0	14	14
30 March	0	10	10
21 April	0	10	10
23 April	0	8	8
24 April	0	7	7
26 April	0	6	6
4 May	28	15	43
	48	*71	119

* A small percentage of these samples may have been from northern sea lions, small numbers of which were often hauled out simultaneously with California sea lions.

The percentages of prey found in the samples from Shilshole also varied by month from March through May. Salmonid remains declined in the samples and hake, herring, and dogfish shark remains increased thus suggesting changes in seasonal availability of prey (Figure 9).

We conclude that for the two areas we sampled from February to May that the major prey of sea lions was hake, herring, dogfish shark, salmonids and miscellaneous codfishes.

Table 25. Frequency of occurrence of prey categories found in California sea lion scat and spewing samples from Puget Sound during 1987.

Prey Category (N=119)	Percent Occurrence Shilshole (N=71)	Everett (N=48)	Total
Pacific whiting (hake) *Merluccius productus*	71.8	91.6	78.9
Pacific herring *Clupea harengus*	36.6	50.0	42.0
Spiny dogfish *Squalus acanthius*	28.1	14.5	22.6
Salmon *Salmonidae sp.*	25.3	6.2	17.6
Cod fishes *Gadidae sp.*	11.2	8.3	10.0
Walleye pollock *Theragra chalcogramma*	5.6	2.0	4.2
Pacific cod *Gadus macrocephalus*	5.6	0	3.3
Shiner perch *Cymatogaster aggregata*	1.4	0	.4
Eelpout *Zoarcidae sp.*	0	2.0	.4
Fish bone	100.0	100.0	100.0
Otoliths	47.8	56.2	51.2

Table 26. Otoliths recovered from scat and spewing samples of California sea lions from Puget Sound during 1987.

Prey Category	Otoliths Recovered					
	Shilshole		Everett		Total	
	Number	Percent	Number	Percent	Number	Percent
Pacific whiting (hake) *Merluccius productus*	100	71.4	52	76.4	152	73.4
Pacific herring *Clupea harengus*	15	10.7	6	8.8	21	10.1
Codfishes *Gadidae sp.*	10	7.1	6	8.8	16	7.2
Walleye pollock *Theragra chalcogramma*	4	2.9	2	3.0	6	3.0
Pacific cod *Gadus macrocephalus*	5	3.6	0	0	5	2.4
Salmon Salmonidae sp.	4	2.9	0	0	4	1.9
Shiner perch *Cymatogaster aggregata*	2	1.4	0	0	2	1.0
Eelpout *Zoarcidae sp.*	0	0	2	3.0	2	1.0
	140	100	68	100	208	100

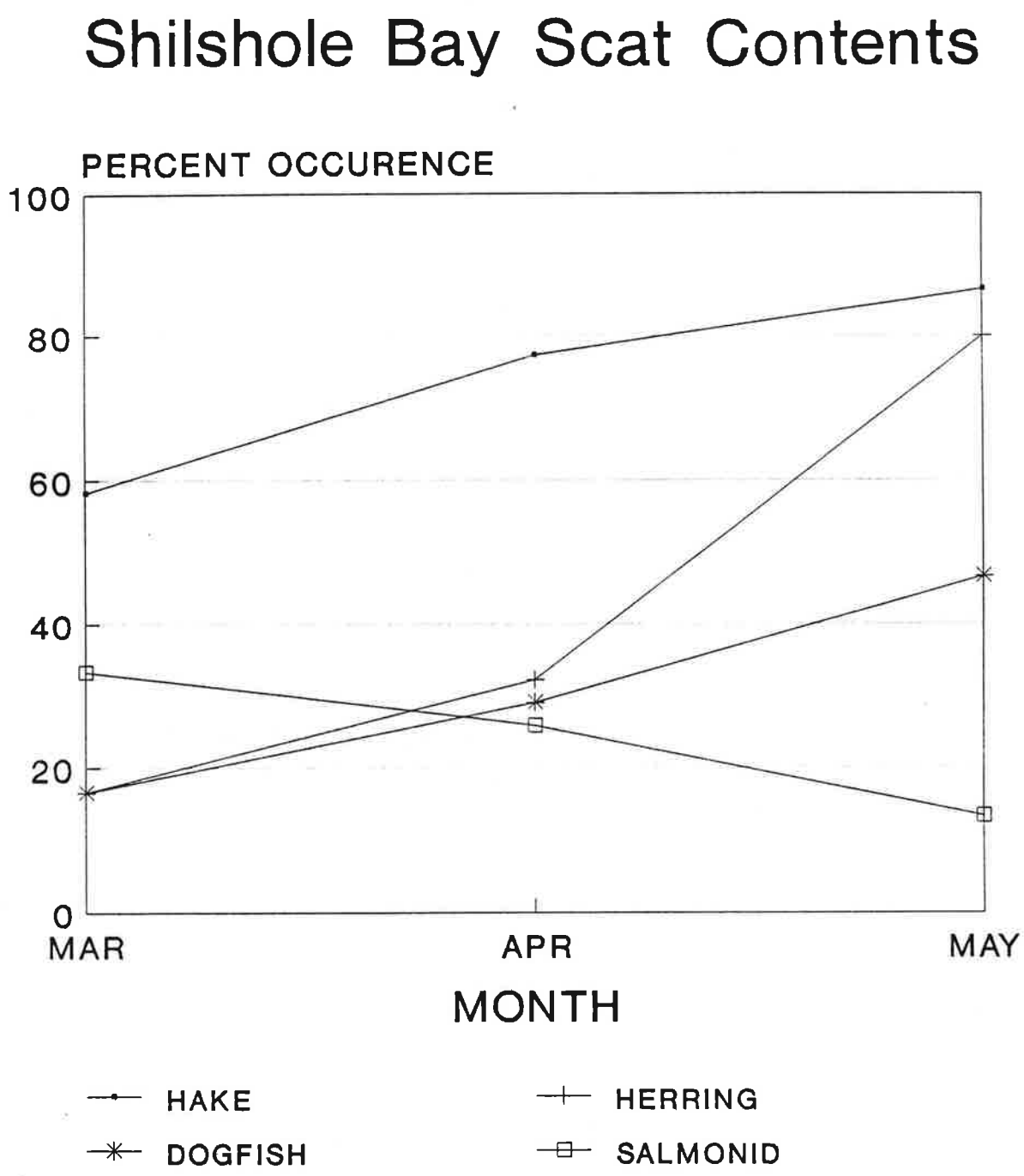

Figure 9 Changes in frequency of occurrence of sea lion prey at Shilshole Bay from March through May 1987.

OTHER MARINE MAMMAL SIGHTINGS

Records were kept of other marine mammals which were observed at the Locks, in the Ship Canal and in Puget Sound during boat censuses and surveys.

Four species of pinnipeds were observed in the Locks vicinity during the season, however, only the California sea lion was observed to forage in this area.

Pinnipeds

Northern Sea Lion (Eumetopias jubatus)

One northern sea lion was observed near the Locks during the season. The animal was observed near the small locks area for about 10 minutes before departing the area. This sea lion appeared to be scanning the area as if curious and did not seem intent on feeding as it left shortly after it was sighted without being chased out. Northern sea lions were sighted frequently during boat surveys and censuses near Shilshole Bay and Meadow Point. Northern sea lions were not sighted in this vicinity until 1 April when small numbers (1 to 4) began to appear. They were observed hauled out or rafting in the water with California sea lions at Meadow Point and the Shilshole jetty barge buoy. All of the northern sea lions observed appeared to be small subadult or juvenile animals.

Northern Elephant Seal (Mirounga angustirostris)

One elephant seal was found stranded on a beach in outer Ship Canal Bay on 22 January 1987. The animal was lethargic, emaciated, and apparently quite ill and was turned over to a local veterinary hospital where it died several

days later. The animal had two pink tags numbers, 5792 and 5820 which indicated that it was a 1 year old male tagged on South Farallon Island, California in 1986 (H. Huber, pers. comm).[5]

Harbor Seal (Phoca vitulina)

Single harbor seals were observed at the Locks on 3 days during the study. These sightings were of small individuals which were probably yearlings or pups of the year. Harbor seals appeared to be excluded from the Locks area by sea lions which were observed chasing seals away from the area.

Cetaceans

Killer Whale (Orcinus orca)

A pod of four killer whales was observed off West Point during a boat survey on 27 April 1987.

Dall's Porpoise Phocoenoides dalli

A pod of four Dall's porpoise was observed off Meadow Point on 2 April 1987.

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[5]Harriet Huber, NMML, 7600 Sand Point Way, Seattle, WA. Pers. Commun, Jan 1987.

SUMMARY AND CONCLUSIONS

Sea Lion Presence and Numbers

Sea lions were present at the Locks from 6 October 1986 to 15 May 1987 for a span of 7.4 months. Sea lions were present at the inner bay/Locks area on 142 out of 151 (94%) days during which coverage was maintained. Numbers of sea lions observed simultaneously at the inner bay ranged from 0 to 8 during the season.

At least 11 different sea lions were known to have entered the Locks area during the season but the actual number of individuals could be much greater due to large aggregations of sea lions in the nearby vicinity. A true estimate of the total number of sea lions involved in predating steelhead could not be made due to the lack of reliable identifying marks. The number of sea lions in the vicinity of the Ship Canal ranged from 1 to 12 from October through February and then increased dramatically in mid-March. Sea lion numbers from mid-March to mid-May ranged from 5 to 137 with a daily mean of 44. A major rafting and haul out site located off Shilshole jetty is within 1 km of the Locks area.

Sea lions were counted in Puget Sound during an aerial survey in mid-April 1987. Total numbers were 650 and at least 18 different haul out sites were noted.

Harassment Program - Diminished Effectiveness

The harassment program during the 1986-87 season was effective in reducing observed predation rates in the inner bay by about 67% using primarily firecrackers. During the previous season, however, a similar harassment program reduced predation rates by about 97%, so from one season to

the next we calculated that our harassment program had a 30% loss of effectiveness. We suspect that if a similar harassment program were conducted during the 1987-88 season that our overall effectiveness would continue to decline because individual sea lions have become habituated to firecrackers. We believe that the use of firecrackers is effective in saving some fish by disrupting the sea lion's foraging behavior and slowing them down but it is clearly not effective as a behavior modifier or conditioning tool which alters long term memory or behavior. At least 3 sea lions which were subjected to nearly continuous harassment during the 1986-87 season continued to return to the Locks and were each sighted on 50 to 60 days throughout the season. At least two of these animals were present in 1985-86. One animal in particular appears to be completely habituated to firecrackers and will not move from the spillway area regardless of the number of firecrackers used. For this reason, continuous harassment was employed during much of March and April of 1987. We are concerned that this continuous harassment (which utilizes many firecrackers) potentially does more harm than good by disrupting steelhead passage. Firecrackers also, at this level of usage, may disrupt and disturb marine birds, fishes and other organisms by the Locks area.

