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UNDER-PIER ECOLOGY OF JUVENILE PACIFIC SALMON (*ONCORHYNCHUS* SPP.) IN COMMENCEMENT BAY, WASHINGTON

by

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ABSTRACT

Studies of the behavior of juvenile salmonids were conducted in 1984 and 1985 at the Port of Tacoma, Washington in response to concerns about the reduction in natural light under piers. Artificial lights were installed under the pier at Terminal Four to test whether they would enhance the under-pier habitat for juvenile salmon. During the spring outmigration period the traps were sampled with ships present and absent alongside the pier, with the artificial lights off and on under the pier, and during ebb and flood tides.

Measurements of light intensity showed that light levels were reduced under the pier by roughly 2-4 orders of magnitude, but were sufficient to facilitate feeding and schooling of juvenile salmon except when ships were present and lights were off.

The species of juvenile Pacific salmon (*Oncorhynchus* spp.) captured included pink (*O. gorbuscha*), chum (*O. keta*), chinook (*O. tshawytscha*) and coho (*O. kisutch*). Pink and chinook salmon and coho catches were not significantly reduced by the presence of ships, but chum salmon catches were. Catches were higher (significantly higher in some cases for chinook salmon) with lights off than with lights on for all species. Ebb-tide catches were generally higher than flood-tide catches for pink and chum salmon and for coho, but chinook salmon catches were about equal during ebb and flood tides.

Laboratory experiments conducted with a light:dark choice chamber showed that pink salmon fry preferred the dark side of the chamber in two of four trials. The fish were randomly distributed between the light and dark sides of the chamber for the other two trials. The other

species showed no preferences for either the light or dark side. These experiments supplemented the under-pier trapping study.

A companion study conducted in 1985 was designed to investigate whether predatory fishes become aggregated in the under-pier habitat during the spring juvenile salmonid outmigration. Trammel net sampling at pier and control sites showed that predators were not abundant in waterways at the Port of Tacoma, they did not become aggregated under piers, and they were not targeting extensively on juvenile salmonids.

ACKNOWLEDGMENTS

Many persons deserve to be recognized for their contributions to this project. We are grateful to Mr. R. Tyler and Dr. Q. Stober of the University of Washington Fisheries Research Institute and Mr. D. Martin of Envirosphere, Inc. for development of the juvenile salmonid trapping systems. The staff at Eastside Net Shop in Bothell, Washington are credited with manufacturing the trapping systems and the trammel nets used in the predation study.

Dr. L. Conquest, University of Washington Center for Quantitative Science, was very helpful in refinement of the experimental design and the data analysis strategy. Ms. Sally Zitzer, University of Washington Academic Computer Center, provided valuable consultation on using the Statistical Package for the Social Sciences.

Mr. D. Fast of the Fisheries Research Institute was instrumental in helping to carry out the laboratory lighting experiments. Mr. B. Snyder of the Big Beef Creek Fish Research Station provided the research vessel and light meter used in the under-pier sampling.

We enjoyed the cooperation of the Puyallup Tribe of Indians beach seine crew in collecting juvenile chum and chinook salmon for the laboratory lighting experiments. Mr. T. Deming, Puyallup Tribe biologist, provided copies of beach seine catch data for 1983 and 1984 in Blair Waterway.

The Port of Tacoma provided the full support for the project and cooperated in installing artificial lights under the pier at Terminal Four. We are grateful to Mr. G. Kucinski of the Port of Tacoma for help in solving logistical problems throughout the study.

GENERAL INTRODUCTION

Background

In 1982 the Port of Tacoma and Puyallup Tribe agreed to undertake steps toward cooperation in management of fish stocks and fish habitat in Commencement Bay and the Puyallup River system. The agreement identified projects and actions to enhance the fisheries and propose processes which would help minimize adverse ecological impacts within the Puyallup River and its estuary. Court rulings (Boldt 1974 and Orrick 1981) have defined the authority of Indian tribes over projects which impact fishery resources.

The principal management agencies with jurisdiction over fisheries within the study area are the Washington Department of Fisheries (salmon, bottomfish, and shellfish), the Washington Department of Game (primarily steelhead), and the Puyallup Tribe, which historically has had a vested interest in both salmon and steelhead stocks and manages its own fishery.

This research was part of the mitigation involving an Army Corps of Engineers permit to extend the pier at the Port of Tacoma's Terminal Four. The experiments were designed to investigate the ecology of juvenile Pacific salmon (*Oncorhynchus* spp.) under piers, especially their behavior in relation to light availability and berthing of ships, which were concerns expressed by the management agencies mentioned above, as well as the U.S. Fish and Wildlife Service.

Due to the importance of under-pier lighting to the overall objectives of the research, representative lighting regime data are discussed before the primary section of this report, under-pier trapping of juvenile salmonids. The section on laboratory lighting experiments was stimulated by questions raised associated with the 1984 under-pier lights and is a supplement to the under-pier trapping results. The role of shading in predation on juvenile salmonids was a companion study conducted in 1985 which contributes to understanding the overall under-pier ecology of juvenile salmonids. The synthesis of results is a comprehensive analysis of the data.

Accumulating data on the role estuaries play in the life histories of Pacific salmon has become an integral component of current research and management efforts. Although the major changes in freshwater salmonid habitat in the last 200 years have been fairly well documented, documentation of changes in estuarine habitat and associated changes in salmonid populations (and behavior) are not (Simenstad et al. 1982). Logging activities, dredging, and filling have been the principal causes of loss of estuarine habitat in the Pacific Northwest.

Study Area

Commencement Bay is located near the southern end of Puget Sound in Washington State (Figure 1). It is oriented in a northwesterly-southeasterly direction and has a rectangular shape approximately 6.4 kilometers long by 4.2 kilometers wide. The southeastern end of Commencement Bay, which was formerly composed of broad tide flats, estuarine inlets, and wetlands (the historical Puyallup River delta), was dredged and filled between 1920 and 1970 to accommodate commercial development, including shipping. It has been estimated that 188 acres

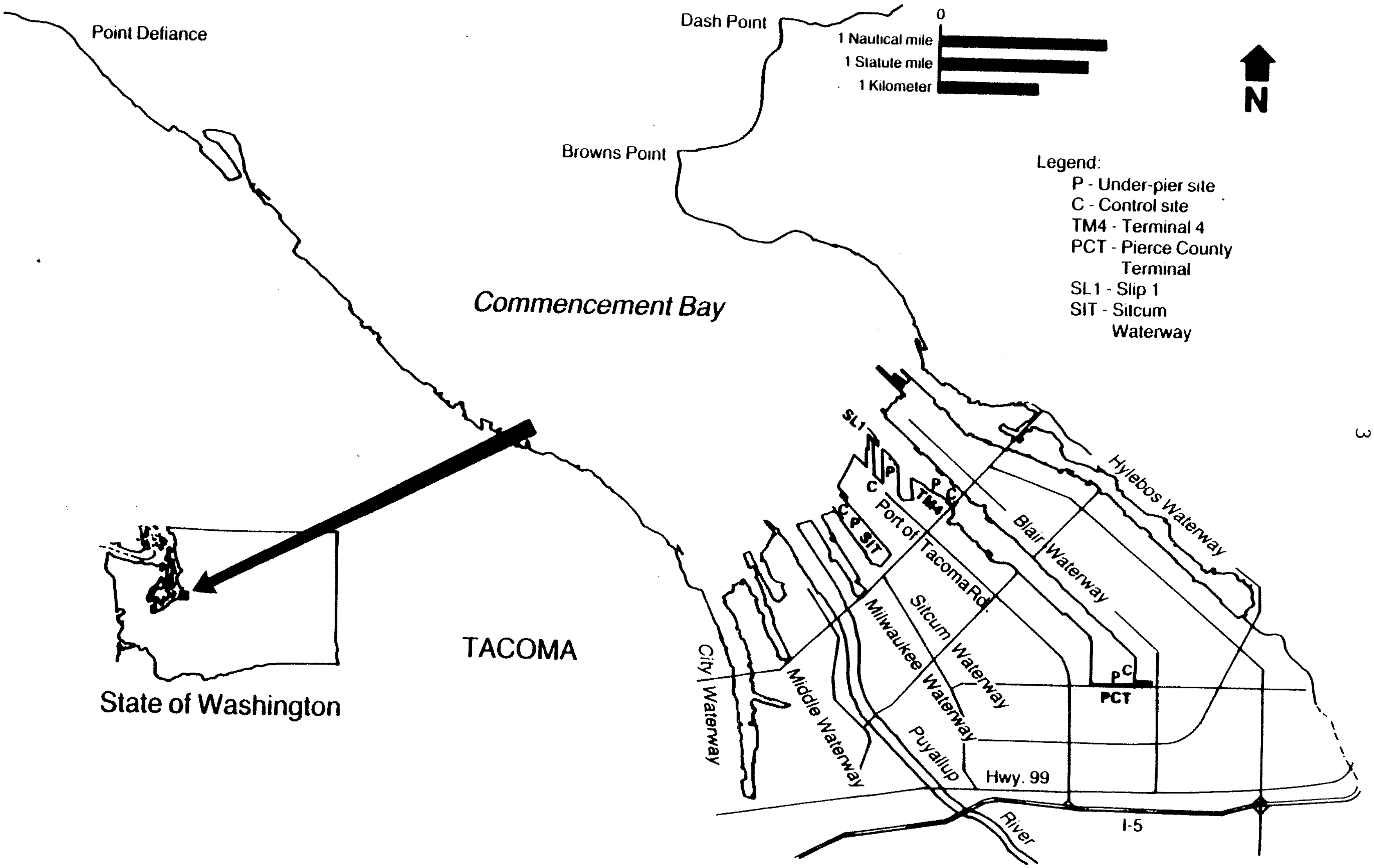

Figure 1. Study area map for Commencement Bay, including sampling sites in Port of Tacoma waterways.

within Commencement Bay are currently occupied by pilings associated with piers and wharves (Fisheries Technical Team 1984). Fifty acres of pilings occur in waters less than 12 feet below mean-lower-low-water, which comprises roughly 8% of the total nearshore habitat available to juvenile salmonids and other fishes in Commencement Bay. The areas most dominated by piers and wharves are Blair and Hylebos waterways, plus the Ruston Way shoreline (the southwest perimeter of the bay).

Major alterations to the Puyallup River include channelization of its lower section, relocation of its mouth, and elimination of approximately 17.4 square kilometers of wetlands (essentially 100% of the original 10 square kilometers of subaerial wetland habitat and 99% of the original 7.4 square kilometers of intertidal wetland habitat (Bortleson et al. 1980)). The only other sources of freshwater discharge in the vicinity of the sampling sites are Hylebos Creek, which flows into the closed end of Hylebos Waterway, and Wapato Creek, which flows into the closed end of Blair Waterway. Both are independent drainages which support minor salmon runs (primarily chum and coho - Tom Deming, Puyallup Tribal Biologist, pers. comm.).

The current study was conducted at the closed, southeastern end of the bay, within the waterways (primarily Blair Waterway) at the Port of Tacoma. All of the juvenile salmonid trapping was carried out at Terminal Four in Blair Waterway. Predator sampling was conducted at Terminal Four and Pierce County Terminal (also in Blair), at Pier 2 in Slip 1, and at Terminal 7 in Sitcum Waterway. Locations of these facilities can be seen in Figure 1, and their specifications are listed in Table 1.

Table 1. Specifications of sampling sites for Port of Tacoma under-pier juvenile salmonid ecology studies.

Site	Construction Date(s)	Materials	Dimensions	Ht. above MLLW	Intertidal Slope	Primary Cargoes
Terminal 4	1968 1984	concrete	1,542 ft. long 114 ft. wide +18 ft. elev.	-45 ft.	2:1	containers general cargo machinery
Terminal 7 (Sitcom Waterway)	1967 1968 1974	wood, concrete, and steel	2,700 ft. long 120 ft. wide +18 ft. elev.	-35 to -50 ft.	2:1	agricultural products ores containers logs farm machinery
Pier 2 (Slip 1)	1922	wood	1,200 ft. long 95 ft. wide +18 ft. elev.	-35 ft.	2:1	rubber agricultural products
Pierce County Terminal	1971 1977	concrete	1,400 ft. long 120 ft. wide +22 ft. elev.	-45 ft.	2:1	automobiles steel farm machinery wood products military cargoes

UNDER-PIER LIGHT QUANTIFICATION

Introduction

A primary focus of this research project has been to assess the impact of the reduction in natural lighting under piers on the behavior of juvenile Pacific salmon. The agencies responsible for management of the affected fisheries expressed concern over this question, which resulted in an agreement to conduct experiments using artificial lights under the pier at Terminal Four. The primary concern was for shading under piers during daylight hours and the influence of berthing of cargo ships at the pier on the degree of under-pier shading. The experiments used floating net traps arrayed perpendicular to the shoreline (see Under-pier Trapping of Juvenile Salmonids, Materials and Methods). One "inner" trap was positioned closest to the bulkhead; a "middle" trap was positioned between the "inner" trap and the "outer" trap, which was positioned just inside of the outer edge of the pier. This inner, middle, and outer trap set-up was designed to assess the migratory behavior of juvenile salmon in the under-pier environment.

Hoar (1958) stated that juvenile Pacific salmon depend mainly on eyesight for locating and capturing prey organisms. The eyes of Pacific salmon, being typical of vertebrates and other teleost fishes, are sensitive to both wavelength (color or quality) and intensity (quantity) of light (Salo 1976). The physical structures (cones, rods, and retinal pigment) are functioning normally in juvenile salmon by the time of emergence from the gravel. Retinomotor responses, summarized in Figure 2, have been quantified in fry and later stages (Ali 1959). The threshold light intensity at which schooling and feeding occur is 10^{-4} ft candles and 10^{-5} ft candles, respectively. Maximum feeding occurs at

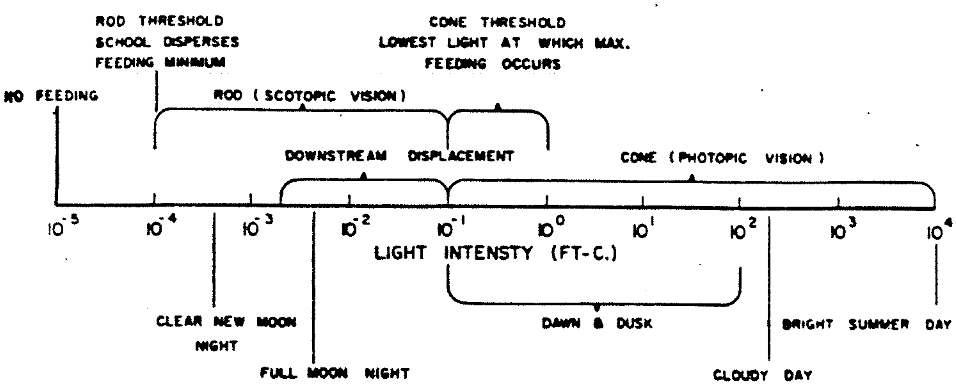

Figure 2. Diagram summarizing the results obtained under various light intensities together with some other responses of <u>Oncorhynchus</u> to different light intensities. Light intensities under natural conditions are also indicated for comparison.

Source: Ali, 1959.

intensities above the cone threshold, which is between 10^{-1} ft candles and 10^{0} ft candles.

Materials and Methods

The 1984 artificial lighting experiments were complicated by problems with the installation and operation of the light fixtures. In brief, some lights were operational from April 12-25 and from May 23 through the end of sampling on June 25, 1984.

In 1985, prior to the start of sampling, light fixtures were installed for each of the two juvenile salmonid trapping systems deployed under the Terminal Four pier . Each set of lights consisted of five 440W quartz street lamps hung from the underside of the pier. The fixtures were strategically positioned to illuminate the inner, middle, and outer traps, plus the areas between the bulkhead and inner trap and between the middle and outer traps (Plate I).

Either one or the other sets of lights was plugged in during sampling in 1985, so that only one of the trap arrays had artificial lights on at any time. This design offered three sets of lighting conditions on any day: lights off, ship absent; lights off, ship present; and either lights on, ship absent or lights on, ship present. The illuminated trap array was alternated each sampling day.

A Li-Cor LI-212-S underwater photometric sensor wired to an LI-185 multifunction meter (both manufactured by Lamda Instruments Corp., Lincoln, Nebraska) was used to measure light intensities under the pier and in the open waterway. Measurements were recorded on selected days when at least one ship was present at the terminal during sampling.

Plate I. Artificial light fixtures over juvenile salmonid trap array under the Terminal Four pier.

Results

Representative samples of light intensity collected in 1985 are presented in Table 2. Readings collected in 1984 are excluded because they would be redundant.

Discussion

The lighting measurements and Plate II illustrate the degree by which natural lighting was inhibited under the pier. Light levels were reduced under the pier by roughly 2-4 orders of magnitude, but, according to the criteria of Ali (1959), were still high enough to facilitate feeding and schooling , except at the inner and middle traps when ships were present and lights were off.

Light availability generally increased from the bulkhead toward the edge of the pier (Plate II). With lights off and ships absent, the light intensities were typically about 100 times greater at the outer trap than at the inner trap.

The quantity of light under the pier was a complex function of time of day, tide level, presence of ships, and use of artificial lights. The presence of a ship reduced the differential between the inner, middle, and outer traps, particularly if the lights were on. Tide level strongly affected light availability under the pier, but the differential effect was reduced when the lights were on (Plate III). The flooding tide normally blocked out more and more light, but as the water level rose, the artificial lights' contribution to the measured value increased.

Table 2. Light intensity measured in ft-candles at a depth of 3 ft under various conditions under and near the Terminal 4 pier in 1985. Tide levels (in feet) were approximated from the Tacoma Marine Supply, Inc., Time-n-Tide table. Under-pier light measurements were recorded near the entrances of the inner, middle, and outer juvenile salmonid traps.

			Lights off ship absent			Lights off ship present			Lights on ship absent			Lights on ship present			
Date	Time	Tide level	inner	middle	outer	inner	middle	outer	inner	middle	outer	inner	middle	outer	Open water-way
April 6	0930	4.0	0.23	3.1	20.7	0.04	0.08	5.5				7.4	10.7	11.3	1,328
	1115	5.0	0.12	0.20	17.2	0.04	0.04	0.82				10.0	15.6	17.9	143
	1300	6.8	0.12	0.39	12.1	0.02	0.04	0.16				12.5	22.3	24.2	391
	1445	8.9	0.04	0.16	10.5	0.04	0.04	0.12				24.2	25.0	26.6	755
	1630	7.2	0.08	0.23	24.2	0.04	0.08	0.31				9.2	22.6	24.6	1,250
April 24	1000	4.2	1.3	4.0	35.1	0.04	0.08	3.1	6.0	7.9	57.2				1,847
	1130	1.6	1.0	3.5	37.7	0.04	0.12	4.6	6.6	9.1	59.8				2,134
	1310	-0.6	1.8	5.3	67.6	0.08	0.20	7.0	4.9	10.3	70.2				2,486
	1455	1.2	1.0	2.5	46.8	0.08	0.20	6.4	7.0	8.6	57.2				1,533
	1640	4.5	0.39	1.3	18.2	0.08	0.12	3.5	9.4	10.5	23.4				1,248
April 30	1015	5.5	0.39	1.4	33.5	0.04	0.08	0.27				8.6	14.0	10.9	2,067
	1145	7.1	0.23	0.82	8.8	0.04	0.04	0.27				6.2	12.1	13.6	2,652
	1330	8.6	0.23	0.82	18.3	0.08	0.35	0.82				7.2	19.9	18.7	2,418
	1515	6.9	0.27	1.2	32.0	0.12	0.20	0.74				10.5	21.8	13.3	2,142
	1700	4.8	0.27	1.3	35.5	0.16	0.08	0.82				8.8	17.6	11.7	1,624
June 4	0905	3.1	0.55	2.5	66.3	0.04	0.08	0.39	3.8	5.0	41.3				481
	1035	-0.5	1.4	5.1	121	0.04	0.08	2.2	5.3	7.2	35.6				1,066
	1220	-3.6	1.6	3.6	97.5	0.04	0.70	14.0	6.9	8.5	37.4				3,315
	1405	-1.1	1.1	2.0	22.6	0.04	0.51	12.5	7.5	9.1	29.0				3,042
	1550	4.1	.51	1.4	18.3	0.04	0.08	16.9	8.7	9.9	20.3				2,457

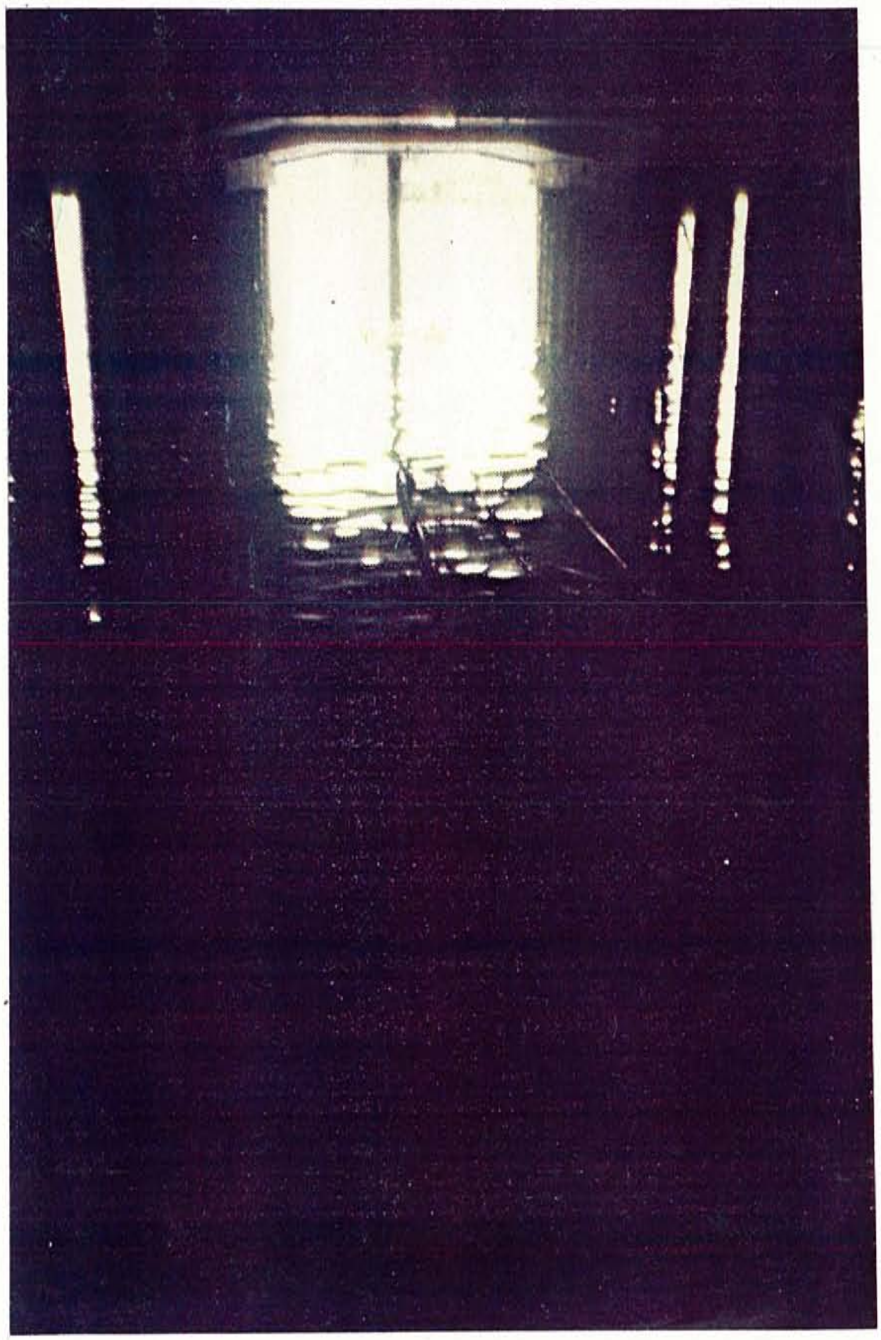

Plate II. Trapping system fishing under the Terminal Four pier and increasing light intensity toward the pier's edge.

