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April 1980

THE EFFECTS OF CONSTRUCTION OF NAVAL FACILITIES ON THE OUTMIGRATION OF JUVENILE SALMONIDS FROM HOOD CANAL, WASHINGTON

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Thomas E. Prinslow
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FINAL REPORT
March 1, 1975 through July 31, 1979
Contract Nos. N68248-76-C-0006
and N68248-77-0005
to
United States Navy
OICC Trident

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FISHERIES RESEARCH INSTITUTE
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Seattle, Washington 98195

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Submitted April 24, 1980

Roy E. Nakatani

Roy E. Nakatani
Acting for the Director

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NAVY 5-YEAR REPORT

ABSTRACT

The U.S. Navy expanded its facilities on Hood Canal, Washington, to serve as the support base for the Trident submarine. Shoreline construction consisted of building a drydock and five offshore piers with access trestles to each pier. As pier construction work was continuous and included the season of outmigration of juvenile salmonids (January through July), a program was established by the Navy with the University of Washington Fisheries Research Institute to monitor the effects of the shoreline construction activities for five seasons of salmon outmigration (1975-1979). The program was divided into four studies: 1) the Outmigration Study which included the effects of piers on the migration and feeding behavior of young salmon; 2) the Lighting Study which included the effects of security lighting systems at the piers on the behavior of salmonids and other fishes; 3) the Dredging Study which included the effects of suspended sediments caused by the dredging of 171,000 cu m of bottom sediments (recent alluvium and glacial till) on juvenile salmonids; and 4) the Food Habits study which investigated the feeding habits of young salmon in the areas of concern as well as in control areas.

The Outmigration Study examined five seasons of outmigration using beach seines and townet surveys to measure abundance and migration pathways of the juvenile salmonids. Chum salmon, Oncorhynchus keta, the prevalent salmonid species - and one of the more sensitive to environmental changes in nearshore environs - varied in abundance from year to year. The variations among the years were not related to the numbers released annually from the hatcheries, although within any year the variation in abundance was closely related to hatchery releases. This suggests large but differing early marine mortality rates from year to year. The migration routes were defined and comparisons were made of the numbers migrating along the west shore and those migrating along the east shore, the site of the support base. There is an indication that the juvenile chum move offshore around the wharves as they migrate north out of the Canal. The effects of this diversion are not known, although from 1976 to 1979 there was a decrease in the relative number of migrants on the east shore migrating past an index area north of the base. This trend was not found with catches south of the base (on the east shore) nor with catches on the west shore. Also, in 1977 and 1978, there was a decrease in abundance in an index area adjacent to the construction site of the Delta Pier. This decrease appears to be temporary as the catch increased in 1979. Although the evidence is circumstantial, these changes in migratory behavior and reduction in catch appear to be related to the construction and operation of the piers. Without a more extensive data base with which to quantify increases in natural mortality rates due to natural environmental

fluctuations, we still remain uncertain as to the significance of these perturbations.

The Dredging Study showed that concentrations of suspended sediments experienced by migrating salmonids at the Delta Pier site (<100 mg/liter) did not approach lethal levels nor was any overt stress indicated. Instances of avoidance of suspended glacial till material at low concentrations (2-10 mg/liter above ambient) were noted in the field, while in the laboratory, avoidance was not shown until a concentration of 182 mg/liter was reached.

The Lighting Study showed that the operational mode of lighting (20-40 ft-c at water surface) at the Explosives Handling Wharf (EHW) may attract outmigrating salmonids, while the security lighting mode (0.2 - 1.2 ft-c at water surface) may be an attractive stimulus only within a localized (5-10 m) zone of the wharf. The effect appears to be temporary (<24 hr). The operational mode may serve as an initial stimulus which, when combined with the abundance of food near the EHW, may cause a 1-2 day delay in the outmigration of chum. The security mode did not appear to cause any delay in the outmigration. Any attraction to the EHW does not appear to harm the outmigrating salmon, as <4% of the predators caught during the study of security mode lighting contained salmonid remains. We suggest that pier lighting be kept at levels equivalent to the security mode as much as possible.

The Food Habits study showed that abundance of epibenthic organisms preferred by chum and pink salmon, principally the harpacticoid copepods, showed a decline in spring coincidental with the peak densities of chum salmon fry. Chum fry appear to select the larger available organisms when feeding both in nearshore and offshore waters. The long-term effects of construction and operation of the shore facilities upon the prey (fish food) communities are expected to be minimal as long as extensive areas of littoral eelgrass habitat are not destroyed.

ACKNOWLEDGMENTS

The individuals contributing to the design, execution, and completion of the projects comprising this study are acknowledged in the annual reports of Salmonid Outmigration, Trident Dredge Study, and Trident Wharf Lighting Studies. The citations are given in this report.

We wish to extend special thanks to LCDR David A. Rein, LCDR A. L. Wynn, Mr. Leo Vasaitis, Mr. Donald Morris, and James Reeves, OICC Trident Environmental Office, who contributed greatly to the planning and completion of all the projects comprising this study.

The U.S. Navy staff at Marginal Wharf and Explosives Handling Wharf deserves credit for its cooperation and support.

Dr. Richard Cardwell and Ms. Scharleen Olsen, Washington State Department of Fisheries, contributed valuable guidance and support, and deserve credit as significant contributors to the studies constituting the dredge monitoring program.

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1.0 INTRODUCTION

by

Thomas E. Prinslow and Nicholas J. Bax

The U.S. Navy has expanded the Bangor Annex, U.S. Naval Torpedo Station on Hood Canal, Washington (Fig. 1-1) as the West coast base for servicing their new Trident submarine fleet. Since 1975, expansion of the Bangor shoreline facilities (Fig. 1-2) has involved dredging for and construction of a drydock-refit pier (the Delta pier), and construction of a service pier, a wharf to load and unload missiles (known as the Explosives Handling Wharf, or EHW), and a wharf to de-magnetize vessels (Table 1-1) (Plates I and II). Prior to 1975 the Marginal wharf and the Small Craft wharf (Fig. 1-2) were present.

As a result of the extensive shoreline wharf construction proposed for completion in the 1980s, biological baseline data were collected in five three-week environmental surveys from June 1973 to July 1975 by the Marine Environment Management Office of the Naval Undersea Center for use in the Environmental Impact Statement for the Trident Facility. The initial Naval Undersea Center surveys were designed to quantify the abundance and distribution of commercially and recreationally important species of marine molluscs and fishes present along the Bangor Annex shoreline. These initial surveys indicated the Bangor shorelines to be diverse in flora and fauna and in excellent environmental condition (Peeling and Goforth 1975). Subsequent, yearly seasonal surveys were conducted by the Naval Undersea Center from 1976 through 1979 monitoring various marine mollusc indicators for determining environmental changes and stress.

Bangor is along the migration route of four species of Pacific salmon[1] and two species of anadromous trout.[2] Naturally produced (wild) and hatchery-produced stocks of all six species are present in Hood Canal. Chum salmon--currently the focus of a massive enhancement program by the Washington State Department of Fisheries (WDF)--is the most abundant salmonid in Hood Canal, accounting for 25% of the State's total chum return (Morrill, in Simenstad and Kinney 1978). Several investigators have concluded that the conditions during early marine life are exceedingly important to overall salmonid growth and survival (*see* Sec. 3.0 for review). The potential impact of the Navy's construction activites and the future operation of the facilities on outmigrating juvenile chum salmon was of concern to the State. Consequently, the Fisheries Research Institute (FRI) of the University of Washington was contracted by the Navy to monitor any impact on salmonid

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[1] Chum (*Oncorhynchus keta*), pink (*O. gorbuscha*), coho (*O. kisutch*), chinook (*O. tschawytcha*).

[2] Steelhead (*Salmo gairdnerii*), cutthroat (*Salmo clarki clarki*).

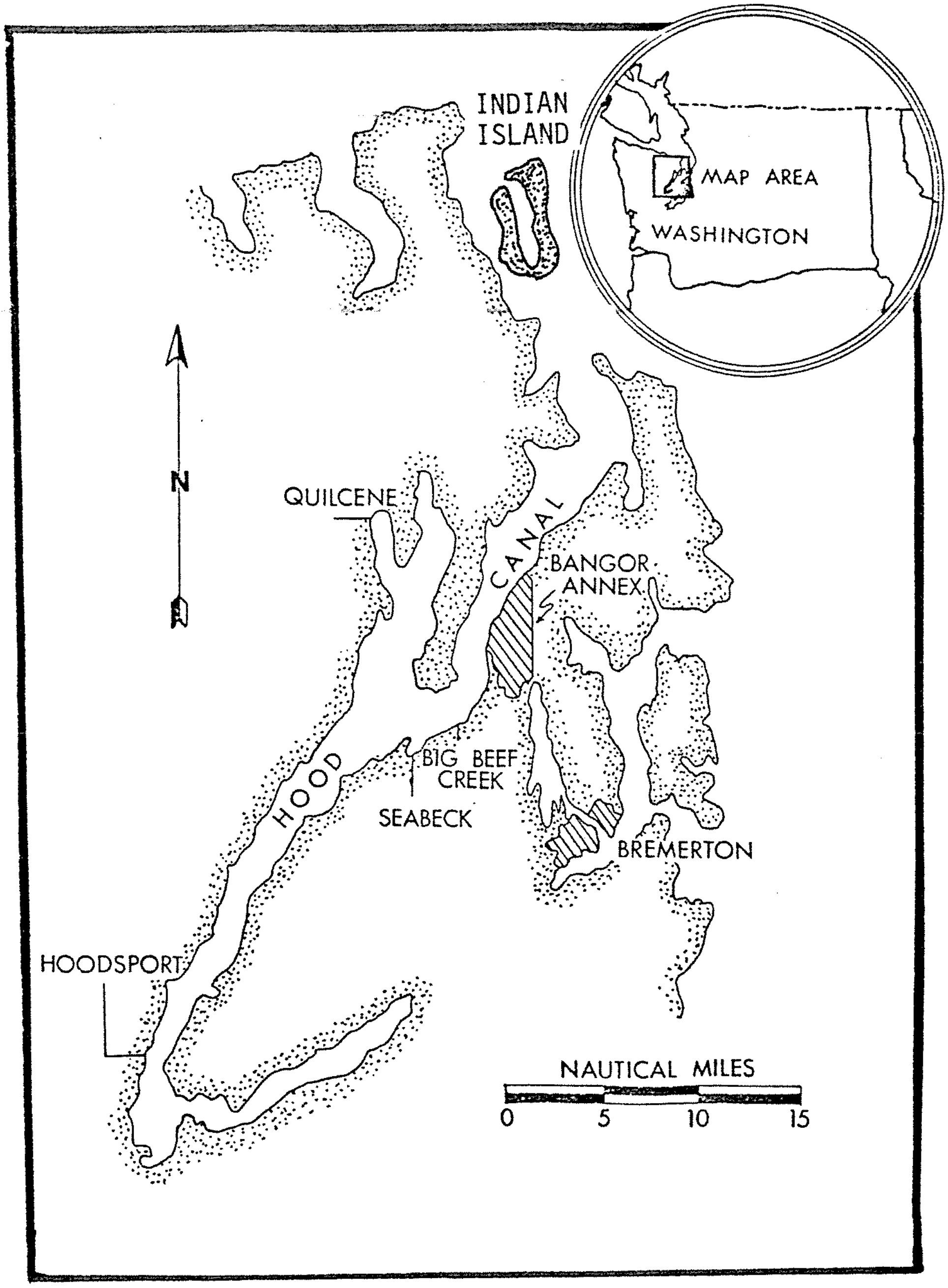

Fig. 1-1. Location of Bangor Annex, Indian Island Annex, and fish hatcheries at Big Beef Creek, Quilcene and Hoodsport.

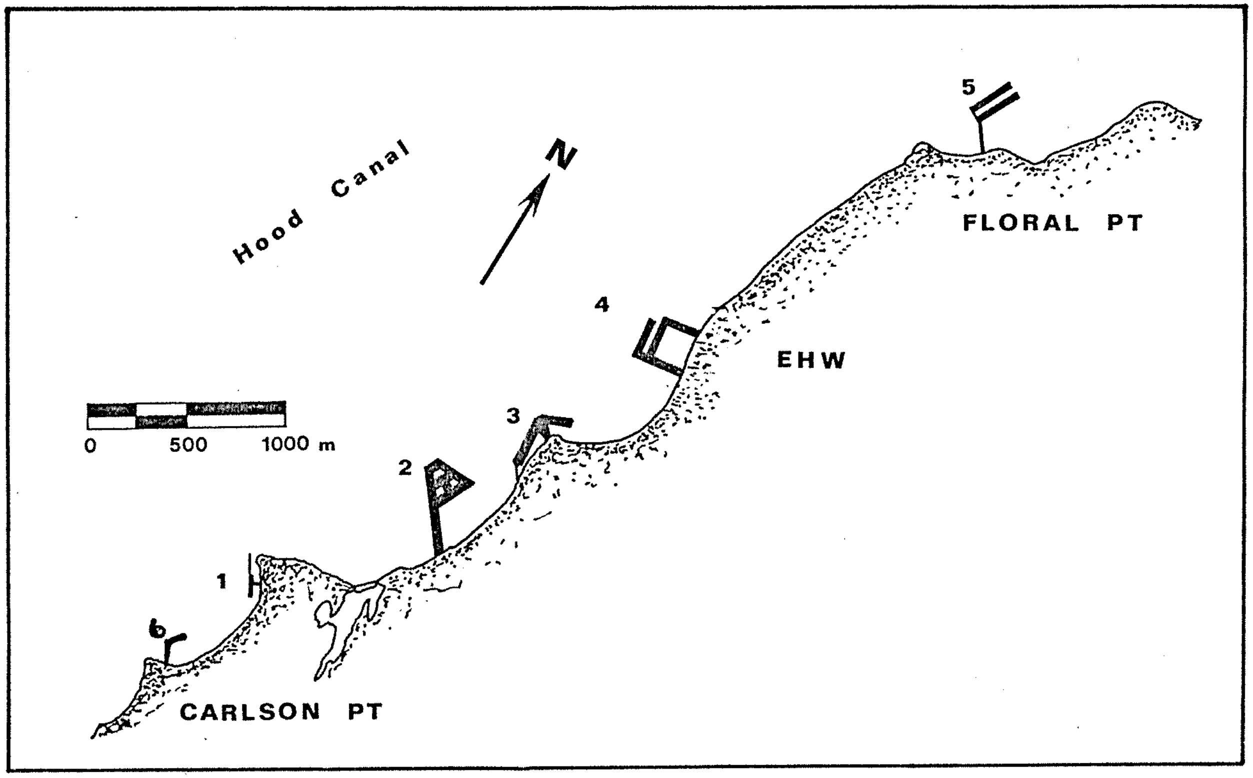

Fig. 1-2. Shoreline of Bangor Annex showing location of the Small Craft Wharf (1), Refit Pier (2), Marginal Wharf (3), Explosives Handling Wharf (4), and Magnetic Silencing Facility (Deperming Wharf) (5). The Service Pier is under construction in 1980 at Carlson Point (6).

Table 1-1. Chronological summary of construction activities at the Bangor shoreline, 1975-1979 (*see* Fig. 1-2 for locations).

Year	Location[a]	Construction Activity
1975	EHW	Initiated construction, including test pile driving in June.
1976	Delta Pier	Began preliminary pile driving, drilling of test wells.
	EHW	Drove pilings and completed wharf area of submarine berth.
1977	Delta Pier	Completed pile driving and trestles. Dredged entrance channel and drydock area. Pumped test wells periodically. Began coffer dam.
	EHW	Completed pile driving and enclosure of submarine berth. Some lighting operational in May.
	MSF	Began pile driving.
1978	Delta Pier	Completed coffer dam and filling operations. Pumped out drydock area and finished dredging within drydock.
	EHW	Completed lighting installation and began operational testing.
	MSF	Drove pilings, installed deck and some lights in June.
1979	Delta Pier	Constructed floor of drydock.
	MSF	Completed electrical work and began operational testing.
	Service Pier	Began pile driving in June.

[a] EHW: Explosives Handling Wharf
MSF: Magnetic Silencing Facility

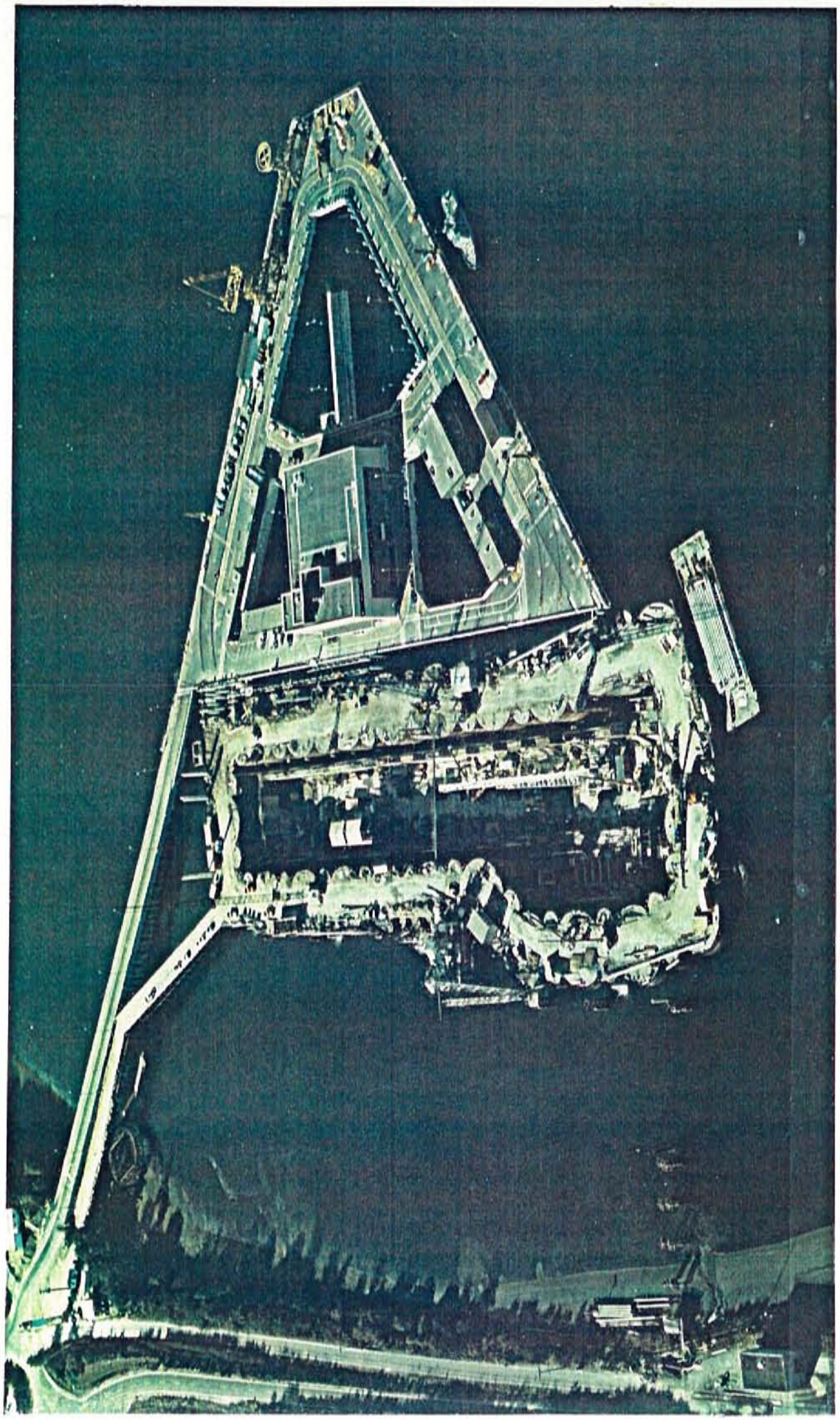

Plate I. Delta Pier: Two Refit Piers and a drydock, U.S. Naval Submarine Base-Bangor, Hood Canal, Washington.

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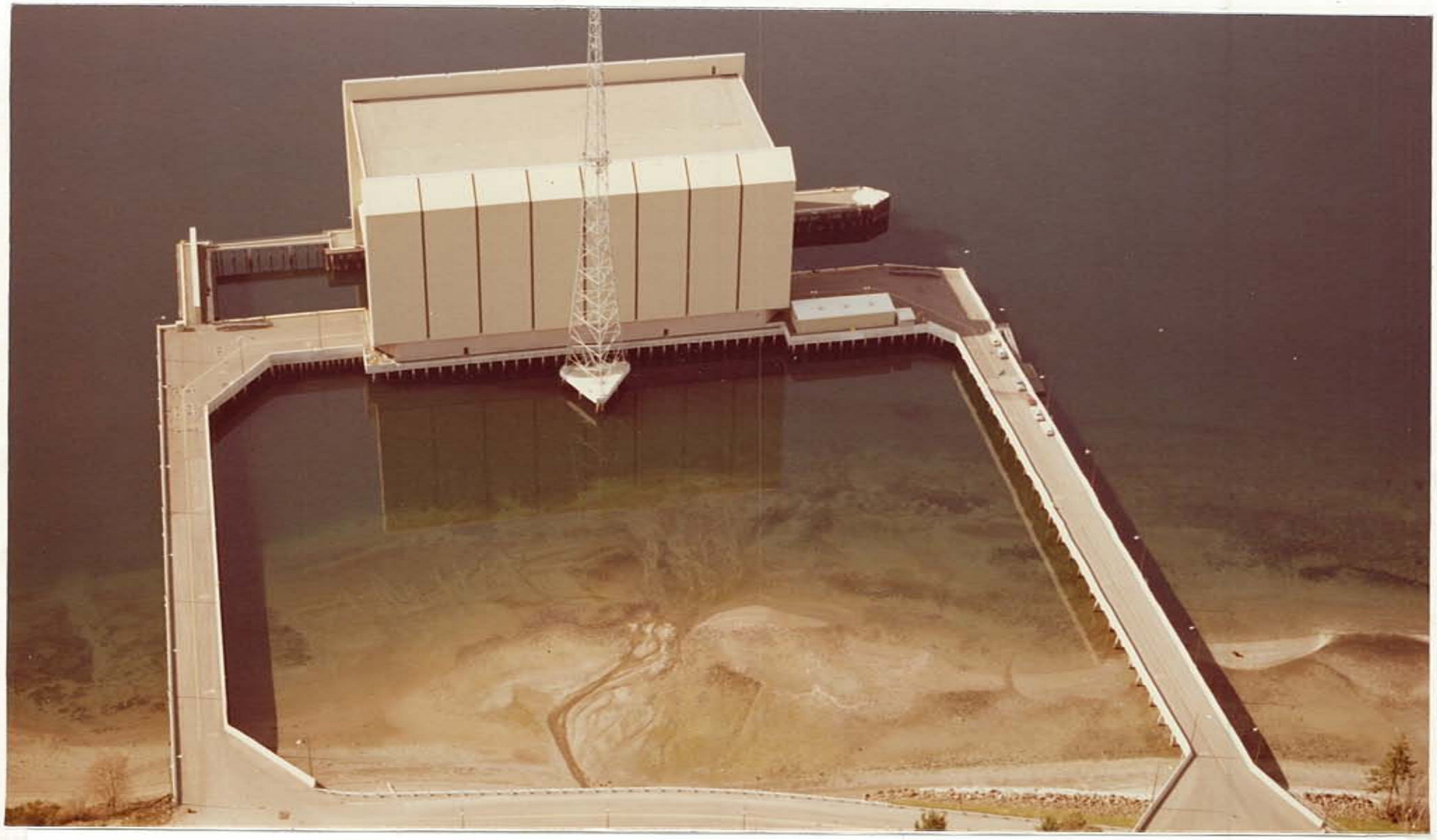

Plate II. Explosives Handling Wharf (EHW), U.S. Naval Submarine Base-Bangor, Hood Canal, Washington.

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outmigrations. This report summarizes the results of the 5 yr (1975-1979) monitoring program. Annual reports for each phase are listed in Table 1-2.

1.1 PROJECT OBJECTIVES

The monitoring program was divided into four principal studies comprising 15 projects (Table 1-3). (1) The Outmigration Study was conducted during each of the five years and provided baseline information on the distribution and abundance of juvenile salmonids as they passed Bangor. Mark-recapture experiments with hatchery-reared chum conducted in 1977, 1978, and 1979 as part of the Outmigration and Lighting studies (*see* below) provided estimates of early marine mortality, patterns and rates of migration, and effects of shoreline facilities on the migrations. (2) The Dredging Study was designed to measure any impact on chum of sediments suspended by dredging for the Refit Pier, and comprised three projects: a literature review in 1975; preliminary static bioassays in 1976; and a comprehensive monitoring program involving *in situ* laboratory and field bioassays in 1977. (3) The Lighting Study was designed to measure any impact of lighting at the EHW on chum and their potential prey (plankton) and predators.[3] The study was comprised of four projects: a literature review and preliminary field test in 1976, additional field tests in 1978, and a comprehensive monitoring program in 1979. (4) The Food Habits Study was designed to document predator-prey interactions between outmigrating chum and pink salmon and their epibenthic and neritic planktonic prey. This study was comprised of three projects--one in 1977, 1978, and 1979--which analyzed stomach contents of the juvenile salmon and examined epibenthic and neritic prey at selected sites in the Bangor area.[4]

As an adjunct to the Outmigration Study, the Indian Island study in 1977 monitored the outmigration of juvenile salmonids past the U.S. Navy's Indian Island Annex, Port Townsend, Washington (Fig. 1-1), to provide baseline information for any future assessment of impact of pier construction.

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[3] Coho and chinook salmon, cutthroat trout, sculpins (*Leptocottus armatus*), hake (*Merluccius productus*), Pacific cod (*Gadus macrocephalus*), and dogfish (Squalus acanthias).

[4] Support for laboratory processing, data analysis, and interpretation was provided by Washington Department of Fisheries.

Table 1-2. List of Annual Reports of FRI-Navy salmonid monitoring projects in Hood Canal, 1975-1979.

1975 Projects

Mortensen, D. J., B. P. Snyder, and E. O. Salo. 1976 An analysis of the literature on the effects of dredging on juvenile salmonids. Special report to the Dep. Navy. Univ. Washington, Fish. Res. Inst., FRI-UW-7605. 37 pp.

Schreiner, J. U., A. Didier, E. O. Salo, and B. P. Snyder. 1975. Salmonid outmigration studies in Hood Canal. Univ. Washington, Fish. Res. Inst., Prog. Rep. 26 pp.

1976 Projects

Martin, D. J., E. O. Salo, and B. P. Snyder. 1977. Field bioassay studies on the tolerances of juvenile salmonids to various levels of suspended solids. Final Report, March 1976 to August 1976, U.S. Dep. Navy. Univ. Washington, Fish. Res. Inst., FRI-UW-7713. 35 pp.

Salo, M. E. 1976. Annotated bibliography on the effects of light on salmonids with reference to Bangor Annex area. 89 pp.

Salo, M. E., E. O. Salo, and B. P. Snyder. 1977. A preliminary study of the effects of pier lighting on fishes. Final Report, July 1976 to September 1976 to the U.S. Navy. Univ Washington, Fish. Res. Inst., FRI-UW-7712. 17 pp.

Schreiner, J. U., E. O. Salo, B. P. Snyder, and C. A. Simenstad. 1977. Salmonid outmigration studies in Hood Canal. Final Report, Phase II. Univ. Washington, Fish. Res. Inst., FRI-UW-7715. 64 pp.

1977 Projects

Bax, N. J., E. O. Salo, B. P. Snyder, C. A. Simenstad, and W. J. Kinney. 1978. Salmonid outmigration studies in Hood Canal. Final Report, Phase III. Univ. Washington, Fish. Res. Inst., FRI-UW-7819. 128 pp.

Moore, D. D., B. P. Snyder, and E. O. Salo. 1977. Indian Island salmonid outmigration monitoring study. Univ. Washington, Fish. Res. Inst., FRI-UW-7734. 37 pp.

Table 1-2. List of Annual Reports of FRI-Navy salmonid monitoring projects in Hood Canal, 1975-1979 - continued.

Salo, E. O., T. E. Prinslow, R. A. Campbell, D. W. Smith and B. P. Snyder. 1979. Trident dredging study: The effects of dredging at the U.S. Naval Submarine Base at Bangor on outmigrating juvenile chum salmon, *Oncorhynchus keta*, in Hood Canal, Washington. Univ. Washington, Fish. Res. Inst., FRI-UW-7918. 206 pp.

Simenstad, C. A., and W. J. Kinney. 1978. Trophic relationships of outmigrating chum salmon in Hood Canal, Washington 1977. Univ. Washington, Fish. Res. Inst., FRI-UW-7810. 75 pp.*

1978 Projects

Bax, N. J., E. O. Salo, and B. P. Snyder. 1979. Salmonid outmigration studies in Hood Canal. Final Report, Phase IV. Univ. Washington, Fish. Res. Inst., FRI-UW-7921. 89 pp.

Prinslow, T. E., E. O. Salo, and B. P. Snyder. 1979. Studies of behavioral effects of a lighted and an unlighted wharf on outmigrating salmonids--March-April 1978. Univ. Washington, Fish. Res. Inst., FRI-UW-7920. 35 pp.

1979 Projects

Bax, N. J., E. O. Salo, and B. P. Snyder. 1980. (in press). Salmonid outmigration studies in Hood Canal. Final Report, Phase V. Univ. Washington, Fish. Res. Inst.

Prinslow, T. E., C. J. Whitmus, J. J. Dawson, N. J. Bax, B. P Snyder, and E. O. Salo. 1980. (in press). Studies of the effects of wharf lighting on outmigrating salmonids 1979. Univ. Washington, Fish. Res. Inst.

Simenstad, C. A., W. J. Kinney, J. R. Cordell, and H. Buechner. 1980. (in prep.) Prey community structure and trophic interactions of juvenile chum and pink salmon in Hood Canal, Washington: A summary of three years' studies. Final Report to Washington Department Fisheries. Univ. Washington, Fish. Res. Inst.*

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*Principal funding provided by Washington State Department of Fisheries.

Table 1-3. A chronological list of FRI-Navy salmonid monitoring projects in Hood Canal, 1975-1979. The four studies: 1) Outmigration; 2) Dredging; 3) Lighting; and 4) Food Habits were divided into the annual projects

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1975

Outmigration, phase I - 3-month beach seining study
Dredging - literature review

1976

Outmigration, phase II - 5-month study
Dredging - preliminary static bioassays - 3.5 months
Lighting - literature review
Lighting - preliminary field tests - 0.5-month study

1977

Outmigration, phase III - 7-month study
Dredging - comprehensive monitoring program - 6 months
Food habits, phase I
Indian Island

1978

Outmigration, phase IV - 6-month study
Lighting - March and April field tests
Food habits, phase II

1979

Outmigration, phase V - 6.5-month study
Lighting - comprehensive monitoring program - 5 months
Food habits, phase III

1.2 PREVIOUS REPORTS

The results of each of the above projects were issued as annual reports;[5] Table 1-2 lists the authors, titles, and FRI publication numbers. In this report these publications are referred to as "Annual Reports".

1.3 SUMMARY REPORT FORMAT

An Abstract precedes the general text of the report and the conclusions based on the 5-year program are presented in Sec. 2.0. Summaries of the Outmigration, Dredging, Lighting, Food Habits, and Indian Island studies appear in Secs. 3.0, 4.0, 5.0, 6.0, and 7.0, respectively. Recommendations for future management of the Bangor areas in terms of the salmonid resources (Sec. 8.0) conclude this report.

A review of pertinent literature appears in each annual report.

1.4 REFERENCES CITED

Peeling, T. J., and H. W. Goforth. 1975. Trident biological surveys: a summary report, June 1973-July 1975. Marine Environmental Office, Chemistry and Environmental Sciences Division, Naval Underseas Center, San Diego, Calif. 84 pp.

Simenstad, C. A., and W. J. Kinney. 1978. Trophic relationships of outmigrating chum salmon in Hood Canal, Washington, 1977. Univ. Washington, Fish. Res. Inst. Final Rep. FRI-UW-7810. 75 pp.

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[5] The 1979 outmigration and lighting reports will be issued in May 1980.

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2.0 CONCLUSIONS

2.1 SALMON OUTMIGRATION

2.1.1 Abundance of Juvenile Salmonids, 1975-1979

Chum salmon juveniles were the most abundant salmonid in the Bangor area during 1975-1979. Pink salmon were the second most abundant in 1976 and 1978 (in Hood Canal pink salmon spawn only in odd years; the juveniles outmigrate the following Spring). The chums and pinks were principally of hatchery origin.

Based on beach seine catch-per-unit-effort (CPUE), chum were most abundant in 1975 (a "good" year) and least abundant in 1976; 1977-1979 were "moderate" years.

Beach seine CPUE data for chum north of the major base facilities decreased relative to east shore mean from 1976 to 1978. This decrease did not appear to be caused by increased offshore movement or crossing to the west shore.

2.1.2 Migration Dynamics

Although the majority of juvenile salmon in Hood Canal originate from hatcheries and rivers located on the west shore, many cross the Canal early in their migration, as CPUEs on the east shore at Bangor were equal to or greater than those on the west shore. Also, marked chum released at Hoodsport in 1977 crossed the Canal (from west to east) within the first day.

By the time the juveniles reach Bangor they are found mainly within 125 m of the shore.

Based on mark-recapture experiments, migration rates decreased as the season progressed, perhaps indicative of increased availability of food and optimum temperatures. In February and March of 1977 and 1979 migration rates averaged 9-14 km/day, but only 4-5 km/day in June.

2.1.3 Size Distribution

The mean size (fork length) of chum fry caught 75 m from shore by townet was consistently greater than those caught near shore (<30 m) by beach seine. The mean size of chum caught by townet did not increase again until more than 300 m off shore.

There was no evidence of a distinct size range at which chum fry moved into the offshore zone, as reported for other areas (as discussed in Bax, Salo, and Snyder 1979). The mean size of nearshore and offshore chum increased equivalently during the outmigration season.

2.1.4 Early Marine Mortality

Generally, within any given year the CPUE of chum at Bangor reflected the timing and quantity of hatchery releases; however, the proportion caught relative to the number released varied among years suggesting that factors such as predation, disease, and food availability significantly affected outmigrating chum within the first 1-3 weeks (time for Hood Canal hatchery fry to reach Bangor) of marine residence. Based on a mark-recapture experiment in February 1978, estimated survival of hatchery-reared chum during the first two days of marine residence was 0.29 ± 0.21 (95% confidence limit). Another experiment (February 1979) gave more variable results: 0.44 ± 0.59.

2.1.5 Food Habits

Harpacticoid copepods and gammarid amphipods of shallow sublittoral habitats were the preferred prey of epibenthic-feeding salmon fry. Dense eelgrass beds, such as at Devil's Hole, had the highest standing stock of these prey.

Chum and pink fry larger than 45 mm (especially hatchery-produced fed fry) foraged principally in the neritic zone, apparently in a crepuscular pattern upon diel-migrating plankters (e.g., *Calanus* sp.). Daylight feeding was limited to the few *large* plankters (e.g., *Epilabidocera* and *Oikopleura*) characterizing the neuston community.

2.2 IMPACT MONITORING

Chum are the most abundant juvenile salmonid outmigrants in Hood Canal and the principal "target species" of the monitoring. Three potential sources of impact were investigated: wharves (the physical structures), wharf lighting (a stimulus), and dredging for wharf construction.

2.2.1 Effect of Wharves[1]

2.2.1.1 Effect of Wharves on Chum

Both CPUE and length-frequency distribution data from 1979 indicated that some of the nearshore-traveling chum moved offshore to pass around the wharves. While this could be interpreted as avoidance, at the EHW in 1978 chum were attracted to the outlying submarine berth during the day. It has not been determined whether this was a function of the offshore movement of nearshore chum as detected in 1979, or the offshore chum seeking shelter or negatively phototrophic planktonic prey in the shaded area below the berth enclosure (Plate II). Beach seine CPUE data suggests avoidance of the nearshore area at the Refit Pier during the years of major construction (1977 and 1978).

2.2.1.2 Effect of Wharves on Chum Prey

Impact of construction of existing waterfront facilities (exclusive of any lighting effects) on food organisms of outmigrating chum, was not investigated.

Highly productive eelgrass beds at Devil's Hole and south of EHW could be seriously disrupted by any future construction at these sites, possibly lowering the area's carrying capacity for outmigrants.

2.2.1.3 Effects of Wharves on Chum Predators

Juvenile salmon comprised <4% of the diet of cutthroat trout, staghorn sculpin and Pacific cod captured in the Bangor area in 1977 and 1979. Few of these predators were present in the area, as total catch was <10 during 1979. The majority of piscivorous fish (total catch 500 in 1979) did not contain salmonid remains.

Sampling for piscivorous fish focused on the EHW (1979 Lighting Study); whether "mature" wharves such as Marginal Wharf, which has been in existence for about 25 yr, attract and harbor predators is unclear. While there was no significant difference in purse seine catch of piscivorous predators at EHW and in areas 300 m north of EHW ("non-wharf"), anglers at Marginal Wharf and recently (1978-1979) at EHW catch pile perch (*Rhacochilus vacca*), cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), dogfish, hake, and at EHW, resident (blackmouth) chinook salmon, suggesting that these species are abundant at the wharves.

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[1] Effects of lighting and dredging are reported separately, Sections 2.2.2 and 2.2.3 below.