Predation Losses and Escapement Shortfalls

We estimated that sea lions predated 2,604 steelhead in the Ship Canal from November 22 to 30 April which accounted for 43% of the total combined run or 42% of the wild run and 44% of the hatchery run. Total losses for the inner and outer Ship Canal Bay were estimated to be 1,000 and 1,604 fish respectively. Predation by sea lions contributed to a 27% shortfall in wild

fish escapement which was estimated to be 1,172 fish. The Lake Washington system escapement goal is 1,600 fish which is the minimum number required to ensure adequate reproductive stock for future runs.

Fish Savings

We estimated that the harassment program saved 1,084 fish during the season of which 531 were of wild stock. If no harassment had been used for the entire season, the escapement of wild fish would have been only 641 or a 60% shortfall.

Tribal Gillnet Fishery Effects

The tribal gillnet fishery in the outer Ship Canal Bay appears to be an important factor influencing sea lion predation on steelhead in the area. We believe that the nets may act as an attractant to sea lions which find fish easy to pick from the nets. The fishery utilizes between 25 and 30 gillnets which are set in Shilshole and the outer Ship Canal Bays. In October through November when the fishery targets coho salmon, the gillnets are in place 24 hours a day, for 5 to 7 days a week. Sea lions, which first arrive in September in this vicinity, began robbing the nets of coho salmon in October and remain in the area throughout the gillnet season. Losses of steelhead to sea lions directly from the gillnets begins in mid-November and proceeds until the end of the commercial fishery. During the 1986-87 fishery, we estimated that sea lions took at least 450 steelhead from the gillnets. We believe that this figure represents a conservative estimate of total losses during the 38-day fishery in 1986-87 since nighttime losses were not included in this total. Sea lions continue to forage at night from the gillnets based on our

observations but we were unable to quantify the losses in 1986-87. We strongly suspect that at times losses could be as high at night as they are during the day.

Steelhead predation rates in the outer bay were 3.24 times greater when the gillnets are set. The predation rates in the inner bay were also influenced by the presence or absence of the tribal gillnets. Predation rates in the inner bay were very low (averaging 3.15 fish per day) when the gillnets were present but increased five-fold to 15.3 fish when the nets were absent. The nets also appear to influence the number of sea lions in the inner and outer bays. In general, when the nets are set in the outer bay, the sea lions tend to stay in the outer bay and rob the nets. When the nets are pulled, the sea lions move inside to feed by the spillway or Locks. Steelhead which are lost to sea lions from the gillnets have not previously been accounted for in quota allocations. The nets may act to condition individual sea lions to feeding on net-caught salmonids since they are set from early October. By the time the steelhead run begins, there are already many sea lions which are habitually feeding on net-caught fish.

Impacts of Net Fishery on Harassment

The tribal net fishery is a primary factor influencing inner bay harassment effectiveness. The use of boat hazing and firecrackers as harassment methods has little if any effect upon predation rates in the inner bay as long as nets are set in the outer bay. Statistical comparisons of predation rates in the inner bay during netting revealed that there were no significant differences in these rates using the Mann-Whitney and t-test regardless of whether harassment was used or not. The netting predation rates were 3.15 and 2.31 fish per day during preharassment and harassment

respectively for a savings of 0.84 fish per day. Harassment may have saved 32 fish (about 10 wild) during the 38 day fishery. We conclude that the benefits of harassment in the inner bay during the net fishery are so minimal that it's not worth the time, effort, or costs involved to continue this effort.

Foraging Locations-Territorial Behavior

Sea lions forage for steelhead in both the inner and outer Ship Canal Bays on net-caught and free swimming fish. At the inner bay which we divided into four major foraging locations, the sea lions appear to set up and defend individual feeding territories. The sea lions which were the most successful at capturing steelhead were those which were the largest and which foraged near the spillway area. The spillway area, which encompasses three territories, appears to be a preferred foraging location since the fish ladder entrance is nearby and it is walled on three sides. At least 72% of all inner bay steelhead kills during preharassment were taken in this area. Sea lions spread out in the inner bay when they are actively feeding. If seven animals were present, three would be near the spillway, one each near the small and large locks and two by the BN bridge. Our observations indicate that sea lions set up feeding territories in the inner bay, from which other (generally smaller) sea lions are excluded.

Sea lions successfully forage for steelhead in the outer bay on net-caught and free swimming fish. A major finding from this season's observations is that relatively high amounts of predation occur in the outer bay on free swimming steelhead throughout the season. It is clear that sea lions can capture free swimming steelhead from certain areas of the outer bay, however, additional data is needed before conclusive rates of predation can be determined.

ACKNOWLEDGEMENTS

The 1986-1987 project was a cooperative effort between the Washington Department of Wildlife (formerly Washington Department of Game), National Marine Fisheries Service, U.S. Army Corps of Engineers and the Muckleshoot and Suquamish Indian tribes. The Washington Department of Wildlife provided funding for two full time field observers and for various field supplies including firecrackers, gas and oil and the use of two small boats. The National Marine Fisheries Service through the Northwest Region and National Marine Mammal Laboratory provided funding for one full time field observer and various equipment and logistical supplies. The Muckleshoot and Suquamish Tribes each provided one part time field observer. The U.S. Army Corps of Engineers, Seattle Office, provided logistical support through use of the Locks facility for work space, boat moorage, and parking and storage. Locks personnel also participated in data collection by recording miscellaneous sea lion sightings throughout the season. We are grateful for the cooperation and helpfulness of the personnel at the Hiram Chittenden Locks in Seattle who assisted us in many ways during this study. We also gratefully acknowledge the cooperation of the management and employees of the Acapulco Restaurant who allowed usage of the grounds to make observations of sea lion foraging. We also wish to thank the concerted efforts of the individual observers including; Doug Bertran, Greg Polkinghorn, Bill Lawrence and Sandra Louie. We thank Lorene Miller and Ruth Harris who spent countless hours correcting and reorganizing earlier drafts of this manuscript on the word processor. We thank M. Dahlheim, C. Fowler, and D. Withrow who critically reviewed earlier drafts of this paper.

We wish to thank R. Wigen and S. Crockford for enlightening us to methods of identifying certain fish taxa from vertebral and skeletal characteristics and for identifying prey from some samples of sea lion scats and spewings.

We wish to dedicate this report to the memory of the late Clay Brunsell, formerly Lockmaster at the Chittenden Locks, who was a friend to many of us involved in this project.

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Appendix Table 1.--Affiliation and participation of individuals cooperating on the sea lion predation control project.

Name	Participation	Affiliation
Bob Pfeifer	F&A	Washington Dept. of Wildlife
Steve Jeffries	F&A	Washington Dept. of Wildlife
*Doug Bertran	F	Washington Dept. of Wildlife
*Mike Johnson	F	Washington Dept. of Wildlife
Chuck Phillips	A	Washington Dept. of Wildlife
Bob Byrne	A	Washington Dept. of Wildlife
Robert L. DeLong	F&A	NOAA, NMFS, NMML
Joe Scordino	A	NOAA, NMFS, NMML
George Antonelis	F	NOAA, NMFS, NMML
Tom Loughlin	F	NOAA, NMFS, NMML
*Pat Gearin	F	NOAA, NMFS, NMML
Bill Dickinson	A	NOAA, NMFS, NMML
Byron Esko	A	U.S. Army Corps of Engineers
Jack Thompson	A	U.S.A.C.E.
Marv Lund	A	U.S.A.C.E.
Will Sandoval	A	Muckleshoot Tribal Fisheries
Sandra Louie	F	Muckleshoot Tribal Fisheries
Randy Hatch	A	Suquamish Tribal Fisheries
Greg Polkinghorn	F	Suquamish Tribal Fisheries
Bill Lawrence	F	Suquamish Tribal Fisheries

* Full time
F-Field Observer
A-Administrative

Appendix Table 2.-- Steelhead counts made in the Chittenden Locks fishway viewing chamber, 1986-87.

Steelhead observed in the fishway viewing chamber were counted from 22 October 1986 through 30 April 1987 to provide an index of their relative abundance and run strength. These counts, however, are only representative of the minimum number present since viewing conditions changed day to day depending on the turbidity of the water in the fishway. Even under ideal (clear) viewing conditions it is unlikely that all fish were counted because of the configuration of the chamber which allows some fish to "hide" out of view near corners or behind partitions. These counts may, however, provide an index of daily passage rates and do indicate the length of the winter steelhead run.

In addition to these counts, all steelhead contained in the fishway viewing chamber were trapped and removed on regularly-spaced occasions throughout the run. The fish were sampled for age and growth information as well as hatchery or wild origin, then released unharmed to the Ship Canal above the spillway dam. On these occasions, it was possible to obtain accurate counts of all steelhead within the viewing chamber as they were individually netted and removed.

It is important to note that numerous individuals have noticed that steelhead entry to the Ship Canal, and the fishway, is erratic during the periods when tribal netting is underway. In addition, intensive sport fishing below the fishway entrance probably also affects the accuracy of chamber counts as a true index of run strength or timing. These fisheries must be taken into account in interpreting viewing chamber count data.

Large numbers of steelhead did not accumulate in the viewing chamber after mid-March 1987 as they did the previous year. We suspect that near continuous harassment and presence of sea lions during this time near the fish ladder prevented fish from schooling and passing through. Fish also pass through the Locks, however, during the upstream migration.

Appendix Table 2 lists the daily visual counts made, and the total counts made when all fish were removed, at the Locks fishway viewing chamber between 22 October 1986 and 30 April 1987.

Appendix Table 2.--Counts of steelhead at the Chittenden Locks Fish Ladder Viewing Chamber and days of tribal gillnetting during the 1986-1987 season.