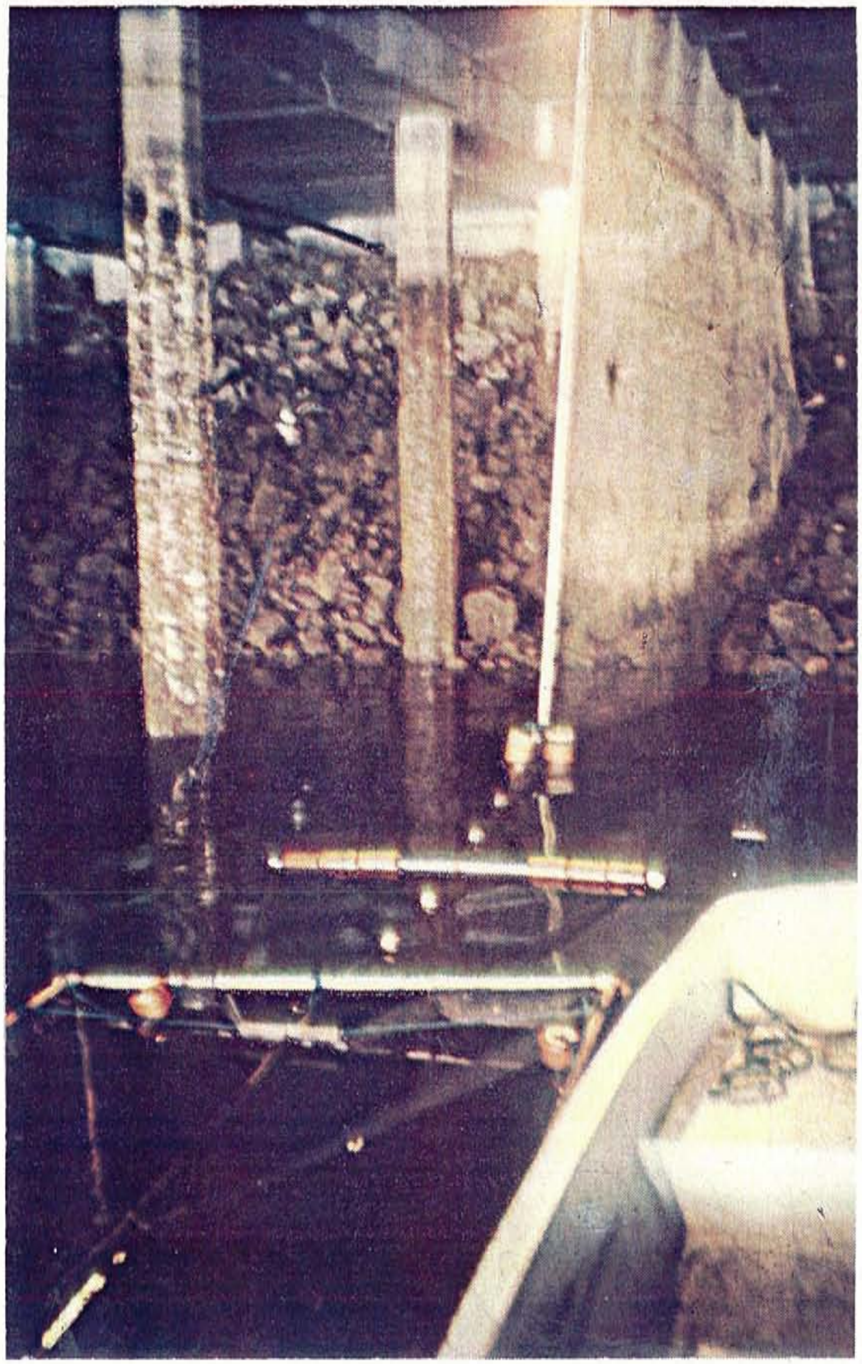

Plate III. Sampling at a relatively low tide level with lights on; fixture is at top of fixed net, illuminating opening of inner trap.

UNDER-PIER TRAPPING OF JUVENILE SALMONIDS

Introduction

As a part of ongoing construction activities at the Port of Tacoma, the pier at Terminal Four in Blair Waterway was extended 300 feet in 1984 (Figure 3). Dredging adjacent to the extension was necessary to facilitate its functioning as a breasting-pier.

The Port of Tacoma provided support in 1984 and 1985 to continue and intensify an under-pier fish trapping study started in 1983 as part of the mitigation requirements. A cooperative agreement to carry out the research was reached by the Port, the Puyallup Tribe, and the University of Washington.

Floating net traps were used to facilitate sampling amidst the matrix of concrete pilings which support the piers in Commencement Bay. The species of juvenile salmonids captured included four of the six Pacific salmon (*Oncorhynchus* spp.): chinook - *O. tshawytscha*; coho - *O. kisutch*; chum - *O. keta*; and pink - *O. gorbuscha* (which are available only in even years).

Experiments conducted during the 1983 salmonid outmigration indicated that the behavior of the fish was influenced by natural and possibly artificial lighting, by shading, and by presence/absence of ships (Martin and Salo 1983). However, the quantity of data collected was small and led to inconclusive results, particularly with respect to artificial lighting. The 1984 and 1985 experiments were conducted with those considerations and the following objectives in mind:

1. To determine under what conditions juvenile salmonids utilize the habitat under the piers in Commencement Bay.

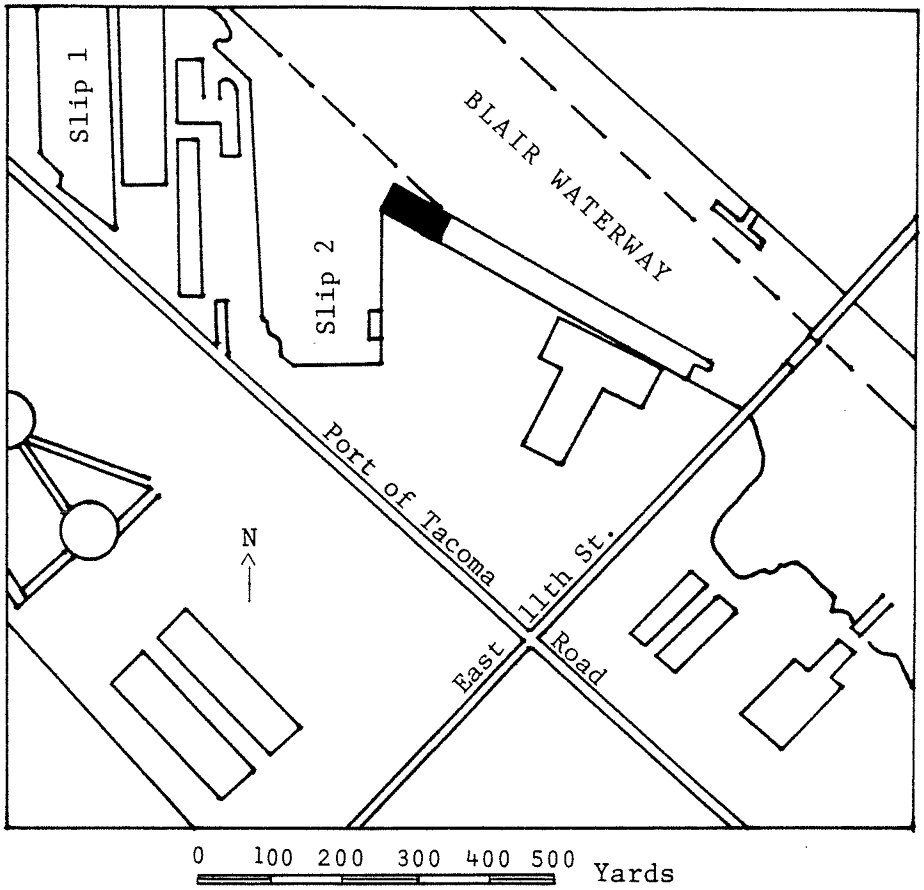

Fig. 3. Vicinity map of Terminal Four, located in Blair Waterway at the Port of Tacoma, showing 300-ft pier extension (darkened area) constructed in 1984.

2. To test whether juvenile salmonids avoid the piers due to low light levels under them and, if so, whether the installation of artificial lights reduces any avoidance by juvenile salmonids.
3. To provide recommendations for the design of pier facilities which will be constructed or modified in the future.

Little is known presently about the use of habitat under piers and wharves by juvenile salmonids, but a brief review of the available literature helped to identify the principal factors which needed to be examined.

It has been well established that tides affect the distributions of juvenile chum, pink, and chinook salmon (Bax 1983; Martin 1966; Mason 1974), which has definite implications regarding their availability to sampling gear. Martin (1966) speculated that juvenile pink salmon seek sheltered nearshore or bay areas during flood tides. Bax had similar thoughts relative to chum salmon. Mason (1974) also observed that tides affect the feeding behavior of chum fry.

Diel changes in the estuarine distributions of juvenile salmonids have been noted (Stober and Salo 1971; Tyler and Bevan 1964). Outmigrating salmon normally school during the day and disperse at night (Schreiner 1977). Schreiner (1977) and also Tyler (1972) postulated that this behavior pattern accounted for increased variability in the catch of juvenile pink and chum salmon during the day. Prinslow et al. (1979) reported that juvenile salmonids sought the shelter of a shaded (submarine berth) area during the day. The same area did not attract fish at night, but a nearby lighted wharf did. Wave length and particularly intensity of light may also play a role in attraction of fish (Salo 1976). Salo et al. (1980) did state that lighting at the wharf they studied had no apparent detrimental effects on outmigrating salmon, but they also cautioned that predators might learn to congregate at the wharf in response to increased concentrations of prey.

Weitkamp (1982) reported on visual and SCUBA observations of juvenile chum and chinook salmon at the Port of Seattle's Terminal 91. Terminal 91 consists of two approximately 2400-ft long piers which run essentially perpendicular to the shoreline. Each pier has 75-ft wide aprons on its east and west sides. The Terminal 4 pier at the Port of Tacoma parallels the shore and is approximately 130 ft wide. Weitkamp (1982) made observations on four days from mid to late May 1981. Juvenile chum and chinook were seen using the zone immediately bordering the piers in numbers equal to or greater than numbers observed at adjacent shoreline areas. The fish did not hesitate to move out into the deeper water (though they remained in the upper 6 ft of the water column) as they swam and fed next to the piers. However, they did not go into the dark zone under the piers and use the shallow riprap areas there. Statements were made that the fish behavior observed did not conform to certain assumptions made before the study and that conclusions drawn from the observations should not be directly applied to other sites. A further illustration of this point is that Oneida trap nets were fished under the pier apron at the Port of Seattle's Terminal 115 in the Duwamish Waterway in 1980 and registered peak catches of 97 juvenile chinook per hour (Weitkamp and Schadt 1982). The same study reported low catches (1-5 chinook over unspecified time intervals) when the Oneida trap sampled under the pier apron at Terminal

37 in Elliott Bay.

The data from the 1983 trapping at Terminal Four (Table 3) did show that no juvenile salmonids were caught in the middle trap, but rather they invariably chose to swim toward the outer trap, near the edge of the pier. Very few juvenile salmon were caught when ships were docked alongside the pier, but this result must be viewed with caution due to the timing of the fish migrations and presence of ships. The low catches recorded when ships were present could possibly have been accounted for solely by low fish abundance.

The experiments have emphasized determining the effects of using artificial lights under the Terminal Four pier to address questions regarding the influence of the dark under-pier habitat on juvenile salmonid behavior during their spring outmigration from fresh water. The artificial lighting scheme has improved each year, and this has yielded improvements in the results. Unfortunately, the artificial lights were not installed in 1983 until the juvenile salmonid outmigration was essentially over. The experiments were hampered by a series of problems in 1984, but some results were obtained. The results obtained in 1985 were more complete.

Materials and Methods

The two trapping systems which were used in 1984 and 1985 were adapted from a prototype system used previously (Martin and Salo 1983). Modifications included continuation of the central lead through the trap to partition each trap into ebb and flood sides; full aluminum frames (Figure 4) to facilitate fishing in strong currents; elimination of the

Table 3. Number of juvenile chinook salmon and other juvenile salmonids caught in net traps located under Terminal Four pier during spring 1983. (Martin and Salo 1983).

Date	Ship present	Time interval	Number of samples	Trap location		
				Outer	Middle	Inner
1983						
5/26	yes	0800-1645	3	0	0	0
5/27	yes	1830	1	0	0	0
5/28	yes	0900-1500	2	2(1)[1]	0	1
5/30	no	1445	1	13	0	10
6/1	no	0745-1930	7	22(1)[1]	0	20[3](1)[2]
6/5	no	1245-1800	2	3(1)[1]	0	0
6/9	no	0800-1800	6	1	0	2
6/10	no	0730-1730	6	0	0	0
6/12	yes	1200-1745	2	0	0	0
	Artificial lights over trap leads and live box					
6/16	no	0730-1330	4	0	0	0
6/17	no	0610-1600	6	0	0	0
			TOTAL	41(3)[1]	0	33(1)[2]

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[1] Chum salmon.

[2] Coho salmon.

[3] Trap not functional for 2 hours (1730-1930).

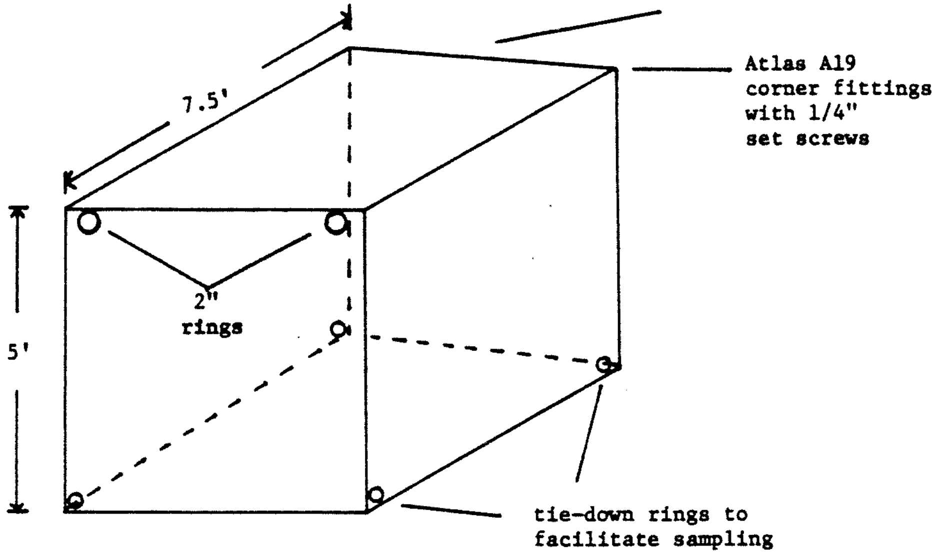


Figure 4. Aluminum frames designed for juvenile salmonid traps used in 1984.

gap between the inner and middle traps; and the addition of inner fykes within each trap to help prevent the fish from escaping (Plate IV).

Each system consisted of three traps arrayed perpendicular to the shoreline and designed to sample the top five feet of the water column (Figure 5). The lead from the inner trap was secured to a steel rod which slid up and down the outer pipe of a double pipe frame (Figure 6). A fixed net was set up from the inner pipe of the double pipe frame to the bulkhead and along the inclusive, partially intertidal zone. The backs of the inner and middle traps were lashed together by means of rings welded to the tops of each frame. A bridle hitched to the rings of the outer trap's frame was linked to a 20-foot long steel cable which was bolted to a fender pile at the outer edge of the pier. Concrete bucket anchors were suspended just off the bottom between the inner and middle traps and between the middle and outer traps to inhibit lateral drift during strong tides.

Specifications of each juvenile salmon sampling system were:

- 3 net traps 7.5' long by 5' wide by 5' deep.
- each frame of 3/4" aluminum pipe, corner fittings so frames can be dismantled into top, bottom, and four 5'-long straight pipe sections.
- tie-down rings lashed on inside corners of frame bottoms.
- 2" rings welded outside of posterior corners of frame tops.
- each trap net made of 1/4" stretch delta mesh knotless nylon (Fablok 8660 or equivalent), open at top.
- internal wings begin at forward corners and extend back 4' to form opening 6" wide by 5' deep.

Plate IV. Juvenile salmonid trap used in 1984 and 1985, showing inner and outer fykes.

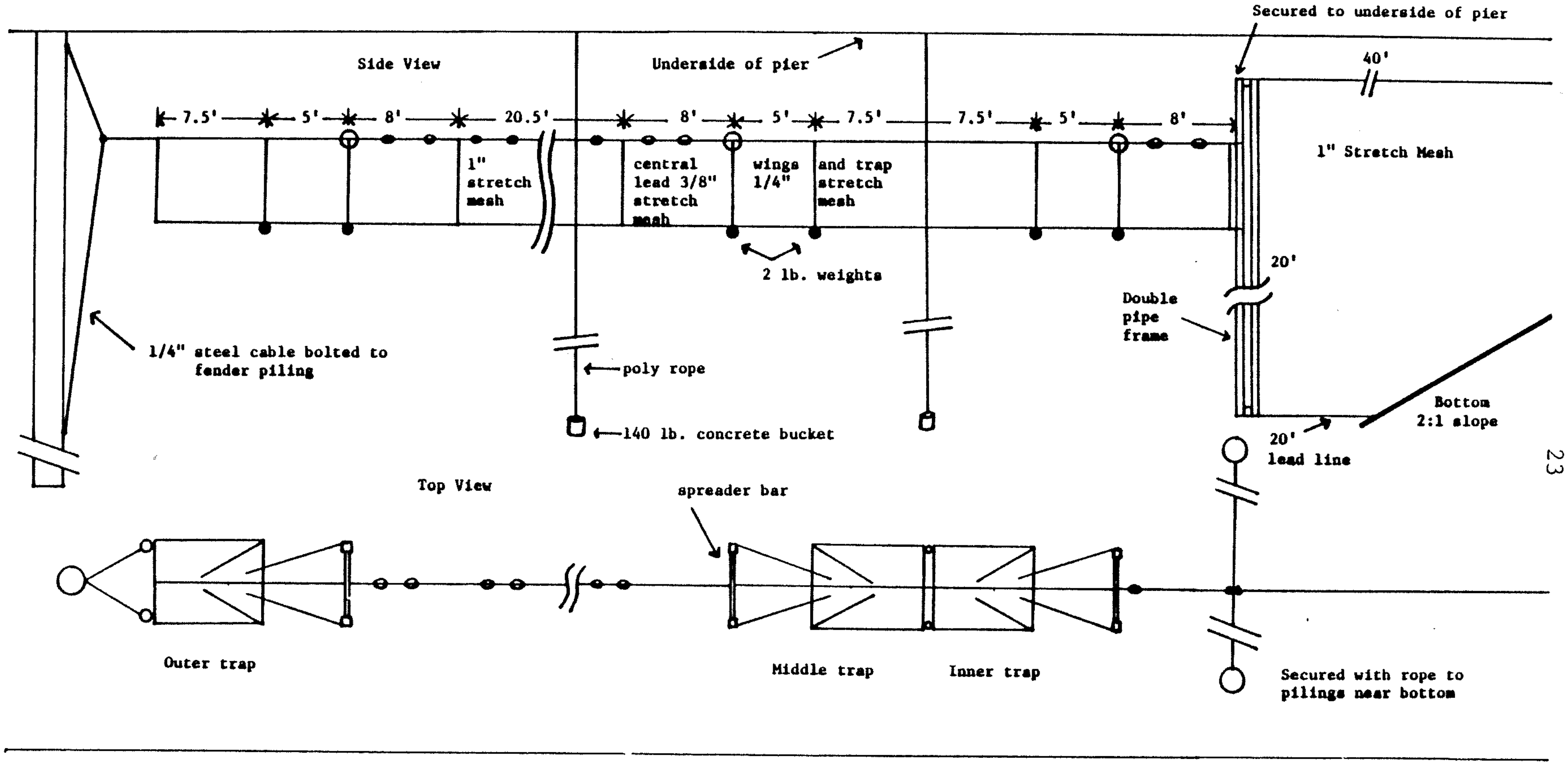


Figure 5. Side and top views of juvenile salmonid trapping system deployed under the Terminal 4 pier.

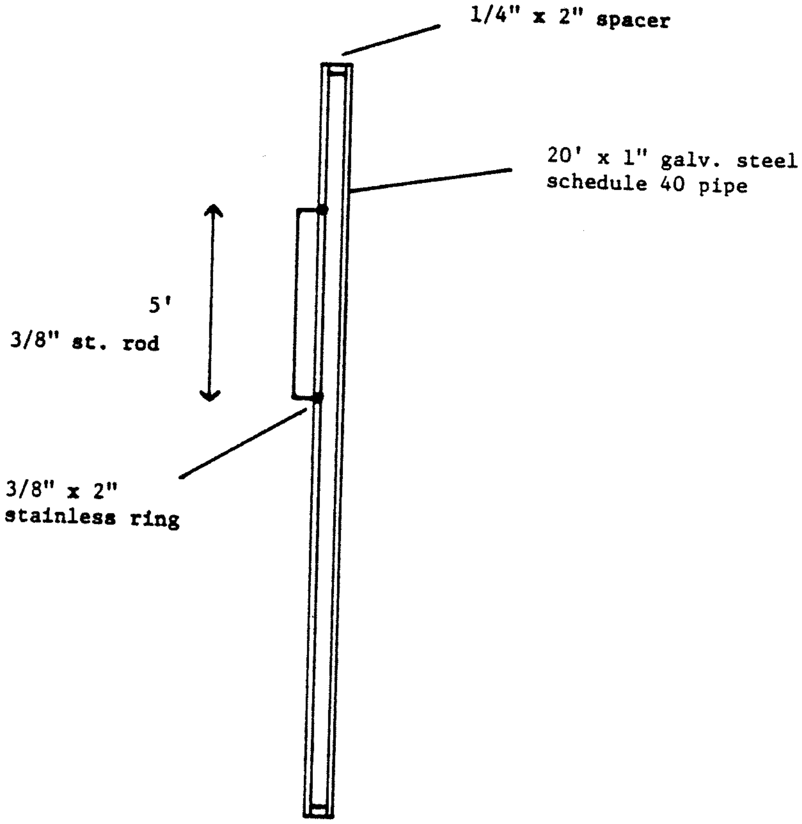


Figure 6. Double pipe frame used to secure fixed net and inner trap.

- external wings begin 5' forward of frame and extend into frame 1' to form opening 12" wide by 5' deep.
- external wings supported by 5.3' spreader bar of 1" PVC pipe and 6 sponge floats.
- openings bisected by central lead 5' deep by 20.5' long of 3/8" stretch mesh knotless nylon (Fablok 8635R or equivalent).
- three 2-lb lead weights on each trap: one at bottom of each front corner of exterior wings and one below the opening at the rear of the exterior wings.
- one lead between outer and middle traps 5' deep by 20.5' long of 1" stretch mesh #105 nylon, hung with 1/4" SB poly float line and OS-1 floats every 2' on top and 30# lead-core leadline on bottom; 5' separating zipper on each end
- one fixed net 20' deep by 40' long of 1" stretch mesh #126 nylon, hung with 5/16" SB poly rope on the top and weighted with 20' of 50# lead-core leadline on the bottom
- one double pipe frame of galvanized steel 20' long with a sliding 5' stainless steel bar
- two 140-lb concrete bucket anchors.

The original intention was to deploy one trapping system under the pier at Terminal Four and a control system at a suitable site along the shore near, but not under, the Terminal Four pier. This design was to test the hypothesis that fish occurred in equal numbers under the pier and along the open shoreline. The initial site selected for the control system was on the east side of Blair Waterway, just north of the 11th Street Bridge. The slope of the shoreline there proved to be much too shallow to allow proper fishing at low tides, so the site was abandoned. Only areas under piers had slopes which were compatible with sampling during all tidal cycles; consequently, the installation of the control trap was delayed until the dredged site where work on the pier extension was in progress became available. Two wood pilings for securing a sampling system were driven, and the control traps were deployed at the construction site on April 7, 1984. But unforeseen circumstances developed which resulted in moving the traps to a second site under the Terminal Four pier in mid-April.

There were two major problems which prohibited continued fishing of the control trapping system. First, the outer piling driven was not long enough, so it had to be moved shoreward approximately 20 feet from the desired location. Extension pipes were added to the piling and the 20.5 ft section of large-mesh lead between the middle and outer traps was removed in an attempt to accommodate the alteration. But the force of the current bent the pipes further shoreward in the flood-tide direction (Plate V). The second problem was the rapid growth of algae on the traps in the open waterway (Plate VI), which aggravated the first problem by clogging the netting and raised serious doubts about gear efficiency.