2.2.2 Effect of Wharf Lighting

Wharf lighting at the EHW has two modes:

- security, for routine inspection below the wharf, and the more intense.
- operational, whenever submarines are present.

EHW security light intensities = 2-13 lux (11 lux - 1 ft-c) at water surface; operational = 2-66 lux (at surface) below wharf trestles and 336-420 lux (at surface) in the submarine berth.

2.2.2.1 Effect of Lighting on Chum

Response of outmigrating chum to lights at EHW was evaluated by net sampling, hydroacoustic monitoring and visual observations in areas adjacent to the wharf trestles; areas directly below the wharf trestles were only accessible to visual observations.

Security lighting (2-13 lux) did not affect chum catch, although we did observe chum congregating below the lights. Increased chum catch in the nearshore areas at EHW in 1978, which was interpreted as attraction, appears, in view of intensive tests in 1979, to have been caused by some other stimulus, which we speculate was the presence of chum prey organisms characterizing this area (see Sec. 6.0). Perhaps chum near the security lights were drawn to them, but no large-scale aggregation of chum in the EHW area resulting from security lighting was detected.

Significantly greater light intensities (200-400 lux) of "partially" and "fully operational" conditions appeared to attract and delay chum but few tests were run under these conditions.

2.2.2.2 Effect of Lighting on Chum Prey

Wharf lighting will probably alter the composition and standing stock of prey communities for chum because the preferred prey are negatively phototropic. Whether sufficient resources of "appropriate" alternative food organisms exist or whether wharf lighting would affect such resources is unknown. Lighting may provide increased feeding opportunities at night.

2.2.2.3 Effect of Lighting on Predators

We found no evidence of significant predation on chum. Predators which did feed on chum were not measurably affected by wharf security lighting.

Dogfish were attracted to security lighting and are important predators on herring. On the other hand, hake also prey heavily on herring but were not attracted to security lights.

During 1978 tests of EHW lights at about one-half operational intensities, we were not equipped to sample quantitatively for predators, but did conduct visual surveys. We observed 39 predators when lights were on compared with 2 when lights were off. This suggests that increased light intensity might affect predators in the wharf area, but to what degree is unknown.

2.2.3 Effects of Dredging

Dredging did not lethally affect nor increase the incidence of disease of juvenile chum salmon in on-site bioassays, but at times it induced avoidance of the area by outmigrants.

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3.0 SALMONID OUTMIGRATION STUDIES

by

Nicholas J. Bax and Clifford J. Whitmus

3.1 INTRODUCTION

Extreme fluctuations in abundance have characterized chum salmon populations, and it is thought that marine survival, especially in the first few weeks of marine residence may be a major cause of these fluctuations (Bakkala 1970). The causes of this mortality are not well documented, but it is known that predation and environmental factors are of importance (Wickett 1958, Birman 1959). More evidence on the early marine mortality of the pink salmon than of the chum is documented, although some restraint must be used in extrapolating these data (Andrievskaya in Bakkala 1970, Gallagher, personal communication).[1] By assuming that chum and pink salmon suffered the same mortality rates and comparing adult returns of these two species to Hooknose Creek, British Columbia, Parker (1962) estimated survival in the coastal juvenile stage as 5.4%, compared with 56.6% in the pelagic stage and 93.0% in the coastal adult stage. Further experiments by Parker (1968) on Bella Coola pink salmon where the smolts were marked at two points along their marine migration route and the percentage returns of marked adults compared, led Parker to the conclusion: "It is now possible to state that during the initial period of sea life *average* daily relative loss to the population was about 2-4% and during the following 410- day period *average* daily loss was about 0.4 to 0.8%." Parker cautions that these results are subject to some difficulties in interpretation due to the possibility of different exploitation exploitation (from fishing) of the two marked groups. Parker felt that the mortalities could be due to predation by coho smolts on the pinks. Other studies by Blackbourn (1976) on Fraser River pinks have implicated environmental variables including river discharge, solar radiation, and the timing and initial size of pinks, as well as the CPUE of adult coho in the area. In fact, Blackbourn explained more than 90% of the variance in the survival of the pinks using groups of three of these factors. Gilhousen (1962), trying to explain Vernon's earlier work (Vernon 1958), where temperature was found to be the most important factor in explaining variations in survival of Fraser River pinks, suggested that higher temperatures led to the earlier offshore movement of the pinks and so increased the chances of predation. Gilhousen goes on to say that "conditions in the marine environment have been so variable that variation in fry abundance have had a secondary effect on total survival."

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[1] Gallagher, A. F., College of Fisheries, University of Washington, Seattle.

It is this extreme variability in marine survival of the economically important chum populations and the possible effects of construction and/or operational activities of the U.S. Naval Submarine Base that prompted this study. Earlier work by Heiser and Finn (1970) had shown buildups of migratory pink and chum fry at bulkheaded areas in Puget Sound. These fry later moved offshore, leading to an "observed increase in predation by coho salmon smolts and cutthroat trout," although no experiments were conducted to confirm this. Other authors have suggested that the movement away from the protective structures (vegetational or man-made) of the nearshore environment leads to an increased level of predation in salmon (Gilhousen 1962) and other species (Major 1977, Cooper and Crowder 1979, Hobson 1979). A factor studied closely in 1979 and described in Section 5.0 of this report was the effect of the pier lighting on the migrating chum. It has been shown by Hoar et al. (1957) that lights attract chum salmon fry while in freshwater,[2] and it is probable that this photopositivity continues in the marine environment (Gosho 1976; Salo 1976; Salo, M., Salo, and Snyder 1977; Prinslow, Salo, and Snyder 1979). Other studies by Bakshtanskii (1970) on the effects of the 24 hr illumination of the Arctic day on the predation on pink and red salmon have shown that the predators (salmon, trout, and salmon juveniles in the river, cod and herring juveniles in the sea) do not lose contact with the schooling fry and are able to completely annihilate them. If the chum fry are forced offshore around the piers and away from the (structural protection) of the nearshore environment or are attracted to the pier lighting, it is possible that the predation upon them might be increased, due either to the decrease in structural protection or to an increase in numbers of predators attracted to the piers or pier lighting.

The outmigration study and the lighting study were concerned principally with the chum salmon smolts routinely passing through the Bangor Annex. In addition, chum smolts from Big Beef Creek hatchery were marked with fluorescent pigment and released from Big Beef Creek and at the Bangor Annex area, to estimate their immediate marine mortality, migration patterns, and reaction to the lighted piers. The data from both of these sources are discussed here.

3.1.1 Objectives of the Outmigration Study

Objectives of the outmigration study were:

1. To collect baseline data on juvenile salmon migrating past the Bangor Annex, and to determine for each species their

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[2] This finding is contradictory to observations in migrating chum fry at Minter Creek, Washington (Ellis, C.H., personal communication and Salo, E. O., personal communication).

relative abundance, their origins (i.e., hatchery or stream), the timing of their migration and their distribution.

2. To investigate the effects of the construction of additional wharves and the effect of those already constructed on the distribution of salmonids in the Bangor Annex area. In 1977 particular emphasis was placed on the effects of dredging for a dry dock (Section 4.0 of this report). Emphasis in 1979 was on the effects of pier lights (Section 5.0 of this report).

3. To gather biological data on the salmonid species, i.e., length, weight, and condition factor, to aid in the explanation of observed locality preferences and any disruption of these due to shoreline construction and construction activities. From 1975 to 1978, biological data collection was restricted to pink and chum salmon. The data collection was extended to include all salmonid species in 1979 as the possiblity of their role as predators of the chum and pink fry.

4. To monitor some of the environmental variables to which the outmigrants were exposed. Variables measured were water temperature, dissolved oxygen concentrations, water visibility, total nonfilterable residues (TNFR), salinity, and weather and tidal conditions. The variations in the catch-per-unit-effort (CPUE) were examined as a variable of gear avoidance or habitat preference.

3.1.2 Objectives of Mark-recapture Study

Objectives of the mark-recapture study were to:

1. Confirm migration rates determined in the outmigration study based on unmarked hatchery releases.

2. Estimate growth rates during the first few weeks of marine existence.

3. Supply marked fish for the effects-of-lighting studies.

4. Estimate early marine mortality.

3.2 METHODS

3.2.1 Fish Sampling

In 1975 it was found that the salmonid juveniles passing the Bangor Annex utilized the littoral and pelagic zones; consequently, in the following years equal emphasis was placed on beach seining and townetting. This study and others (Stober and Salo 1971, Tyler 1972) have shown that the majority of pink and chum salmon juveniles is in the surface waters at the early stages of their outmigration, so the sampling was concentrated on the surface waters. In January, a 10-m handheld beach seine was used until salmonids began to be caught with regularity. Subsequently, a 37-m floating beach seine, deployed from an outboard skiff 30 m from shore (Plate III), and a 3-m x 6-m surface townet towed between two vessels (Plate IV) were used. Complete descriptions of these gear and their operation can be found in the annual reports (Schreiner 1977). Beach seine locations and townet transects are shown in Fig. 3-1.

Depending upon the size of the catch, a subsample of no more than 100 chum and pink fry was retained for length-weight analysis. The remaining salmon and nonsalmonid fishes were released after sorting. In 1979 the captured coho and chinook juveniles were measured before release. The subsamples of chum and/or pink juveniles collected in 1975-1978 were stored in saltwater over ice until being worked up directly after the day's sampling. Our and Parker's (1963) experiments have shown substantial changes in the length and weight of salmon fry after death. To increase the precision of our length-weight analysis in 1979, the subsamples were retained in 5% buffered saltwater formalin for 7 days before measuring, by which time the variations in these length and weight changes had been reduced. The effect of this change of technique on fish lengths will have to be controlled if year-to-year fluctuations in fish size are to be analyzed.

3.2.2 Environmental Sampling

Environmental data were not sampled consistently in 1975 and 1976. In 1977 dissolved oxygen, water temperature, salinity, TNFR, and visibility were measured after most samples. In 1978 temperature, salinity, and visibility were measured. In 1979 water temperatures were measured, along with weather and tidal conditions, which were recorded for each sample in all years. For details of environmental measurements see annual reports (Table 1-2).

3.2.3 Data Analysis

The catch data were recorded as catch-per-unit-effort where a unit of effort was defined as a 10 min tow for the surface townet or one set of the beach seine. The CPUE's for the two gear types are not directly comparable. In 1976, when townet transect durations varied considerably, the catches were multiplied by the ratio of the transect duration to the standard 10 min transect. This method introduces errors when large amounts of debris or fish are caught, as the efficiency of the net will decrease with time. As no knowledge of the magnitude of this

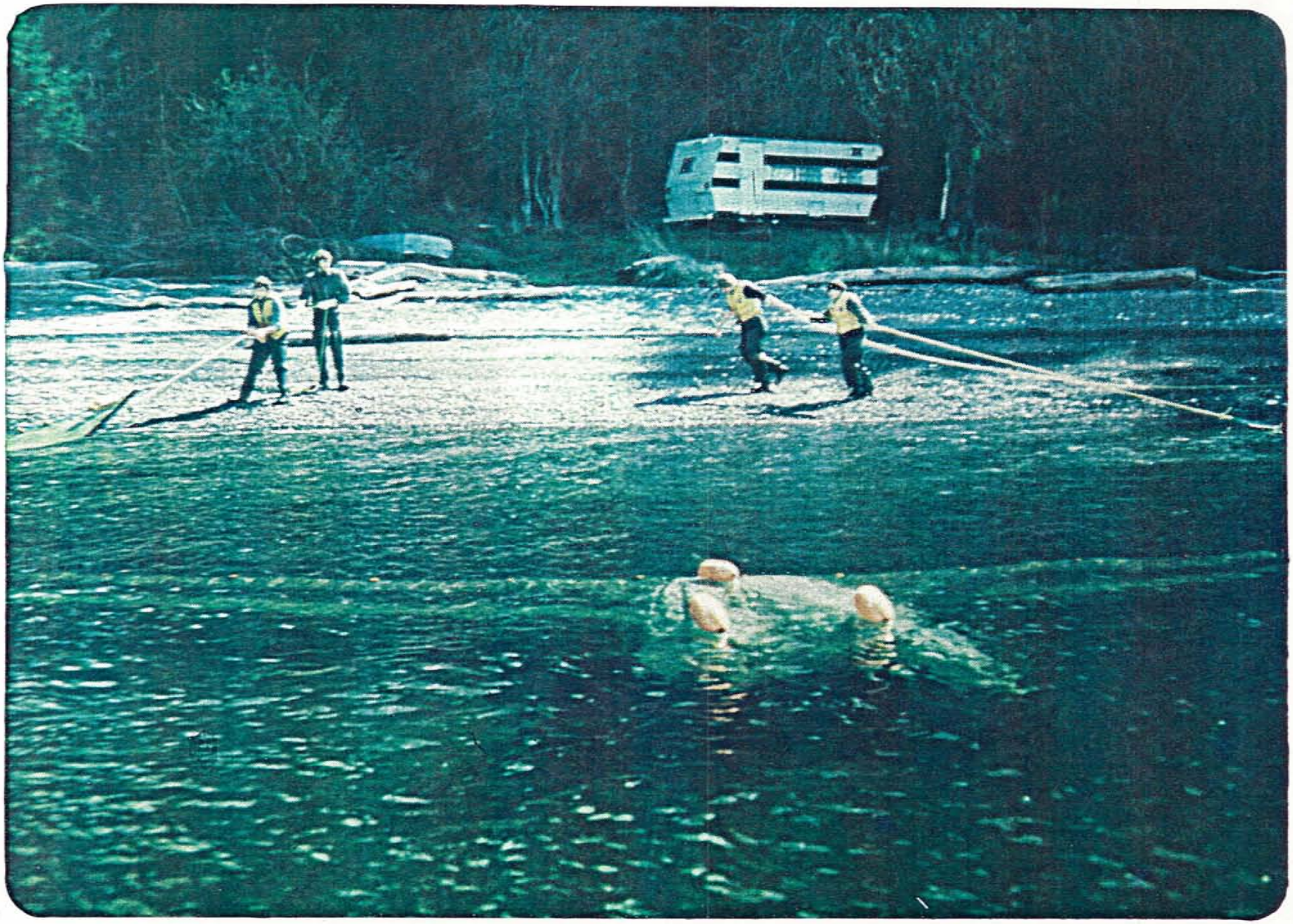

Plate III. Beach seining at Bangor, Hood Canal, Washington.

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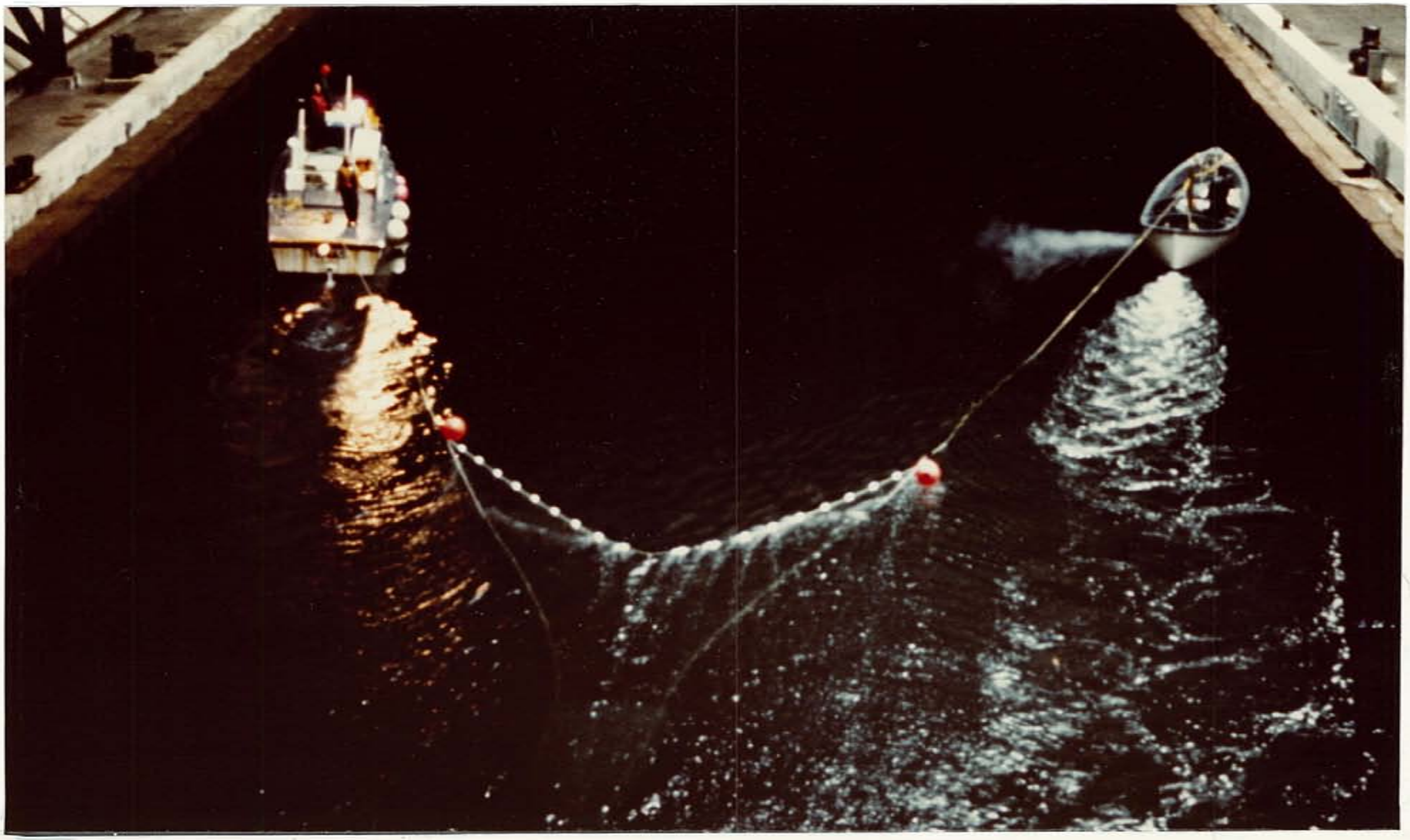

Plate IV. Townetting at night in EHW submarine berth, Bangor, Hood Canal, Washington.

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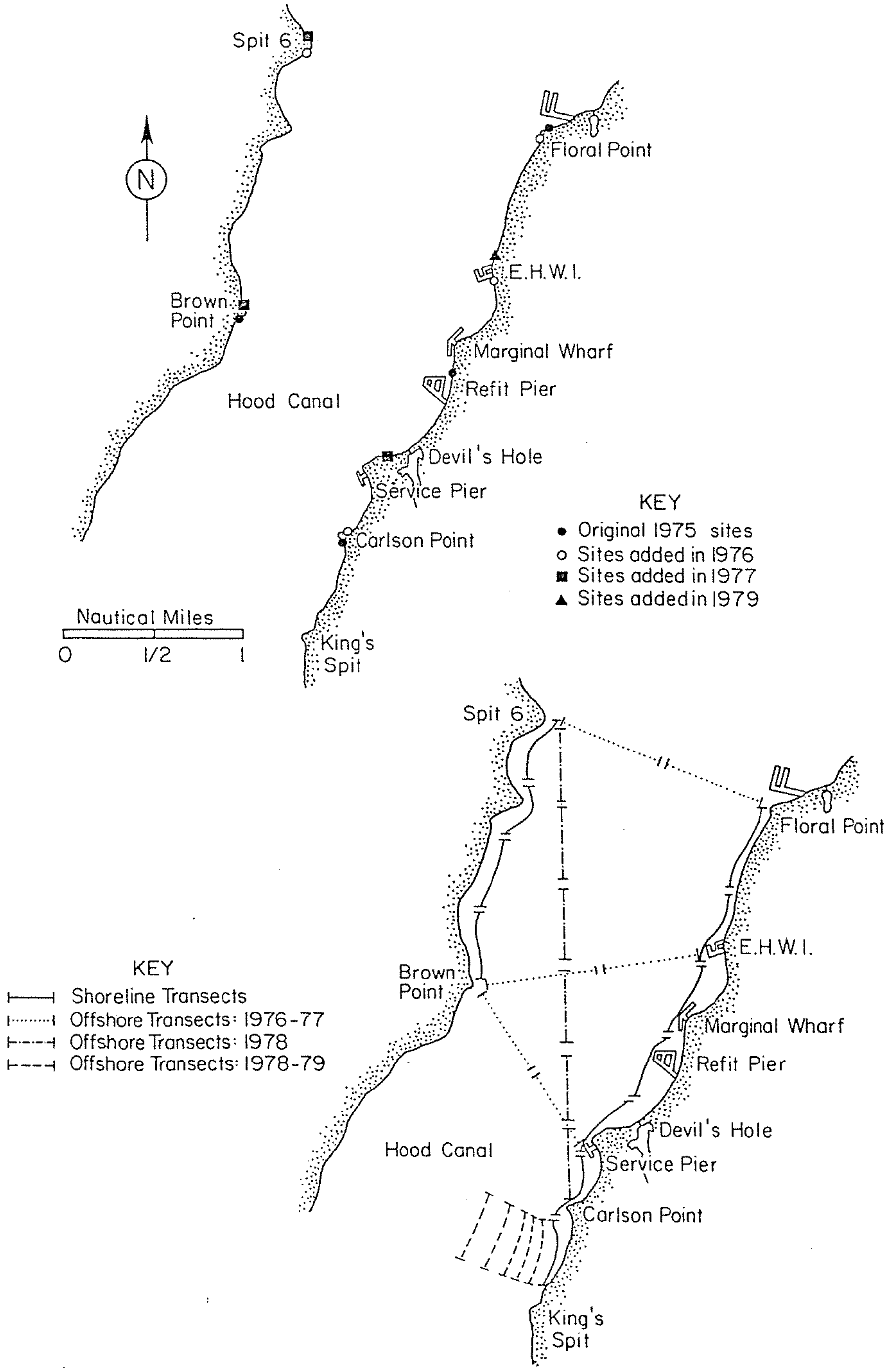

Fig. 3-1. Beach seine sites and townet transects sampled at Bangor Annex, Hood Canal, from 1975 to 1979.

decrease was available, no additional correction was attempted. In 1977 to 1979 townet transects were set at 10 min duration so no correction was required, with the sole exception of a 2 min transect inside the Explosive Handling Wharf (EHW) in 1979. The catches from this transect were increased by a factor of 5 for comparison with a standard 10 min transect. Because sometimes fry were observed ahead of the purseline, having yet to fall back into the bag, at the end of 2 min it was felt that this might be an underestimate.

In most cases, the CPUE data were found to be lognormally distributed and the following transformation was used, before parametric analysis of the data, to obtain the dependent variable (D.V.):

$$\text{D.V.} = \log_{10} (\text{CPUE} + 1)$$

In cases where the CPUE from a particular site was either not lognormally distributed or caused heteroscedasticity of the data, nonparametric statistical analysis was used to compare it with the remaining sites. Earlier data were reanalyzed where necessary to obtain compatibility between years.

All analyses were carried out on the University of Washington's central computer, and the 5 years of data are recorded on magnetic tape.

3.2.4 Comparison of the CPUE Data over 5 Years

Not all of the data collected could be used for between-year comparisons, as new sampling locations were added to meet contractual obligations. Also, some of the locations changed physically as installations were completed and became operational. A further constraint on the data comparison is that daytime sampling was conducted from 1975 through 1978, daytime and nighttime sampling in 1977, and nighttime only in 1979. The nighttime sampling added in 1977 to account for diurnal changes in fish distribution had to be suspended in 1978 when funding was decreased. In 1979, when the effects of pier lighting were of major concern, nighttime sampling was substituted for daytime sampling.

To account for these changes, three sites away from the construction area--Carlson Point, Floral Point, and Brown Point--were used in the 5 yr comparison. Only data from the 37-m beach seine were used as townetting was infrequent in 1975. To account for the diurnal changes, data from 1977, when both nighttime and daytime sampling occurred, were used to index the change in salmonid distribution over 24 hr. Using only sites away from the construction and lighting, day and night catches at the same location on the same stage of tide and in the same sampling week were compared. The data from 1979 were then adjusted so that direct comparisons between years could be made. The following formulae were generated:

Chum juveniles - 37-m beach seine
CPUE at day = CPUE at night * 1.92
Coho smolts - 37-m beach seine
CPUE at day = CPUE at night * 0.47

Night and day are defined in this instance as 1 hr after dusk until 1 hr before dawn and 1 hr after dawn until 1 hr before dusk, respectively.

The CPUE data for 1975 need to be treated with caution, as a different vessel was used in that year, and the netting efficiency was probably lower.

3.2.5 Mark-recapture Methods

3.2.5.1 Marking Mortality and Retention

The marking of juvenile chum salmon with fluorescent pigment, as described by Jackson (1959), was selected as the most efficient technique. Fish in 1977 and 1978 were marked with a system developed by Washington State Department of Fisheries (Whitmus and Olsen 1979), and in 1979 a modified version was used (Fig. 3-2).

Marking mortality in 1977 ranged from 1.2% to 6.2%, while in 1978 and 1979 it was less than 1%. Pigment retention in 1978 was the lowest (40-65%), while in 1977 it was approximately 92%. With the refinement of the technique in 1979, 90-95% retention with less than 1% mortality was achieved.

3.2.5.2 Early Marine Mortality

Estimates of the early marine mortality of juvenile chum salmon in Hood Canal, where recruitment is a variable, were based on repeated releases at standardized intervals. An initial group of marked smolts was released from Big Beef Creek, and subsequent marked groups were released at 48- and 96-hr intervals at the "center" or focus of the first group's distribution as determined by beach seining and townetting. The procedure is described in Table 3-1.

Table 3-1. Procedure for deriving survival estimate using a mark-recapture experiment with multiple releases.

Time	t_0	t_1	$t_2 \cdot \cdot \cdot$	
Population	N_0	N_1	$N_2 \cdot \cdot \cdot$	
Marks added	M_0	M_1	$M_2 \cdot \cdot \cdot$	
Sample taken		n_1	$n_2 \cdot \cdot \cdot$	
Mark recaptures		m_{01}	$m_{02} \cdot \cdot \cdot$	
			m_{12}	$m_{13} \cdot \cdot \cdot$
				m_{23}

S_0 = survival of marked fish from t_0 to time t_1.

$m_{02}' = m_{02} + m_{03} + \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot$ = sum of all recaptures from marking at t_0 after t_1.

$m_{12}' = m_{12} + m_{13} + \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot$ = sum of all recaptures from marking at time t_1 after t_2.

$$S_0 = \frac{m_{02}'}{m_{12}'} \times \frac{m_1}{m_0}$$

Relative error of the estimate of S_0 is approximately

$$\left(\frac{1}{m_{02}'} + \frac{1}{m_{12}'}\right)^{1/2}$$

(i.e. $\frac{\text{var } \hat{S}_0}{S_0} = \frac{1}{m_{02}'} + \frac{1}{m_{12}'}$ or S.E. $\hat{S}_0 = S_0 \left(\frac{1}{m_{02}'} + \frac{1}{m_{12}'}\right)^{1/2}$)

Fig. 3-2. Spray-marking apparatus used in mark-recapture experiments with chum salmon in Hood Canal.

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3.3 RESULTS AND DISCUSSION

3.3.1 General Comparison Between Years

Chum salmon juveniles were the most abundant salmon in the survey area. In even years (1976 and 1978) pink salmon juveniles were second in abundance. No pink salmon were caught in the odd years. More coho were caught than chinook; however, the peak of the chinook migration may have occurred after the sampling season. Too few juvenile steelhead and cutthroat trout were caught to draw conclusions about habitat preferences or annual abundance. A small number (<100 per year) of adult chinook, steelhead, and cutthroat trout were caught.

3.3.1.1 Yearly Variations in Abundance

3.3.1.1.1 Chum Salmon. The CPUE data from selected sampling locations (see Sec. 3.2.4) were analyzed (Fig. 3-3). The differences in chum abundance among the years is apparent and was significant when tested with ANOVA (Table 3-2). The same time period was used for each year, which meant restricting the data used to the weeks sampled in 1975. Figure 3-3 shows that 1975 was an extremely good year for outmigrants, followed by a poor year in 1976, and then three moderate years from 1977 through 1979. At the time of the outmigration period which this analysis covers, we think that the chum juveniles are principally of hatchery origin (Section 3.3.2.1). Although within any given year the CPUE of chum at Bangor is related to hatchery releases, from year to year the proportion of hatchery fry caught at Bangor varies (Table 3-3). This suggests that factors operating during the first 1-3 weeks of marine life (the time taken for fry released from the hatcheries to reach Bangor Annex) are significantly affecting the size of the outmigrating populations. The importance of the early marine environment to salmonid juveniles' survival has been documented by many authors, as described previously. Gilhousen (1962) suggests that the factors affecting survival in the marine environment may be of such importance that variations in fry abundance may exert only a secondary effect on overall survival.

That these data suggest a high variability in the survival of juvenile chum salmon in the first 1-3 weeks of their marine life could indicate the usefulness of the sampling technique as a predictor of adult returns if the majority of variability in the marine survival has occurred before sampling takes place. A similar technique of forecasting has been used by Tyler (1972) who, using a surface townet, obtained a coefficient of determination (R^2) of 0.71 between forecasts developed from fry indices and returns.

3.3.1.1.2 Pink salmon. Pink salmon juveniles were present in the sampling area only in 1976 and 1978. With only 2 yr of data it is dif-

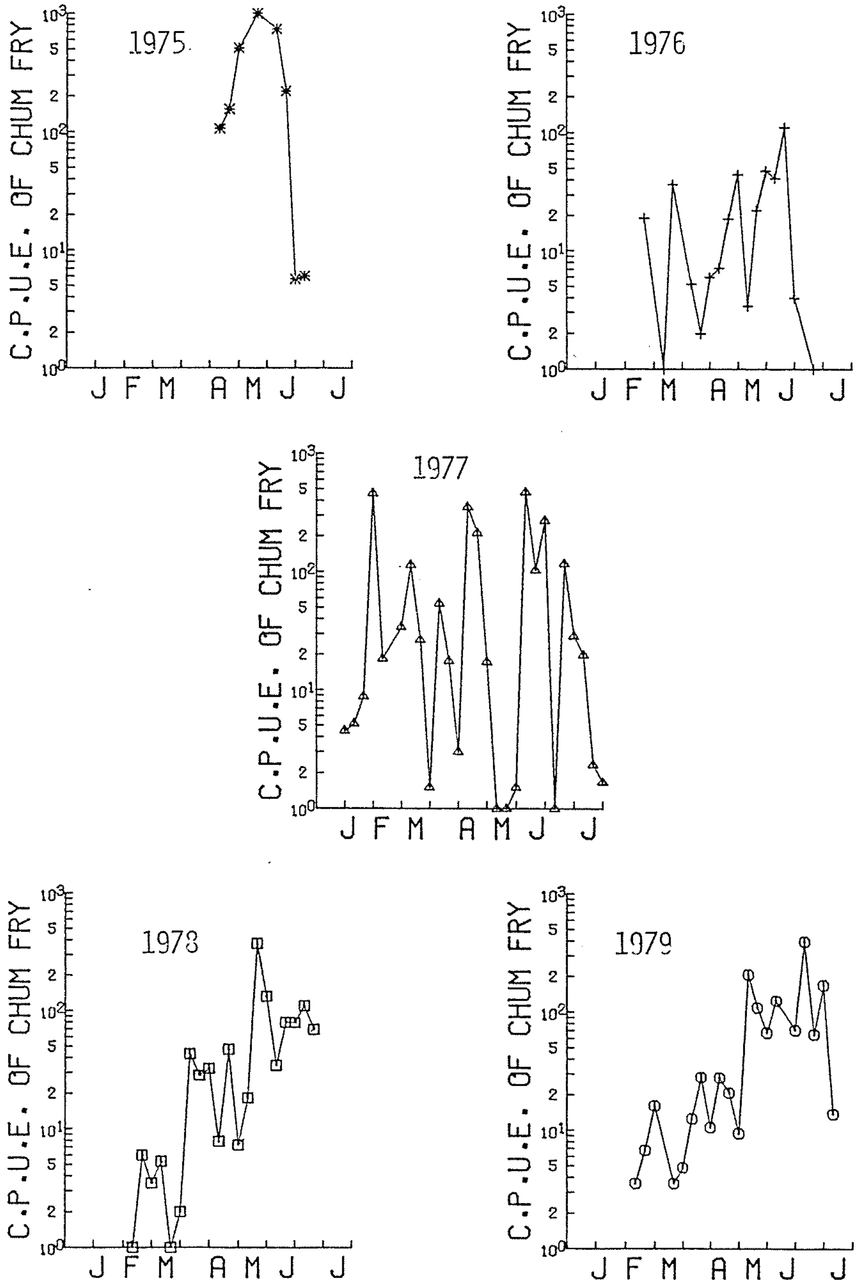

Fig. 3-3. Comparison of CPUE of juvenile chum salmon with the beach seine at selected sites - Hood Canal from 1975-1979.

Table 3-2. Analysis of variance to show the yearly variations in CPUE of juvenile salmonids.

Chum Salmon 1975-1979
ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance of F
Total	191.669	209	.917		
Groups	38.771	13	2.982	4.432	.001
Year	19.264	4	4.816	7.156	.001
Week	15.881	9	1.765	2.622	.007
2-way interactions	42.530	32	1.329	1.975	.003
Year-week	42.530	32	1.329	1.975	.003
Error	110.369	164	.673		

	Significant groups in SNK multiple comparison*				
Year	1975	1979	1978	1977	1976
$\bar{x}$	1.79	1.41	1.17	1.06	0.79
Groups	———	———	———	———	
				———	———

Pink Salmon 1976 + 1978
ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance of F
Total	136.355	320	.426		
Groups	17.787	19	.936	2.558	.001
Year	.054	1	.054	.147	.702
Week	17.715	18	.984	2.689	.001
2-way interactions	14.641	17	.861	2.353	.002
Year-week	14.641	17	.861	2.353	.002
Error	103.927	284	.366		

*Years non-significantly different from each other at the 5 percent confidence level are underlined

Table 3-3. A comparison of the mean CPUE of salmonid juveniles, as determined with the 37-m beach seine, and hatchery releases from the Hood Canal, Quilcene, and George Adams fish hatcheries.

Species	Year	$\overline{\text{CPUE}}$[a]	Hatchery releases (millions)
Chum	1975	233[b]	14.9
	1976	15	12.3
	1977	45	20.2
	1978	47	14.7
	1979	57	unavailable
Pink	1976	8	1.5
	1978	9	2.4
Coho	1975	1.0	1.7
	1976	0.6	2.2
	1977	0.9	2.0
	1978	1.6	0.9
	1979	0.4	unavailable

[a] $\overline{\text{CPUE}}$ is the retransformed mean of the dependent variable.

[b] This value may be suspect; see text, Sec. 3.2.4.

ficult to ascertain what degree of variance in the abundance of juvenile pinks occurs in Hood Canal and how the 2 yr in which we have data compare to an "average" year. There were no significant differences between CPUE in 1976 and 1978 (Table 3-2 and Fig. 3-4). The size of this difference is not as large as was observed for chum juveniles between the same 2 yr (Figs. 3-3 and 3-4). For chum juveniles 1976 was, according to our data, a noticeably poor year. That this was not the case for the pink juveniles suggests a difference in the factors affecting early marine survival of the two species. As was noticed with chum salmon, the mean annual CPUE did not appear to be closely related with annual hatchery releases (Table 3-3).

3.3.1.1.3 Coho salmon. The CPUE data for coho salmon during the 5 yr are shown in Fig. 3-5. As the coho smolts are often large enough to outswim the net, the CPUE figures may underestimate the numbers of the larger sizes. Large differences in CPUE are apparent from year to year, the most noticeable being the high CPUE in 1978 and the low CPUE in 1979. This annual variation in CPUE did not appear to be correlated with either total yearly hatchery releases or with the variations observed in other species (Table 3-3).

3.3.1.2 East-west Shore Distribution

Only pink and chum are considered for analysis of distribution patterns as they are the only species captured in large enough quantities.

3.3.1.2.1 Chum salmon. In 1975, it was noticed with some surprise that, although the vast majority of the fry entering Hood Canal came from hatcheries and rivers on the west shore, the CPUE of chum fry indicated a substantial number of fry on the east shore. Analysis of the data over the 5 yr period show that townet CPUE was in fact higher along the east shore than the west shore in all years (Table 3-4). This contradicts CPUE data from the 37-m beach seine which show equal number of fry on both sides of the Canal except in 1979 (Table 3-4).

The lower townet catches on the west shore, may, to some extent, be an artifact of the bathymetry, as townet transects at comparable depths are a greater distance from the shoreline than on the east shore. This leads to decreased catches (Sec. 3.3.1.4). The causes of the higher catches on the east shore with the beach seine in 1979 are not known. It cannot be entirely explained by diurnal variations, as the nighttime catches in 1977 do not show a difference between shores (Table 3-4). It is not due to the additional east shore beach site in 1979--North EHW which had the highest CPUE of all beach seine sites--as this site was excluded from the analysis.[3] Possibly the changes on the

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[3] For a detailed analysis of site preference, see Bax, N. J., E. O. Salo, and B. P. Snyder. (In preparation.) Salmonid outmigration studies in Hood Canal. Final Report. Phase V, January to July 1979. University of Washington, Fisheries Research Institute, Seattle.