Date	Steelhead Counts	Year	Nets	Comments
Oct. 23	0	1986	No	
Nov. 22	0	"	No	School of 10-15 SH. in bay
Nov. 26	0	"	Yes	
Nov. 27	0	"	Yes	
Nov. 28	1	"	Yes	
Dec. 1	0	"	Yes	
Dec. 2	0	"	Yes	
Dec. 3	3	"	Yes	
Dec. 4	1	"	Yes	
Dec. 5	4	"	No	
Dec. 6	5	"	No	
Dec. 7	No data	"	Yes	In by 1200
Dec. 8	1	"	Yes	
Dec. 9	0	"	Yes	
Dec. 10	0	"	Yes	
Dec. 11	0	"	Yes	Nets pulled by 1200
Dec. 12	3	"	No	
Dec. 13	0	"	No	School of 8-12 SH in bay
Dec. 14	0	"	Yes	Nets set by 1200
Dec. 15	0	"	Yes	
Dec. 16	0	"	Yes	
Dec. 17	0	"	Yes	
Dec. 1	No data	"	Yes	
Dec. 19	1	"	No	School of 15-20 SH in bay
Dec. 20	4	"	No	

Appendix Table 2.--Continued

Date	Steelhead Counts	Year	Nets	Comments
Dec. 21	8	"	Yes	In by 1200
Dec. 2	No data	"	Yes	
Dec. 23	0	"	Yes	Nets pulled by 1200
Dec. 24	0	"	No	
Dec. 25	No data	"	No	
Dec. 26	0	"	No	Obs. school of 15-20 SH in bay
Dec. 27	0	"	No	
Dec. 28	No data	"	Yes	Nets set by 1200
Dec. 29	0	"	Yes	
Dec. 30	1	"	Yes	Nets pulled by 1200
Dec. 31	1	"	No	
Jan. 1	No data	1987	No	
Jan. 2	0	"	No	
Jan. 3	0	"	No	
Jan. 4	1	"	Yes	Nets set by 1200
Jan. 5	2	"	Yes	
Jan. 6	2	"	Yes	Begin harassment
Jan. 7	1	"	Yes	
Jan. 8	1	"	Yes	
Jan. 9	6	"	Yes	Nets pulled by 1200
Jan. 10	30	"	No	
Jan. 11	40	"	No	
Jan. 12	27	"	Yes	Nets in by 1200
Jan. 13	23	1987	Yes	
Jan. 14	19	"	Yes	
Jan. 15	20	"	Yes	
Jan. 16	23	"	Yes	
Jan. 17	31	"	No	
Jan. 18	36	"	No	
Jan. 19	45	"	No	
Jan. 20	20	"	No	Capture attempt
Jan. 21	22	"	Yes	Capture attempt
Jan. 22	2	"	Yes	
Jan. 23	5	"	Yes	Nets pulled by 1200
Jan. 24	12	"	No	
Jan. 25	35	"	No	
Jan. 26	15	"	No	Capture attempt
Jan. 27	17	"	No	
Jan. 28	15	"	No	
Jan. 29	20	"	Yes	Nets set by 1200
Jan. 30	20	"	Yes	Pulled by 1200
Jan. 31	34	"	No	
Feb. 1	35	"	No	
Feb. 2	40	"	No	
Feb. 3	36	"	No	

Appendix Table 2.--Continued

Date	Steelhead Counts	Year	Nets	Comments
Feb. 4	33	"	No	
Feb. 5	42	"	No	
Feb. 6	50	"	No	
Feb. 7	65	"	No	
Feb. 8	60	"	No	
Feb. 9	37	"	Yes	SH removed by noon - Nets in by 1200
Feb. 10	0	"	Yes	Nets out by 1200-last day of netting
Feb. 11	2	"		
Feb. 12	12	"		
Feb. 13	13	"		
Feb. 14	17	"		
Feb. 15	23	"		
Feb. 16	25	"		
Feb. 17	22	"		
Feb. 18	19	"		
Feb. 19	22	"		
Feb. 20	14	"		
Feb. 21	15	"		
Feb. 22	13	"		
Feb. 23	19	"		
Feb. 24	32	"		
Feb. 25	30	"		
Feb. 26	33	"		
Feb. 27	30	1987		
Feb. 28	10	"		
Mar. 1	6	"		
Mar. 2	10	"		
Mar. 3	10	"		
Mar. 4	18	"		
Mar. 5	20	"		
Mar. 6	25	"		
Mar. 7	30	"		
Mar. 8	46	"		
Mar. 9	30	"		
Mar. 10	25	"		
Mar. 11	25	"		
Mar. 12	10	"		
Mar. 13	15	"		
Mar. 14	15	"		
Mar. 15	25	"		
Mar. 16	25	"		
Mar. 17	10	"		
Mar. 18	13	"		Fish removed

Appendix Table 2.--Continued

Date	Steelhead Counts	Year	Nets	Comments
Mar. 19	0	"		
Mar. 20	1	"		
Mar. 21	0	"		
Mar. 22	1	"		
Mar. 23	0	"		
Mar. 24	1	"		
Mar. 25	2	"		
Mar. 26	0	"		
Mar. 27	0	"		
Mar. 28	0	"		
Mar. 29	0	"		
Mar. 30	0	"		
Mar. 31	0	"		
Apr. 1-30	No steelhead observed in view chamber			

Appendix 3.

Records were kept by the Locks tower personnel on the presence of sea lions in the Locks vicinity throughout the season. This log enabled us to document the first and last seasonal presence of sea lions and also provides information about daily presence in December. Few records were maintained from 5 January to 30 April since state and federal biologists were present on a daily basis during this period. These records also indicate that sea lions foraged at the Locks until at least 15 May 1987.

Appendix Table 3. Marine Mammal Observation Log from the Chittenden Locks Control Tower during 1986-87.

Date	Time	Who Made Sighting	Where	Comments
10/6/86	0725	Wilder	Spillway	
10/7/86	1150	Wilder	Spillway	
10/17/86	1500	Lund	Spillway	
10/19/86	2000	Visitor	Spillway	
10/20/86	1115	Lund	Spillway	Harbor Seal
10/22/86	0855	McGraw	Large Lock	
10/22/86	1100	McGraw	Spillway	2
10/25/86	1730	Lacoste	Large Lock	1
10/27/86	0745	Wilder	Large Lock	1
10/28/86	0715	Edmondson	Large Lock-Spillway	(all day)
11/6/86	1315	Dodge	Spillway	
11-7/86	1600	Edmondson	LH Large	
11/8/86	1500	Edmondson	LH Large	
11/9/86	1610	Edmondson	LH Large	
11/17/86	0730	Jeffries	Spillway	1
11/18/86	1250	Lund	below S.L.	Small
11/19/86	0830	Dodge	Spillway	
11/20/86	0745	----	Small Lock	1
11/21/86	0955	Lund	Spillway	humpback
11/22/86	1525	Edmondson	Spillway	humpback
11/23/86	0800	----	Spillway	humpback
11/24/86	0745	Lund	Spillway	two
11/25/86	1000	Jeffries	below R.R. Bridge	
11/26/86	0735	Dodge	Spillway	
11/27/86	1200	Dodge	Spillway	
11/28/86	0730	Dodge	below L.L.	
12/1/86	0820	Dodge	By R.R. Bridge	
12/2/86	0830	Gearin	2 in outer bay	
12/3/86	----	Gearin	----	none all day
12/4/86	0900	Gearin	3 in outer bay	
12/5/86	1030	Gearin	1 in and out	
12/6/87	1200	Meyer	Lower half	
12/7/86	1030	Meyer	Lower half	
12/8/86	0800	Hill	Lower half	
12/9/86	0830	Lund	Lower half	
12/10/86	0800	Gearin	inside by fishway	
12/11/86	0815	Gearin	2 inside cable	
12/12/86	0830	Gearin	3 inside cable	
12/13/96	0400	Meyer	3 or 4 inside cable	
12/14/86	0800	Nitta	1 lower half	
12/15/86	0825	Meyer	4 below SWR	
12/18/86	0115	Meyer	Below large lock	
12/20/86	0830	Meyer	Below Spillway	
12/21/86	0830	Jensen	2 below lock spillway	

Appendix Table 3.--Continued

Date	Time	Who Made Sighting	Where	Comments
12/22/86	0930	Donelon	2 below spillway	
12/23/86	0830	Gearin	1 below spillway	
12/24/86	0030	Brunsell	1 small lock	
12/24/86	0400	Brunsell	Lower half large lock	
12/25/86	0205	Turner	Lower half sheer wall	
12/25/86	1055	----	Fish ladder	
12/27/86	0800	Meyer	Below bridge	
12/28/86	0800	Edmondson	2 below spillway	
12/29/86	0830	Brunsell	2 below small lock	
12/30/86	1440	Edmondson	4 below large lock	
1/1/87	0755	----	1 small lock	
1/3/87	0850	Wilder	Spillway	4 seal?
1/4/87	0850	Wilder	Spillway	2 seal?
1/11/87	0645	Edmondson	Spillway1 lion	
5/4/87	1940	Gearin	By cable	1-2 Zc-feedin
5/5/87	0730	Donelon	Cable	1 fish taken
5/6/87	0910	----	Cable	4 fish taken
5/7/87	1100	----	in large lock	
5/8/87	0635	Nitta	front of spillway	1 animal
5/9/87	0715	Nitta	front of #3 LL	1 animal
5/10/87	1030	Nitta	front of #3 LL	1 animal
5/11/87	0800	Donelon	Large Locks Westend	
5/12/87	0730	----	Large Locks Westend	
5/13/87	0945	Donelon	Spillway	1 fish taken
5/14/87	1130	Donelon	Large Locks Westend	1 fish taken
5/14/87	1330	Donelon	Large Locks Westend	1 fish taken
5/15/87	0530	Nitta	Front of spillway	
5/15/87	1345	Donelon	Spillway	1 fish taken
5/15/87	last day sea lions observed at Locks in Spring 1987			

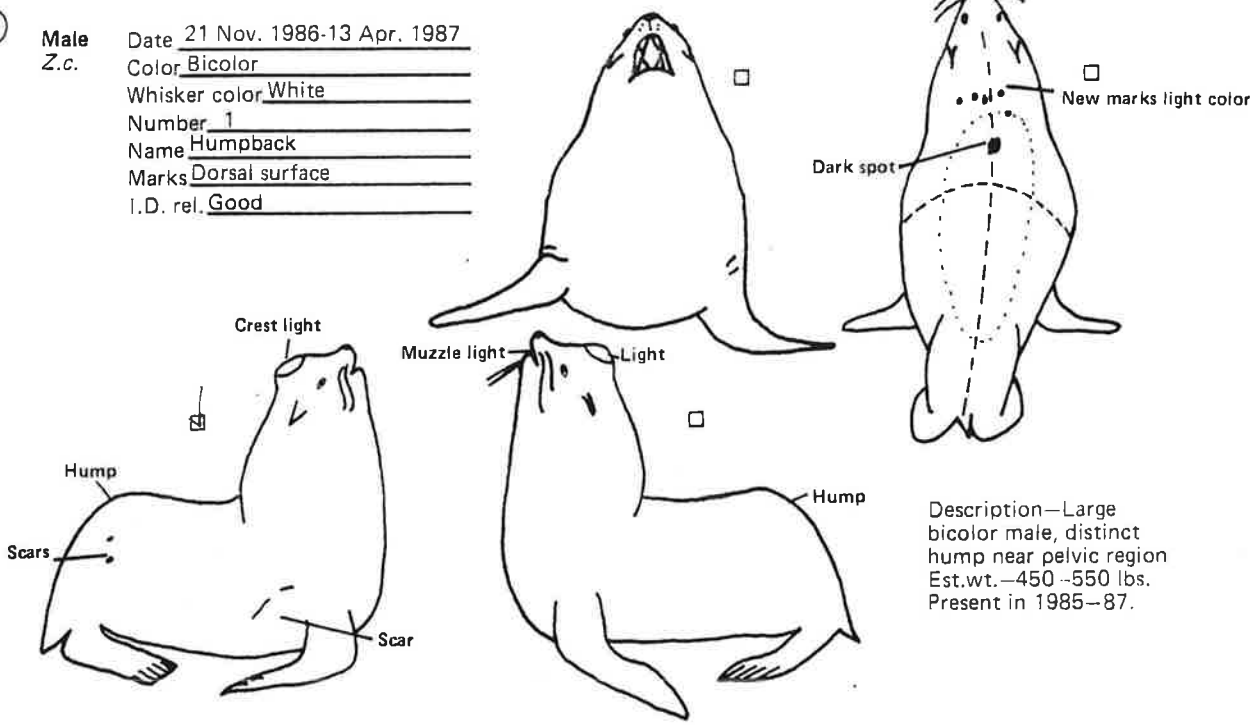
Appendix Table 4. Identification cards of California Sea Lions observed at inner Ship Canal (Locks area) during the 1986-1987 season.

