Washington Department of Game

Fishery Management Report 86-20

CONTROL OF CALIFORNIA SEA LION PREDATION OF WINTER-RUN STEELHEAD AT THE HIRAM M. CHITTENDEN LOCKS, SEATTLE, DECEMBER 1985-APRIL 1986

with

Observations on Sea Lion Abundance and Distribution in Puget Sound

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October 1986

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Cover Photos: *Upper left:* *California sea lions rafted in Elliott Bay. Pat Gearin photo.*

Lower: *California sea lion consuming a steelhead at the Chittenden Locks. Grant Haller photo courtesy of the* Post-Intelligencer.

ABSTRACT

A study/predation control program was conducted at the Hiram M. Chittenden Locks in Seattle, Washington from 30 December through 23 April 1986. The principal objectives were to document the rate and effects of predation on winter-run steelhead (*Salmo gairdneri* Richardson) by California sea lions (*Zalophus californianus*); to control and minimize predation in order to increase the escapement of wild winter-runs to the Lake Washington watershed; to evaluate and recommend potential long term procedures for control of steelhead predation; and to document the abundance and distribution of California sea lions in Puget Sound.

The control methods tested focused primarily on a coordinated use of seal bombs and activation of acoustic harassment devices (AHDs). These methods were employed only at the Chittenden Locks and immediate vicinity (inner Salmon Bay). Documentation of sea lion abundance and distribution occurred mainly in east central Puget Sound (Meadow Pt. to Alki Pt.).

The sea lion predation rate on returning winter-run steelhead was determined through an 8-day observation period where sea lions were allowed to predate freely. Observations were conducted daily (dawn to dusk), often round-the-clock.

Harassment was conducted for 83 days, from 7 January through 1 April. The initial form of harassment (seal bombs thrown in concert with AHD start-up) was almost 100% successful in keeping sea lions from their preferred foraging area, as long as harassment was applied. Thus, these methods were not abandoned to experiment on others during the primary harassment phase.

Sea lions were allowed to resume uninhibited predation during a post-harassment phase, designed to check predation rates determined in the pre-harassment phase. The use of AHDs alone, i.e. not in concert with thrown seal bombs, was tested during this period.

From one to five sea lions were present daily at the Chittenden Locks during the pre-harassment phase. Steelhead were predated at an average rate of 19 fish per day, which is extrapolated to an estimated loss of 1213 wild, and 1564 hatchery steelhead over the course of an average run, had there been no harassment.

Harassment reduced successful predation 96.7%, and cut steelhead losses to an estimated 20 wild and 30 hatchery fish during the harassment phase. Observed predation rates during all phases of this study are analyzed in relation to average and expected wild and hatchery winter-run steelhead runs returning to the Lake Washington system.

An estimated 1803 steelhead (919 hatchery, 884 wild) were saved with the partial control program. We estimate that 2685 steelhead (1173 wild, 1512 hatchery) could be saved with a season-long control program.

Boat and aerial surveys were made of marine mammals (principally California sea lions) in Puget Sound (principally Elliott Bay, Shilshole Bay, and Port Gardner). A count of 1015 California sea lions on 1 April 1986 represents the highest count for Washington to date. Total counts at key areas in the study area, as well as descriptions of the most-used haulout sites, are provided.

California sea lions habituated to AHDs used alone during the post-harassment period, and resumed predation on steelhead at a significant level, although less than that observed during the pre-harassment phase.

Seal bombs thrown in concert with activated AHDs were effective in keeping California sea lions from heavily predating winter-run steelhead returning to the Lake Washington system. These methods are proposed for control that may be required in the future, however recommendations are detailed for experiments with alternative control methods which were not tested. The number of California sea lions frequenting the study area is expected to increase in the future, and sea lion interactions with fisheries and with anadromous fish entering the Lake Washington system are expected to continue, if not escalate.

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Supplies, equipment, and partial funding for the project were provided by the Washington Department of Game. The U.S. Army Corps of Engineers (Seattle District) also contributed funds in support of temporary staff.

This project would not have been possible without the significant cooperation and logistical support of the Seattle District of the U.S. Army Corps of Engineers. We are particularly appreciative of the support we received from biologist Jack Thompson of the Corps, whose good cheer and helpful advice and coordination at the Locks frequently warmed cold, rainy mornings. Jack also contributed extensive comments on the initial report draft.

We appreciate the assistance from all of the other individuals who participated in various aspects of this study, most of whom were volunteers, and are listed in Appendix Table 9.2. We also express special appreciation to the Seattle Post-Intelligencer for providing the photo used on the cover, and to KING-5 News for providing a helicopter and pilot for aerial survey of sea lion distribution and abundance in Puget Sound.

We express special thanks to the National Marine Fisheries Service of NOAA (Enforcement Division and National Marine Mammal Laboratory) who provided full-time support for one of the observers at the Locks, as well as laboratory facilities and assistance. In particular, Mike Albertson forewent all of his regular enforcement activities to work full-time at the Locks, for which we are very grateful.

Staff of the Visitor's Center at the Chittenden Locks, and members of Greenpeace volunteered advice and data that was helpful in planning the study. Substantial assistance in data gathering, observation, and planning was provided by staff of the Muckleshoot Tribe's Fisheries Department, for which we are very grateful.

Dr. Steven Millard of the University of Washington Health Sciences' Biostatistical Consulting Service corroborated the authors' selection of statistical methods, and offered helpful suggestions for improvement of data presentation. Bob Everitt graciously agreed to review the manuscript.

Finally, we extend our appreciation to all of the Locks personnel for their helpful cooperation.

1.0 INTRODUCTION

This report summarizes the 1985-86 investigations of California sea lion (*Zalophus californianus*) predation on steelhead trout (*Salmo gairdneri*) near the Lake Washington Ship Canal fishway at the Hiram M. Chittenden Locks (hereafter referred to as "Locks") (Figure 1.1). (Throughout this report we refer to the following areas: Shilshole Bay refers to marine areas west of the narrowed mouth of Salmon Bay, the latter commencing at the southern entrance to the Shilshole Bay marina; Salmon Bay refers to estuarine waters between the southern entrance to the Shilshole Bay marina and the Locks spillway dam.)

California sea lions first began appearing at the Locks with regularity six to seven years ago according to Locks personnel, Department of Game Wildlife Agents and biologists, and local fishermen (Appendix 9.1). Initially, in the early 1980's, only one or two sea lions were observed at the Locks by steelhead plunk anglers and Locks personnel. In the last several years, however, at least three to four or more sea lions have been observed regularly at the Locks. The sea lions also appear to be arriving earlier in the year (October) and staying later (May) in the last several years.

The presence of sea lions in this area corresponds to an influx of sea lions into Puget Sound, first noted in Port Gardner near Everett, Washington in April 1979 (Everitt et al. 1980). Everitt et al. (1979) reported no sea lion hauling areas east of Race Rocks in the Strait of Juan de Fuca in 1978. The appearance of 108 sea lions at Port Gardner in the spring of 1979 represented a change in distribution from previous years, and was perhaps related to a local abundance of prey (Everitt et al. 1980; Everitt et al. 1981).

The months when sea lions are observed at the Locks corresponds to the timing of the winter steelhead run which passes through the Locks to spawn in the tributaries of Lakes Washington and Sammamish. The presence of sea lions also overlaps to some degree the coho salmon and cutthroat trout runs entering the system. The coho salmon run (estimated at 55,110 hatchery plus wild in 1985) extends from early September through February, with the peak occurring in the first week of October (T. Flynn, WDF, pers. comm.).

Although sea lions have been observed to predate steelhead at the Locks for four to five years, it appears that the predation rate may have increased in the last several years. This may be due in part to the increase in sea lion numbers, and to their extended presence in the vicinity.

(Throughout this report, a fish "run" refers to all of the fish [in this case steelhead] returning to the watershed of origin [Lake Washington]. A run may include hatchery fish only, wild fish only,

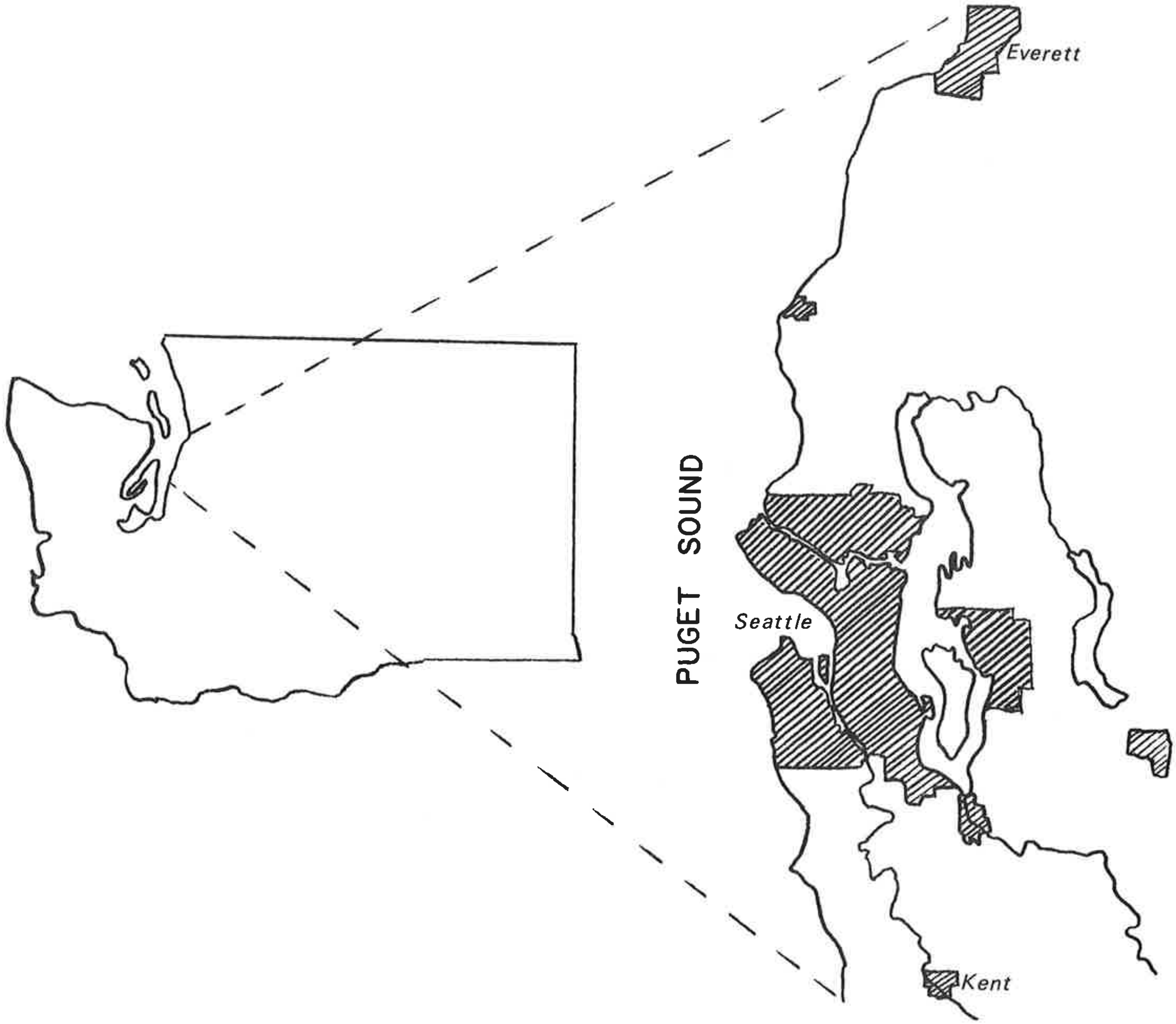


Figure 1.1. Location of the study area in relation to western Washington, Seattle, and vicinity.

or both, depending on the context. "Escapement" is the minimum number of [steelhead] that is required to adequately seed the available spawning and rearing habitat. As a practical example, the escapement goal for the Lake Washington watershed is 1600 wild steelhead, while the returning run of wild fish averages about 2400.)

Some initial steps were taken to address the sea lion interaction problem in 1984 when seal bombs were used intermittently by State Wildlife Agents to chase away sea lions. In 1984, fixed acoustic harassment devices (AHD's) were tested at the Locks by State Wildlife Biologists with mixed results. The devices worked for only a short time before the sea lions appeared to ignore or habituate to their sound.

The Corps of Engineers began gathering organized observations of sea lion presence at the Locks in February and March 1985 (Appendix Table 9.4). These data, at a minimum, indicate that at least one to three sea lions were present with regularity at the Locks between 4 February and 28 March.

In the winter of 1985, 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 observed taken.

It became apparent that there was a serious potential resource conflict when the 1985 wild winter-run steelhead spawning escapement in the Lake Washington watershed was estimated to total only 474 fish (Freymond and Foley 1986). Concern was voiced by various user groups, including sport fishermen and local Indian tribes, that the sea lions were seriously depleting the wild and hatchery steelhead runs, and also disrupting and competing with on-going sport and tribal fisheries. The winter steelhead run which migrates through Salmon Bay supports at least four active fisheries, including a Salmon and Shilshole Bay commercial fishery (Muckleshoot and Suquamish Tribes), plus sport fisheries at Salmon Bay, and in the Cedar and Sammamish Rivers.

We conducted this study during the 1985-86 steelhead run to estimate predation impact and to determine methods for controlling and minimizing such predation. A primary objective of the study effort was to increase the escapement of the 1986 wild winter steelhead run by reducing overall sea lion predation. The overall objectives were to:

1: Document the rate and effect of predation by sea lions on steelhead trout;

2: Control and minimize predation, thereby increasing steelhead escapement;

3: Conduct harassment experiments (on a time-available basis) testing various methods to determine the most efficient and effective control measures for long term usage;

5: Based on the results of these experiments, evaluate and recommend potential long term procedures for steelhead predation control;

6: Collect data on the abundance, distribution, and general biology of California sea lions in Puget Sound; and

7. Provide recommendations for future sea lion studies at the Locks and in Puget Sound.

This report also provides background information on California sea lions regarding their biology, distribution, and abundance in Puget Sound. Recommendations and cost analysis figures are provided regarding future studies at the Locks and in Puget Sound.

2.0 MATERIALS AND METHODS

In late December 1985, a cooperative research effort was undertaken at the Locks in order to document interactions between California sea lions and winter-run steelhead trout. This study was conducted by the Washington Department of Game in cooperation with the National Marine Fisheries Service (Enforcement Division and National Marine Mammal Laboratory) and the Muckleshoot Indian Tribe. In addition, input into the planning of this project was provided by members of the U.S. Army Corps of Engineers (Seattle District), Suquamish Indian Tribe, Washington Department of Fisheries, Greenpeace, park technicians of the Hiram M. Chittenden Locks Visitors' Center, and private citizens. A list of participants and their affiliations is provided in Appendix Table 9.2.

Data was collected during 102 days of observation between 30 December 1985 and 17 April 1986.

Collection of data on sea lion distribution and abundance was incidental to the principal objectives relating to controlling steelhead losses in 1985-86.

In order to achieve the objectives relating to control of predation, we divided the study into three phases:

1: Estimation of predation losses (Pre-harassment);

2: Predation control (Harassment); and

3: Post-harassment assessment and experimentation.

2.1 Study Sites

The primary study site was within the Salmon Bay 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 2.1). The Salmon 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 the inland waters, principally Lakes Union and Washington. About 100,000 recreational and commercial vessels and more than two million tons of cargo annually pass through the Locks.

The Lake Washington Ship Canal is of major biological importance, being the migratory corridor from Puget Sound for major runs of anadromous salmon and trout of great economic value destined for the Lake Washington and Lake Sammamish watersheds. Three species of salmon, including chinook, coho, and sockeye, and two species of sea-run trout (steelhead and cutthroat) utilize this route for passage between salt water and freshwater spawning and rearing areas in these lakes and their tributaries.

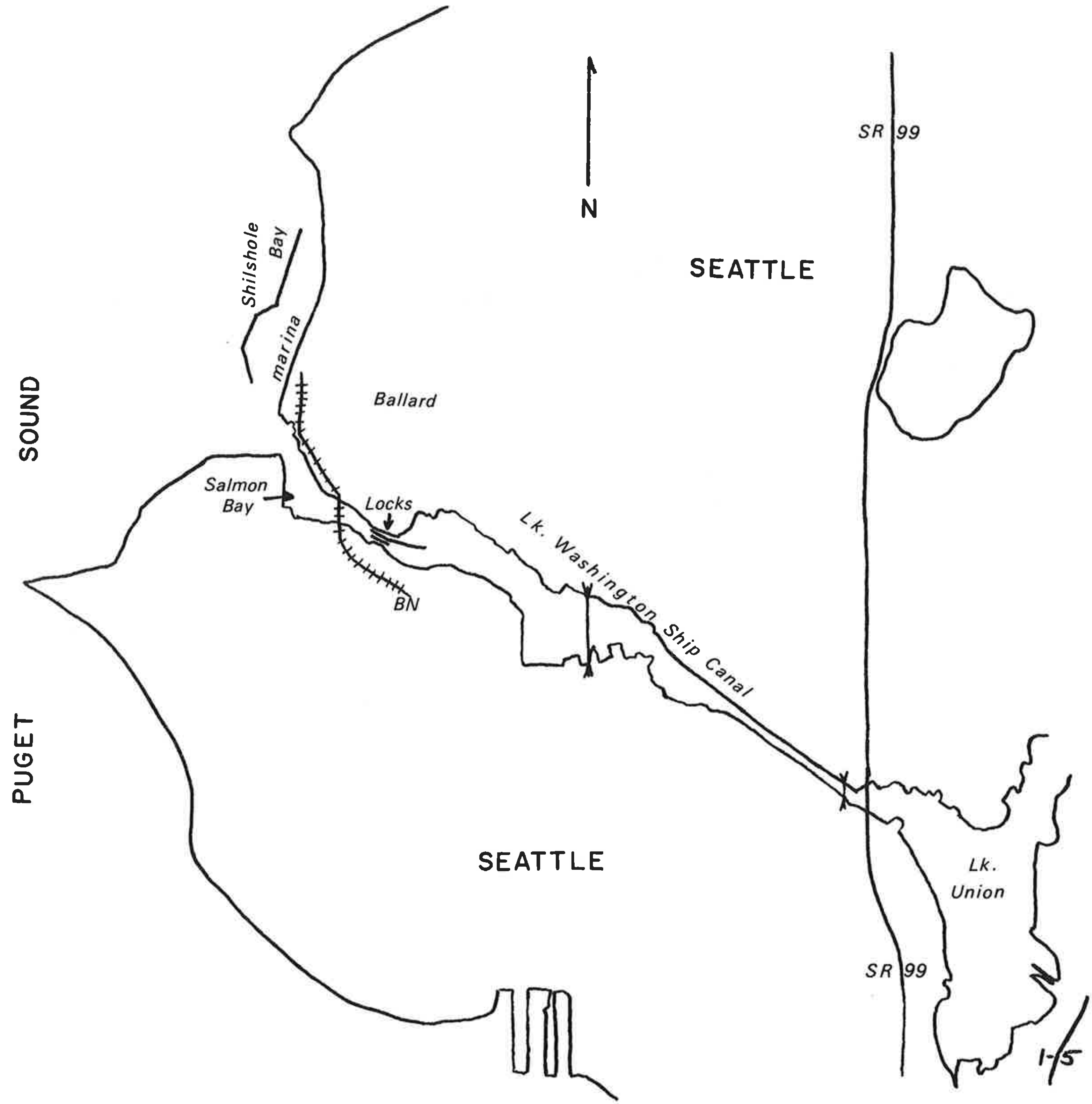


Figure 2.1. Vicinity map of Shilshole Bay, Salmon Bay, and the Hiram Chittenden ("Government") Locks.

The Lake Washington Ship Canal and associated Chittenden Locks was constructed by the 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 of the system. An increase in "attraction water" near the fishway entrance was also incorporated into the new facilities at that time.

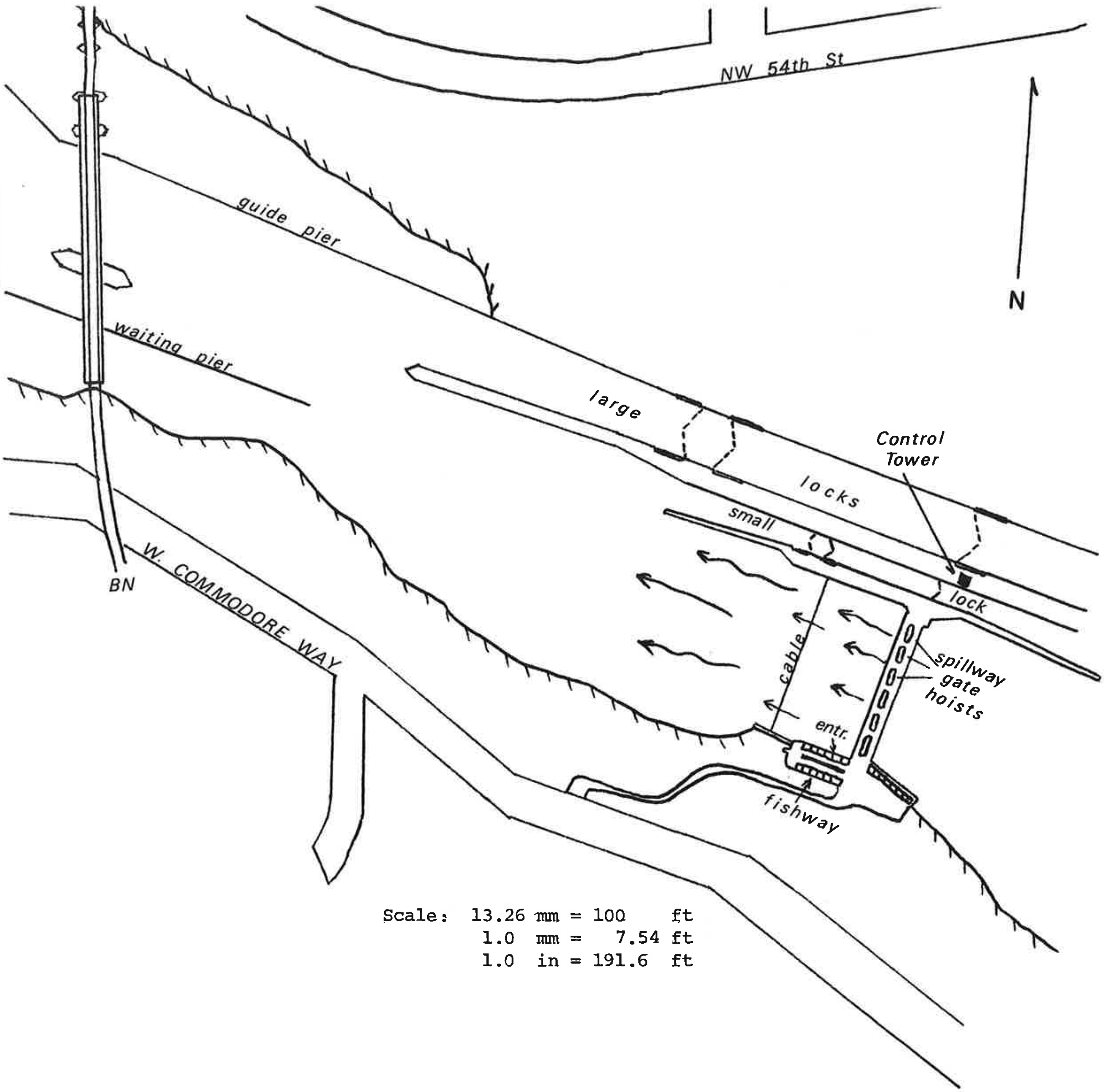
Vessel passage through the Ship Canal is accomplished using either of two parallel locking chambers (one small and one large). The small lock is 9.1m (30 ft) in width and 47.7m (150 ft) in length. The large lock is 24.3m (80 ft) in width and 251m (825 ft) in length. Each has an average depth of 15.1m (50 ft) (Figure 2.2).