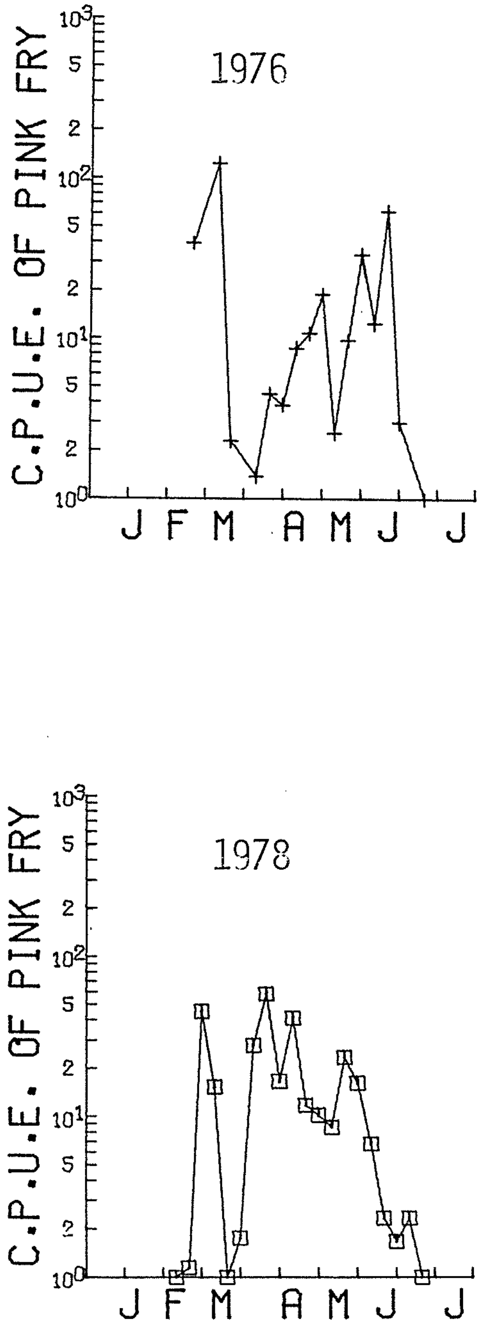

Fig. 3-4. Comparison of CPUE of juvenile pink salmon with the beach seine at selected sites in Hood Canal 1976 and 1978.

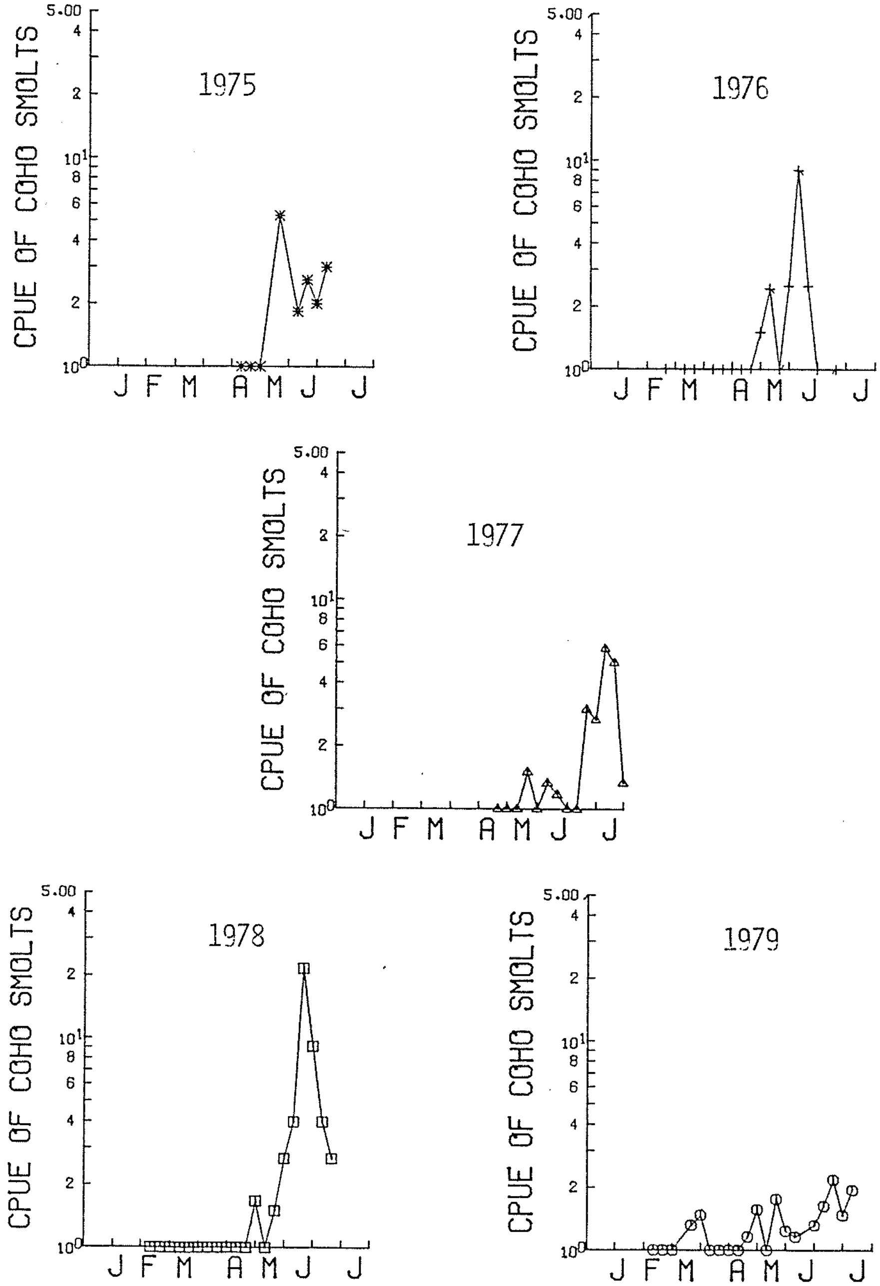

Fig. 3-5. Comparison of CPUE of juvenile coho salmon with the beach seine at selected sites in Hood Canal from 1975-1979.

Table 3-4. Comparison of CPUE of chum and pink on the east and west shores from 1975 to 1979, using t-tests.

Gear	Year	East-West	S.E.	t	D.F.	t prob.
		Chum Salmon				
Beach seine	1975	.3120	.3505	.890	49	.378
	1976	.1092	.1472	.742	164	.459
	1977	.0668	.0572	1.169	925	.243
	(night only)	.1046	.0655	1.597	135.5	.113
	1978	.1004	.1045	.961	337	.337
	1979	.3382	.0777	4.355	373	.000
Townet	1976	.3942	.1648	2.392	165	.018
	1977	.1790	.0564	3.176	976	.002
	1978	.3416	.0938	3.641	364	.000
	1979	.2413	.0117	2.161	265	.032
		Pink Salmon				
Beach seine	1976	-.0202	.1247	-.162	164	.872
	1978	-.0616	.0814	-.757	337	.450
Townet	1976	.1856	.1167	1.590	165	.114
	1978	.0187	.0554	.338	216.6	.736

east shore since 1977--construction of degaussing wharf and use of lighting at the EHW and the Refit Pier--caused this change in distribution, but we have no direct evidence for this.

This higher catch on the east shore in 1979 is unlikely to be caused by a redistribution of fry from the west shore to the east shore in the vicinity of Bangor Annex. Our offshore distribution data show few fry being found in the middle of the canal; additionally data from the 1977 Hoodsport mark-recapture study (Whitmus and Olsen 1979) show an immediate crossing to the east shore by some of the fry. Differences in our own length-weight relationships and the time taken to reach the Bangor Annex area between the east and the west shore groups suggest that the two groups remain distinct at least until they have passed the Bangor Annex. Therefore, the higher catch on the east shore in 1979 is most likely due to a localized redistribution of the fry at night on the east shore leading to an increased probability of their capture with the beach seine. Schreiner (1977) speculated that the high spring runoff in Hood Canal may result in salinity gradients from east to west shore which the fry could respond to. Thus, east-west distribution may also be a function of other environmental variables.

3.3.1.2.2 Pink salmon. Data on the distribution of pink fry for 1976 and 1978 show a similar proportion of fry on each side of the canal (Table 3-4). As with the chum salmon, this implies that pink fry must have crossed the canal before reaching Bangor, as minimal numbers of pink fry are found in midcanal at Bangor Annex.

3.3.1.3 Location Preferences and their Yearly Variation

Observations on chum salmon were the only data used in these analyses, and 1975, the pilot year, was excluded. Data on the less abundant species are available.

The differences in CPUE of chum among locations have been analyzed on a within-year bases and are presented in the annual reports. It is the purpose here to reanalyze these data to measure the changes in CPUE of chum at selected locations among the years.

3.3.1.3.1 Beach seine locations. The data were analyzed separately for the east and west shores in order to observe yearly fluctuations of location preferences on a shore where construction and wharf activities had taken place (east shore) and one where they had not (west shore). Using the logarithmically transformed catch data as dependent variable and location, week and year as the three independent variables, a three-way analysis of variance was run. All three independent variables had a significant relationship with CPUE on the east shore (Table 3-5). On the west shore only location and week were found to have a significant relationship with CPUE. Changes in location preference among years are measured by the two-way interaction between

Table 3-5. Three-way analysis of variance showing the effects of sampling location, week and their interactions on the CPUE of chum salmon juveniles with the beach seine at Bangor Annex from 1976 to 1979.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-Statistic	Significance of F
		East Shore			
Total	477.300	646	.739		
Cells	92.760	23	4.033	7.773	.001
Location	16.628	6	2.771	5.342	.001
Week	69.361	14	4.954	9.549	.001
Year	11.864	3	3.955	7.623	.001
2-way interactions	134.466	141	.954	1.838	.001
Location-week	60.118	84	.716	1.379	.021
Location-year	15.435	17	.908	1.750	.032
Week-year	49.069	40	1.227	2.364	.001
Error	250.074	482	.519		
		West Shore			
Total	179.691	297	.605		
Cells	40.001	20	2.000	4.602	.001
Location	12.634	3	4.211	9.690	.001
Week	27.366	14	1.955	4.498	.001
Year	1.799	3	.600	1.380	.250
2-way interaction	57.550	88	.654	1.505	.011
Location-week	14.308	42	.341	.784	.824
Location-year	2.881	7	.412	.947	.472
Week-year	39.516	39	1.013	2.331	.001
Error	82.140	189	.435		

location and year, which was found to be significant on the east shore (p = 0.032) but not significant on the west shore (p = 0.472). Thus it appears likely that the construction and/or wharf activities had an effect on location preferences over the 4 yr of study.

The next step in the analysis was to determine which locations on the east shore might be responsible for any changes in location preferences. To account for yearly and weekly variations in overall abundance, the weekly mean CPUE of all regularly sampled sites on the east shore was calculated and the deviation of the weekly mean CPUE at individual locations from this group mean determined. These deviations for each location were the dependent variables used in the subsequent analysis. For ease of graphical representation the weekly deviations for each location were averaged over the sampling period (February-July) before plotting (Fig. 3-6a). The same analysis was repeated for west shore sites as a comparison (Fig. 3-6b).

The location showing the most variability in catch relative to the east shore mean was South Marginal Wharf, where a pronounced decline took place in 1977 and 1978. During these 2 yr, substantial construction activities were occurring on the Refit Pier a short distance offshore (Fig. 1-2). It is possible that these activities caused the observed decreases in relative abundance. If this was the case, then the increase in relative catch upon cessation of major construction activities in 1979 implies that no permanent decrease in abundance in the area was occurring. A cautionary note here is that as 1979 sampling was conducted at night, while previous years' sampling was during the day, the proximity of lighted wharves to the South Marginal Wharf sampling site may have influenced the 1979 results. During 1978 tests (Prinslow et al. 1979), significantly more chum were caught nearshore at EHW when lights were on than off; intensity was 8-12 lux in this area. Lights at Marginal Wharf produce up to 14 lux at surface and cover a larger area than at EWH because of their greater height above water. Lights at the Refit Pier produced 7 lux at surface near the sampling site. Thus, the South Marginal Wharf site was influenced by light of intensity comparable to that which attracted chum.

A decrease in the catch at south Floral Point relative to the mean from 1976 to 1979 was observed. As Floral Point is farther north and consequently farther along the migration route than the major Bangor shoreline facilities there is concern over this apparent decrease in relative abundance. To determine the significance of this trend the two northernmost sampling locations (south and north Floral Point) were compared with the two southernmost sampling locations on the Base (south and north Carlson Point). A linear regression equation was fitted to each of the two sets of data with weekly deviation from the mean as the ordinate and time (weeks from the start of sampling in 1976) as the abscissa. The results in Table 3-6 show that there was no change in relative abundance at the southern end of the Base ($p>.25$), whereas at the northern end of the Base there was a decline in rela-

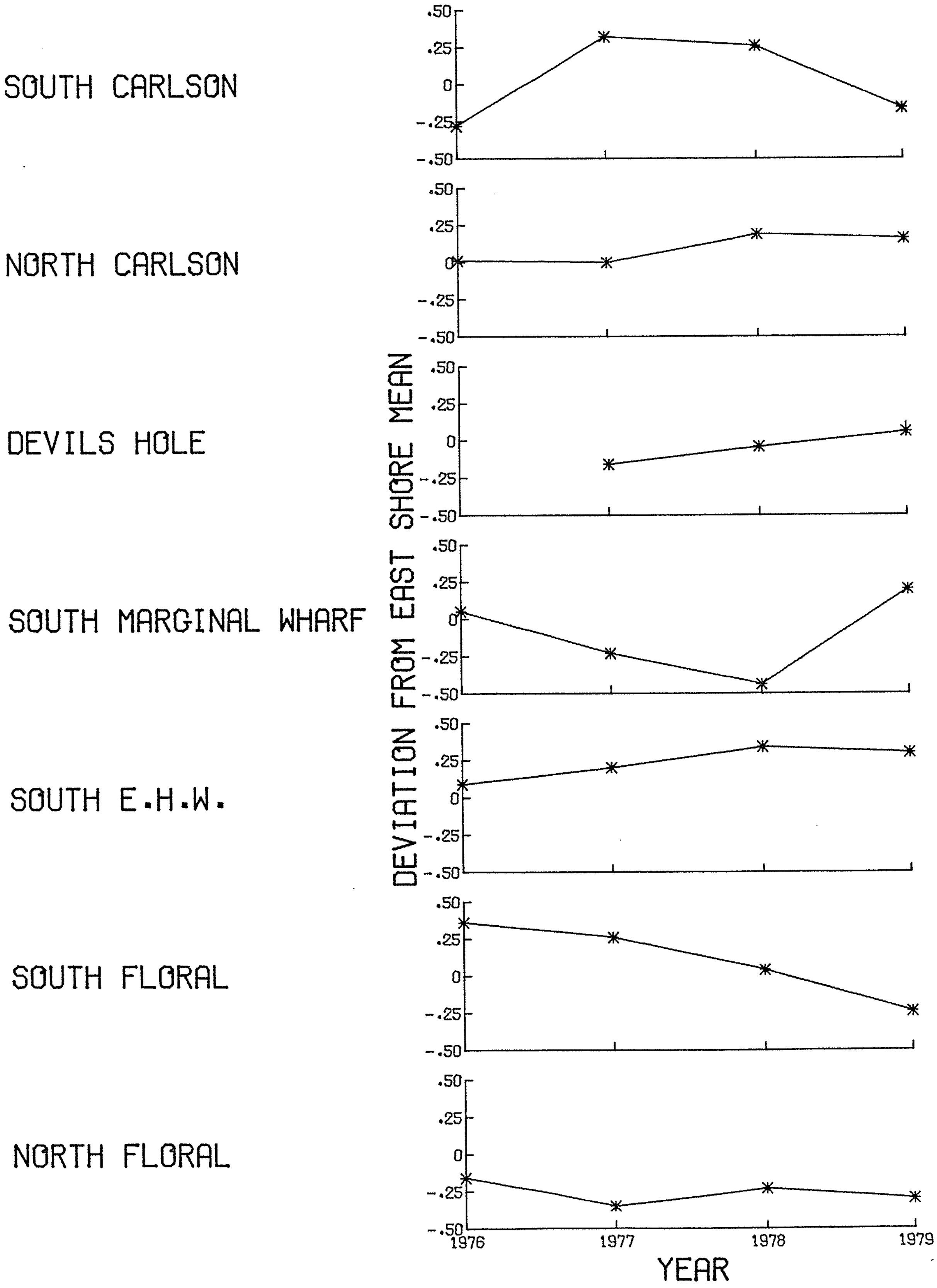

Fig. 3-6a. Average yearly deviation of the (logarithmically transformed) CPUE of juvenile chum salmon at individual beach seine locations from the east shore mean at Bangor Annex, Hood Canal from 1976 to 1979.

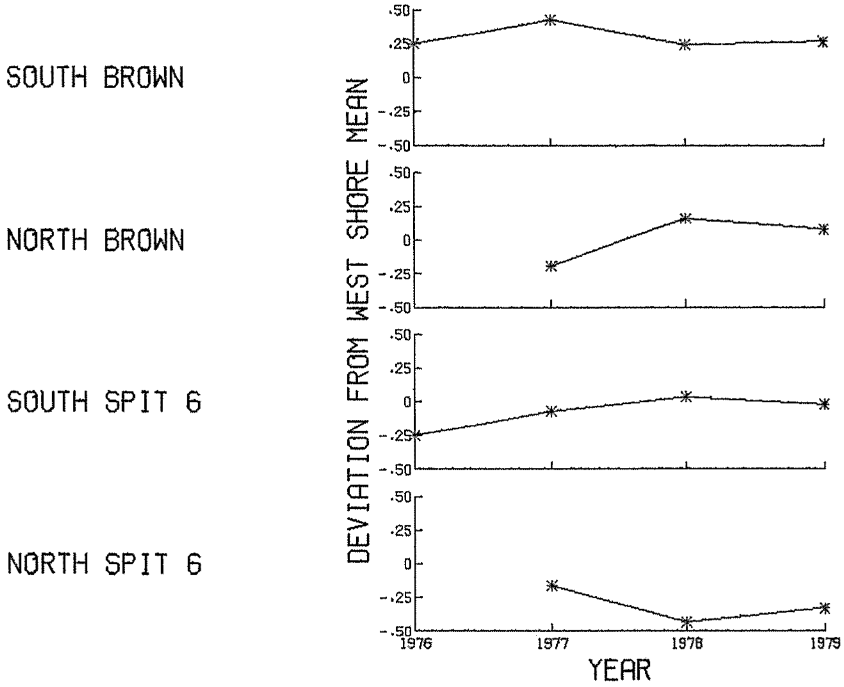

Fig. 3-6b. Average yearly deviation of the (logarithmically transformed) CPUE of juvenile chum salmon at individual beach seine locations from the west shore mean at Bangor Annex, Hood Canal from 1976 to 1979.

Table 3-6. Linear regression to find overall trend in CPUE of chum salmon with the beach seine north and south of major construction activities at Bangor Annex, from 1976 to 1979. *See* text for explanation of dependent variables.

Location	Regression equation	Number of observations	R^2	Significance H_o: B = 0 H_a: B $\neq$ 0
South (Carlson Point)	$Y_i = -.0253 + .0009\ X_i$	119	.0056	$p > .25$
North (Floral Pt.)	$Y_i = .1610 - .0024\ X_i$	117	.0504	$.025 > p > .01$

tive abundance ($.025 > p > .01$). The extremely low coefficient of determination (r^2) for these equations shows that only a small part of the total variability in relative catch is explained by this simple linear trend.

The cause of the decline in catch at Floral Point relative to the mean is not known. One hypothesis tested was that the shoreline structures at the Base were causing an increasingly large proportion of the migrating chum to move offshore. If this was the case, then it would be expected to find an increase in catches of chum offshore at Floral Point relative to the mean offshore catch on the east shore. Such an increase was not found (Fig. 3-7); however, there was also no decrease corresponding to that found for the nearshore sampling. This implies that the decrease in abundance of chum juveniles passing Base facilities was restricted to the smaller nearshore juveniles.

3.3.1.3.2 Townet transects. We do not have data for the townet comparable to that of the beach seine. For 1976-1978 the townet transects were run continuous with one another. Due to differing tidal and weather conditions changing the distance towed relative to shore during the standard 10 min period, the end points of a townet transect varied from day to day. Thus, on one day the EHW would be included in one transect, while under different tidal and weather conditions it would be included in the adjacent transect. To account for this discrepancy in 1979, the transects were arranged to be a short distance apart. This flexibility allowed each transect to be in the same area under all weather and tidal conditions.

There were no significant differences found between shoreline transects from 1976-1978, at least partly due to the reason outlined above. In 1979 with the more controlled transect pattern, differences were found. The transect inside the EHW had a higher CPUE than any other east shore transect irrespective of pier lighting. The catch at the Small Craft Wharf was higher than the remaining east shore locations, an effect perhaps mediated by the pier or its lighting and its proximity to shore. The remaining east shoreline transects were not different from one another. The importance of these observations in regard to forced offshore movement of the chum juveniles is discussed in the following section.

3.3.2 Offshore Distribution

The offshore sampling transects in 1976 and 1977 were almost perpendicular to the shore; thus, a standard 10 min tow fished a distance of about 75 m from the shore to the middle to the Canal (Fig. 3-1). This made an estimation of the offshore distribution difficult, so in 1978 two series of transects were set up, one series traveling obliquely across the Canal and the other series running parallel to, and

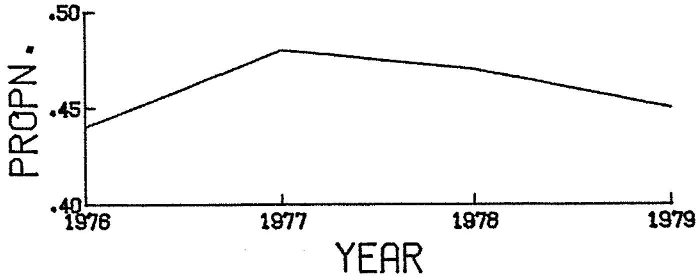

Fig. 3-7. Relationship between townet CPUE of juvenile chum caught offshore at Floral Point and the east shore mean townet CPUE expressed as the proportion, from 1976 to 1979.

at increasing distance from the shore at Carlson Point to King's Spit (Fig. 3-1). Although trends in offshore distribution seemed apparent, the high variability in the catches made statistical interpretation difficult. To reduce this variation in 1979, the offshore transects were restricted to the parallel series on which the effort was doubled. The results, in terms of chum of the 1978 and 1979 seasons, are discussed.

To analyze these data the proportion of the total catch of the transect series caught on each transect was calculated. Bartlett's correction factor was used for zero catches (Zar 1974, p. 186). To normalize this transformed data the arcsine transformation was used before statistical analysis. As distance from shore was the independent variable in these analyses the cross-canal transects were grouped into three pairs, each pair being an equal distance from shore.

3.3.2.1 Cross-canal Transects

The cross-canal tows show a decreasing catch as the distance from shore increases (Fig. 3-8). The proportion of the total catch caught on any transect was highest on the transect closest to the shore on each side of the Canal (Table 3-7). The four remaining transects had a proportion of the total catch comparable among themselves, but lower than the transects closer to shore. No seasonal trend in the relationship between distance from shore and CPUE was apparent ($p>.25$).

The decline in juvenile chum abundance with increasing distance from shore, although present, was not as pronounced as expected. This was due to the nature of the transect design where each transect covers an area changing rapidly with regard to distance from shore. Thus effects of the increasing distance from shore on chum abundance would be masked. This problem does not arise with the parallel tows where each transect follows the shoreline at a predetermined distance.

3.3.2.2 Parallel Transects

As found for the cross-canal transects there was a decline in the abundance of chum with increasing distance from shore (Fig. 3-9). This decline was highly significant in 1978 and 1979 (Table 3-7). In 1978 the first two transects (up to 125 m from shore) had a higher proportion of the catch than the remaining transects, while in 1979 only the first transect (75 m from shore) had a higher catch than the remaining transects. Thus the majority (50-75% of townet catch and 100% of beach seine catch) of juvenile chum passing Bangor Annex can be found within the first 125 m of shore.

The similarity in the offshore distribution of the chum between the two years is surprising in one regard: the data in 1978 were

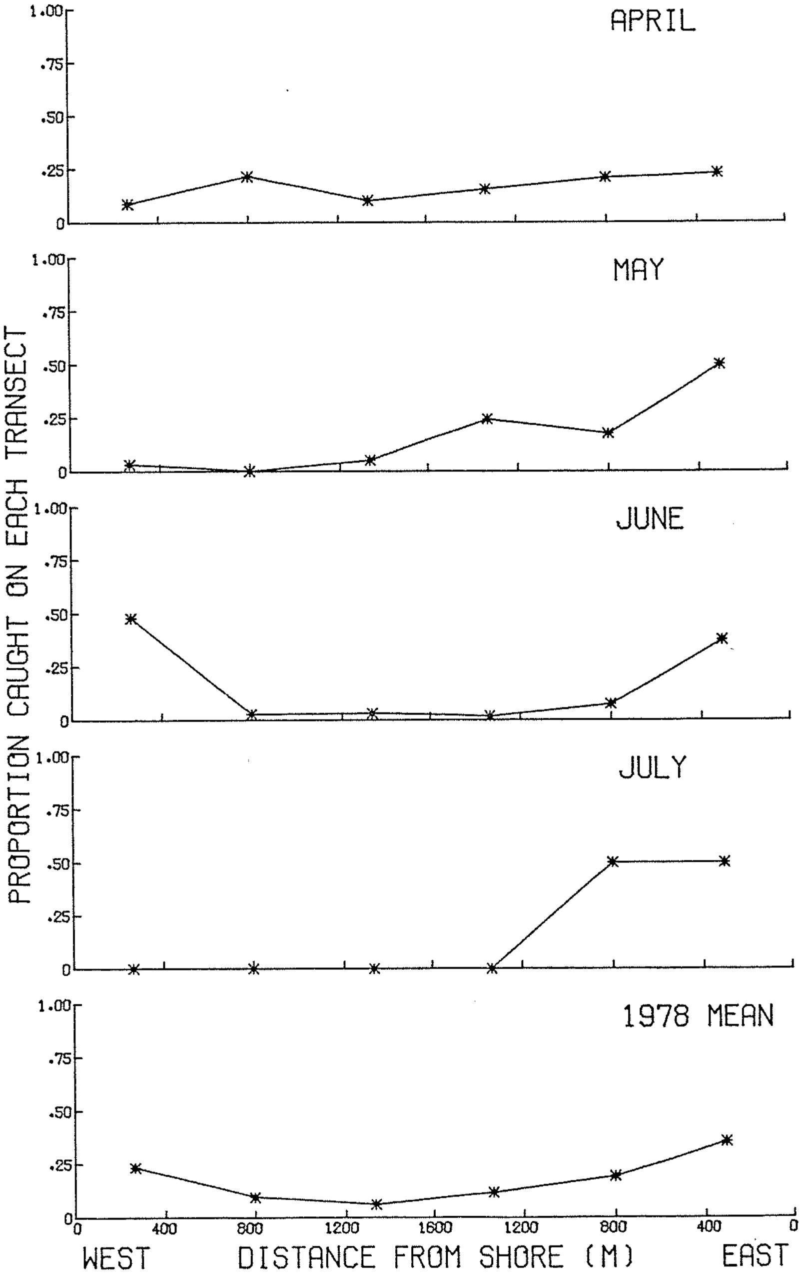

Fig. 3-8. Change of CPUE of juvenile chum with distance from shore on cross-canal townet transects in 1978.

Table 3-7. Analysis of the effect of distance from shore on the distribution of juvenile chum caught with the surface townet (_see_ text for description).

Cross-canal transects 1978

ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	13,637.028	59			
Location	1,542.920	2	771.460	3.636	.05 > p > .01
Error	12,094.108	57	212.177		

Significant groups in multiple comparison*

Transects	Nearshore	Offshore	Mid-canal
x̄	17.82	8.87	6.18
Groups	———	———	
		———	———

Parallel Tows 1978

ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	17,529.884	59			
Location	4,968.248	5	993.650	4.272	.005 > p > .0025
Error	12,561.636	54	232.623		

Significant groups in multiple comparison*

Distance from shore (m)	75	125	160	300	225	550
x̄	28.06	18.67	6.81	5.40	4.69	3.33
Groups	———	———				
		———	———	———	———	———

Parallel Tows 1979

ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	16,355.894	95			
Location	4.651.578	5	930.316	7.15	p < .0005
Error	11,704.317	90	130.048		

Significant groups in multiple comparison*

Distance from shore (m)	75	125	160	300	225	550
x̄	36.74	26.41	23.83	19.47	17.50	16.09
Groups	———					
		———	———	———	———	———

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* Years non-significantly different from each other at the 5 percent significant level are underlined.

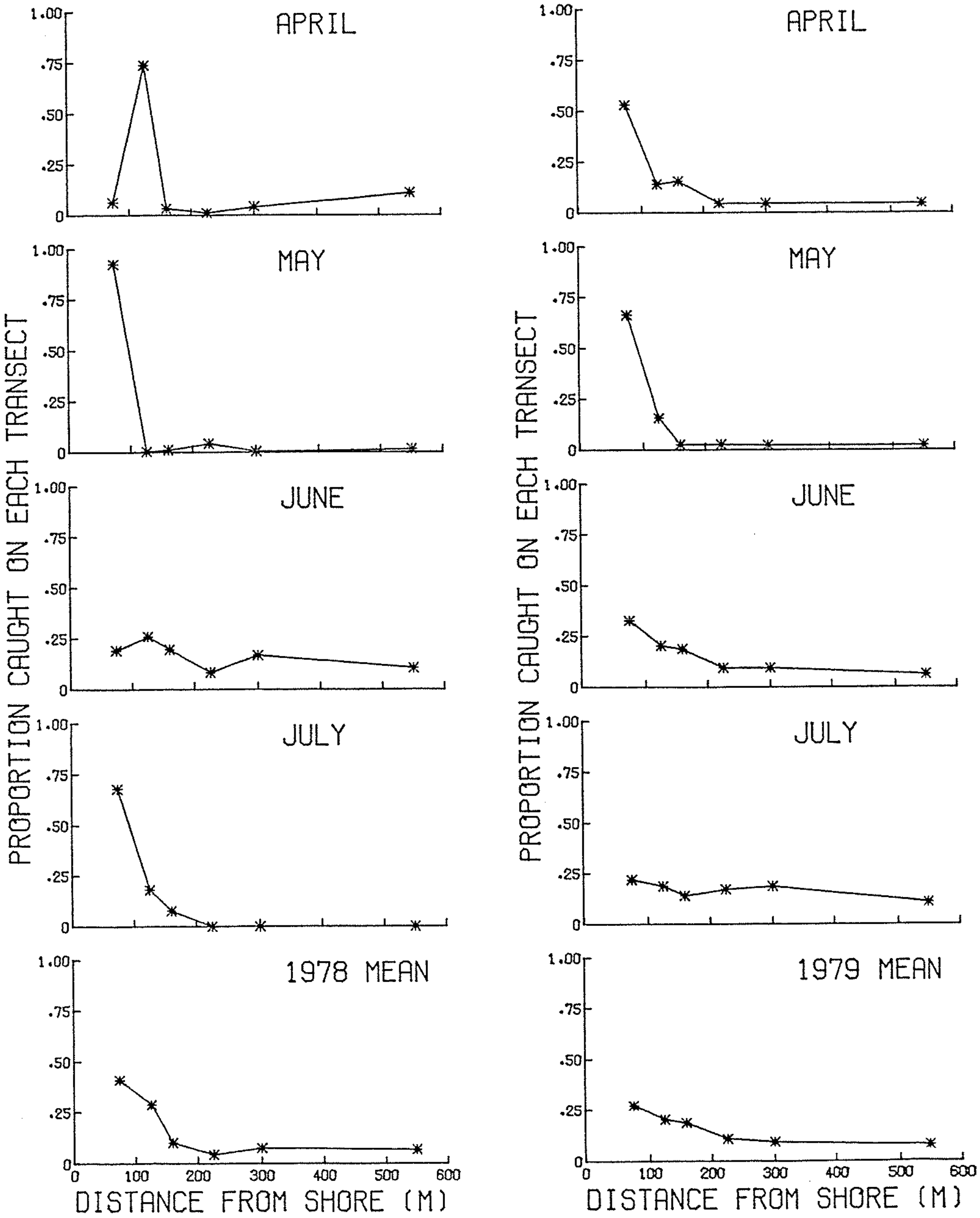

Fig. 3-9. Effect of distance from shore on the CPUE of juvenile chum on parallel townet transects off Carlson Point in 1978 and 1979.

collected during the day, while the 1979 data were collected at night. There is no indication of the nocturnal offshore movement suggested in 1977 by the smaller daytime beach seine catches as compared with the nighttime catches (Section 3.2.4). It is possible that the juveniles utilizing the epibenthic habitat during the day do move offshore at night but mostly into the area within 100 m of shore. The juveniles utilizing the pelagic zone do not appear to display a nocturnal offshore movement.

3.3.2.3 Effect of Piers and Wharves on the Offshore Migration

As discussed in Section 3.3.2.2 of this report, the catch of chum juveniles with the townet did not decrease around the perimeter of the piers, although these transects were far enough from shore so that a decrease was expected. The catch was higher for the transect inside EHW than for all other transects. Thus, we conclude that there was an offshore movement of the juvenile chum around the piers and also a buildup of juveniles inside the perimeter of the one wharf studied. Before it can be accepted that this response of offshore movement may lead to increased predation on chum--as suggested by Gilhousen (1962) and Heiser and Finn (1970) for nearshore migrants--it must be shown that those chum captured around the wharves came, at least in part, from the nearshore zone.

The chum caught in the nearshore zone with the beach seine have a mean size smaller than those caught simultaneously with the townet in the pelagic zone (Figs. 3-10a and 3-10b). After this initial increase in size with increasing distance from shore, there is no further increase until over 300 m from shore when again there is an increase in mean size (Fig. 3-10c and Table 3-8). The townet transects along the east shore vary from 75 m from shore, on unobstructed shorelines, to 400 m from shore around the Delta Pier. Along these transects, the mean size would be expected to be constant or increasing slightly offshore around piers. A two-way analysis of variance, with the lengths of chum fry as the dependent variable and sampling transect and week and the independent variables (Table 3-8) was applied using weeks (May-July) with catches of at least 25 chum fry per transect. Two distinct groups of transects were distinguishable. The three transects at the south of the Base, from King's Spit to the Delta Pier, had a larger mean size of chum than the four transects at the north of the Base from Marginal Wharf to Floral Point. Length frequency distributions of the catches showed the decrease in the mean size at the north of the Base to be due to an increased number of smaller fish, while the range in size remained the same. This decrease in mean size was still evident at Floral Point after the major wharves had been passed. Apparently chum in the nearshore environment moved offshore when they encountered shoreline structures. Such an offshore movement could increase the availability of the fry to predators, although at the Bangor Annex we found no significant predation (Section 5.0).

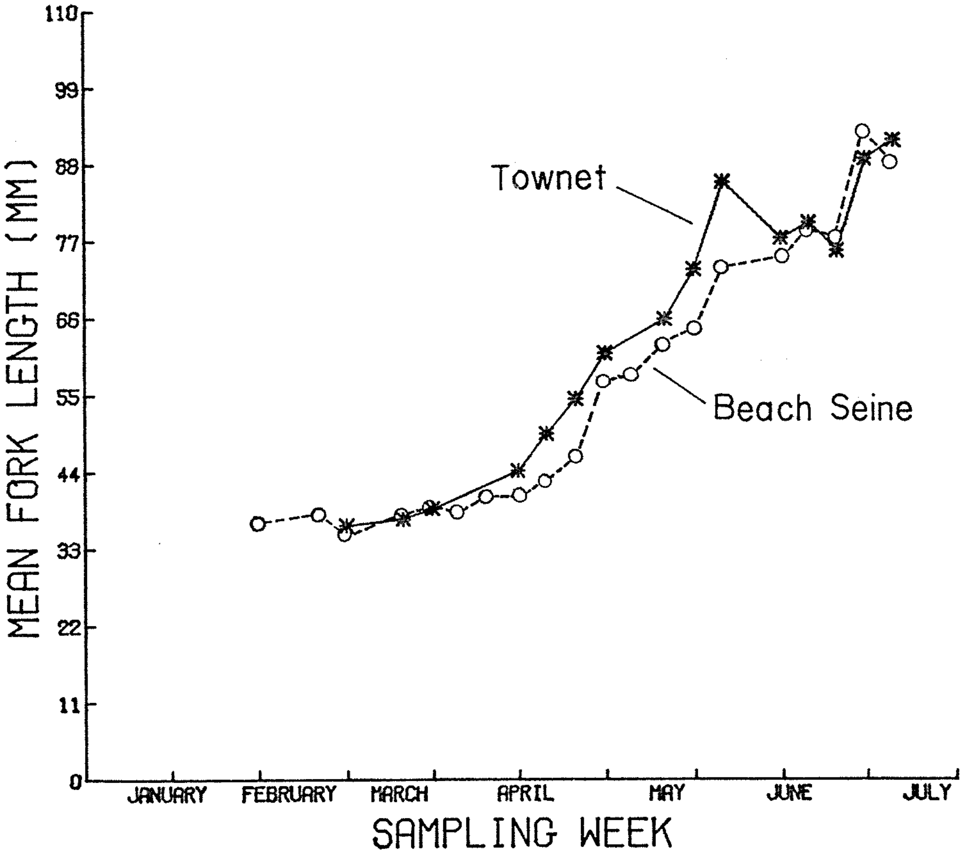

Fig. 3-10a. Comparison of the mean length of chum juveniles caught with the beach seine and the townet in 1979.