Zalophus californianus

(1)

Male
Z.c.

Date 21 Nov. 1986-13 Apr. 1987
Color Bicolor
Whisker color White
Number 1
Name Humpback
Marks Dorsal surface
I.D. rel. Good



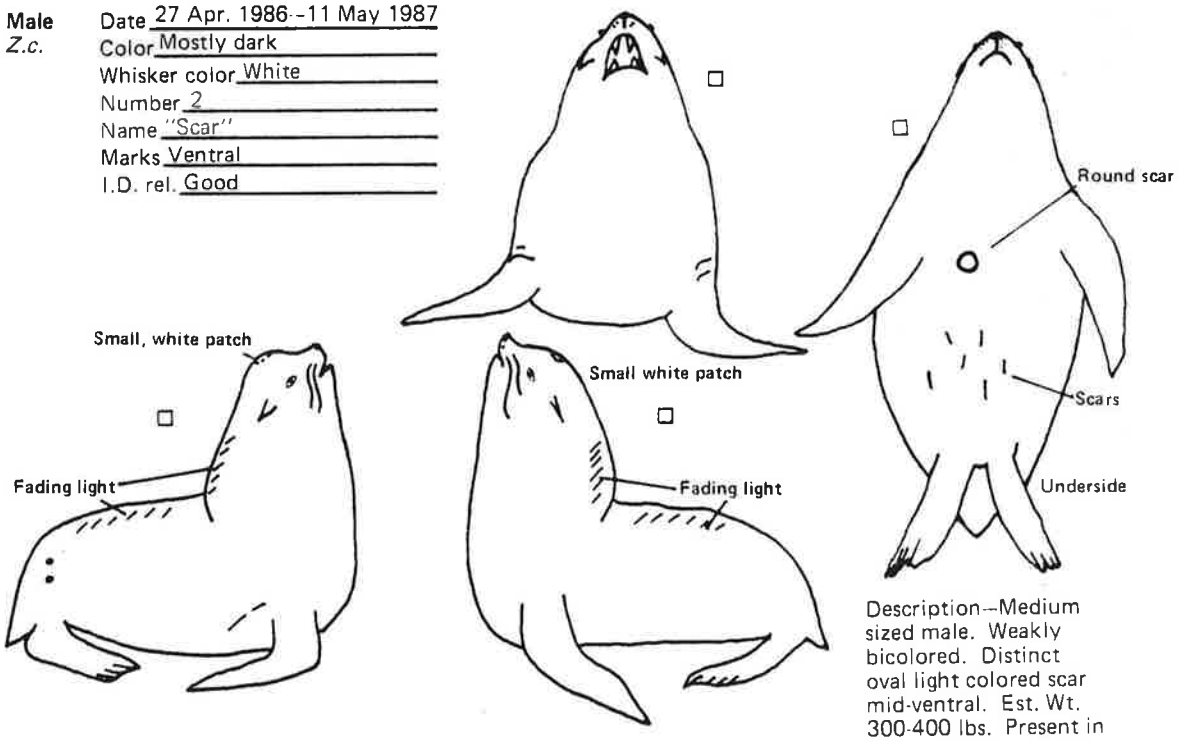
Description—Large bicolor male, distinct hump near pelvic region Est.wt.—450–550 lbs. Present in 1985–87.

Zalophus californianus

(2)

Male
Z.c.

Date 27 Apr. 1986–11 May 1987
Color Mostly dark
Whisker color White
Number 2
Name "Scar"
Marks Ventral
I.D. rel. Good

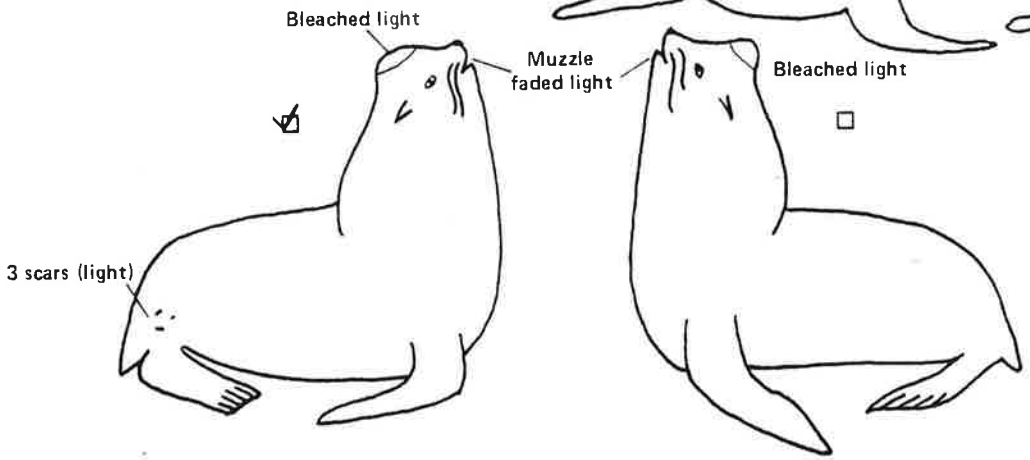


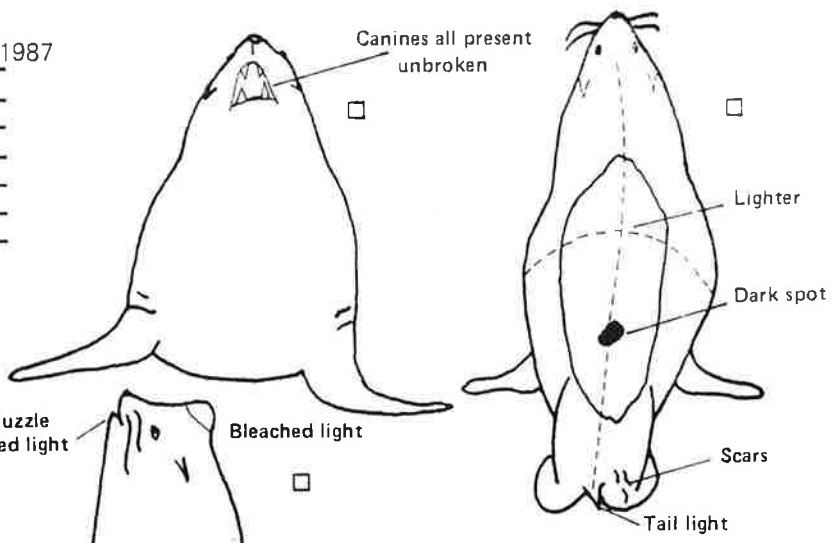
Description—Medium sized male. Weakly bicolored. Distinct oval light colored scar mid-ventral. Est. Wt. 300-400 lbs. Present in 1985–87.

Zalophus californianus

(3) Male *Z.c.*

Date 22 Nov. 1986--23 Apr. 1987
Color Bicolor
Whisker color White
Number 3
Name "Thrasher"
Marks Dorsal
I.D. rel. Good "seasonal"



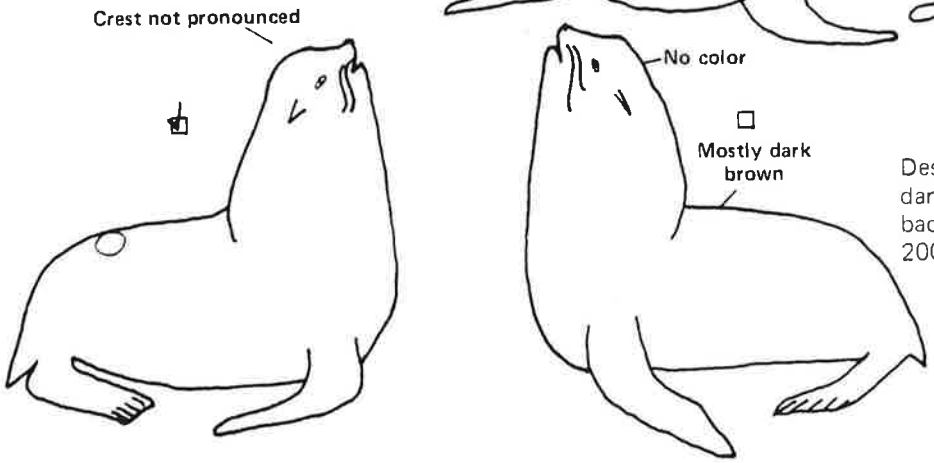


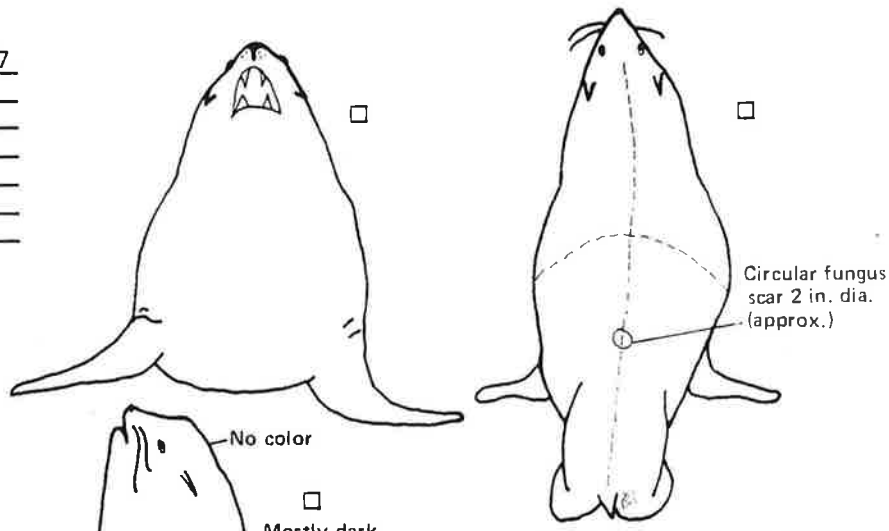
Description—Large bicolor male. Skull crest is prominent. Dark spot 4 -6 cm. in diameter on lower back. Three small scars on right rear flank. Est. wt. 450–550 lbs.