The control traps were sampled on April 7, 9, and 10, 1984. Subfiles designated "T1ONLY" and "T1CTRL" contained the data for the time periods before and while the control traps were deployed, respectively. Data collected after removal of the control traps were divided into subfiles based upon the status of the lighting experiments.

All sampling was done from a 13' Boston Whaler. The experimental

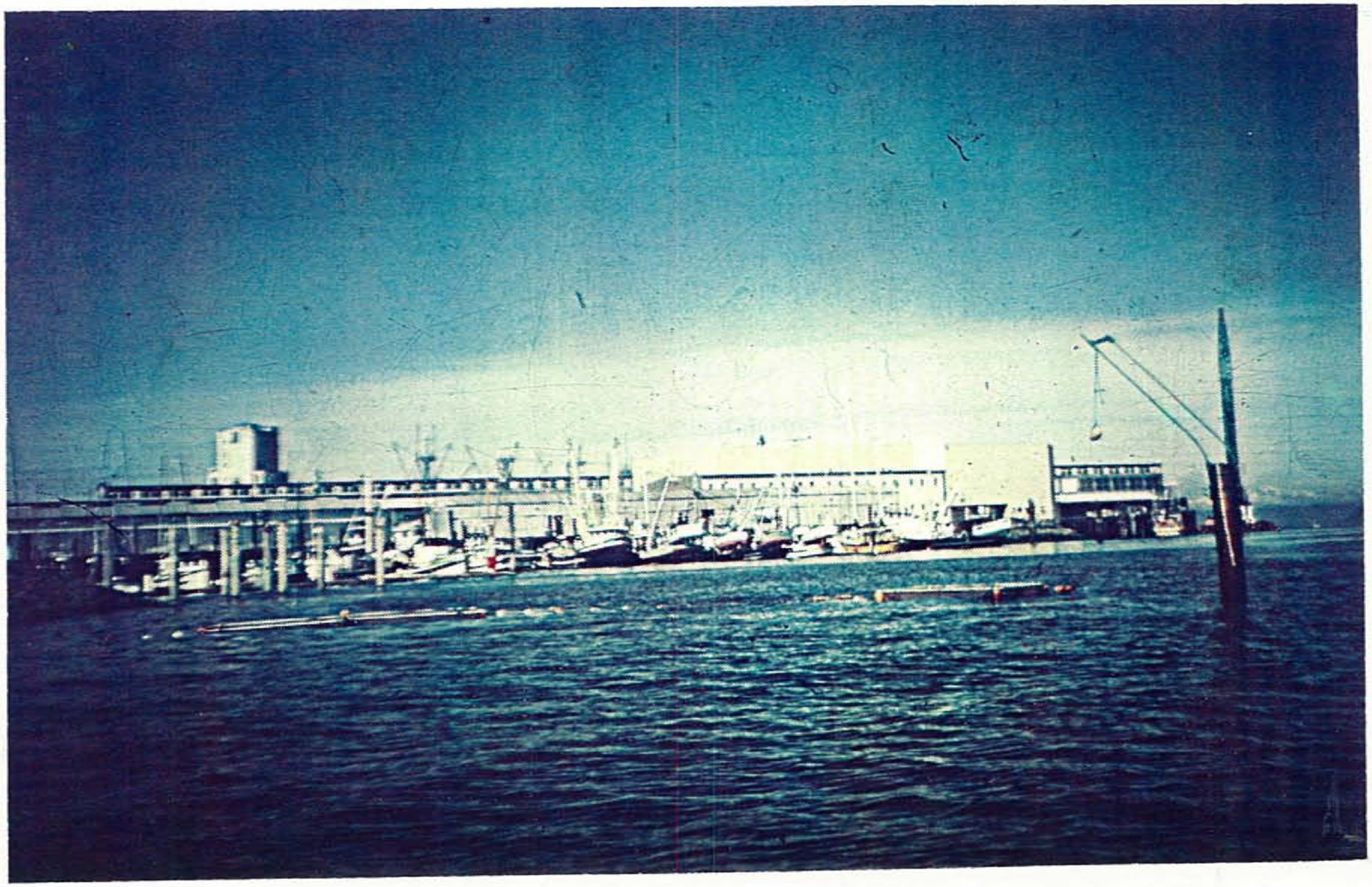


Plate V. Control traps in Blair Waterway. Note how piling extension pipes were bent by the force of the current.

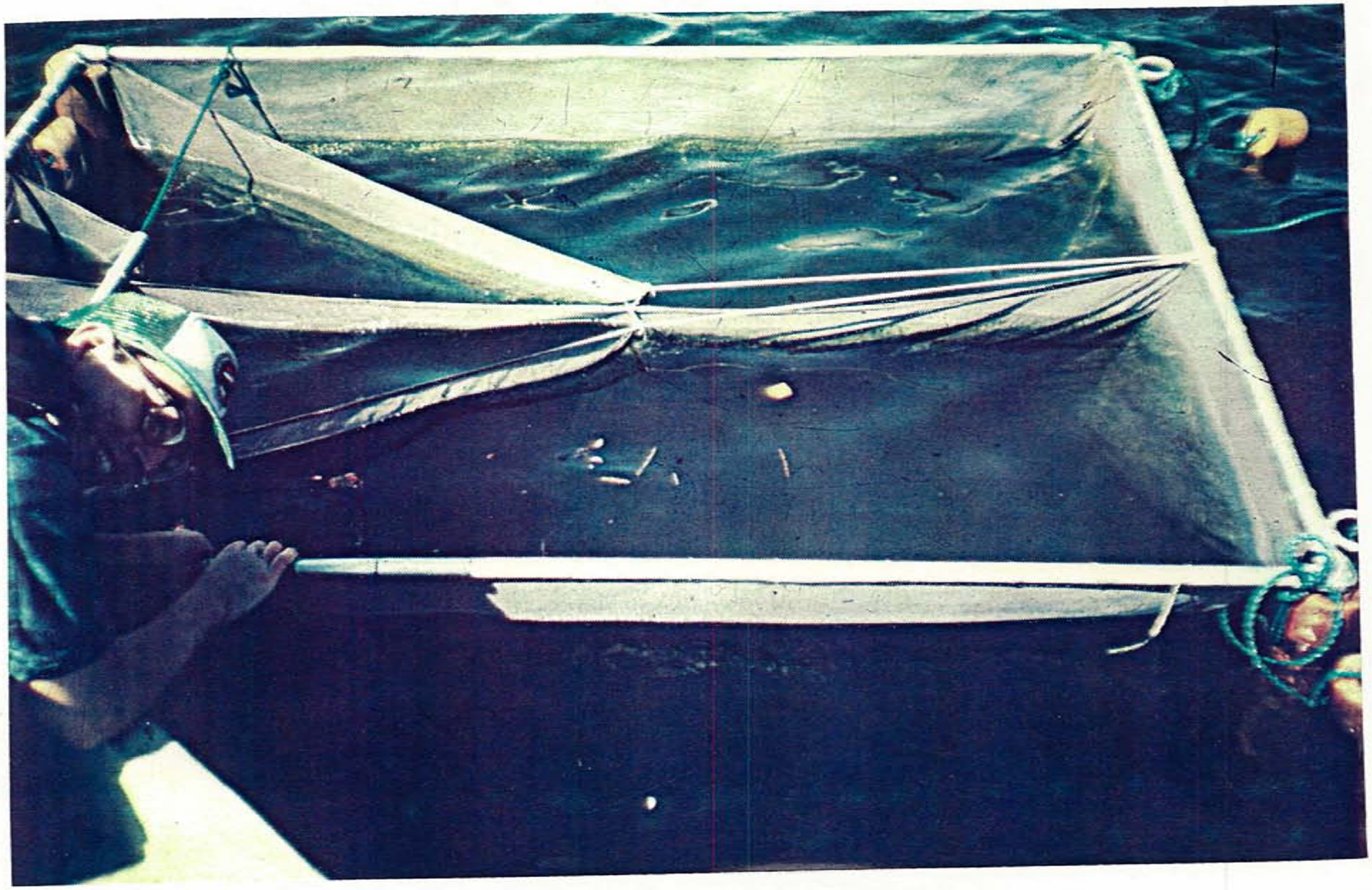


Plate VI. Outer control trap, depicting susceptibility to rapid algae growth on netting.

design called for collecting approximately equal numbers of samples during ebb and flood tides, during day and night times, with artificial lights on and off, and with ships present and absent alongside the pier. The need for continuously repetitive sampling under all experimental conditions was also anticipated due to fluctuating cycles of fish abundance. A sampling period of one hour was selected to decrease the possibility of fish escaping from the traps and to increase the number of samples collected. The first day of sampling under the Terminal Four pier was March 19. Samples were collected on 51 days, until June 25, for a total sampling season of 99 days in 1984.

The sampling scheme employed in 1985 was similar to that of 1984, but additional emphasis was placed on artificial lighting and presence/absence of ships at the cargo terminal, nighttime sampling was de-emphasized, and the sampling interval was increased from 1 hour to 1-1/2 hours. Sampling in 1985 commenced on April 1 and ceased on July 1.

The 1984 data file was divided into subfiles to facilitate separation of breaks in the experimental design (due mainly to lighting problems) and the sequence of interspecific outmigration timing. The 1985 data file was coded only on the basis of the outmigration timing to restrict the analysis to the appropriate data set for each species.

The catches for June 10 and 11, 1985 were treated as outliers (dropped from the analysis) for coho and chinook salmon. A Puyallup River freshet resulted in abnormally high coho and chinook catches, which we considered to be populations of fish different from the normal outmigrant populations after consulting with Dr. L. Conquest at the Center for Quantitative Science.

The catch data were analyzed primarily with Statistical Package for the Social Sciences (SPSS) procedures on the University of Washington Cyber computer system. The SPSS CONDESCRIPTIVE command was used to compute sample means, maxima, 95% confidence intervals for the means, standard deviations, and coefficients of variation. The coefficient of variation (C.V.) is a useful quantity for indicating the potential for determining statistical differences between experimental factors (Conquest 1983). Due to the high C.V.'s of the raw data, a decision was made to use a square root (variable) + square root (variable + 1) transformation. This transformation was first proposed by Freeman and Tukey (1950) and is becoming increasingly popular among statisticians for its utility to stabilize the variance (Dr. L. Conquest, University of Washington Center for Quantitative Science, personal communication), particularly if the data contain numerous low counts (Snedecor and Cochran 1980).

Each trapping system consisted of inner, middle, and outer traps, each separated into north (flood) and south (ebb) sides. Statistical analyses were performed on each of these (6) traps individually and in the following combinations, for each species:

North inner	South inner	Total inner
North middle	South middle	Total middle
North outer	South outer	Total outer
Total North	Total South	Total

The appendix tables contain the results of analyses performed with the transformed data, but the descriptive statistics included in the tables are the actual means, maxima, and 95% confidence intervals for the means. Analyses of variance were run using the SPSS ONEWAY, ANOVA, and MANOVA routines. These were supplemented with corresponding nonparametric tests in 1985. A nonparametric test was also used for the 1984 day/night time effect.

One-way ANOVA tables and group statistics are presented in separate appendices for each experimental factor for the total catch of each species. Tables for variables other than the total catch were included whenever the results were significant at the .05 level or less.

Two-way ANOVAS were restricted to those most likely to yield biologically meaningful results. The utility of these was primarily to test for interaction between the effects. Due to the importance of the ships and lights effects to satisfying the objectives of the research, two-way ANOVA results for the total catch of each species were included whether or not the interactions were significant. Tables of two-way ANOVAS involving other combinations of effects were included only when the interactions of the two effects were significant at the .05 level or less.

The 1984 results appear in Appendices A-H. The 1985 results follow in Appendices I-Q. There was no sampling in 1985 for the control and time effects.

1984 Results and Discussion

Results

The daily catch per unit of effort (CPUE) for the three primary species captured is listed in Table 4 and plotted in Figures 7, 8, and 9. Note that the seasonal sequence of occurrence was pink salmon, then chum salmon and lastly, chinook salmon. The pink salmon CPUE consistently exceeded that of the other two species by greater than an order of magnitude.

Pink salmon was the only abundant species during the time the control trap was operating. A test of the null hypothesis that catches under the pier were equal to catches at the control site (Appendix A) was barely nonsignificant (with higher catches under the pier; p = .07) for the total catch, but significantly more (p = .02) juvenile pink salmon were caught under the pier than at the control in the outer trap.

Analyses of variance of the null hypothesis that daytime catches were equal to nighttime catches (Appendix B) showed no significant differences for any of the species (though daytime catches were higher). The probabilities were .07 for total pink salmon, .13 for total chum salmon, and .24 for total chinook salmon. However, nonparametric tests showed that significantly more total pink salmon (p<.0001) and total chum salmon (p = .02) were captured during the day than at night. More chinook salmon were also captured during the day, but the difference was nonsignificant (p = .07).

Results of testing the hypothesis that fish were caught in equal numbers with ships present and with ships absent alongside the pier (Appendix C) did not show significant differences for any of the

Table 4. Mean catch per sample per day for juvenile pink, chum, and chinook salmon under the Terminal 4 pier during the 1984 outmigration in Commencement Bay.

Date		Pink	Chum	Chinook	n
March	19	.50	0	0	2
	20	.20	0	0	5
	22	3.50	0	0	2
	24	64.00	2.50	0	2
	27	.83	0	0	6
	28	5.86	0	0	7
	30	1.44	0	0	9
April	3	17.83	0	0	6
	4	38.00	0	0	7
	6	52.75	.75	0	4
	7	12.00	.08	0	6
	9	2.33	0	0	6
	10	.67	.33	0	3
	12	1.17	.17	0	6
	14	1.50	.33	.17	6
	16	.25	0	0	4
	17	1.00	0	1.00	1
	19	1.43	0	.71	7
	21	1.29	0	.43	7
	23	.83	0	0	6
	25	65.33	1.33	.17	6
	26	0	0	0	14
	28	1.00	.08	.08	12
	30	.40	0	0	10
May	2	4.58	.17	0	12
	3	.67	.33	.33	12
	7	.75	0	.13	8
	9	0	0	0	12
	12	0	0	0	12
	14	0	0	0	12
	16	0	0	0	12
	18	0	0	0	12
	22	0	0	0	12
	24	.08	0	.08	12
	29	0	.17	.08	12
	30	0	0	0	12
	31	0	0	0	12
June	4	0	.17	0	6
	6	0	0	0	8
	8	0	.08	.08	12
	9	0	0	0	12
	11	0	0	0	12

Table 4 (continued).

Date		Pink	Chum	Chinook	n
June	12	0	0	.25	8
	14	0	0	0	10
	16	0	0	0	12
	18	0	0	.08	12
	19	0	0	.08	12
	20	0	0	0	12
	22	0	0	0	12
	23	0	0	.17	12
	25	0	0	0	10

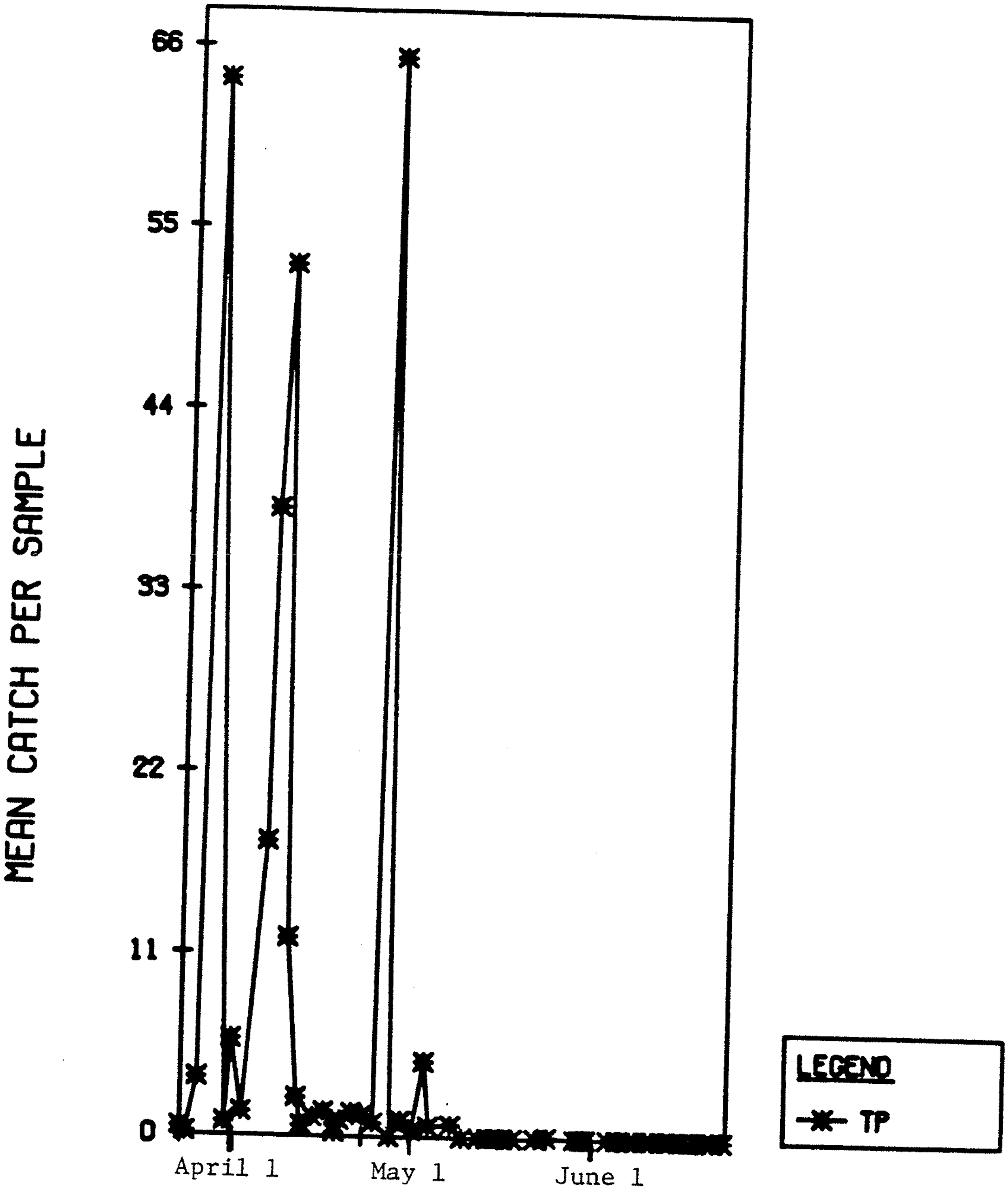


Figure 7. Daily CPUE for pink salmon over the sampling season March 19 - June 25, 1984.

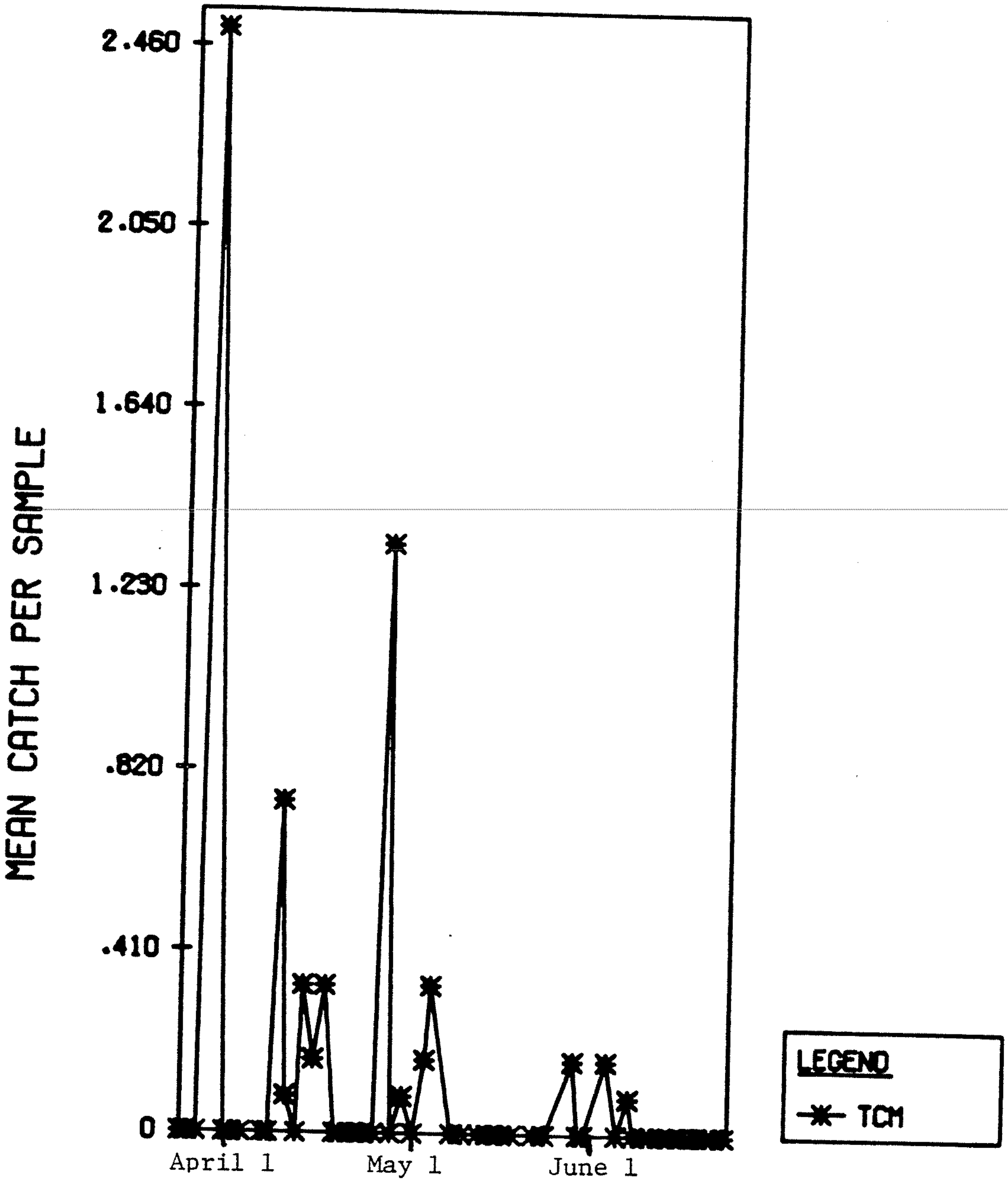


Figure 8. Daily CPUE for chum salmon over the sampling season March 19 - June 25, 1984.