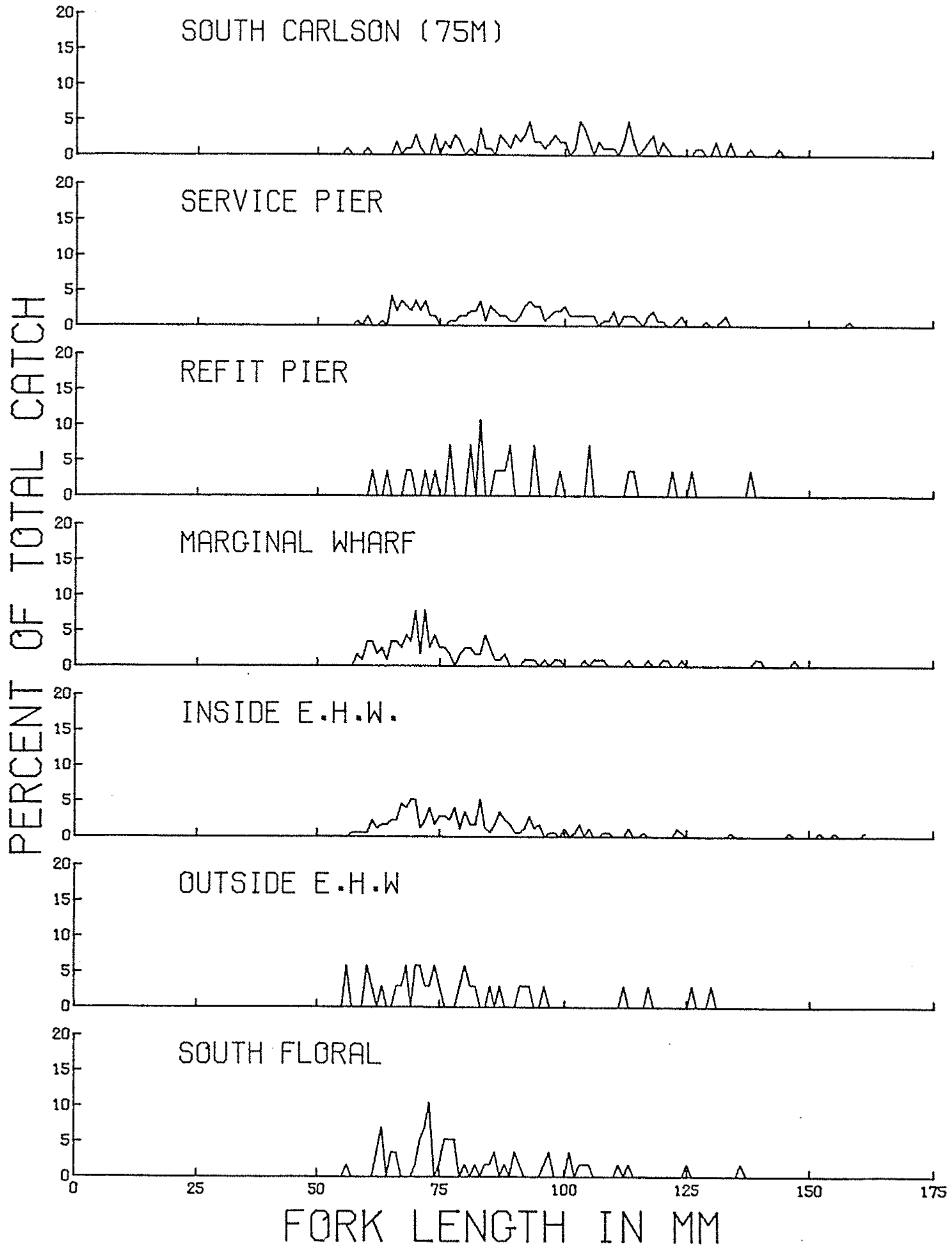

Fig. 3-10b. Percent length frequency distribution of juvenile chums caught with the surface townet along the Bangor Annex shoreline on July 4, 1979.

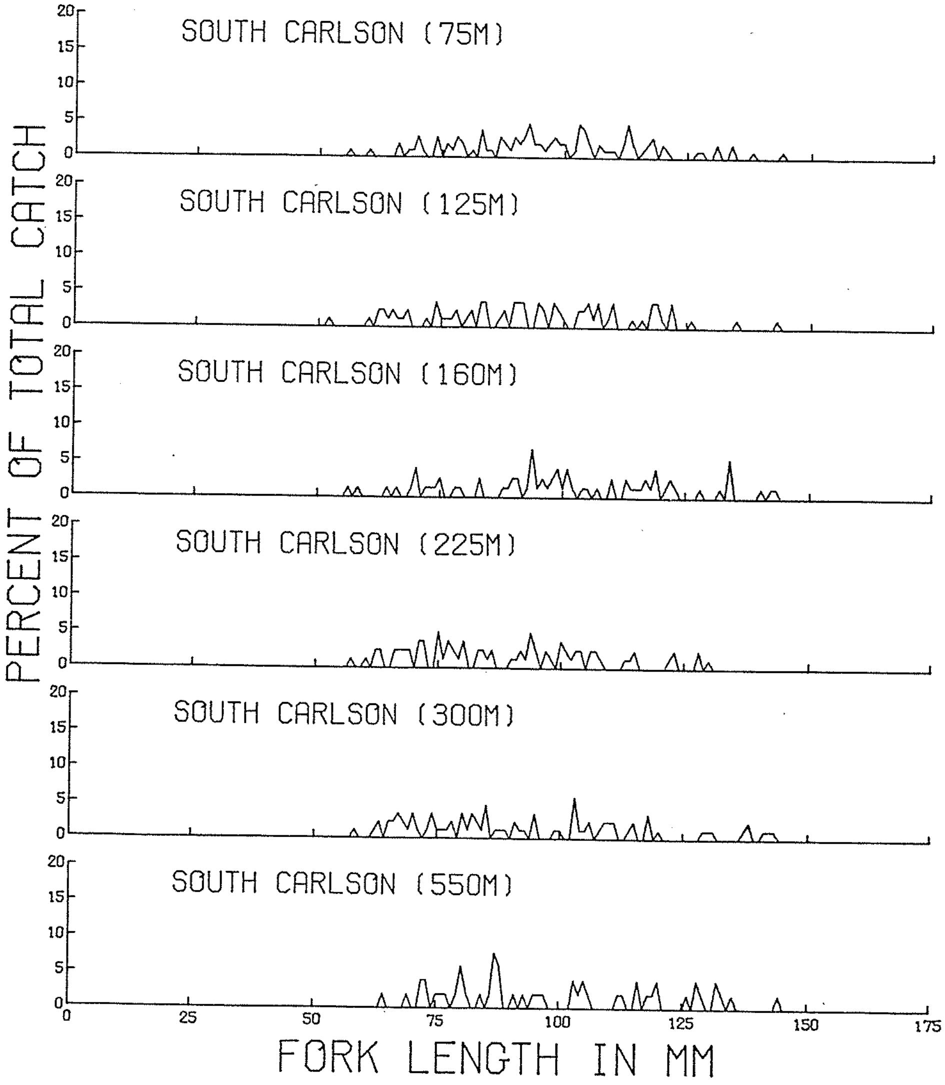

Fig. 3-10c. Percent length frequency distribution of juvenile chums caught with the surface townet at varying distances from shore on July 4, 1979.

Table 3-8. Analysis of variance showing changes in the size of chum fry caught with the surface townet at Bangor Annex from June 11 to July 4, 1979.

Parallel transects
ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	656,041.019	2,402			
Cells	142,769.519	8	17,847.190	84.378	.001
Location	2,733.035	5	546.607	2.584	.025
Week	140,572.781	3	46,857.594	221.546	.001
2-way interaction	10,106.339	15	673.756	3.186	.001
Error	503,165.161	2,379	211.503		

Significant groups in multiple comparison*

Distance from shore (m)	160	225	75	125	300	550
$\bar{x}$	80.96	81.08	81.53	81.64	81.88	84.44
Groups						

Table 3-8. Analysis of variance showing changes in the size of chum fry caught with the surface townet at Bangor Annex from June 11 to July 4, 1979 - continued.

Shoreline transects

ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	632,975.244	2,912			
Cells	78,030.182	9	8,760.020	47.583	.001
Location	25,235.069	6	4,205.845	23.082	.001
Week	61,149.630	3	20,383.210	111.867	.001
2-way interaction	29,087.982	17	1,711.058	9.391	.001
Error	525,857.080	2,886	182.210		

Significant groups in multiple comparison*

Location	South Carlson	Refit Pier	Service Pier	South Floral	Inside EHW	Outside EHW	Marginal Wharf
$\bar{x}$	81.52	80.71	79.01	76.28	75.68	75.53	75.51
	———	———					
		———	———				
				———	———	———	———

---

*Locations not significantly different from each other (p = .05) are underlined.

3.3.3 Mark-recapture Results and Discussion

3.3.3.1 Migratory Behavior

3.3.3.1.1 Migration Rate. Marked groups of juvenile chum salmon were released from Big Beef Creek in February and March of 1978 and February, March, April, and June of 1979. In all of these releases the fish were approximately the same size (48-53 mm). The 1978 releases did not appear to migrate at the same rates as the 1979 and 1977 releases.

Marked releases in February and March of 1977 indicate the fish move approximately 13 km/day (km/day defined as the distance traveled by the peak of the distribution 3 days after release, divided by 3). In 1979 marked fish migrated at a rate of 9 km/day in February and 14 km/day in March. The migration rate in 1978 was considerably slower with fish moving 4 km/day in February and 5 km/day in March. The 1978 releases were characterized by marked fish migrating to Bangor within 1 or 2 days, but then residing at Bangor (EHW) for a period of time before migrating out of Hood Canal. This residence then affects the calculated migration rate. This difference in behavior could have been induced by the EHW security lighting (Prinslow, Salo, and Snyder 1979).

The migration rate in 1979 decreased as the outmigration season progressed; from 8 and 14 km/day in February and March to 7 in April and less than 3 in June. Marked releases in April and June 1977 from Hoodsport show the same trend as the 1979 Big Beef Creek releases. The rate of migration decreased from ∿ 8 km/day in April to ∿ 5 km/day in June.

The reason for this change in migration speed is unknown. We do not know if the fish are actually swimming faster earlier in the year or if the fish later in the year are just "hanging around." Fish early in the year may not swim any faster than later fish, but may utilize tidal action to a greater extent. While increased food availability during late spring may account for the difference in migration rates (Sec. 6.0), other factors such as temperature, tide-current, and visibility may also be involved and make speculation impractical.

3.3.3.1.2 Size of Fry Related to Migration Rate. To test the relationship between size and migration speed, a two-way Model I ANOVA was performed on day, speed, and length for marked fish captured in June 1979 by beach seine and townet. The speed was determined by taking the midpoint of the daily distributions and assigning "fast" to fish north of the midpoint and "slow" to those south. From this analysis it was determined that for the beach seine catches, larger fish ($\bar{x}$ = 51.8 mm) were traveling faster than smaller ($\bar{x}$ = 50.2 mm), and for the townet the opposite was true (Table 3-9). Both of these

Table 3-9. A two-way analysis of variance on the effect of sampling day and speed of migration on length of marked recaptures.

Source of variation	Sum of squares	DF	Mean square	F	Significance of F
			Beach seine		
Day	213.057	3	71.019	3.650	.014
Speed	166.262	1	166.262	8.545	.004
Interactions	266.664	3	88.888	4.568	.004
Residual	3560.815	183	19.458		
Total	4163.288	190	21.912		
			Townet		
Day	138.761	2	69.380	2.826	.070
Speed	121.191	1	121.191	4.937	.031
Interactions	185.187	2	92.593	3.772	.031
Residual	1080.098	44	24.548		
Total	1634.500	49	33.357		

analyses had significant unexplained interactions which indicate the migration speed is related (to some extent) to size, although it is not the only contributing factor (Table 3-9).

3.3.3.2 Growth Rate

In the experiment of June 1977 when marked fish were released from Hoodsport, over a 30-day period $\sim$2500 fish were captured and of these 168 were individually weighed and measured. These data were used to estimate growth rate.

Ricker (1975) states that over short periods of time an exponential curve may be used to express growth. An exponential curve was fitted, regressing log weight on day. From this regression the daily growth rate for June 1977 releases was calculated to be 5.8% body weight/day. A linear regression was fitted to condition factor on day, showing an increase of 17.3% over the 30-day study period.

Growth rates estimated from captured fish may be biased by one or more of the following:

1. The sampling gear may be size-selective, causing either an over- or underestimation of growth rate.
2. Size-selective mortality may have caused an overestimation of growth.
3. The larger fish in the population may have migrated out of Hood Canal (no longer available for sampling) causing an underestimation of growth rate.

The June release of marked fish was the only group in 1979 that was available for sampling for a period long enough to allow for an estimate of growth rate. Over a 25-day period, 339 marked fish were captured and their growth rate was calculated to be 6.7% body weight/day with a condition factor increase of 34.2%.

Differences in growth rates between the June 1977 and June 1979 groups were significant ($0.01 < p < 0.02$) by the student's t-test of the means which was used to compare slopes (Zar 1974, p. 228).

The difference in growth rates may be due to several factors:

1. There was a difference in food availability between years.
2. There was a difference in growth characteristics between the Hoodsport and Big Beef stocks.

3. There was a difference in the amount of energy used for migration, (i.e., a difference in migration swimming speed) instead of growth.

4. There was a difference in mortality between the Hoodsport and Big Beef stocks.

3.3.3.3 Survival Estimates

A survival estimate was derived from the February 1978 release of marked fish from Big Beef Creek. An effective release number (ER) was used and it is defined as the actual release (AR) number minus the loss of marks (LM) due to emigration from the sampling area (ER = AR - LM). (In this the emigration was from the east to west shores.) Marked fish were captured on the west shore only on day 1. Because the survival estimate was based on captures of marks on days 2 and 4, it was assumed that there was no loss of marks from the east to west shores. From these data the following survival estimates (± 95% confidence limits) were found:

1. Survival from day 0 to day 2 was 0.29 ± 0.21.
2. Survival from day 0 to day 4 was 0.14 ± 0.11.

The 1979 estimates were also based on marked fish released in February. The following assumptions were made:

1. The rate of loss to the west shore was estimated using only townet catches on day 2. Beach seine data were excluded because of unequal effort between the shores and few captures.

2. Day 2 catches were used because it was assumed that the movement to the west shore was a continuing process and would be better represented by data at the time of the second release.

3. The rate of loss to the west shore of the day 2 release of marks was the same as the rate of loss of the initial Big Beef Creek release after two days.

From these assumptions the rate of loss to the west shore was calculated as 38%. The survival estimate was then computed to be 0.44 ± 0.59 for the first 2 days of marine existence. It should be noted that, as discussed in Section 3.3.1.2.1, outmigration data do not indicate any east-west shore movement at Bangor. This is true for most of the fry migrating past Bangor Annex, in that the west-to-east movement takes place near the point of release, e.g., Hoodsport, George Adams, Hamma Hamma (Whitmus and Olsen 1979). Since most of the Hood Canal chum production is south of Bangor, by the time the fry have reached the Base the west-east movement has been reduced to an undetectable level. Releases from Big Beef are close enough to Bangor Annex that this movement is still detectable.

While these survival estimates for 1978 and 1979 must be regarded with some degree of caution due to the small number of captures, they give some indication that the juvenile chum experience heavy early marine mortality, as Parker (1965) proposed for pink salmon.

3.4 CONCLUSIONS

3.4.1 Outmigration Studies

1. Chum salmon juveniles were the predominant salmonid species in the survey area. Pink salmon juveniles were caught only in even years when they were the second most abundant. Far fewer coho and chinook smolts were caught than chums or pinks. A small number of adult chinook and adult and juvenile steelhead was caught.

2. Juvenile salmon abundance varied from year to year. These year-to-year variations were not related to the total hatchery releases for each year. Within any year, juvenile salmon abundance was closely related with individual hatchery releases.

3. The origins of the majority of juvenile salmonids in Hood Canal are rivers and hatcheries on the west shore. At Bangor Annex an equivalent or larger number of these juveniles are found on the east shore compared with the west shore. Evidence suggests that this crossing of the Canal occurs within the first few days after entry into the Canal.

4. Yearly changes in location preferences of juvenile chum salmon were found on the east shore of the survey area, but not on the west shore. It is suggested that these changes may be partly due to construction activities.

5. A decline in the nearshore catch of chum juveniles north of the major construction area relative to the east shore mean was found from 1976 to 1979. No compensatory increase in the catch in the offshore zone or on the west shore was observed.

6. The catch of juvenile chum decreased sharply with increasing distance from shore both at day and at night. Movement from the epibenthic zone to the pelagic zone (<125 m from shore) occurred at night. Juveniles already in the pelagic zone did not appear to move farther offshore at night.

7. The catch of juvenile chum offshore around the wharves was higher than in a corresponding distance offshore when wharves were not present. Length frequency analysis suggested that some of the smaller chum juveniles utilizing the nearshore environment moved offshore into the pelagic zone upon reaching the wharves.

8. As discussed in Sec. 5.0, there was no evidence of significant predation on the chum juveniles at the EHW; other wharf areas not sampled for predators.

3.4.2 Mark-recapture Studies

1. The migration rate of chum salmon fry emigrating from Hood Canal decreases during the outmigration season.

2. Migration speed is related (to some extent) to size.

3. Growth rates of chum salmon fry can be up to 6.7% body weight gain per day during their early marine existence.

4. Survival estimates were quite variable but indicate that there may be a high early marine mortality rate.

5. During 1978 some EHW lighting regimes appeared to delay outmigration.

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4.0 DREDGE MONITORING

by

Thomas E. Prinslow

4.1 INTRODUCTION

In 1975 the U.S. Department of the Navy requested the Fisheries Research Institute (FRI) of the University of Washington to survey the literature on suspended sediments to help predict any effects on salmon of dredging operations proposed for a gravity drydock at the U.S. Naval Submarine Base--Bangor on Hood Canal, Washington (Plate I). The dredge site was located in a primary feeding, rearing, and migrating passageway for chum, coho, and chinook juvenile salmon (Schreiner 1977). The proposed dredging period coincided with salmonid outmigrations, which would expose the salmon to dredge-created suspended sediments.

Following the literature review the Navy contracted FRI to monitor the effects of dredging during the salmonid outmigration period.

Dredging creates higher suspended sediment concentrations than normally found under natural conditions. Impacts are variable, often temporary and localized, and usually have a severe impact on the benthos; most studies have concerned these benthic effects (*see* Mortensen, Snyder and Salo 1976 for review).

4.1.1 *Preliminary Studies*

4.1.1.1 *Literature Review*

Mortensen et al. (1976) found that 1) directly, suspended solids (including organic compounds as well as sediments) may harm and even kill fish by clogging gills and/or abrading skin, and by lowering fishes' resistance to disease, 2) indirectly, suspended solids screen out light, thus limiting primary production and oxygen production through photosynthesis, reduce the dissolved oxygen level by exposing nutrients to bacterial breakdown, and release toxic substances into the surrounding waters; 3) the effects of suspended solids depend largely on characteristics such as size, shape, and concentration of the sediment particles as well as the amount of organic and toxic materials released by the suspension of these sediments; and 4) no specific criteria had been established on the concentration of suspended sediments allowable in the habitat of juvenile salmonids.

4.1.1.2 Baseline Criteria

To establish these baseline criteria, Martin, Salo and Snyder (1977) conducted preliminary static and avoidance-behavior bioassays on salmonids from near the proposed construction site. The authors concluded that the condition of the salmon was critical to their ability to withstand different levels of suspended sediment. Healthy fish withstood concentrations of 3056 mg/liter, while fish infected with disease (vibriosis) had LC_{50} values of only 81 mg/liter. It was unknown whether the salmon contracted the disease because of some experimental procedure, or whether the disease was present in the outmigrating populations. The salmon avoided a sediment plume created in the laboratory of about 70 mg/liter. It was unknown how fish might respond in their natural environment, but the results suggested that sediment concentrations of 70+ mg/liter might impact the oumigrating salmon.

4.1.2 Dredge Monitoring Program

4.1.2.1 Inception

Consequently, during October 1976 the U.S. Navy Department of Ecology (USNDE) sought to establish what concentration of sediment the dredging operation at Bangor would generate. On-site tests with actual dredging equipment produced sediment concentrations of less than 30 mg/liter in the nearshore migration area (up to 30 m from shore) of the salmon. This was believed to be a tolerable concentration for the outmigrants, although the effects of dredging, even limited to these concentrations, were unknown. Therefore, the Washington State Department of Fisheries (WDF) recommended that dredging be monitored for impact on salmon and benthos. A cooperative monitoring program was agreed upon by the U.S. Navy, WDF, and FRI (Fig. 4-1). The USNDE and WDF were responsible for monitoring water quality in the dredging area, especially within the 30-m shorline zone, and both agencies gathered data on sediments and evaluated the impact on shellfish populations. Aerial surveillance was provided by the U.S. Navy to determine the shape, direction, and extent of the plume formed by the suspended sediments. Washington Department of Fisheries provided general surveillance of the program. Fisheries Research Institute monitored the impact of dredging on juvenile salmon. A detailed analysis appears in Salo et al. (1979). The following sections provide a brief overview.

4.1.2.2 Experimental Objectives and Design

To determine any impact of dredging on juvenile salmon, FRI conducted laboratory and field experiments with juvenile chum (*Oncorhychus keta*):

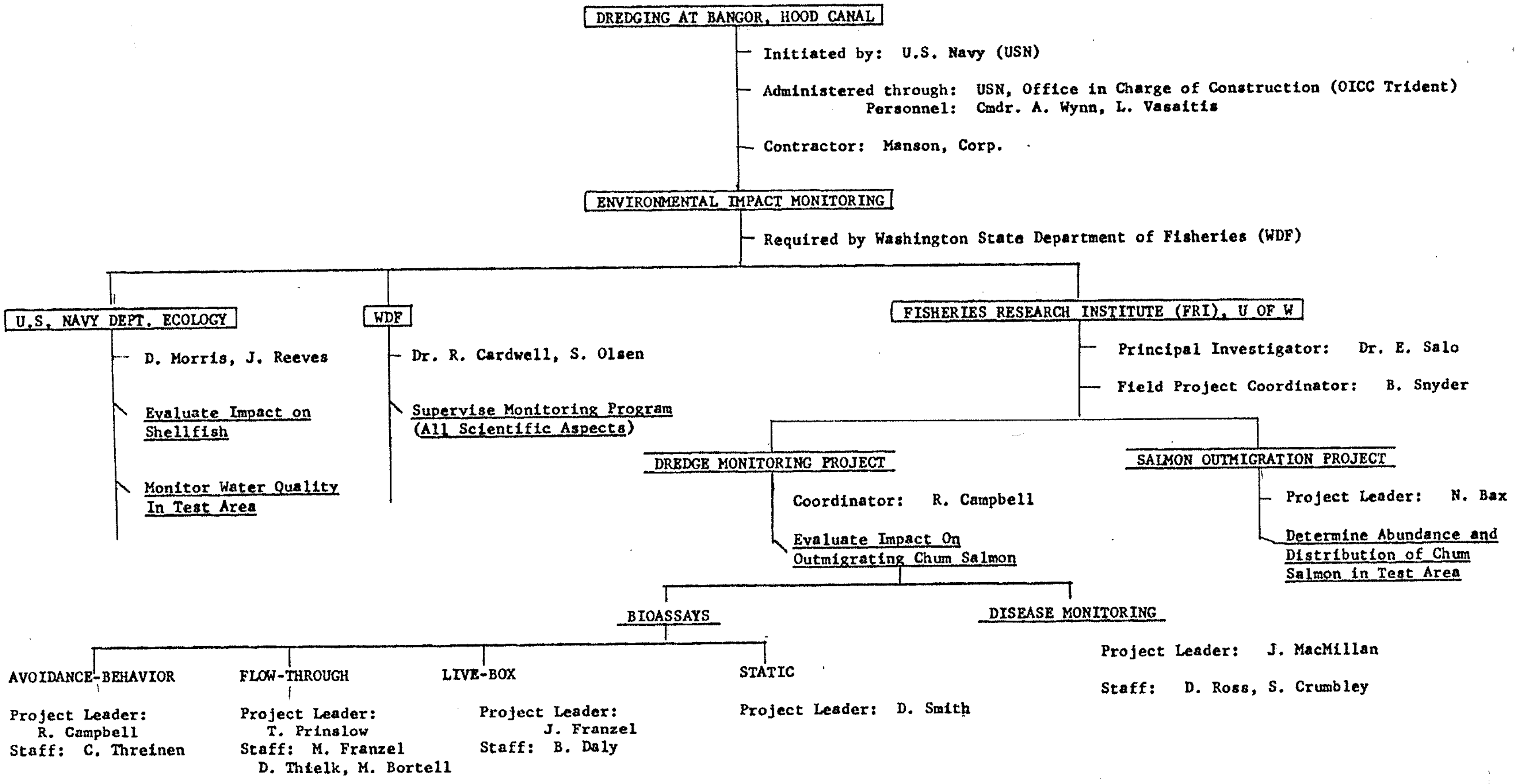

Fig. 4-1. Cooperative scheme for monitoring dredging at Bangor.

Static Bioassays (Fig. 4-2) were laboratory-based experiments subjecting chum held in tanks to different concentrations of suspended sediments from the dredge site for various lengths of time to determine median lethal concentrations (LC_{50}s) and any sublethal stress measured as changes in blood plasma glucose concentrations.

Flow-through Bioassays (Fig. 4-3) were designed to simulate dredge-area conditions in the laboratory by pumping seawater continuously for 96 hr periods from the area to raceway troughs which contained the juvenile chum.

Live-box Bioassays (Fig. 4-4) directly exposed test chum to dredge site conditions by mooring the boxes containing chum at four locations surrounding, and as close to the dredge, as possible.

Avoidance-behavior Bioassays (Fig. 4-5) comprised both laboratory and field experiments. Field tests were designed to detect any avoidance of the dredging area or of the sediment plume by the migrating salmonids. A 37-m floating beach seine and a 3- x 6-m surface trawl (townet) (Plates III and V) were used to sample the area. Concurrent laboratory tests determined threshold avoidance levels by offering chum a choice of water containing various concentrations of suspended sediments or control water without sediments.

Incidence of Disease in bioassay chum and "wild" chum migrating through the area was monitored to determine if exposure to suspended sediments increased their susceptibility to pathogens.

These experiments were conducted from 1 wk before to 1 wk after the dredging period. The University of Washington's floating research laboratory, RV KUMTUKS, which was moored 500 m north of the dredge site, housed the static, flow-through and avoidance-behavior bioassays, and served as base for field operations.

4.1.2.3 Dredging at Bangor--Description

Between February and July 1977, approximately 171,000 m^3 of bottom sediments were dredged from Hood Canal using a 10-m^3 clam-shovel dredge to remove the two layer of sediment, recent alluvium (overburden) and glacial till. Sediments suspended by the dredge (Plate VI) formed a plume which was difficult to discern from either ground level or from the sea surface, but was clearly evident from the air. The sediments settled relatively fast and seldom did the concentrations of suspended sediments exceed 30 mg/liter along the shoreline. Strong currents continuously changed the shape, direction, and extent of the plume.

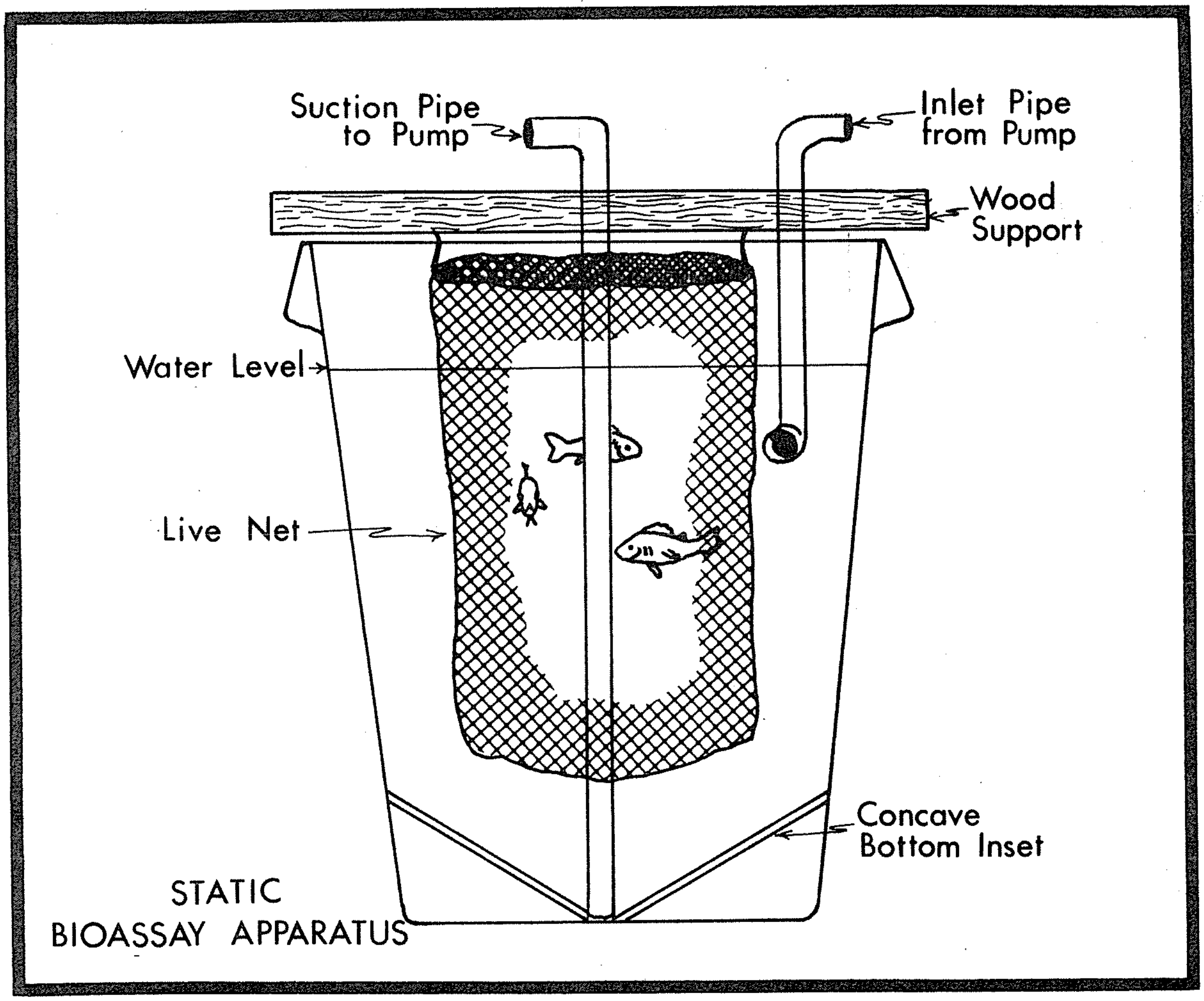

Fig. 4-2. Static bioassay apparatus.

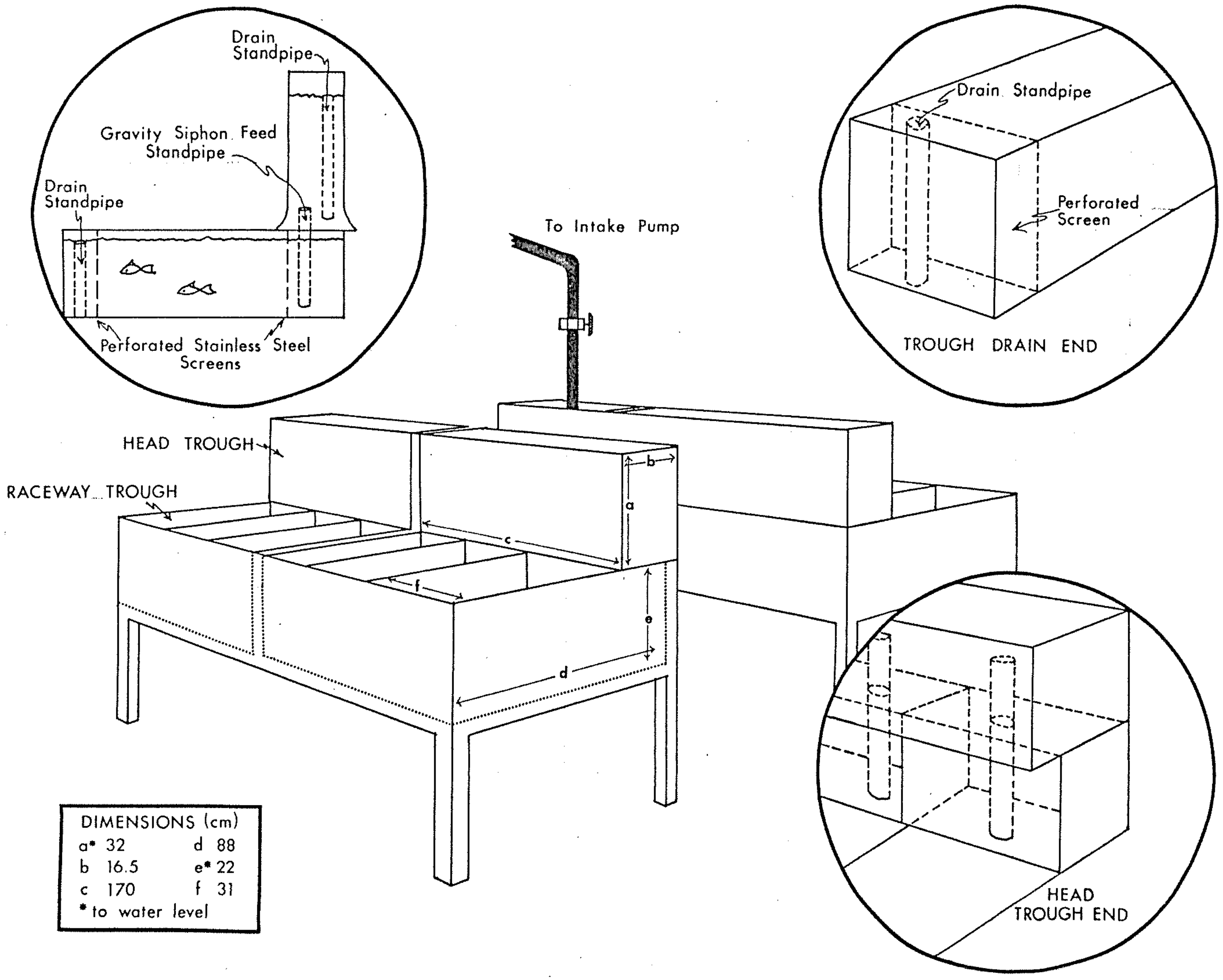

Fig. 4-3. Flow-through bioassay experimental tank system.

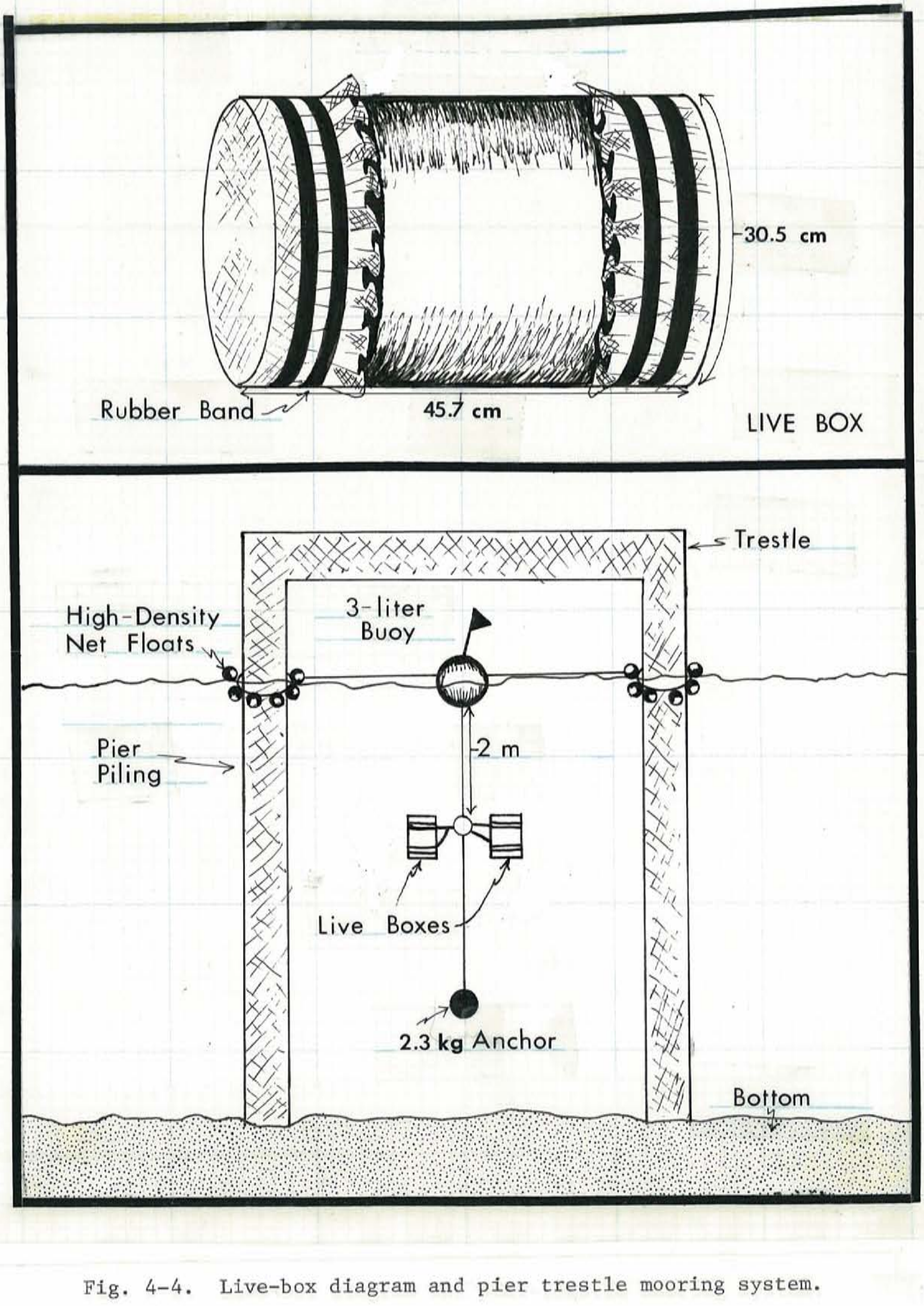

Fig. 4-4. Live-box diagram and pier trestle mooring system.