In addition to the primary study site in Salmon Bay, several other areas are considered secondary study sites as they related to sea lion distribution and occurrence within the Locks area. In general, these secondary areas included 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 2.3). Hood Canal and the inlets south and west of Case Inlet are not included within the study area. Marine waters surveyed frequently within this study area included Elliott Bay, the Duwamish waterways, West Point, Shilshole Bay, and Meadow Point (Figure 2.4).

2.2 Pre-Harassment Phase

The pre-harassment phase of this study was conducted between 30 December 1985 through 6 January 1986. The objectives during this phase were threefold: to assess overall predation losses of steelhead through derivation of an estimate of the rate of daily predation on steelhead, which could be used 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 by sea lions.

During this eight day period, observers were stationed at the Locks for six 8-hour shifts (0730-1530) and for two continuous 24-hour shifts (Table 4.1). During these shifts observers made rounds by foot around the vicinity of the Locks and observed sea lions and steelhead predation incidents. Data collected included time of sea lion arrival and departure, 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, relative size of fish killed, sex of fish (if possible), and whether the fish was consumed whole, broken apart, or if portions were not eaten. We collected some information on actual foraging behavior, and methods sea lions utilized to capture fish. When possible we noted the location caught fish were first observed and when they were consumed. The pre-harassment phase of the study was terminated at 0530 on 7 January when the harassment phase was initiated.



Scale: 13.26 mm = 100 ft
1.0 mm = 7.54 ft
1.0 in = 191.6 ft

Figure 2.2. Plan view of the Chittenden Locks and spillway dam area.

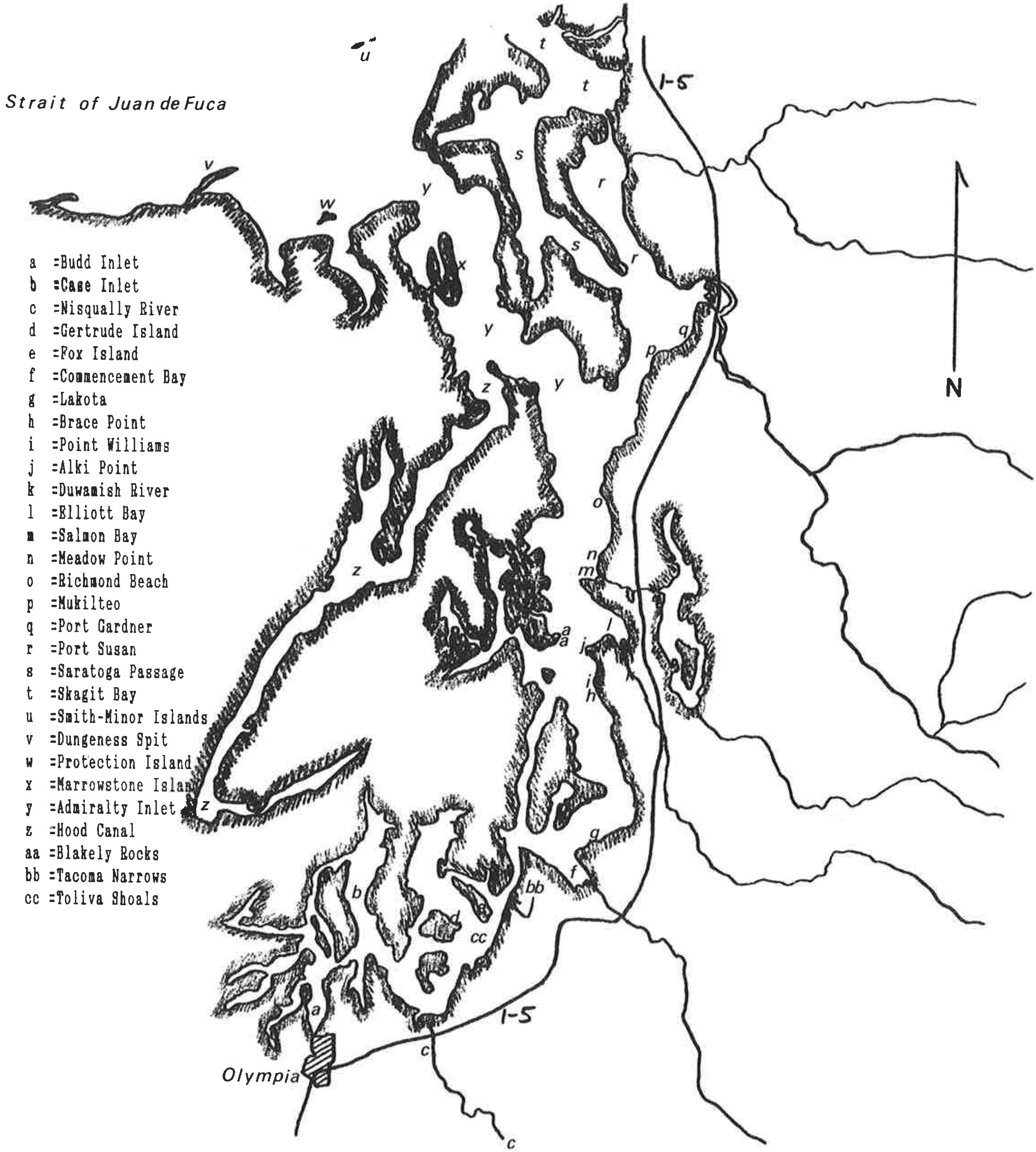


Figure 2.3. Puget Sound areas surveyed by air or boat for abundance and distribution of sea lions.

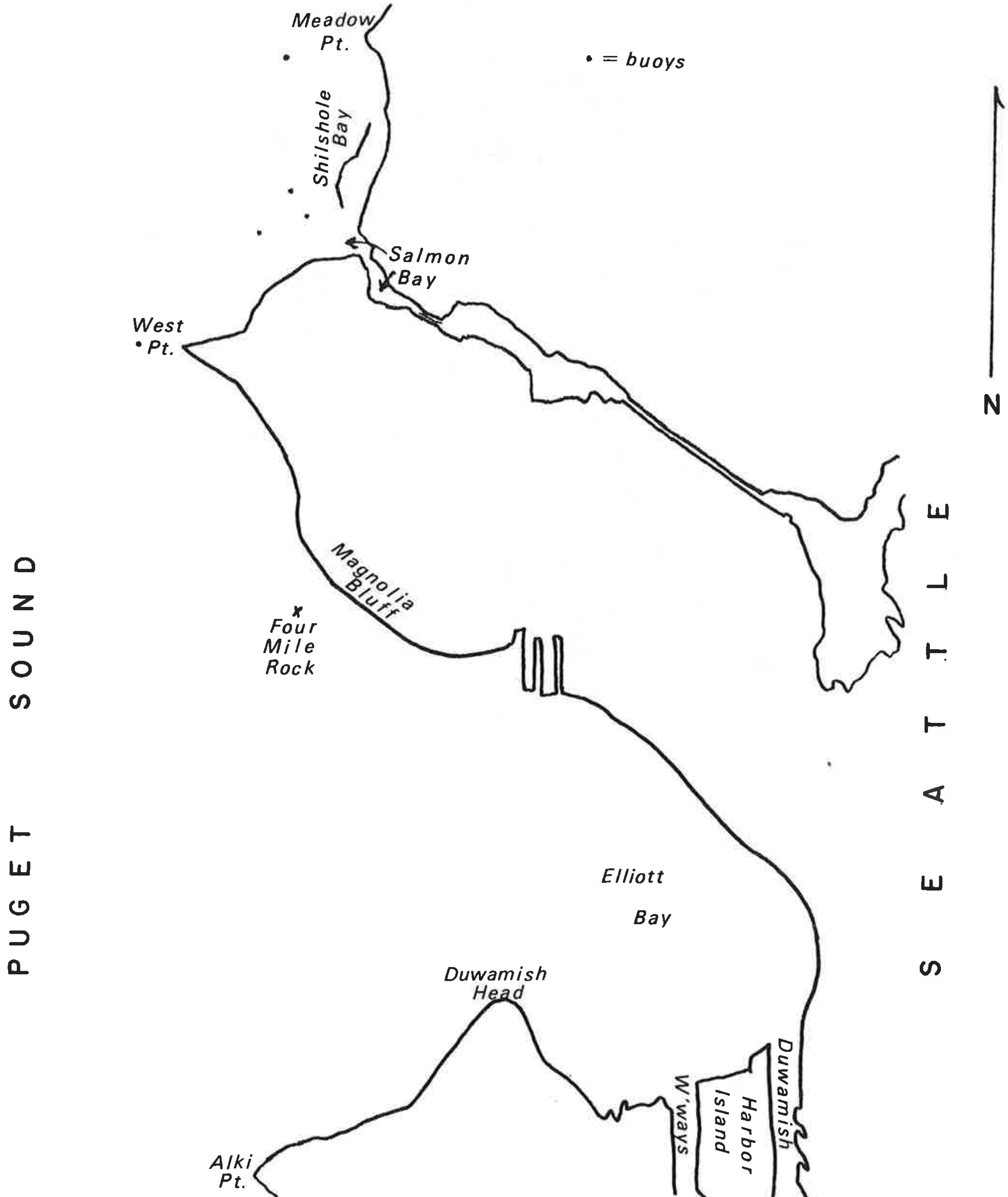


Figure 2.4. Geographic areas near Salmon Bay frequently surveyed by boat for sea lion abundance and distribution.

Our observations were of behavioral events (namely steelhead kills) as defined by Altmann (1973). While strict focal-animal or focal-subgroup sampling was not always possible, we were able to sample (observe) all occurrences of steelhead kill events. This information may be utilized in estimating the rate of occurrence of the behavioral event, as well as temporal changes in the rate by the animal group observed (Altmann 1973), even if not all of the overall population or focal-group can be identified when documenting the behavioral occurences. Thus, while various animals from the greater Alki Point-Port Gardner "population" could be feeding intermittently at the Locks (as opposed to four or five "residents" or repeat predators), this would not invalidate the count data on steelhead kills by the group of sea lions under observation.

Observational techniques were intrinsically the same in the subsequent two phases of the study, although observation was not as continuous during the third phase.

2.3 Harassment Phase

We conducted the harassment phase of the study from 7 January through 2 April 1986. Control of predation was attempted by two methods of sea lion harassment: seal bombs and acoustic harassment devices (AHD's). 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 15-25 feet before exploding, causing a flash of light and a slight percussion in the water.

The AHD device (Sealchaser) was designed and built by Cascade Applied Sciences, Philomath, Oregon, as a method to deter seals and sea lions which are 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 underwater sounds which are within the normal hearing range of pinnipeds (12 to 17 KHz), but are inaudible to fish (Mate and Greenlaw 1982).

We used two AHD devices during this study. One device operated two transducers placed 50m apart near the fishway cable; the other was kept in a small skiff for manual use when chasing sea lions from the Locks area.

The general strategy employed for chasing sea lions from the Locks was to use seal bombs in conjunction with the AHD devices. This was accomplished either by shore-based methods, or by using a 4.7m (15.3 ft) Boston Whaler to chase sea lions from the spillway dam area out into outer Salmon Bay or Shilshole Bay.

We maintained an average of 16 hours of coverage per day during the harassment phase from Monday through Friday. Spot coverage was used on weekends, and averaged about five hours per day. Weekday coverage was generally conducted between 0600-2200 hours. Weekend coverage was more sporadic, but centered on the hours 0600-1800. We conducted three 24-hour shifts during this phase of the study to assess late night and early morning presence and feeding of sea lions.

During all shifts, any sea lion observed was chased out immediately by first throwing several seal bombs. The AHDs on the cable were then turned on. The AHDs were left on for 20 to 30 minutes following the sighting. We tossed seal bombs from shore by the walkway crossing the spillway dam, and also off the finger piers adjacent the small and large locks (Figure 2.2). When the boat was available and directly accessible we used it as a platform to throw seal bombs and engage the mobile AHD. Using the boat was in most cases preferred to shore-based harassment because it enabled the observer to chase the sea lion(s) well out of the spillway dam vicinity. We placed little emphasis on trying to identify sea lions during this phase in order to minimize steelhead predation losses. During this phase we collected data on the number of sea lions present per day, and steelhead predation observed. Data parameters collected were similar to those collected during the initial phase of the study.

2.4 Post-Harassment Phase

Phase three of the study was conducted between 2 April through 11 April. The primary objective of this phase of the study was to verify the beneficial effects of the previous 83 days' harassment (changes in observed predation rate). We also utilized this period to collect more information on sea lion identification and feeding behavior, and to test the AHD device independent of the seal bombs.

The last seal bombs were discharged on 1 April. From 2 April to 8 April, observers were present at the Locks for eight hour shifts (generally 0700-1500). Data collected during this week was similar to that collected during the first phase. We placed particular emphasis on identifying individual sea lions and documenting predation rates and feeding behavior to determine if the same sea lions were present as earlier, and if predation rates and behavior were similar.

The AHD alone was tested from 9 to 11 April. The purpose of this test was to evaluate the short term startle effect of the AHD.

2.5 Adult Steelhead Counts

We made counts of steelhead in the fishway viewing chamber on a daily basis. Due to the variable turbidity of the water in the chamber, however, these counts should only be considered as an index for actual steelhead passage. Some additional notes were made on steelhead schools observed in Salmon Bay, and their reaction to the presence of sea lions. Because of these limitations, we have reported the data in Appendix 9.2 and Appendix Table 9.3.

2.6 Sea Lion Surveys, Census, and Behavior

We decided early in the study that periodic weekly or bi-weekly surveys and censuses would be conducted in the vicinity of Salmon Bay in order to obtain information about the abundance and distribution of sea lions potentially using the Salmon Bay area. Sea lions had been observed in the vicinity near Meadow Point and Duwamish Head in the previous year (Figure 2.4). We surveyed the following areas repeatedly by boat: Meadow Point, Shilshole Bay, Salmon Bay, West Point, Four Mile Rock, Elliott Bay, and the Duwamish waterways (East and West channels) and Duwamish Head. Alki Point was also surveyed three times by boat. We counted sea lions seen during these surveys,and noted what their behavior was, i.e. rafting, fishing, etc. We noted the direction of movement when it could be determined that sea lions were moving in a specific direction. We also recorded any foraging (fishing) behavior.

Two aerial surveys were conducted in early April 1986 to obtain information on the abundance and distribution of sea lions in Puget Sound. We flew the first survey on 1 April in a DeHavilland Beaver; the second survey was flown on 4 April in a Hughes 500 helicopter. Surveys were flown between 400 and 600 feet of altitude between 90 and 130 mph. Aerial slides of major sea lion centers of abundance were taken, and later projected onto a large sheet of white paper, where the images were counted to obtain a total estimate of sea lion numbers in the areas surveyed.

We also took photos during boat and aerial surveys to record specific haul out areas and sea lion behavior. Several trips were made to Port Gardner at Everett in order to collect scat and take photos of hauled out sea lions.

In order to evaluate sea lion feeding habits in areas outside of Salmon Bay, scats and spewings (vomitus) were collected opportunistically during the study from known sea lion haulout sites. Analysis of scats and spewings is one method of evaluating feeding habits of pinnipeds and although limited to some extent, it was favored in this study because it is non-lethal and non-intrusive. Scats and spewings were soaked in soapy water for several days and then broken apart and sorted into identifiable food components through a series of three nested sieves 2.36, 1.40, and 1.00 mm in diameter, respectively. The methods generally followed those described by Treacy and Crawford (1981).

Prey taxa were identified from otolith (fish ear bones) or cephalopod (octopus or squid) beak identification using the National Marine Mammal Laboratory research collection of otoliths and cephalopods.

Primary prey were delineated by determining their percent occurrence in the total number of samples, and their numerical value by counting the number of otoliths or beaks recovered in the samples. No attempt was made to identify fish bones, scales, or other parts at this time due to time constraints.

Notes were made on any other feeding observed in areas outside of Salmon Bay during boat surveys and censuses (Sections 4.4.1 and 4.4.2).

2.7 Alternative Control Methods Evaluation

We recognized that seal bombs and AHDs are not the only methods which may be effective in limiting predation on steelhead by sea lions at the Locks. We broached a very limited evaluation of an engineered solution to the problem through discussions with engineers, biologists, and other technical staff of the Corps of Engineers. Extensive discussions were held with marine mammal experts from the National Marine Fisheries Service regarding the feasibility of capturing California sea lions for transport well out of the Salmon Bay area, and we also reviewed literature pertinent to this option. Some limited testing of recordings of killer whale vocalizations occurred at the Locks during the post-harassment phase, principally to observe the more obvious effects on sea lions or steelhead.

3.0 SPECIES ACCOUNTS

3.1 Steelhead

Steelhead are the sea-run (anadromous) form of rainbow trout (*Salmo gairdneri* Richardson). The species occurs in two ecotypes, winter-runs and summer-runs, which are principally isolated genetically through temporal and, often, geographic separation. (Virtually all steelhead returning to the Lake Washington watershed are of the winter-run form.) The natural distribution of the species occurs from southern California north to the Bering Sea, and west into Soviet and Japanese Pacific coastal regions (Scott and Crossman 1973).

Steelhead exhibit a highly variable life history. Wild steelhead characteristically spawn in freshwater streams where juveniles rear for two years prior to emigration to salt water. Marine residence prior to the spawning run typically spans slightly less than two years. However, freshwater residence as well as marine residence may vary from one to three or more years, with virtually all possible combinations of fresh and marine residence being exhibited (Crawford et al. 1977).

Wild winter-runs returning to Lake Washington exhibit a limited number of life history classes, with most rearing two years in the lake system, and returning to spawn after about two years of marine growth. The sex ratio of the returning population is nearly 1:1. Adult trout average 70 cm (27.5"), however some individuals up to 93 cm (36.6") having spent three years at sea have been noted.

Wild steelhead returning to the lakes begin to appear at Salmon Bay in early December, and the last fish dribble in through late April or early May; peak numbers of wild fish are moving through the Locks area in February and March.

Hatchery stocks of winter-run steelhead are also stocked into the Lake Washington system. They differ in life history from the wild stocks principally by exhibiting only one year of freshwater residence (in a hatchery or rearing pond), and earlier return timing (late November through mid-February). There is also a smaller percentage of older fish which have spent three or more years in salt water in the hatchery component of the overall run.

Hatchery winter-runs which have historically been stocked into the Lake Washington watershed have been of Chambers Creek (South Tacoma) origin.

3.1.1 Statewide Winter-run Steelhead Management History

Winter-run steelhead populations in most areas have, with rare exceptions, always been managed for wild returns, often with augmentation by hatchery smolt releases. In most cases the latter have been stocked to augment natural production where fishing pressure is intense.

The management of wild steelhead stocks in Washington was intensified in the mid- to late 1970's, and considerable attention was devoted to identifying possible ill effects from large-scale enhancement with hatchery fish atop natural steelhead populations. Where systems are currently being managed primarily for wild returnees (as in Lake Washington), harvests by all parties are designed to maximize the catch of hatchery fish (if stocked atop wild production), while also assuring attainment of established escapement goals set for wild production. Any wild return above the escapement goal is considered harvestable by all parties (sport and tribal).

3.1.2 Lake Washington Winter-runs -- Management Background

While a very few summer-run steelhead are rumored to ascend the Cedar River, virtually all steelhead returning to the Lake Washington watershed are of the winter-run variety. Winter-runs, by somewhat arbitrary definition, return from late November through April. While most of the tributaries of Lakes Washington and Sammamish support at least a few steelhead spawners, the principal spawning streams include the Cedar River and its principal tributaries (Rock, Madson, Maxwell, Peterson Creeks), plus Issaquah, Big Bear, Little Bear, North, and Swamp Creeks (Figure 3.1).

Winter-runs in the Lake Washington basin have always been managed for wild stocks. However, the first enhancement with hatchery-produced smolts began in 1958, and the wild portion of the returning run received heightened attention and more intensive management beginning in the late 1970's.

Tribal (commercial) steelhead fisheries occur in the extreme terminal area of Salmon Bay (although in some earlier years netting took place within the freshwater areas of the Lake Washington Ship Canal or Lake Washington). Sport fisheries take place at Salmon Bay, and in the Sammamish and Cedar Rivers. Both sport and tribal fisheries are managed to maximize the harvest of hatchery returnees. Harvestable surpluses (if any) of wild returnees are allocated 50:50, with fishing effort adjusted for both parties in an effort to harvest only the available surplus.

The estimated total wild run size returning to Lake Washington since the 1980-81 season has ranged from 1995 to 3193, and averages 2400. We believe that since certain spawning and rearing areas within the watershed are currently underseeded (upper Cedar River mainstem and

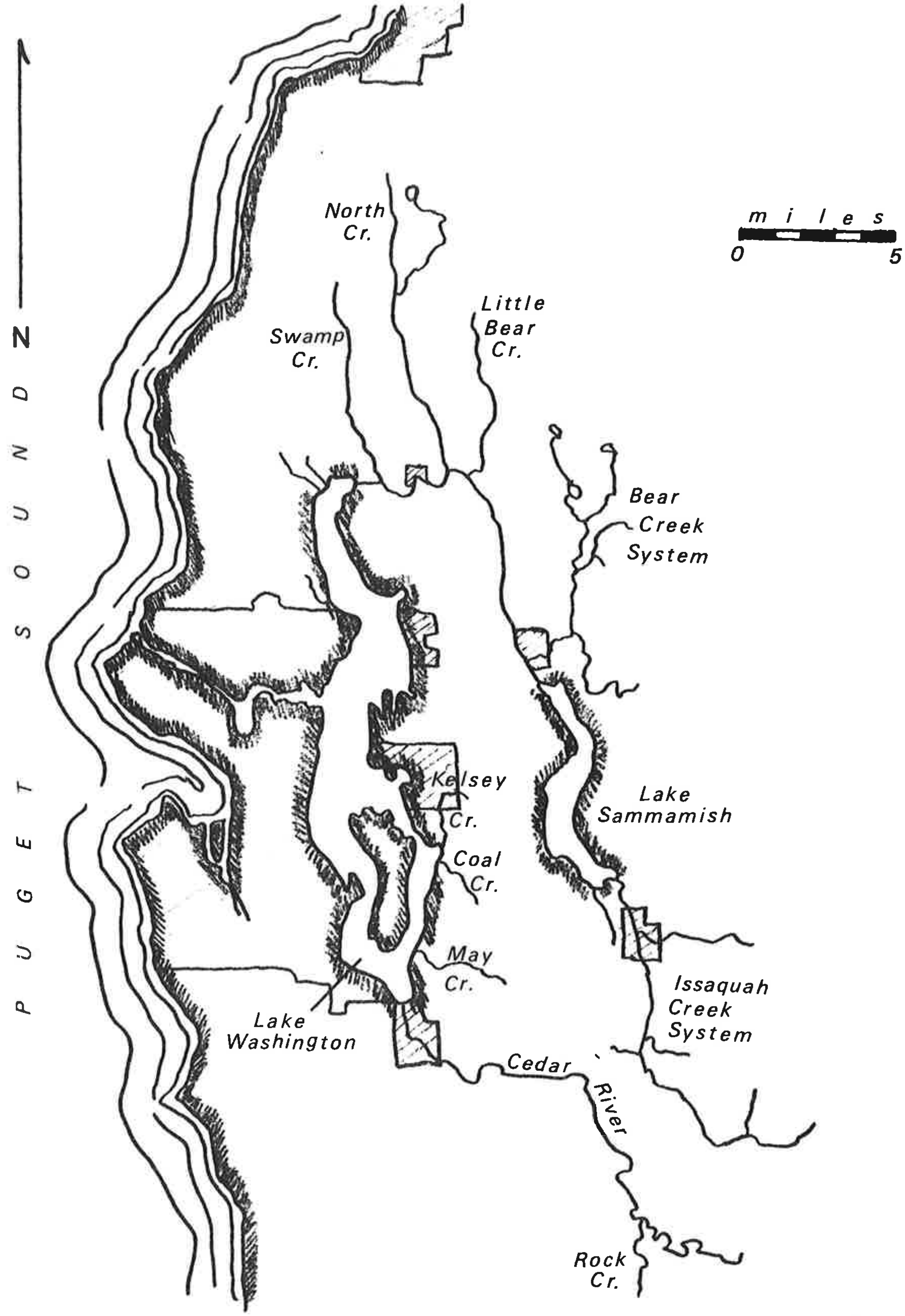


Figure 3.1. Map of the Lake Washington watershed showing principal spawning streams utilized by winter-run steelhead.

its tributaries are blocked to anadromous fish), the overall wild run size return can be boosted to around 3600 when the habitat is fully utilized.