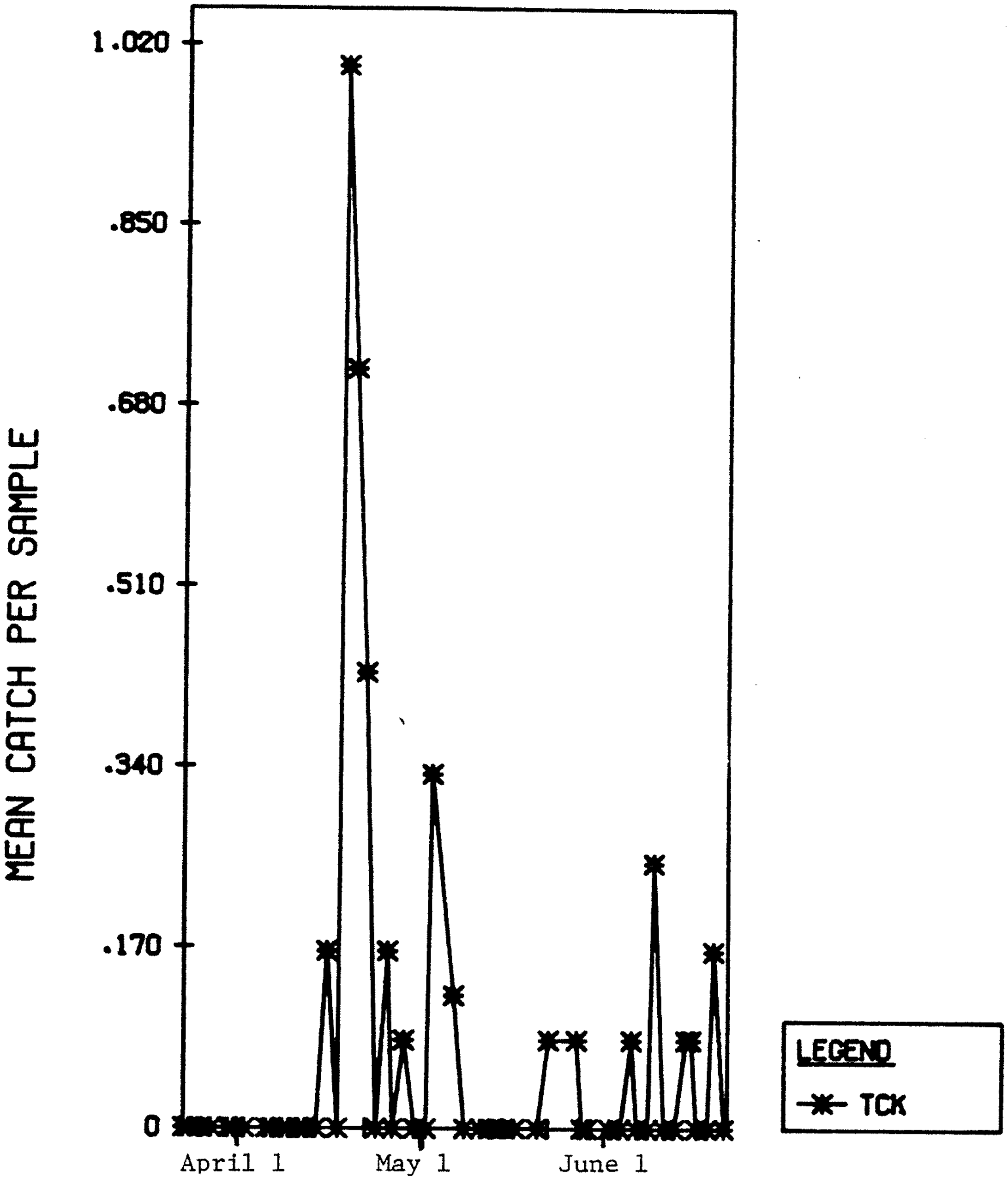


Figure 9. Daily CPUE for chinook salmon over the sampling season March 19 - June 25, 1984.

variables for pink or chinook salmon. Although higher numbers were caught for all variables except NMIDP and TMIDP with ships absent, the differences were not large enough to overcome the variability within the data. The probabilities of significant differences were .16 for total pink salmon, and .22 for total chinook salmon. There were significantly more total chum salmon caught (p = .04) with ships absent than with ships present.

Results of testing the hypothesis that fish were caught in equal numbers with and without artificial lights on under the pier are presented in Appendix C. Catches were greater with the lights off for all 12 variables for each species; the differences were statistically significant for total outer chinook and for total chinook (Table C-3; p = .03 in both cases). The probabilities of significant differences were p = .57 for total pink salmon and p = .12 for total chum salmon.

The results of the two-way ANOVAS for ships present/absent by lights off/on (Appendix E) showed no significant interactions between the ships and lights effects for any of the variables. The interaction probabilities were .78, .54, and .36 for total pink, total chum, and total chinook salmon, respectively.

The two-way ANOVAS for day/night time by lights off/on yielded no significant interactions and are not listed in the appendices. However, it is noteworthy that more chinook salmon were caught with lights on than with lights off at night.

Tests of the null hypothesis that catches during ebb tides were equal to catches during flood tides (Appendix F) yielded mixed results. The difference was nonsignificant (p = .40) for total pink salmon, but significant (p = .02) for total outer pink salmon and for south outer pink salmon (p = .04), with higher catches during ebb tides. Total chum salmon catches were not significantly different (p = .15), but north outer and total outer chum salmon catches were significantly higher (p = .01 and p = .04, respectively) during ebb tides. The results were nonsignificant (p = .85), and the statistics were remarkably equal, for total chinook salmon.

The SPSS MANOVA routine is a multivariate ANOVA which was used to make paired comparisons to assess whether there was directional movement positively or negatively oriented to the tidal cycle. That is, the hypothesis that equal numbers of fish were captured in the north versus south partitions of the traps during either ebb or flood tides was tested. The analysis also tested the hypothesis that catches on the north side were equal to catches on the south side. Results of the tests (Appendix G) did not indicate tidal orientation for any of the species. This conclusion is drawn from the lack of significant interaction between the north-south (norsou) catches and ebb-flood tides (p = .66 for pink salmon, .24 for chum salmon, and .17 for chinook salmon). Differences in total catches in the north versus south trap partitions were non-significant (p = .43) for pink salmon; they were barely non-significant (p = .07) for chum salmon; and they were significant (p = .03) for chinook salmon, with a higher CPUE in the north partitions.

The final ANOVAs which were run involved testing the null hypothesis of equal catches at the three traps locations with respect to the shoreline: inner, middle, and outer (Figure 5). A one-way ANOVA for trap location and two-way ANOVAs for location by each of the other main effects (time, tide, ships, and lights) were run.

Results of the one-way ANOVA for trap location (Appendix H) are presented by north and south components, with means, maxima, 95% confidence intervals, and separation of group subsets listed. Significantly fewer fish were caught in the middle trap than in the inner or outer traps for three of the six variables (north pink, south pink, and north chinook). No chinook salmon were caught in the south inner trap, which was significantly different from the outer trap, but not from the middle trap.

The two-way ANOVAs which included trap location combined with the other main effects gave no significant interactions.

Discussion

The timing of the pink and chum salmon catches was loosely correlated with known occurrence of those species in Washington estuaries (Healey 1982; Simenstad et al 1982). However, our results indicated a longer period of estuarine residence than reported by Healey (1982). The increase in size of the juvenile pink salmon as the season progressed indicates use of the nearshore waterway habitat as rearing grounds, and the number of pinks trapped shows they do utilize the area under piers. We speculate that the largest catch (374 juvenile pinks in the north inner trap on April 25) could have been an outmigrating school from the Nisqually River system at the southern end of Puget Sound. To our knowledge, the 1984 production of pink salmon in the Puyallup River system resulted only from natural spawning runs (which are healthy relative to natural chum runs) in South Prairie, Kapowsin, and Voight's

Creeks (Washington Department of Fisheries, unpublished spawning ground survey data). Several creeks in the Puyallup system support small runs of chum salmon, and several hundred thousand hatchery-reared chum were released by Puyallup Tribe fisheries biologists in 1984.

The timing and magnitude of the chinook salmon catches were considerably different than expected. The 1983 under-pier trapping data (Table 3) recorded peak catches at the end of May and beginning of June. The peak abundance of fish expected to appear from releases at the Washington Department of Fisheries Voight's Creek Salmon Hatchery never materialized as catches. Removing the traps for cleaning on June 1 did not result in higher catches. Beach seine samples collected in Blair Waterway (Puyallup Tribe of Indians, unpublished data) did record peak catches from late May to early June (46 fish on June 1), which could indicate either that juvenile chinook were avoiding the Terminal 4 pier or that the fish were concentrated on the opposite side of the waterway. An alternative explanation is that later in the season the juvenile chinook were moving further offshore and were not available to the traps. The 1983 FRI townetting in Blair Waterway continued to catch chinook after the under-pier trapping CPUE declined (Cliff Whitmus, personal communication), which tends to support this theory.

The control versus under-pier pink salmon catches can be compared if the assumption holds that fish did not more easily see, and thus avoid, the traps in the open waterway. Although the under-pier mean catch was nearly twice that of the control catch, the difference was not statistically significant because of the variability of data. Under the pier, juvenile pinks were apparently less strongly associated with the shoreline than they were at the control site.

The problem of variance in the data--induced by light-mediated daytime schooling activity, as reported by Schreiner (1977) and Tyler (1972)--was discussed by Bax (1983). It is well illustrated in the results of the time-of-day analysis. Daytime catches were always higher, and, although night-time catches appeared minimal, the ANOVA results did not yield statistically significant differences. The degree of significance probably reflects the relative importance of schooling and night activity to each species. Pink salmon are obligatory schoolers, while chum are faculative schoolers, and chinook school irregularly. Hoar (1958) stated that pinks school constantly and exhibit the most specialized behavior of the Oncorhynchids. Evidence suggests that pink and chum fry reverse their diel activity pattern from night active during downstream migration to day active upon entering salt water (Neave 1955; Hoar 1956). Schooling behavior - which requires day activeness - increases in importance to chum (and particularly to pink) salmon in the marine environment (Shelbourne 1966). Hoar (1976) took a more comprehensive look at previous work on pink salmon schooling (Neave 1955; Hoar 1956, 1958; Coburn and McCart (1967) and cautioned that some of the conclusions drawn from it were probably in error. He stressed the point that salmonid behavior is highly adaptive to varying environmental stimuli, as reflected by the formation of pelagic schools of pink salmon in the estuarine and marine environments. Shelbourne (1966) found that entry to salt water was a stronger stimulus to schooling in chum fry than were differences in temperature or photoperiod.

The results produced a hint that ships made under-pier habitat less attractive to juvenile salmon. It could be that ships alongside the pier are a physical barrier to under-pier recruitment or create sound waves which the fish avoid. Sound avoidance is unlikely, however. The presence of ships reduced the reluctance of pink salmon to enter the middle trap, which might have been due to an altered lighting regime or the cutting off of open water at the edge of the pier.

The results of the one-way ANOVA for lights were not surprising for pink salmon. The data were collected when 150 watt bulbs were in use, and the sample size for "lights-on" was very low. Significant results might have been obtained for chum, but the timing of their migration did not coincide well with availability of lights. There were significant results for chinook, despite the low numbers caught. Since catches were greater with lights off than with lights on for all species, it appears that juvenile pink, chum, and chinook salmon prefer shaded habitat and may use the area under piers for cover. This agrees with the observations of Iwata (1982) in Japan. However, the results could also be due to the fishes' ability to see the traps better when the lights are on and thus avoid capture.

The lack of significant interaction for the day/nighttime by lights on/off two-way ANOVA means basically that the fish were not attracted to the lights at night. That chinook was the only species with higher night-time catches with lights on than with lights off lends further support to the hypothesis that juvenile chinook are relatively more active than juvenile pink and chum salmon at night. The lighting experiments reported by Salo et al. (1980) were conducted only at night.

They concluded that relatively low surface intensities (0.2 - 1.2 ft.-candles) did not alter the catch of juvenile chum salmon. Though fish were observed congregating below the lights, there was speculation that this behavior was primarily a response to prey organisms concentrating in the lighted area.

The results of the two-way ANOVA for presence/absence of ships by lights off/on seem to indicate that the lighting factor had an overriding effect on the ships factor. This interpretation is drawn from examination of the cell means. Since catches were greater with lights off than with lights on, the lack of interaction (e.g. increased catches with lights on when ships were present compared to catches with lights off and ships present) should not be expected.

The results of the tide ANOVA indicated a lack of intraspecific differences between ebb and flood tides for the total catches. However, it appears that juvenile pink and chum salmon lost their affinity for nearshore habitat during ebb tides, which loosely agrees with findings for chum salmon in southern British Columbia estuaries (M. Healey, unpublished observations). Tide-oriented directional movements were not detected. However, even if they do exist in Blair Waterway, such movements could be masked by erratic current patterns and gyres generated by strong tides. Pilings also produced current perturbations under the pier, which were evidenced by fluctuating movements of the traps both with and against the direction of the tide.

Higher catches of chinook in the north trap partitions possibly demonstrates an affinity for nearshore habitat as they entered the waterway, then a later movement toward the channel as they migrated seaward into Commencement Bay. This hypothesis is supported by the continued catching of juvenile chinook in the townet after they had ceased appearing in the under-pier traps during 1983 sampling.

The results of the one-way ANOVA for trap location were in agreement with the 1983 results, which showed that juvenile salmon were not caught in the middle trap. The maxima for pink salmon catches indicate that schools of juvenile pinks entered the inner and outer traps, but not the middle trap. No juvenile chum were caught in the middle trap; the nonsignificant result can be accounted for by the variance and low values of the catches. Chinook catches were also low, but they were less variable, so significant results were obtained. There is no obvious explanation for why juvenile salmon were hesitant to enter the middle trap. We can speculate that they swim toward the edge of the pier where there is more light (which may not agree with the lighting results), or they may be swimming toward more open water (as Weitkamp (1982) found at piers in Elliott Bay).

1985 Results and Discussion

Results

The daily catch per unit of effort (CPUE) for the three primary species captured is listed in Table 5 and plotted in Figures 10, 11, and 12. Chum salmon and coho were caught over almost the entire sampling season, while chinook salmon catches were restricted primarily to the second half of the season. Plots of coho and chinook catches with and without June 10 and 11 are included to illustrate the changes in scale associated with the outlying data.

Table 5. Mean catch per sample per day for juvenile coho, chum, and chinook salmon under the Terminal 4 pier during the 1985 outmigration in Commencement Bay.

Date		Coho	Chum	Chinook	n
April	1	0	0	0	8
	2	0	0	0	8
	3	.13	.25	0	8
	8	0	0	0	8
	9	0	0	0	8
	10	0	.25	0	8
	15	.25	.38	0	8
	16	0	0	0	8
	17	0	0	0	8
	22	.25	.63	0	8
	23	.25	.13	0	8
	24	0	.13	0	8
	29	.13	1.00	0	8
	30	.13	.63	0	8
May	1	.13	.25	.13	8
	2	.63	.38	0	8
	6	.50	0	0	8
	7	.75	.13	.25	8
	8	.38	.88	.13	8
	9	.38	1.38	.13	8
	13	0	.25	0	8
	14	0	.63	0	8
	15	0	0	0	8
	16	0	0	0	8
	20	.13	.63	.25	8
	21	.33	1.00	.92	12
	22	.25	.83	.17	12
	23	.25	2.00	.25	8
	25	.50	1.20	.60	10
	28	1.13	.13	1.63	8
	29	.25	0	.13	8
	30	.38	0	.25	8
June	3	0	0	.13	8
	4	.63	.13	0	8
	5	.50	.25	.13	8
	10	44.38	.88	24.38	8
	11	41.75	1.25	11.12	8
	12	4.60	0	2.30	10
	17	2.63	.38	1.50	8
	18	1.75	.25	.63	8
	19	2.25	.13	1.25	8
	24	0	0	.88	8
	25	.13	0	.13	8
	26	.25	0	.13	8
July	1	0	.10	0	8

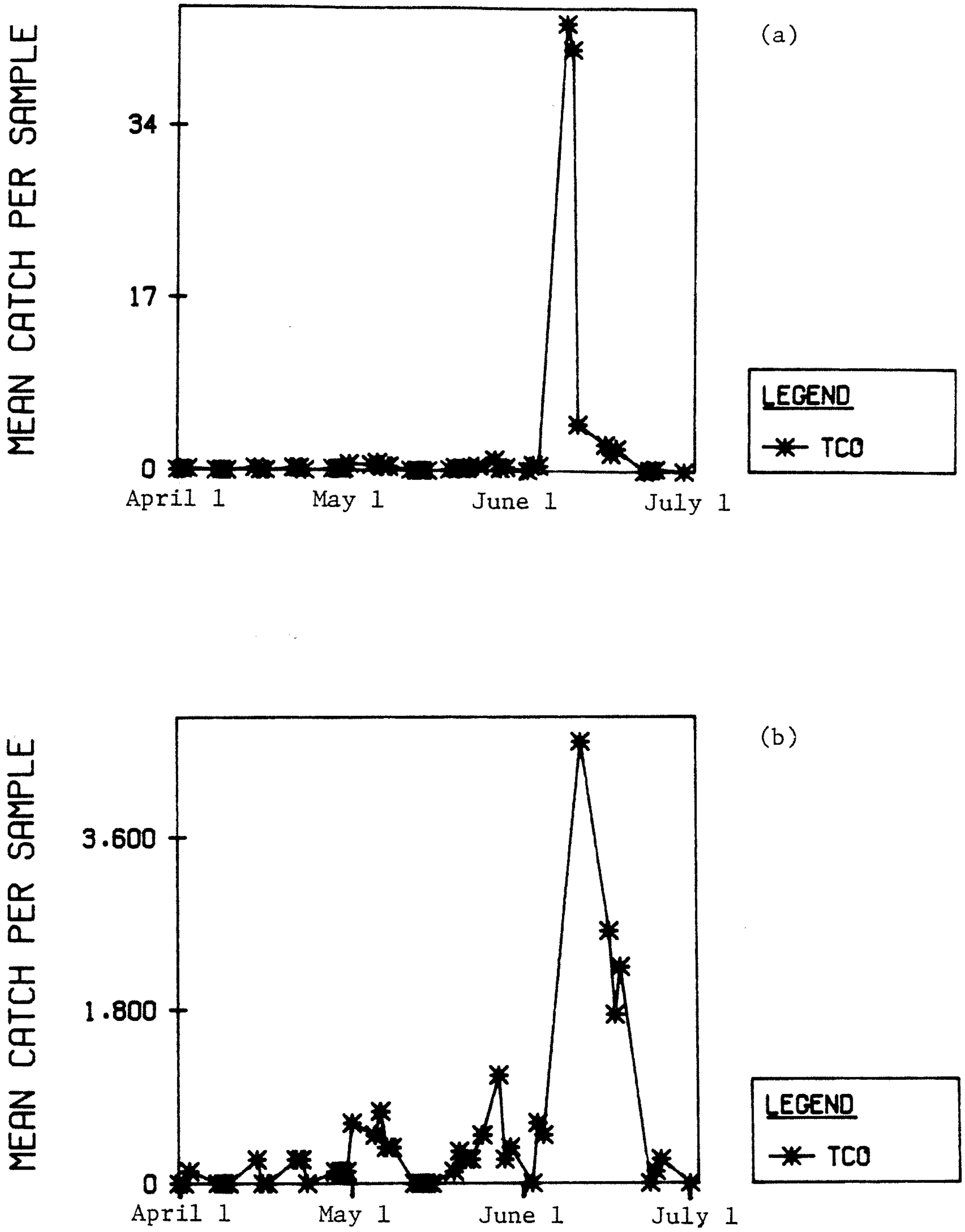


Fig. 10. Daily CPUE for coho salmon over the sampling season April 1 - July 1, 1985, with (a) the full data set, and (b) the two outlier days removed (note change in scale).

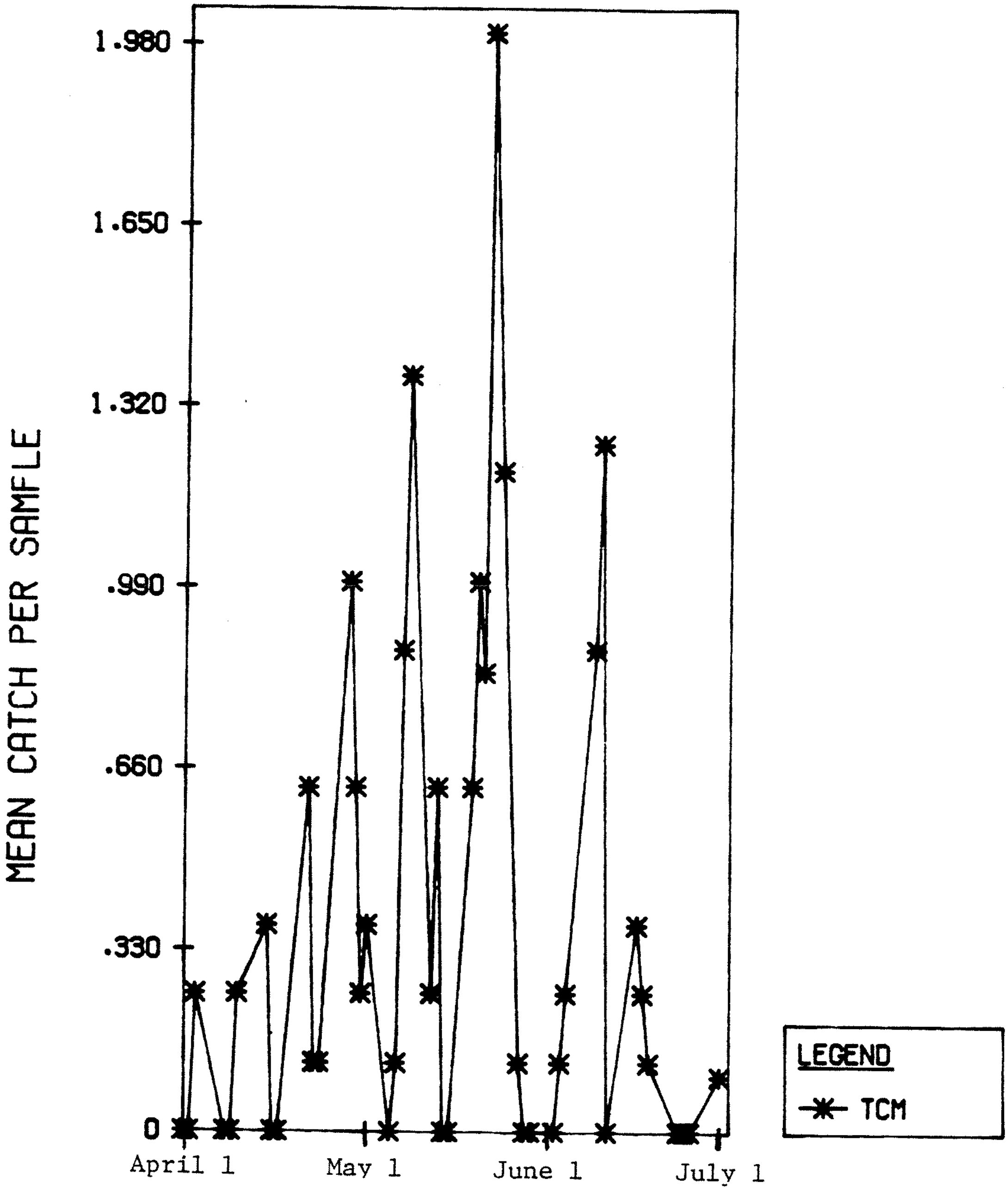


Figure 11. Daily CPUE for chum salmon over the sampling season April 1 - July 1, 1985.

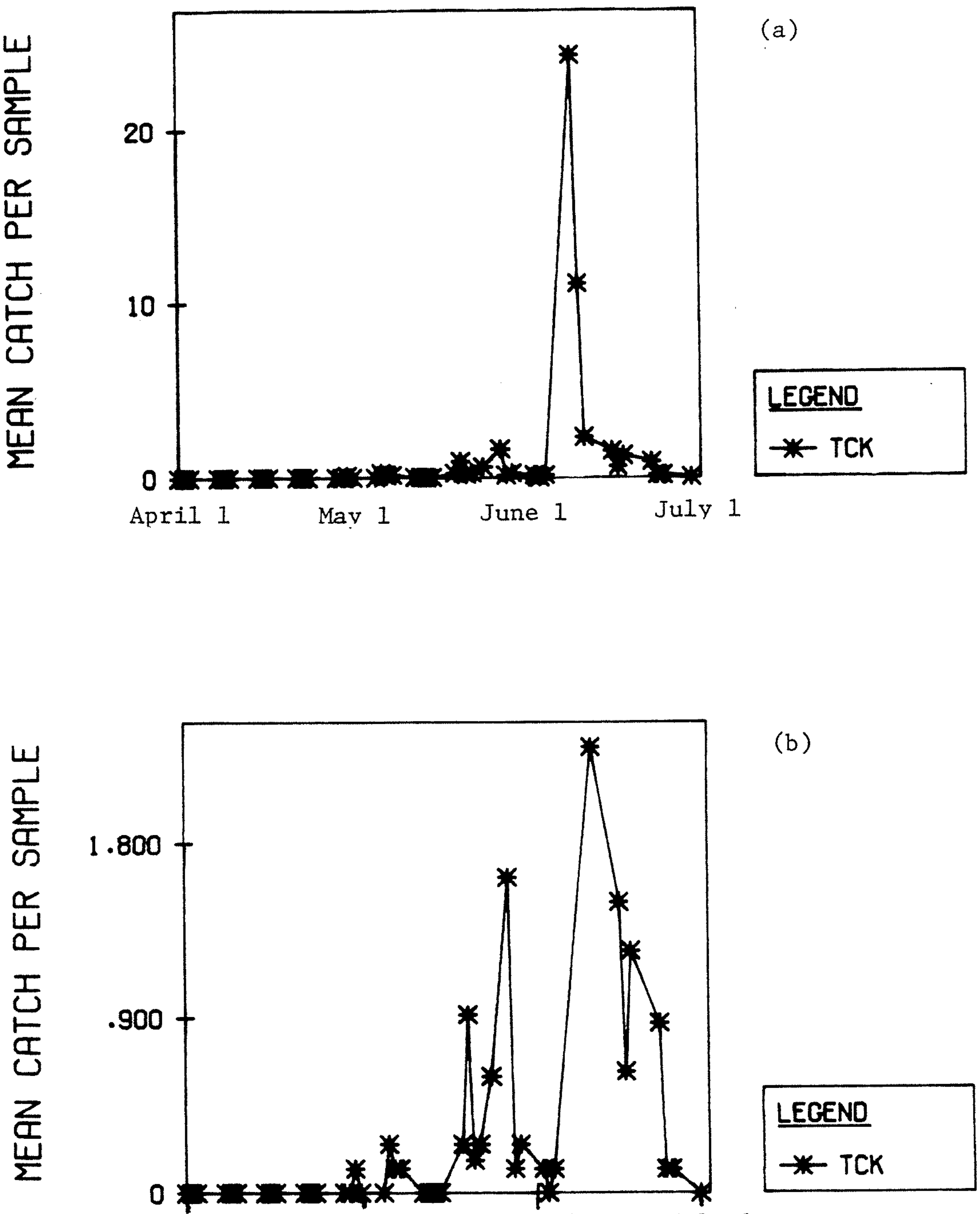


Fig. 12. Daily CPUE for chinook salmon over the sampling season April 1 - July 1, 1985, with (a) the full data set, and (b) the two outlier days removed (note change in scale).