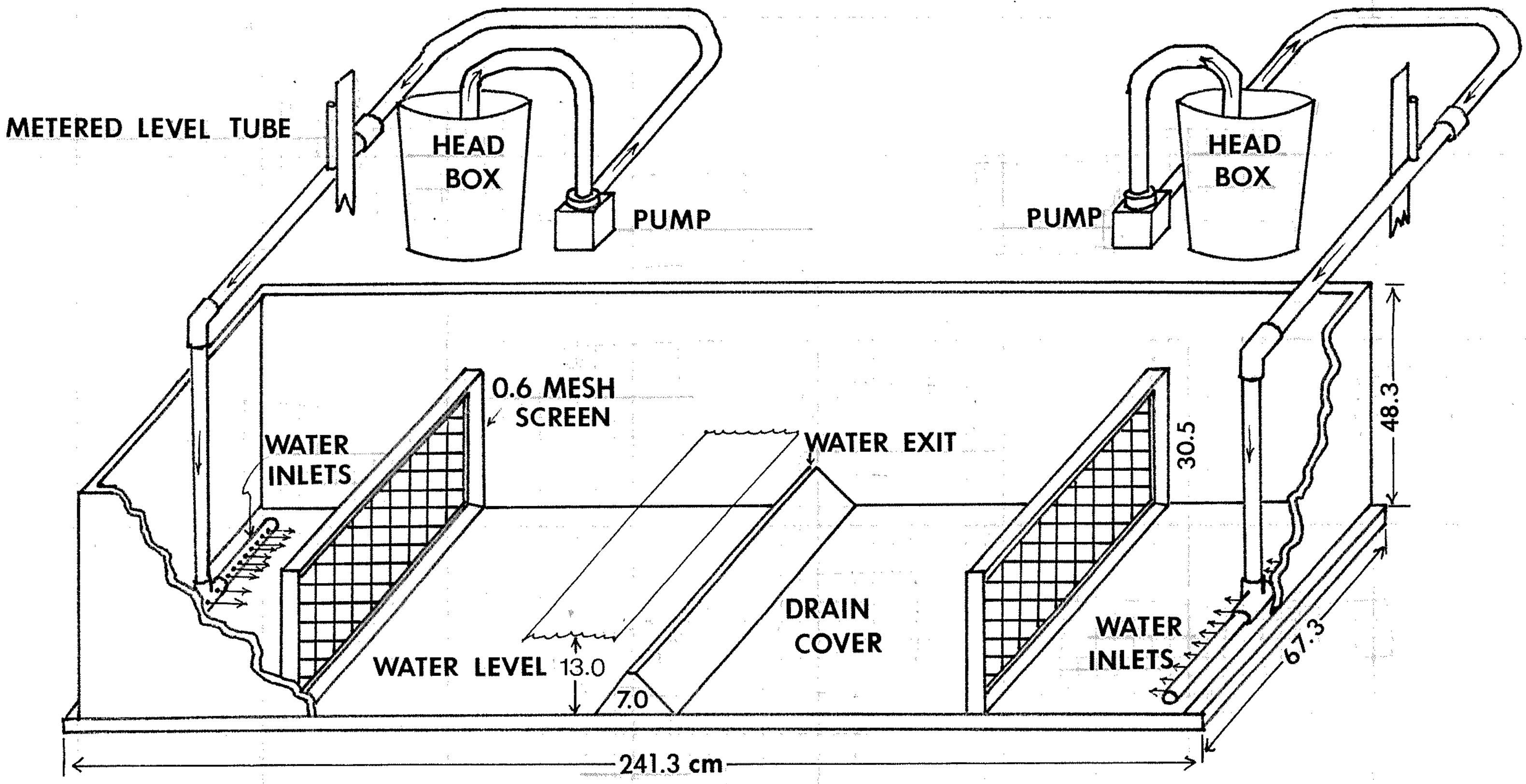

Fig. 4-5. Test chanber used during laboratory avoidance-behavior experiments. Water was delivered from head boxes to each end of the test chamber and exited through the center drain cover.

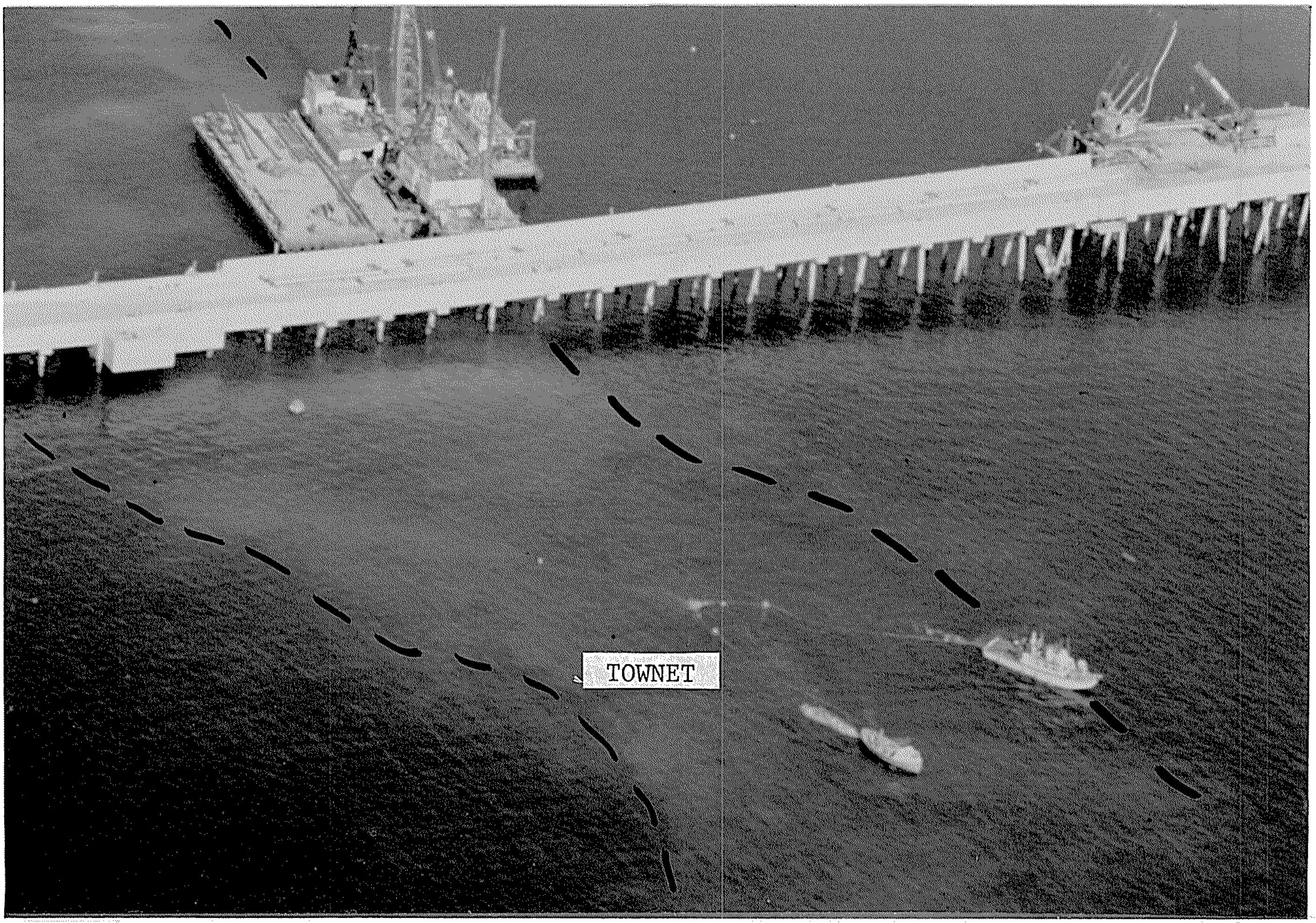

Plate V. Townetting through the dredging plume, Bangor, Hood Canal, Washington.

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Plate VI. Aerial view of dredge, scow, and plume at the Refit Pier; plume enveloping live boxes suspended from trestle.

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4.2 SALMON BIOASSAYS--RESULTS AND DISCUSSION

4.2.1 Static Bioassays

Ninety-six hour LC_{50} values for the static bioassays varied between 15.8 and 54.9 g/liter, three order of magnitude higher than suspended sediments concentrations found near the dredging operations (approximately 4-94 mg/liter). These data suggest that any direct effects suffered by chum salmon migrating through the dredging area were negligible.

The juvenile chum salmon were more tolerant of overburden (mean particle diameter = 0.044 mm) than of glacial till (mean particle diameter = 0.064 mm). Furthermore, larger fish were more tolerant than smaller fish. Difference in dissolved metal concentrations accounted in whole or in part for the differences in tolerance of the salmon to the two types of sediment.

There was no significant difference in blood plasma glucose concentrations between controls and test fish subjected to 150-200 mg/liter glacial till, suggesting that chum exposed to suspended sediments in the dredge area (maximum recorded concentration = 94 mg/liter) were not significantly stressed.

4.2.2 Flow-through Bioassays

Suspended sediment concentrations in test trough water, averaging 10 mg/liter with a maximum of 37 mg/liter, did not lethally affect chum. Chum mortalities experienced from mid-May on were associated with increasing water temperatures, disease epizootics, and handling stresses.

4.2.3 Live-box Bioassays

Suspended sediment concentrations at the four test sites averaged 9.4 mg/liter for the study with a range of 4.0 to 94.0 mg/liter. Mortalities were <2% from January to mid-May; increasing mortalities thereafter were associated with decreasing condition of the fish and an onset of disease, but not with suspended sediment.

4.2.4 Avoidance-behavior Bioassays

In both the field and the laboratory, any avoidance by the chum appeared to be caused by the concentration of the sediments and not by any contaminants that might be associated with the sediments. Although static bioassays suggested that tolerance was affected by contaminants, evidently avoidance was not.

In some townet transects near the dredge area, chum abundance was correlated with tide height except when the ebb tide was accompanied by an increase in suspended sediment concentrations from 2.0 to 9.8 mg/liter above ambient (ambient concentrations--10 mg/liter). This was interpreted as avoidance. Chum avoiding the plume appeared to disperse during daylight and accumulate on the edge of the plume after dark.

In laboratory tests no significant response was detected with overburden sediments ranging from 25.6 to 262.0 mg/liter. There was an increased frequency of avoidance to glacial till as the concentrations increased from 35 to 190 mg/liter. Based on the laboratory tests, a conservative threshold avoidance concentration of glacial till for chum was 182 mg/liter. It was unknown why this concentration was nine times greater than concentrations in the field which elicited avoidance.

4.2.5 Disease Monitoring

Dredging did not increase the incidence of disease as <2% of the chums caught in the dredging area had detectable diseases. Chums held in net pens for bioassays had few disease problems from February to April; however, from May through June when water temperatures exceeded 12°C mortalities increased until a 100% mortality from vibrosis was experienced even in isolated pens holding chums at low densities. This indicates that chums are extremely sensitive when confined, leading one to speculate on the possible stress imposed on hatchery stocks released into the natural environment late in the season.

4.2.6 Comments on Technique

Bioassays evaluating environmental stress such as dredging face design problems different from static bioassays monitoring controlled levels of known toxicants. Sprague (1973) describes the use of live boxes in outfall studies where "the character of the waste and its toxicity would usually be fluctuating with time". Such field bioassays expose test organisms to actual conditions, but at the expense of convenience, monitoring frequency and precision associated with laboratory bioassays. Field bioassays also encounter problems of suitable control sites and physical destruction of equipment (Finn 1975; Salo et al. 1979). One study of dredging impact on salmonids (Wright, Phinney, and Brix 1977) comprised of moving a laboratory-contained flowthrough bioassay to the dredge site. The FRI dredging study at Bangor incorporated both strategies, using four on-site laboratory and field bioassays. The following discussion highlights a detailed critique appearing in Salo et al. (1979).

Of the four bioassays, the live-box most effectively exposed the test salmonids to actual dredging conditions. For example, because the concentration of suspended sediment in the plume varied with intensity of dredging activity, type of sediment layer dredged and currents, live boxes moored directly in the dredging area were superior to the fixed test water intake system of the flow-through bioassay. Encumbent difficulties with the live-box bioassay of monitoring *in situ* water quality and fish response would be eased by continuous recording devices and viewing windows in the live box itself such as those described by Bardach, Ryther and McLarney (1972, p. 188).

In conclusion, bioassays monitoring the impact of a fluctuating stress must strategically locate test sites to incorporate the full range of stress conditions, and sample exhaustively to quantify the variations in the stress.

4.3 CONCLUSIONS

1) Suspended solids in the dredge area were neither lethal, to chum salmon nor did they increase the incidence of diseases of the juvenile salmon in either live-box or flow-through bioassays.

2) Concentrations of suspended solids in the dredge area were generally <30 mg/liter (as Total Nonfilterable Residue, TNFR). The maximum concentration measured was 94 mg/liter.

3) Laboratory-based static and avoidance behavior bioassays established 96-hr LC_{50} values of 15,800-54,900 mg/liter and threshold avoidance levels of 182 mg/liter (avoidance of suspended solids).

4) There was evidence of avoidance of suspended solids by outmigrating salmon in the dredge area at lower levels (2-10 mg/liter above ambient), but any negative impact was not detected.

5) Sediment particles, rather than organic or toxic materials released, elicited these responses.

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5.0 EFFECTS OF A LIGHTED WHARF ON JUVENILE SALMON: SUMMARY OF STUDIES CONDUCTED 1976-1979.

by

Thomas E. Prinslow

5.1 INTRODUCTION

During 1976-1977 the U. S. Navy constructed a wharf to load and unload the Trident Missile at the U. S. Naval Submarine Base - Bangor on Hood Canal, Washington (Fig. 1-2). Security lighting at the wharf, called the Explosives Handling Wharf (EHW), illuminates the surface of the water under the pier portion of the structure and the large covered submarine berth (Plate II). Because little was known of the effects of the lighting on migrating salmon and resident fishes in the Canal, the Washington State Department of Fisheries (WDF) required the U.S. Navy to assess any impact of the EHW lighting on outmigrating salmonids - primarily chum (*Oncorhynchus keta*) on an annual basis and pink (*O. gorbuscha*) on the even years (Schreiner 1977). Consequently, a literature review and three field studies were conducted between 1976 and 1979 to supplement ongoing Navy-supported research by the Fisheries Research Institute (FRI) of the University of Washington on salmon outmigration in Hood Canal (see Schreiner et al. 1977; Bax et al. 1978; Bax, Salo, and Snyder 1979; and Sec. 3.0 of this report). This section reviews the objectives, results and conclusions of the previous studies. Recommendations regarding the use of wharf lighting and areas requiring further investigation are in Sec. 8.0.

5.2 PREVIOUS STUDIES

5.2.1 Overview: Empirical Approach vs. Classical Design

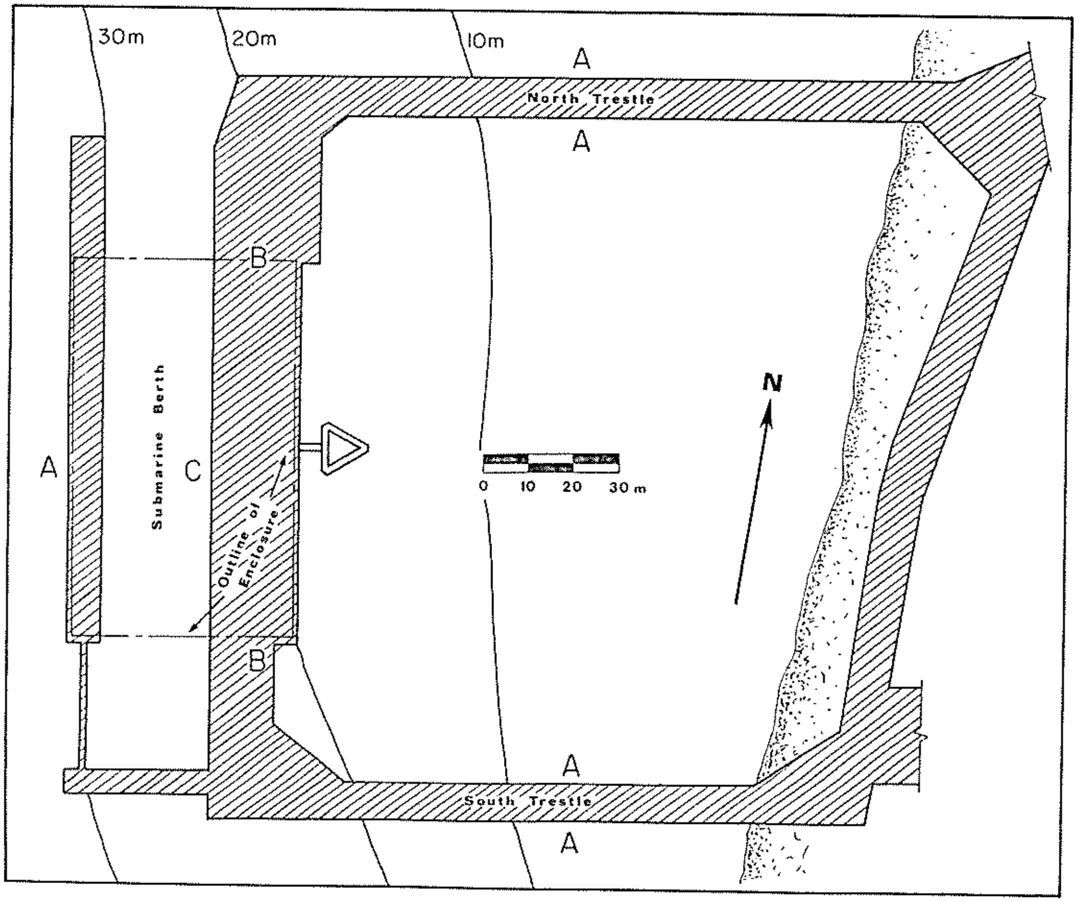
The 1976, 1978, and 1979 studies were not conceived as phases of a specific long-range project. Rather, objectives broadened and the sampling design grew more complex as additional studies evolved and each completed phase left questions unanswered; these became objectives for later investigation.

5.2.2 1976-1979 Studies: Objectives & Results

This section attempts to clarify the complicated sequence of studies by presenting the objectives and results of the four studies in a simplified question-answer format summarized in Table 5-1. The reader is referred to the separate annual reports for detailed discussion and analysis.

SECURITY

Light Zone	Fixture	Surface Intensity (ft-c)
A	150W Spot 35W SOX	0.2-1.2
B	150W Spot	0.3
C	40W Fluorescent	0.2



OPERATIONAL

Light Zone	Fixture	Surface Intensity (ft-c)
A	150W Spot 35W SOX 250, 400 & 500W Street	1.2-6.0
B	150W Spot	0.3
C	40W Fluorescent 1500W Quartz 400 & 1000W Metal Halide	30.1-38.3

Fig. 5- 1. EHW lighting areas showing difference in fixtures and intensity produced at the water's surface during security and operational modes; 10-m depth contours approximate.

Table 5-1. Summary of objectives and results of FRI lighting studies, 1976-1979.

1976	1976	1978	1979
Literature Review	Simulation of Security Lights	Tests of Partial Operational Lights	Tests of Security Lights
OBJECTIVES	OBJECTIVES	OBJECTIVES	OBJECTIVES
1. What does existing literature suggest about the effect of pier lights on juvenile salmon?	1. Do fish in Hood Canal (including but not limited to salmon) respond to pier lights (simulating those at EHW*)? 2. Do fish respond to different wavelengths (color) of light?	1. Do salmon respond to EHW lights (at ∿ 1/2 operational intensities)? 2. Do salmon respond to the unlighted wharf? 3. Are salmon delayed in their migration by any response to the unlighted wharf or partial operational lights?	1. Do EHW security lights affect predation on salmon? 2. Are salmon delayed in their migration by any response to the unlighted wharf or to security lights? 3. Do salmon respond to wharf or light stimuli - i.e., is the response detected in 1978 repeatable? 4. Do salmon respond to different wavelengths of light?
RESULTS	RESULTS	RESULTS	RESULTS
1. Salmon respond to light; whether the response is attraction or repulsion, and the degree of the response depends on light intensity.	1. Yes, fish are attracted to pier lights; unsure about salmon in particular. 2. Yes, greatest attraction to yellow or white, followed by amber, green, blue and red.	1. Yes, salmon are attracted to lights at night. 2. Yes, salmon are attracted to the wharf during the day, but not at night. 3. Outmigration delayed by 1-2 days (see Sec. 5.2.4).	1. No. security lights do not affect predation. Predation rate (as measured by purse seine, beach seine and townet catches of pelagic piscivorous predators and their gut contents) was insignificant with lights on or off. (Bottom-dwelling piscivores - rockfish, ling cod, cabezon - not sampled). 2. No, salmon are not delayed. 3. Inconclusive; wharf and light stimuli in 1979 were different from 1978's. Seasonally, salmon attracted to wharf but not lights. Nightly, salmon sometimes attracted to lights, but not consistently. 4. Inconclusive; only two colors tested and not enough samples.

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*The EHW was under construction during these experiments.

5.2.2.1 1976 Literature Review (Salo 1976)

Q: What does existing literature suggest about the effect of pier lights on juvenile salmon?

A: Salmon respond to light; at times it is an attraction and at other times is is a repulsion, and the degree of the response depend upon light intensity.

5.2.2.2 1976 Pier Lighting (Salo, Salo and Snyder 1977) Simulation of Security Lights

Q: Do fish in Hood Canal (including but not limited to salmon) respond to pier lights (simulating those at EHW[1])?

A: Yes, fish are attracted to pier lights; unsure about salmon in particular.

Q: Do fish respond to different wavelengths (color) of light?

A: Yes, greatest attraction to yellow or white, followed by amber, green, blue, and red.

5.2.2.3 1978 Pier Lighting (Prinslow, Salo and Snyder 1979) Tests of "Security Lighting" (∿ 0.2 - 1.0 ft-c) and Partial Operational Lighting"(∿ 20 ft-c)[2]

Q: Do salmon respond to EHW security lights?

A: Yes, salmon are attracted to the security lighting, but the effect is localized to within 5-10 m of the wharf (*see* Sec. 5.2).

Q: Do salmon respond to EHW lighting at ∿ 1/2 operational intensities?

A: Inconclusive; salmon appeared to be attracted to operational lighting at night, but sampling effort was inadequate to confirm this effect.

Q: Do salmon respond to the unlighted wharf?

A: Yes, salmon are attracted to the wharf during the day, but not at night.

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[1] The EHW was under construction during these experiments.

[2] For definition of "Security Lighting" and "Operational Lighting" see page 5-5.

Q: Are salmon delayed in their migration by a response either to the unlighted wharf or to the partial operational lighting mode?

A: Outmigration maybe delayed by 1-2 days (*see* Sec. 5.2.4).

5.2.2.4 1979 Pier Lighting (Prinslow et al. 1979)

Tests of Security Lights (0.2 ft-c)

Q: Does EHW security lighting affect predation on salmon?

A: No, security lighting does not affect predation. Predation rate (as measured by the gut contents of pelagic piscivorous predators captured by purse seine, beach seine, and townet catches) was insignificant with lights on or off. (Bottom-dwelling piscivores - rockfish, ling cod, cabezon - were not sampled).

Q: Are salmon delayed in their migration by any response to the unlighted wharf or to the security lighting mode?

A: No, salmon are not delayed.

Q: Do salmon respond to wharf or light stimuli - i.e., is the response detected in 1978 repeatable?

A: Yes, salmon respond to the security lighting mode in 1979 as they did to the same mode in 1978; operational lighting mode not tested in this respect (in 1979). At night, salmon attracted to unlighted wharf area, probably in response to food organisms in eelgrass beds adjacent to wharf. Area not sampled during day.

Q: Do salmon respond to different wavelengths of light?

A: Inconclusive; only two colors tested and not enough samples.

5.2.3 Differences among 1976-1979 Studies

Investigation of delay of migration and attraction to wharf and/or light stimuli was complicated as: there were differences in the lights being tested; the background of the area being tested had changed; the exposure of fish to extraneous lighting had changed; sampling techniques had changed; and possibly the behavior of the fish had changed as well.

5.2.3.1 Lights

EHW lighting has two modes: security and operational. Operational lighting is used whenever nuclear submarines are present at the wharf. Under present (1979) arrangements, security lighting provides 0.2-1.0 ft-c at the water surface, while operational lighting provides 0.2-6.0 ft-c below the pier trestles and 30.7-38.3 ft-c in the submarine berth. This intensity more than doubles that tested in 1978 which significantly attracted juvenile chum and pink salmon to the wharf. While thorough testing of salmonid response to these intensities was beyond the scope of work prescribed by the Navy, several brief experiments during June 1979 (see Prinslow et al. 1980) suggested a strong attraction. Similar operational lighting exists at the Refit Pier (see Fig. 1-2) and would be used at two additional wharves proposed for the Bangor shoreline.

The 1976 experiments simulated the proposed under-wharf security lighting because the EHW was under construction; only the south trestle was available for tests. During the 1978 tests lighting was complete and illuminated waters under the entire wharf, in particular the covered submarine berth which received approximately 20 ft-c at the water surface compared with ∿ 1 ft-c elsewhere below the wharf. This intensity was adequate to photograph, in color, night townetting operations (Plate IV). In contrast, the berth received only 0.2 ft-c during 1979 tests because the Navy revised the definition of lighting adequate for nightly inspections. Furthermore, the submarine berth received this amount of illumination every night so that, effectively, 1979 experiments did not sample this area under "control" (lights off) conditions. This could explain the attraction of chum to the lighted wharf during 1978 but not 1979, i.e., to "partially operational" but not "security lighting.

5.2.3.2 Sampling

The EHW presented a large and complex habitat to sample effectively. Lamp configurations, light intensities, presence of pilings and water depth varied around the wharf (Fig. 5-1). New techniques were added with each study to better define fish distribution and abundance, which also added complexity to interpreting results. For example, 1976 studies used hydroacoustic and visual surveys, which effectively monitored changes in fish distribution but did not identify species present. In 1978, studies used a 37-m beach seine and a 3 x 6-m townet (surface trawl), as well as visual surveys, to sample fish in the EHW area; these methods identified and enumerated the species but did not sample directly below the lights among the pilings where visual surveys suggested the fish congregated. Therefore 1979 studies again used hydroacoustic monitors to survey this area, but found that in many places the small separation between pilings (<1m) interfered with the acoustic echo. Furthermore, strong and variable currents prevented using gill or trammel nets, so chum distribution and abundance among the pilings remained unquantified. The 1979 study also sought to identify any predators on the juvenile salmon by collecting these fish with a 10 x 65-m purse seine (Fig. 5-2); yet this gear could not sample among the pilings either, so any benthic or pile-dwelling piscivores remained unidentified. Thus the conclusion that predation on chum at EHW was insignificant must be qualified to include only predators available to the purse seine.

5.2.3.3 Time and Emphasis

With the hindsight afforded by three seasons of studies, the <10-day periods allotted for 1976 and 1978 tests were inadequate. For example, the increased catch of chum in the nearshore areas at EHW in 1978 was interpreted as attraction to security lights; it appears, in view of intensive tests in 1979, to have been caused by some other stimulus, which we speculate may have been the presence of chum prey organisms characterizing this area (see Sec. 6.0). Even the intensive 6-month sampling efforts of the 1979 study left the issues of resident benthic and/or pile-dwelling predators, and prey response to wavelength (see below) unresolved. And additional time may not help: the EHW area is dynamic, with salmon migrating through in pulses of different size and timing. Changes are rapid and even daily descriptions of distribution and abundance are frustratingly inadequate (cf. mark-recapture attempts to track groups of chum - Whitmus and Olsen 1979, Prinslow et al. 1980, and Sec. 3.0 of this report). Yet we attempted to draw our conclusions from these estimates.

5.2.3.4 Behavior

One final complicating issue is that of predictable behavior. The 1976-1979 studies assumed that from year to year the different populations of juvenile salmonids would respond equally to the wharf and to the lights. Such responses may be affected by unmeasured environmental or physiological factors (Gallagher 1979).

5.2.4 Mark-recapture Data Re-evaluation

Prinslow et al. (1979) reported that the 1978 mark-recapture tests did not firmly establish whether or not EHW lighting delayed outmigrants; however, an analysis comparing 1978 results with those of 1977 and 1979 involving mark-recapture tests has shown that EHW lighting in 1978 was associated with a 1-2 day delay of outmigrants (Table 5-2). Lighting during the 1978 study was the most intense tested.

Migration rates computed for Table 5-2 were derived by: 1) tracking the chums for 3-4 days after release using beach seine and townet;

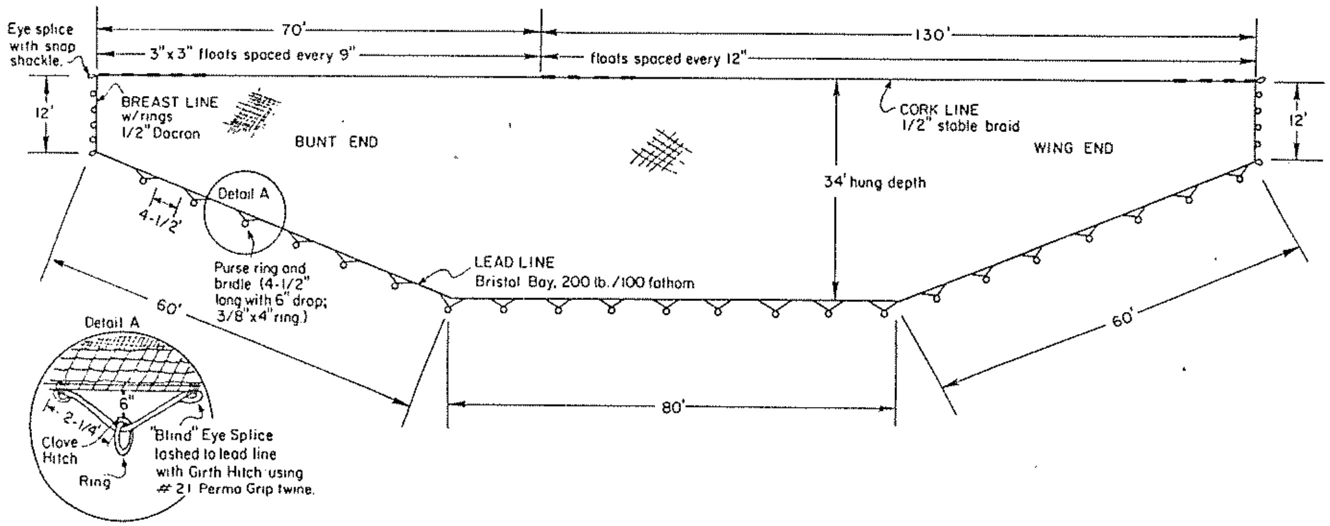


Fig. 5-2. Purse seine used during EHW lighting study, 1979. Bunt end consisted of two panels, one of 1/4-in mesh and one of 1/2-in mesh; the body and wing end consisted of 1-in mesh.

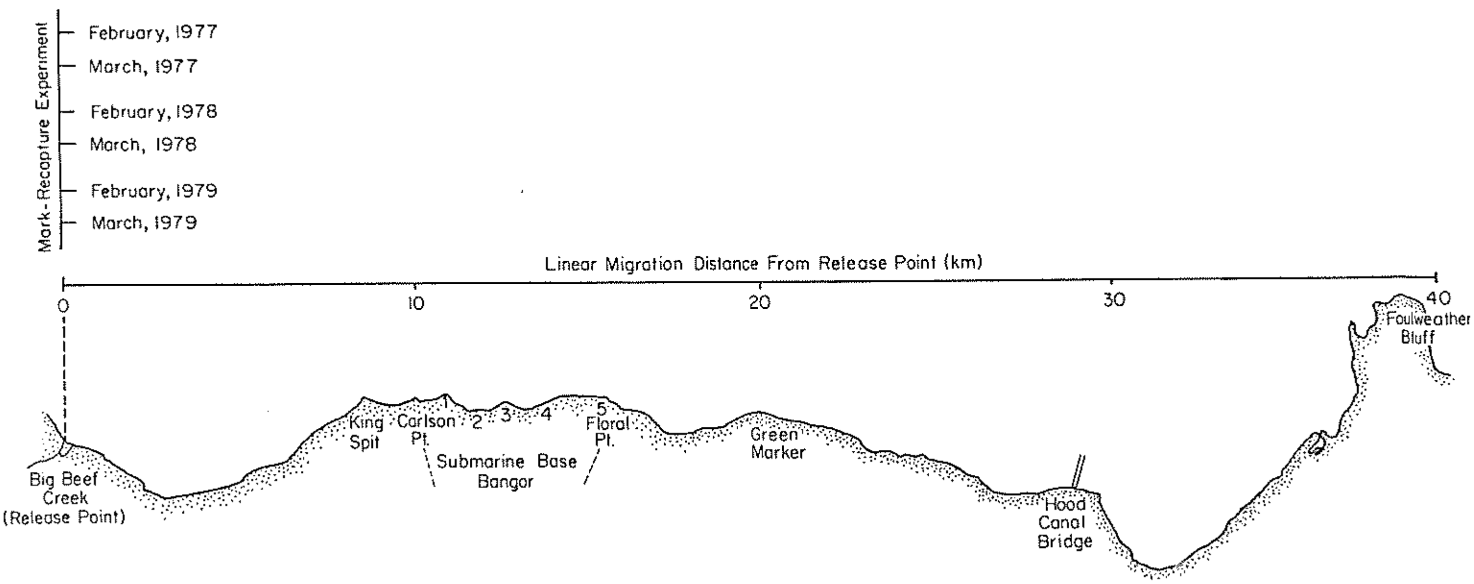
Table 5-2. Mark-recapture test results from February and March 1977, 1978 and 1979; chums released from Big Beef Creek and tracked for 3-4 days as they moved out of Hood Canal. Refer to diagram below for locations listed. Numbers 1, 2, 3, 4, and 5 in diagram refer to the Service Pier, Refit Pier, Marginal Wharf, EHW, and Magnetic Silencing Facility, respectively.

Test period	Population locus at day: 1	2	3	4	Average migration rate (km/day)
	(km from release point)				
February 1977	4	13	39	na[a]	13
March 1977	14	na	na	na	14
February 1978	13	13	13	na	4
March 1978	1	13	13	20	5
February 1979	8	16	na	na	8
March 1979	14	40+[b]	na	na	14

[a] na: not attempted

[b] none caught in surveys from Bangor to Foul Weather Bluff, so chum assumed to have passed out of Hood Canal

MIGRATION RATE (DISTANCE TRAVELED BY POPULATION LOCUS DURING DAYS 1-4 OF EXPERIMENT)



2) defining the location of the population on a given day as that area along the shoreline with the greatest catch-per-unit-effort (CPUE); and 3) then defining migration rate as the linear distance from release point to location of peak CPUE divided by the number of days after release when the peak CPUE was observed at that location.

During February and March 1977, chum migrated at ∿ 13 km/day in both tests (Table 5-2). The EHW is ∿13 km from the release point, so the chum reached and moved past the wharf within 2 days of release, and at that time the EHW was under construction and unlighted. During tests in February 1979, the EHW was completed but unlighted, and marked chum migrated at ∿8 km/day, moving constantly and passing EHW within 2 days of release. During tests in March 1979, the chum migrated faster (∿14 km/day), again passing the wharf within 2 days of release. In contrast, marked chum in February and March 1978 tests took the same time to reach the Base (1-2 days), but stayed longer at the Base (an additional 1-2 days versus <1 day in 1977 and 1979); the resulting migration rates were ∿4 km/day in February and ∿5 km/day in March. During February 1978 the operational lights were on full intensity (*see* Sec. 5.2.3.1), while in March 1978 they were about 1/2 operational in the submarine berth. While a 1-2 day delay of migration was associated with this intense (200-400 lux) lighting at EHW, it is unlikely that salmon attracted to the lights on their first night in the area would remain at the unlighted wharf through the following day until the next night, simply because of their first response to the lights. It is more likely that, once attracted to the wharf, they encountered favorable feeding conditions and remained an additional 1-2 days before moving on.