The current wild steelhead escapement goal for the watershed is an agreed-to figure negotiated between the Department of Game and the Muckleshoot Tribe. Whereas the latest escapement methodology sets the goal at 1367, 1600 has been the agreed-to goal for the past two years (1984-85 and 1985-86).

Stocking levels of hatchery smolts has been fairly constant in recent years, and the returning hatchery steelhead run has averaged about 2500, similar to the wild run. We do not anticipate any large scale increases in the hatchery smolt program in this system in the immediate future.

3.2 California Sea Lions

Members of the genus *Zalophus* occur in three disjunct populations, one in the sea of Japan (which may now be extinct), one on the west coast of North America, and one in the Galapagos Islands. Scheffer (1958) assigns each of these populations subspecific status within the species *californianus*. The subspecies considered in this report is from the west coast of North America and is known as the California sea lion (*Zalophus californianus californianus*).

The California sea lion is a medium-sized otariid which breeds mostly on offshore islands in California and Mexico. Adult males weigh 200 to 300 kg (440-660 lbs) and are 200 to 250 cm (6.5-8.2 ft) in length, while adult females weigh 50 to 100 kg (110-220 lbs) and measure 150 to 200 cm (4.9-6.5 ft) (Peterson and Bartholomew 1967). Adult males can be easily distinguished from females by their large size and distinctive saggital (skull) crest. Pelage coloration is typically dark to chocolate brown.

California sea lions breed on islands in the Gulf of California and along the west coast of Mexico south to Mazatlan, and off the Baja California and California coasts northward to the Farallon Islands. After the breeding season ends in the summer, the adult and sub-adult males generally move northward along the coast. Some unknown percentage of these males move as far north as Vancouver Island, British Columbia (Peterson and Bartholomew 1967). The northern-most record of their occurrence is the Gulf of Alaska in about 1978 (B. Everitt, pers. comm.). The females and young either remain in the vicinity of the breeding rookeries year-round, or some apparently move southward (Peterson and Bartholomew 1967).

California sea lions occur in Washington waters from fall until spring (Everitt et al. 1980). Within these waters, they are considered as seasonal migrants, moving northward following the breeding season in late summer, and back southward to the rookeries in the spring. Only subadult and adult male California sea lions are known to occur in Washington.

In modern times they were first sighted in Washington on islets off the coast in 1950 (Kenyon and Scheffer 1962). Large numbers of sea lions were first recorded in Washington's inland waters in the spring of 1979 when 108 were observed in Port Gardner (Everitt et al. 1980). There were no reported haulouts of California sea lions in Washington waters east of Race Rocks B.C. prior to 1979 (Everitt et al. 1979). These observations indicate that California sea lions are extending their range within Washington State. This range extension could be considered either an initial colonization phase, or a recolonization of their pre-historical range.

California sea lion bones have been recovered from pre-historic midden deposits along the coast of Washington State at the Ozette Archeological Site (Huelsbeck 1983). Other evidence of California sea lions occurring in the Pacific Northwest in pre-historic times are noted from the west coast of Vancouver Island, B.C. (Loy 1983).

3.2.1 Population Trends in the Pacific Northwest

The extension and dispersal of California sea lions into new areas of Washington State has continued and increased from 1979 to 1986. This trend follows closely the patterns of dispersal and colonization observed in British Columbia around Vancouver Island (Bigg 1984).

The Canadian Department of Fisheries and Oceans conducted extensive surveys in British Columbia for sea lions in the 1950's and 1960's and noted only a few California sea lions in the vicinity of Barkley Sound (Bigg 1984). By the late 1960's a small colony had formed at Race Rocks (north central Strait of Juan de Fuca), and up to 300 were noted in Barkley Sound in the winter of 1970-71 (cited in Bigg 1984). Censuses off Vancouver Island during 1972-84 suggest that numbers increased slightly between 1972 and 1978, but increased sharply by 1982, and again by 1984 (Bigg 1984). The number of California sea lions in British Columbia increased 10-fold between 1972 and 1984 with most of the increase taking place since 1980 (Bigg op. cit.). The maximum number of sea lions observed since the initial 1950 survey was 4496 in 1984 in British Columbia.

An increase in the number of California sea lions off Vancouver Island and within Washington waters was expected due to a steady increase in the breeding population off California over the last 50 years. The numbers of California sea lions reached an all time low of 400 to 1000 animals in the early 1930's due primarily to commercial exploitation (Bartholomew and Boolootian 1960). By 1975, the population off southern California had increased to at least 27,000 (Mate 1976). Since that time, the population has continued to increase at the rate of about 5% per year (De Master et al. 1982).

The current estimated California sea lion population worldwide is estimated at 177,000 individuals with about 74,000 in California, 83,000 in Mexico, and 20,000 on the Galapagos Islands (National Marine Fisheries Service. 1984).

The number of *Zalophus* within Washington's inland waters appears to have steadily increased since 1979. The data tabulated below illustrate that the trend in Puget Sound is akin to that seen in British Columbia. Their number in Puget Sound appears to have increased about nine-fold in the last seven years, based on the number of sea lions counted in Port Gardner near Everett, Washington.

Date	Count	Source
Apr 1979	108	Everitt et al. (1979)
27 Apr 1980	186	Munn (WDG files)
1981	---	(No Data)
30 Apr 1982	140	Munn (WDG files)
6 Apr 1983	213	" " "
27 Apr 1984	320	" " "
5 Apr 1985	525	Richter " "
1 Apr 1986	961	This Study

With the increase in numbers, the animals are appearing in areas not previously noted. Rafts of *Zalophus* have been reported in Hood Canal and off Whidbey Island in 1986 (J. Scordino, pers. comm.). Groups have been observed in southern Puget Sound off Fox Island, and as far south as the Nisqually delta in 1986 (from WDG aerial surveys, April 1986). A large influx of *Zalophus* occurred in the Seattle area of Elliott Bay and the Duwamish waterway in 1986. A 1986 estimate of numbers is presented in Section 4.4.1.

Only adult and sub-adult male sea lions have been noted within the waters of British Columbia and Washington (Bigg 1984; Everitt et al. 1980; Beach et al. 1985).

3.2.2 Food Habits

The California sea lion is known to be an opportunistic feeder on a variety of prey species (Antonelis and Fiscus 1980). They appear to feed primarily in shallow water in both day and night (Mate 1976). Some of the more common prey in California near breeding rookeries in the Channel Islands are: Pacific whiting (hake), *Merluccius productus*; market squid, *Loligo opalescens*; anchovy, *Engraulis spp.*; and rockfish, *Sebastes spp.* (Antonelis et al. 1984; Fiscus 1979; Fiscus and Baines 1966; Scheffer and Neff 1948).

North of the current breeding range, where predominantly migratory males are found, the diet shifts to those species which are locally and seasonally abundant. *Zalophus* appear to move into specific areas during the non-breeding season in relation to local abundances of prey. In general,they congregate near the mouths of rivers or in other areas where prey are abundant.

Seasonal aggregations of *Zalophus* near the mouth of the Columbia and Fraser Rivers are believed to be related to large concentrations of smelt, *Eulachon sp.* (Beach et al. 1985; Bigg 1985). Sea lions which congregate near the mouths of the Rogue River in Oregon, and Klamath River in California feed predominantly on lamprey, *Lampetra sp.*

(Bowlby, 1981; Jameson and Kenyon 1977; Roffe and Mate 1984). In British Columbia, Pacific herring, *Clupea pallasii*, are important prey in the inland waters, and gadids are important along the outer coast (P. Olesiuk, pers. comm.).

Little information is available about the diet of *Zalophus* in Washington State. One study, however, indicates that Pacific whiting (hake) may be an important food near Port Gardner (Everitt et al. 1981). Hake are present in all areas of Puget Sound, but occur in numbers large enough to support a commercial fishery only in Saratoga Passage and Port Susan, which are immediately north and west of Port Gardner (Kimura and Millikan 1977).

California sea lions are known to consume free swimming salmon, as well as those caught on hook and line (Briggs and Davis 1972; Fiscus 1980). However, the overall importance of salmonids in the diet of *Zalophus* has not been adequately determined. One of the major questions remaining is the success rate of *Zalophus* feeding on free swimming salmonids as opposed to caught fish taken from gillnets or hook and line.

3.2.3 Historic Fisheries Interactions

The Marine Mammal Protection Act of 1972 (MMPA) established a moratorium on the taking and importation of marine mammals and marine mammal products by U.S. citizens. "Taking" as defined under this Act includes killing and harassment of any marine mammals.

The MMPA established responsibility of management of marine mammals as under federal control. The National Marine Fisheries Service (NMFS) is charged with enforcement of the MMPA and management of marine mammal stocks. The State of Washington Department of Game (WDG)is currently investigating the feasibility of returning marine mammal management to the state. However, at this time responsibility for marine mammal management is still relegated to the federal government (NMFS). Thus, any measures conducted by WDG to control, harass, transport, or otherwise "take" marine mammals, including sea lions, must be officially permitted by NMFS.

The primary objective of the MMPA was to replenish stocks of depleted marine mammals by prohibiting all taking of marine mammals, and by maintaining stocks at their optimum sustainable populations (OSP). The National Marine Fisheries Service has defined OSP to be that population level between the maximum net productivity level (MNPL) and the maximum population level (K).

Initially, the MMPA put a complete moratorium on the taking of any marine mammals by U.S. citizens unless specifically exempted from the moratorium. Problems immediately arose between commercial and sport fisheries and marine mammals as they became more abundant and brazen in their interactions with fisheries. This has been particularly true for California sea lions.

California sea lions cause damage to fisheries catch or gear in seven major fisheries in California (Miller et al. 1982) (Table 3.1). The largest dollar losses occur in the following fisheries: salmon trolling, commercial sport boat fishing, Pacific herring fisheries, and the halibut gillnet fishery (Miller op. cit.). The total damage to catch by California sea lions in all California fisheries was estimated to be $394,886 in 1980, and the total damage to gear was $80,350 (Table 3.1). The total dollar value loss in these fisheries due to interactions with sea lions was over $475,000. It was determined that California sea lions were responsible for about 79 percent of the total annual fisheries dollar losses in California due to all marine mammals (Miller Op. cit.).

An estimated 1560 (range 1258 to 1834) sea lion mortalities occur per year due to fishery interactions in California (Miller Op. cit.).

Interactions between California sea lions and fisheries have been documented in Oregon and Washington, primarily near the Columbia River and adjacent waters (Beach et al. 1985; Everitt and Beach 1982). California sea lion males congregate near the mouth of the Columbia River in late winter-early spring at the time of the Eulachon smelt run. In the spring of 1980 and 1981, *Zalophus* were regularly observed near Longview, Washington, with individuals as far upriver as Bonneville Dam (Beach et al. 1985). It is during the late fall and winter months that direct interactions with nearshore gillnet fisheries and California sea lions become most acute. Because of the large size and strength of these animals, they are capable of completely removing salmon from nets and inflicting serious damage to gear (Everitt et al. 1981).

Interactions between *Zalophus* and fisheries in the inland waters of Washington are not well documented. This may be because large numbers of *Zalophus* have not occurred (in recent times) in the inland waters until after 1978 (Everitt et al. 1980). Recent evidence, however, indicates that *Zalophus* numbers have increased about 10-fold in the last seven to eight years in Puget Sound (Section 4.4). This increase in sea lion numbers appears to have led to increased fishery interactions in certain areas, notably the mouths of the Lake Washington Ship Canal and the Green/Duwamish Rivers at Seattle.

The Salmon Bay/Ship Canal and Elliott Bay/Duwamish River estuaries support active steelhead gillnet fisheries by the Muckleshoot and Suquamish Indian tribes. Sea lions have interacted with the fisheries in both areas for the last few years by robbing nets and causing gear damage (W. Sandoval, pers. comm.).

Zalophus are opportunistic predators and feed on a wide range of prey species, primarily fishes and cephalopods (Antonelis et al. 1984). They appear to be adept at exploiting distinct local and seasonal prey resources and "switching" their diet to accomodate changes in prey abundance and distribution (Bailey and Ainley 1982). We would expect, therefore, that if *Zalophus* numbers continue to increase, and as they continue to explore the inland waters, that

Table 3.1. Depredation rate, dollar loss, and take of sea lions in California fisheries. (Data from Miller et al. 1982. Where species-specific losses are not given, loss is prorated according to composition of take).

	% Depredation	Value of fishery losses: Catch loss	Gear loss	Sea lion mortality
1. Commercial salmon troll fishery ('80)	1.90%	274,000	12,200	300
2. Halibut gill net fishery (1980)	6.94%	32,368	24,071	242
3. Pacific herring fishery ('79/'80)	.46-.62%	40,600	4550	0
4. Partyboat bottom-fishery (1980)	?	27,000	10,730	0
5. Partyboat salmon fishery (1980)	0.32%	6000	360	0
6. Salmon recreational skiff fishery (1980)	.02-.18%	2300	0	0
7. Hook and line fishery (1980)	0.44%	1500	0	0
(8-12.) Other misc. fisheries	.00-7.1%	11,118	1382	1019
Totals		$394,886	$80,350	1571

increased fishery interactions will occur. The most likely fisheries to be impacted by future interactions would be those which operate durng the months when most sea lions are present in Puget Sound (November-May), and in areas where sea lions are most abundant (Everett, Seattle, Fox Island, etc.). Gadid, Pacific herring, and salmonid fisheries would be the most likely fisheries to be affected by increasing sea lion predation and fisheries interactions.

3.2.4 Previous Control Attempts

California sea lions were commercially exploited in California in the 1800's and early 1900's (Mate 1976). Commercial exploitation was discontinued in the early 1930's when the California population was estimated at only 400 to 1000 animals.

The enactment of the MMPA in 1972 placed a moratorium on the taking of marine mammals by U.S. citizens. Commercial fisheries, however, are exempt from certain regulations within this Act, and are allowed to take animals under specific conditions.

Since the MMPA came into effect, control of marine mammals which adversely impact fisheries have emphasized non-lethal approaches. Table 3.2 lists seven different options which are available to control marine mammals interacting with fisheries.

Not all of these options have been tested on California sea lions. Population control methods presently can be ruled out (option 1, Table 3.2), since they conflict with the MMPA regulations.

Acoustic harassment has been experimentally tested in California, Oregon, and Washington, primarily by using acoustic harassment devices (AHD's). These experiments have shown mixed results, although they do appear to have some short term value (Geiger and Jeffries 1986; Hanan and Scholl 1985; Mate 1984).

Killer whale vocalizations have been experimentally tested on harbor seals and fur seals, however these tests have also shown mixed results (Anderson and Hawkins 1978; Shaughnessy et al. 1981).

Capture and removal experiments of wild sea lions in the water have not been attempted to date.

Food aversion conditioning of sea lions has been experimentally tested on captive sea lions with positive results (Kuljis 1986).

At present, pain inducement has not been experimentally tested on sea lions, although it does show some potential application when used on bears.

We know of no successful or unsuccessful attempts to experimentally exclude sea lions from fishing grounds by physical restraint (barriers).

Table 3.2. List of potential options to control sea lion - fishery interactons.

Method	Tested?
#1 Population Control	
a) shooting/killing	Yes
b) sterilization	Yes
#2 Acoustic Harassment	
a) AHD's	Yes
b) cracker shells	Yes
c) seal bombs	Yes
d) *Orca* sounds	Yes
#3 Capture-removal	No
#4 Food Aversion Conditioning	Yes
#5 Exclusion/Physical Restraint	No
#6 Pain Inducement	
a) rubber bullets, etc.	No
#7 No Action	Yes

In general, attempts to control sea lion-fishery problems are in their early stages of development, and in no case has there been determined a single highly successful method which has application over a broad geographic area and for a large number of independent fisheries.

4.0 RESULTS AND DISCUSSION

4.1 Estimation of Predation (Pre-Harassment Study)

The pre-harassment study was conducted beginning at 0730 on 30 December through 0530 on 7 January. The primary objectives were to estimate total steelhead loss over the course of the season, gather information on the number of sea lions involved, and document their feeding behavior. Observers were therefore stationed at the Locks to document fish kills, sea lion presence and behavior. The 24-hour day was divided into three 8-hour shifts (0730-1530, 1530-2330, 2330-0730). Total coverage time for this period is noted in Table 4.1.

4.1.1 Sea Lion Presence

Sea lions were present at the Locks during eight of nine days between 30 December and 7 January. An actual arrival time was only noted on one of these days (0430 on 3 January). Sea lions were already present in the vicinity on six mornings when the observer first came on duty at 0730. On three of the eight days in which sea lions were present, all had departed by late afternoon (Table 4.1). On four of the eight days, sea lions were still present when the observer departed (Table 4.1). Sea lions were observed to maintain a continuous 24 hour presence at the Locks on only one day. The data on arrival and departure times are not conclusive enough to delineate a distinct pattern of presence. However, a general pattern appears to be:

1: 0730-1530 - continuous presence of sea lions
2: 1530-2330 - sea lions depart at dark
3: 2330-0730 - sea lions return in early AM between 0430 and 0730.

4.1.2 Numbers of Sea Lions

Numbers of individual sea lions simultaneously observed at the Locks ranged from zero to five animals over the pre-harassment period (Table 4.1). No sea lions were observed on 30 December. Their absence on the 30th may have been related to the presence of numerous tribal gill nets deployed in outer Salmon Bay and Shilshole Bay on the night of 29-30 December. We had noted that the number of sea lions actively foraging in the fishway area was closely correlated with netting activity in the outer Salmon Bay area - when netting occurred, few to no animals foraged near the spillway dam on the day immediately following a night's fishing.

Due to this potential bias, we did not include data from this date when determining average number of sea lions present or predation rates. This is justifiable in that we were most interested in predation rates that occur after the commercial fishery, when most of the wild steelhead are immigrating. (However, it would be valuable, in the future, to estimate the daily kill rate over a 7-10 day period when the gillnetting is occurring simultaneously. This kill rate would

Table 4.1. Presence of California sea lions at the Chittenden Locks prior to harassment, December 1985-January 1986.

Date	Coverage	1st Sighting	Last Sighting	# Lions
30 December*	0730-1510	none	none	0
31 December	0730-1540	0730	1540**	1
1 January	0730-1500	0730	1445	3
2 January	0730-2400	0730	1710	1
3 January	0000-2400	0430	1610	2
4 January	0724-0930	0724	0930**	2
5 January	0822-1645	0822	1645**	3
6 January	0715-2400	0715	in all day	4
7 January	0000-1550	0000	0740***	5

An aggregate of 21 California sea lions were seen over 8 days, for a mean of 2.625 sea lions present per day.

* 30 December data were not incorporated into the calculation of mean number of sea lions present daily (see text Section 4.1.2).
** Lions were still present when observers left the Locks.
*** Harassment commenced.

then be applied only to that portion of the run, as it would very likely be a lower figure than that which occurs when the sea lions do most of their foraging near the spillway dam.) The average number present per day was 2.625 (range 1-5) for the eight days of 31 December through 7 January (Table 4.1).

4.1.3 Sea Lion Identification

Two of the five sea lions observed during this period were identified by using relative size, color, and distinctive marks. All of the animals identified were considered sub-adult males. The following is a description of four sea lions observed on 6 January.

"Humpback" - The largest of the sea lions observed.
Estimated weight: 400-500 lbs.
Estimated length: 6-7 feet.
Distinctive marks: A distinct hump dorsally near the pelvic region. The animal is bi-colored, being somewhat tawny or straw-colored dorsally near the posterior third of the body. The sagittal crest is distinct and the area around the muzzle and crest lighter in color than the rest of the head, shoulders, or back which are a darker chocolate brown.

"Scar" -
Estimated weight: 250-350 lbs.
Estimated length: 5.5-6 feet.
Distinctive marks: A small, uniformly dark brown sea lion. The sagittal crest is not well developed, yet is noticeable. The animal has a small pink-colored scar near the sternum on the mid-central portion of the body. The scar is round to oval in shape and about 5 cm (2") in diameter.

(Intermediate male) -
Estimated weight: 300-400 lbs.
Estimated length: 6-6.5 feet.
Distinctive marks: None which could be readily used for identification. The animal is bi-colored, being tawny or straw-colored dorsally in the posterior third of the body and near the muzzle and sagittal crest. The remaining areas are darker brown in color. No distinctive scars or wounds were noted.

(Small male) -
Estimated weight: 150-200 lbs.
Estimated length: 5-5.5 feet.
Distinctive marks: None which could be used for identification purposes. The animal is a uniform dark brown in color. The sagittal crest is not pronounced.

(Note that the sea lion immortalized in the popular press as "Herschel" was not observed at the Locks during the study period (mid-December 1985 through mid-April 1986). Herschel was a large sea lion observed at the Locks for several years prior to this study. First named in 1985 by locks employee Glenn Williams, he became famous overnight by the use of his name by an assortment of media. "Herschel" became, therefore, somewhat of a generic term for any sea lions seen at the Locks.)

4.1.3.1 Repeated sightings

We made repeated sightings of two sea lions which possessed distinctive marks ("Humpback" and "Scar"). "Humpback" was sighted on eight consecutive days during this study period indicating that he was a consistent resident. Scar was noted on two of these days, however he may not have been recognized on other days when he may have been present. The mark on the animal (being small and ventral in location) is not easily seen. The use of natural marks for repeated identification of individuals is considered to be reliable for only one sea lion ("Humpback"). For this reason, we do not consider this method to be reliable for identifying most sea lions in the water.

4.1.4 Estimate of Total Sea Lions

We couldn't make a true estimate of total sea lions utilizing the Locks because none were tagged or marked, and because natural marks were unreliable. In the future, the question of sea lion abundance could be answered by tagging and marking the animals which occur at the Locks. The two identifications made, however, allowed us to at least hypothesize the most likely patterns of sea lion presence and abundance at the Locks.

One sea lion ("Humpback") was known to occur on a daily basis. Another ("Scar") was present on at least several days within one week. It seems likely, therefore, to expect sea lions to continue to return to the Locks once they realize the benefits of abundant and accessible prey. For 1986, we hypothesized that there were five to six "repeat offenders", that is animals which returned on a regular basis, and any number of randomly occurring animals which may or may not have returned.