Results of testing the hypothesis that fish were caught in equal numbers with ships present and with ships absent alongside the pier are presented in Appendix I. Significantly fewer juvenile chum were caught with ships present than with ships absent for 7 of the 12 variables tested, including total chum ($p = .004$), while the differences were nonsignificant for total coho and total chinook ($p = .17$ and .38, respectively). In contrast, significantly more chum ($p = .01$) were caught in the middle trap and significantly more chinook ($p = .03$) were caught in the south inner trap when ships were present at the cargo terminal.

Results of testing the hypothesis that fish were trapped in equal numbers with and without artificial lights on under the pier are presented in Appendix J. The differences were nonsignificant for both total coho and total chum ($p = .56$ and .59, respectively), while they were barely nonsignificant for total chinook ($p = .07$). The Wilcoxon nonparametric test gave a significant difference for total chinook ($p = .045$) and for total north chinook ($p = .048$). This test was nonsignificant for total inner chinook ($p = .085$) and for north inner chinook ($p = .099$), while the ANOVA was significant for each of these variables ($p = .03$ for total inner chinook and $p = .04$ for north inner chinook). It is important to note that catches were greater with lights off than with lights on for all variables for all species.

The two-way ANOVA for ships present/absent by lights off/on (Appendix K) yielded nonsignificant interaction for the total catches of each species ($p = .87$ for coho; $p = .38$ for chum; and $p = .26$ for chinook). There were significant interactions for total middle coho (p = .05), south middle chum (p = .05), total south chinook (p = .008), and south inner chinook (p = .002).

Analysis of the hypothesis that catches during ebb tides were equal to catches during flood tides (Appendix L) indicated that catches during ebb tides were higher for all variables which showed significant differences. The differences were highly significant for total coho (p = .008), total north coho (p = .01), total inner coho (p = .006), and north inner coho (p = .007). Chum salmon was the species most sensitive to the tide effect, with 7 of the 12 variables yielding significant results: total chum (p = .001), total outer chum (p = .04), total inner chum (p = .001), total south chum (p = .02), south outer chum (p = .03), total north chum (p = .002), and north inner chum (p = .003). There were no significant differences for chinook salmon (p = .63 for total chinook).

The SPSS MANOVA routine tested two hypotheses: 1) that catches in the north trap partitions were equal to catches in the south trap partitions, and 2) that equal numbers of fish were captured in the north versus south trap partitions during either ebb or flood tides. Rejection of the second hypothesis would indicate that fish were being caught in greater numbers either in the north traps during flood tides (moving with the tide) or in the south traps during flood tides (moving against the tides), or vice versa during ebb tides. The second hypothesis is equivalent to the question as to whether or not there was directional migration positively or negatively oriented to the tidal cycle. The results (Appendix M) showed that, for each species, significantly more fish were captured in the north trap partitions than in the south trap partitions (variable Norsou: p = .0001 for coho; p = .03 for chum; and p = .002 for chinook). No significant tidal directional movement was evident from the tide-norsou interactions (p = .08 for coho; p = .26 for chum; and p = .89 for chinook).

The one-way ANOVA for trap location (inner, middle, and outer) is presented by north and south components for each species. The results (Appendix N) were highly significant (p <.01) for all analyses. Juvenile coho had an affinity for the inner trap relative to the middle and outer traps. Juvenile chum catches were higher in the inner and outer traps than in the middle trap on the north side, but the inner trap catch could not be separated from that of the middle trap on the south side. North chinook catches were greater in the outer trap than in the inner and middle traps. South chinook catches were higher in the outer trap than the middle trap, but the inner trap catch was not significantly different from middle or outer trap catches.

Two-way analyses of variance for trap location by the ships (Appendix O), lights (Appendix P), or tide (Appendix Q) effects yielded limited interactions for chum and coho, but no interactions for chinook salmon. The two-way ANOVA for location by ships was significant (p = .02) for total chum. Catches were about equally distributed between the inner, middle, and outer traps with ships present, but higher in both the inner and outer traps than in the middle trap with ships absent. The two-way ANOVA for location by lights was significant (p = .05) for total north coho. The inner trap catch was greater with lights off, while the outer trap catch was greater with lights on. Interactions of location with tide were significant for total coho (p = .01), total north coho (p = .02), total chum (p = .02), and total north chum (p = .003). In each case, the interaction was attributable to higher catches in the inner trap during ebb tides.

Discussion

The seasonal timing of the chum and chinook catches was fairly well correlated with known occurrence of those species in Washington estuaries (Healey 1982; Simenstad et al. 1982). The seasonal pattern of the chum CPUE's approximated a normal distribution, but the chinook CPUE's appeared to be biased by releases from hatcheries.

The appearance of high numbers of coho fry in the traps is an anomaly worthy of further discussion, since coho normally reside in fresh water for at least the first year of life. Attrition of coho fry from the Puyallup system may be partly attributable to the removal of large organic debris (LOD, i.e., woody material) from the river (a concern noted by Fisheries Technical Team [1984]). LOD is an integral component of instream rearing habitat--it enhances cover, pool development, and stream stability. Grette (1985) observed that juvenile coho were closely associated with instream cover in the form of LOD during the winter. He also noted that water velocity appeared to be the most important determinant of coho distribution (coho sought low velocity habitat). Therefore, any comprehensive salmon management plan for the Puyallup system might consider habitat improvement projects in the upper Puyallup system, where large scale coho fry plants are being made (Mr. Don Ferron, Voights Creek Hatchery manager, pers. comm.). Literature citations (Allee 1974; Chapman 1962; Pritchard 1940) have noted the poor survival rate of coho fry in the marine environment.

The 1985 results with regard to ships were very similar to those of 1984, which also produced a hint that ships made under-pier habitat less attractive to juvenile salmon. However, as ships were not present a large percentage of the time, extra effort was made to sample when they were present. Chum again, as in 1984, demonstrated their sensitivity to the presence of ships.

As in 1984, CPUE's were higher for all variables for all species with artificial lights off than with them on. The results were about the same for coho in 1985 as they were for pink salmon in 1984. The results for chum were less significant in 1985 than in 1984. Chinook were again the most sensitive to lights, with some variables having significantly greater catches with the lights off. These results should be examined with caution, however, since they could be influenced by the ability of the fish to see the traps.

There was no evidence for interaction between the "ships effect" and the "lights effect" for the total catches for any species, which was also the case in 1984. However, differing interactions were evident for the component variables. Total middle coho and south inner chinook catches were highest when the lights were off with ships absent, which indicates that ships absent and lights off was the preferred condition for those fish. In contrast, south middle chum had increased catches when ships were present and lights were on, while total south chinook had increased catches when ships were present and lights were off. Presence of ships apparently reduced the hesitancy of chum to enter the middle trap, which will be discussed in further detail below.

To explain why consistently more fish were caught during ebb versus flood tides requires speculation regarding current patterns as they affect the Puyallup River plume and movement of fish in Blair Waterway. Two theories have been considered. The first theorizes that the extent of the Puyallup River plume into Blair Waterway is greater during ebb tides than during flood tides. However, this theory is not supported by data for current patterns in Commencement Bay (McGary and Lincoln 1977; Northwest Consultant Oceanographers 1981). A second theory is perhaps more plausible. It theorizes that, since juvenile salmon (especially smaller fish) tend to follow the path of least resistance, they go with the current as they enter the waterway through the central part of the channel during flood tides. At slack and ebb periods, the fish are able to disperse to their preferred nearshore habitats (where velocities are lower), and they become more available to the under-pier traps. The relatively large chinook juveniles, being stronger swimmers, did not display as high a vulnerability to displacements by tidal currents compared to chum and coho salmon in 1985 (and chum and pink salmon in 1984).

Although there were no significant tidal directional movements detected, the results tend to reflect the above theory. That is, chinook were relatively free to move about compared to the other species, which were comprised of smaller individuals and were more likely to be entrained by tidal currents. Also, detection of tidal directional movements is hindered by the erratic current patterns and gyres generated by strong tides in Blair Waterway. Pilings also created current perturbations under the pier, as evidenced by fluctuating movements of the traps both with and against the direction of the tide.

Significantly higher catches in the north versus south trap partitions probably demonstrates an affinity for nearshore habitat (which was exhibited by all three species in 1985) as fish entered the waterway in search of estuarine rearing areas. The results indicated that the fish moved toward deeper water in the channel as they grew and subsequently migrated seaward into Commencement Bay. This was also seen for chinook and chum in 1984, whereas juvenile pinks apparently had a longer waterway residence time and affinity for the under-pier habitat.

The results of the one-way ANOVA for trap location were in agreement with the 1983 and 1984 results, which showed that juvenile salmon generally were not caught in the middle trap. There is no obvious explanation for this behavior, but examination of the data leads me to speculate that it could be an acoustic response, since fish are known to use their acoustico-lateralis systems to detect water movement and structures during navigation (Lagler et al. 1977). Juvenile salmon encountered a barrier (the trap lead perpendicular to the shore) and may have determined (acoustically) the shoreward blockage, then sought the only open escape route -- toward the open pier face. Current could possibly be an aid to their navigation. Weitkamp (1982) observed that juvenile salmon would not enter the under-pier habitat at the Port of Seattle's Terminal 91. However, Weitkamp's Elliott Bay work was done at piers which are perpendicular to the normal current pattern and probably deflect the current, presenting a stimulus to juvenile salmon to which they responded in a way he interpreted as pier avoidance. In contrast, at Tacoma's Terminal Four the current flows perpendicular to the shore, and the fish behaved differently. Coho fry were closely associated with the estuarine shoreline - a behavior which would not be expected of yearling coho (Simenstad et al. 1982). Chum were more equitably distributed between the inner and outer traps, which displays their impartiality for either nearshore or offshore under-pier habitat. Chinook tended to prefer the deeper habitat toward the pier's edge.

The relatively even distribution of total chum catches among the inner, middle, and outer traps when ships were present alongside the pier could be related to the acoustical response stated above. We hypothesize that a ship presents an acoustically detectable barrier at the pier's edge which accounted for a reduction in hesitancy of chum juveniles to enter the middle trap. This behavior could also be related to a reduced differential in the lighting regime under the pier when ships were present.

The interaction results for the trap location by lights effects for total north coho indicates three behavior patterns:

1. juvenile coho preferred the dark, nearshore environment when the lights were off,
2. some of the fish headed toward the outer edge of the pier when the lights were on, and
3. the fish were being caught in the outer trap with lights on, so the traps were effective irrespective of the fishes' ability to see them under the brightest condition available.

The interaction results of trap location and tide (increased catches in the inner trap on ebb tides for chum and coho) contradicted the 1984 results for chum salmon. However, the 1984 interaction was no longer significant when rerun with the restricted data set. The preference for the nearshore area seen during ebb tides in 1985 appears to agree with that observed by Healey (1982) regarding the influence of tidal state on the behavior of chum fry in estuaries. Coho fry behaved similarly to chum fry under the pier.

LABORATORY LIGHTING EXPERIMENTS

Introduction

Laboratory lighting experiments were conducted in 1984 and 1985 in addition to the under-pier artificial lighting experiments. In 1984 tests were made during the peak of the pink salmon outmigration (late March and early April) and in 1985 tests were made on juvenile chum salmon, chinook salmon, and coho. The tests supplemented the under-pier trapping experiments by providing further data on fish preferences for lighted or shaded habitats.

Materials and Methods

A series of photoresponse tests, modified from Carey and Noakes (1981), were performed at the Fisheries Research Institute with juvenile pink salmon trapped on March 24, 1984. Equivalent tests were performed in a Tacoma Marine Supply storage shed with juvenile chum and chinook salmon beach seined by Puyallup Tribal biologists on May 30 and with juvenile coho trapped under the Terminal Four pier on June 11, 1985. All the fish were recent migrants to salt water. The pink salmon ranged in size from 30 to 40 mm fork length, the chum salmon were 45 to 80 mm, the chinook salmon were 70 to 110 mm, and the coho were 35 to 65 mm.

The tests were designed to measure the direction of phototaxis, given a choice between light and dark sides of a holding chamber (Figure 13). The fish were free to swim under the center partition separating the two sides of the chamber. Two chambers illuminated by an overhead 75W bulb were used for pink salmon. A single chamber with natural lighting was used for the other three species. A black plastic sheet

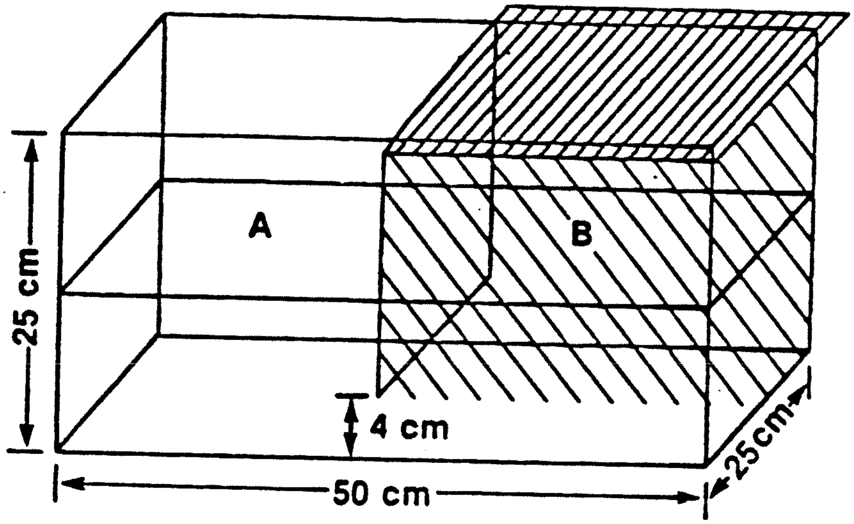


Figure 13. Oblique view of the light:dark choice chamber with its reversible lid. A, light compartment; B, dark compartment (not to scale). The dimensions shown are those of the chamber used for pink salmon. The dimensions were doubled for chum salmon, chinook salmon, and coho. (Source: Carey and Noakes 1981)

with a 4" by 6" observation port was hung over the chambers to screen the fish from extraneous movement.

Randomly selected juvenile salmon were placed in the chamber and allowed to adjust for a half hour; then a lid was placed on one side of the chamber. The fish were allowed ten minutes to adjust, then the number of fish on the lighted side of the chamber was counted at the end of each minute for ten minutes. The lid was then switched to the other side, and the experiment was repeated after another ten-minute adjustment period.

Chi-square (χ^2) goodness-of-fit analysis was used to test the null hypothesis:

H_o: The fish were randomly distributed on the light and dark sides; versus the alternative hypothesis:

H_a: There was a preference for one side.

Yate's correction for continuity was applied, since the number of classes was 2 (Zar 1974):

$$\chi^2 = \frac{(|f_1 - f_2| - 1)^2}{n}$$

where

χ^2 = the observed chi-square value,

f_1 = the mean number of fish on the light side,

f_2 = the mean number of fish on the dark side, and

n = the total number of fish in each replicate.

The observed chi-square values were tested at the .05 level of significance.

Results

The results of the laboratory lighting experiments are shown in Tables 6, 7, 8, and 9 for pink salmon, coho, chum salmon, and chinook salmon, respectively.

Juvenile pink salmon preferred the dark side of the choice chamber over the lighted side for two of the four trials. Nonsignificant results were obtained for the other two trials, which means that the fish were randomly distributed between the light and dark sides of the chamber for those tests.

The null hypothesis of random distribution between the light and dark sides of the choice chamber could not be rejected for any of the tests with coho, chum salmon, or chinook salmon. In other words, none of those species had any detectable preference for either the shaded or lighted half of the chamber.

Discussion

The 1985 results differ from those obtained in 1984 for pink salmon, when two of the four photoresponse tests conducted yielded the conclusion that pink salmon preferred the dark side of the choice chamber. One possible explanation of these results is related to the sizes of the fish tested, their respective capture sites, the amount of time they had been in salt water, and their degree of affinity for nearshore habitat.

The pink salmon used for the 1984 tests had (judging from their small size) entered salt water very recently and were captured under the Terminal four pier. The test results obtained from them led Ratté and

Table 6. Results of photoresponse tests conducted March 24, 1984 on juvenile pink salmon. n = 24 for each test. Counts are number of fish observed on light side.

	Time (min.)									
	1	2	3	4	5	6	7	8	9	10
Chamber 1										
Test 1	0	1	4	9	11	11	18	13	15	10
Test 2	1	9	3	1	3	6	1	8	10	11
Chamber 2										
Test 1	1	4	5	4	8	3	7	8	9	6
Test 2	11	11	7	14	14	20	13	17	18	14

Chi-square analyses:

Tabled value, $X^2_{.05,\ 1} = 3.841$

	Observed values	Conclusion
Chamber 1		
Test 1	$\frac{(\lvert 9.2 - 14.8 \rvert - 1)^2}{24} = 0.88$	Do not reject Ho, ($.25<p<.50$)
Test 2	$\frac{(\lvert 5.3 - 18.7 \rvert - 1)^2}{24} = 6.41$	Reject Ho, ($.01<p<.025$)
Chamber 2		
Test 1	$\frac{(\lvert 5.5 - 18.5 \rvert - 1)^2}{24} = 6.00$	Reject Ho, ($.01<p<.025$)
Test 2	$\frac{(\lvert 13.9 - 10.1 \rvert - 1)^2}{24} = 0.33$	Do not reject Ho, ($.50<p<.75$)

Table 7. Results of photoresponse tests conducted June 11, 1985, on juvenile coho salmon. n = 30 for each test. Counts are number of fish observed on light side.

	Time (min.)									
	1	2	3	4	5	6	7	8	9	10
Series 1										
Test 1	9	8	14	10	11	9	9	10	8	13
Test 2	11	16	17	15	12	14	13	15	14	16
Series 2										
Test 1	9	14	10	10	11	10	9	8	11	10
Test 2	12	16	13	11	15	10	14	13	16	12

Chi-square analyses:

Tabled value, $X^2_{.05,1} = 3.841$

	Observed values	Conclusion
Series 1		
Test 1	$\frac{(\lvert 10.1 - 19.9\rvert - 1)^2}{30} = 2.58$	Do not reject H_o; (.10<p<.25)
Test 2	$\frac{(\lvert 14.3 - 15.7\rvert - 1)^2}{30} = 0.01$	Do not reject H_o; (.90<p<.95)
Series 2		
Test 1	$\frac{(\lvert 10.3 - 19.7\rvert - 1)^2}{30} = 2.35$	Do not reject H_o; (.10<p<.25)
Test 2	$\frac{(\lvert 13.2 - 16.8\rvert - 1)^2}{30} = 0.23$	Do not reject H_o; (.75<p<.90)

Table 8. Results of photoresponse tests conducted May 30, 1985, on juvenile chum salmon. n = 30 for each test. Counts are number of fish observed on light side.

	Time (min.)									
	1	2	3	4	5	6	7	8	9	10
Series 1										
Test 1	19	21	20	18	17	22	21	20	18	17
Test 2	18	20	19	17	15	16	18	17	16	17
Series 2										
Test 1	17	19	22	17	18	20	19	17	20	19
Test 2	21	21	20	19	21	20	20	19	21	21

Chi-square analyses:

Tabled value, $X^2_{.05,1} = 3.841$

	Observed values	Conclusion
Series 1		
Test 1	$\frac{(\lvert 19.3 - 10.7 \rvert - 1)^2}{30} = 1.93$	Do not reject H_o; $(.10<p<.25)$
Test 2	$\frac{(\lvert 17.3 - 12.7 \rvert - 1)^2}{30} = 1.45$	Do not reject H_o; $(.75<p<.90)$
Series 2		
Test 1	$\frac{(\lvert 18.8 - 11.2 \rvert - 1)^2}{30} = 1.45$	Do not reject H_o; $(.10<p<.25)$
Test 2	$\frac{(\lvert 20.3 - 9.7 \rvert - 1)^2}{30} = 3.07$	Do not reject H_o; $(.05<p<.10)$

Table 9. Results of photoresponse tests conducted May 30, 1985, on juvenile chinook salmon. n = 30 for each test. Counts are number of fish observed on light side.

	Time (min.)									
	1	2	3	4	5	6	7	8	9	10
Series 1										
Test 1	11	16	13	12	11	12	7	8	11	14
Test 2	15	18	16	15	16	16	14	17	15	18
Series 2										
Test 1	18	16	16	17	16	16	17	16	18	17
Test 2	17	21	22	20	21	19	16	18	17	18

Chi-square analyses:

Tabled value, $X^2_{.05,1} = 3.841$

	Observed values		Conclusion
Series 1			
Test 1	$\frac{(\lvert 11.5 - 18.5 \rvert - 1)^2}{30}$	= 1.20	Do not reject H_o; ($.25 < p < .50$)
Test 2	$\frac{(\lvert 16.0 - 14.0 \rvert - 1)^2}{30}$	= 0.03	Do not reject H_o; ($.75 < p < .90$)
Series 2			
Test 1	$\frac{(\lvert 16.7 - 13.3 \rvert - 1)^2}{30}$	= 0.19	Do not reject H_o; ($.50 < p < .75$)
Test 2	$\frac{(\lvert 18.9 - 11.1 \rvert - 1)^2}{30}$	= 1.54	Do not reject H_o; ($.10 < p < .25$)

Salo (1985) to state that their data suggested that the dark areas under piers provided a potentially valuable habitat for juvenile salmonids during their early marine life history stages. However, the chum and chinook salmon juveniles tested in 1985 were obtained by beach seining; most of them were captured approximately two miles from the Puyallup River mouth, along the Ruston Way shoreline. These chum and chinook juveniles were also substantially larger than were the pink juveniles tested in 1984. These factors indicate that the chum and chinook juveniles had probably been in the marine environment longer than had the pink juveniles and were already progressing seaward; therefore, they would not be likely to find a shaded habitat desirable since they were essentially on the threshold of assuming a more or less pelagic life history stage.

The results of the coho photoresponse tests require an alternative explanation to that offered for chum and chinook salmon. The coho tested were relatively small and were captured in traps under the Terminal Four pier. Although the results were nonsignificant, it is notable that, for each of the four replicates, the mean count for coho was greater on the dark side than on the light side.

THE ROLE OF SHADING IN PREDATION ON JUVENILE SALMONIDS

Introduction

This part of the research was designed to study the effects of a proposed extension of the wharf at Pierce County Terminal at the southeast end of Blair Waterway.