5.2.5 Wavelength Tests

Because attenuation of light in sea water is a function of wavelength, intensity, and depth, it was hypothesized that any attraction of salmonids to wharf lighting might be mitigated by manipulation of wavelength and intensity of these lights. Investigations begun in 1976 focused on security instead of operational lighting, as "security" is the more frequently used mode. Security lighting at EHW consists primarily of 150-W incandescent spotlamps below the trestles, and 35-W low-pressure sodium vapor (*SOX*) lamps affixed to the sides of the trestles. The spotlamps emit a "white" and the SOX lamps, a "yellow" light.

During preliminary tests in 1976 (Salo et al. 1977), spotlamps with colored glass lenses were substituted for the "white" spotlamps to alter wavelength. While the glass lenses did alter the *color* of emitted light (as detected by the human eye), they did not emit a narrow band of light associated with monochromatic lamps. For example, a "red" spotlamp emitted wavelengths from 400 to 800 nm while the entire visible spectrum is only 400-750 nm. Nonetheless, this simplistic approach found differential attraction of fish, with "white" and "yellow" lights most attractive, and "red" light least attractive. However, these tests were conducted in July when the majority of salmon migration was over and no attempt was made to identify and enumerate species attracted so it was unclear what proportion of attracted fish were salmon. Furthermore, it was unclear whether the color or the intensity of the light elicited the response. Subsequent tests in 1979, which were limited to "white" and "yellow" lights but incorporated net sampling, did not detect any attraction of chum to these lights. In view of the minimal response of chum to security lights at the EHW (*see* above), this is not surprising.

5.3 DISCUSSION

5.3.1 Use of Wharf Lighting

While thorough testing of salmonid response to operational intensities was beyond the scope of work prescribed by the Navy, several brief experiments during June 1979 (*see* Prinslow et al. 1980) suggested a strong attraction. Similar operational lighting exists at the Refit Pier (*see* Fig. 1-2) and would be used at the Service Pier presently under construction at Carlson Point.

Thus when the Base is in operation and a submarine is berthed during the period of salmon outmigration, the lights will probably attract the salmon to a degree dependent on intensity. Although mark-recapture experiments suggest that there will be no lingering effect, it is uncertain what impact frequency of use of operational lighting might have on outmigrants. Furthermore, gathering evidence (Parker 1965, 1977; Gunsolus 1978; Gallagher 1979) implicates the first weeks of marine existence of juvenile salmon as critical to their survival. Chum salmon from Hood Canal hatcheries pass the Bangor Base during this period and might be most sensitive to any perturbations resulting from the wharves and lighting.

Operational lighting at the Bangor Base would create a large area with light intensity comparable to dusk/dawn when predators are active and prey defense mechanisms are ineffective (Hobson 1979). This could impact salmon since, in contrast to present findings in Hood Canal, there are areas of Puget Sound where predation on juvenile salmonids is significant, e.g., Nisqually reach sea-run cutthroat trout diet is 24% juvenile salmonids (Fresh et al. 1979).

Although we did not find any harm accrued by juvenile salmon from *security lighting* at the EHW, this conclusion should not be incautiously applied to future operation of the Base as a whole under security and operational lighting modes. After several years of continuous lighted use, the wharves at Bangor might harbor increased populations of predators. The above-cited Nisqually study, as well as studies in the Columbia, Snake, and Sacramento rivers (Sims, Bentley, and Johnsen 1977 and 1978 ref. for Sacramento) and elsewhere (Cooney et al. 1978, Cardwell and Fresh 1979, in press) have demonstrated significant predation on juvenile salmonids as well as territoriality and apparent learned behavior (e.g., squawfish waiting for outmigrants at fish ladders or just below spillways). Any attraction of salmon to lighted facilities in such systems could result in increased predation.

5.4 CONCLUSIONS

With the above reservations noted, we conclude that:

1. EHW operational lighting (0.2-38.3 ft-c at water surface) may strongly attract outmigrating salmonids: 1978 tests at 20-40 ft-c significantly increased catch of salmon at the wharf, and delayed outmigration for 1-2 days.
2. EHW security lighting (0.2 - 1.2 ft-c at water surface) is an attractive stimulus to which outmigrating salmonids may respond; any effect appears to be temporary and localized within 5-10 m of the wharf.
3. The attraction to security lights was not evident at all times, suggesting that other factors may override the stimulus (Gallagher 1979).
4. Outmigrating salmon were also attracted to the unlighted wharf.
5. The wharf does not appear to harbor resident pelagic predator populations of adult salmon, trout, hake, sculpin or dogfish. Benthic or pile-dwelling predators may be present.
6. EHW security lighting appears to repel pelagic predators, i.e., catch with lights off was greater than with lights on. Alternately, this may simply reflect net avoidance.
7. Attraction to EHW does not appear to harm the outmigrating salmon.
8. Wavelength tests were inconclusive but the testing was not adequate.
9. Mark-recapture tests found a 1-2 day delay of migration caused by the operational lighting mode, but not by the security lighting mode or the wharf itself.
10. Acoustic tests located fish concentrating below lighted pier trestles but could not discriminate species recorded.

5.4.1 Implications for Future Study

5.4.1.1 Transition Zone

Proposed lighting at the Bangor Base would create a large area with light intensity comparable to dusk/dawn when predators are active and prey defense mechanisms are ineffective (Hobson 1979). This could impact herring fisheries and perhaps salmon since, in contrast to present findings in Hood Canal, there are systems where predation on juvenile salmonids is significant, e.g., Nisqually reach sea-run cutthroat trout diet is 24% juvenile salmonids (Fresh et al. 1979).

5.4.1.2 Wharves Effect

The four existing and three proposed wharves at Bangor would produce a 5-km-long reef-like habitat of pier pilings which might harbor increased populations of predators. The structural complexity, on the other hand, might also favor prey populations (Cooper and Crowder 1979).

The wharf lights might also increase production of phyto- and zooplankton, providing important nourishment for food-limited early-outmigrating salmonids (Simenstad and Kinney 1978). These early outmigrants are particularly important in maintaining genetically vigorous wild stocks.

5.4.2 Use of Wharf Lighting

Although we did not find any harm accrued by juvenile salmon from security lighting at the EHW, this conclusion should not be extrapolated to other freshwater, estuarine or marine facilities linked with salmon without first evaluating potential predation pressure or mechanical damage (e.g., turbines) in each system. The above-cited Nisqually study, as well as studies in the Columbia, Snake, and Sacramento rivers (Sims, Bentley and Johnson 1977 and 1978) and elsewhere (Cooney et al. 1978; Cardwell and Fresh 1979, in press) have demonstrated significant predation on juvenile salmonids as well as territoriality and apparent learned behavior (e.g., squawfish waiting for outmigrants at fish ladders or just below spillways). Any attraction of salmon to lighted facilities in such systems could result in increased predation.

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6.0 TROPHIC RELATIONSHIPS OF OUTMIGRATING CHUM AND PINK FRY, 1977-1979

by

Charles A. Simenstad

6.1 INTRODUCTION

6.1.1 Development of Studies

Interactions between the planktivorous salmon fry and their prey resources were examined as a part of the investigations of chum and pink fry outmigration in northern Hood Canal. Since the outmigration behavior of the juvenile salmon appears to depend upon the composition and availability of prey organisms (see below, 6.4.1), these influences had to be identified. It was also necessary to evaluate the importance of different shoreline habitats in supporting preferred food organisms of chum and pink fry.

Stomach contents of, and the planktonic prey communities utilized by, chum and pink fry were systematically sampled in conjunction with intensive sampling of juvenile salmonids. Support for the collections was derived principally from U.S. Navy funds, while laboratory processing, data analysis and interpretation were supported by the Washington State Department of Fisheries.

6.1.2 Objectives

The central objective of the studies was to document predator-prey interactions between migrating chum and pink fry and their epibenthic and neritic planktonic prey.

Component objectives were to:

1) Describe the temporal and spatial prey composition and consumption by chum and pink fry.

2) Describe the temporal and spatial composition of epibenthic and neritic zooplankton communities.

3) Evaluate the characteristic selective predation by chum and pink fry upon "available" zooplankton.

4) Evaluate trophic importance of characteristic nearshore habitats.

5) Correlate observed outmigration behavior of chum and pink fry with food habits and distribution and composition of prey resources.

6.1.3 Previous Reports of Results

Preliminary results of the trophic relationships studies in Hood Canal were reported in Simenstad (1977), Schreiner et al. (1977), Simenstad and Kinney (1978), Bax et al. (1978), and Simenstad and Kinney (1979).

6.2 MATERIALS AND METHODS

6.2.1 Fish Capture

(Described in Sec. 3.2)

6.2.2 Epibenthic and Neritic Zooplankton Sampling

Epibenthic zooplankton was collected from three shallow sublittoral habitats: at South Brown Point, North Carlson Point, and Devil's Hole Delta (*see* Fig. 3-1). While the two points are characterized by similar sand substrate with eelgrass, Brown Point is more affected by current and wave energy and has a steeper slope than Carlson Point. Devil's Hole Delta, the most protected habitat, is characterized by considerable eelgrass beds and is the only site with any freshwater dilution (from the small Devil's Hole creek/lake). Seasonal production of benthic algae is high between April and October at Devil's Hole and Carlson Point, but minimal at Brown Point.

Sampling was conducted from the 8-m whaleboat *Monty Python* anchored at approximately the -0.3-m tide level, using a SCUBA diver-operated suction pump, as described in Simenstad and Kinney (1978). The 1-m^2-area sampling cylinder that was used in 1977 was modified in 1978 by reducing the area to 0.25 m^2 and enclosing the top of the cylinder and peripheral portholes with 0.209-mm Nitex mesh in order to keep out extra-areal organisms (Fig. 6-1).

Epibenthic plankton samples totalled 84 (each in two fractions) in 1977, occurring biweekly between December 30, 1976 and July 22, 1977, from Brown Point, Carlson Point, and Devil's Hole. In 1978, 138 plankton pump samples were collected biweekly between February and December at these sites, including a diel series of 19 samples at Carlson Point on May 15. An additional 69 samples were collected at the Explosives Handling Wharf (EHW) in 1978. Forty-five epibenthic plankton samples were collected monthly between January and June in 1979.

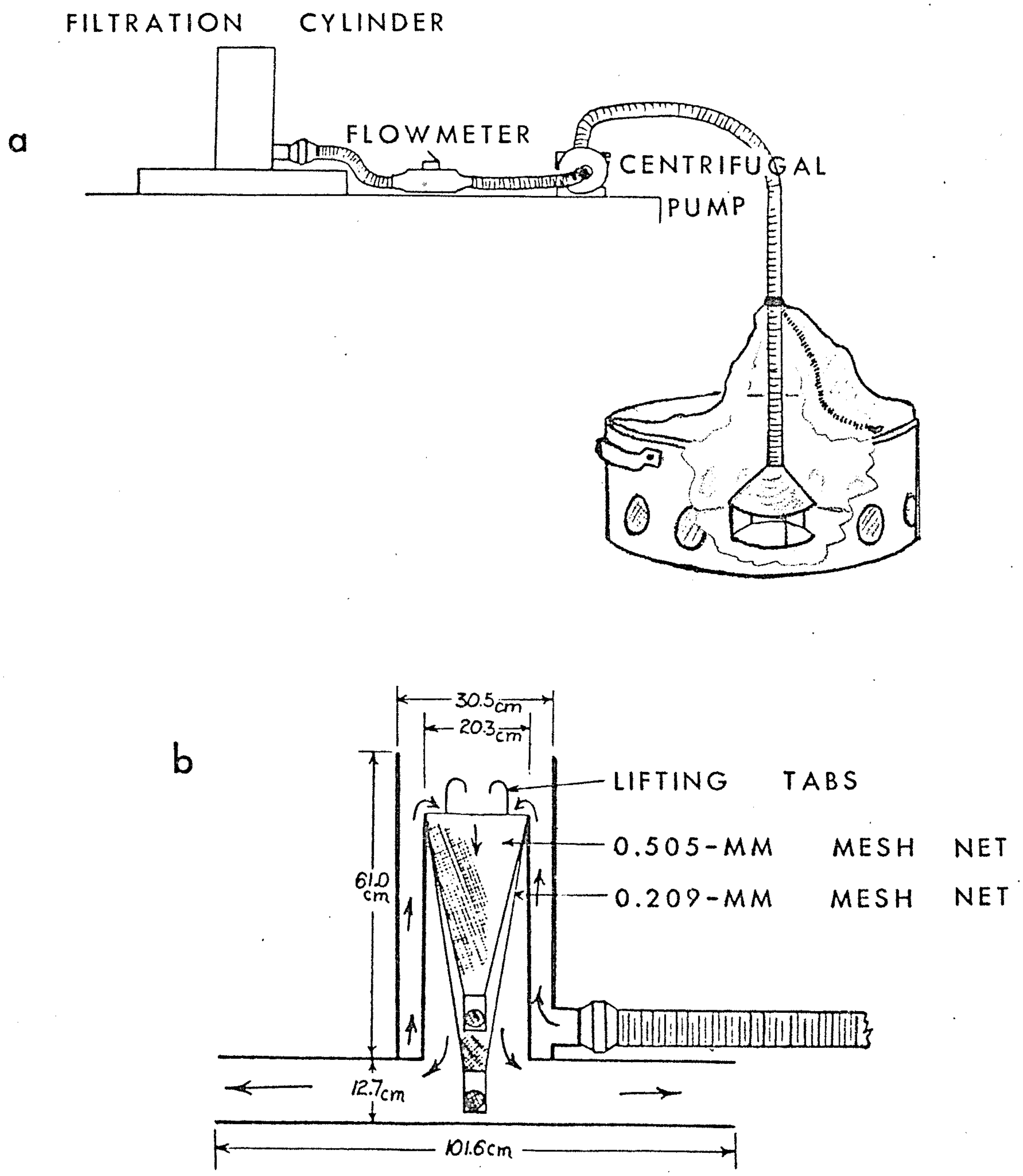


Fig. 6-1. Components of epibenthic suction-pump sampling system (a) and construction detail of filtration cylinder (b).

Beginning in June 1978, surface neritic zooplankton was collected just offshore of the three principal epibenthic sites. Oblique tows were made farther offshore of these areas as well as in mid-canal along a transect between Brown and Carlson points. A standard 60-cm fiberglass bongo net frame was equipped with Nitex nets of 0.333-mm mesh having an area/aspect ratio of 8:1. A General Oceanics propeller flowmeter was centered in one frame to determine the volume of water filtered during each haul, and a BKG recording depth meter was periodically used to determine the depth path of the gear during oblique hauls. The Monty Python's engine speed was set to 1000 rpm for both tow types. The tow speed was recorded to be within a range of 1.8-2.7 knots/hour. The sampling gear was attached to a steel cable fed from a hydraulic winch mounted on the boom of the vessel and passed through a meter block at the tip of the boom.

Surface tows were made with the boom positioned 35° off the port stern of the vessel to reduce the effects of prop agitation in the samples. The gear was lowered 0.3 m below the surface as the vessel approached the epibenthic sites, causing the vessel to heel into a spiral transect around the pivot of the bongo nets. This method enabled us to tow as long as necessary to collect a sufficient sample size without leaving the immediate area under investigation and also may have reduced the influence of tidal currents on the variability in catchability of organisms between sites. Tow duration was 5 min. Sampling efficiency was limited only by extensive blooms of filamentous diatoms which clogged the nets on several occasions.

Oblique tows were made with the boom positioned straight off the stern of the vessel. The gear was released from the boat after recording the flowmeter readout and 22 m of cable were rapidly paid out from the winch before being stopped (approximate depth 15 m) and recovered at a constant speed (approximately 0.25 m/sec) while the whaleboat was held at a constant speed on a straight course parallel to shore during the tow.

After both surface and oblique tows, the gear was lifted out of the water and carefully hosed down with seawater to concentrate organisms in the cod-end buckets of the nets. Once on board, the contents were transferred to labelled PVC jars and fixed in a 5% solution of buffered seawater formalin. End flowmeter readout, as well as tow length, time, position, weather, etc., were recorded.

Two hundred neritic plankton samples were collected between June 21, 1978 and June 5, 1979. Sampling proceeded on a weekly schedule through August 9, but was thereafter reduced to once monthly concurrent with epibenthic sampling. The total includes 24 samples from a day/night collection on May 23 in conjunction with the EHW lighting study.

6.2.3 Stomach Analysis Procedure

Upon capture fish were fixed in 10% buffered seawater formalin (4% formaldehyde). Since many samples are routinely stored for several to many months before processing, and formalin/seawater fixatives progressively drop in pH, causing contraction of proteins in small crustaceans that make taxonomically important limbs brittle and break away, most samples were transferred after at least 7 days of fixation to vials and preserved in a 45% isopropanol solution with 5% propylene glycol added. Our experiments have shown that while preservation in isopropanol of formalin-fixed (4 days) fry causes a considerable (12.6%) decrease in fish body weight after 3 months, there was only a 0.9% decrease in body length of the fixed fry.

Stomach analyses were performed using a standardized, quantitative procedure described in Simenstad and Kinney (1978, 1979) which provides data on frequency of occurrence and numerical and gravimetric composition of prey taxa to the lowest taxonomic level possible (i.e., species, genus, family) and including life history stage.

6.2.4 Zooplankton Sorting and Identification

After 7 days of fixation in 5% formalin, plankton samples were sieved to remove the formalin and then preserved in 45% isopropanol with 5% propylene glycol in labelled vials. Rose bengal was also added to the 0.209-mm epibenthic pump fractions at this time in order to stain the organisms for easier sorting. Prior to sorting, the 0.209-mm fraction also required panning to float the organisms away from fine sand, and subsampling to accommodate large numbers of organisms. This subsampling method utilized a stoppered 10-cc glass syringe with a 2-mm orifice in conjunction with a 250-cc flask. The sample in preservative was brought to 200 cc, the syringe was placed into the flask and gently filled with fluid, then forcibly expelled back into the flask in order to agitate the sample before each of five 2-cc subsamples was withdrawn.

The 0.505-mm fractions of each epibenthic pump replicate were completely identified and enumerated. In 1978 gammarid amphipods and the remainder of this fraction were rinsed with isopropanol and water to remove glycerol and dried at 70°C for 24 hr, then weighed separately to the nearest thousandth of a gram. The two weights were combined and recorded as total fraction dry weight.

Neritic plankton samples were split using a Cooney plankton splitter. Summertime samples during diatom blooms were extremely difficult to subsample and examine.

The total lengths of up to 100 specimens of harpacticoid, calanoid, and cyclopoid copepods and gammarid amphipods from selected samples were measured in order to determine the size frequency of these taxa which are utilized by juvenile salmonids. Total length minus antennae and setae was measured to the nearest 0.1 mm on amphipods and calanoids and to the nearest 0.025 mm on harpacticoids and cyclopoids, using a calibrated measuring eyepiece in a dissecting microscope.

All plankton samples were preserved after examination in 45% isopropanol with 5% propylene glycol. Reference specimens were isolated, indexed, and preserved in 70% ethanol with 5% propylene glycol.

6.2.5 Data Analysis and Presentation

All data were recorded directly onto FRI's MESA/EDS-type computer forms, which utilize the NODC taxonomic code, a ten-digit system enabling coding of aquatic organisms to any phylogenetic level. This code system is currently in use in several ecosystem studies in Puget Sound and Alaska.

Raw data were verified and checked for accuracy, keypunched and stored on magnetic tape for interactive processing. Tabulation and basic statistical analyses of the data were performed using computer program packages specifically developed for FRI's (MESA/EDS) stomach content and zooplankton data (see Simenstad, Kinney, and Miller 1980, in preparation).

A modification of Pinkas, Oliphant, and Iverson (1971) "Index of Relative Importance" (IRI) was used to rank the importance of prey organisms. The IRI values for prey taxa are displayed both graphically and in tabular form where justified by sample size (n greater than 10). The three-axis IRI graphs illustrate frequency of occurrence (the proportion of stomachs containing a specific prey organism) plotted sequentially on the horizontal axis and the percentage of total abundance and percentage of total biomass plotted above and below the horizontal, respectively (Fig. 6-2). Prey taxa in differing stages of digestion (e.g., partly digested shrimp, "Natantia-unidentified," as opposed to family, "Pandalidae," or species, "*Pandalus borealis*") are graphed separately.

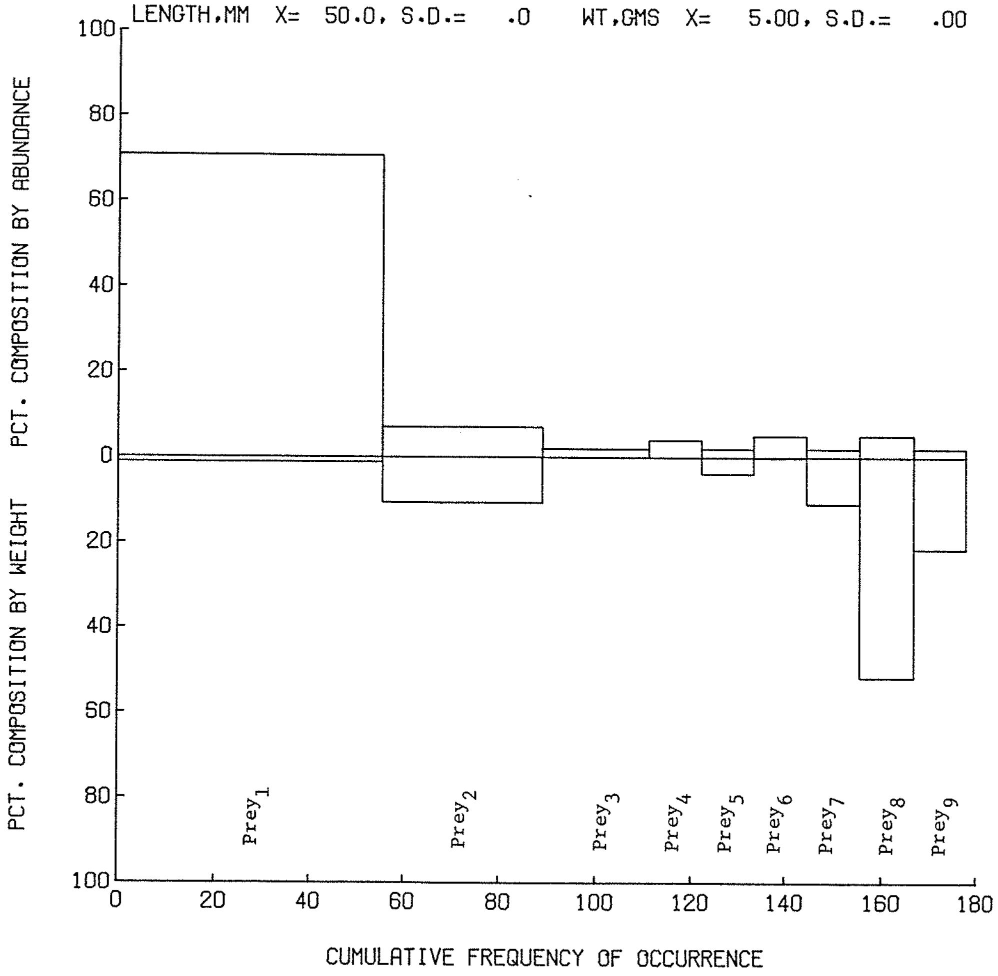
All prey groups, including those assigned to a broad taxonomic level (family, order, or class) because of advanced digestion, have been arranged from left to right by decreasing frequency of occurrence. The IRI value was computed as follows:

$$\text{IRI} = \%\ \text{frequency of occurrence}_i \quad (\%\ \text{numerical composition}_i + \%\ \text{gravimetric composition}_i)$$

and is equivalent to the area encompassed by each prey category "i" composing the IRI diagrams. In order to compare the IRI values between prey spectra with different sample sizes, the overall importance of

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. EXAMPL, STATION PT.

PREDATOR 8755010202 - ONCORHYNCHUS KETA
(CHUM SALMON) ADJUSTED SAMPLE SIZE = 9
LENGTH,MM X= 50.0, S.D.= .0 WT,GMS X= 5.00, S.D.= .00



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
Prey$_1$	55.56	70.71	1.18	3993.5	68.45
Prey$_2$	33.33	7.07	10.68	591.6	10.14
Prey$_3$	22.22	2.02	.03	45.6	.78
Prey$_4$	11.11	4.04	.00	44.9	.77
Prey$_5$	11.11	2.02	3.84	65.1	1.12
Prey$_6$	11.11	5.05	.12	57.4	.98
Prey$_7$	11.11	2.02	10.90	143.5	2.46
Prey$_8$	11.11	5.05	51.72	630.8	10.81
Prey$_9$	11.11	2.02	21.54	261.8	4.49

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.51	.34	.49
SHANNON-WEINER DIVERSITY	1.70	1.93	1.64
EVENNESS INDEX	.54	.61	.52

Fig. 6-2. Sample Index of Relative Importance (IRI) diagram.

general prey taxa (e.g., all shrimp, including "unidentified Natantia" and those identified to family and species, added together) has been discussed as a percentage of the total combined IRI (areas) of the different prey taxa.

Three quantitative indices of the numerical and biomass composition of predator diets are used to describe trophic diversity (<u>see</u> Pielou 1975):

1) Percent dominance index:

$$\% \text{ dominance} = (P_i^2)$$

where p_i's are ratios of the number or biomass of prey i to the total prey abundance or biomass.

2) Shannon-Wiener diversity index:

$$H' = -\sum_{i=1}^{s} (p_i \ln_2 p_i)$$

where p_i's are the same as above.

3) Evenness index:

$$e = \bar{H}/\ln S$$

where $\bar{H}$ = mean H and S = number of species and lnS is equivalent to H_{max}.

Diet overlap has been measured using a modified index of affinity. (Sanders 1960) or Percent Similarity Index (PSI) (Cailliet and Barry 1979):

$$\% S = \min p_i$$

where p_i's are the ratios of the IRI of prey i to the sum of all prey IRI's.

Ivlev's index of electivity (Ivlev 1961)

$$E = \frac{r-p}{}$$

was used to evaluate the relative difference between prey taxa composition (where r = % of total numbers in predator's ration) or "realized availability" (Hyatt 1979) and the plankton community composition (where p = % of total numbers in community) or the "apparently available" food organisms.

6.3 RESULTS

6.3.1 Prey Composition of Outmigrating Chum and Pink Salmon

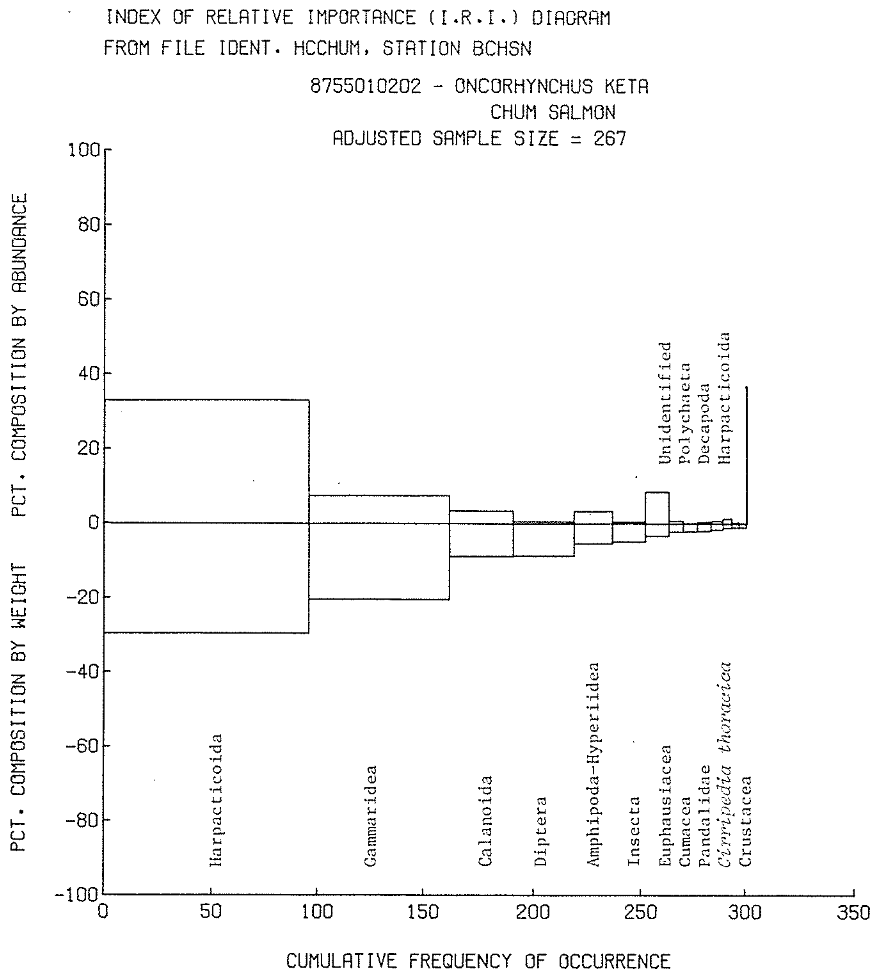
In general, the small (30-40 mm) chum fry, which directly enter Hood Canal from naturally-producing populations or from the spawning channel at Big Beef Creek, prey upon epibenthic organisms common to shallow sublittoral habitats, i.e., harpacticoid copepods, gammarid amphipods, polychaete annelids, and free crustacean eggs (Fig. 6-3 and Table 6-1). As the fish grow or enter the Canal as larger fed fry from hatcheries, their prey spectra involve more neritic organisms, i.e., euphausiids, calanoid copepods, hyperiid amphipods, decapod larvae, common to neritic environments (Fig. 6-4). Insects, which are primarily terrestrial forms drifting in the neuston, are captured by chum salmon of all sizes.

The harpacticoid copepods were not identified to species due to difficult taxonomy. The prominent gammarid amphipod species were *Calliopiella pratti* and *Ischyrocerus* sp.; the common calanoids were *Pseudocalanus minutus* (in smaller fish) and *Calanus pacificus* (in larger fish); hyperiid amphipods were primarily *Parathemisto pacific*; and the decapod larvae included forms of pinnotherid and grapsid crabs and caridean shrimp. Insect groups included Diptera, Homoptera (aphipoidea), and Hymenoptera.

Pink salmon fry appeared to prey more upon neritic organisms than did chum fry. In 1978, the only year studied with significant pink fry outmigration, calanoid copepods and copepod larvae dominated the prey composition while harpacticoid copepods, gammarid amphipods and other epibenthic organisms were not important in the stomach contents of pink fry captured in shallow sublittoral habitats (Fig. 6-5). The principal calanoids appeared to be *Calanus* sp., *Epilabidocera amphitrites* and *Pseudocalanus minutus*. The pelagic larvacean *Oikopleura* sp. (probably *O. dioica*) also appeared in the prey spectrum but was not consumed frequently.

Overlap in prey spectra (as Percent Similarity Index - PSI - of percent total IRI), indicative of general similarity in feeding behavior and prey resources, of chum fry captured in shallow sublittoral habitats was higher between habitats within the year of collection (i.e., $\text{PSI}_{\bar{x}}$ = 60.72) than between year of collection within habitat ($\text{PSI}_{\bar{x}}$ = 25.78)(Table 6-2). Although there was considerable variability in the PSI values, even within the same month, diet similarity appeared to be consistently higher for larger, neritic-feeding chum fry captured late in the outmigration period.

Despite over 1-cm differences in length of co-occurring chum and pink fry captured in shallow sublittoral habitats in late April 1978, the overlap in their prey spectra approached or exceeded 50%. The chum fry captured at Carlson Point had predominantly consumed hyperiid


INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. HCCHUM, STATION BCHSN

8755010202 - ONCORHYNCHUS KETA
CHUM SALMON
ADJUSTED SAMPLE SIZE = 267

```
INDEX OF RELATIVE IMPORTANCE (I.R.I.) TABLE
USING FILEID= HCCHUM. STATION= BCHSN FOR PLOT
*********************************************

                                FREQ   NUM.   GRAV.  PREY     PERCENT
        PREY ITEM               OCCUR  COMP.  COMP.  I.R.I.  TOTAL IRI
----------------------------    -----  -----  -----  ------  ---------

HARPACTICOIDA                   95.88  33.10  29.53  6004.4    67.18
GAMMARIDEA                      66.29   7.50  20.42  1850.5    20.70
CALANOIDA                       28.46   3.32   8.77   344.0     3.85
DIPTERA                         28.09    .55   8.65   258.4     2.89
AMPHIPODA-HYPERIIDEA            17.60   3.25   5.42   152.6     1.71
INSECTA                         15.73    .47   4.84    83.6      .93
EUPHAUSIACEA                    10.86   8.47   3.34   128.3     1.44
CUMACEA                          7.12    .72   2.19    20.7      .23
PANDALIDAE                       7.12    .14   2.19    16.6      .19
CIRRIPEDIA THORACICA             6.74    .39   2.08    16.7      .19
CRUSTACEA                        5.62    .67   1.73    13.5      .15
UNIDENTIFIED                     4.12   1.28   1.27    10.5      .12
POLYCHAETA                       3.37    .30   1.04     4.5      .05
DECAPODA                         3.37    .16   1.04     4.0      .05
HARPACTICOIDA                     .37  36.77    .12    13.8      .15


PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC
COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT
(BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

DIVERSITY INDICES BASED ON FRACTION OF TOTAL IRI --
    PERCENT DOMINANCE INDEX       .50
    SHANNON-WEINER DIVERSITY     1.56
    EVENNESS INDEX                .30
```

Fig. 6-3. Index of Relative Importance (IRI) diagram for chum salmon caught in the beach seine, Bangor Annex, Hood Canal.

Table 6-1. Prey taxa composition, based on percent of total index of relative importance, of beach seine-caught chum fry in northern Hood Canal according to fish size interval, 1977.

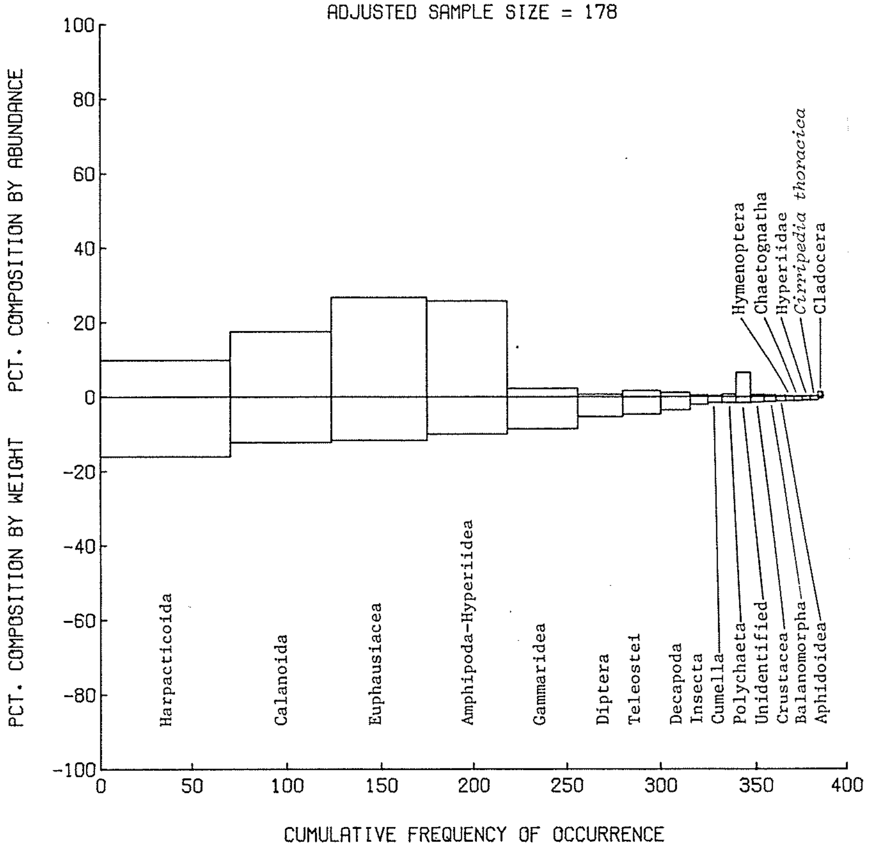
Sample	Fish length interval (mm)							
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
April 20 - May 19, 1977								
(n)	(12)	(29)	(24)	(2)				
Harpacticoid copepods	34.85	10.65	13.89	22.78				
Polychaete annelids	22.20	0.46	0.57					
Unidentified eggs	24.37	2.55	0.19					
Calanoid copepods	6.23	4.97	8.35	5.64				
Gammarid amphipods	4.58	5.42	5.33					
Euphausiids	4.26	73.89	65.88	66.87				
Barnacle larvae	2.28	0.24	0.92					
Fish larvae	0.28	0.60	0.91					
Insects	0.24	0.33	1.30	4.71				
Tunicate larvae	0.24	0.04	0.17					
Cumaceans	0.24	0.15						
Hyperiid amphipods		0.59	0.32					
Decapod larvae		0.08						
Mesogastropods		0.04	0.14					
Cladocerans			1.69					
May 20 - June 19, 1977								
(n)	(1)	(2)	(9)	(2)				
Harpacticoid copepods	55.43	4.91	52.84					
Calanoid copepods	17.43	26.55	13.67	29.46				
Gammarid amphipods	13.91		11.69	3.80				
Decapod larvae	13.20			3.80				
Hyperiid amphipods		60.32	7.55	51.40				
Euphausiids		4.11	2.14					
Insects		4.11	0.23	3.80				
Mesogastropods			6.59					
Unidentified eggs			2.97	7.73				
Fish larvae			1.88					
Bopyrid isopods			0.23					
Cumaceans			0.23					

Table 6-1. Prey taxa composition, based on percent of total index of relative importance, of beach seine-caught chum fry in northern Hood Canal according to fish size interval, 1977 - continued.