Zalophus californianus

(4) Male *Z.c.*

Date 2 Jan. 1987–30Jan. 1987
Color Uniform dark brown
Whisker color Mixed
Number 4
Name Pox
Marks Mid dorsal
I.D. rel. Good





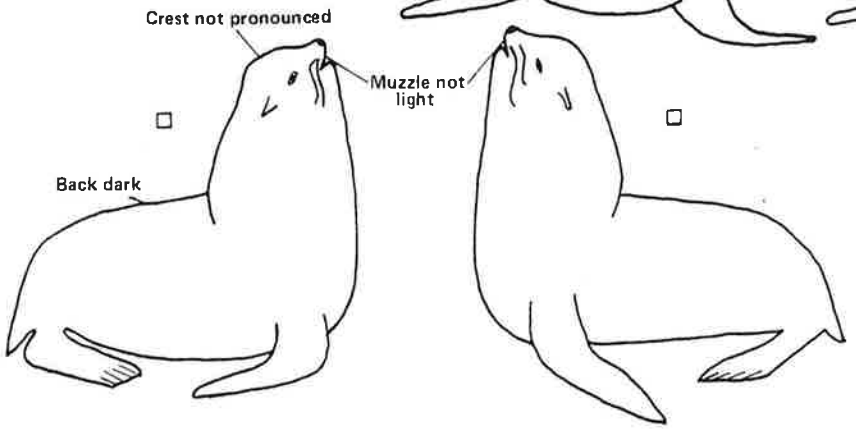
Description—Smaller mostly uniform dark brown. Circular mark on mid back 5–6cm in diameter Est. wt. 200–300 lbs.

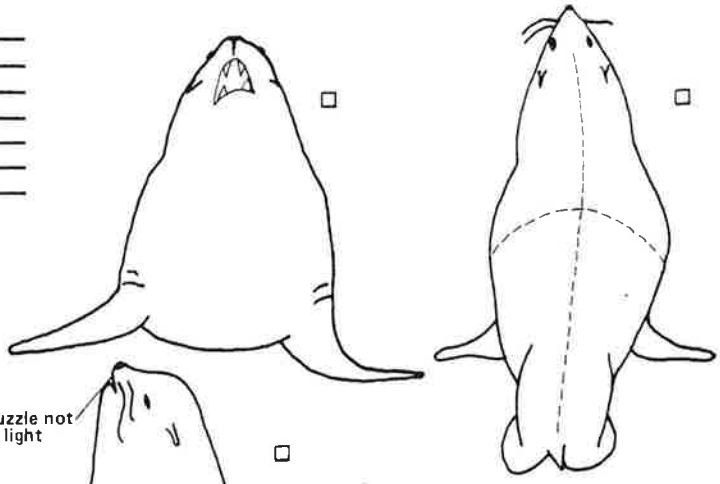
Appendix 4.-- Continued

Zalophus californianus

(5) **Male** *Z.c.*

Date 5 Dec. 1987
Color Uniform dark brown
Whisker color Mixed
Number 5
Name Speedy
Marks None
I.D. rel. Poor





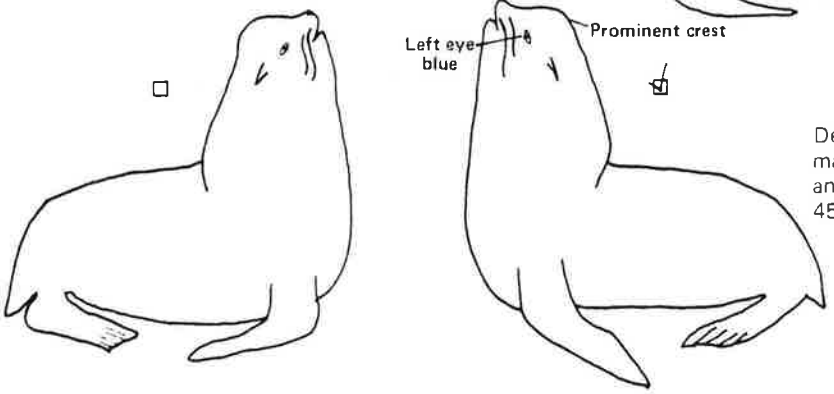
Description– Smallest animal. Uniform dark brown color. No distinct markings. Est. wt. 125-200 lbs.

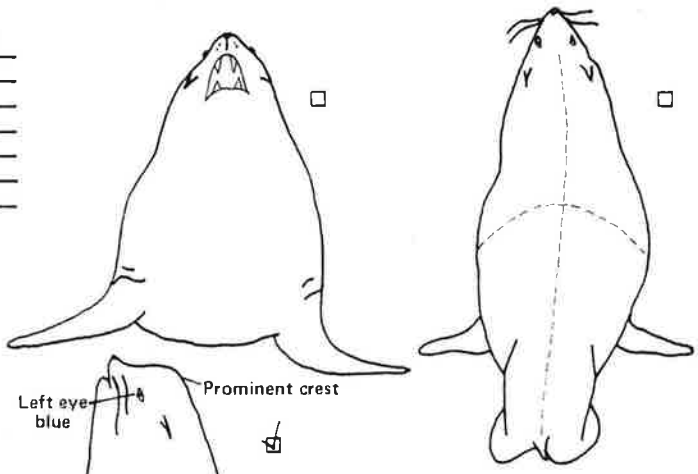
Zalophus californianus

(6) **Male** *Z.c.*

Date 26 Dec. 1986–6 Apr. 1987
Color Bicolor
Whisker color White
Number 6
Name Blue eye
Marks Left eye
I.D. rel. Poor

Usually sighted on bell buoy at channel entrance.





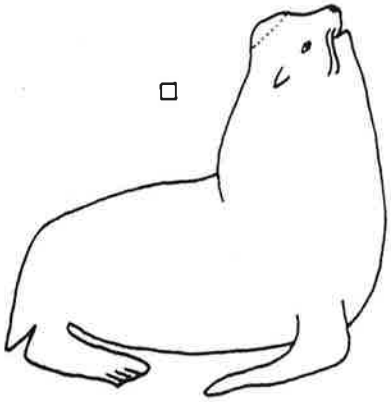
Description–Medium size bicolor male. Left eye is distinctly blue and possibly blind. Est. wt. 350–450 lbs.

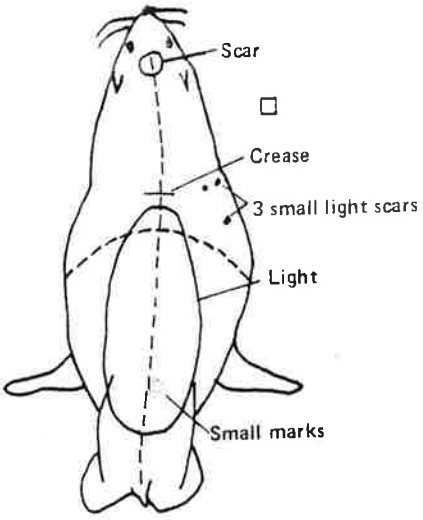
Appendix 4.-- Continued

Zalophus californianus

(7) **Male** *Z.c.*

Date 7 April 1987
Color Bicolor
Whisker color White
Number 7
Name Knothead
Marks Scar on crest of head
I.D. rel. Good



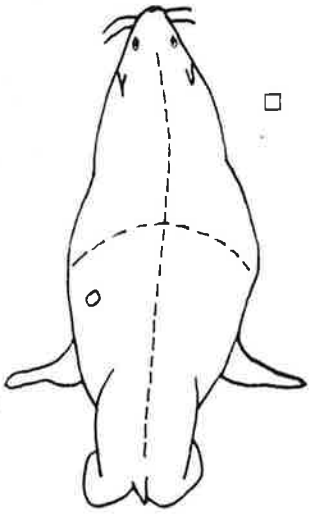


Description—Large bicolor male with distinct "knot" on head. Appears to have been wounded on head. Est. wt. 400—500 lbs.

Zalophus californianus

(8) **Male** *Z.c.*

Date 21 April 1987
Color Dark brown
Whisker color Mixed
Number 8
Name Left flank
Marks Left flank
I.D. rel. Poor

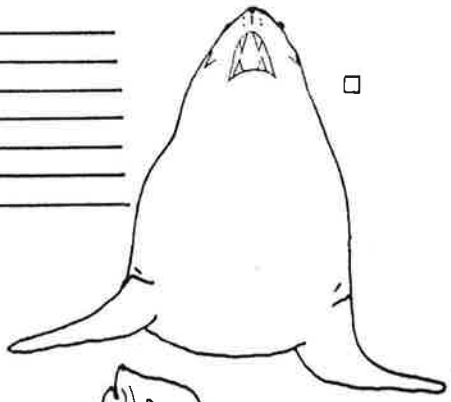


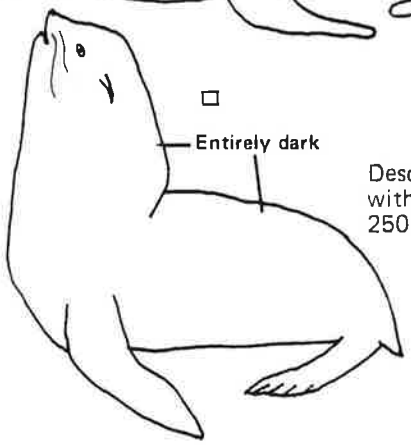
Description--Small uniform dark brown color. Small white scar on left flank 2-3 cm. in diameter. Est wt. 150 -250 lbs.