We consider the potential to be great for increasing numbers of sea lions to utilize the Locks area as a foraging area in the future due to the large numbers present in the vicinity (see Sections 2.6 and 4.4).

4.1.5 Predation Rates and Steelhead Losses

We determined steelhead predation rates for the period 31 December through 7 January in order to further estimate the total potential loss over the course of the fish run. We stratified the 24-hour day into three 8-hour shifts (0730-1530, 1530-2330, 2330-0730). Fish killed during these 8-hour shifts were noted and totaled to determine a mean hourly kill rate for each stratum. Hourly kill rates for each stratum were then standardized (multiplied by eight hours) to determine the mean number of fish killed per stratum. These means were then added to determine a daily (24-hour) kill rate (Table 4.2). We used this method instead of totalling numbers of observed fish kills and dividing by total days because shift coverage was not equal each day.

Using this method, we estimated that an average of 18.549 steelhead were killed by sea lions per day during the pre-harassment sample period (Table 4.2). This figure was then used to extrapolate potential steelhead fish loss over the course of the fish run without sea lion harassment.

We do not consider this method of determining potential seasonal fish loss an optimal method (i.e. extrapolating seasonal figures based on a small sample). However, it was necessary in order to begin harassment as soon as possible.

4.1.5.1 Statistical procedures

We certainly desired to have some measure of the precision of our estimate of the hourly steelhead kill rate. While the behavioral occurrences of steelhead kills is most likely distributed as a Poisson variable, we also calculated a 95% confidence interval on the estimated mean hourly predation rate as though it were a normally distributed variable. We could only calculate both, however, for the 0730-1530 time stratum, for there were too few steelhead killed in the other two strata to allow a determination of confidence limits for a Poisson random variable with n=3 or less.

If we assume the hourly mean kill rate is normally distributed, the following confidence limits and standardized kill rates (derived by multiplying the mean hourly kill rate by eight) may be estimated:

Time Stratum	95% C.I. on Hourly Kill Rate	Standardized Kill Rates & # Fish Killed/24 Hours
0730-1530	0.96-3.35	8-27
1530-2330	0.00-0.28	0- 2
2330-0730	0.00-1.71	0-14
		8-43

For comparison purposes, a confidence limit may be calculated on the standardized kill rate for the 0730-1530 time stratum:

$$X \sim \text{Poisson } (8y)$$

where y = mean # fish killed per hour
and X = # killed/8 hours)

Table 4.2 Number of California sea lions and winter-run steelhead kills observed at the Chittenden Locks during the pre-harassment study period, and estimated steelhead kill rates.

Date	Observer Coverage	# of Hours	Min. # of Sea Lions	# of S'head Killed	Kill per Hour	Kill in 8 Hrs.
31 December	0730-1530	8	1	12	1.50	12
1 January	0730-1500	7.5	3	16	2.13	17
2 January	0730-1530	8	1	11	1.34	11
2 January	1530-2330	8	1	0	0.00	0
2-3 January	2330-0730	9	1	0	0.00	0
3 January	0730-1530	8	2	13	1.63	13
3 January	1530-2330	8	1	1	0.12	8
4 January	0700-0930	2.5	2	incomplete data	--	--
5 January	0815-1530	7.25	3	32	4.41	35
5 January	1530-1645	1.25	3	0	0.00	0
6 January	0730-1530	8	4	15	1.88	15
6 January	1530-2330	8	4	0	0.00	0
6-7 January	2330-0630	7	2	2	0.29	2
			Total:	102		

Time Stratum	Total Hours Covered	Number of Fish Killed per Stratum RANGE	TOTAL	Mean Hourly Kill Rate (Fish/Hr.)	Standardized Kill Rate (Fish/8-Hr.)
0730-1530[a]	46.75	11-32	97	2.075	16.599
1530-2330[b]	25.25	0-3	3	0.119	0.950
2330-0730[c]	16.00	0-2	2	0.125	1.000
24-Hour Totals:	88.00	---	102	1.159	18.549

[a] The number of strata sampled = 6
[b] " " " " " = 3
[c] " " " " " = 2

* See Table 4.10 for a breakdown of kills by time stratum.

While the Poisson confidence limit can only be calculated for the 0730-1530 time stratum, it is interesting to note the similarity in the limits estimates:

Time Stratum	95% C.I. on Standardized Kill Rate	# Fish Killed/24 Hours
0730-1530	10.1-27.5	10-28

Specific methods for the calculation of the Poisson confidence limits are reported by Zar (1984: 408).

4.1.5.2 Estimates of steelhead losses

Winter steelhead passage through Salmon Bay extends through a period of five months (150 days), beginning in late November to early December and ending in late April to early May, with the peak in mid-February (WDG file records).

An estimate of the total number of steelhead of both races that could be lost to sea lion predation extending from 1 December through 1 April (151 days) may be derived by a simple multiplication of the total number of days (151) and the estimated mean daily predation rate (18.549). This results in a figure of 2801 steelhead of both races for the year. This season-long estimate is based on the following assumptions:

1: The overall sea lion predation rate is constant, which implies:
2. The predation rate is independent of the number of steelhead entering Salmon Bay, given some base level of fish entry;
3: Sea lions are present at the Locks daily; and
4: The average number of sea lions present daily is constant.

(In future years, it would be very desirable to check the validity of these assumptions by documenting uninhibited sea lion predation for at least as long as in 1985-6, preferably longer.)

The estimate of 2801 is not presented as a precise figure of potential steelhead losses, but only as an index which indicates that under the noted assumptions, potentially 2801 steelhead of both races combined could have been lost to sea lions in 1985-86. Some measure of the precision of this estimate is given by the two confidence limits and expanded daily predation rates for the 0730-1530 time stratum given above. (Since almost all of the predation took place in this time stratum, the indicated ranges are a fair measure of the overall precision of the estimated total losses.) Given the constraints, a confidence limit on the estimated total season-long losses without any harassment would be 1157 to 4047 (if the daily kill rate parameter is normally distributed), or 1510 to 4077 (if the standardized daily kill rate is distributed as a Poisson random variable).

The actual number of fish lost could be higher or lower than 2801, depending upon which assumptions hold true. For example, we know, based on observations, that steelhead entry is not constant over the run. A graph of wild steelhead returns plotted against time is most likely bell-shaped. And, hatchery returns are skewed to the earlier portion of the annual fish run. In any case, daily fish entry to the Locks area may be related to local environmental factors, including weather, spillway dam discharge, rainfall, and tide.

Predation levels are also not constant, and are probably related to the rate of steelhead entry into the Locks area, ambient light, or other factors. The two assumptions which are likely to be most often met are numbers three and four. Sea lions were present for a period of eight straight days during the pre-harassment period, and were present in the same numbers in late April following the harassment phase of the study.

Table 4.3 presents data on the proportion of the run composed of wild winter-run steelhead, by statistical week, as determined by sampling scales from landed steelhead during the tribal gillnet fishery (1 December through 6 January in 1985-6) or from fish collected from the Locks fishway (after 6 January). It also tabulates estimated weekly losses of wild winter-runs based on the mean daily predation rate. These data indicate that 1213 wild steelhead would have been lost over the course of the 1985-86 run had there been no harassment.

A similar calculation for hatchery winter-runs (Table 4.4) estimates that 1564 hatchery fish could be lost over the same time period.

Table 4.3 Estimated wild winter-run steelhead losses to California sea lions at Salmon Bay with no harassment, based upon the mean daily predation rate during the 1985-86 run return.

STATISTICAL WEEK	DECEMBER 1-7	8-14	15-21	22-28	29-31	JANUARY 1-4	5-11	12-18	19-25	26-1	FEB 2-8	9-15
NUMBER OF DAYS	7	7	7	7	3	4	7	7	7	7	7	7
NUMBER OF STEELHEAD KILLED [a]	130	130	130	130	56	74	130	130	130	130	130	130
WILD FRACTION	.154	.109	.162	.081	.164	.118	.038	.150	.263	.225	.188	.150
WILD STEELHEAD LOSSES	20	14	21	11	9	9	5	20	34	29	24	20

STATISTICAL WEEK	FEB 16-22	23-1	MARCH 2-8	9-15	16-22	23-29	30-5	APRIL 6-12	13-19	20-26	27-30
NUMBER OF DAYS	7	7	7	7	7	7	7	7	7	7	4
NUMBER OF STEELHEAD KILLED [a]	130	130	130	130	130	130	130	130	130	130	74
WILD FRACTION	.253	.357	.486	.614	.743	.871	1.000	1.000	1.000	1.000	1.000
WILD STEELHEAD LOSSES	33	46	63	80	97	84	130	130	130	130	74

[a] At a predation rate of 18.549 steelhead/day.

ESTIMATED TOTAL WILD STEELHEAD LOSSES: 1213

Table 4.4 Estimated hatchery winter-run steelhead losses to California sea lions at Salmon Bay with no harassment, based upon the mean daily predation rate during the 1985-86 run return.

STATISTICAL		D E C E M B E R					J A N U A R Y				F E B	
WEEK	1-7	8-14	15-21	22-28	29-31	1-4	5-11	12-18	19-25	26-1	2-8	9-15
NUMBER OF DAYS	7	7	7	7	3	4	7	7	7	7	7	7
NUMBER OF STEELHEAD KILLED [a]	130	130	130	130	56	74	130	130	130	130	130	130
HATCHERY FRACTION	.846	.891	.838	.919	.836	.882	.962	.850	.737	.775	.812	.850
HATCHERY STEELHEAD LOSSES	110	116	109	119	47	65	125	111	96	101	106	111

STATISTICAL	F E B		M A R C H					A P R I L			
WEEK	16-22	23-1	2-8	9-15	16-22	23-29	30-5	6-12	13-19	20-26	27-30
NUMBER OF DAYS	7	7	7	7	7	7	7	7	7	7	4
NUMBER OF STEELHEAD KILLED [a]	130	130	130	130	130	130	130	130	130	130	74
HATCHERY FRACTION	.747	.643	.514	.386	.257	.129	0.000	0.000	0.000	0.000	0.000
HATCHERY STEELHEAD LOSSES	97	84	67	50	33	17	0	0	0	0	0

[a] At a predation rate of 18.549 steelhead/day.

ESTIMATED TOTAL HATCHERY STEELHEAD LOSSES: 1564

4.1.6 Sea Lion Behavior

Sea lion behavior observed at the Locks can be broadly divided into two general types of behavior: non-foraging and foraging. Non-foraging behavior involved either surface resting-grooming, or interactions with other sea lions. Foraging behavior involved pursuit, capture, killing, and consuming prey.

A foraging sea lion's behavior was characterized by continuous movement. The movements consisted of a continuous series of shallow dives averaging one to three minutes in duration, followed by a short (10-60 second) period of surface resting 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.

4.1.6.1 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. This 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 apart into chunks. It appeared that smaller fish were consumed whole more often than larger fish, though not always. Large fish (> than an estimated weight of 4.5 kg, or 10 lbs) were observed to be eaten whole on numerous occasions. Only 18% of the total fish observed eaten, however, were eaten whole. The remainder (82%) were broken apart and consumed.

Of fish that were broken apart, in most cases the head was eaten first. At this stage, the fish was either broken further apart or swallowed as 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 one third or one half broken, the remainder would be swallowed whole.

All fish observed eaten 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.

4.1.6.2 Feeding locations

Sea lions foraged for steelhead in several areas of the Ship Canal including: both locks, near the Burlington Northern (bascule) railroad bridge, and near the fishway (Figure 2.2). The primary foraging area was within the cable area, near the fishway (Figure 2.2). Sixty-six percent of fish observed taken were caught within the cable area adjacent to the fishway entrances. The remainder (34%) were taken in the large and small locks, near the railroad bridge, or in the open area between the bridge and the cable.

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 may be individual feeding territories. For example, if four animals were present, one would forage near the fishway, one each in the small and large locks, and one by the railroad bridge.

It was not unusual to see sea lions together for short periods of time, however they did not appear to forage together for extended periods. On several occasions, it appeared that larger sea lions displaced smaller ones from foraging areas by chasing them out. Observations of active displacement were very rare, which suggests that the observed segregation was passively enforced by some sort of mutual exclusion from preferred foraging areas.

4.1.6.3 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 and who foraged near the fishway were the most successful at catching fish.

One sea lion which could be readily identified (Humpback) appeared to be the most successful predator, accounting for at least 60% of all observed fish kills over the sample period. This male (which was also the largest) was present on a daily basis and foraged near the fishway. Humpback averaged 12 fish taken per eight hours over the pre-harassment sample period. We observed Humpback consume 12 <u>whole</u>

fish on one day over an eight hour time span. (He also may have killed other fish during the day at times or locations not observed by us.) We estimated that this animal consumed 72 to 84 pounds of fish (6-7 pound average fish weight) during this eight hour period.

Little is known about daily caloric requirements of sea lions in the wild, but observations of a captive 600 pound male indicate that they can survive on 96 lbs of fish per week (Scheffer 1958). The observed consumption rates of individuals at the Locks (wild sea lions) appear to greatly exceed those of captive animals. For the wild sea lions, upwards of 10-12 percent of the body weight per day may be consumed.

4.1.6.4 Wastage

The percent of fish not eaten (wastage) appeared to be small, although it was difficult to estimate. Portions of fish were discarded generally after the animal had caught a number of fish and was probably sated. Overall, we would estimate the amount of fish discarded or wasted at less than 10% of the total fish weight.

4.1.6.5 Sex of caught fish

It was often difficult or impossible to tell the sex of steelhead being eaten, particularly for male fish. In most cases we relied on telltale secondary sex characters, such as roe in ripening females, which were sometimes evident when the fish were ripped apart. In a similar manner, we could sometimes detect the hooked jaw (kype) of ripening males, or body conformation was clearly that of one sex or the other.

Of the 18 fish which could be positively identified as to sex, 15 (83%) were females and three (17%) were males. Sea lions were observed to eat the roe on most occasions after it was separated from the body.

4.1.6.6 Diurnal time of fish consumption

The hours when fish are taken at the Locks appears to be primarily a function of daylight. Only two fish were observed taken when it was dark over the sample period. All others were taken during daylight hours. The predation rates were highest during the period with the highest ambient light (0730-1530) and lowest during the period of the least light (2330-0730). During the sample period the average time of sunrise was 0759 and sunset 1630. The overall daily rates of predation for each eight hour time stratum were: 0730-1530 - 17 fish; 1530-2330 - 1.00 fish; and 2330-0730 - 1.00 fish (Table 4.2).

The predation rates appeared to be fairly constant over the primary feeding time from 0800 to 1530 with an average of two fish taken per hour.

Another reason for believing that light is a primary factor is based on observations of first kills in a day at the Locks. On days in which observations were begun at least one half hour before sunrise, and California sea lions were present, the first kill was noted shortly after first light (Table 4.5).

4.2 Predation Control (Harassment Phase)

We harassed sea lions from the Locks from 7 January through 1 April. The primary objective during this phase of the study was to minimize steelhead predation losses and thereby increase the escapement of wild steelhead. Sea lions were chased from the Locks when first sighted by using seal bombs and AHDs either from shore or from a boat. (We made little effort to identify individual sea lions during this period in order to chase them away before they began feeding. This was because our primary goal during this period was to chase sea lions away as soon as they were sighted (i.e. before they began feeding). Specific individuals were rarely identified.)

We maintained two eight hour shifts at the Locks on Monday through Friday (generally 0600-2200). Weekend coverage was more sporadic, but averaged about eight hours per day. In addition, we maintained six 24-hour shifts during this phase of the study in order to estimate late night and early morning predation. A total of 1107 hours of coverage was maintained at the Locks during the 83 days of the harassment phase (Table 4.6).

4.2.1 Sea Lion Presence

Sea lions were observed at the Locks on 60 (72%) of the days during the harassment phase of the study. No sea lions were observed on 20 days (24%). The longest period of time when sea lions were not observed at the Locks was three days (8-10 January) following the beginning of harassment, and again on 7-9 February (Table 4.6). The longest period when sea lions were observed was for 12 straight days from 21 March through 1 April (Table 4.6).

The number of sea lions observed at the Locks during the harassment phase was lower than the pre-harassment phase. The average number observed per day was only 0.78 (range 1-3) during the harassment phase (Table 4.6), which contrasts with 2.62 during the pre-harassment phase (Section 4.1.1, Table 4.1).

4.2.2 Sea Lion Harassment

We chased sea lions from the Locks when they were first sighted by observers, generally beginning in the early morning. Since sea lions often returned to the Locks several hours later, it was often necessary to chase them out more than one time per day. Each time sea lions were observed at the Locks they were recorded as sightings, and not as different individuals since it was possible that the same animals

Table 4.5 First observed steelhead kill by sea lions at the Chittenden Locks in relation to sunrise, January 1986.

Date	Time Observer(s) Began Coverage	Time of First Kill	Official Time of Sunrise
31 December	0730	0803	0800
1 January	0730	0806	0800
2 January	0730	0759	0800
3 January	0000	0754	0800
4 January	0724	0748	0800
5 January*	0822	----	0800
6 January	0715	0826	0758

*Coverage began after sunrise; the first kill had probably already occurred.

Table 4.6 Sightings of California sea lions at the Chittenden Locks, number of steelhead observed eaten, and observer coverage time, 27 December 1985-14 May 1986.

Date	Observer Coverage	Number of Sea Lion Sightings	Minimum Number of Sea Lions	Observed Number of Steelhead Killed
27 December	0700-1030	0	0	0
30 December	0730-1510	0	0	0
31 December	0730-1540	1	1	12
1 January	0730-1500	3	3	16
2 January	0730-2400	1	1	11
3 January	0000-2400	2	2	14
4 January	0700-0930	2	2	--
5 January	0822-1645	3	3	32
6 January	0715-2400	4	4	15
7 January	0000-1550	4	5	2
		(Begin Harassment)		
8 January	0700-2400	0	0	0
9 January	0700-1700	0	0	0
10 January	0720-1500	0	0	0
11 January	0700-1700	1	1	1
12 January	2145-2340	1	1	1
13 January	0700-1530	4	2	1
14 January	0700-1900	7	2	2
15 January	0600-2000	1	1	2
16 January	0600-2100	2	1	0
17 January	0600-2100	0	0	0
18 January	0600-1800	2	2	0
19 January	1400-2200	2	2	3
20 January	0045-0230 0600-2200	6	2	0
21 January	0600-2200	0	0	0
22 January	0700-2100	0	0	0
23 January	0600-2200	4	1	0
24 January	0600-2100	1	1	0
25 January	0600-1830	2	1	0
26 January	0630-2400	2	2	0
27 January	0000-2400	2	2	0
28 January	0000-2400	8	1	2
29 January	0000-2400	2	3	3
30 January	0700-2200	1	1	0
31 January	0730-2200	0	0	0

Table 4.6 (Continued).

Date	Observer Coverage	Number of Sea Lion Sightings	Minimum Number of Sea Lions	Observed Number of Steelhead Killed
1 February	0600-1100 1430-1830	0	0	0
2 February	0645-2130	1	1	0
3 February	0600-2115	2	1	0
4 February	0600-2200	2	1	1
5 February	0800-2100	3	3	0
6 February	0600-2100	2	2	2
7 February	0600-2030	0	0	0
8 February	0600-1815	0	0	0
9 February	0730-1800	0	0	0
10 February	0730-2100	1	1	0
11 Febraury	0700-2100	0	0	0
12 February	0630-2200	3	1	0
13 February	0900-1900	0	0	0
14 February	0600-2200	0	0	0
15 Febraury	no coverage	---	---	---
16 February	0610-1800	4	3	2
17 February	no coverage	---	---	---
18 February	0600-2200	0	0	0
19 February	0600-2100	1	1	0
20 February	0600-2200	1	3	0
21 February	0600-2200	1	1	0
22 February	0815-1400	3	2	0
23 Febraury	0600-1800	5	1	0
24 February	0600-2200	2	3	0
25 February	0650-1800	0	0	0
26 February	0550-2200	1	1	1
27 February	0700-2200	1	1	0
28 February	0700-2200	1	1	0
1 March	0730-2000	2	2	0
2 March	0700-1830	4	2	0
3 March	0600-2250	3	3	1
4 March	0600-2200	0	0	0
5 March	0600-2215	2	1	0
6 March	0600-2100	1	1	0
7 March	0600-2200	4	1	1
8 March	0645-1400	1	2	0
9 March	no coverage	---	---	---
10 March	0600-1400 2245-2400	5	2	0

Table 4.6 (Continued).

Date	Observer Coverage	Number of Sea Lion Sightings	Minimum Number of Sea Lions	Observed Number of Steelhead Killed
11 March	0000-2400	6	2	0
12 March	0000-2400	2	2	4
13 March	0000-2200	4	1	0
14 March	0800-2200	4	3	1
15 March	0630-1330	0	0	0
16 March	1400-1500	1	1	0
17 March	0700-2200	1	2	0
18 March	0600-2200	2	1	0
19 March	0600-2100	0	0	0
20 March	0600-2100	0	0	0
21 March	0600-2100	2	2	0
22 March	0930-1500	2	1	0
23 March	no coverage	---	---	---
24 March	0700-2200	2	1	0
25 March	0800-2200	2	2	0
26 March	0650-2200	4	2	0
27 March	0700-2200	2	1	0
28 March	0545-2200	7	2	4
29 March	1230-1300	1	3	0
30 March	1000-1100	1	1	0
31 March	0645-1430	3	3	0
1 April	0655-0715 1100-1120 1445-1500	1	1	0
		(End Harassment)		
2 April	0730-1400	3	3	4
3 April	0730-1300	3	3	5
4 April	0600-0900 1340-1400	3	3	1
5 April	no coverage	---	---	---
6 April	no coverage	---	---	---
7 April	0700-1500	4	4	9
8 April	0700-1500	4	4	8
9 April	0800-1140	4	4	no data
10 April	0830-1600	4	4	no data
11 April	0945-1600	3	3	no data
		(End Post-Harassment)		
12 April	1735-1750	0	0	0
23 April	1020-1130	0	0	0
14 May	0840-0915	1	1	0

were returning more than once on any given day. The total number of sea lion sightings during the 83 day period was 149, for an average of 1.8 sightings per day (range 1-8).

We made multiple sightings of sea lions during 40 of the 83 days, and single sightings on 20 days. There were 20 days when we saw no sea lions.

Sea lions were chased from the Locks 144 times during the course of the 83 day harassment period for an average of 1.73 times per day.

4.2.3 Predation Rates

The observed fish loss to sea lion predation was considerably lower during the harassment phase than during the pre-harassment phase of the study. The observed fish loss dropped from 18.549 fish per day prior to harassment to 0.608 fish per day during harassment (Table 4.7).

4.2.4 Steelhead Losses/Savings

Based on the discussion found in Section 4.1.5, we estimate that had there been no harassment, 1540 steelhead (hatchery and wild winter-runs combined) would have been lost to the predators during this time period (18.549 fish/day X 83 days). Since there was a low level of successful predation during the 83-day harassment period, we estimated an actual combined loss of 50 fish of both races (0.608 X 83).

We used periodically-gathered scale data on hatchery and wild fish origin to estimate that 20 wild steelhead and 30 hatchery steelhead were lost despite the harassment (Table 4.8).

The estimated number of fish saved from sea lion predation over the 83 days was 1490 steelhead. This figure was determined by subtracting the estimated fish loss during harassment (50) from the estimated loss with no harassment (1540). After applying appropriate hatchery: wild proportions by one-week time intervals, we calculated that 454 of the 1490 fish saved were of wild origin, and 1036 were of hatchery origin.