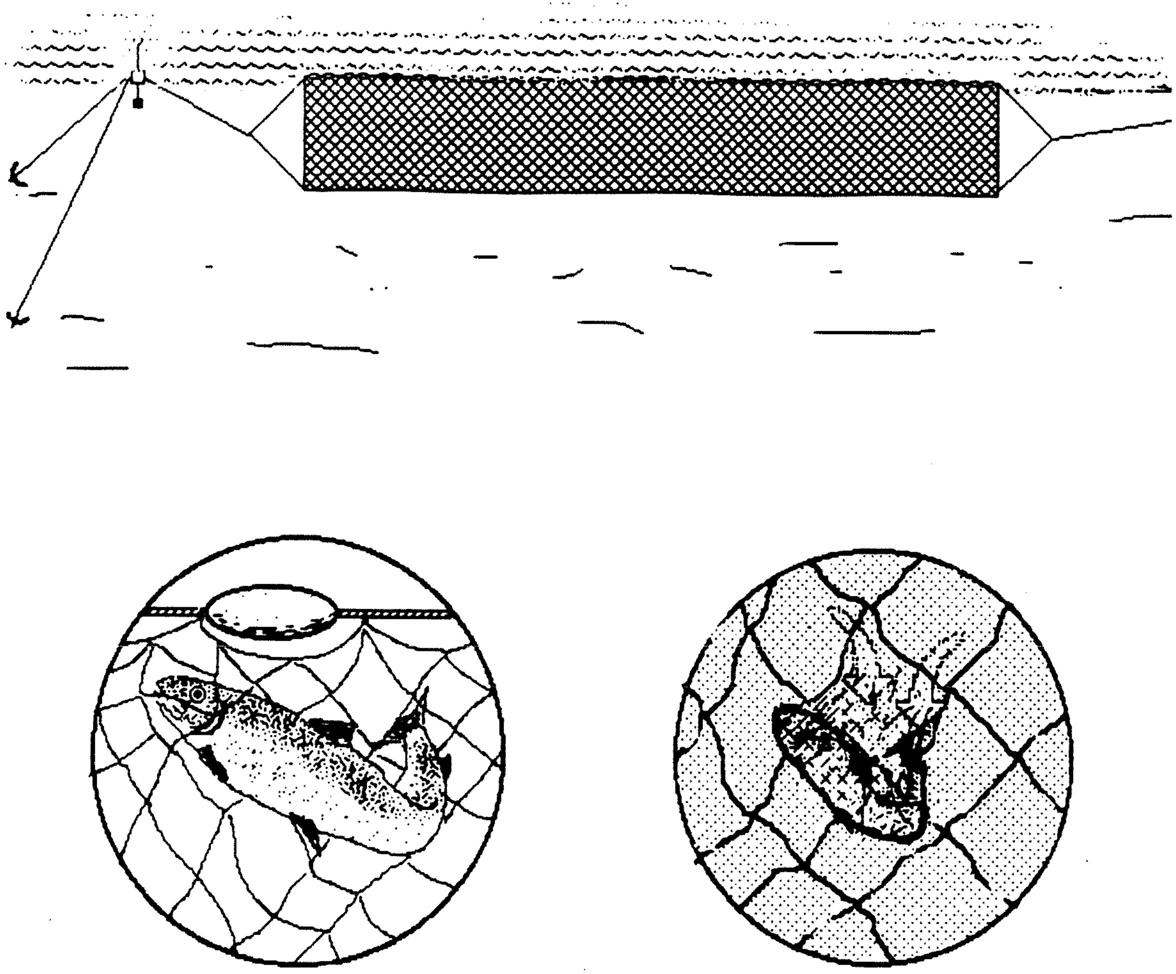
Although the extension was not constructed, the study involved the potential for predatory fishes to increase numerically in an area in response to the availability of juvenile salmon during the spring outmigration period. Specifically, the primary objective was to determine whether predators became aggregated in artificially created, shaded habitat (i.e., under piers) which might provide cover for them from which to prey upon salmon.

The issue is complex. Habitat structures can serve as refuge for prey and predator alike (Cooper and Crowder 1979). But, since most juvenile salmon predators use vision to feed (Fresh and Cardwell, unpublished manuscript), the reduction in available light in shaded areas could actually hinder their efforts to locate prey. In fact, degree of exposure of prey can significantly affect their vulnerability to predation (Ware 1972). At this point the literature is confusing, since citations can be found stating that chum salmon are both attracted to and repelled by piers and wharves. Chum salmon have been observed to shift from nearshore migration routes to offshore routes when they encountered a wharf in Hood Canal, which possibly indicates an avoidance response (Salo et al. 1980); while in the same study, in other instances the chum salmon were apparently attracted to the wharves during daylight hours. Cooper and Crowder (1979) also speculated that structures such as wharves may cause juvenile salmon to become disoriented due to current perturbations (which have been observed at Terminal Four) and thus more susceptible to predation.

Studies of predation on juvenile salmonids have typically been limited to analysis of the predators' food habits. Such studies can produce erroneous conclusions if they are not supported by data on the numbers and composition of the species involved (Fresh and Cardwell, unpublished manuscript). This study presented an opportunity to simultaneously monitor changes in predator and prey populations. Fresh et al. (1978) listed 17 potential predators on juvenile salmon for the Nisqually Reach area of southern Puget Sound, but noted that only three of them - maturing chinook salmon (blackmouth), copper rockfish (*Sebastes caurinus* Richardson), and staghorn sculpins (*Loptocottus armatus*) - are known to prey extensively on nearshore fishes. Their analysis showed only staghorn sculpins to have juvenile salmon in their stomach contents; staghorn sculpins were not more abundant around the dock they studied than elsewhere in the study area. Extensive gill net sampling by White (1975) at pier and control sites in Lake Washington prompted him to conclude that fish in general were not more abundant at piers and that piers did not provide refuge for (unspecified) predators.

Materials and Methods

The sampling problem required the use of gear which was portable and also versatile, i.e. capable of capturing a wide size range of fish. Trammel nets were chosen over variable mesh gill nets (Figure 14) because they are much less size selective (Hubert 1983; Koike and



GILL NET

TRAMMEL NET

Figure 14. Trammel net used in waterways at the Port of Tacoma and comparison of capture technique to gill net.

Takeuchi 1985) and significantly more effective than gill nets (White 1959).

Specifications of the floating trammel nets used were:

- two 6' deep by 65' long
- two 6' deep by 75' long
- each net consisted of a 2" stretch mesh #139 inner wall between a pair of 20" stretch mesh #9 outer walls; all multifilament, dyed green
- 50# leadcore leadline
- 1/4" SB poly rope floatline with 2 OS-1SC floats every 3 feet.

The nets were fished perpendicular to the shore in pairs - one net under a pier and the other control net at a nearby location in the open waterway. The under-pier nets were secured on each end to lines hung from the underside of the piers. Stainless steel quicklinks allowed them to slide up and down the lines in order to sample the top 5 feet of the water column at all tide levels. The control nets were secured on the shoreward end with a line tied to solid objects; the channelward end was secured with a pair of 12 lb. anchors and marked with buoys and gillnet lights.

Two sampling sites were used each week from the four selected: Sitcum Waterway, Slip 1, Terminal Four, and Pierce County Terminal (Figure 1). Weekly sampling occurred for a minimum of a 24-hour period over the entire season (Feb. 4 - June 25) and for a 48-hour period during the peak of the juvenile salmonid outmigration (April 30 - May 29). The nets were sampled every eight hours. Potential predators of juvenile salmon were either preserved intact or they were weighed and measured and their digestive tracts were retained in 10% buffered seawater formalin solution.

The sampling methodology was designed to test two pairs of hypotheses:

1. H_o: Predatory fish species become aggregated in artificially created, shaded habitat (under piers);

   versus

   H_a: Predatory fish species do not become aggregated under piers. And

2. H_o: Predatory fish species target on juvenile salmonids during the spring outmigration period;

   versus

   H_a: Predatory fish species do not target on juvenile salmonids during the spring outmigration.

These hypotheses were addressed in a qualitative, rather than statistical, manner.

Results

The twelve species of fish captured which were categorized as potential predators of juvenile salmonids include: steelhead trout (*Salmo gairdneri*), cutthroat trout (*S. clarki*), Dolly Varden trout (*Salvelinus malma*), chinook salmon, coho, Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), Pacific hake (*Merluccius productus*), Pacific tomcod (*Microgadus proximus*), prickly sculpin (*Cottus asper*), Pacific staghorn sculpin, and brown rockfish (*Sebastes auriculatus*). A summary of the numbers of each species caught at control and under-pier sites, broken down by life history stage, appears in Table 10. Their dates and sites of capture are compiled in Table 11.

For a complete listing of stomach contents analysis results, refer to Appendix R. Table R-1 contains the data for salmonid species, and Table R-2 contains the data for nonsalmonid species.

Also noteworthy, but not pertinent to the objectives of this research, was the large number of seaperch (Embiotocidae) in the catch at under-pier sampling sites. They were particularly abundant at Pierce County Terminal, where a total of 140 striped seaperch (Embiotoca lateralis Agassiz) and 111 pile perch (Rhacochilus vacca) were caught and released. Striped seaperch were observed bearing young at Pierce County Terminal on June 18.

Discussion

One striking result was the overall low total number of potential predators captured. We are confident that this was not due to inefficiency of the sampling gear, but that predatory fish were not abundant in the waterways sampled.

There was no evidence found to support the first null hypothesis that predatory fish species become aggregated in artificially created, shaded, under-pier habitat. In fact, since other salmonids are the most often reported predators of juvenile salmonids (Fresh and Cardwell, unpublished manuscript), the data indicate (since nine salmonids were caught at control sites compared to two at pier sites) that predators were less abundant in the shaded habitat. The majority of the

Table 10. Summary of potential juvenile salmonid predators captured in 1985 at under-pier and control sites in waterways at the Port of Tacoma, broken down by life history stages.

Control catch				Under-pier catch			
Total No.	Species	No. Adults	No. Juveniles	Total No.	Species	No. Adults	No. Juveniles
2	Steelhead trout	1	1		--		
3	Cutthroat trout	2	1	1	Cutthroat trout	1	0
1	Dolly Varden trout	1	0		--		
1	Chinook salmon	0	1		--		
2	Coho salmon	1	1	1	Coho salmon	0	1
1	Pacific cod	1	0	1	Pacific cod	1	0
	--			2	Walleye pollock	1	1
	--			1	Pacific hake	1	0
	--			2	Pacific tomcod	2	0
1	Prickly sculpin	1	0		--		
6	Staghorn sculpin	6	0	7	Staghorn sculpin	6	1
	--			4	Brown rockfish	3	1
17	Total catch	13	4	19	Total catch	15	4

Table 11. Compilation of potential juvenile salmonid predators captured in trammel nets at under-pier and control sites in waterways at the Port of Tacoma during 1985. Abbreviations in parentheses for the sampling sites are SIT = Sitcum Waterway, TM4 = Terminal Four, SL1 = Slip One, PCT = Pierce County Terminal.

Week #	Date	Control catch	Under-pier catch
1	Feb 4	0	0
2	Feb 11	1 Goldeneye (SIT)	1 Juvenile coho salmon (TM4)
3	Feb 18	1 Steelhead trout (SIT) 1 Juvenile coho salmon (TM4)	1 Walleye pollock (TM4)
4	Feb 25	0	2 Staghorn sculpin (SIT)
5	Mar 4	1 Prickly sculpin (SL1)	1 Brown rockfish (SL1)
6	Mar 11	1 Cutthroat trout (PCT) 1 Pacific cod (PCT)	1 Staghorn sculpin (PCT)
7	Mar 18	0	0
8	Mar 28	1 Cutthroat trout (PCT)	0
9	Apr 2	0	1 Staghorn sculpin (PCT)
10	Apr 9	0	0
11	Apr 16	0	0
12	Apr 23	1 Juvenile steelhead trout (SL1)	1 Pacific cod (PCT)
13a	Apr 30	0	0
13b	May 1	0	0
14a	May 7	1 Juvenile chinook salmon (PCT)	1 Staghorn sculpin (PCT)
14b	May 8	0	0
15a	May 14	0	1 Staghorn sculpin (PCT)
15b	May 15	1 Dolly Varden trout (SIT)	0
16a	May 21	0	1 Walleye pollock (SL1)
16b	May 22	0	0
17a	May 28	1 Staghorn sculpin (SL1) 1 Cutthroat trout (SL1)	0
17b	May 29	0	1 Brown rockfish (SL1)
18	Jun 4	1 Staghorn sculpin (PCT)	1 Brown rockfish (SL1)
19	Jun 11	3 Staghorn sculpin (PCT)	0
20	Jun 18	1 Coho salmon (PCT) 1 Staghorn sculpin (PCT)	1 Pacific hake (SL1)
21	Jun 25	0	1 Staghorn sculpin (PCT) 1 Brown rockfish (SL1) 1 Cutthroat trout (SL1) 2 Pacific tomcod (SL1)

nonsalmonid species classified as potential predators should be placed on the list with considerable reservations (C. Simenstad, pers. comm.), particularly the four gadids (although walleye pollock have been observed to prey on juvenile salmon [Armstrong and Winslow 1968]), and the brown rockfish, which is, more accurately, a member of the pier-piling fish assemblage.

There was also no evidence found in support of the second null hypothesis that predatory fish species were targeting on juvenile salmonids during the spring outmigration period. Not only was there no increase in number of predators caught during the outmigration, but the stomach and gut contents did not have a single prey item which could be identified as a juvenile salmonid.

A weakness in the methodology was the 8-hour sampling interval. It is possible that some predation on juvenile salmonids escaped detection due to digestion of stomach contents. We recommend some "real-time" collection of samples during the annual sampling of the spring outmigration conducted by the Puyallup Tribal biologists.

Although we cannot conclude that predation did not occur, it is safe to state that predation on juvenile salmonids by predatory fish species was not intense at our sampling sites. This finding is supported by other research (McCabe et al. 1962) at the Columbia River estuary, where predation on juvenile salmonids was found to be "insignificant," which led to the conclusion that the Columbia River estuary is a refuge from predators for juvenile salmonids.

Visual observations made by Heiser and Finn (1970) at marinas in Puget Sound reported that predation upon juvenile salmon in marina areas was less than expected and possibly less than the rate of predation at control sites (adjacent beaches). Weitkamp (1982) reported seeing no species of fish likely to be predators of juvenile salmon at the piers of Terminal 91, Port of Seattle. Salo et al. (1980) reported that most of the piscivorous fish captured in their overall study area did not have juvenile salmonids in their stomachs. Juvenile salmon were less than 4% of the total diet of suspected predatory species (cutthroat trout, staghorn sculpins, and Pacific cod).

SYNTHESIS OF RESULTS

Light levels under the Terminal Four pier were reduced 2 to 4 orders of magnitude compared to levels in the open waterway, but generally remained sufficient to facilitate feeding and schooling of juvenile Pacific salmon.

The experiments with artificial lights produced no evidence that juvenile salmon would benefit from installation of lights under the piers at the Port of Tacoma. It is possible that lights under piers would be detrimental to juvenile salmonids, especially chinook and pink salmon. The results of the photoresponse tests support these findings, since the fish obtained by under-pier trapping showed some preference for dark habitat (especially pink salmon fry, and somewhat for coho fry). Juvenile chinook may have avoided the traps when the lights were on.

The ANOVA results for the ships effect and the lights effect indicated that the under-pier behavior of coho fry parallels the under-pier ecology of pink salmon fry in some respects. The observed coho behavior could be a vestige of their freshwater ecology, i.e., seeking cover in low velocity habitat. The pier may have partially filled the role that instream cover plays during the normal coho life history. The results obtained during the limited time a control trap array was in use indicated that pink salmon fry preferred the dark under-pier habitat during their early marine life history.

Results for the day/night time effect showed that chinook juveniles were more active than chum and much more active than pink juveniles at night, which reflects the reliance on light-mediated schooling of pink and chum salmon.

The presence of ships had limited adverse effects on the use of under-pier habitat by juvenile salmonids, particularly when considering the fraction of the time ships were docked at the cargo terminal. Coho, pink salmon and chinook salmon were not significantly affected, and ships were present at the pier less than one-fourth of the time.

It appeared that outmigrating salmonids entering Blair Waterway may have been concentrated toward the center of the shipping channel by strong flood tide currents; later, weaker currents allowed them to explore nearshore areas in search of rearing habitat. Due to the absence of native wetlands in the waterway, estuarine residence time was probably limited, as most of the fish tended to migrate seaward through the shipping channel. However, the results of the ships-by-lights interaction suggest that those chinook which chose to reside longer in the waterway could have displayed a preference for the dark habitat available when ships were present and lights were off.

Simenstad et al. (unpublished technical report) have addressed the issue of utilization of Commencement Bay with respect to juvenile salmonid feeding ecology. Their major findings include:

1. Prey composition was highly skewed toward planktonic and neustonic organisms in Commencement Bay, whereas in an undeveloped estuary epibenthic organisms dominate the diet of juvenile salmonids (Fresh et al. 1979). This is due to an overall scarcity of preferred wetland foraging habitats in Commencement Bay. However, juvenile salmonids were often able to focus their foraging upon locales where wetland habitats

were available and the associated harpacticoid copepods and chironomids (preferred prey items) could be found.

2. Juvenile salmonids captured by under-pier trapping were particularly dependent upon planktonic and neustonic prey organisms. Drift insects were prevalent in the diets of fish from both the inner and outer traps. The methods of data collection did not allow definitive comparisons of the quantity of food available to juvenile salmon under piers and in other habitats in Commencement Bay.
3. There was a size-dependent shift from epibenthic to planktonic and neustonic feeding ecology displayed by chum salmon at 45-55 mm FL and by chinook salmon at 65-75 mm FL. The "patchy" distribution of planktonic and neustonic prey forced the fish to obtain a wide area to secure food.

The data did not indicate that potential predators of juvenile salmonids utilized shaded under-pier habitat as cover from which to pursue prey or, in fact, that they were targeting heavily on juvenile salmonids. This observation agrees with the findings of other studies.

It is plausible that piers sometimes serve as refuges for juvenile salmonids. An intensive study done in an east coast estuary (U.S. Dept. of Transportation 1984) found that a pier complex known as the Westway Project provided a staging area which juvenile striped bass (_Morone saxatilis_) used during movements out of the Hudson River. The Westway pier complex had overall equal utilization of the sampled habitat types in the estuary. Fish took refuge in the shallow water and under-pier habitats to avoid strong tidal currents (and probably other, uncited reasons), but the under-pier areas were noted to offer superior protection and opportunity for juveniles to conserve and even accumulate energy for movements into the marine environment. In overall perspective, the Westway area was considered a segment representing low-energy winter habitat of a larger wintering area for juvenile striped bass. Since natural shorelines at the Hudson River estuary had been replaced by development, piers offered the only remaining available shelter for juvenile anadromous fish species.

The situation for juvenile Pacific salmon in the Puyallup River estuary in some ways parallels that of juvenile striped bass in the Hudson River estuary. Both are developed areas lacking natural rearing habitats; both include piers which occupy a substantial portion of the available habitat; and both are under evaluation for their roles in ecology of anadromous fishes. The Westway project serves juvenile striped bass as a staging area during winter outmigrations from the Hudson River. Piers in Commencement Bay apparently offer some refuge to juvenile Pacific salmon - probably from predators as well as from currents - particularly to those fish which are dependent upon the estuary for an extended time of residency. However, further enhancement of the adjacent rearing habitats would be necessary if an estuarine ecosystem capable of supporting juvenile salmonids at this critical period of their life histories is to exist for the Puyallup system. Then, whatever role under-pier habitat plays in juvenile salmonid ecology can be more fully realized.

RECOMMENDATIONS

1. We do not recommend the installation of lights under the piers at the Port of Tacoma.
2. Juvenile salmonid wetland rearing habitat should be enhanced in the Puyallup estuary, or fish should be hatchery-reared for longer periods so they are less dependent on estuarine residency. A synchrony of these alternatives would be appropriate.
3. Consider habitat improvement projects in the upper Puyallup River system to benefit survival of coho parr and stimulate adult returns.
4. If further study of predation on juvenile salmonids is desired, it could be accomplished by collection of samples during spring beach seining and stomach contents analysis at the Fisheries Research Institute lab.

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APPENDICES

Key to variables:

Acronyms which were established to represent the variables are listed below for pink salmon:

NINP - North inner pink salmon catch
NMIDP - " middle " " "
NOUTP - " outer " " "
TNP - Total north " " "
SINP - South inner " " "
SMIDP - " middle " " "
SOUTP - " outer " " "
TSP - Total south " " "
TINP - " inner " " "
TMIDP - " middle " " "
TOUTP - " outer " " "
TP - " pink salmon catch

Equivalent acronyms for the other three species were established based on the above by replacing the "P" with "CM" for chum salmon, "CK" for chinook salmon, and "CO" for coho.

APPENDIX A

Control versus under-pier trapping effect, 1984

Table A-1. Analysis of the effect of control versus under-pier traps on catches of juvenile pink salmon.

Variable TP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	506.903	29			
Trap	56.595	1	56.594	3.519	p = .07
Error	450.308	28	16.082		

Group	n	Mean	95% Confidence Interval for Mean
Control	15	2.33	-1.37 to 6.03
Under-pier	15	9.40	-3.44 to 22.24

Variable TOUTP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	365.396	29			
Trap	65.237	1	65.237	6.086	p = .02
Error	300.159	28	10.719		

Group	n	Mean	95% Confidence Interval for Mean
Control	15	0.07	-0.76 to 0.21
Under-pier	15	8.40	-4.43 to 21.23

APPENDIX B

Day/night time effect, 1984

Table B-1. Analysis of the effect of day versus night times on catches of juvenile pink salmon.

Variable TP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	7246.666	262			
Time	94.069	1	94.069	3.433	p = .07
Error	7152.597	261	27.405		

Group	n	Mean	95% Confidence Interval for Mean
Day	218	6.69	2.10 to 11.28
Night	45	0.38	0.10 to 0.65

Mann-Whitney Two Sample Rank Test

$R_1 = 1,966$

$$U = (45)(218) + \frac{(45)(46)}{2} - 1,966 = 8,879$$

$$Z = \frac{8,879 - \frac{(45)(218)}{2}}{\sqrt{\frac{(45)(218)}{263^2 - 263} \quad \frac{263^3 - 263 - 5,146,740}{12}}} = 10.10$$

$P < .0001$

Table B-2. Analysis of the effect of day versus night times on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	81.976	262			
Time	.728	1	.728	2.341	p = .13
Error	81.248	261	.311		

Group	n	Mean	95% Confidence Interval for Mean
Day	218	0.13	0.04 to 0.23
Night	45	0	0 to 0

Mann-Whitney Two Sample Rank Test

$R_1 = 5{,}625$

$$U = (45)(218) + \frac{(45)(46)}{2} - 5{,}625 = 5{,}220$$

$$Z = \frac{5{,}220 - \frac{(45)(218)}{2}}{\sqrt{\frac{(45)(218)}{263^2-263} \quad \frac{263^3 - 263 - 15{,}438{,}726}{12}}} = 1.743$$

$P \cong .02$

Table B-3. Analysis of the effect of day versus night times on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	38.842	182			
Time	.295	1	.295	1.385	p = .24
Error	38.547	181	.213		

Group	n	Mean	95% Confidence Interval for Mean
Day	151	0.11	0.05 to 0.16
Night	32	0.03	-0.03 to 0.10

Mann-Whitney Two Sample Rank Test

$R_1 = 2810.5$

$$U = (32)(151) + \frac{32(33)}{2} - 2810.5 = 2549.5$$

$$Z = \frac{2549.5 - \frac{(32)(151)}{2}}{\sqrt{\frac{(32)(151)}{183^2-183} \quad \frac{183^3 - 18^3 - 4{,}827{,}984}{12}}} = 1.06$$

$P \cong .07$

APPENDIX C

Presence/absence of ships effect, 1984

Table C-1. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile pink salmon.

Variable TP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	6147.995	107			
Ship	115.680	1	115.680	2.033	p = 0.16
Error	6032.315	106	56.909		

Group	n	Mean	95% Confidence Interval for Mean
Present	49	6.69	-1.96 to 15.35
Absent	59	17.41	2.14 to 32.67

Table C-2. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	81.763	247			
Ship	1.357	1	1.357	4.153	p = 0.04
Error	80.406	246	0.327		

Group	n	Mean	95% Confidence Interval for Mean
Present	115	0.04	-0.01 to 0.08
Absent	133	0.19	0.04 to 0.34

Table C-3. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	56.452	380			
Ship	.228	1	.228	1.541	p = .22
Error	56.224	379	.148		

Group	n	Mean	95% Confidence Interval for Mean
Present	134	0.05	0.004 to 0.09
Absent	247	0.08	0.05 to 0.12

APPENDIX D

Lights off/on effect, 1984

Table D-1. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile pink salmon.