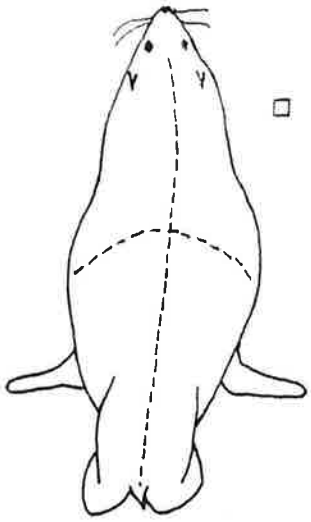
Zalophus californianus

(9) **Male** *Z.c.*

Date 5 Mar. 87
Color Dark brown
Whisker color Mixed
Number 9
Name No name
Marks None
I.D. rel. Poor





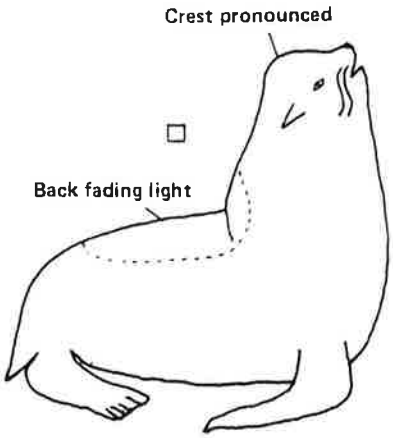


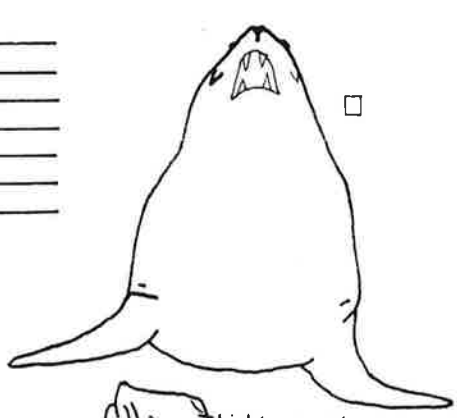
Description –Small dark brown animal with no distinct marks. Est. wt. 200–250 lbs.

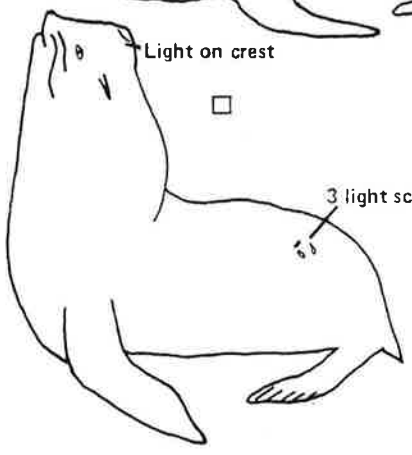
Zalophus californianus

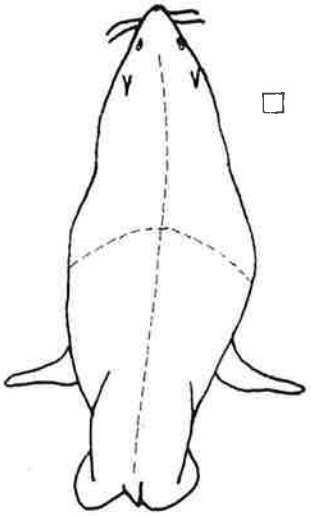
(10) **Male** *Z.c.*

Date 29 Mar. 87
Color Weakly bicolor
Whisker color Mixed
Number 10
Name 3-spot
Marks Left flank
I.D. rel. Poor







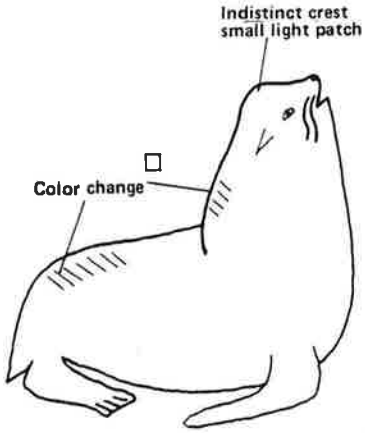


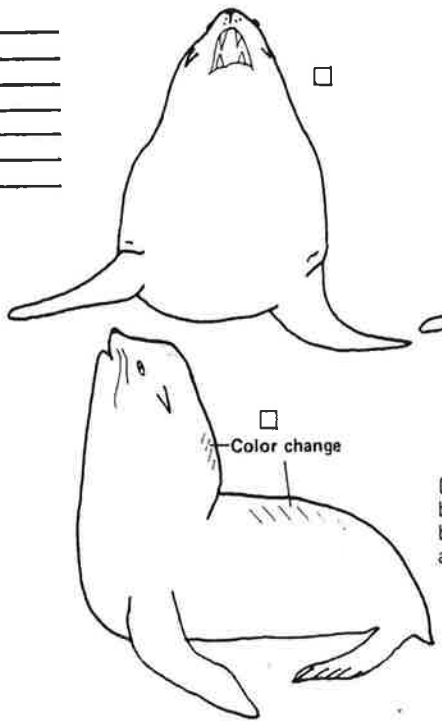
Description--Medium size weakly bicolor male. Three small scars or marks on left flank--2-3 cm. Est wt. 250–350 lbs.

Zalophus californianus

(11) Male
Z.c.

Date 30 Mar. 87
Color Mostly dark brown
Whisker color White
Number 11
Name Spud
Marks None
I.D. rel. Poor





Description -Medium sized, weakly bicolor, mostly dark brown but beginning to fade lighter on back and head. Est. wt. 250–350 lbs.

Appendix Table 5.1 Estimation of outer Ship Canal Bay steelhead takes in December, 1986.

Date	Official Hours of Light	Adjusted Official Hours of Light*	Lit Hours Gear Set**	Netted Daylight Steelhead Take Rate	Estimated Steelhead Takes	Lit Hours Gear not Set	Non-netted Daylight Steelhead Take Rate	Estimated Steelhead Takes
1	8.83	9.61	9.61	2.3212	22.31	0.00	0.7157	0.00
2	8.67	9.45	9.44	2.3212	21.91	0.00	0.7157	0.00
3	8.67	9.45	9.44	2.3212	21.91	0.00	0.7157	0.00
4	8.67	9.45	4.75	2.3212	11.03	4.70	0.7157	3.36
5	8.67	9.45	0.00	2.3212	0.00	9.45	0.7157	6.76
6	8.67	9.45	0.00	2.3212	0.00	9.45	0.7157	6.76
7	8.53	9.31	4.65	2.3212	10.79	4.66	0.7157	3.34
8	8.53	9.31	9.30	2.3212	21.59	0.00	0.7157	0.00
9	8.53	9.31	9.30	2.3212	21.59	0.00	0.7157	0.00
10	8.53	9.31	9.30	2.3212	21.59	0.00	0.7157	0.00
11	8.53	9.31	4.65	2.3212	10.79	4.66	0.7157	3.34
12	8.43	9.21	0.00	2.3212	0.00	9.21	0.7157	6.59
13	8.43	9.21	0.00	2.3212	0.00	9.21	0.7157	6.59
14	8.43	9.21	4.55	2.3212	10.56	4.66	0.7157	3.34
15	8.43	9.21	9.20	2.3212	21.36	0.00	0.7157	0.00
16	8.43	9.21	9.20	2.3212	21.36	0.00	0.7157	0.00
17	8.40	9.18	9.20	2.3212	21.36	0.00	0.7157	0.00
18	8.40	9.18	4.50	2.3212	10.45	4.68	0.7157	3.35
19	8.40	9.18	0.00	2.3212	0.00	9.18	0.7157	6.57
20	8.40	9.18	0.00	2.3212	0.00	9.18	0.7157	6.57
21	8.40	9.18	4.50	2.3212	10.45	4.68	0.7157	3.35
22	8.37	9.15	9.14	2.3212	21.22	0.00	0.7157	0.00
23	8.37	9.15	4.45	2.3212	10.33	4.70	0.7157	3.36
24	8.37	9.15	0.00	2.3212	0.00	9.15	0.7157	6.55
25	8.37	9.15	0.00	2.3212	0.00	9.15	0.7157	6.55
26	8.37	9.15	0.00	2.3212	0.00	9.15	0.7157	6.55
27	8.40	9.18	0.00	2.3212	0.00	9.18	0.7157	6.57
28	8.40	9.18	4.42	2.3212	10.26	4.76	0.7157	3.41
29	8.40	9.18	9.17	2.3212	21.29	0.00	0.7157	0.00
30	8.40	9.18	4.42	2.3212	10.26	4.76	0.7157	3.41
31	8.40	9.18	0.00	2.3212	0.00	9.18	0.7157	6.57
				Subtotals:	332			103

* 0.7771 hours added (mean of difference between observed and official day length in January).

** Assumed nets set @ 1200 and pulled @ 1200 where not specifically observed; (.7771 hrs/2) added for half-days.

Appendix Table 5.2 Estimation of outer Ship Canal Bay steelhead takes in January, 1987. Observed fish kills shown in parentheses.

Date	Known Hours of Light	Adjusted Official Hours of Light	Adjusted Official Hours of Light*	Lit Hours Gear Set**	Netted Daylight Steelhead Take Rate	Estimated (Observed) Steelhead Takes	Lit Hours Gear not Set	Non-netted Daylight Steelhead Take Rate	Estimated (Observed) Steelhead Takes
1		8.45	9.23	0.00	2.3212	0.00	9.23	0.7157	6.61
2		8.45	9.23	0.00	2.3212	0.00	9.23	0.7157	6.61
3		8.45	9.23	0.00	2.3212	0.00	9.23	0.7157	6.61
4		8.45	9.23	4.40	2.3212	10.21	4.83	0.7157	3.46
5		8.45	9.23	9.22	2.3212	21.40	0.00	0.7157	0.00
6		8.57	9.35	9.34	2.3212	21.68	0.00	0.7157	0.00
7	9.28			9.28	2.3212	(13)+9.54	0.00	0.7157	0.00
8	9.73			9.73	2.3212	(17)	0.00	0.7157	0.00
9	9.57			3.78	2.3212	(15)	5.79	0.7157	(2)+ 1.50
10		8.57	9.35	0.00	2.3212	0.00	9.35	0.7157	6.69
11	9.33			0.00	2.3212	0.00	9.33	0.7157	(2)
12	9.58			5.75	2.3212	(24)	3.83	0.7157	(2)
13	9.68			9.68	2.3212	(1)+20.54	0.00	0.7157	0.00
14		8.68	9.46	9.46	2.3212	21.96	0.00	0.7157	0.00
15	9.08			9.08	2.3212	(2)+18.17	0.00	0.7157	0.00
16	9.97			3.75	2.3212	(5)+ 1.16	6.22	0.7157	4.45
17		8.82	9.60	0.00	2.3212	0.00	9.60	0.7157	6.87
18		8.82	9.60	0.00	2.3212	0.00	9.60	0.7157	6.87
19		8.82	9.60	0.00	2.3212	0.00	9.60	0.7157	6.87
20		8.82	9.60	0.00	2.3212	0.00	9.60	0.7157	6.87
21		9.02	9.80	4.55	2.3212	10.56	5.25	0.7157	3.76
22	9.42			9.42	2.3212	(24)+0.39	0.00	0.7157	0.00
23		9.02	9.80	4.55	2.3212	10.56	5.25	0.7157	3.76
24		9.02	9.80	0.00	2.3212	0.00	9.80	0.7157	7.01
25		9.02	9.80	0.00	2.3212	0.00	9.80	0.7157	7.01
26		9.20	9.98	0.00	2.3212	0.00	9.98	0.7157	7.14
27	9.72			0.00	2.3212	0.00	9.72	0.7157	(11)+2.97
28	9.72			0.00	2.3212	0.00	9.72	0.7157	(7)+3.18
29	10.08			6.33	2.3212	(14)	3.75	0.7157	(2)
30	10.18			5.33	2.3212	(9)	4.85	0.7157	(1)
31		9.47	10.25	0.00	2.3212	0.00	10.25	0.7157	7.34
					Subtotals:	270			132

* 0.7771 hours added (mean of difference between observed and official day length in January).