The actual number of fish lost over the 83 day period was probably greater than the observed and extrapolated estimate, because weekend and night coverage was somewhat sporadic. Since predation pressure appeared to be constant over the 83 day period, it's likely that more fish than the observed average were taken during days when coverage was incomplete. It appeared to us that constant harassment pressure was needed in order to keep sea lions from feeding, for they were extremely persistent in returning to the Locks area to feed.

To give the wild fish "savings" some perspective, 454 represents 20.1% of the estimated total wild run of 2262 that returned. If the harassment had continued through April (and also started in early December)

Table 4.7 Mean number of steelhead killed by California sea lions at the Chittenden Locks during 8-hour and 24-hour time strata, before and during lion harassment.

Time Stratum	NUMBER OF STEELHEAD KILLED Pre-Harassment	During Harassment
0730-1530	16.599	0.314
1530-2330	0.950	0.087
2330-0730	1.000	0.207
24-hour	18.549	0.608

Table 4.8 Estimated hatchery and wild winter-run steelhead losses to California sea lions at Salmon Bay during harassment, based upon an observed predation rate of 0.608 fish/day between 7 January and 1 April 1986.

STATISTICAL WEEK	JANUARY 5-11	12-18	19-25	26-1	FEB 2-8	9-15
NUMBER OF DAYS	4	7	7	7	7	7
NUMBER OF STEELHEAD KILLED [a]	2	4	4	4	4	4
% HATCHERY	96.2	85.0	73.7	77.5	81.2	85.0
% WILD	3.8	15.0	26.3	22.5	18.8	15.0
STEELHEAD LOSSES						
HATCHERY:	2	3	3	3	3	4
WILD:	0	1	1	1	1	1

STATISTICAL WEEK	FEB 16-22	23-1	MARCH 2-8	9-15	16-22	23-29	30-5
NUMBER OF DAYS	7	7	7	7	7	7	2
NUMBER OF STEELHEAD KILLED [a]	4	4	4	4	4	4	1
% HATCHERY	74.7	64.3	51.4	38.6	25.7	12.9	0.0
% WILD	25.3	35.7	48.6	61.4	74.3	87.1	100.0
STEELHEAD LOSSES							
HATCHERY:	3	3	2	2	1	1	0
WILD:	1	2	2	3	3	3	1

[a] At a predation rate of 0.608 steelhead/day.

ESTIMATED TOTAL HATCHERY STEELHEAD LOSSES: 30
ESTIMATED TOTAL WILD STEELHEAD LOSSES: 20

many more wild fish would have been saved. If our estimate of 219 wild fish lost in April is correct (Section 4.3.5), a similar rate of "protection", or reduced predation in April as in January-March would have allowed us to save 201 wild fish. The January through April total would then have been 655, or 29.0% of the wild run.

4.2.5 Sea Lion Behavior

The use of harassment techniques to drive sea lions from the Locks did alter their overall behavior. The sea lions appeared to exhibit a higher degree of cautious behavior when present in the Locks vicinity. The cautious behavior was characterized by their movements. Sea lions tended to reduce their overall visibility at the Locks by staying under water longer, remaining on the surface for shorter periods, and by swimming alongside piers and barriers where they were not fully exposed to view.

Sea lions also altered their primary foraging location and began feeding further out from the spillway dam. Prior to harassment, 66% of observed fish kills occurred close to the fishway within the cable area. Only 29% of observed fish kills occurred in this vicinity during harassment.

4.2.6 Reactions to Harassment Stimuli

The sea lions initially exhibited distinct and immediate reactions to the acoustic harassment device and seal bombs by an immediate dive response and then vacating the area rapidly. When seal bombs were first used, the animals appeared to be quite alarmed and left the area immediately, often leaping clear of the water and swimming for several miles out into Puget Sound. They were not observed to return for three full days following the initial harassment encounter on 7 January.

As time went on, however, sea lions appeared to be less disturbed by the harassment. The seal bombs still had a short term startle effect, but they were not as effective in keeping them out for long time periods. They also appeared to not move as rapidly out of the area and would not go as far out. They would often linger in the area below the railroad bridge or the mouth of Salmon Bay (out of range of seal bombs thrown from shore) before returning within several hours.

The AHDs were utilized as a secondary reinforcing stimulus. The devices were activated within one or two minutes after the first seal bombs were thrown and then left on for 20 to 30 minutes. This methodology was used because sea lions were known to become conditioned to these devices for long term usage when they were used at the Locks in 1983-84. The AHDs as utilized during the study did appear to be effective for short term use, for sea lions did not return when they were operating. This observation, however, may have been due primarily to the coincident use of seal bombs.

The most effective and long term harassment method was utilizing a small boat from which to throw seal bombs and operate the AHD, while chasing sea lions well out of the area.

4.3 Post-Harassment Assessment and Experimentation

The post-harassment phase of the study was conducted from 1 April through 11 April. During this period we endeavored to determine the overall effect of the harassment program, and to collect data about the abundance, distribution, and biology of sea lions in Puget Sound.

Regular harassment of sea lions was discontinued on 1 April at 0650, when the last seal bombs were used.

4.3.1 Sea Lion Presence

California sea lions were present at the Locks for each day of the eight days during which coverage was maintained (Table 4.9). This is very similar to the pattern observed for the eight-day pre-harassment period, when sea lions were observed on each day as well.

4.3.2 Sea Lion Numbers

During the post-harassment period, there were an average of 3.5 sea lions at the Locks each day (range 3-4) (Table 4.10). This is an increase in average numbers from both the pre-harassment and harassment phases of the study when 2.62 and 0.78 sea lions per day were present, respectively.

4.3.3 Sea Lion Identification

Two of the four sea lions observed at the Locks during the post-harassment period were the same animals which were seen earlier at the Locks. One was the humpbacked male, and the other the smaller male with the ventral scar. The other two animals could not be positively identified. These observations indicate that at least two of the sea lions which occurred at the Locks were practically seasonal residents who occurred throughout the season (1 January to 11 April). In addition, their presence following a rather intensive harassment period indicates the feeding opportunity at the Locks is very attractive to these individuals.

4.3.4 Predation Rates

Sea lions returned, and continued to predate steelhead at the Locks within one day after harassment was discontinued. Although we could not directly compare daily predation rates from this period with the

Table 4.9. Observed fish kills and hours of coverage during post-harassment observations at the Chittenden Locks, 2-8 April, 1986.

Date	Coverage	Number of Sea Lions Present	No. of Steelhead Killed	Total Hours of Coverage
2 April	0730-1350	3	4	6.4
3 April	0730-1300	3	5	5.5
4 April	0600-0900	3	0	3.0
7 April	0700-1430	4	9	7.5
8 April	0700-1500	4	8	8.0
	Totals*	17	26	30.4

* The aggregate mean number of steelhead killed per hour = 0.855

Table 4.10 Estimated hatchery, wild, and total steelhead losses to sea lions at Salmon Bay over the entire run with and without harassment, and number of steelhead saved with partial control (harassment).

		Estimated Total Steelhead Loss[a]	Estimated Wild Steelhead Loss[b]	Estimated Hatchery Steelhead Loss[b]
Pre-Harassment	12/ 1-12/30:	556	72	484
	12/31- 1/ 7:	149	18	131
During Harassment[c]		50	20	30
Post Harassment		219	219	0
		974	329	645

[a] steelhead either taken from set nets or from Ship Canal open water areas.
[b] hatchery:wild breakout based on contemporaneous scale data.
[c] harassment period: 8 January through 1 April.
Note: all losses in the 12/31-1/7 period are assumed to be accounted open water fish losses. The kill rate from 12/31-1/7 was applied to the 12/1-12/30 period.

LOSSES WITHOUT HARASSMENT

151 days X 18.549 steelhead/day = 2801 = total SH loss (1157-4047)[d] (1510-4077)[e]

wild steelhead loss = 1213
hatchery steelhead loss = 1564
2777[f]

[d] 95% conf. int. assuming a normal distribution of the daily kill rate; 0730-1530 time stratum only.
[e] 95% conf. int. assuming a Poisson distribution of the standardized daily kill rate; 0730-1530 time stratum only.
[f] 2777 does not equal 2801 due to rounding error when applying hatchery/wild percentages to estimated weekly steelhead losses.

SAVINGS WITH PARTIAL PREDATION CONTROL

	Hatchery	Wild	Total
loss w/no control:	1564	1213	2777
1985-86 losses:	- 645	- 329	- 974
savings:	919	884	1803

previous periods, overall predation rates appeared to be less than during the pre-harassment phase. Hourly kill rates were 0.855 fish per hour during the coverage time from 0600-1500 as compared to 2.075 fish per hour during similar time periods in the pre-harassment study (Tables 4.2 and 4.9).

Sea lions appeared to alter their foraging locations following the 83 days of harassment. The humpbacked male which we observed forage almost exclusively inside the cable near the fishway prior to harassment moved to the area by the railroad bridge and the large locks. In general, most sea lions appeared to forage further out away from the fishway (and away from the perceived source of harassment) during this period. Of the 26 fish which we observed taken during this time, 73% were taken outside the cable area as opposed to 34% during the pre-harassment period. This observation indicates that sea lions were aware of the potential for harassment and altered their behavior by moving further out where they were less susceptible to being harassed.

4.3.5 Steelhead Losses

4.3.5.1 Post-harassment period

We had to terminate the day-long (but not 24-hour) observation and harassment program on 1 April because of budget/staff limitations. As noted in Table 4.9, we continued to lose wild steelhead in April. It's unfortunate that we were unable to duplicate the procedures used in the pre-harassment study to estimate, even roughly, the diurnal predation rate. However, it is fairly safe to assume that, as before, predation was minimal between 2330 and 0730 hours.

In order to make a rough estimate of April steelhead losses, we used the early-April predation rate of 0.855 fish/hour for the 0730-1530 time stratum and applied it to the entire month. For the 1530-2330 time block, we reduced the 0.855 figure by 94.3%, which was the difference between the rates in the same two time strata during the pre-harassment study. The predation rates for April were also standardized to 8-hour intervals, viz.: 6.84 fish from 0730 to 1530; 0.40 fish from 1530 to 2330.

For the 30 days of April, using these methods and assumptions, we estimated that 205 steelhead were killed between 0730 and 1530, and 12 were taken between 1530 and 2330. A 94.3% reduction in the nighttime predation rate from the pre-harassment period (1.00 fish/8 hours to 0.057 fish/8 hours) results in an estimate of 2 fish taken between 2330 and 0730 in April. Thus, 219 additional wild steelhead were lost to sea lions in April:

April Daily Time Stratum	Test Period Kill Rate (2-8 April)	Standardized 8-hr Kill Rate	Wild Winter-run[a] Steelhead Losses During April (30 Days)
0730-1530	0.855 fish/hr	6.84	205
1530-2330	0.049 fish/hr[b]	0.40	12
2330-0730	0.007 fish/hr[c]	0.06	2
	24-hour:	7.30	TOTAL: 219

[a] All steelhead entering in April are assumed to be wild, and that sea lions present take fish numbers sufficient to satiate, despite declining run strength.
[b] Proportional reduction of the 0730-1530 kill rate, based on pre-harassment period; see text.
[c] Proportional reduction of the pre-harassment 2330-0730 kill rate; see text.

4.3.5.2 Season-long losses/savings

We estimate that a total of 974 steelhead of both races combined were predated over the course of the 1985-86 run. Of these 645 were hatchery fish, and 329 were of wild origin (Table 4.10).

These losses can be placed into perspective by comparing them to the probable losses had no harassment taken place. Under that scenario (given a continuous daily predation rate of 18.549 fish/day over 151 days) 2801 steelhead would have been killed, of which 1564 would have been hatchery fish, and 1213 wild fish (Table 4.10).

By subtraction, we can estimate the number of hatchery and wild fish that were saved by the 1985-86 control program. As shown in Table 4.10, 1803 fish were saved, of which 919 were hatchery fish, and 884 were wild.

Potential savings of a complete control program over the entire run (1 December through April) was estimated by applying the observed predation rate of 0.608 fish/day during the harassment phase to the entire run, and factoring in wild and hatchery proportions from scale analysis data. As seen in Tables 4.11 and 4.12, only 92 fish would be lost (40 wild plus 52 hatchery), and 2685 fish would be saved from what would otherwise be a loss of 2777 steelhead.

It is important to note that the Department does not consider the Lake Washington watershed fully seeded with wild steelhead (it is not at its full production potential, nor is the ultimate basin-wide escapement goal being met: while the existing escapement goal for accessible areas [1600] is being met, a dam blocks access to a substantial area of the upper Cedar River). When full escapements have been achieved for a period of time, average wild runs returning may approach 4200. Unchecked losses to sea lions at 1985-86 levels (1213 wild) would constitute about 28.9% of the basin's potential wild steelhead production. However,

Table 4.11 Hypothetical hatchery and wild winter-run steelhead losses to California sea lions at Salmon Bay with continuous harassment, based upon a mean daily predation rate of 0.608, with 1985-86 hatchery and wild run strengths and return timing.

STATISTICAL WEEK	DECEMBER 1-7	8-14	15-21	22-28	29-31	JANUARY 1-4	5-11	12-18	19-25	26-1	FEB 2-8	9-15
NUMBER OF DAYS	7	7	7	7	3	4	7	7	7	7	7	7
NUMBER OF STEELHEAD KILLED [a]	4	4	4	4	2	2	4	4	4	4	4	4
% HATCHERY	84.6	89.1	83.8	91.9	83.6	88.2	96.2	85.0	73.7	77.5	81.2	85.0
% WILD	15.4	10.9	16.2	8.1	16.4	11.8	3.8	15.0	26.3	22.5	18.8	15.0
STEELHEAD LOSSES HATCHERY:	4	4	4	4	2	2	4	4	3	3	3	4
WILD:	1	0	1	0	0	0	0	1	1	1	1	1

STATISTICAL WEEK	FEB 16-22	23-1	MARCH 2-8	9-15	16-22	23-29	30-5	APRIL 6-12	13-19	20-26	27-30
NUMBER OF DAYS	7	7	7	7	7	7	7	7	7	7	4
NUMBER OF STEELHEAD KILLED [a]	4	4	4	4	4	4	4	4	4	4	2
% HATCHERY	74.7	64.3	51.4	38.6	25.7	12.9	0.0	0.0	0.0	0.0	0.0
% WILD	25.3	35.7	48.6	61.4	74.3	87.1	100.0	100.0	100.0	100.0	100.0
STEELHEAD LOSSES HATCHERY:	3	3	2	2	1	1	0	0	0	0	0
WILD:	1	2	2	3	3	4	4	4	4	4	2

[a] At a predation rate of 0.608 steelhead/day.

ESTIMATED TOTAL HATCHERY STEELHEAD LOSSES: 52
ESTIMATED TOTAL WILD STEELHEAD LOSSES: 40

Table 4.12 Hypothetical steelhead savings with harassment applied over the entire run return period.

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151 days X 0.608 kills/day = 92 kills (40 wild, 52 hatchery)[a]

Total "uncontrolled" fish losses =	2777[b]	(1213 wild,	1564 hatchery)
Estimated loss with total control =	92	40	52
Potential savings =	2685	1173	1512

[a] See Table 4.5
[b] See Table 4.7

with control in effect throughout the wild run return, and if losses can be held to 0.608 steelhead (both races combined) per day, wild fish losses may be held to as little as 40 fish using methods similar to ours. This would represent 1.0% of an average run of 4200.

We emphasize that with more rigorous observation and harassment (no nightly or weekend gaps), the daily kill rate in the immediate Locks vicinity can probably be held to near zero using the methods employed in 1985-86.

However, a major unknown is whether sea lion predation rates can be controlled to a similar degree in future years using these methods, particularly if the number of animals in the area increases, and/or <u>individual</u> animals habitually forage at the Locks. Also, sea lion foraging success may increase, even in the face of harassment, if returning fish densities increase, and/or the number of sea lions foraging at the Locks concurrently is greater than the average number we observed in 1985-86.

4.3.5.3 <u>Evaluation of control program success</u>

In recent years the wild steelhead run returning to the Lake Washington system has ranged from 1995 to 3193, and averaged 2400 from 1982 through 1986 (n=5). Since stock:recruitment relationships are in the early years of development for the Lake Washington watershed, the Department's Fisheries Management Division had projected an average return of wild winter-runs in 1984-85, or 2490 fish. After accounting for wild fish harvests plus escapements in that cycle year (983 fish), a 1507 fish "shortfall" existed from the predicted return, which was tentatively attributed to sea lion predation.

This seems to be a very reasonable assumption, for the anticipated wild run returning in 1984-85 (2490) was almost the same as that predicted to return in 1985-86 (2500), where we estimated that 1213 wild fish would have been lost had there been no control (which was the case in 1984-85). Our 1986 end-of-season accounting of wild fish taken incidentally in the tribal harvest, when added to the measured escapement and estimated losses to sea lions in 1986, totals 2262, close to the pre-season prediction of 2500.

The estimated total of wild steelhead lost to sea lions in 1985-86 (330) represents 14.6% of the estimated total wild run (330/2262 = 0.146). A similar factor for 1984-85 would be 60.5% <u>if we were correct in ascribing our "shortfall" of 1507 wild fish to sea lion predation</u> (1507/2490 = 0.605). <u>If the assumptions are correct</u>, this is a 75.9% reduction in the proportion of the wild run taken by sea lions at the Locks. This is a reasonable figure, for we observed a 96.7% drop in the steelhead kill rate between the pre-harassment and harassment phases of this study (Table 4.7). A "reduction in the benefits" from 96.7% to 75.9% could easily be accounted for by our lack of harassment during April, when an estimated 219 fish were lost, as well as most of December, when a few wild steelhead are returning.

We succeeded in meeting our escapement goal in 1986, for an estimated 1816 wild steelhead spawned throughout the watershed (WDG file data). Thus, our principal objective (Section 1.0) was met. We feel that this was largely due to the control program, for wild fish losses without a control program would have resulted in only 933 fish, far less than the 1600 needed:

	2262	estimated wild run size
-	1213	estimated losses with no harassment
-	116	incidental tribal harvest of wild fish
	933	escapement (sport catch of wild fish = 0)

Without question, the Wild Steelhead Release regulation in effect in 1985-6 which required that all sport anglers release wild (unmarked) fish was helpful, however sport harvests of wild fish in past years has averaged only 584 fish on runs of comparable size. If this level of potential wild fish savings (584) is added to the escapement under the no-harassment scenario (933), 1517 results, which is still less than the agreed-to escapement goal of 1600. Thus, predation control was required to achieve the desired escapement.

4.3.6 Acoustic Harassment Device Testing

Five AHD test trials were made at the Locks from 7 to 11 April to observe the short term startle effect of the device. One device was used near the spillway area. The AHD was activated when one or more sea lions were within 25 m (82') of the device. The results of these tests are provided in the following account.

Test #1 - 7 April
AHD on: 1430-1435
Sea lions present: 2

Result: Both sea lions dove immediately after the AHD was actuated, and were next seen 50 m (164') out by the railroad bridge. The animals stayed in the bridge area at a distance of about 150 m (492') from the AHD until it was turned off at 1435.

1450: Both sea lions returned to the spillway vicinity, 30 m (98') from the AHD.

1452: Both sea lions were inside the cable area, and continued foraging.

Test #2 - 9 April
AHD on: 0845-0945
Sea lions present: 2

Result: An immediate dive response was exhibited by both sea lions. They were next sighted 75 m (246') out swimming away from the AHD.

0850: Both sea lions were about 200 m (656') away from the AHD and remained in that area.

0925: Both sea lions were in the same area as at 0850.

0945: The AHD was turned off. Two sea lions were observed under the railroad bridge out about 150 m (492').

0955: Two sea lions were back inside the cable by the AHD, and had resumed foraging behavior.

Test #3 - 11 April
AHD on: 1016-1025
Sea lions present: 3

Result: The AHD was activated when the three sea lions were in the AHD vicinity; one had just caught a steelhead. There was an immediate dive response by all three lions when the device was activated. The sea lion with the fish lost it. All of the sea lions moved out of the AHD vicinity to about 150 m (492') away, by the railroad bridge.

1025: The AHD was turned off.

1102: One sea lion returned and resumed foraging in the spillway area.

1145: Only one lion had returned when the device was turned off.

Test #4 - 11 April
AHD on: 1455-1501
Sea lions present: 1

Result: There was an immediate dive response and the animal departed. It was next observed 150 m (492') out.

1500: The sea lion is still out beneath the railroad bridge.

1501: The AHD was turned off.

1510: The sea lion returned, and was back inside the cable, foraging.

Test #5 - 11 April
AHD on: 1512-1545
Sea lions present: 1

Result: There was an immediate dive response and the animal departed.

1522: Two sea lions were sighted 150 m (492') out.

1533: Two sea lions were in the large lock, foraging. One captured a fish at 1534.

1540: One sea lion returns inside the cable and resumes foraging while the AHD is still on.

1545: The AHD was turned off.

1550: Three sea lions are now in the AHD vicinity, foraging. One was in the large lock, and two were inside the cable, in the spillway vicinity.

Overall Result:

The tests resulted in an immediate dive response by all sea lions each time the AHD was activated. The animals all departed the immediate spillway (and AHD) vicinity, and moved out of range of the device, approximately 150-200 m (492'-656') away. They resumed foraging at this distance even as the device was still activated.

On four of the tests (##1-4) the sea lions returned to the AHD vicinity within an average of 17 minutes (range 9-37) after the device was turned off. On one test (#5) one sea lion returned to the AHD vicinity before the device was turned off. This was the third test of the day involving that animal, and indicates that it quickly habituated to the sound.

Conclusion:

The AHD does appear to have some short term value in chasing sea lions from within the immediate range of an activated transducer. The animals, however, returned quickly after the device was deactivated, indicating that they learn to simply move out of range and wait until the sound source is deactivated.

It appears based on these tests that the AHD by itself is not effective in chasing sea lions further than 200 m (656') away, or in keeping them away for long periods of time.

4.4 Sea Lion Distribution, Abundance, and Biology in Puget Sound

We conducted sea lion boat surveys periodically in the vicinity of the Locks and Elliott Bay from 7 January through 23 April 1986. Sea lions were counted during these surveys and we noted locations where they were hauled out or rafting in the water (Figure 2.4).

4.4.1 Elliott Bay and Vicinity

We surveyed this region 20 times from 10 January through 12 April 1986. Sea lions were first noted as occurring in the vicinity of Elliott Bay in early December. At that time, they were interacting with the Muckleshoot Indian steelhead gillnet fishery in the Duwamish waterway (Walt Pacheco, pers. comm.). We regularly observed rafts of sea lions during the survey in January through mid-March in the east and west channels of the Duwamish Waterway (Table 4.13; Plate 4.1).

During late February to mid-March, there appeared to be a shift in sea lion distribution as they moved out of the Duwamish Waterway proper and began congregating in Elliott Bay at the mouth of the Duwamish channels (Table 4.13). As their overall numbers began dropping in Elliott Bay, smaller rafts began appearing off Duwamish Head. Duwamish Head may be utilized by sea lions as a staging area during their movements in and out of the vicinity. The maximum count for Elliott Bay and vicinity was 186 on 24 February (Table 4.13).

Sea lions were reported to have occurred as many as 20 miles up the Green River (aka Duwamish River) by fishermen during January and February. However, we could not confirm these reports. It is possible, however, that individuals or small groups of sea lions could travel this far up the Green River, for they are known to travel further than 20 miles up the Columbia River (Beach et al. 1985).