Variable TP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	2178.541	42			
Lights	17.605	1	17.605	.334	p = .57
Error	2160.936	41	52.706		

Group	n	Mean	95% Confidence Interval for Mean
Off	37	11.65	-9.62 to 32.91
On	6	0.50	-0.08 to 1.08

Table D-2. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	37.101	240			
Lights	.382	1	.382	2.481	p = .12
Error	36.719	239	.154		

Group	n	Mean	95% Confidence Interval for Mean
Off	135	0.10	-0.02 to 0.23
On	106	0.01	-0.01 to 0.03

Table D-3. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chinook salmon.

Variable TOUTCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	24.598	240			
Lights	0.466	1	0.466	4.614	p = .03
Error	24.132	239	0.101		

Group	n	Mean	95% Confidence Interval for Mean
Off	135	0.08	0.04 to 0.13
On	106	0.02	-0.01 to 0.05

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	40.681	240			
Lights	0.775	1	0.775	4.641	p = .03
Error	39.906	239	0.167		

Group	n	Mean	95% Confidence Interval for Mean
Off	135	0.12	0.06 to 0.18
On	106	0.04	0.001 to 0.08

APPENDIX E

Ships effect by lights effect, 1984

Table E-1. Two-way analysis of variance for the effects of presence/absence of ships by lights off/on on catches of juvenile pink salmon.

Variable TP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	2178.541	42	51.870		
Main effects	30.096	2	15.048	.274	p = .76
Ships	12.490	1	12.490	.227	p = .64
Lights	15.617	1	15.617	.284	p = .60
2-way interaction	4.299	1	4.299	.078	p = .78
Explained	34.395	3	11.465	.209	p = .89
Residual	2144.147	39	54.978		

CELL MEANS (Sample sizes in parentheses)

Ships	Absent	Present
	16.40 (25)	1.33 (18)

Lights	Off	On
	11.65 (87)	0.50 (6)

		Lights	
		Off	On
Ships	Absent	18.59 (22)	0.33 (3)
	Present	1.47 (15)	0.67 (3)

Table E-2. Two-way analysis of variance for the effects of presence/absence of ships by lights off/on on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	37.102	240	.155		
Main effects	.385	2	.192	1.244	p = .29
Ships	.003	1	.003	.018	p = .89
Lights	.383	1	.383	2.478	p = .12
2-way interaction	.058	1	.058	.374	p = .54
Explained	.443	3	.148	.954	p = .42
Residual	36.659	237	.155		

CELL MEANS (Sample sizes in parentheses)

Ships	Absent	Present
	0.07 (173)	0.04 (68)

Lights	Off	On
	0.10 (135)	0.01 (106)

		Lights	
		Off	On
Ships	Absent	0.12 (98)	0 (75)
	Present	0.05 (37)	0.03 (31)

Table E-3. Two-way analysis of variance for the effects of presence/absence of ships by lights off/on on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	40.680	240	.170		
Main effects	.788	2	.394	2.348	p = .10
Ships	.013	1	.013	.075	p = .78
Lights	.771	1	.771	4.595	p = .03
2-way interaction	.140	1	.140	.836	p = .36
Explained	.928	3	.309	1.844	p = .14
Residual	39.753	237	.168		

CELL MEANS (Sample sizes in parentheses)

Ships	Absent	Present
	0.09 (173)	0.07 (68)

Lights	Off	On
	0.12 (135)	0.04 (106)

		Lights	
		Off	On
Ships	Absent	0.11 (98)	0.05 (75)
	Present	0.14 (37)	0 (31)

APPENDIX F

Ebb/flood tide effect, 1984

Table F-1. Analysis of the effect of ebb versus flood tides on catches of juvenile pink salmon.

Variable TP — ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	6147.995	107			
Tide	40.904	1	40.904	0.710	p = 0.40
Error	6107.091	106	57.614		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	54	12.61	3.46 to 21.77
Flood	54	12.48	-3.69 to 28.65

Variable TOUTP — ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	1453.793	107			
Tide	87.376	1	87.376	6.778	p = 0.01
Error	1366.417	106	12.891		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	54	8.09	1.70 to 14.49
Flood	54	0.83	0.45 to 1.22

Variable 5OUTP — ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	505.638	107			
Tide	19.589	1	19.589	4.272	p = 0.04
Error	486.049	106	4.585		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	54	2.96	-0.57 to 6.50
Flood	54	0.28	0.08 to 0.47

Table F-2. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TCM ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	81.763	247			
Tide	0.542	1	0.542	1.641	p = 0.20
Error	81.221	264	0.330		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	121	0.14	0.03 to 0.25
Flood	127	0.09	-0.04 to 0.22

Variable NOUTCM ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	24.986	247			
Tide	0.627	1	0.627	6.331	p = 0.01
Error	24.359	246	0.099		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	121	0.09	0.001 to 0.18
Flood	127	0	0 to 0

Variable TOUTCM ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	34.801	247			
Tide	0.570	1	0.570	4.098	p = 0.04
Error	34.231	246	0.139		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	121	0.11	0.02 to 0.20
Flood	127	0.02	-0.01 to 0.06

Table F-3. Analysis of the effect of ebb versus flood tides on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	56.451	380			
Tide	.005	1	.005	.034	p = .85
Error	56.446	379	.149		

Group	n	Mean	95% Confidence Interval for Mean
Ebb	183	0.07	0.03 to 0.11
Flood	198	0.07	0.03 to 0.11

APPENDIX G

Tidal orientation effect, 1984

Table G-1. Analysis of the effect of tidal orientation and trap partitioning on catches of juvenile pink salmon.

Variables TNP, TSP

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	10.824	1	10.824	0.625	p = 0.43
Tide-Norsou interaction	3.468	1	3.468	0.200	p = 0.66
Error	3053.546	106	28.807		

Group	n	Mean	95% Confidence Interval for Mean
TNP	108	8.13	3.56 to 15.90
Ebb	54	8.48	0.97 to 15.99
Flood	54	7.78	-6.13 to 21.68
TSP	108	4.42	0.21 to 8.62
Ebb	54	4.13	0.37 to 7.89
Flood	54	4.70	-2.97 to 12.38

Table G-2. Analysis of the effect of tidal orientation and trap partitioning on catches of juvenile chum salmon.

Variables TNCM, TSCM

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	0.459	1	0.459	3.309	p = 0.07
Tide-Norsou interaction	0.196	1	0.196	1.411	p = 0.24
Error	40.610	246	0.139		

Group	n	Mean	95% Confidence Interval for Mean
TNCM	248	0.09	0.01 to 0.17
Ebb	121	0.12	0.02 to 0.22
Flood	127	0.07	-0.06 to 0.20
TSCM	248	0.02	0.002 to 0.05
Ebb	121	0.03	-0.003 to 0.05
Flood	127	0.02	-0.01 to 0.06

Table G-3. Analysis of the effect of tidal orientation and trap partitioning on catches of juvenile chinook salmon.

Variables TNCK, TSCK

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	0.359	1	0.359	4.603	p = 0.03
Tide-Norsou interaction	0.149	1	0.149	1.910	p = 0.17
Error	29.473	379	0.078		

Group	n	Mean	95% Confidence Interval for Mean
TNCK	381	0.05	0.03 to 0.07
Ebb	183	0.04	0.01 to 0.07
Flood	198	0.06	0.02 to 0.10
TSCK	381	0.02	0.01 to 0.03
Ebb	183	0.03	0.003 to 0.05
Flood	198	0.01	-0.004 to 0.02

APPENDIX H

Trap location (inner, middle, outer) effect, 1984

Table H-1. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile pink salmon in north trap partitions.

Variable NP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	2945.025	323			
Location	59.895	2	29.948	3.332	p = 0.04
Error	2885.130	320	8.988		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	108	5.26	374	-1.84 to 12.36
Middle	108	0.03	2	-0.01 to 0.07
Outer	108	2.84	115	0.14 to 5.55

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle
Mean	0.03

Subset 2

Group	Outer	Inner
Mean	2.84	5.26

Table H-2. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile pink salmon in south trap partitions.

Variable SP

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	1530.972	323			
Location	38.222	2	19.111	4.110	p = 0.02
Error	1492.750	321	4.650		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	108	2.79	207	-1.06 to 6.64
Middle	108	0.01	1	-0.01 to 0.03
Outer	108	1.62	91	-0.14 to 3.38

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle
Mean	0.01

Subset 2

Group	Outer	Inner
Mean	1.62	2.79

Table H-3. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chum salmon in north trap partitions.

Variable NCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	50.515	743			
Location	0.245	2	0.122	1.803	p = 0.17
Error	50.270	741	0.068		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	248	0.05	8	-0.02 to 0.11
Middle	248	0	0	0 to 0
Outer	248	0.04	5	0.000 to 0.09

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Outer	Inner
Mean	0.000	0.04	0.05

Table H-4. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chum salmon in south trap partitions.

Variable SCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	7.952	743			
Location	0.056	2	0.028	2.649	p = 0.07
Error	7.895	741	0.011		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	248	0.004	2	-0.004 to 0.01
Middle	248	0	0	0 to 0
Outer	248	0.02	2	-0.001 to 0.04

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Inner	Outer
Mean	0	0.004	0.02

Table H-5. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chinook salmon in north trap partitions.

Variable NCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	18.696	1187			
Location	0.153	2	0.077	4.895	p = 0.01
Error	18.543	1185	0.016		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	396	0.02	1	0.01 to 0.04
Middle	396	0	0	0 to 0
Outer	396	0.03	1	0.01 to 0.04

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle
Mean	0

Subset 2

Group	Inner	Outer
Mean	0.02	0.03

Table H-6. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chinook salmon in south trap partitions.

Variable SCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	6.959	1187			
Location	0.052	2	0.026	4.447	p = 0.01
Error	6.907	1185	0.006		

Group	n	Mean	Maximum	95% C.I. for mean
Inner	396	0	0	0 to 0
Middle	396	0.003	1	-0.002 to 0.01
Outer	396	0.02	1	0.003 to 0.03

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Inner	Middle
Mean	0	0.003

Subset 2

Group	Middle	Outer
Mean	0.003	0.02

APPENDIX I

Presence/absence of ships effect, 1985

Table I-1. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile coho salmon.

Variable TCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	493.675	297			
Ships	3.112	1	3.112	1.878	p = .17
Error	490.563	296	1.657		

Group	n	Mean	95% Confidence interval for mean
Absent	210	.643	.413 to .873
Present	88	.398	.138 to .658

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TCO
by SHIPS          Absent                     Present

             SH        =        0       SH        =        1
             Mean rank      number      Mean rank      number
              152.02         210         143.48          88

                                          Corrected for ties
                U             W           Z       2-tailed p
             8710.5        1.0403                   .2982
```

Table I-2. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	411.124	297			
Ships	11.481	1	11.481	8.504	p = .004
Error	399.643	296	1.350		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.551	.404 to .698
Present	64	.141	.053 to .228

Mann-Whitney U - Wilcoxon Rank Sum W Test

TCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	154.82	234	130.03	64
			Corrected for ties	
	U	W	Z	2-tailed p
	6242.0	8322.0	2.6652	.0077

Table I-3. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TOUTCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	173.398	297			
Ships	3.604	1	3.604	6.283	p = .01
Error	169.794	296	.574		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.282	.190 to .374
Present	64	.062	.002 to .123

Mann-Whitney U - Wilcoxon Rank Sum W Test

TOUTCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	153.63	234	134.41	64
			Corrected for ties	
	U	W	Z	2-tailed p
	6522.0	8602.0	2.4759	.0133

Table I-4. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TMIDCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	9.832	297			
Ships	.148	1	.148	4.513	p = .03
Error	9.684	296	.033		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.009	-.003 to .020
Present	64	.047	-.006 to .100

Mann-Whitney U - Wilcoxon Rank Sum W Test

TMIDCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	148.27	234	153.98	64
			Corrected for ties	
	U	W	Z	2-tailed p
	7201.0	9855.0	-2.1119	.0347

Table I-5. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TINCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	136.898	297			
Ships	3.513	1	3.513	7.795	p = .006
Error	133.385	296	.451		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.261	.165 to .357
Present	64	.062	-.013 to .075

Mann-Whitney U - Wilcoxon Rank Sum W Test

TINCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	154.15	234	132.50	64
			Corrected for ties	
	U	W	Z	2-tailed ties
	6400.0	8480.0	2.9200	.0035

Table I-6. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TSCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	126.582	297			
Ships	1.737	1	1.737	4.117	p = .04
Error	124.846	296	.422		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.218	.140 to .296
Present	64	.016	.002 to .123

Mann-Whitney U - Wilcoxon Rank Sum W Test

TSCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	152.58	234	138.24	64
			Corrected for ties	
	U	W	Z	2-tailed p
	6767.5	8847.5	1.9915	.0464

Table I-7. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable SOUTCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	61.703	297			
Ships	.951	1	.951	4.633	p = .03
Error	60.752	296	.205		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.128	.072 to .184
Present	64	.016	-.016 to .047

Mann-Whitney U - Wilcoxon Rank Sum W Test

SOUTCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	152.16	234	139.79	64
			Corrected for ties	
	U	W	Z	2-tailed p
	6866.5	8946.5	2.1573	.0310

Table I-8. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable TNCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	185.120	297			
Ships	4.287	1	4.287	7.018	p = .009
Error	180.833	296	.611		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.333	.229 to .438
Present	64	.078	.011 to .146

Mann-Whitney U - Wilcoxon Rank Sum W Test

TNCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	154.01	234	133.02	64
			Corrected for ties	
	U	W	Z	2-tailed p
	6433.5	8513.5	2.5528	.0107

Table I-9. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chum salmon.

Variable NINCM

ANOVA Summary Table

Source of variation	Sum of squares	Degress of freedom	Mean square	F ratio	Significance
Total	89.123	297			
Ships	1.700	1	1.700	5.756	p = .02
Error	87.423	296	.295		

Group	n	Mean	95% Confidence interval for mean
Absent	234	.179	.097 to .261
Present	64	.016	-.016 to .047

Mann-Whitney U - Wilcoxon Rank Sum W Test

NINCM by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	152.84	234	137.27	64

		Corrected for ties	
U	W	Z	2-tailed p
6705.5	8785.5	2.4928	.0127

Table I-10. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	286.230	209			
Ships	1.064	1	1.064	.776	p = .38
Error	285.166	208	1.371		

Group	n	Mean	95% Confidence interval for mean
Absent	152	.553	.343 to .763
Present	58	.345	.144 to .545

Mann-Whitney U - Wilcoxon Rank Sum W Test

TCK by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	107.00	152	101.58	58
			Corrected for ties	
	U	W	Z	2-tailed p
	4180.5	5891.5	.7688	.4420

Table I-11. Analysis of the effect of presence/absence of ships alongside the Terminal Four pier on catches of juvenile chinook salmon.

Variable SINCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	19.276	209			
Ships	.414	1	.414	4.570	p = .03
Error	18.862	208	.091		

Group	n	Mean	95% Confidence interval for mean
Absent	152	.020	-.009 to .049
Present	58	.130	-.003 to .210

Mann-Whitney U - Wilcoxon Rank Sum W Test

SINCK by SHIPS	Absent		Present	
	SH =	0	SH =	1
	Mean rank	number	Mean rank	number
	103.88	152	109.74	58
			Corrected for ties	
	U	W	Z	2-tailed p
	4162.0	6365.0	-2.1650	.0304

APPENDIX J

Lights off/on effect, 1985

Table J-1. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile coho salmon.

Variable TCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	493.675	297			
Lights	0.563	1	0.563	0.338	p = 0.56
Error	493.112	296	1.666		

Group	n	Mean	95% confidence interval for mean
Off	149	0.644	0.375 to 0.913
On	149	0.497	0.257 to 0.736

Wilcoxon Matched-Pairs Signed-Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
149	95	29	29.21	25	25.52	-0.900	0.368

Table J-2. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	411.124	297			
Lights	0.410	1	0.410	0.295	p = 0.59
Errors	410.714	296	1.388		

Group	n	Mean	95% confidence interval for mean
Off	149	0.510	0.318 to 0.702
On	149	0.416	0.275 to 0.557

Wilcoxon Matched-Pairs Signed-Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
149	94	31	27.34	24	28.85	-0.649	0.516

Table J-3. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	286.230	209			
Lights	4.563	1	4.563	3.370	p = 0.07
Error	281.667	208	1.354		

Group	n	Mean	95% confidence interval for mean
Off	105	0.648	0.371 to 0.924
On	105	0.343	0.176 to 0.510

Wilcoxon Matched-Pairs Signed-Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
105	63	27	22.67	15	19.40	-2.007	0.045

Table J-4. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chinook salmon.

Variable TINCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	63.241	209			
Lights	1.506	1	1.506	5.075	p = 0.03
Error	61.735	208	0.297		

Group	n	Mean	95% confidence interval for mean
Off	105	0.219	0.088 to 0.350
On	105	0.067	-0.001 to 0.134

Wilcoxon Matched-Pairs Signed-Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
105	88	14	8.93	4	11.50	-1.720	0.085

Table J-5. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chinook salmon.

Variable TNCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	223.481	209			
Lights	3.741	1	3.741	3.541	p = 0.06
Error	219.740	208	1.056		

Group	n	Mean	95% confidence interval for mean
Off	105	0.505	0.239 to 0.771
On	105	0.238	0.097 to 0.379

Wilcoxon Matched-Pairs Signed Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
105	72	23	17.00	10	17.00	-1.974	0.048

Table J-6. Analysis of the effect of using artificial lights under the Terminal Four pier on catches of juvenile chinook salmon.

Variable NINCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	46.286	209			
Lights	.964	1	.964	4.422	p = .04
Error	45.322	208	.218		

Group	n	Mean	95% confidence interval for mean
Off	105	.162	.042 to .282
On	105	.038	-.015 to .091

Wilcoxon Matched-Pairs Signed-Ranks Test

		- Ranks		+ Ranks			
n	Ties	n	Mean	n	Mean	z	2-Tailed p
105	93	10	6.00	2	9.00	-1.647	0.099

APPENDIX K

Ships effect by lights effect, 1985

Table K-1. A two-way ANOVA for the effects of presence/absence of ships by lights off/on on catches of juvenile coho salmon.

Variable TCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	493.675	297	1.662		
Main effects	3.715	2	1.858	1.115	p = 0.33
Ships	3.152	1	3.152	1.891	p = 0.17
Lights	0.603	1	0.603	0.362	p = 0.55
2-way interaction	0.044	1	0.044	0.026	p = 0.87
Explained	3.759	3	1.253	0.752	p = 0.52
Residual	489.916	294	1.666		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.643 (210)	0.398 (88)

Lights	Off	On
	0.644 (149)	0.497 (149)

		Lights	
		Off	On
Ships	Absent	0 (104)	0.594 (106)
	Present	0.533 (45)	0.256 (43)

Table K-2. A two-way ANOVA for the effects of presence/absence of ships by lights off/on on catches of juvenile coho salmon.

Variable TMIDCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	8.523	297	0.029		
Main effects	0.031	2	0.016	0.546	p = 0.58
Ships	0.030	1	0.030	1.038	p = 0.31
Lights	0.001	1	0.001	0.048	p = 0.83
2-way interaction	0.107	1	0.107	3.752	p = 0.05
Explained	0.138	3	0.046	1.615	p = 0.19
Residual	8.385	294	0.029		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.010 (210)	0.023 (88)

Lights	Off	On
	0.013 (149)	0.013 (149)

		Lights	
		Off	On
Ships	Absent	0.692 (104)	0.019 (106)
	Present	0.044 (45)	0 (43)

Table K-3. A two-way ANOVA for the effects of presence/absence of ships by lights off/on on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	411.124	297	1.384		
Main effects	11.965	2	5.983	4.418	p = 0.01
Ships	11.555	1	11.555	8.533	p = 0.004
Lights	0.484	1	0.484	0.357	p = 0.55
2-way interaction	1.037	1	1.037	0.766	p = 0.38
Explained	13.002	3	4.334	3.201	p = 0.02
Residual	398.121	294	1.354		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.551 (234)	0.141 (64)

Lights	Off	On
	0.510 (149)	0.416 (149)

		Lights	
		Off	On
Ships	Absent	0.269 (116)	0.475 (118)
	Present	0.091 (33)	0.194 (31)

Table K-4. A two-way ANOVA for the effects of presence/absence of ships by lights off/on on catches of juvenile chum salmon.

Variable SMIDCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	7.893	297	0.027		
Main effects	0.080	2	0.040	1.524	p = 0.22
Ships	0.053	1	0.053	2.023	p = 0.16
Lights	0.028	1	0.028	1.071	p = 0.30
2-way interaction	0.105	1	0.105	4.004	p = 0.05
Explained	0.185	3	0.062	2.351	p = 0.07
Residual	7.708	294	0.026		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.009 (234)	0.031 (64)

Lights	Off	On
	0.007 (149)	0.020 (149)

		Lights Off	On
Ships	Absent	0.009 (116)	0.008 (118)
	Present	0 (33)	0.065 (31)

Table K-5. A two-way ANOVA for the effects of presence/absence of ships by lights off/on for juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	286.230	209	1.370		
Main effects	5.627	2	2.814	2.078	p = .13
Ships	1.064	1	1.064	.786	p = .38
Lights	4.563	1	4.563	3.371	p = .07
2-way Interaction	1.729	1	1.729	1.277	p = .26
Explained	7.357	3	2.452	1.811	p = .15
Residual	278.873	206	1.354		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.553 (152)	0.345 (58)

Lights	Off	On
	0.648 (105)	0.343 (105)

Ships		Lights Off	Lights On
	Absent	0.671 (76)	0.434 (76)
	Present	0.586 (29)	0.103 (29)

Table K-6. A two-way ANOVA for the effects of presence/absence of ships by lights off/on for juvenile chinook salmon.

Variable NINCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	46.286	209	.221		
Main effects	1.251	2	.665	2.862	p = .06
Ships	.287	1	.287	1.314	p = .25
Lights	.964	1	.964	4.411	p = .04
2-way Interaction	.029	1	.029	.132	p = .72
Explained	1.280	3	.427	1.952	p = .12
Residual	45.006	206	.218		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.125 (152)	0.034 (58)

Lights	Off	On
	0.162 (105)	0.038 (105)

		Lights	
		Off	On
Ships	Absent	0.197 (76)	0.053 (76)
	Present	0.069 (29)	0 (29)

Table K-7. A two-way ANOVA for the effects of presence/absence of ships by lights off/on for juvenile chinook salmon.

Variable TSCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	50.554	209	.242		
Main effects	.265	2	.133	.563	p = .57
Ships	.225	1	.225	.952	p = .33
Lights	.041	1	.041	.173	p = .68
2-way Interaction	1.704	1	1.704	7.226	p = .008
Explained	1.970	3	.657	2.784	p = .04
Residual	48.584	206	.236		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.105 (152)	0.172 (58)

Lights	Off	On
	0.143 (105)	0.105 (105)

		Lights	
		Off	On
Ships	Absent	0.079 (76)	0.132 (76)
	Present	0.310 (29)	0.034 (29)

Table K-8. A two-way ANOVA for the effects of presence/absence of ships by lights off/on for juvenile chinook salmon.

Variable SINCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	19.276	209	.092		
Main effects	.475	2	.237	2.731	p = .07
Ships	.414	1	.414	4.768	p = .03
Lights	.060	1	.060	.695	p = .41
2-way Interaction	.897	1	.897	10.324	p = .002
Explained	1.372	3	.457	5.262	p = .002
Residual	17.904	206	.087		

CELL Means (Sample sizes in parentheses)

Ships	Absent	Present
	0.020 (152)	0.103 (58)

Lights	Off	On
	0.057 (105)	0.029 (105)

		Lights	
		Off	On
Ships	Absent	0.207 (29)	0 (29)
	Present	0 (76)	0.039 (76)

APPENDIX L

Ebb/flood tide effect, 1985

Table L-1. Analysis of the effect of ebb versus flood tides on catches of juvenile coho salmon.

Variable TCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	493.675	297			
Tide	11.793	1	11.793	7.244	p = 0.008
Error	481.882	296	1.628		

Group	n	Mean	95% confidence interval for mean
Ebb	142	0.775	0.479 to 1.070
Flood	156	0.385	0.174 to 0.595

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TCO
 By Tide                 Ebb                      Flood

    Tide         =              1.   Tide        =            2.
    Mean Rank              Number    Mean Rank             Number
      161.19                  142      138.86                 156

                                         Correct for Ties
       U              W               Z           2-Tailed P
    9416.0         22889.0         2.9790           0.0029
```

Table L-2. Analysis of the effect of ebb versus flood tides on catches of juvenile coho salmon.