Sample	Fish length interval (mm)							
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
June 20 - July 21, 1977								
(n)			(6)	(13)		(8)	(5)	(1)
Calanoid copepods			22.28	22.34		41.33	31.50	
Hyperiid amphipods			16.19	29.58		42.15	55.84	58.93
Insects			14.86	18.39		1.14		
Harpacticoid copepods			12.57	7.59		4.19	2.50	
Gammarid amphipods			12.33	4.41		0.94		
Copepod larvae			7.65					
Cumaceans			7.38	1.64		0.22		
Decapod larvae			2.07	2.31		4.67	3.05	41.07
Sphaeromatid isopods			1.22					
Polychaete annelids			0.66					
Caligoid copepods			0.56					
Ostracods			0.56	3.01				
Caprellid amphipods			0.56					
Fish larvae			0.56	0.57		0.22	0.58	
Unidentified eggs			0.56			0.89		
Euphausiids				6.42		3.58	5.36	
Chaetognaths				0.57		0.22	0.59	
Cladocerans				1.84				
Barnacle larvae						0.22		
Bopyrid isopods						0.22		
Mysids							0.59	

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. HCCHUM, STATION TOWNT

8755010202 - ONCORHYNCHUS KETA
CHUM SALMON
ADJUSTED SAMPLE SIZE = 178



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	70.22	9.87	16.03	1818.8	23.04
CALANOIDA	53.37	17.53	12.18	1585.4	20.08
EUPHAUSIACEA	51.12	26.68	11.67	1960.6	24.84
AMPHIPODA-HYPERIIDEA	43.82	25.73	10.00	1565.9	19.84
GAMMARIDEA	37.64	2.27	8.59	408.8	5.18
DIPTERA	23.60	.65	5.38	142.3	1.80
TELEOSTEI	20.79	1.65	4.74	133.0	1.68
DECAPODA	15.73	1.13	3.59	74.2	.94
INSECTA	9.55	.38	2.18	24.5	.31
CUMELLA	7.30	.27	1.67	14.1	.18
POLYCHAETA	7.30	.66	1.67	17.0	.22
UNIDENTIFIED	7.30	6.44	1.67	59.2	.75
CRUSTACEA	6.74	.56	1.54	14.2	.18
BALANOMORPHA	6.18	.41	1.41	11.2	.14
APHIDOIDEA	5.62	.20	1.28	8.3	.11
HYMENOPTERA	5.06	.06	1.15	6.2	.08
CHAETOGNATHA	5.06	.09	1.15	6.3	.08
HYPERIIDAE	4.49	.07	1.03	4.9	.06
CIRRIPEDIA THORACICA	4.49	.16	1.03	5.3	.07
CLADOCERA	2.25	1.26	.51	4.0	.05
COPEPODA	.56	1.07	.13	.7	.01

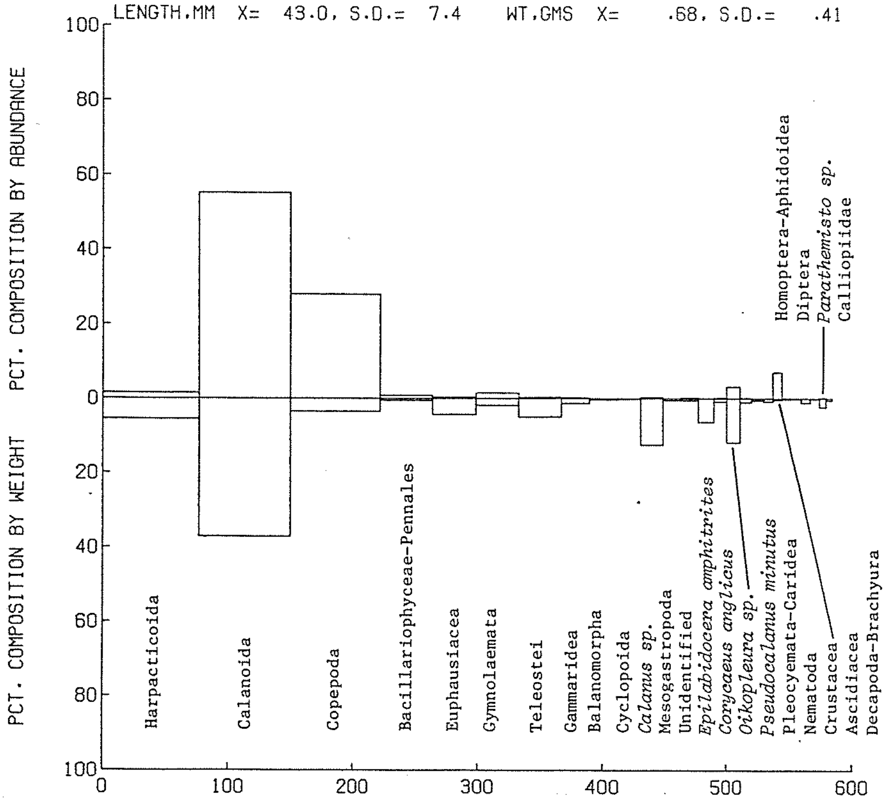
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC
COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT
(BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

DIVERSITY INDICES BASED ON FRACTION OF TOTAL IRI --
PERCENT DOMINANCE INDEX .20
SHANNON-WEINER DIVERSITY 2.64
EVENNESS INDEX .45

Fig. 6-4. Index of Relative Importance (IRI) diagram for chum salmon caught in the townet, Bangor Annex, Hood Canal.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. 1978 , STATION AL BS

PREDATOR 8755010201 - ONCORHYNCHUS GORBUSCHA
(PINK SALMON) ADJUSTED SAMPLE SIZE = 55
LENGTH.MM X= 43.0, S.D.= 7.4 WT,GMS X= .68, S.D.= .41



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	76.36	1.61	5.42	536.9	5.02
CALANOIDA	72.73	55.20	37.08	6711.5	62.70
COPEPODA	72.73	28.10	3.42	2292.7	21.42
BACILLARIOPHYCEAE PENNALES	41.82	.80	.50	54.3	.51
EUPHAUSIACEA	34.55	.32	4.25	157.6	1.47
GYMNOLAEMATA	34.55	1.62	1.71	115.1	1.08
TELEOSTEI	34.55	.33	5.02	184.6	1.72
GAMMARIDEA	21.82	.12	1.31	31.1	.29
BALANOMORPHA	21.82	.08	.27	7.7	.07
CYCLOPOIDA	18.18	.06	.23	5.1	.05
CALANUS SP.	18.18	.34	12.38	231.1	2.16
MESOGASTROPODA	14.55	.07	.38	6.6	.06
UNIDENTIFIED	14.55	.21	.38	8.7	.08
EPILABIDOCERA AMPHITRITES	12.73	.08	6.30	81.2	.76
CORYCAEUS ANGLICUS	10.91	.18	.74	10.1	.09
OIKOPLEURA SP.	10.91	3.21	11.72	162.9	1.52
PSEUDOCALANUS MINUTUS	9.09	.17	.95	10.1	.09
PLEOCYEMATA-CARIDEA	9.09	.02	.52	4.9	.05
NEMATOCERA	7.27	.02	.74	5.5	.05
CRUSTACEA	7.27	7.01	.29	53.1	.50
ASCIDIACEA	7.27	.04	.09	.9	.01
DECAPODA-BRACHYURA	7.27	.01	.09	.6	.01
HOMOPTERA-APHIDOIDEA	7.27	.02	1.13	8.3	.08
DIPTERA	7.27	.01	.09	.6	.01
PARATHEMISTO SP.	5.45	.18	2.25	13.3	.12
CALLIOPIIDAE	5.45	.03	.47	2.7	.03

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.39	.18	.44
SHANNON-WEINER DIVERSITY	1.89	3.34	1.83
EVENNESS INDEX	.34	.60	.33

Fig. 6-5. Index of Relative Importance (IRI) diagram for pink salmon caught in the beach seine, Bangor Annex, Hood Canal.

Table 6-2. Overlap (Percent Similarity Index) in prey composition of chum fry within habitat and between habitats within year of collection.

Between years, within habitat

		1977 vs. 1978	1977 vs. 1979	1978 vs. 1979	$\bar{x}$ =
Carlson Point:	April	17.70	7.18	41.37	22.08
	May				
	June		4.88		4.88
Devil's Hole Delta:	April	33.58	20.69	30.65	28.31
	May	15.97			
	June				
Brown Point:	April		50.81		50.81
	May	30.36			30.36
	June				
	$\bar{x}$ =	24.40	20.89	36.01	27.29

Between habitats, within years:

		Carlson Pt. vs. Devil's Hole Delta	Carlson Pt. vs. Brown Pt.	Devil's Hole Delta vs. Brown Pt.	$\bar{x}$ =
1977	April	28.06	85.84	26.35	46.75
	May			86.60	86.60
	June				
1978	April	57.45			57.45
	May	82.70	67.34	64.89	71.64
	June				
1979	April	50.45	17.70	22.58	30.24
	May				
	June	83.03	78.83	85.87	82.58
	$\bar{x}$ =	60.34	62.43	57.26	62.54

amphipods, which pink fry had not, while pink fry had fed extensively on copepod larvae (nauplii). Diet overlap was higher at Devil's Hole Delta, where harpacticoid copepods of the extensive eelgrass beds in that habitat formed the major dietary component of both species. By early May, when the fry of the two species were approximately the same size, overlap had increased to almost 75% as both species focused their foraging upon pelagic larvaceans and calanoid copepods. The only difference in the two diet spectra at this time was the predominance of gymnolaemata (bryzoan) zooecia in the prey spectrum of the pink fry. In mid-May, chum fry were still almost exactly the same size as co-occurring pink fry, but diet overlap was relatively low (23.44%). Neritic organisms predominated in the diet of both species, however: calanoid copepods and hyperiid amphipods in the case of the chum fry and larvaceans in the case of the pink fry. By late May, however, both species were concentrating their foraging on calanoid copepods (*Calanus pacificus* and *Epilabidocera amphitrites*) and illustrated the highest diet overlap of any period.

Differences in prey composition were evident between chum fry marked and released from Big Beef Creek and those unmarked conspecifics captured with them in northern Hood Canal during the 1979 outmigration (Table 6-3). Although much of this variation is probably due to differences in size between the marked and unmarked fry, overlap values between marked fry were generally higher (despite size differences) than the overlap between marked and unmarked chum fry. Diet overlap also increased with the progression of the outmigration and apparent transition to neritic feeding. Early in the outmigration period taxonomic prey compositions among different size groups of unmarked fry were not consistent, while the marked fry often illustrated similar prey composition across different size intervals. By June, however, larvaceans (*Oikopleura* sp.) constituted the principal prey component for all chum fry; only the 50-59 mm-long unmarked chum fry had less than 80% of the total prey IRI contributed by these pelagic tunicates.

6.3.2 Composition and Standing Stock of Epibenthic and Neritic Zooplankton

6.3.2.1 Epibenthic Community Composition

Composition of the epibenthic zooplankton community was predominated by crustaceans. As illustrated by the Carlson Point collections, in 1977, 49 of the 102 (48%) of the identifiable taxa were crustaceans. Complete taxonomic composition appears in Simenstad, Kinney, and Miller (1980, in preparation). Harpacticoid copepods and gammarid amphipods dominated the numerical and gravimetric composition of the community, contributing 69.2% and 10.1% of the total number of organisms and 16.3% and 20.8% of the total biomass, respectively. Calanoid copepods (2.9% total abundance [not including eggs]; 5.3% total biomass), asellotan isopods (1.7%; 4.0%), barnacle larvae (1.1%; 2.4%), nematodes (1.7%;

Table 6-3. Overlap (Percent Similarity Index) in prey composition of marked and unmarked chum fry, according to size interval, during three periods of the 1979 outmigration.

Date			Size Interval						
			40-49 mm marked	40-49 mm unmarked	50-59 mm marked	50-59 mm unmarked	60-69 mm marked	60-69 mm unmarked	70-79 mm marked
February 6, 1979									
	30-39 mm	unmarked	15.06		22.69				
	40-49 mm	marked			71.78				
April 25, 1979									
	40-49 mm	unmarked				21.62		8.50	
	50-59 mm	unmarked						62.35	
June 5, 1979									
	40-49 mm	marked			91.95	67.97	90.72	90.05	85.54
	50-59 mm	marked				63.62	89.55	86.92	90.25
		unmarked					65.44	65.57	59.92
	60-69 mm	marked						87.42	84.31
		unmarked							84.83

5.0%), cumaceans (0.7%; 3.9%), caprellid amphipods (0.3%; 1.9%) and mesogastropods (0.7%; 2.1%) also contributed significantly to the total standing stock of epibenthic organisms.

In 1978, which encompassed a complete 12 month sampling period, 98 of 152 (64%) identified taxa were crustaceans. Harpacticoid copepods comprised 63.5% of the total abundance and 17.3% of the total biomass of epibenthic organisms; gammarid amphipods comprised 2.9% of the total abundance and 12.3% of the total biomass. Asellutan isopods (5.8% total abundance; 6.3% total biomass), cyclopoid copepods (5.9%; 1.2%) ostracods (3.7%; 1.4%), calanoid copepods (3.1%; 1.2%), caprellid amphipods (appearing prominently in December; 1.5%; 24.7%) and crustacean and other (unidentified) eggs (6.6%; 2.8%) were also important components of the epibenthic community during this period.

In 1979, which involved sampling only during the chum salmon outmigration, crustaceans accounted for 94.3% of the total abundance (12.2% eggs) and 86.7% of the total biomass (1.2% eggs) of epibenthic organisms. Harpacticoid copepods contributed 42.2% of the total abundance and 12.9% of the total biomass and gammarid amphipods, 4% of the total abundance and 18.2% of the total biomass (not including eggs). Crustacean and other (unidentified) eggs (14.1% of total abundance; 1.5% of total biomass), calanoid copepods (8.1%; 2.3%) cyclopoid copepods (5.4%; 0.7%), ostracods (4.2%; 0.7%), asellotan isopods (2.2%; 1.6%), copepod larvae (1.3%; 0.4%), and mesogastropods (1.7%; 4.5%) were also important components of the epibenthic community during this period.

While the harpacticoid copepods were not typically identified to species, the families Tegastidae and Porcellididae were readily identifiable. Representative subsamples of harpacticoid copepods collected in 1977 were identified by Ms. Beverly Kask of the Pacific Biological Station, Nanaimo, B.C., Canada. Among these samples the prevalent species were Harpacticus sp., Dactylopodia sp., Amphiascopsis cinctus and species of the families Ectinosomidae and Laophontidae (Simenstad and Kinney 1978).

As evidenced by the extensive collections at Carlson Point, Aoroides columbiae, Pontogeneia sp. and Synchelidium shoemakeri were the numerically prominent species of gammarid amphipod, while Photis sp., Amphithoe sp., Calliopiella pratti, Podoceropsis sp. and Westwoodilla caecula also occurred frequently but less abundantly over the 14 sampling periods in 1978. In the restricted (5-month) samples collected at Carlson Point in 1979, Podoceropsis and Ischyrocerus sp. were more prominant than in 1978. Taxonomic identification of gammarid amphipods from the 1977 collections are not comparable with those from 1978 and 1979. A subsample from collections at Brown Point from March 17-July 22, 1977, however, was specifically identified and shown to include predominantly the undescribed Pontogeneia sp., Calliopius sp., Calliopiella pratti, and Anisogammarus pugettensis (Simenstad and

Kinney 1978); the latter species was completely unreported from the 1978 and 1979 collections.

Among the other contributory species, Paracalanus parvus, Pseudocalanus minutus dominated the calanoid copepods, Munna ubiquita, the asellotan isopods, Cumella sp. the cumaceans, Caprella laeviuscula the caprellid amphipods and Lacuna sp. the mesogastropods.

6.3.2.2 Epibenthic Community Standing Stock

Between December 30, 1976 and June 22, 1977, the density of epibenthic zooplankton at the three sampling sites averaged 23,433.5 ± 39,513.2 individuals (including eggs) per m^3. Densities at Carlson Point, the site with the most comprehensive series of samples during that period, fluctuated broadly among a minimum of 4,962.3 ± 5,519.6/m^3 on February 17 to a maximum of 118,628.3 ± 108,932.7/m^3 on April 21 (Fig. 6-6). In 1978, after modification of the sampling technique to reduce sample contamination, densities averaged 24,301.5 ± 18,248.5/m^3 with an early minima of 10,000.0 ± 4,690.4/m^3 on February 21, another of 11,426 ± 2,529.5/m^3 on June 28 and a late minimum of 11,021.7 ± 2,660.7/m^3 on December 15. An early spring maximum of 50,853.6 ± 36,565.9/m^3 occurred on April 6 and densities were generally sustained at that level between August and November. Density estimates between mid-January and early June 1979 indicated only one peak of 59,643.3 ± 6,718.2/m^3 on March 9, approximately a month earlier than in 1978, and averaged 29,947.7 ± 18,488.1/m^3 over the 6-month period.

The majority of the fluctuations in zooplankton density were a function of the density of harpacticoid copepods, the numerically predominant taxa in the community. Calanoid copepods, gammarid amphipods, crustacean eggs, cyclopoid copepods, cladocerans, ostracods, and isopods comprised the majority of remaining zooplankters, often with several periods of high numerical contribution, i.e., crustacean eggs in April-May 1977 and 1979, asellotan isopods in November-December 1978, and cyclopoid copepods in April-May 1978.

During the three years studied, the general decline in harpacticoid copepod densities in early spring appeared to coincide with the peak densities (CPUE) of chum salmon fry in shallow sublittoral habitats (see Fig. 3-3). The extended sampling in 1978, however, indicated an increase in harpacticoid density after the period of chum and pink salmon outmigration, suggesting that epibenthic-feeding salmon fry could be involved in depression of the harpacticoid resources during the most intensive period of their predation upon the epibenthic community.

Densities of epibenthic organisms at the three principal sampling sites followed a similar trend during the 1977 outmigration period, with all sites showing similar density maxima from mid-April to early

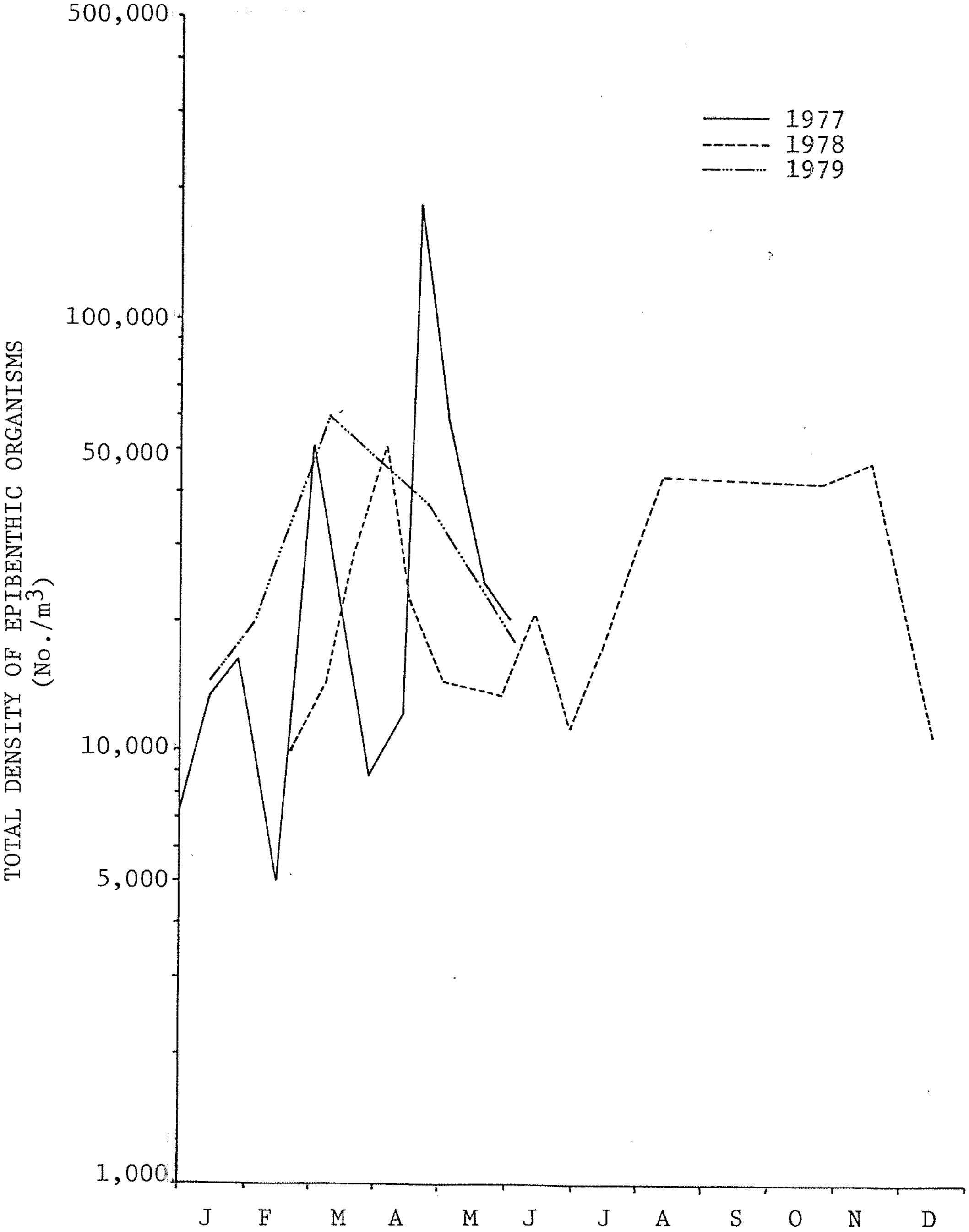


Fig. 6-6. Comparison of total density of epibenthic organisms in the Bangor Annex area of Hood Canal, 1977-1979.

May (Simenstad and Kinney 1978). Densities of harpacticoid copepods tended to be more variable among sites. Devil's Hole Delta, with its extensive eelgrass habitat, typically had the highest densities while the community at Carlson Point showed more frequent and extreme fluctuations than the other sites. Densities of gammarid amphipods also varied considerably between sites and were especially variable at Brown Point.

Estimates of standing crop (g/m^3) of epibenthic zooplankton varied considerably over the 3 years (Fig. 6-7). Under the earlier, less effective sampling methodology in 1977, the mean standing crop was 0.063 ± 0.120 g/m^3 with December-early-January and March-April minima of approximately 0.025 g/m^3 and maxima of 0.056 g/m^3 in late January and 0.129 g/m^3 in early May. With the improvements in sampling efficiency, the standing crop estimates were dramatically higher in 1978, averaging 0.801 ± 0.814 g/m^3. A late winter-early spring maximum of approximately 0.8 g/m^3, associated with the exponential expansion in harpacticoid copepod densities, was followed by a general depression between early April and mid-July, also correlated with depletion of harpacticoid copepods. From July through December the standing stock increased to a maximum of 2.59 g/m^3 on November 17, due in part to high densities of harpacticoid copepods after July and the appearance of juvenile shrimp and caprellid amphipods, relatively large zooplankters, during that period. In 1979 standing crop estimates showed trends and magnitudes much different than 1978, including an early decline from maximum around 1.9 g/m^3 in January and February to a minimum of 0.78 g/m^3 in late April. This trend also coincided with the abundance of juvenile shrimp and the decline in harpacticoid copepod densities.

The 1977 estimates appear to have been compromised by less accurate biomass measurements than were obtained for the latter two years; in addition, the improvements in the 1978-79 sampling methodology appear to have resulted in more effective collection of large zooplankters, such as gammarid amphipods and juvenile caridean shrimp, which may have been able to escape the epibenthic pump's suction during the 1977 sampling.

6.3.2.3 Neritic Community Composition

All but 7 of the 42 taxa identified from the June-July 1978 neritic samples were crustaceans, predominantly calanoid (9 families, 12 species) and cyclopoid copepods (2 families, 2 species); complete taxonomic composition appears in Simenstad et al. (1980, in preparation). The prevalent species were the calanoids, *Paracalanus* sp. (probably *P. parvus*) and *Pseudocalanus* sp. (probably *P. minuta*). Unidentifiable juvenile caridean shrimp were also common. Calanoid copepods completely dominated the more comprehensive samples collected between early February and early June 1979. *Paracalanus* sp. were, however, relatively rare during that period and *Pseudocalanus minutus* and *Acartia*

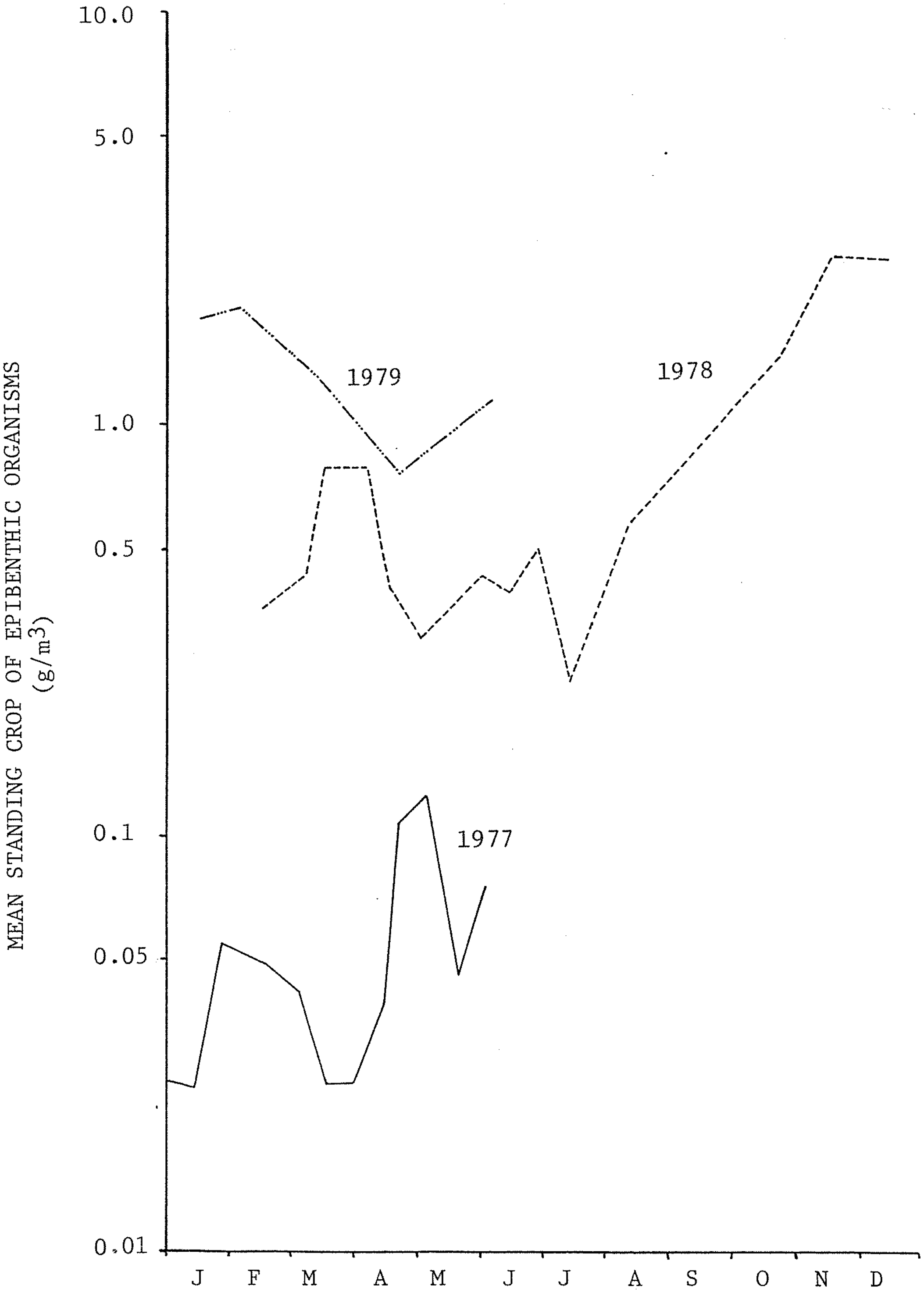


Fig. 6-7. Comparison of mean standing crop of epibenthic organisms in the Bangor Annex area of Hood Canal, 1977-1979.

longiremis constituted the most common neritic species. Pelagic larvacea, Oikopleura sp., which were quite rare in the 1978 collections ranked third among the identifiable species.

During the 1979 outmigration the numerical dominance of Pseudocalanus declined and by May was replaced by Acartia (Fig. 6-8). By late May, when our sampling terminated, the proportional representation of Calanus, Tortanus, and Paracalanus had increased to approximately that of Pseudocalanus.

6.3.2.4 Neritic Community Standing Stock

Although the sampling of neritic zooplankton was conducted monthly between July 1978 to June 1979, funds for processing the samples limited the analysis to the July 1978 and February, April, and June 1979 collections at Carlson Point. The density of neritic organisms on two dates in June 1978 averaged 407.6 ± 480.8 g/m^3 but varied considerably (Fig. 6-9). The three collections during the 1979 chum outmigration averaged 999.9 ± 952.1 g/m^3 with the maximum estimate of 2,120.9 ± 674.3 g/m^3occurring in late April.

Standing crop followed the same general trends as density (Fig. 6-9). The mean standing crop in July 1978 was 0.028 ± 0.018 g/m^3 while the mean of the 1979 estimates was 0.054 ± 0.035 g/m^3 with a maximum of 0.078 ± 0.013 g/m^3 in late April.

6.3.3 Evidence and Characteristics of Prey Selectivity

Positive electivity of epibenthic organisms by chum fry occurring in shallow sublittoral habitats, as measured by Ivlev's coefficient, E, appears to shift from crustacean larvae, juvenile shrimp, and calanoid copepods early in the outmigration period to gammarid amphipods, harpacticoid copepods, euphausiids, crustacean eggs, and hyperiid amphipods during the peak outmigration period and to calanoid copepods and hyperiid amphipods as the migration ends (Simenstad and Kinney 1978). Insects always had positive values of E, primarily because they could drift on the water's surface and were not well sampled by the plankton pump.

Size selection of harpacticoid copepods and gammarid amphipods was readily apparent. As an illustration, the sizes (metasome lengths) of harpacticoid copepods characterizing the Brown Point epibenthic plankton community were 0.817 ± 0.174 mm, through the period of the 1977 outmigration period (Simenstad and Kinney 1978), whereas the sizes of harpacticoids found in the stomach contents of juvenile chums captured adjacent to the plankton pumping site ranged from 1.499 ± 0.132 mm to 0.781 ± 0.182 mm. In some instances the largest harpacticoids consumed by the chum fry were completely out of range of those sampled by the

1979

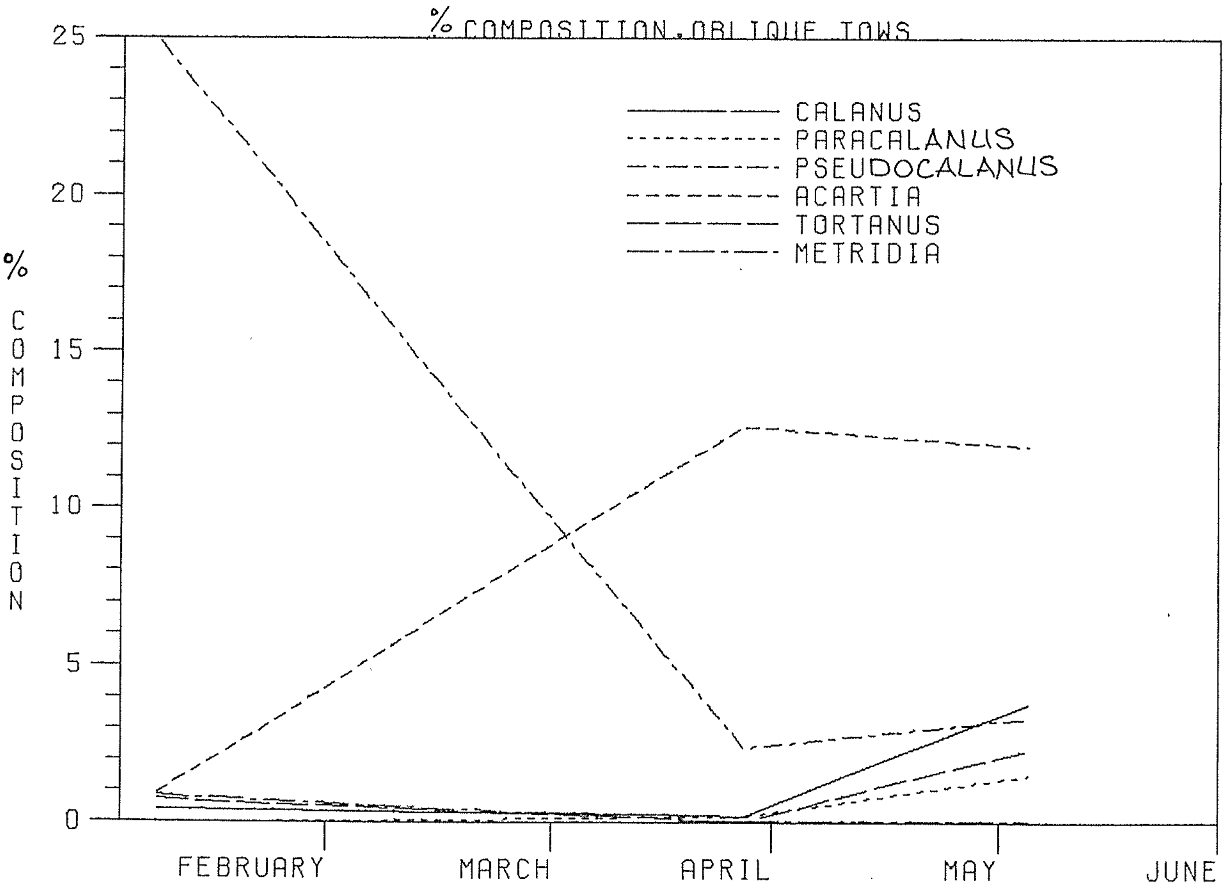


Fig. 6-8. Percent numerical composition of neritic zooplankton collected in 15-m oblique tows at Carlson Point, February-June 1979.

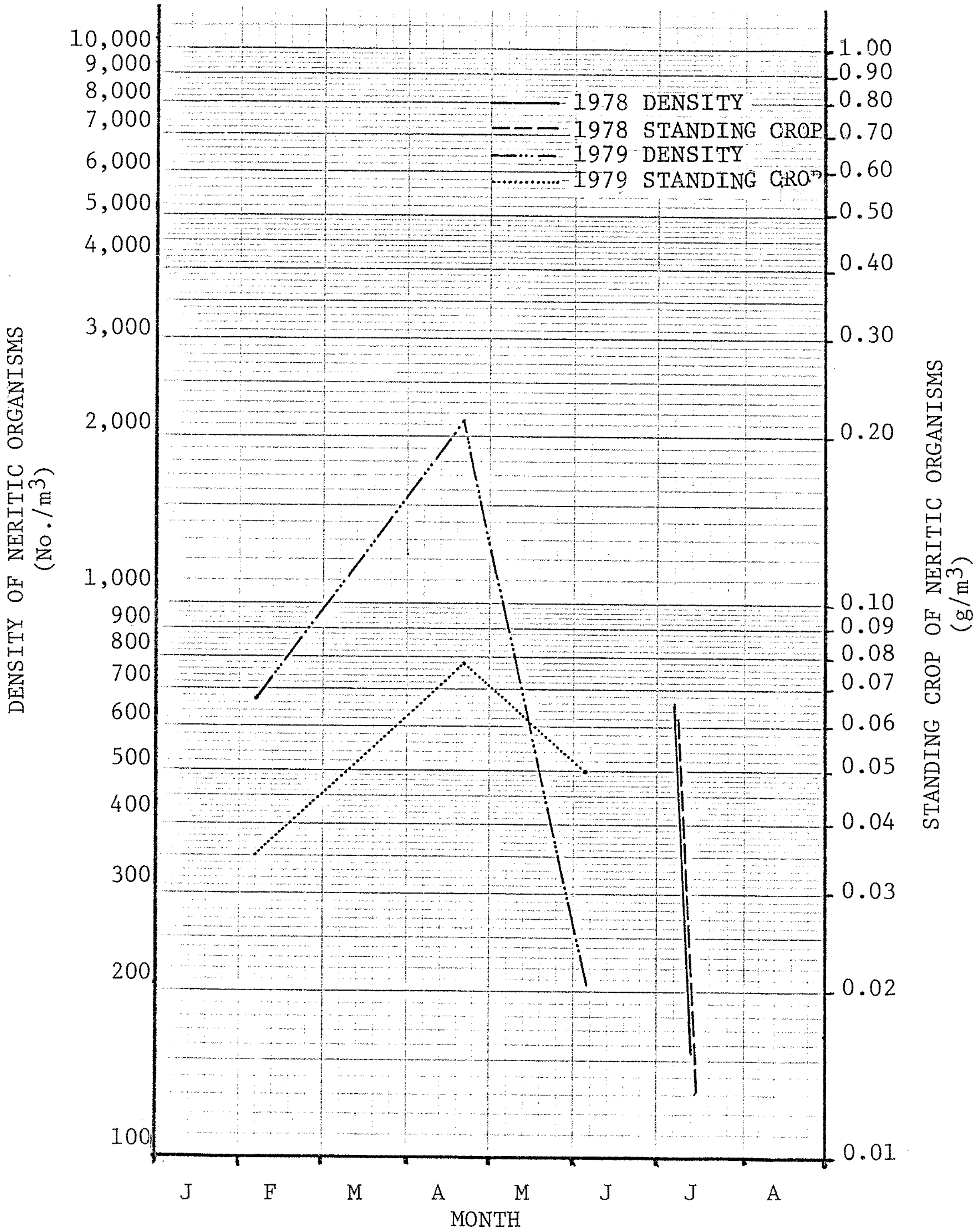


Fig. 6-9. Density and standing crop of neritic zooplankton at Carlson Point, northern Hood Canal in July 1978 and February-June 1979.

plankton pump. We interpret this to be an effect of predator selection of an extremely rare component of the epibenthic plankton community rather than a sampling bias. In addition, the mean harpacticoid sizes were typically larger in the stomach contents of chum fry caught in neritic waters than those from fry caught in shallow sublittoral habitats. This probably reflects size selective predation as a function of predator size since chums caught in neritic waters with the townet are generally larger than those caught in shallow sublittoral habitats by the beach seine.