We commonly observed individuals and small groups of sea lions around the shoreline of Elliott Bay off the downtown Seattle ferry terminals, Pier 56, Pier 70, Magnolia Bluff, and at other areas (Plate 4.2). The majority of these sightings were of animals moving north or south along the shore. We observed few animals in the middle or offshore areas of Elliott Bay. These observations indicate that sea lions preferred to stay close to shore (within 200 m, or 650') during their movements to and from this area.

We identified only one haulout location in the Elliott Bay vicinity during these surveys. This site was on a temporary construction raft which was placed off Duwamish Head during dredging operations. The raft was removed after three to four days, and therefore was unavailable for long term usage. The maximum number of *Zalophus* observed hauled out at one time on this raft was 18.

We observed sea lions successfully foraging in Elliott Bay only three times during these surveys. Two of these observations were at the mouth of the west channel of the Duwamish Waterway near Todd Shipyards. The species of fish sought was not determined in either case, but fish captured appeared to be a small flatfish and herring, respectively. One other sea lion was observed thrashing and swallowing a bright salmonid-like fish in the vicinity of Pier 70.

One sea lion scat was collected from the construction raft off Duwamish Head on 26 February. This scat yielded eight otoliths and numerous bones from Pacific herring.

Table 4.13. Abundance and distribution surveys of California sea lions in Elliott Bay and vicinity.

Date	Duwamish Waterways E. Channel	Duwamish Waterways W. Channel	Elliott Bay	Duwamish Head	TOTAL
10 January	25	N/S*	0	0	25
11 January	17	N/S	6	0	23
16 January	20	0	0	0	20
24 January	37	1	2	0	40
31 January	52	6	0	0	58
5 February	27	41	0	0	68
7 February	22	12	77	0	111
18 February	79	2	1	0	82
21 February	23	64	7	0	94
24 Febraury	62	69	55	0	186
26 February	4	15	26	10	55
28 February	7	13	16	0	36
1 March	0	6	14	38	58
6 March	0	4	21	15	41
12 March	9	1	4	24	38
19 March	0	0	2	11	13
25 March	0	0	0	2	2
1 April	0	0	0	0	0
10 April	0	0	0	4	4
12 April	N/S	N/S	0	15	15

* N/S = No Survey

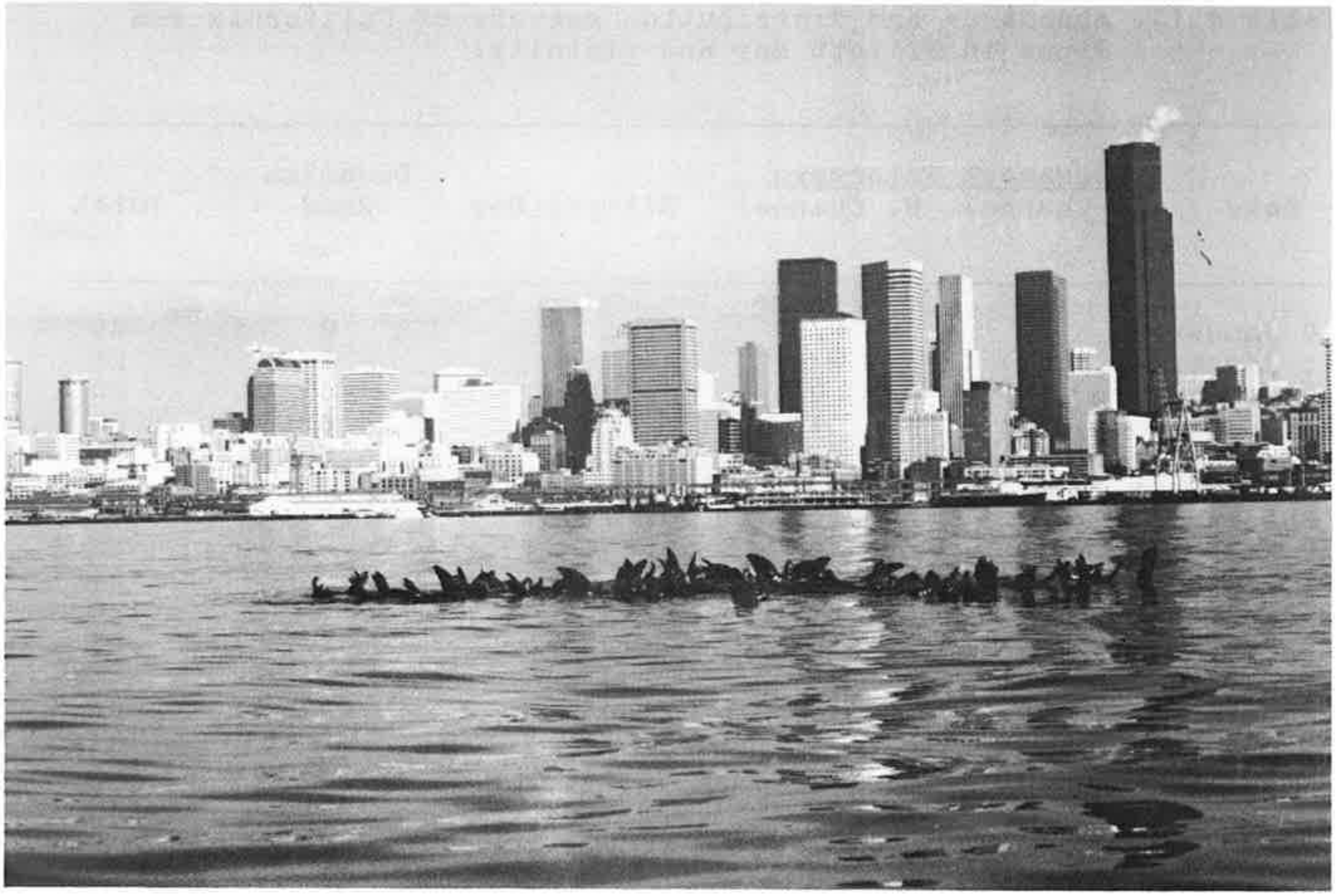

Plate 4.1. Rafting group of about 50 California sea lions near the mouth of the Duwamish River in Elliott Bay at Seattle, Washington, 7 February 1986.

Plate 4.2. Rafting group of California sea lions in Elliott Bay at Seattle, Washington, 7 February 1986.

On one survey what appeared to be the humpbacked male which frequented the Locks area was observed in the east channel of the Duwamish. Although we feel quite certain that this was the same animal, we feel it best to note this as a possible sighting since the animal was not marked or tagged.

4.4.2 Chittenden Locks and Vicinity

We conducted periodic boat surveys in the vicinity of the Locks in order to locate hauling and rafting areas, and to collect data regarding sea lion presence and abundance in this area. We conducted a total of 37 surveys (including two aerial surveys) in this area from 7 January through 23 April 1986. Sea lions were sighted on 12 (32%) of these surveys (Table 4.14). The maximum number of lions counted was 119 on 10 April.

These surveys do not include counts of sea lions which were made at the Locks on any given day. The surveys were often made in conjunction with a harassment episode so as to differentiate between harassed animals and those which "naturally" occurred in the vicinity.

The number of sea lions observed in this area was quite low (range 1-4) (Plates 4.3, 4.5) until 10 April when several large groups appeared in the vicinity (Plate 4.4). We believe that these animals moved south from the Port Gardner area, for we noted rafts along the shore from Port Gardner south to Duwamish Head during this time. A total of 165 sea lions were observed between Meadow Point and Elliott Bay on 10 April. This large group of sea lions appeared to have mostly departed the area by late March.

We identified three haul-out sites in the Chittenden Locks vicinity during the surveys. Each of these sites were on offshore buoys. The maximum number observed on each buoy was: Meadow Point channel buoy (1) (Plate 4.3), Shilshole Bay bell buoy (4) (Plate 4.5), and the West Point channel buoy (1). No sea lions which were hauled out on buoys were identified as animals which frequented the Locks. We conducted two surveys during darkness to see if sea lions were hauling out in the Locks vicinity at night, but did not see any hauled out.

We did not observe any sea lions feeding in the aforementioned areas during the surveys. No scats were collected, although buoys were checked on a regular basis.

4.4.3 West Point to Elliott Bay

The area from West Point to the north side of Elliott Bay was surveyed during the same days as the Elliott Bay surveys. We occasionally sighted individual sea lions or small groups of two to four animals in the area near Four Mile Rock.

Table 4.14. Census counts of California sea lions in the vicinity of the Chittenden Locks, Seattle, 7 January-23 April 1986.

Date	Time	Salmon Bay	Shilshole Bay	Meadow Point	West Point	TOTAL
7 January	1300-1400	0	1	0	0	1
11 January	1345-1410	0	0	0	0	0
12 January	2220-2300	0	0	0	0	0
13 January	1020-1120	0	1	0	N/S*	1
15 January	1040-1100	0	0	0	0	0
16 January	0950-1020	0	0	0	0	0
17 January	0800-0845	0	0	0	N/S	0
21 January	1410-1500	0	0	0	0	0
22 January	1115-1210	0	0	0	0	0
23 January	1500-1525	0	0	0	1	1
24 January	1445-1510	0	0	0	0	0
27 January	0020-0130	0	1	0	0	1
28 January	1030-1110	0	0	0	0	0
29 January	1145-1210	0	0	0	0	0
31 January	1100-1140	0	0	0	0	0
5 February	1310-1330	1	3	N/S	0	4
7 February	1000-1030	0	0	N/S	0	0
11 February	1230-1300	0	0	0	0	0
18 February	1435-1450	0	0	N/S	0	0
20 February	1500-1540	0	0	0	0	0
21 February	0920-0950	0	0	N/S	0	0
24 February	0725-0740	0	0	N/S	0	0
26 February	0655-0710	0	0	N/S	0	0
28 February	0900-0915	0	0	N/S	0	0
1 March	1500-1530	0	0	0	0	0
6 March	1300-1620	0	0	0	2	2
11 March	0930-1010	0	0	0	0	0
12 March	0950-1015	0	0	0	0	0
19 March	1150-1210	1	0	N/S	0	1
20 March	1400-1500	0	0	0	0	0
21 March	1430-1500	0	0	0	0	0
24 March	1230-1300	0	0	0	0	0
25 March	1230-1300	2	0	0	0	2
1 April	1011-1016	1	0	0	0	1
10 April	1200-1250	0	2	61	56	119
12 April	1610-1700	0	2	23	4	29
23 April	1140-1300	0	7	15	1	23

* = No Survey

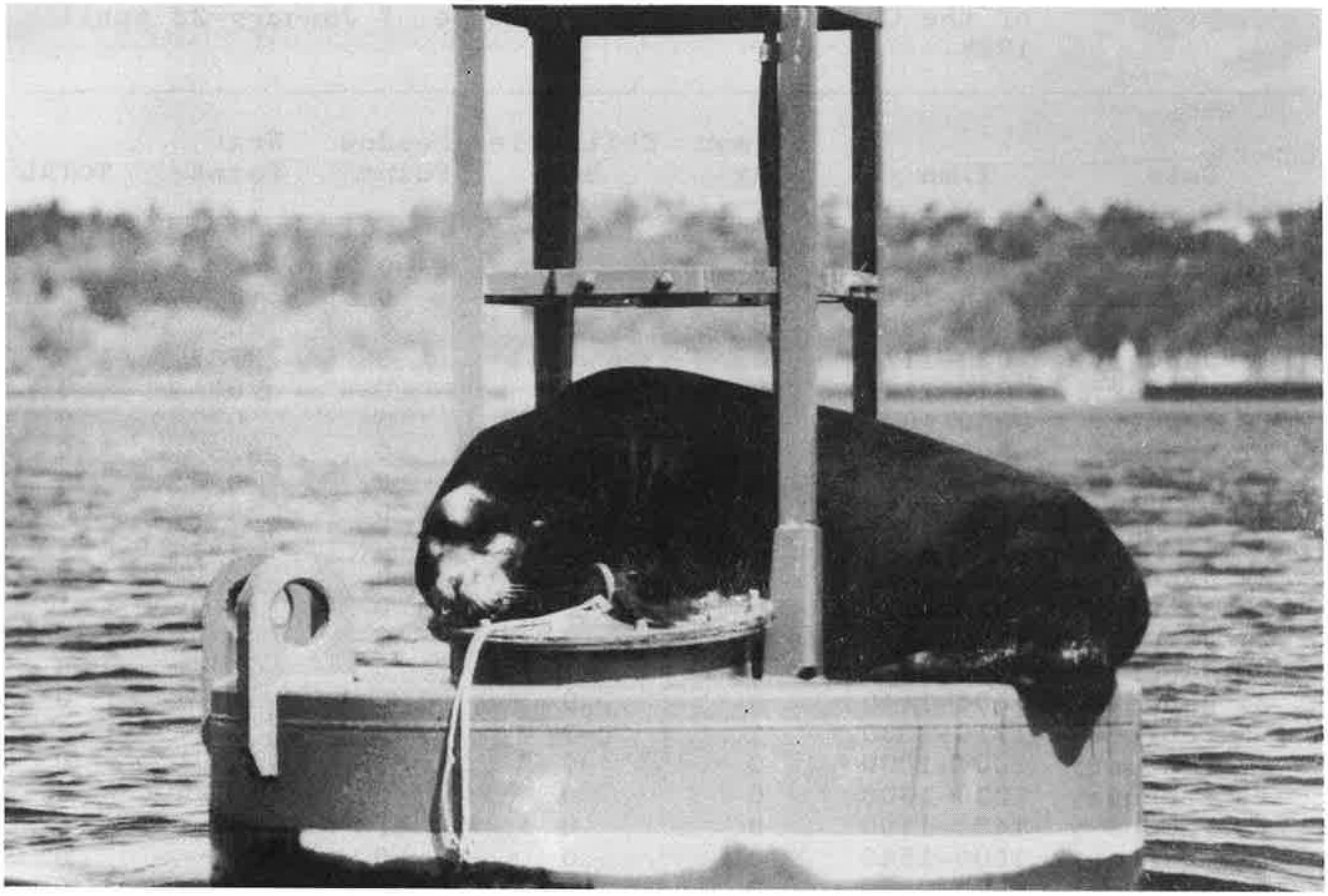

Plate 4.3. A large "bull" California sea lion on a channel marker buoy off Meadow Point, near Shilshole Bay, 12 April 1986.

Plate 4.4. One California sea lion hauled out on a channel marker buoy, with about 60 rafting (foreground and background) off Meadow Point near Shilshole Bay, 10 April 1986.

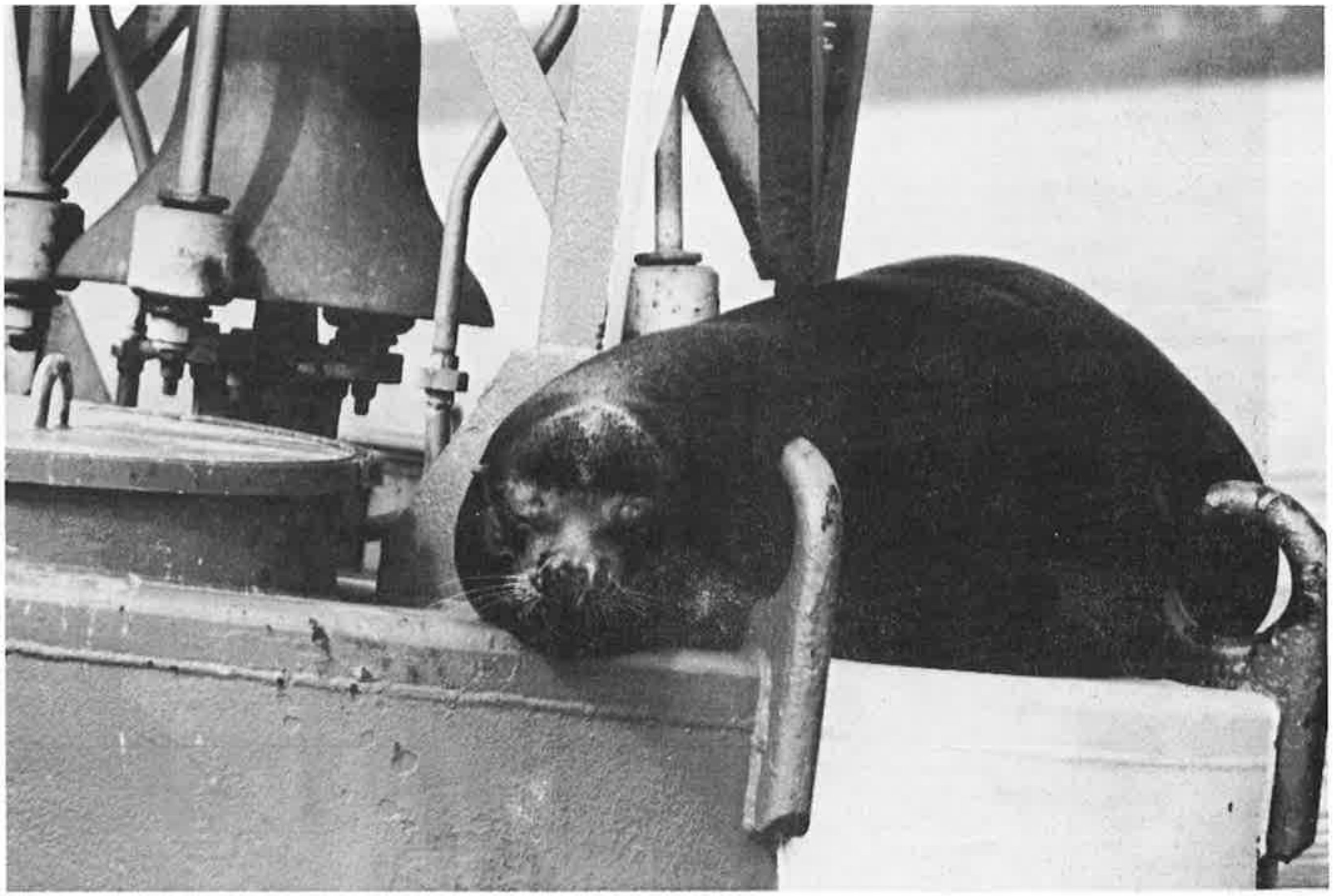

Plate 4.5. One large "bull" California sea lion hauled out on the bell buoy at the mouth of Shilshole Bay, 10 April 1986.

4.4.4 Other Marine Mammal Species Sighted

We spotted two other species of marine mammals during the boat surveys. We sighted single harbor seals (*Phoca vitulina*) on three occasions, and northern sea lions (*Eumetopias jubatus*) were sighted four times. Single northern sea lions were observed twice, and on two occasions we observed single animals rafting with California sea lions.

4.4.5 Aerial Surveys

We flew an aerial survey on 1 April 1986 in order to assess the distribution of California sea lions in Puget Sound. We did not cover certain areas of the Sound on this survey. Areas not covered include: Case Inlet and the inlets south and west of Case Inlet; Hood Canal; Skagit Bay; the San Juan Islands; and the western Strait of Juan de Fuca. The southeastern Strait of Juan de Fuca was flown from Admiralty Inlet to Dungeness Spit.

We tallied a total of 1015 California sea lions on this aerial survey (Table 4.15). (Similar numbers and distribution patterns were observed during the 4 April survey as well.) This count represents the most sea lions counted in Washington State during any one survey to date. The count, however, is only a minimum estimate of sea lions in the inland waters of Washington since many areas were not surveyed.

4.4.6 Haul-out Sites

We identified a total of 15 individual sea lion haul-out sites during the aerial and boat surveys (Table 4.16). All of these sites were on manmade objects which were either stationary (buoys, oil rigs, Port Gardner barges) or temporary (log booms, Foss barge, construction raft).

The largest single haul-out site observed was under an oil rig (Sedco 708) which was stationed off Gedney Island in Port Gardner on the survey date (Plate 4.6). We estimated that over 300 lions were hauled out here in mid-April (Plates 4.7, 4.8). This oil rig is not available to sea lions on a consistent basis because the pontoons are periodically lowered into the water. In addition, the rig was removed from the area some time in mid- to late 1986.

The barge off the Port Gardner jetty is probably the platform which is most consistently utilized as a haul-out by large numbers of sea lions in Puget Sound (Plate 4.10). As many as 190 sea lions were observed hauled out on this platform (actually two mated barges). We estimate that there is space on this platform to accomodate 500 to 600 sea lions.

4.4.7 Sea Lion Food Habits

A total of 98 sea lion scats and two spewings (vomitus samples) were

Table 4.15. Location and number of California sea lions observed during Puget Sound aerial survey, 1 April 1986.

Time	Location	No. of *Zalophus*	(# in Water)
0909	(Takeoff-Olympia)	(0)	
0915	Budd Inlet	0	
0925	Nisqually delta	2	(2)
0934	Gertrude Island	0	
0936	Fox Island	56	(10)
0945	Commencement Bay	0	
0955	Lakota	4	(4)
1002	Brace Point	2	(2)
1003	Point Williams	1	(1)
1005	Alki Point	0	
1008	Duwamish waterways	0	
1010	Elliott Bay	0	
1011	Four Mile Rock	0	
1015	Salmon Bay	1	
1016	Meadow Point	0	
1020	Richmond Beach	3	(3)
1029	Mukilteo	1	(1)
1031	Port Gardner*		
	Oil Rig	734	(734)
	Port Susan	196	(168)
	Log booms	15	
1208	Smith-Minor Islands	0	
1225	Dungeness Spit	0	
1240	Protection Island	0	
1250	Marrowstone Island	0	
1325	Blakely Rock	0	
1338	Tacoma Narrows	0	
1342	Toliva Shoals	0	
1358	(Touchdown-Olympia)		
	TOTAL:	1015	

*Includes Port Susan and Saratoga Passage.

Table 4.16. California sea lion haul-out sites identified during aerial and boat surveys of Puget Sound and adjacent waters, January-April 1986.

Location	Maximum Number Hauled Out
Fox Island Acoustic Range (3 rafts)	56
Toliva Shoals Buoy*	1
Duwamish Head Construction Raft	18
West Point Buoy (Green)	1
Shilshole Bay Bell Buoy (Red)	4
Meadow Point Buoy (Green)	1
Port Gardner	
Log Boom*	50+
Barge (stationary)	190
SEDCO 708 Oil Rig	300+
Foss Barge	16
Yellow Buoy	2
Barge Buoy	1
Channel Buoy	1

*These animals were observed during an aerial survey conducted on 4 April 1986.

Plate 4.6. A large rafting group (ca. 700) of California sea lions near the oil rig SEDCO 708 off Gedney Island near Port Gardner, near Everett, Washington, 1 April 1986.

Plate 4.7. A group of California sea lions hauled out beneath the oil rig SEDCO 708 near Port Gardner, near Everett, Washington, 17 April 1986. Note the variance in animal size.

Plate 4.8. A group of California sea lions hauled out beneath the oil rig SEDCO 708 near Port Gardner, near Everett, Washington, 17 April 1986.

Plate 4.9. A group of California sea lions hauled out on a Foss barge at Port Gardner, at Everett, Washington, 17 April 1986.

Plate 4.10. California sea lions rafting and hauled out on a barge in Port Gardner at the mouth of the Snohomish River at Everett, Washington, 4 April 1986. About 190 were on the barge, and about 75 rafted together in the water nearby.