** Assumed nets set @ 1200 and pulled @ 1200 where not specifically observed; (.7771 hrs/2) added for half-days.

Appendix Table 5.3 Estimation of outer Ship Canal Bay steelhead takes in February, 1987.

Date	Official Hours of Light	Adjusted Official Hours of Light*	Lit Hours Gear Set**	Netted Daylight Steelhead Take Rate	Estimated Steelhead Takes	Lit Hours Gear not Set	Non-netted Daylight Steelhead Take Rate	Estimated Steelhead Takes
1	9.47	10.25	0.00	2.3212	0.00	10.25	0.7157	7.33
2	9.47	10.25	0.00	2.3212	0.00	10.25	0.7157	7.33
3	9.47	10.25	0.00	2.3212	0.00	10.25	0.7157	7.33
4	9.47	10.25	0.00	2.3212	0.00	10.25	0.7157	7.33
5	9.68	10.46	0.00	2.3212	0.00	10.46	0.7157	7.48
6	9.68	10.46	0.00	2.3212	0.00	10.46	0.7157	7.48
7	9.68	10.46	0.00	2.3212	0.00	10.46	0.7157	7.48
8	9.68	10.46	0.00	2.3212	0.00	10.46	0.7157	7.48
9	9.68	10.46	4.97	2.3212	11.54	5.49	0.7157	3.93
10	9.97	10.75	4.99	2.3212	11.58	5.76	0.7157	4.12
11	9.97	10.75	0.00	2.3212	0.00	10.75	0.7157	7.69
12	9.97	10.75	0.00	2.3212	0.00	10.75	0.7157	7.69
13	9.97	10.75	0.00	2.3212	0.00	10.75	0.7157	7.69
14	9.97	10.75	0.00	2.3212	0.00	10.75	0.7157	7.69
15	10.22	11.00	0.00	2.3212	0.00	11.00	0.7157	7.87
16	10.22	11.00	0.00	2.3212	0.00	11.00	0.7157	7.87
17	10.22	11.00	0.00	2.3212	0.00	11.00	0.7157	7.87
18	10.22	11.00	0.00	2.3212	0.00	11.00	0.7157	7.87
19	10.22	11.00	0.00	2.3212	0.00	11.00	0.7157	7.87
20	10.50	11.28	0.00	2.3212	0.00	11.28	0.7157	8.07
21	10.50	11.28	0.00	2.3212	0.00	11.28	0.7157	8.07
22	10.50	11.28	0.00	2.3212	0.00	11.28	0.7157	8.07
23	10.50	11.28	0.00	2.3212	0.00	11.28	0.7157	8.07
24	10.50	11.28	0.00	2.3212	0.00	11.28	0.7157	8.07
25	10.78	11.56	0.00	2.3212	0.00	11.56	0.7157	8.27
26	10.78	11.56	0.00	2.3212	0.00	11.56	0.7157	8.27
27	10.78	11.56	0.00	2.3212	0.00	11.56	0.7157	8.27
28	10.78	11.56	0.00	2.3212	0.00	11.56	0.7157	8.27
				Subtotals:	23			211

* 0.7771 hours added (mean of difference between observed and official day length in January).

** Assumed nets set @ 1200 and pulled @ 1200 where not specifically observed; (.7771 hrs/2) added for half-days.

Appendix Table 5.4 Estimation of outer Ship Canal Bay steelhead takes in March, 1987.

Date	Official Hours of Light	Adjusted Official Hours of Light*	Lit Hours Gear Set	Netted Daylight Steelhead Take Rate	Estimated Steelhead Takes	Lit Hours Gear not Set	Non-netted Daylight Steelhead Take Rate	Estimated Steelhead Takes
1	10.78	11.56	0.00	2.3212	0.00	11.56	0.7157	8.27
2	11.07	11.85	0.00	2.3212	0.00	11.85	0.7157	8.48
3	11.07	11.85	0.00	2.3212	0.00	11.85	0.7157	8.48
4	11.07	11.85	0.00	2.3212	0.00	11.85	0.7157	8.48
5	11.07	11.85	0.00	2.3212	0.00	11.85	0.7157	8.48
6	11.07	11.85	0.00	2.3212	0.00	11.85	0.7157	8.48
7	11.37	12.15	0.00	2.3212	0.00	12.15	0.7157	8.69
8	11.37	12.15	0.00	2.3212	0.00	12.15	0.7157	8.69
9	11.37	12.15	0.00	2.3212	0.00	12.15	0.7157	8.69
10	11.37	12.15	0.00	2.3212	0.00	12.15	0.7157	8.69
11	11.37	12.15	0.00	2.3212	0.00	12.15	0.7157	8.69
12	11.65	12.43	0.00	2.3212	0.00	12.43	0.7157	8.89
13	11.65	12.43	0.00	2.3212	0.00	12.43	0.7157	8.89
14	11.65	12.43	0.00	2.3212	0.00	12.43	0.7157	8.89
15	11.65	12.43	0.00	2.3212	0.00	12.43	0.7157	8.89
16	11.65	12.43	0.00	2.3212	0.00	12.43	0.7157	8.89
17	11.93	12.71	0.00	2.3212	0.00	12.71	0.7157	9.09
18	11.93	12.71	0.00	2.3212	0.00	12.71	0.7157	9.09
19	11.93	12.71	0.00	2.3212	0.00	12.71	0.7157	9.09
20	11.93	12.71	0.00	2.3212	0.00	12.71	0.7157	9.09
21	11.93	12.71	0.00	2.3212	0.00	12.71	0.7157	9.09
22	12.25	13.03	0.00	2.3212	0.00	13.03	0.7157	9.32
23	12.25	13.03	0.00	2.3212	0.00	13.03	0.7157	9.32
24	12.25	13.03	0.00	2.3212	0.00	13.03	0.7157	9.32
25	12.25	13.03	0.00	2.3212	0.00	13.03	0.7157	9.32
26	12.25	13.03	0.00	2.3212	0.00	13.03	0.7157	9.32
27	12.53	13.31	0.00	2.3212	0.00	13.31	0.7157	9.52
28	12.53	13.31	0.00	2.3212	0.00	13.31	0.7157	9.52
29	12.53	13.31	0.00	2.3212	0.00	13.31	0.7157	9.52
30	12.53	13.31	0.00	2.3212	0.00	13.31	0.7157	9.52
31	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
				Subtotals:	0			279

* 0.7771 hours added (mean of difference between observed and official day length in January).

Appendix Table 5.5 Estimation of outer Ship Canal Bay steelhead takes in April, 1987.

Date	Official Hours of Light	Adjusted Official Hours of Light*	Lit Hours Gear Set	Netted Daylight Steelhead Take Rate	Estimated Steelhead Takes	Lit Hours Gear not Set	Non-netted Daylight Steelhead Take Rate	Estimated Steelhead Takes
1	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
2	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
3	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
4	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
5	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
6	12.83	13.61	0.00	2.3212	0.00	13.61	0.7157	9.74
7	13.12	13.90	0.00	2.3212	0.00	13.90	0.7157	9.95
8	13.12	13.90	0.00	2.3212	0.00	13.90	0.7157	9.95
9	13.12	13.90	0.00	2.3212	0.00	13.90	0.7157	9.95
10	13.12	13.90	0.00	2.3212	0.00	13.90	0.7157	9.95
11	13.38	14.16	0.00	2.3212	0.00	14.16	0.7157	10.13
12	13.38	14.16	0.00	2.3212	0.00	14.16	0.7157	10.13
13	13.38	14.16	0.00	2.3212	0.00	14.16	0.7157	10.13
14	13.38	14.16	0.00	2.3212	0.00	14.16	0.7157	10.13
15	13.38	14.16	0.00	2.3212	0.00	14.16	0.7157	10.13
16	13.68	14.46	0.00	2.3212	0.00	14.46	0.7157	10.35
17	13.68	14.46	0.00	2.3212	0.00	14.46	0.7157	10.35
18	13.68	14.46	0.00	2.3212	0.00	14.46	0.7157	10.35
19	13.68	14.46	0.00	2.3212	0.00	14.46	0.7157	10.35
20	13.68	14.46	0.00	2.3212	0.00	14.46	0.7157	10.35
21	13.95	14.73	0.00	2.3212	0.00	14.73	0.7157	10.54
22	13.95	14.73	0.00	2.3212	0.00	14.73	0.7157	10.54
23	13.95	14.73	0.00	2.3212	0.00	14.73	0.7157	10.54
24	13.95	14.73	0.00	2.3212	0.00	14.73	0.7157	10.54
25	13.95	14.73	0.00	2.3212	0.00	14.73	0.7157	10.54
				Subtotals:	0			253
				5-month Totals:	626			978

Total netting takes: 626
Total non-netting takes: 978
1604

Total hatchery takes: 807
Total wild takes: 797
1604

* 0.7771 hours added (mean of difference between observed and official day length in January).

Appendix Table 5.6 Daily hatchery and wild steelhead takes by sea lions in outer Ship Canal Bay, Dec. 1986.