Variable TINCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	297.241	297			
Tide	7.655	1	7.655	7.824	p = 0.006
Error	289.586	296	0.978		

Group	n	Mean	95% confidence interval for mean
Ebb	142	0.592	0.350 to 0.833
Flood	156	0.263	0.107 to 0.419

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TINCO
By Tide                     Ebb                         Flood

   Tide          =                  1.    Tide      =             2.
   Mean Rank                   Number     Mean Rank          Number
     159.68                      142        140.23              156

                                               Correct for Ties
       U                    W                 Z         2-Tailed P
     9630.5             22674.5           2.8198          0.0048
```

Table L-3. Analysis of the effect of ebb versus flood tides on catches of juvenile coho salmon.

Variable TNCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	385.111	297			
Tide	7.871	1	7.871	6.176	p = 0.01
Error	377.240	296	1.275		

Group	n	Mean	95% confidence interval for mean
Ebb	142	0.613	0.346 to 0.879
Flood	156	0.263	0.088 to 0.438

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TNCO

 By Tide                  Ebb                       Flood

     Tide        =                1.   Tide      =               2.
     Mean Rank                Number   Mean Rank             Number
       158.81                    142     141.02                 156

                                             Correct for Ties
        U                W               Z        2-Tailed P
      9753.5          22551.5          2.7138        0.0067
```

Table L-4. Analysis of the effect of ebb versus flood tides on catches of juvenile coho salmon.

Variable NINCO

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	189.152	297			
Tide	4.638	1	4.638	7.440	p = 0.007
Error	184.514	296	0.623		

Group	n	Mean	95% confidence interval for mean
Ebb	142	0.444	0.239 to 0.649
Flood	156	0.154	0.054 to 0.254

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
NINCO
By Tide                   Ebb                    Flood

  Tide        =            1.  Tide        =           2.
  Mean Rank            Number  Mean Rank          Number
    157.54                142    142.18              156

                                      Correct for Ties
      U              W              Z        2-Tailed P
   9934.5        22370.5         2.5676          0.0102
```

Table L-5. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	411.124	297			
Tide	15.679	1	15.679	11.736	p = 0.001
Error	395.445	296	1.336		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.678	0.460 to 0.896
Flood	152	0.257	0.165 to 0.348

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TCM
 By Tide                    Ebb                      Flood

    Tide          =               1.  Tide       =             2.
    Mean Rank               Number    Mean Rank          Number
      159.58                  146       139.82             152

                                         Correct for Ties
      U               W                Z         2-Tailed P
    9625.0         23298.0          2.5848         0.0097
```

Table L-6. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TINCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	136.898	297			
Tide	5.311	1	5.311	11.947	p = 0.001
Error	131.587	296	0.445		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.342	0.150 to 0.384
Flood	152	0.086	0.037 to 0.134

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
TINCM

By Tide                    Ebb                        Flood

   Tide          =               1.   Tide      =             2.
   Mean Rank                 Number   Mean Rank           Number
     159.89                     146     139.52               152

                                            Correct for Ties
        U               W                Z         2-Tailed P
     9579.0          23344.0          3.3445          0.0008
```

Table L-7. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TOUTCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	173.398	297			
Tide	2.449	1	2.449	4.240	p = 0.04
Error	170.949	296	0.578		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.315	0.184 to 0.446
Flood	152	0.158	0.086 to 0.230

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
TOUTCM
By Tide                    Ebb                       Flood

   Tide        =                1.    Tide     =               2.
   Mean Rank               Number     Mean Rank           Number
    154.51                   146        144.68              152

                                         Correct for Ties
      U              W                 Z        2-Tailed P
   10364.0        22559.0            1.5412       0.1233
```

Table L-8. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TNCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	185.120	297			
Tide	6.021	1	6.021	9.951	p = 0.002
Error	179.099	296	0.605		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.411	0.256 to 0.565
Flood	152	0.151	0.083 to 0.220

Mann-Whitney U - Wilcoxon Rank Sum W Test

TNCM

By Tide Ebb Flood

Tide =	1.	Tide =	2.
Mean Rank	Number	Mean Rank	Number
159.11	146	140.27	152

		Correct for Ties	
U	W	Z	2-Tailed P
9692.5	23230.5	2.7911	0.0053

Table L-9. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable NINCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	89.123	297			
Tide	3.802	1	3.802	13.190	p = 0.0003
Error	85.321	296	0.288		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.253	0.126 to 0.381
Flood	152	0.039	0.008 to 0.071

Mann-Whitney U - Wilcoxon Rank Sum W Test

NINCM
By Tide

Ebb		Flood	
Tide = 1. Mean Rank	Number	Tide = 2. Mean Rank	Number
158.62	146	140.74	152

		Correct for Ties	
U	W	Z	2-Tailed P
9765.0	23158.0	3.4833	0.0005

Table L-10. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable TSCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	126.582	297			
Tide	2.268	1	2.268	5.400	p = 0.02
Error	124.314	296	0.420		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.267	0.150 to 0.384
Flood	152	0.105	0.056 to 0.155

Mann-Whitney U - Wilcoxon Rank Sum W Test

```
 TSCM
By Tide                 Ebb                        Flood

    Tide        =             1.    Tide      =              2.
    Mean Rank             Number    Mean Rank            Number
      154.57                146       144.63               152

                                          Correct for Ties
         U                 W             Z         2-Tailed P
      10356.0           22567.0       1.6803          0.0929
```

Table L-11. Analysis of the effect of ebb versus flood tides on catches of juvenile chum salmon.

Variable SOUTCM

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	61.703	297			
Tide	0.962	1	0.962	4.687	p = 0.03
Error	60.741	296	0.205		

Group	n	Mean	95% confidence interval for mean
Ebb	146	0.158	0.074 to 0.241
Flood	152	0.053	0.017 to 0.089

Mann-Whitney U - Wilcoxon Rank Sum W Test

SOUTCM
By Tide

	Ebb		Flood	
	Tide =	1.	Tide =	2.
	Mean Rank	Number	Mean Rank	Number
	153.97	146	145.21	152

		Correct for Ties	
U	W	Z	2-Tailed P
10444.0	22479.0	1.8592	0.0630

Table L-12. Analysis of the effect of ebb versus flood tides on catches of juvenile chinook salmon.

Variable TCK

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Total	286.230	209			
Tide	0.326	1	0.326	0.237	p = 0.63
Error	285.904	208	1.375		

Group	n	Mean	95% confidence interval for mean
Ebb	100	0.510	0.289 to 0.731
Flood	110	0.364	0.178 to 0.550

Mann-Whitney U - Wilcoxon Rank Sum W Test

TCK
By Tide

Ebb		Flood	
Tide =	1.	Tide =	2.
Mean Rank	Number	Mean Rank	Number
108.24	100	103.01	110

		Correct for Ties	
U	W	Z	2-Tailed P
5226.0	10824.0	0.8290	0.4071

APPENDIX M

Tidal orientation effect, 1985

Table M-1. Analysis of the effects of tidal orientation and trap partitioning on catches of juvenile coho salmon.

Variables TNCO, TSCO

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	11.432	1	11.432	14.766	p = 0.0001
Tide-Norsou interaction	2.370	1	2.370	3.061	p = 0.08
Error	229.174	296	0.774		

Group	n	Mean	95% confidence interval for mean
TNCO	298	0.430	0.210 to 0.648
Ebb	142	0.613	0.346 to 0.879
Flood	156	0.263	0.088 to 0.438
TSCO	298	0.141	0.032 to 0.249
Ebb	142	0.162	0.070 to 0.254
Flood	156	0.122	-0.002 to 0.245

Table M-2. Analysis of the effects of tidal orientation and trap particioning on catches of juvenile chum salmon.

Variables TNCM, TSCM

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	1.692	1	1.692	4.739	p = 0.03
Tide-Norsou interaction	0.449	1	0.449	1.258	p = 0.26
Error	105.692	296	0.357		

Group	n	Mean	95% confidence interval for mean
TNCM	298	0.278	0.168 to 0.389
Ebb	146	0.411	0.256 to 0.565
Flood	152	0.151	0.083 to 0.220
TSCM	298	0.184	0.102 to 0.267
Ebb	146	0.267	0.150 to 0.384
Flood	152	0.105	0.056 to 0.155

Table M-3. Analysis of the effects of tidal orientation and trap partitioning on catches of juvenile chinook salmon.

Variables TNCK, TSCK

MANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
Norsou	6.296	1	6.296	10.004	p = 0.002
Tide-Norsou interaction	0.012	1	0.012	0.019	p = 0.89
Error	130.908	208	0.629		

Group	n	Mean	95% confidence interval for mean
TNCK	210	0.372	0.158 to 0.585
Ebb	100	0.370	0.167 to 0.573
Flood	110	0.373	0.150 to 0.596
TSCK	210	0.124	0.037 to 0.191
Ebb	100	0.140	0.051 to 0.229
Flood	110	0.109	0.025 to 0.156

APPENDIX N

Trap location (inner, middle, outer) effect, 1985

Table N-1. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile coho salmon in north trap partitions.

Variable NCO ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	267.218	893			
Location	8.779	2	4.389	15.132	p = 0.000
Error	258.440	891	0.290		

Kruskal-Wallis One-Way ANOVA

NCO
By Locatn

Locatn	1	2	3
Number	298	298	298
Mean Ranks	478.92	420.48	443.09

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
894	7.761	0.021	41.264	0.000

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	298	0.292	7	0.181 to 0.403
Middle	298	0.010	2	-0.005 to 0.025
Outer	298	0.128	8	-0.050 to 0.205

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Outer
Mean	0.010	0.128

Subset 2

Group	Inner
Mean	0.292

Table N-2. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile coho salmon in south trap partitions.

Variable SCO

ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	79.469	893			
Location	2.157	2	1.078	12.427	p = 0.000
Error	77.312	891	0.087		

Kruskal-Wallis One-Way ANOVA

SCO
By Locatn

Locatn	1	2	3
Number	298	298	298
Mean Ranks	465.55	436.99	439.96

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
894	2.203	0.332	28.107	0.000

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	298	0.128	9	0.051 to 0.204
Middle	298	0.003	1	-0.003 to 0.010
Outer	298	0.010	1	-0.001 to 0.021

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Outer
Mean	0.003	0.010

Subset 2

Group	Inner
Mean	0.128

Table N-3. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chum salmon in north trap partitions.

Variable NCM — ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	122.841	893			
Location	3.318	2	1.659	12.366	p = 0.000
Error	119.523	891	0.134		

Kruskal-Wallis One-Way ANOVA

NCM
By Locatn

Locatn	1	2	3
Number	298	298	298
Mean Ranks	460.11	417.98	464.41

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
894	5.884	0.053	30.363	0.000

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	298	0.144	6	0.079 to 0.209
Middle	298	0.003	1	-0.003 to 0.010
Outer	298	0.131	3	0.084 to 0.178

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle
Mean	0.003

Subset 2

Group	Outer	Inner
Mean	0.131	0.144

Table N-4. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chum salmon in south trap partitions.

Variable SCM ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	79.616	893			
Location	1.237	2	0.088	7.032	p = 0.001
Error	78.379	891	0.619		

Kruskal-Wallis One-Way ANOVA

SCM
By Locatn

Locatn	1	2	3
Number	298	298	298
Mean Ranks	449.51	431.45	461.55

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
894	2.052	0.358	14.611	0.001

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	298	0.067	3	0.032 to 0.103
Middle	298	0.013	1	0.000 to 0.027
Outer	298	0.104	3	0.059 to 0.149

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Inner
Mean	0.013	0.067

Subset 2

Group	Inner	Outer
Mean	0.067	0.104

Table N-5. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chinook salmon in north trap partitions.

Variable NCK — ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	141.771	629			
Location	6.867	2	3.433	15.957	p = 0.000
Error	134.905	627	0.215		

Kruskal-Wallis One-Way ANOVA

NCK
By Locatn

Locatn	1	2	3
Number	210	210	210
Mean Ranks	311.48	293.50	341.52

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
630	7.461	0.024	38.232	0.000

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	210	0.100	4	0.034 to 0.166
Middle	210	0	0	0 to 0
Outer	210	0.271	6	0.164 to 0.379

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Inner
Mean	0	0.100

Subset 2

Group	Outer
Mean	0.271

Table N-6. One-way analysis of variance, descriptive statistics, and separation of subgroups for the effect of trap location on catches of juvenile chinook salmon in south trap partitions.

Variable SCK ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	36.927	629			
Location	0.689	2	0.344	5.960	p = 0.003
Error	36.238	627	0.058		

Kruskal-Wallis One-Way ANOVA

SCK
By Locatn

Locatn	1	2	3
Number	210	210	210
Mean Ranks	314.56	305.50	326.44

			Corrected for Ties	
Cases	Chi-Square	Significance	Chi-Square	Significance
630	1.399	0.497	15.164	0.001

Group	n	Mean	Maximum	95% Confidence Interval for Mean
Inner	210	0.043	2	0.007 to 0.079
Middle	210	0	0	0 to 0
Outer	210	0.081	2	0.037 to 0.125

Significant Subsets in Scheffe's Multiple Comparison at 0.05 Level

Subset 1

Group	Middle	Inner
Mean	0	0.043

Subset 2

Group	Inner	Outer
Mean	0.043	0.081

APPENDIX O

Location effect by ships effect, 1985

Table 0-1. A two-way ANOVA for the effects of trap location by ships for juvenile chum salmon.

Variable TCM		ANOVA Summary Table			
Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	244.614	893	0.274		
Main effects	10.873	3	3.624	13.900	p = 0.001
Location	8.221	2	4.111	15.766	p = 0.001
Ships	2.651	1	2.651	10.169	p = 0.001
Interaction	2.203	2	1.101	4.224	p = 0.02
Explained	13.076	5	2.615	10.030	p = 0.001
Residual	231.538	888	0.261		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.211 (298)	0.017 (298)	0.235 (298)

Ships	Absent	Present
	0.551 (234)	0.141 (64)

	Ships	
Location	Absent	Present
Inner	0.261 (234)	0.031 (64)
Middle	0.009 (234)	0.047 (64)
Outer	0.281 (234)	0.062 (64)

APPENDIX P

Location effect by lights effect, 1985

Table P-1. A two-way ANOVA for the effects of trap location by lights for juvenile chum salmon.

Variable TNCO ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	267.218	893	0.299		
Main effects	8.806	3	2.935	10.156	p = 0.001
Location	8.779	2	4.389	15.186	p = 0.001
Lights	0.028	1	0.028	0.097	p = 0.76
Interaction	1.754	2	0.877	3.034	p = 0.05
Explained	10.560	5	2.112	7.308	p = 0.001
Residual	256.658	888	0.289		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.292 (298)	0.010 (298)	0.128 (298)

Lights	Off	On
	0.450 (149)	0.409 (149)

	Lights	
Location	Off	On
Inner	0.376 (149)	0.208 (149)
Middle	0.007 (149)	0.013 (149)
Outer	0.067 (149)	0.188 (149)

APPENDIX Q

Location effect by tide effect, 1985

Table Q-1. A two-way ANOVA for the effects of trap location by tide for juvenile coho salmon.

Variable TCO ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	379.499	893	0.425		
Main effects	22.186	3	7.395	18.564	p = 0.001
Location	19.043	2	9.521	23.901	p = 0.001
Tide	3.143	1	3.143	7.891	p = 0.01
Interaction	3.567	2	1.784	4.477	p = 0.01
Explained	25.753	5	5.151	12.929	p = 0.001
Residual	353.746	888	0.398		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.419 (298)	0.013 (298)	0.138 (298)

Tide	Ebb	Flood
	0.775 (142)	0.385 (156)

	Tide	
Location	Ebb	Flood
Inner	0.592 (142)	0.263 (156)
Middle	0.007 (142)	0.019 (156)
Outer	0.176 (142)	0.103 (156)

Table Q-2. A two-way ANOVA for the effects of trap location by tide for juvenile coho salmon.

Variable TNCO		ANOVA Summary Table			
Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	267.218	893	0.299		
Main effects	10.970	3	3.657	12.781	p = 0.001
Location	8.779	2	4.389	15.342	p = 0.001
Tide	2.192	1	2.192	7.660	p = 0.01
Interaction	2.194	2	1.097	3.834	p = 0.02
Explained	13.164	5	2.633	9.202	p = 0.001
Residual	254.054	888	0.286		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.292 (298)	0.010 (298)	0.128 (298)

Tide	Ebb	Flood
	0.613 (142)	0.263 (156)

	Tide	
Location	Ebb	Flood
Inner	0.444 (142)	0.154 (156)
Middle	0.007 (142)	0.013 (156)
Outer	0.162 (142)	0.096 (156)

Table Q-3. A two-way ANOVA for the effects of trap location by tide for juvenile chum salmon.

Variable TCM		ANOVA Summary Table			
Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	244.614	893	0.274		
Main effects	12.212	3	4.071	15.690	p = 0.001
Location	8.221	2	4.111	15.844	p = 0.001
Tide	3.991	1	3.991	15.382	p = 0.001
Interaction	2.014	2	1.007	3.882	p = 0.02
Explained	14.227	5	2.845	10.967	p = 0.001
Residual	230.387	888	0.259		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.211 (298)	0.017 (298)	0.235 (298)

Tide	Ebb	Flood
	0.678 (146)	0.257 (152)

	Tide	
Location	Ebb	Flood
Inner	0.342 (146)	0.086 (152)
Middle	0.021 (146)	0.013 (152)
Outer	0.315 (146)	0.257 (152)

Table Q-4. A two-way ANOVA for the effects of trap location by tide for juvenile chum salmon.

Variable TNCM ANOVA Summary Table

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance
Total	122.841	893	0.138		
Main effects	4.737	3	1.579	12.032	p = 0.001
Location	3.318	2	1.659	12.641	p = 0.001
Tide	1.419	1	1.419	10.814	p = 0.001
Interaction	1.573	2	0.787	5.994	p = 0.003
Explained	6.310	5	1.262	9.617	p = 0.001
Residual	116.531	888	0.131		

CELL Means (sample sizes in parentheses)

Location	Inner	Middle	Outer
	0.144 (298)	0.003 (298)	0.131 (298)

Tide	Ebb	Flood
	0.411 (146)	0.151 (152)

	Tide	
Location	Ebb	Flood
Inner	0.253 (146)	0.039 (152)
Middle	0 (146)	0.007 (152)
Outer	0.158 (146)	0.105 (152)

APPENDIX R

Predator stomach contents

Table R-1. Results of stomach contents analysis for salmonid predator species captured with trammel nets in waterways at the Port of Tacoma during February-June 1985.

Predator					Prey organism (data from nonempty predator stomachs)							
			Size range				Number		Biomass			
Species	Total No.	# Empty stomachs	Length (mm)	Weight (g)	Scientific name	% Freq. occurrence	Total	Mean	Total	Mean	% Total abundance	% Total biomass
Steelhead trout	2	1	221-730	110-3800	Hemiptera	100.0	1	1.0	0.00	0.00	11.11	0.22
					Wood	100.0	8	8.0	0.30	0.30	88.89	32.86
Cutthroat trout	4	1	235-305	120-260	Copepoda-Notodelphyoida	33.3	1	0.3	0.01	0.00	0.93	0.14
					Gnorimosphaeroma oregonensis	66.7	96	32.0	2.09	0.70	89.72	58.02
					Anisogammarus pugettensis	33.3	1	0.3	0.02	0.01	0.93	0.58
					Eogammarus confervicolus	66.7	6	2.0	0.09	0.03	5.61	2.62
					Decapoda-Brachyura	33.3	1	0.3	0.01	0.00	0.93	0.18
					Gasterosteus aculeatus	33.3	1	0.3	0.27	0.09	0.93	7.42
					Cottidae	33.3	1	0.3	0.71	0.24	0.93	19.70
Dolly Varden trout	1	0	359-359	450-450	Stichaeidae	100.0	1	1.0	2.74	2.74	100.00	99.93
Chinook salmon	1	0	297-297	300-300	*Xenacanthomysis pseudomacropsi*	100.0	4	4.0	0.03	0.03	30.77	0.62
					Neomysis kadiakensis	100.0	8	8.0	0.45	0.45	61.54	9.96
					Teleostei	100.0	1	1.0	4.01	4.01	7.69	89.39
Coho salmon	3	1	236-372	145-1340	*Cyphocaris challengeri*	50.0	973	486.5	1.63	0.81	99.69	8.90
					Teleostei	50.0	1	0.5	0.64	0.32	0.10	3.50
					Clupea harengus pallasi	50.0	2	1.0	16.00	8.00	0.20	87.51

Table R-2. Results of stomach contents analysis for nonsalmonid predator species captured with trammel nets in waterways at the Port of Tacoma during February-June 1985.

Predator					Prey organism (data from nonempty predator stomachs)							
			Size range				Number		Biomass (g)			
Species	Total No.	# Empty stomachs	Length (mm)	Weight (g)	Scientific name	% Freq. occurrence	Total	Mean	Total	Mean	% of Total abundance	% of Total biomass
Pacific cod	2	0	535-602	1410-2200	Nereidae	50.0	1	0.5	0.59	0.29	5.00	0.77
					Heptacarpus brevirostris	50.0	1	0.5	0.72	0.36	5.00	0.95
					Pandalus sp.	50.0	1	0.5	3.18	1.59	5.00	4.17
					Crangonidae	50.0	1	0.5	0.22	0.11	5.00	0.28
					Cancer magister	50.0	3	1.5	38.64	19.32	15.00	50.97
					Hemigrapsus oregonensis	50.0	1	0.5	8.20	4.10	5.00	10.81
					Ascidiacea	50.0	7	3.5	4.81	2.40	35.00	6.34
					Teleostei	50.0	1	0.5	0.35	0.17	5.00	0.46
					Cottidae	50.0	2	1.0	7.11	3.56	10.00	9.38
					Stichaeidea	50.0	1	0.5	0.36	0.18	5.00	0.48
					Lumpenus sagitta	50.0	1	0.5	11.65	5.82	5.00	15.36
Walleye pollock	2	1	260-388	142-360	Pleocyemata-Caridea	100.0	5	5.0	2.54	2.54	100.00	99.76
Pacific hake	1	1	425-425	450-450	--							
Pacific tomcod	2	0	251-266	155-188	Polychaeta	50.0	1	0.5	0.09	0.04	5.56	30.53
					Mysida	50.0	1	0.5	0.00	0.00	5.56	1.12
					Gammaridea	50.0	1	0.5	0.00	0.00	5.56	0.24
					Orchomene sp.	50.0	7	3.5	0.02	0.01	38.89	8.62
					Pleocyemata-Caridea	100.0	4	2.0	0.03	0.02	22.22	10.92
					Cancer sp.	50.0	2	1.0	0.08	0.04	11.11	27.32
					Teleostei	50.0	2	1.0	0.05	0.02	11.11	16.09
Prickly sculpin	1	1	162-162	67-67	--							

Table R-2, cont'd

Predator					Prey organism (data from nonempty predator stomachs)							
			Size Range				Number		Biomass (g)			
Species	Total No.	# Empty stomachs	Length (mm)	Weight (g)	Scientific name	% Freq. occurrence	Total	Mean	Total	Mean	% of Total abundance	% of Total biomass
Staghorn sculpin	13	5	147-222	55-215	Polychaeta	12.5	1	0.1	0.82	0.10	9.09	6.42
					Nereidae	12.5	2	0.3	8.13	1.02	18.18	63.96
					Gammaridea	12.5	1	0.1	0.02	0.00	9.09	0.13
					Eogammarus confervicolus	25.0	2	0.3	0.01	0.00	18.18	0.09
					Decapoda	12.5	1	0.1	0.01	0.00	9.09	0.07
					Pleocyemata-Caridea	12.5	1	0.1	0.07	0.01	9.09	0.51
					Cancer magister	12.5	1	0.1	2.12	0.27	9.09	16.69
					Teleostei	25.0	2	0.3	0.87	0.11	18.18	6.87
Brown rockfish	4	1	257-277	260-430	*Gnorimosphaeroma oregonensis*	33.3	9	3.0	0.38	0.13	56.25	3.72
					Pleocyemata-Caridea	33.3	2	0.7	0.16	0.05	12.50	1.57
					Pandalus danae	33.3	3	1.0	4.10	1.37	18.75	40.15
					Decapoda-Brachyura	33.3	1	0.3	0.28	0.09	6.25	2.72
					Leptocottus armatus	33.3	1	0.3	5.09	1.70	6.25	49.86