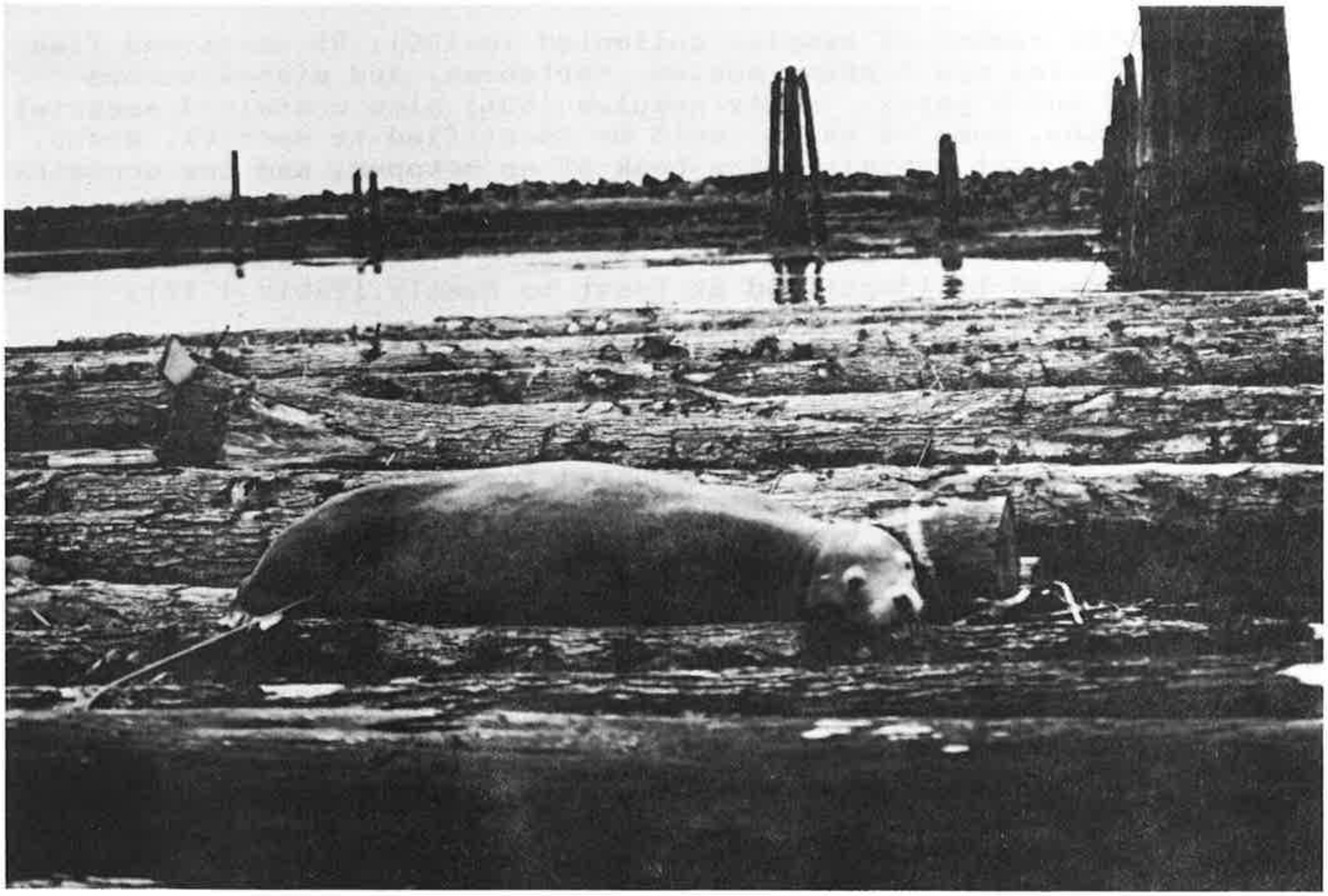

Plate 4.11. One California sea lion hauled out on a log boom at the mouth of the Snohomish River at Everett, Washington, 17 April 1986. The jetty in the background separates the river mouth from Port Gardner.

collected during the study period. Only one scat was collected in Elliott Bay on 26 February; the remainder were collected in Port Gardner on the haulout barge or beneath the oil rig Sedco 708 on 17 April.

Of the total number of samples collected (n=100), 95 contained fish bone, including eye lenses, scales, vertebrae, and miscellaneous spines and mouth parts. Sixty samples (60%) also contained saggital fish otoliths, some of which could be identified to species, genus, or Family. One scat contained the beak of an octopus, and one contained the mouthparts of a lamprey.

A total of 287 fish otoliths were recovered from the samples of which 266 (93%) could be identified at least to Family (Table 4.17).

Pacific whiting or hake was the species with the highest representation in the samples. It was recovered in 41% of the total sample, and accounted for 65% of the total identified otoliths. The species which was second in occurrence was Pacific herring which was recovered in 12% of the total samples, and accounted for 16% of the total identifiable otoliths. Walleye pollock and Pacific cod were next, being recovered in 3% and 2% of the total sample, respectively, and accounted for 4.1% and 0.7% of the total identifiable otoliths. *Octopus sp.* were found in only 1% of the samples, representing one individual. Lamprey occurred in 1% of the sample, also representing a single individual.

Some otoliths which could not be identified to species because of breakage or wear could be identified at least to Family. These otoliths were grouped into the Gadidae which includes cod, pollock, and hake. Miscellaneous gadids were recovered in 6% of the total sample and accounted for 14% of the total identifiable otoliths (Table 4.17). These data indicate the importance of gadid fishes in the diet of sea lions near Port Gardner. Overall, gadid fishes (including cod, pollock and hake) were recovered in 52% of the total samples and accounted for 84% of the total identifiable otoliths.

The single most prevalent prey recovered in these samples was hake which are known to be significant prey from other studies (Antonelis et al. 1984; Everitt et al. 1981). These data suggest that the large seasonal sea lion population near Port Gardner may be in response to a large aggregation of hake in this region during the same time of year (Kimura and Millikan 1977).

No salmonid (salmon or steelhead) otoliths or remains were recovered from the samples despite the presence of large numbers of salmon or steelhead in the region near the mouth of the Snohomish River. These findings suggest that salmonids are not taken in significant numbers in that area.

Three observations of actual sea lion foraging were made during the boat surveys and censuses conducted during this study. All three of these observations occurred in Elliott Bay. It was not possible to

Table. 4.17. Prey items recovered in 100 California sea lion scats and spewings from Port Gardner and Elliott Bay in 1986.

Name	% of Samples	# of Otoliths	% of Total
Pacific whiting (hake) *Merluccius productus*	41	173	65.0
Pacific herring *Clupea harengus pallasi*	12	43	16.2
Walleye pollock *Theragra chalcogramma*	3	11	4.1
Pacific cod *Gadus macrocephalus*	2	2	0.7
Miscellaneous codfishes (Gadidae)[a]	6	37	14.0
Octopus[b] *Octopus spp.*	1	--	----
Pacific lamprey[c] *Entosphenus tridentatus*	1	--	----

[a] Gadidae: includes cod, pollock, and hake otoliths not identifiable to species.

[b] Octopus: one upper and one lower octopus beak was recovered, accounting for one individual.

[c] Lamprey: Part of the buccal mouth parts of one lamprey were recovered in one scat.

Note: One scat from Elliott Bay contained 10 herring otoliths.

positively identify the prey species in these cases, however they appeared to be a herring, flatfish, and salmonid-like fish, respectively.

The lack of any dietary evidence of significant salmonid predation by sea lions outside of Salmon Bay indicates that salmonids may not be taken in significant numbers except in areas where they are concentrated and enclosed within artificial boundaries.

4.5 Alternate Control Methods Evaluation

We held discussions with various engineers and biologists of the staff of the Seattle District of the Corps of Engineers regarding the feasibility of constructing a permanent structure below the fishway entrance which would create an area (refuge) where returning steelhead could avoid sea lion predation.

Although we intend to pursue additional discussions along these lines, the apparent opinion of the Corps staff at present is that a structural solution is uneconomical, and may be infeasible given the flows and debris in the spillway dam apron area. The operation and maintenance of such a structure may be considerably higher than a simple annual program of harassment, funded by the Corps.

While we did not attempt to capture and transport any sea lions during our study, we have recommended that this be explored (Section 6.0). If only a few animals are active in the Locks area ("repeat offenders"), capturing and transporting them a long distance from the Ballard area may be cost-effective.

A small amount of time was spent testing underwater hydrophones and transmission of killer whale vocalizations. However, the available equipment did not have sufficient power to allow any conclusions regarding its effectiveness.

5.0 MANAGEMENT COSTS OF THE 1985-86 CONTROL PROGRAM

A primary question relating to managing a sea lion predation control program at the Chittenden Locks is: How much protection for wild winter-run steelhead is needed, or enough?

The ultimate escapement goal for the entire watershed currently is set at 1983 fish. If runs returning from optimum escapements (ca. 1983) average 3000, a harvestable number of 1135 results. Potential season-long predation rates of 1200 wild steelhead (Table 4.3) would eliminate harvestable surpluses on an annual basis. Thus, some form of sea lion predation control appears to be essential if there are to be any appreciable future sport or tribal harvests of wild stocks (assuming 1985-86 predation rates or greater occur in future years).

Since the California sea lions quickly returned to successfully forage at the Locks immediately after harassment was terminated (Section 4.3), any harassment as a method to control predation must be continuous or nearly so throughout the returning wild run.

While methods other than what we employed may be more effective, and ultimately more cost-effective, the costs of our 1985-86 program are given below, and are then adjusted to represent the costs for a more complete program of predation control.

5.1 Personnel

A project leader is required to supervise the day-to-day management of the harassment/control, supervise observers/harassers, consult and coordinate with pertinent agency personnel, and participate in active harassment/control. (In 1985-86, most of these duties were carried out by the local District Fishery Biologist, which created an unacceptably heavy additional workload, and seriously robbed time needed to manage other programs.)

We found that at least three full-time workers are needed during the control period to allow for some rotation of personnel on the nighttime (2330-0730) shift, and to accommodate personnel needs on weekends and holidays.

A large amount of time was required of the lead field biologist and the District Fishery Biologist to draft, word process, review, compile, and coordinate reproduction of the initial project report. Virtually all of these tasks can and should be conducted by a future project leader, for which time would need to be allocated. Word processing would have to be conducted by the project leader, by additional secretarial staff, or be contracted.

5.1.1 1985-86 Program

Personnel costs incurred for the 1985-86 program are summarized below:

Position	Tenure	Gross Monthly Salary	Overhead	Benefits	Total
Biologist I (c)	4 mos.	1358	407 [a]	418	8732 [b]

[a] Dept. of Game administrative overhead currently 30%.
[b] $6000 allocated for project; balance of salary, benefits, and supplies costs were borne by regional fishery management operations budget, and wildlife management monies earmarked for other research project(s).
[c] One additional employee was "donated" by NMFS for full-time observing.

5.1.2 Future Program

Following are the minimum personnel needs to adequately carry out a predation control program in 1986-87 (and future years?).

Position	Tenure	Gross Monthly Salary	Overhead	Benefits	Monthly Total	Grand Total
Bio IV	3 wks.	1102	330	337	(1769)	1,769
Bio I (1)	5 mos.	1392	418	437	2247	11,235
Fish & Game Tech. Aide (2)	4.5 mos.	2284	685	791	3760	18,800
					5835	30,035
Clerk-Typist	1 mo.	981	294	196	(1471)	1,471
						33,275

5.2 Equipment

Materials and equipment used in 1985-86 included seal bombs for primary harassment (expendable), as well as acoustic harassment devices (AHDs) (non-expendable). One of the acoustic devices was lost (not budgeted), and needs to be replaced. Gas, oil, and maintenance costs were incurred to run a 16' Boston Whaler during harassment, and to maintain the AHDs. Photographic records were kept of particular sea lions having notable characteristics, and to document site characteristics and methods. These records incurred development and printing costs beyond mere film procurement,some of which was necessarily custom work. About

$1000 of the Department's Marine Mammal Project budget was diverted to the work at the Locks. Last, there were numerous miscellaneous supplies costs for the day-to-day operation (notebooks, foul weather gear, etc.).

We found that two cases of seal bombs (1296 pieces) was inadequate, and that damage can occur to previously-purchased AHDs. In the future, if animal capture and translocation is attempted, approximately $2-3000 additional dollars need to be budgeted.

5.2.1 <u>1985-86 Program</u>

Following are the equipment costs incurred in 1985-86:

Item	Cost	
Seal bombs - 2 cases (1296 pieces)	420	
Photographic film, mailers, & lab work	367	
AHD transducer (1)	500	
Aerial surveys (10 hrs)	800	
Gas, oil, and boat maintenance	450	(125 gas & oil)
Notebooks	36	
Raingear	80	
Batteries and misc.	10	
TOTAL:	2663	

5.2.2 <u>Future Program</u>

Following are the anticipated equipment needs for a more complete program of predation control, using methods similar to 1985-86 methods.

Item	Cost
Puget Sound aerial surveys (20 hrs)	1600
Seal bombs - 3 cases (1944 pieces)	630
Photographic film, mailers, and lab work	100
Gas, oil, and boat maintenance	375
Notebooks	25
Raingear	160
Miscellaneous	20
TOTAL:	2910

In summary, only $6000 was appropriated for the control project in 1985-86, yet staff salaries, materials, and services totalled $24,100 for the <u>partial</u> control program (this figure does <u>not</u> include the value of time donated for control activities by enforcement staff of WDG and NMFS, or by tribal biologists). All labor and materials beyond that which could be acquired for $6000 was borne by Washington Department of Game (WDG) regional fishery management staff, tribal biologists, other volunteers, and WDG wildlife staff time and equipment otherwise committed to other funded projects. Coordination of all activities on the project by all volunteers and "extra" agency personnel fell on the District Fishery Biologist.

We expect that an estimated annual budget of $36,200 will assure adequate staff and materials to effect control of California sea lion predation in 1986-87, and possibly future years, if the need persists.

5.3 Relationship to Resource Values

The $36,200 price tag for near-complete predation control using this past season's methods can be placed into perspective when the values of the sport and commercial fisheries associated with Lake Washington winter-run steelhead are examined.

The commercial value of the tribal share of the harvestable surplus of wild returnees, and half of the returning hatchery fish is fairly straightforward. The average value of landed winter-runs from Area 10A in 1985-86 ranged from $1.50 to $2.25 per pound, and the average fish weight was 7.5 lbs. in November, 7.4 lbs. in December, and 7.7 lbs. in January (Bill Taylor, pers. comm.). Taking a median dollar value of $1.88/lb. and a mean weight for the three-month period of 7.53 lbs. yields an average value of $14.16 per fish.

Placing a dollar value on the returning fish that are available to be taken in a sport fishery is not nearly as simple a matter. There is a substantial body of literature on this complex subject, and we will not give it detailed treatment here. Richards and Peterson (1976) discuss many of the more important principles, and offer a net economic value of $50.67 for a day's fishing for winter-run steelhead (which includes anglers' valuation of aesthetic intangibles and social benefits). This 1977 value is adjusted upward to $67 in our calculations to 1980 dollars based on the Consumer Price Index.

A slightly different approach was taken by Brown, Sorhus, and Meyer (1982) who conducted a steelhead sport fishery study in Oregon similar to that of Richards and Peterson (1976), however they expressed net value in terms of each steelhead landed rather than in terms of angler days. Their average 1977 estimate was $74 per steelhead, or $94 in 1980 dollars (Fisheries Management Division 1983).

We have used both sport values ("Value #1" and "Value #2") in our calculations (Table 5.2) for comparison. The lesser value is probably more applicable to the Lake Washington fisheries, for most of the users do not have to drive relatively long distances to partake of their sport. Nevertheless, we cannot assume that these "urban" users would assign a net economic value to their caught fish any less than the Oregon anglers. Only a separate, local study would confirm that supposition.

Table 5.1 tabulates the numbers of harvestable returnees by both commercial fishermen and sport anglers. Since development of a stock: recruit relationship for the Lake Washington steelhead run is in a very embryonic stage of development, we have included a range of values for

Table 5.1 Sport and tribal allocations of hatchery and wild winter-run steelhead returning to Lake Washington, based on average (1981-85) returns, and at theoretical basin-wide full wild production.

		Existing Average Wild Production	Potential Wild Full Basin Production
Mean Hatchery Run Size	1752 [a]		
Number Harvestable	1752		
Sport Allocation	**876**		
Commercial Allocation	**876**		
Mean Wild Run Size		2400 [b]	2567-3309 [d]
Escapement Goal		1363 [c]	1808
Number Harvestable		1037	759-1501
Sport Allocation		**519**	**380-751**
Commercial Allocation		**518**	**379-750**
Sport Total (Hatchery + Wild)		**1395-1627**	
Commercial Total (Hatchery + Wild)		**1394-1626**	

[a] Based on a mean smolt stocking level of 55,835, and mean return to catch of 1.1+ steelhead at 0.0245; 0.0049 for 1.2+; and these two age groups representing 93.7% of the total catch (6.3% as other age classifications).

[b] Assumes that about 1500 wild steelhead were lost to sea lions during the 1984-85 run return; an actual mean wild run of 2399 was rounded to 2400.

[c] Latest (6/86) basin-wide goal, minus habitat above the Landsburg diversion dam. Revised as current methodology is updated with latest habitat and research information.

[d] Lower figure based on maximum sustainable harvest (MSH) management and observed stock:recruit ratio of 1.42:1; higher number based on MSH management and Puget Sound average s:r ratio of 1.83:1. "Full basin production" includes the mainstem Cedar River above Landsburg, plus its tributaries.

Table 5.2 Annual net economic value of sport and commercially-caught winter-run steelhead returning to Lake Washington, with benefit: cost ratios to an annual #36,200 sea lion control program. An uncontrollable 1.4% predation rate at Salmon Bay is assumed. Net economic multipliers are footnoted, and harvestable numbers used in the calculation of total run values are from Table 5.1.

AGGREGATE ECONOMIC VALUES OF AVERAGE RETURNS (X $1000)

		Sport	Commercial	Total	Benefit:Cost
Hatchery Returns	Value #1: [a]	241.3	12.2	253.6	7.0:1
	Value #2: [b]	81.2	(12.2)	93.5	2.6:1
Ave. Wild Returns	Value #1:	142.8	7.3	150.1	4.2:1
	Value #2:	48.0	(7.3)	55.3	1.5:1
Full Pr'n Wild Returns [c]	Value #1:	104.5-206.7	5.3-10.5	109.8-217.2	3.0-6.0:1
	Value #2:	35.1- 69.6	(5.3-10.5)	40.4- 80.1	1.12-2.2:1
Average Combined Hat.+ Wild Returns	Value #1:	384.3	19.5	403.8	11.2:1
	Value #2:	129.3	(19.5)	148.8	4.1:1
Combined Full Pr'n Hat.+ Wild Returns	Value #1:	346.0-448.2	17.5-22.7	363.5-470.9	10.0-13.0:1
	Value #2:	116.4-150.8	(17.5-22.7)	133.9-173.5	3.7- 4.8:1

[a] Net economic value of each steelhead = $67/day, ave. 4.17 days/steelhead; (Richards and Peterson 1976).

[b] Net economic value of each steelhead = $94; Brown, Sorhus, and Meyer (1982).

[c] Economic values calculated on two run sizes based on two stock:recruit values: 1.42 for the 1981 brood; possible 1.83 based on results seen in other Puget Sound and coastal systems.

average wild run size returning when the watershed is fully seeded. Thus, the combined total of hatchery and wild fish available to sport and commercial fishermen is also expressed as a range. However, since there is, of course, uncertainty as to ultimate wild returns to the watershed, we have presented values of the existing returns of both hatchery and wild fish in Table 5.2.

The salient point in Table 5.2 is that the benefit:cost ratio for a $36,200 sea lion predation control program is at least 4.1:1 for the combined fisheries based on average hatchery and wild stock returns. The ratio is much higher if the higher sport value for the fish (Value #1) is used, and especially if a higher stock:recruit ratio of 1.83 is assumed to be correct and is applied to production based on basin-wide seeding (13.0:1). Also, if there were no hatchery-based fishery, the B:C ratio would still be at least 1.5:1 on only current average returns of wild stocks.

Another interpretation of the data in Table 5.2 is that an annual program of sea lion predation control costing $36,200 would assure maintenance of an annual winter-run steelhead fishery valued conservatively at $134,000, but more realistically at about $471,000.

5.3.1 B:C Ratio Based on Steelhead Saved

The benefit to cost ratio of a control program can also be viewed in terms of the value of the fish which would be saved by the control program, rather than in terms of the overall value of the runs returning. The data tabulated below show this relationship:

		Intrinsic Sport Value[a]	Commercial[a] Value	Benefit:Cost Ratio Sport	Commercial	Combined
Actual 1985-6 fish savings:	1803[b]	#1: $251,730	$12,744	7.0:1	0.35:1	7.3:1
		#2: $ 84,694		2.3:1		2.7:1
Theoretical season-long savings:	2685[c]	#1: $375,221	$19,003	10.4:1	0.52:1	10.9:1
		#2: $126,242		3.5:1		4.0:1

[a] Assumes fish saved are apportioned to each user group on a 50:50 basis.
[b] Table 4.10
[c] Table 4.12

6.0 SUMMARY AND CONCLUSIONS

6.1 Summary

1. The management of marine mammals, including California sea lions, is the responsibility of the National Marine Fisheries Service (USDC/NOAA) under the provisions of the Marine Mammal Protection Act (MMPA) of 1972. The MMPA prohibits the taking of any marine mammal; control of marine mammals which adversely affect fisheries has emphasized non-lethal approaches. In general, attempts to control sea lion-fishery problems are in the early stages of development. In no case has there been determined a highly successful method which has application over a broad geographic area and for a large number of independent fisheries.

2. The number of California sea lions within Washington's inland waters has steadily increased since 1979. Their numbers in Puget Sound appear to have increased nine-fold in the last seven years, as indexed by counts in the Port Gardner (Everett) area. With the increase in numbers, sea lions are appearing in areas where not previously noted.

3. Increasing numbers of California sea lions predating on winter-run steelhead at the Chittenden (Ballard) Locks in recent years prompted the study-control program in 1985-86. The principal objectives were to document the predation rate and its effect on steelhead in the Salmon Bay area; to control and minimize such predation so as to maximize the escapement of wild steelhead stocks to the Lake Washington system; to evaluate and recommend potential long term procedures for steelhead predation control; and to document the abundance and distribution of sea lions in Puget Sound.

4. The study/control program was divided into three phases: a pre-harassment documentation/observation phase; a harassment phase; and a post-harassment documentation/observation phase, which included some testing of alternative control methods.

5. Harassment was confined to the Salmon Bay area below the Hiram M. Chittenden Government Locks at Ballard. Boat surveys of sea lion abundance and distribution occurred from southern Elliott Bay and Duwamish Head to the mouth of the Snohomish River at Everett. Aerial surveys of Puget Sound ranged from Olympia north to the northern extent of Port Susan and Saratoga Passage; southern shores of the Strait of Juan de Fuca were surveyed west to Dungeness Spit.

6. An average of 2.6 sea lions were present at the Locks daily, and killed 102 steelhead during the pre-harassment study period. California sea lions killed an average of 18.55 steelhead per day during this period (30 December through 6 January).

7. Wastage of steelhead caught by sea lions at the Locks was difficult to estimate, but may be less than 10% of the total weight of fish eaten.

8. Almost all steelhead were taken during hours of daylight. Predation rates were highest between 0730 and 1530 (30 December - 1 April). Sea lions consistently brought captured steelhead to the surface alive where they were dispatched, and then consumed above water.

9. California sea lions were present at the Locks during eight of the nine days of the pre-harassment observation period; on 75% of the days during the harassment phase; and 100% of the days on which observations took place during the post-harassment phase.