Month	Day	Estimated Total Steelhead Takes	Hat. Fraction	No. S'head	Wild Fraction	No. S'head	Total S'head
12	1	22.31	0.750	16.73	0.250	5.58	22.31
	2	21.91	0.750	16.43	0.250	5.48	21.91
	3	21.91	0.750	16.43	0.250	5.48	21.91
	4	14.43	0.750	10.82	0.250	3.61	14.43
	5	6.76	0.750	5.07	0.250	1.69	6.76
	6	6.76	0.750	5.07	0.250	1.69	6.76
	7	14.13	1.000	14.13	0.000	0.00	14.13
	8	21.59	1.000	21.59	0.000	0.00	21.59
	9	21.59	1.000	21.59	0.000	0.00	21.59
	10	21.59	1.000	21.59	0.000	0.00	21.59
	11	14.13	1.000	14.13	0.000	0.00	14.13
	12	6.59	1.000	6.59	0.000	0.00	6.59
	13	6.59	1.000	6.59	0.000	0.00	6.59
	14	13.90	0.750	10.43	0.250	3.48	13.90
	15	21.36	0.750	16.02	0.250	5.34	21.36
	16	21.36	0.750	16.02	0.250	5.34	21.36
	17	21.36	0.750	16.02	0.250	5.34	21.36
	18	13.80	0.750	10.35	0.250	3.45	13.80
	19	6.57	0.750	4.93	0.250	1.64	6.57
	20	6.57	0.750	4.93	0.250	1.64	6.57
	21	13.80	0.775	10.70	0.225	3.11	13.80
	22	21.22	0.775	16.45	0.225	4.77	21.22
	23	13.69	0.775	10.61	0.225	3.08	13.69
	24	6.55	0.775	5.08	0.225	1.47	6.55
	25	6.55	0.775	5.08	0.225	1.47	6.55
	26	6.55	0.775	5.08	0.225	1.47	6.55
	27	6.57	0.775	5.09	0.225	1.48	6.57
	28	13.67	0.800	10.94	0.200	2.73	13.67
	29	21.29	0.800	17.03	0.200	4.26	21.29
	30	13.67	0.800	10.94	0.200	2.73	13.67
	31	6.57	0.800	5.26	0.200	1.31	6.57
			Sum:	358	Sum:	78	Sum: 435

Appendix Table 5.7 Daily hatchery and wild steelhead takes by sea lions in outer Ship Canal Bay, Jan. 1987.

Month	Day	Estimated Total Steelhead Takes	Hat. Fraction	No. S'head	Wild Fraction	No. S'head	Total S'head
1	1	6.61	0.800	5.29	0.200	1.32	6.61
	2	6.61	0.800	5.29	0.200	1.32	6.61
	3	6.61	0.800	5.29	0.200	1.32	6.61
	4	13.67	0.656	8.97	0.344	4.70	13.67
	5	21.40	0.656	14.04	0.344	7.36	21.40
	6	21.68	0.656	14.22	0.344	7.46	21.68
	7	22.54	0.656	14.79	0.344	7.75	22.54
	8	17.00	0.656	11.15	0.344	5.85	17.00
	9	18.50	0.656	12.14	0.344	6.36	18.50
	10	6.69	0.656	4.39	0.344	2.30	6.69
	11	2.00	0.833	1.67	0.167	0.33	2.00
	12	26.00	0.833	21.66	0.167	4.34	26.00
	13	21.54	0.833	17.94	0.167	3.60	21.54
	14	21.96	0.833	18.29	0.167	3.67	21.96
	15	20.17	0.833	16.80	0.167	3.37	20.17
	16	10.25	0.833	8.54	0.167	1.71	10.25
	17	6.87	0.833	5.72	0.167	1.15	6.87
	18	6.87	0.613	4.21	0.387	2.66	6.87
	19	6.87	0.613	4.21	0.387	2.66	6.87
	20	6.87	0.613	4.21	0.387	2.66	6.87
	21	14.32	0.613	8.78	0.387	5.54	14.32
	22	24.39	0.613	14.95	0.387	9.44	24.39
	23	14.32	0.613	8.78	0.387	5.54	14.32
	24	7.01	0.613	4.30	0.387	2.71	7.01
	25	7.01	0.393	2.75	0.607	4.26	7.01
	26	7.14	0.393	2.81	0.607	4.33	7.14
	27	13.97	0.393	5.49	0.607	8.48	13.97
	28	10.18	0.393	4.00	0.607	6.18	10.18
	29	16.00	0.393	6.29	0.607	9.71	16.00
	30	10.00	0.393	3.93	0.607	6.07	10.00
	31	7.34	0.393	2.88	0.607	4.46	7.34
			Sum:	264	Sum:	139	Sum: 402

Appendix Table 5.8 Daily hatchery and wild steelhead takes by sea lions in outer Ship Canal Bay, Feb. 1987.

Month	Day	Estimated Total Steelhead Takes	Hat. Fraction	No. S'head	Wild Fraction	No. S'head	Total S'head
2	1	7.34	0.343	2.52	0.657	4.82	7.34
	2	7.34	0.343	2.52	0.657	4.82	7.34
	3	7.34	0.343	2.52	0.657	4.82	7.34
	4	7.34	0.343	2.52	0.657	4.82	7.34
	5	7.49	0.343	2.57	0.657	4.92	7.49
	6	7.49	0.343	2.57	0.657	4.92	7.49
	7	7.49	0.343	2.57	0.657	4.92	7.49
	8	7.49	0.293	2.19	0.707	5.30	7.49
	9	15.47	0.293	4.53	0.707	10.94	15.47
	10	15.70	0.293	4.60	0.707	11.10	15.70
	11	7.69	0.293	2.25	0.707	5.44	7.69
	12	7.69	0.293	2.25	0.707	5.44	7.69
	13	7.69	0.293	2.25	0.707	5.44	7.69
	14	7.69	0.293	2.25	0.707	5.44	7.69
	15	7.87	0.483	3.80	0.517	4.07	7.87
	16	7.87	0.483	3.80	0.517	4.07	7.87
	17	7.87	0.483	3.80	0.517	4.07	7.87
	18	7.87	0.483	3.80	0.517	4.07	7.87
	19	7.87	0.483	3.80	0.517	4.07	7.87
	20	8.07	0.483	3.90	0.517	4.17	8.07
	21	8.07	0.483	3.90	0.517	4.17	8.07
	22	8.07	0.672	5.42	0.328	2.65	8.07
	23	8.07	0.672	5.42	0.328	2.65	8.07
	24	8.07	0.672	5.42	0.328	2.65	8.07
	25	8.27	0.672	5.56	0.328	2.71	8.27
	26	8.27	0.672	5.56	0.328	2.71	8.27
	27	8.27	0.672	5.56	0.328	2.71	8.27
	28	8.27	0.672	5.56	0.328	2.71	8.27
			Sum:	103	Sum:	131	Sum: 234

Appendix Table 5.9 Daily hatchery and wild steelhead takes by sea lions in outer Ship Canal Bay, Mar. 1987.

Month	Day	Estimated Total Steelhead Takes	Hat. Fraction	No. S'head	Wild Fraction	No. S'head	Total S'head
3	1	8.27	0.404	3.34	0.596	4.93	8.27
	2	8.48	0.404	3.43	0.596	5.05	8.48
	3	8.48	0.404	3.43	0.596	5.05	8.48
	4	8.48	0.404	3.43	0.596	5.05	8.48
	5	8.48	0.404	3.43	0.596	5.05	8.48
	6	8.48	0.404	3.43	0.596	5.05	8.48
	7	8.70	0.404	3.51	0.596	5.19	8.70
	8	8.70	0.136	1.18	0.864	7.52	8.70
	9	8.70	0.136	1.18	0.864	7.52	8.70
	10	8.70	0.136	1.18	0.864	7.52	8.70
	11	8.70	0.136	1.18	0.864	7.52	8.70
	12	8.90	0.136	1.21	0.864	7.69	8.90
	13	8.90	0.136	1.21	0.864	7.69	8.90
	14	8.90	0.136	1.21	0.864	7.69	8.90
	15	8.90	0.514	4.57	0.486	4.33	8.90
	16	8.90	0.514	4.57	0.486	4.33	8.90
	17	9.10	0.514	4.68	0.486	4.42	9.10
	18	9.10	0.514	4.68	0.486	4.42	9.10
	19	9.10	0.514	4.68	0.486	4.42	9.10
	20	9.10	0.514	4.68	0.486	4.42	9.10
	21	9.10	0.514	4.68	0.486	4.42	9.10
	22	9.33	0.257	2.40	0.743	6.93	9.33
	23	9.33	0.257	2.40	0.743	6.93	9.33
	24	9.33	0.257	2.40	0.743	6.93	9.33
	25	9.33	0.257	2.40	0.743	6.93	9.33
	26	9.33	0.257	2.40	0.743	6.93	9.33
	27	9.53	0.257	2.45	0.743	7.08	9.53
	28	9.53	0.257	2.45	0.743	7.08	9.53
	29	9.53	0.000	0.00	1.000	9.53	9.53
	30	9.53	0.000	0.00	1.000	9.53	9.53
	31	9.74	0.000	0.00	1.000	9.74	9.74
			Sum:	82	Sum:	197	Sum: 279

Appendix Table 5.10 Daily hatchery and wild steelhead takes by sea lions in outer Ship Canal Bay, Apr. 1987.

Month	Day	Estimated Total Steelhead Takes	Hat. Fraction	No. S'head	Wild Fraction	No. S'head	Total S'head
4	1	9.74	0.000	0.00	1.000	9.74	9.74
	2	9.74	0.000	0.00	1.000	9.74	9.74
	3	9.74	0.000	0.00	1.000	9.74	9.74
	4	9.74	0.000	0.00	1.000	9.74	9.74
	5	9.74	0.000	0.00	1.000	9.74	9.74
	6	9.74	0.000	0.00	1.000	9.74	9.74
	7	9.95	0.000	0.00	1.000	9.95	9.95
	8	9.95	0.000	0.00	1.000	9.95	9.95
	9	9.95	0.000	0.00	1.000	9.95	9.95
	10	9.95	0.000	0.00	1.000	9.95	9.95
	11	10.13	0.000	0.00	1.000	10.13	10.13
	12	10.13	0.000	0.00	1.000	10.13	10.13
	13	10.13	0.000	0.00	1.000	10.13	10.13
	14	10.13	0.000	0.00	1.000	10.13	10.13
	15	10.13	0.000	0.00	1.000	10.13	10.13
	16	10.35	0.000	0.00	1.000	10.35	10.35
	17	10.35	0.000	0.00	1.000	10.35	10.35
	18	10.35	0.000	0.00	1.000	10.35	10.35
	19	10.35	0.000	0.00	1.000	10.35	10.35
	20	10.35	0.000	0.00	1.000	10.35	10.35
	21	10.54	0.000	0.00	1.000	10.54	10.54
	22	10.54	0.000	0.00	1.000	10.54	10.54
	23	10.54	0.000	0.00	1.000	10.54	10.54
	24	10.54	0.000	0.00	1.000	10.54	10.54
	25	10.54	0.000	0.00	1.000	10.54	10.54
			Sum:	0	Sum:	253	Sum: 253