10. The pre-harassment predation rate was used to extrapolate potential steelhead losses during the harassment period had there been no harassment. We estimated that had there been no harassment between 7 January and 1 April that 2801 steelhead (roughly 1225 wild and 1576 hatchery) would have been lost during this time period. Based on a 95% confidence interval on the mean daily predation rate, the total loss figure could have ranged from 1510 to 4077. The 2801 figure seems reasonable based on past run sizes and observed escapements.

11. Sea lions were chased from the Locks area 144 times during the 83-day harassment period, for an average of 1.74 times per day.

12. The daily predation rate during the harassment phase was reduced 96.7% from the pre-harassment period. An estimated total of 50 steelhead of both races were killed by sea lions during the 83-day harassment period.

13. The behavior of the sea lions appeared to be modified by the harassment in that animals which returned to forage during the harassment period were more cautious, and generally foraged further away from the earlier prime feeding areas, and away from the active harassment areas (AHD and seal bombs).

14. A predation rate of 7.30 steelhead per day was observed in the early portion of the post-harassment phase. An estimated 219 wild steelhead were lost in April if this rate was constant over the month.

15. Season-long steelhead losses to sea lions at the Locks were estimated at 974 in total (645 hatchery, 329 wild). Overall, the number of fish saved when compared with projected losses with <u>no</u> harassment was 1803 fish (884 wild, 919 hatchery).

16. The total potential number of steelhead that could be saved if harassment were extended to cover the entire steelhead run was estimated as 2685, with a loss of only 92 fish (40 wild plus 52 hatchery).

17. The estimated total loss of wild steelhead in 1985-86 was 330, or 14.6% of the entire wild run returning. This compares with an estimated 60.5% the previous year when there was no harassment (a 75.9% reduction).

18. The control program in 1985-86 saved sufficient wild fish to assure an adequate escapement to spawning areas in the watershed. Sport fishing regulations designed to require release of wild steelhead could not, by themselves, account for this increased escapement.

19. Meadow Point, Shilshole Bay, Salmon Bay, West Point, Four Mile Rock, Elliott Bay, the Duwamish waterways, and Alki Point were boat surveyed frequently to note sea lion abundance and behavior. Several surveys also occurred in the Port Gardner area. Animal counts at specific sites ranged from zero to 79, with the largest accumulations occurring in the waterways of the Duwamish (except much larger rafts of sea lions occurred in Port Gardner and nearby Port Susan. Observations of feeding or successful foraging in these areas were few. Based on scat analysis, fish caught were principally bottom flatfish and herring. Numbers of California sea lions seen in Salmon Bay, Shilshole Bay, Meadow Point, or at West Point were consistently low (0-3) until 10 April, when an aggregation apparently moved south from Everett.

20. A total of 15 haulout sites were identified during aerial and boat surveys. All were on man-made objects that were either stationary or temporary. Barges off the Snohomish River mouth at Port Gardner are the platforms most consistently utilized for haulout by large numbers of sea lions. There is space on the barges for 500-600 sea lions.

21. A total of 98 sea lion scats and two spewings were analyzed (Port Gardner, except one scat from Elliott Bay). Hake comprised 65% of the total sample, followed by herring (16.2%), pollock (4.1%), cod (0.7%), and miscellaneous codfishes (14.0%). No salmonid remains were found in the samples.

22. The lack of any dietary evidence of significant salmonid predation by sea lions outside of Salmon Bay indicates that salmonids (steelhead and salmon) may not be taken in significant numbers except in areas where they are concentrated and enclosed within artificial boundaries.

23. An annual budget of approximately $36,200 is needed to conduct a similar control program in future years. This budget would support temporary staff without burdening permanent management staff with seasonal control duties. The sport and commercial value of the wild and hatchery steelhead runs to Lake Washington are such that a minimal benefit:cost ratio for such a budget is 1.5:1, but would more typically be around 4.1:1.

24. Alternate methods of sea lion control at the Locks need to be tested for effectiveness and possible greater efficiency and less cost. Research in this area would need to be budgeted for at a level above that required for the basic control program, however personnel and some equipment involved in the control program could probably be shared.

25. Considering apparent trends in sea lion abundance in Puget Sound, a continued control program is recommended at the Locks. However, wild and hatchery steelhead run sizes will be monitored annually, and the continued need for predation control assessed, and sun-setted if necessary or practical.

26. Commercial gillnets should be monitored to assess the number of steelhead lost to sea lions. Such monitoring should occur at both Salmon Bay and the Duwamish Waterways.

27. Significant, successful California sea lion predation on winter-run steelhead has only been documented in Puget Sound at the Chittenden Locks. The unavoidable detention of fish seeking the entrance to the spillway dam fishway greatly facilitates their capture by sea lions, which do not demonstrate such predation at the mouths of the adjacent river systems (which support far larger steelhead runs). We conclude that the spillway dam structure, locks, and fishway constitute a partial barrier to returning steelhead, or a foraging environment which greatly facilitates their predation by sea lions.

6.2 Conclusions

An inescapable conclusion of our many hours observing California sea lions at the Locks as well as the mouths of the Green/Duwamish and Snohomish Rivers is that conditions at the Chittenden Locks spillway dam and fishway were such that capture of steelhead was greatly facilitated at this site over conditions in open estuaries and river mouths. No steelhead kills were confirmed in these other areas, despite far larger accumulations of sea lions, substantially larger numbers of steelhead migrants, and often-present angler-observers. It appeared that fish were detained in entering the fishway or the locks sufficiently for the sea lions to capture them with relative ease.

The relatively confined, walled nature of the spillway area, as opposed to the more natural river mouths or estuaries, may create a foraging environment that is irresistably attractive to at least some of the many sea lions now residing seasonally in Puget Sound. Or, detained fish may be somewhat more dense in an areal sense, which when coupled with the artificial nature of the locks area, combine to facilitate steelhead foraging and captures.

One large sea lion ("Humpback") was observed to kill 60% of all steelhead taken at the Locks during the pre-harassment phase of the study. This suggests that foraging success is not equal between animals and that certain animals may be more efficient predators within the Locks area, or learn over time. By removing the most efficient predator, it might be possible to reduce overall predation. We do not consider this method feasible if large numbers of sea lions are involved at the Locks, since the foraging space of removed animals would probably be quickly filled by new animals (density dependance).

A very important point regarding sea lion control at the Locks is our lack of an accurate estimate of the actual total number of sea lions using the Locks area. We know that on a daily basis at least one to five lions are generally present, and that at least two of these animals returned continuously throughout the season. Lacking reliable marks which can be consistently identified, however, we cannot estimate the total number of individual sea lions which occur at the Locks during the season. This is an important point because future control strategies are related to total numbers of sea lions involved.

Food aversion conditioning and capture/removal of sea lions could be considered effective control strategies if the total number of animals conditioned or removed is small (up to 10). If the total number is large, however, then these strategies would not be as effective or as easily implemented.

Considering apparent trends in sea lion numbers and their distribution in Puget Sound, we expect that sea lion interactions with steelhead will continue (if not increase) in the future at the Chittenden Locks. All indications are that sea lion numbers in Puget Sound will continue to increase. There may also be increased interaction with steelhead, or other anadromous salmonids, in other areas of Puget Sound (e.g. Elliott Bay or Port Gardner). The recommendations which follow, based on the results of this and other studies, seek to control and ameliorate these expected future interactions, particularly at the Locks.

7.0 RECOMMENDATIONS

1. Our primary recommendation for control of steelhead losses at the Chittenden Locks is for a continued program of control which primarily includes acoustic harassment combined with experimental tests of other control methods.

   Acoustic harassment can be utilized in a manner similar to that used in this 1986 study by using a combination of seal bombs and acoustic harassment devices (AHDs). We believe that these methods were quite successful during the 1986 season, for the observed steelhead predation rate dropped approximately 97% from that observed during the pre-harassment phase of the study. These methods, however, are only effective for short durations, and require a nearly constant presence by observers. We feel, therefore, that other methods should be tested to determine if more long-term, less costly, and less labor-intensive alternatives are available.

2. We recommend testing killer whale (*Orcinus orca*) vocalizations to determine the effect they may have on sea lions. This method has not been adequately tested on sea lions, and may prove to be a long term, cost-effective control tool. The Chittenden Locks appear to be an ideal test site for *Orca* vocalizations due to frequent visitations by sea lions and the enclosed nature of the Ship Canal at the Locks.

   Underwater insonification equipment is very costly. A high quality tape playback device, transducer, and amplifier costs approximately $20,000. Although there is a chance some of this equipment may be borrowed, additional costs related to this type of research would need to be budgeted.

3. We also suggest experiments with food (taste) aversion, using the non-lethal chemical lithium chloride (LiCl). This method has been experimentally tested on California sea lions with good results (Kuljis 1986). The objective of this method is to condition sea lions to avoid certain foods by using emetic or aversion agents. In principle, when an animal ingests a specific food type and becomes nauseous and vomits, it will subsequently associate illness with the flavor of the ingested food and avoid that food upon later encounter. This method holds a great deal of promise for use at the Locks if sea lions would accept dead fish, and if the total number of sea lions to be conditioned is not too large.

4. We consider it important to determine the total number of individual sea lions which utilize the Locks as a foraging area, and therefore strongly recommend that a capture/tagging program be conducted during the 1987 season (December 1986-early 1987). The primary objective would be to mark all sea lions which frequent the Locks with reliable and easily-identifiable marks. Individual sea lions could then be identified, and records kept of their daily and seasonal presence by specific location. These data could then be used to obtain a much more accurate estimate of total animals involved.

Marking could be accomplished through use of a variety of methods, including pelage dyes or bleaches, or use of uniquely-marked spaghetti tags. The latter could be applied through use of a bow and arrow, with harmless attachment in the superficial blubber layer. The total cost of marking materials would probably not exceed $200, and initial marking and observations could be accomplished by the permanent and temporary staff conducting other aspects of the regular control program.

5. We also recommend consideration of one or more capture, tagging, and removal experiments following the estimate of total numbers present. If it turns out that only a small number of sea lions are involved at the Locks, the removal of one or two principal ("alpha") predators might reduce predation by a large percentage. In addition, if we maintain a rigorous and immediate harassment regime when any sea lion first shows up, they might not be as bold or difficult to keep away over time.

6. The control season should be extended to five months in order to cover the entire length of the steelhead run (1 December through April) in order to maximize fish savings. (The $36,200 figure for a control program [Section 5.1.1] is for an extended control season.) The extended season would also allow researchers to make observations of predation on other salmonids (e.g. coho and cutthroat).

7. We suggest that long term solutions to the Chittenden Locks problem be considered by the agencies involved, and that additional future planning sessions be held to consider potential future sea lion/fisheries interactions, for we believe that they will continue, and expand in the Puget Sound area.

7.1 Additional Related Studies

While documented losses of steelhead to sea lions have only been made at the Chittenden Locks, it would be prudent to continue to monitor the abundance and distribution of sea lions in Puget Sound, particularly in the Duwamish-Shilshole Bay-Port Gardner areas. We recommend continued effort to gather such information on sea lion abundance, distribution, and biology in Puget Sound. We suggest that periodic boat surveys and censuses be continued in the vicinity of Shilshole and Elliott Bay. We also suggest that annual aerial surveys be conducted to compare with the aerial surveys made in the springs of 1985 and 1986. These initial surveys, particularly the 1986 survey which covered a broader geographic area, can serve as a "baseline" in future years to identify trends in sea lion numbers and distribution.

Food habits of the sea lions should receive continued study through weekly scat collections, if possible from all haulout sites, particularly the Port Gardner barges and any large oil rigs or other suitable haulouts such as the SEDCO 708 oil rig, where large numbers of sea lions congregate.

In order to obtain a more accurate estimate of steelhead predated by sea lions at the Locks, it is necessary to estimate the numbers of fish lost to sea lions from gillnets during the Muckleshoot and Suquamish tribal fisheries for winter-runs returning to Lake Washington. Set nets should be monitored (all or a subsample for portions of the fishery) in an attempt to quantify these losses.

Similar set net monitoring should be conducted at the Duwamish Waterway during the winter-run steelhead gillnet fisheries to determine the level of steelhead losses to sea lions at that location. While steelhead are not detained at that location by having to negotiate a man-made barrier dam and locks, losses to sea lions are reported to still occur from fishing gear. The Duwamish mouth area fishery should be closely monitored due to the potential for increased adverse interactions (steelhead losses) in the future, for large numbers of sea lions were observed in the vicinity in 1986.

Because of our prediction of increased sea lion-fishery interactions and fish losses in the future, we feel that an effort should be made to record and investigate reports of any other such interactions on a statewide basis. These data may prove useful in the future when planning management options.

We understand that many of these recommendations cannot be realistically accomplished with existing budgetary constraints or conflicting priorities of the management agencies affected. However, ideally, these agencies could cooperate and pool resources to begin initiation of the needed studies or surveys in an effort to minimize future problems relating to the increasing numbers of sea lion-fishery interactions.

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9.0 APPENDICES

Appendix 9.1. History of sea lion presence at the Hiram M. Chittenden Locks.

We conducted interviews with Locks personnel, local steelhead anglers, and Department of Game Enforcement staff in order to reconstruct the history of sea lion occurrence at the Locks (Appendix Table 9.1). These interviews point out the general agreement that sea lions have only occurred at the Locks with regularity for the last six to seven years.

Several individuals (M. Lund and C. Wilder, both USACE) noted that sea lions were possibly seen as many as 10-15 years ago, but only very rarely. Harbor seal were observed frequently at the Locks 10-15 years ago according to the same sources, but recently such sightings have become rare. All of the individuals interviewed noted that initially (in the early 1980's) only one or two sea lions were observed at the Locks, and then for only several months of the year. In the last two to three years, however, as many as four to five sea lions have been observed on a regular basis, and the animals are sighted for longer periods.

In the last several years, one of the local steelheaders (Gene Pitzer) has observed sea lions at the Locks as early as mid-October and as late as mid-May, a period of seven months. Kim Chandler, a WDG Enforcement Agent, became alerted to the steelhead predation problem only within the last three years.

Based on these interviews, it appears that there has been an increasing trend of sea lion numbers, presence, and steelhead/sea lion interactions in the last six to seven years at the Locks. There appear to be more sea lions each year, and their presence in the area appears to have increased in terms of daily regularity and seasonal usage.

The overall pattern which emerges from observations in 1985-86 is of four to five sea lions occurring regularly at the Locks from December through April (five months). Irregular sightings of one or two individuals have been noted for a period of about seven months from mid-October to mid-May.

It would be expected if this trend continues, that increasing numbers of steelhead (and possibly salmon) would be predated each year. If this trend is maintained through 1987, we would expect to see more sea lions, which are arriving earlier and staying later in the year, and which therefore are potentially predating larger numbers of fish.

Appendix Table 9.1. Data on sea lion presence at the Ballard Locks from interviews with anglers and staff of the Ballard Locks and Department of Game.

Name	Years At Locks	Years of Regular Sea Lion Observations	Affiliation
Marvin Lund	20	5 to 6	Army Corps
Al Jensen	15	5	" "
Charles Wilder	13	4 to 5	" "
Larry Meyer	10	4 to 5	" "
Glenn Williams	7	6 to 7	" "

Name	Years Fishing At Locks	Years of Regular Sea Lion Observations	Affiliation
Harold McBride	13	6 to 7	Sport Steelheader
Gene Pitzer	10	4 to 5	" "
Tom Bawden	9	5 to 6	" "

Name	Years Working Locks Area	Years of Regular Sea Lion Observations	Affiliation
Kim Chandler	8+	3 to 4	WDG Enforcement

Appendix 9.2. Steelhead counts made in the Ballard Locks fishway viewing chamber, 1985-86.

The number of steelhead observed in the fishway viewing chamber was counted from 23 November 1985 through 11 April 1986 in order 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 do, however, at least provide an index of numbers present and 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 six 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. By comparing the visual counts made the same day, or late the previous day with the removal counts it is possible to establish a rough correction factor for counts made through the viewing chamber windows, and to adjust the visual counts made throughout the season.

It is important to note that numerous individuals have noticed that steelhead entry to inner Salmon Bay, 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.

Appendix Table 9.3 lists the daily visual counts made, and the total counts made when all fish were removed, at the Locks fishway viewing chamber between 23 November 1985 and 11 April 1986.

Appendix Table 9.2. Affiliation and participation of individuals cooperating on the sea lion predation control project.

Name	Participation	Affiliation
Bob Pfeifer	(Principal Investigator)	Wash. St. Game Dept.
Alex Bradbury	F	" " " "
Bob Byrne	F	" " " "
Kim Chandler	F & A	" " " "
Bob Everitt	F & A	" " " "
Pat Gearin*	F	" " " "
Steve Jeffries	F & A	" " " "
Steve Penland	F	" " " "
Chuck Phillips	A	" " " "
Deborah Swatfigure	F & A	" " " "
Mike Albertson*	F	NMFS/NOAA
Robert De Long	F & A	"
Bill Dickinson	F & A	"
Wayne Lewis	A	"
Joe Scordino	A	"
Marilyn Dalheim	F & A	"
Paul Hickey	F	Muckleshoot Tribe
Walt Pacheko	F	"
Will Sandoval	F & A	"
Tony Forsman	A	Suquamish Tribe
Randy Hatch	A	"
Dick Geist	A	Wa. St. Dep. Fisheries
Mark Hind	A	" " " "
Byron Esko	A	Corps of Engineers
Jack Thompson	F & A	" " "
Michael Pope	A	Locks Visitors' Ctr.
Mark Savage	A	" " "
Fred Felleman	F & A	UW Fish. Co-Op Unit
Tag Gornall	A	marine mammal vet
Vivia Boe	F & A	Greenpeace
Lee Christie	F	"
Bill Keller	F & A	"

* Full-time
A = Administrative or planning input
F = Field assistance

Appendix Table 9.3. Visual counts of winter-run steelhead made at the Ballard Locks fishway viewing chamber, 23 November 1985 through 11 April 1986.

Date	# S'Hd	Date	# S'Hd	Date	# S'hd
11/23	0				
		1/ 1	25	2/ 1	--
11/30	1	1/ 2	12	2/ 2	23
		1/ 3	24	2/ 3	30
12/ 2	0	1/ 4	--	2/ 4	25
		1/ 5	--	2/ 5*	(29)
12/ 6	6	1/ 6	27	2/ 6	2
12/ 7	14	1/ 7	--	2/ 7	12
12/ 8	5	1/ 8	27	2/ 8	12
12/ 9	4	1/ 9*	(48)	2/ 9	14
12/12*	(17)	1/10	3	2/10	21
12/19	9	1/11	6	2/11	12
12/20	12	1/12	--	2/12	11
12/21	15	1/13	12	2/13	8
12/22	20	1/14	--	2/14	8
12/23	15	1/15	31	2/15	--
		1/16	28	2/16	9
12/26	35	1/17	--	2/17	--
12/27*	(48)	1/18	--	2/18	20
12/28	1	1/19	--	2/19	23
12/29	7	1/20	40	2/20	30
12/30	12	1/21	50	2/21	33
12/31	20	1/22*	(44)	2/22	--
		1/23	--	2/23	25
		1/24	26	2/24	40
		1/25	--	2/25	50
		1/26	40	2/26*	(78)
		1/27	40	2/27	25
		1/28	40	2/28	25
		1/29	--		
		1/30	50		
		1/31	--		

*The numbers in parentheses indicate the number of fish removed from the viewing chamber. Concurrent counts were made on 22 January (41) and 26 February (50), usually an hour or so before actual fish removal. It is possible that we lost some fish while initiating the removal process.

Appendix Table 9.3 (Continued).

Date	# S'hd	Date	# S'hd
3/ 1	6	4/ 1	--
3/ 2	12	4/ 2	16
3/ 3	40	4/ 3	17
3/ 4	37	4/ 4	13
3/ 5	30	4/ 5	--
3/ 6	30	4/ 6	--
3/ 7	37	4/ 7	20
3/ 8	25	4/ 8	14
3/ 9	--	4/ 9	15
3/10	--	4/10	7
3/11	30	4/11	13
3/12	30		
3/13	17		
3/14	20		
3/15	20		
3/16	--		
3/17	20		
3/18	14		
3/19	18		
3/20	10		
3/21	10		
3/22	17		
3/23	28		
3/24	25		
3/25	15		
3/26	16		
3/27	12		
3/28	21		
3/29	20		
3/30	--		
3/31	12		

Appendix Table 9.4 Miscellaneous observations of sea lions at the Chittenden Locks by Locks personnel, 4 February - 28 March 1985.

Date	Time	Location	# Sea Lions
4 February	1600	Seal[a] below spillway	1
5 February	1500	Seals below spillway	2
6 February	0800	Seals below spillway and fishway entrance	2
8 February	1030	Seal at lock entrances	1
10 February	1200	Seals below spillway	2
11 February	1000	Seals below spillway	2
15 February	1050	---	1
16 February	0845	Seals below spillway	2
17 February	0830	Seals below spillway	2
18 February	1655	Seal below spillway	1
19 February	0835	Seals in large lock	2
20 February	1540	Seal or lion; lg. lock entr.	1
21 February	0530	Sea lion in large lock	1
	1515	Sea lions at fishway	2
22 February	0945	Sea lions in large lock	2
23 February	1200	Sea lions below spillway	2
24 February	1010	Sea lion in large lock	1
25 February	0730	Sea lion below spillway	1
26 February	1455	Sea lion in large lock	1
28 February	0005	Sea lions below spillways	2
	1240	Sea lions in large lock	2
6 March	1700	Sea lion in large lock	1
12 March	1300	Sea lions below spillway	2
13 March	1330	Sea lion (w/hump)...?	1
16 March	0915	Sea lion in large lock	1
17 March	0800	Sea lion in large lock	1
18 March	0700	Sea lion in large lock	1
24 March	1355	Sea lion in large lock	1
25 March	0650	Sea lions in large lock	3
26 March	0030	Sea lion below spillway	1
27 March	0600	Sea lions in large lock	2
28 March	0600	Sea lions below spillway	2

[a] It was not clear from the Corps data whether these "seals" were harbor seals or sea lions.

A PERSONAL POSTSCRIPT FROM THE PROJECT LEADER

At the time this report was going to the printers, I was introduced to a delightful children's book recently published entitled

Herschel's Special Dream
by
Kristin Gay
Evergreen Pacific Publishing
4535 Union Bay Place NE
Seattle
ISBN 0-9609036-6-6

It has been a great joy reading this book to my own small children, particularly after having been so intimately involved with the sea lion predation problem. Readers of the book who have read this report carefully will notice the close similarity between the chest scar possessed by the book's Herschel and that which was described for the sea lion dubbed "Scar" by senior author Pat Gearin. There are other aspects of the story which closely mirror the sites and circumstances which we experienced through our study.

We recognize that our report will be of interest to many of the general public, and I have provided copies to key libraries and the Seattle Aquarium. We anticipate continued coverage of our control efforts by local media. Thus, I feel it is important that folks understand the attitude of the person principally responsible for the actions taken at the Locks to control sea lion predation on returning winter-run steelhead.

I find sea lions to be wondrous and beautiful creatures, admirably adapted to their environment. While I am responsible for assuring preservation of the wild and hatchery runs of steelhead returning to the Lake Washington watershed, I could not help but admire the sea lions' skill in capturing and dispatching vigorous, wild steelhead at the Locks.

Kristin's book emphasizes the theme that man should live in harmony with all other creatures. I certainly share that goal. I hope that most of the general public will recognize that our harassment efforts at the Locks are the most humane means presently available to address the <u>management problem</u> of assuring adequate passage of steelhead to their spawning and rearing areas above the Locks.

Bob Pfeifer
Mill Creek, Wash.
October, 1986

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