There was some evidence, though far from conclusive, that intense size-specific predation was depressing the mean size distributions of epibenthic harpacticoids during the peak outmigration period (Fig. 6-10), suggesting overexploitation of the prey source. This cannot be verified, however, without some basic knowledge of the species composition and life history patterns of the prominent harpacticoid copepods.

There was also some suggestion of size-selective predation upon gammarid amphipods (Simenstad and Kinney 1978), although the sample sizes for measurable organisms from the contents of chum fry stomachs were not sufficient to compare with individual epibenthic plankton samples except in one instance, May 18, 1978, when the size distribution of amphipods consumed by chum fry contained distinctly larger amphipods. Unlike the harpacticoids, however, there was not any indication of declining size distributions during the peak outmigration period.

Size-selection of gammarid amphipods was also evidenced by the species composition of those consumed by chum fry, which was relatively confined to <u>Calliopiella pratti</u> ($\bar{x}$ biomass/individual = 0.0004 g), <u>Pontogeneia</u> sp. ($\bar{x}$ = 0.0006 g), and <u>Ischyrocerus</u> sp. ($\bar{x}$ = 0.0002 g), while the more abundant amphipod species were much smaller, i.e., $<$ 0.0001 g/individual.

Chum fry feeding in neritic waters also illustrated highly selective feeding behavior. Direct comparisons between chum fry prey spectra concurrent with neritic zooplankton collections in late June and mid-July 1978 illustrated numerical selectivity for larvaceans (<u>Oikopleura</u> sp.), chaetognaths, fish eggs, juvenile euphausiids and shrimp, and hyperiid amphipods (<u>Parathemisto pacifica</u>).

Despite the predominance of calanoid copepods in the prey spectra of neritic-feeding chum fry, electivity values for calanoids were negative in both comparisons. This is not surprising considering the high abundance of calanoids, especially <u>Pseudocalanus</u>, in the surface waters of the Canal at this time. When species and size frequency distributions of calanoids in the prey spectra of the chum fry and the ambient environment are compared, however, selectivity for large calanoid species is quite apparent (Fig. 6-11). The two largest species,

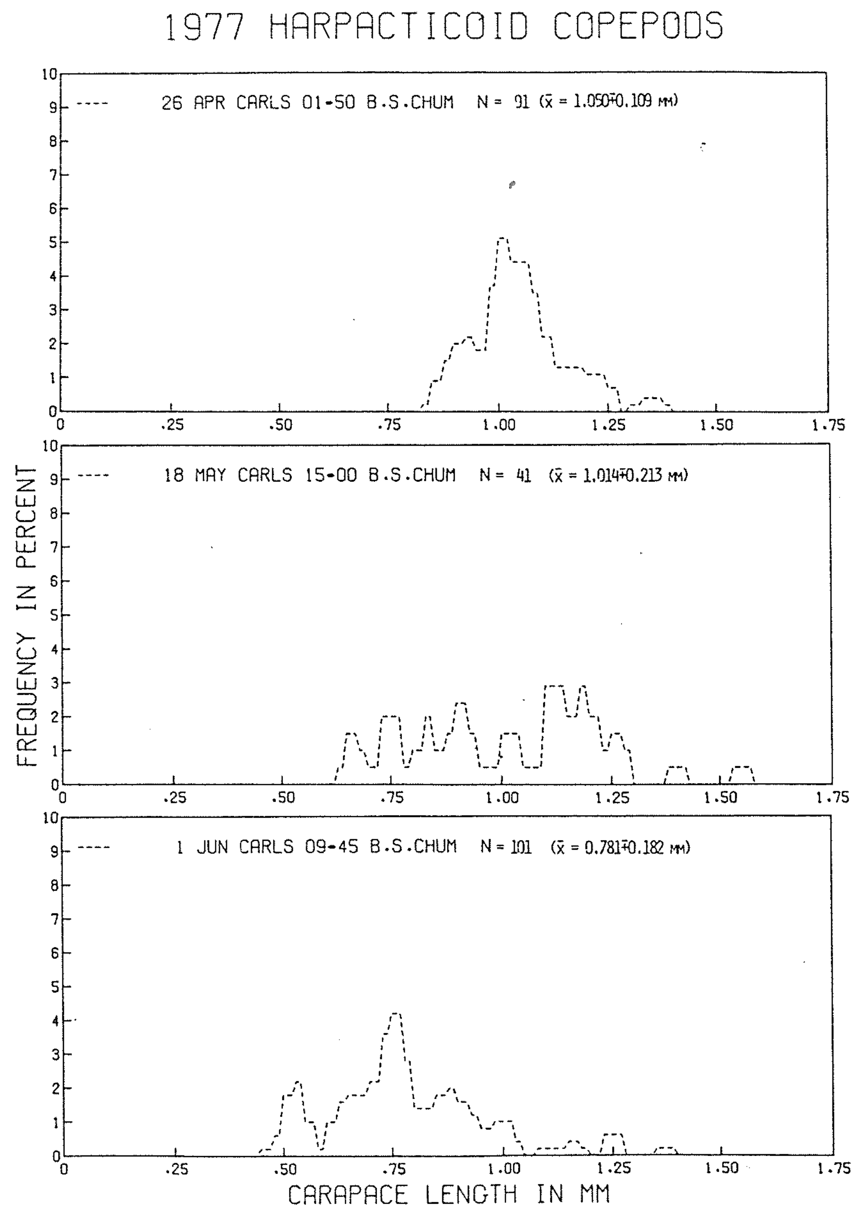


Fig. 6-10. Harpacticoid copepod size (metasome lengths) distribution from stomach contents of outmigrating chum fry caught in shallow sublittoral environments in northern Hood Canal, Washington, 1977.

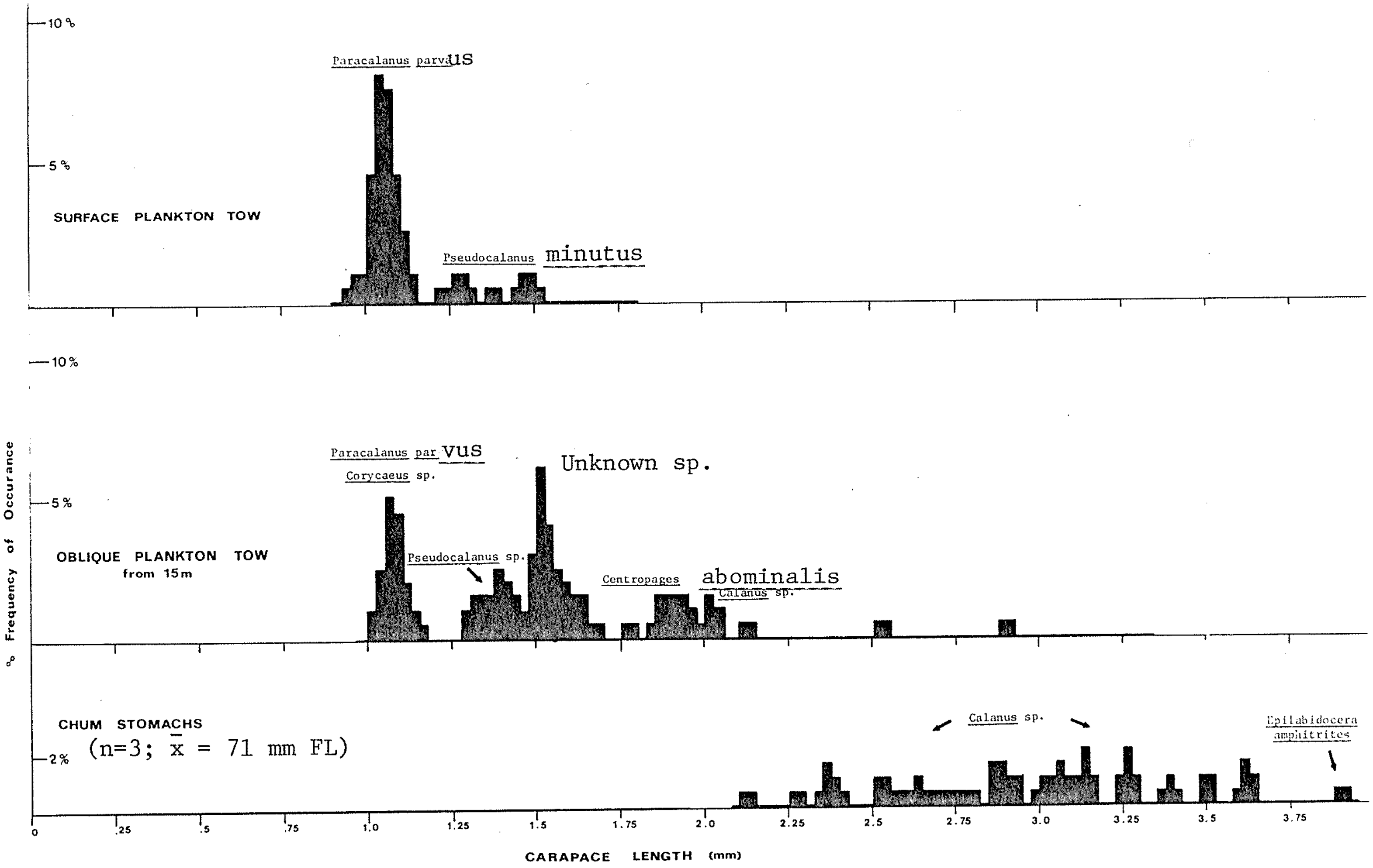


Fig. 6-11. Size frequency of plankters from neritic plankton tows and townet-caught chum fry stomachs from Brown Point, 27 June 1978.

Calanus sp. (complex of *C. pacificus* and *C. marshallae*) and *Epilabidocera amphitrites* are extremely rare compared to the abundant but smaller *Pseudocalanus*, *Paracalanus*, and *Centropages*, as well as the similarly-sized cyclopoid copepod, *Corycaeus* sp. Thus, given the numerical composition of the calanoid and cyclopoid copepod community, electivity would be high for the *Calanus* and *Epilabidocera* component of the community.

There are a number of alternative hypotheses to the apparent neritic prey selectivity: (1) the bongo net and sampling design do not realistically sample the composition of the plankton community in the top 3 m of the water column, e.g., zooplankters avoid the net; (2) the townet collections do not capture fish feeding in the surface plankton community; or (3) the daytime composition of the plankton community is not spatially or temporally characteristic of that in which the chum fry have fed. Of these alternative hypotheses, the first two are the least plausible; the capture of such highly motile crustaceans such as hyperiid amphipods indicates that the bongo net is an efficient sampler of large planktonic crustaceans and the townet's effective capture of marked chum fry suggests that inefficient sampling will not explain these discrepancies.

The most valid hypothesis, therefore, is that the chum fry collected by the townet have fed either in a deeper stratum where larvaceans, hyperiid amphipods, and large calanoid species are more abundant, or are foraging in a crepuscular manner, i.e., at dusk and dawn when that plankton community has vertically migrated closer to the surface. Cooney (1971), Damkaer (1964), and Frost (Department of Oceanography, University of Washington, unpublished data, personal communication) provide evidence that *Calanus* calanoid copepods are typically most abundant in the diffuse scattering layer which usually occurs deeper than 50 m during daylight in Hood Canal. The diel vertical migration of this community is unfortunately not well known, so it is up to conjecture or more detailed sampling to determine whether these plankters migrate into the surface waters, within range of the crepuscular-feeding chum fry, or the chum fry are actually feeding in deeper strata. It would appear from Damkaer's (1964) collections in Dabob Bay, though limited to December 1960, that there was some diel migration toward the surface of the *Calanus* sp. copepods, although the highest densities still resided well below the pycnocline. Only *Epilabidocera* occurs predominantly in the surface waters. The smaller species, i.e., *Pseudocalanus* sp. and *Paracalanus* sp., were restricted to the surface layers and *Coryceaus* sp. to just below the pycnocline. Thus, even if the copepod taxa exploited by the chum were within the top 5 m of the water column, the prey density was still significantly lower than the plankton community they pass through during the day. Unless the chum were feeding below the pycnocline, the implication of high selectivity toward large zooplankton is reinforced rather than rejected. Further analysis of the oblique bongo net samples and the stage of digestion of the component plankters in the stomach samples may provide a clearer indication of the actual feeding situation during the salmon outmigration.

6.4 DISCUSSION

6.4.1 Relationship Between Migration Behavior and Prey Resources

The migration behavior of juvenile chum and pink salmon (*see* Sec. 3.0) in terms of occupation of shallow sublittoral and neritic habitats and speed of outmigration through northern Hood Canal appears to correlate with the availability and density of preferred food organisms. Chum fry entering the Canal early in the outmigration period (February-March), especially small native chum and pink fry, encounter a relatively low state of prey resources in both shallow sublittoral and neritic environments. The very short residence times (rapid outmigration rates) documented for chum fry during this period suggests that one behavioral response to low prey availability might be immediate migration out of the Canal. Although larger, neritic-feeding fish were not utilized in the early mark-release experiments, it appears that even these fish, such as the fed fry released by hatcheries on Hood Canal, are constrained to feed upon large epibenthic organisms such as gammarid amphipods in the absence of large neritic zooplankters, i.e., *Calanus* copepods.

With the development of the epibenthic and neritic zooplankton communities late in the outmigration period (April-June), the migration rate of the chum fry declines and residence time increases almost as if in response to the increased frequency of encounter of preferred prey organisms. During this period the salmon fry appear to initiate feeding upon epibenthic zooplankton in the shallow sublittoral habitats. The fry appear to disperse their daytime schools at night and, upon reaching 40-45 mm in (fork) length, begin to feed upon neritic organisms. Until 55-60 mm in length, however, they continue to school and migrate through shallow sublittoral habitats during the day; but upon reaching this threshold size they rapidly shift to a predominantly neritic feeding behavior and epibenthic organisms seldom dominate their diet.

While the mechanism explaining the transition from epibenthic to neritic feeding has not been firmly established, a principal candidate is prey size as a function of the ontogeny of the salmon fry during their outmigration (Foskett 1951; Okada and Taniguchi 1971; LeBrasseur 1969). Our data indicate that the Hood Canal chum fry 35-45 mm in length select the largest harpacticoid copepods available, which is consistent with much of the recent literature for other planktivorous fish species (Brooks and Dodson 1965; Confer and Blades 1975; Werner and Hall 1974; Galbraith 1967). In contrast, Feller and Kaczynski (1975) documented selection for the *smaller* fraction of the available size distribution of harpacticoids (also using an epibenthic pump). The chum fry they examined were smaller than the size range we utilized, which may explain the differences. An alternative explanation is that the two epibenthic pump systems had opposite biases in their sampling of representative harpacticoid size distributions; composition of the two size distributions, however, indicated no significant differences.

Healey (1979) illustrated a rather consistent foraging upon harpacticoid copepods during the chum fry outmigration through the Nanaimo River estuary. Residence time in that estuary was considered to be relatively short and would therefore have been confined to epibenthic-feeding fry. Healey also documented that the principal harpacticoid fed upon by the chum fry was the comparatively rare species *Harpacticus uniremis*, which Sibert (1979) noted to be reasonably large (∿1.5 mm) and distinctively marked as adults. Both Healey and Sibert suggested that the residence and productivity of chum fry in the Nanaimo River estuary was linked in some way to the production of just *H. uniremis*.

6.4.2 Importance of Nearshore Habitats and Particular Prey Assemblages

Harpacticoid copepods and gammarid amphipods of shallow sublittoral habitats appear to be the preferred prey of epibenthic-feeding salmon fry. The highest standing stock estimates of these organisms typically occurred in semiprotected, sandy shoreline habitats characterized by dense eelgrass beds, such as our sampling site at Devil's Hole Delta. As such, these habitats should be considered as optimal for the nearshore residence and foraging of chum and pink fry and may contribute disproportionately to the total carrying capacity of shallow sublittoral habitats for fry.

Kikuchi (1974) documented the importance of eelgrass beds as habitat for epibenthic macrofauna and the fish that feed upon them. He estimated densities of epibenthic organisms from 8,020/m^2 (well-protected muddy bottom) to 13,918/m^2 (less-protected sandy bottom) in an eelgrass bed in Tomioka Bay, Japan (using a 0.5-mm sieve mesh screen). Densities of epibenthic fauna in a thick eelgrass meadow at Port Williams, along the Strait of Juan de Fuca, were estimated to be 177,490 ± 127,796/m^3 by Simenstad et al. (1980, in preparation), of which a predominant proportion (81%) were harpacticoid copepods. Density estimates for the epibenthic community at Devil's Hole Delta approached 100,000/m^3 in mid-April 1977; estimates for Devil's Hole Delta are not available for 1978 and 1979 when the epibenthic plankton pump was obviously more effective in capturing epibenthic zooplankton. If the residence time of epibenthic-feeding fry in Hood Canal early in the outmigration is directly linked to the abundance of large harpacticoid copepods, as our and other data suggest, the maintenance of shallow sublittoral eelgrass habitat is important to the early marine life history of the Canal's chum salmon populations.

The neritic habitat, with its abundance of large zooplankters, including calanoid and cyclopoid copepods, euphausiids, hyperiid amphipods, and larvaceans, is the principal foraging habitat for chum and pink fry larger than 45 mm (especially hatchery-produced fed fry) later in the outmigration period, i.e., mid-April through early July. Our knowledge of the distribution, structure, standing stock, and behavior of the particularly preferred prey organisms is too limited to provide a direct inference of the foraging behavior of the salmon fry. Our data suggest that they forage in a crepuscular pattern upon diel-migrating plankters (e.g., *Calanus* sp.) and limit their daylight feeding to the few large plankters which characterize the neuston community (e.g., *Epilabidocera* and *Oikopleura*).

6.4.3 Potential Effects of Construction and Operation of Navy Facilities upon Feeding Ecology of Outmigrating Salmon Fry in the Bangor Region

While the sampling plan, salmon fry available for stomach analysis, and zooplankton sampling were limited in scope and not specifically designed to evaluate potential effects of construction and operation of Navy facilities at Bangor, some deductions may be drawn from the available data.

The apparent importance of shallow sublittoral habitats associated with eelgrass beds as foraging habitat indicates that destruction or disruption of these habitats would reduce the total carrying capacity of that region for outmigrating chum fry and reduce their dependent utilization of that region early in the outmigration period. The persistent schooling of 40-50 mm chum fry in these regions during the daylight period, even though they may have already made the transition from epibenthic feeding to neritic feeding, also suggests that such behavior involves a stategy to minimize predation. Whether or not predation is actually manifested (and data described in earlier sections and other reports [Simenstad and Kinney 1978] suggest that it may not be affected by other nearshore fish), the behavior is a firmly established element of the fry's behavioral repertoire.

Studies of the chum salmon populations of Big Beef Creek (Koski 1975, Schroder 1977) have indicated that early outmigrating fry tend to have lower marine survival rates than those which migrate later. As has been described in other sections, residence time in the Canal also appears to increase with the progression of the fry outmigration. Thus any decrease in foraging habitat or alteration of the nearshore environment which decreases the residence time of the migrating fry has the potential to decrease the total marine survival of those fry passing through northern Hood Canal.

Design and placement of the nearshore piers and shore structures outside the shallow sublittoral zone have probably minimized the long-term impact of the Trident construction activities upon nearshore habitats important to migrating salmon fry as long as properly high water quality is maintained in the area. The effect of high intensity lighting upon the diel foraging behavior of chum fry in the vicinity of the EHW is more difficult to predict. While no plankton or trophics sampling was performed specifically around an experiment testing lighting effects, one survey was performed in May 1979 to evaluate the relative availability of nearshore zooplankton around the EHW complex under various lighting regimes and at a nonlighted control station. Funding was not available for detailed quantitative and taxonomic analyses of the samples, but qualitative interpretations suggest that there were no major differences in the availability of epibenthic zooplankton, but that certain taxa of neritic zooplankton were dramatically enhanced. Polychaete annelids and fish larvae were the most notable organisms attracted to the lighted areas. However, examination of the acoustic recording charts and oblique bongo net samples indicated that under the influence of the artificial lighting the nocturnal negatively phototrophic behavior of normal, diel-migrating zooplankters was inhibited. This effectively reduced the abundance of such organisms as calanoid copepods and euphausiids in surface neritic waters where salmon fry would be feeding. Since many of the attracted zooplankton do not contribute much to the diet of chum and pink fry, the net effect of lighting may be to reduce the actual availability of zooplankton under and adjacent to the EHW even though illumination is sufficient to maintain feeding conditions during normal periods of darkness. But because feeding could be maintained in lighted shallow sublittoral habitats and the area coverage of the lighting in the neritic zone is relatively minimal, it is questionable that this negative effect is significant. Extensive expansion of lighting in the nearshore region or increased illumination may, however, alter this conclusion.

The attraction of piscivorous predators into the lighted areas, where they could prey upon feeding salmon fry, is discussed under a separate section (Sec. 5.0).

6.5 CONCLUSIONS

1. Juvenile chum and pink salmon migrating through northern Hood Canal prey predominantly upon epibenthic and neritic crustaceans, depending upon fish size and time period in the outmigration. Harpacticoid copepods and gammarid amphipods were the prevalent epibenthic prey while calanoid copepods, euphausiids, hyperiid amphipods, and larvaceans were the prevalent neritic prey organisms.

2. Prey overlap of chum fry captured in shallow sublittoral habitats was higher between habitats within year of collection than between year of collection within habitat. Overlap was generally higher for neritic-feeding ("offshore") chum fry, especially late in the outmigration period.

3. Co-occurring chum and pink fry had relatively overlapping prey spectra, particularly when of the same general size or when feeding upon neritic prey organisms.

4. Prey overlap was higher among marked samples of chum fry than between similarly-sized marked and unmarked samples.

5. The composition of the epibenthic zooplankton community preyed upon by juvenile chum and pink salmon was predominated by harpacticoid copepods, whose abundance also accounted for the majority of the fluctuations in zooplankton density.

6. In all three years the general decline in harpacticoid copepod densities in early spring appeared to coincide with peak densities of chum salmon fry in shallow sublittoral habitats, suggesting the epibenthic-feeding salmon fry could be involved in depression of harpacticoid prey populations during the most intensive period of their outmigration.

7. Of the shallow sublittoral habitats sampled, semi-protected, sandy areas with extensive eelgrass beds generated the highest estimates of standing stock of epibenthic organisms.

8. Limited sampling of the neritic zooplankton community indicated that calanoid copepods dominated the community, followed by juvenile caridean shrimp, cyclopoid copepods and larvaceans; larvaceans were particularly abundant only in 1979.

9. Chum fry appear to be highly selective in their feeding upon both epibenthic and neritic organisms. In most instances selection appeared to be based upon the sizes of the prey organisms, where the largest organisms of a prey taxa were the most preferred, even though they were numerically rarer than smaller organisms of the taxa. The resulting interpretation is that the prey community actually utilized by the juvenile chum and pink salmon is only a small fraction of the total zooplankton resource.

10. Considering the design of the U.S. Navy facilities along the Bangor shoreline of northern Hood Canal, the long-term effects of construction and operation upon the prey communities of outmigrating chum and pink fry are expected to be minimal as long as extensive areas of shallow sublittoral eelgrass bed habitat are not destroyed. However, illumination of the nearshore environment during the night is likely to alter the composition and standing

stock of the prey communities available to the salmon fry during their normal crepuscular feeding periods but may also provide for increased feeding opportunities during hours of darkness. However, design of sampling, available specimens for stomach analysis and limited zooplankton sampling does not permit an adequate assessment of the lighting effects, especially at the potential illumination regimes that are expected to be in effect during salmonid outmigration periods.

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7.0 INDIAN ISLAND SALMONID MONITORING - 1977

[Summary Prepared by Thomas E. Prinslow]

7.1 INTRODUCTION

As part of the expansion of Hood Canal facilities for the Trident submarine the U. S. Navy constructed during 1977-1978 a two-berth ammunition loading pier and wharf (275 x 35 m and 230 x 20 m) extending 300 m into Port Townsend Bay from Walan Point, Indian Island Annex (Figs. 7-1 and 7-2).

To provide baseline information for any future assessment of impact of construction on juvenile chum salmon (*Oncorhynchus keta*)[1] migrating through the area, the Fisheries Research Institute, University of Washington conducted biweekly surveys during January-July 1977 in conjunction with intensive outmigration studies in the Bangor area of Hood Canal (Fig. 1-1) (Bax et al. 1978 and Sec. 3.0). A final report was prepared in 1977 (Moore, Snyder, and Salo 1977). Concurrent impact work with Pacific cod (*Gadus macrocephalus*) was reported elsewhere (Karp and Miller 1977).

7.2 METHODS

Migration of chum in the Indian Island area was monitored by sampling 12 nearshore and 18 offshore sites (Figs. 7-3 and 7-4) using beach seine and townet (*see* Sec. 3.1.2 for design specifications and deployment technique).

7.3 RESULTS AND DISCUSSION

Peak migration periods of chum traveling near shore (available to beach seine) in the Indian Island area occurred in mid-April and early June, while those traveling offshore (available to townet) were increasing in abundance at the termination of sampling in mid-July (Fig. 7-5).

Peak migration periods at Bangor (Fig. 7-6) preceded those at Indian Island. The peak abundance of nearshore chum at Bangor in early June was probably reflected by later townet catches at Indian Island since during June growth rates are maximal (Whitmus and Olsen 1979), and chum switch from nearshore to offshore movement as they grow (Gerke and Kaczynski 1979; Feller 1974).

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[1] Chum are the predominant salmonid in Hood Canal.

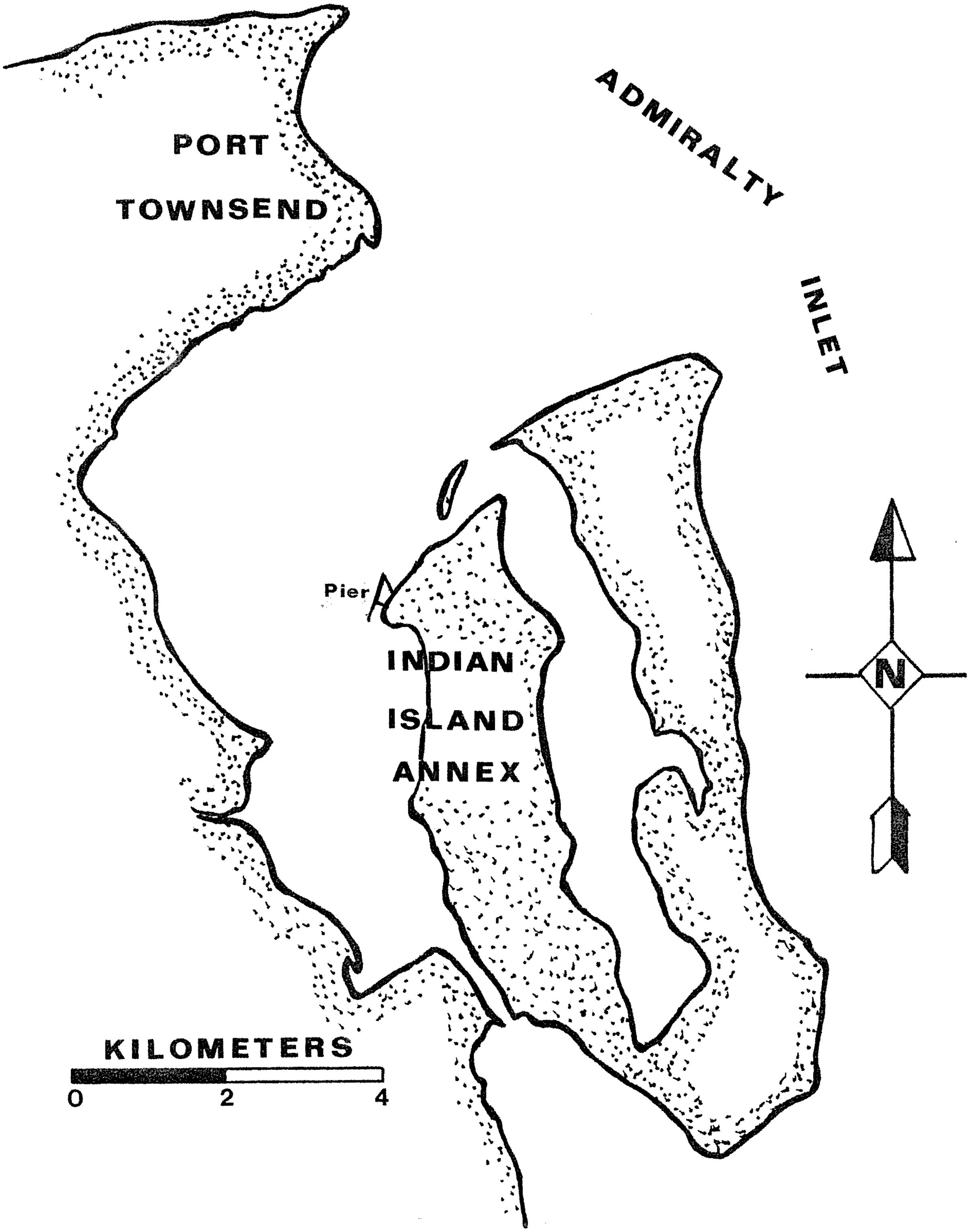

Fig. 7-1. Location of Indian Island Annex and proposed pier.

March 1977

April 1977

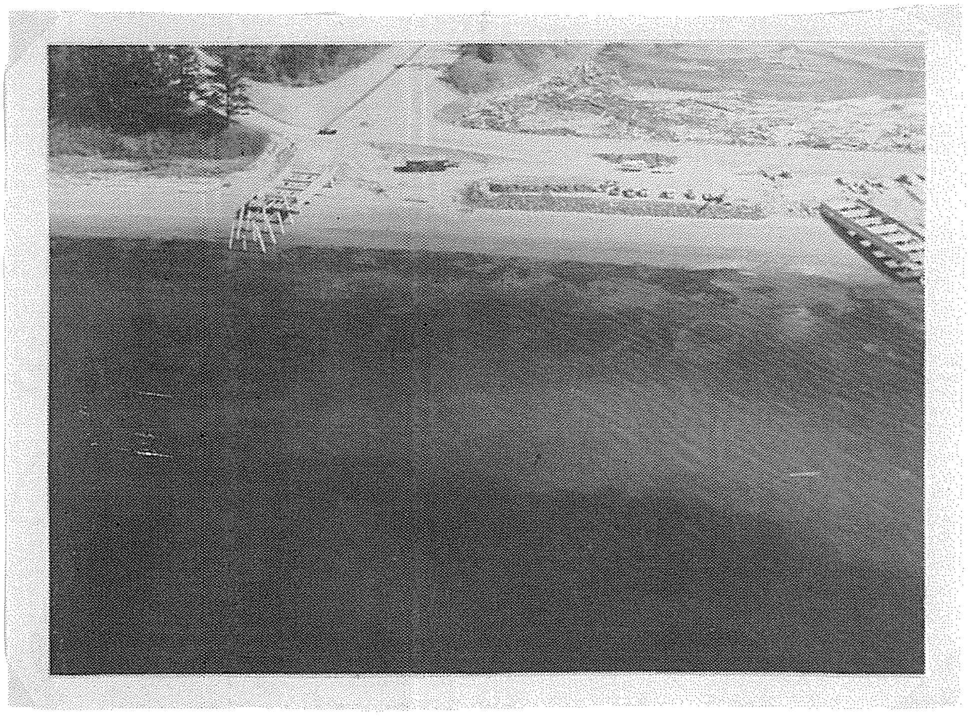

Fig. 7-2. Walan Point, site of pier construction; March 1977 - prior to construction; April 1977 - construction begun.

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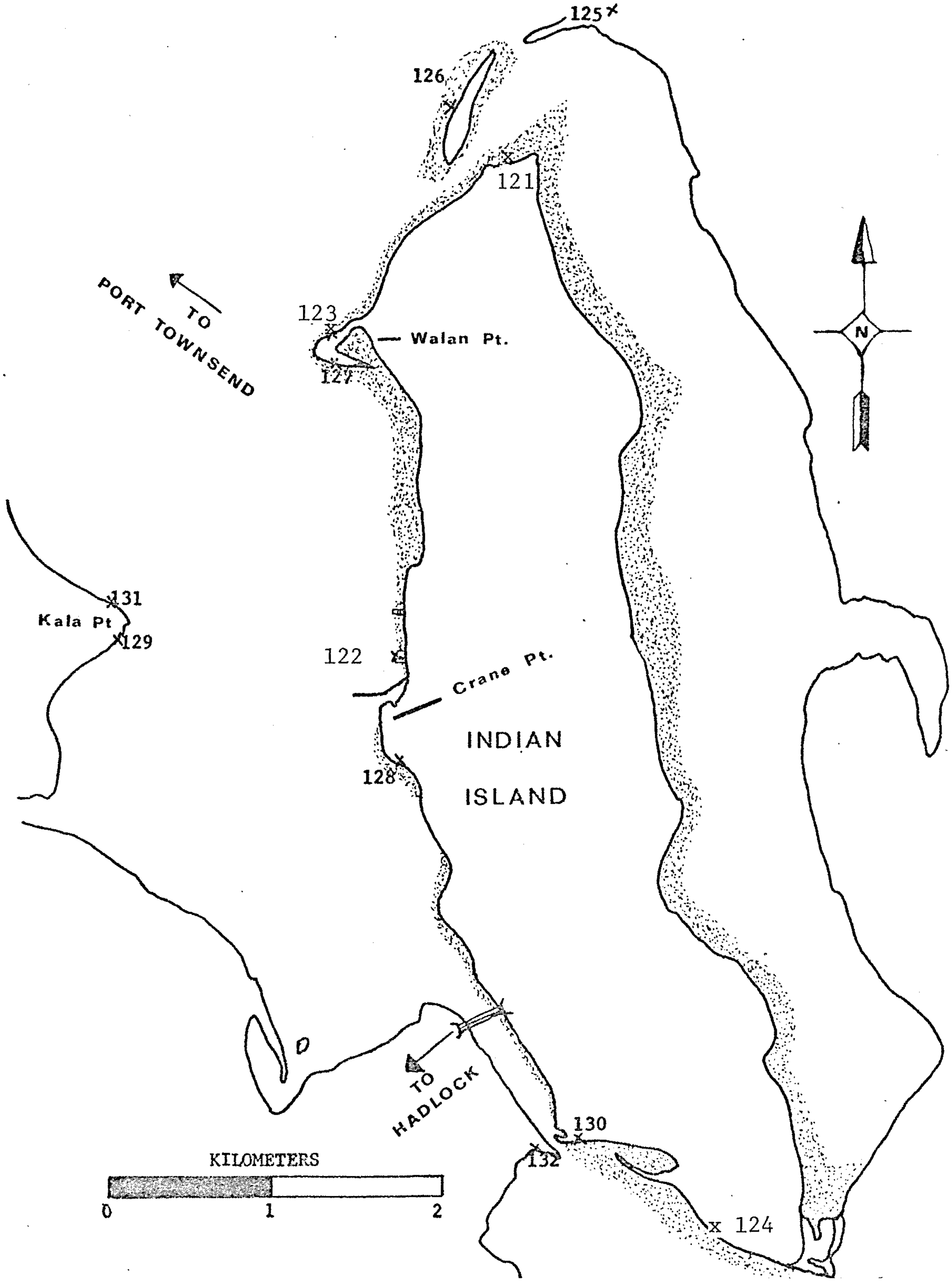

Fig. 7-3. Beach seine sampling sites at Indian Island, Washington, January-July 1977.

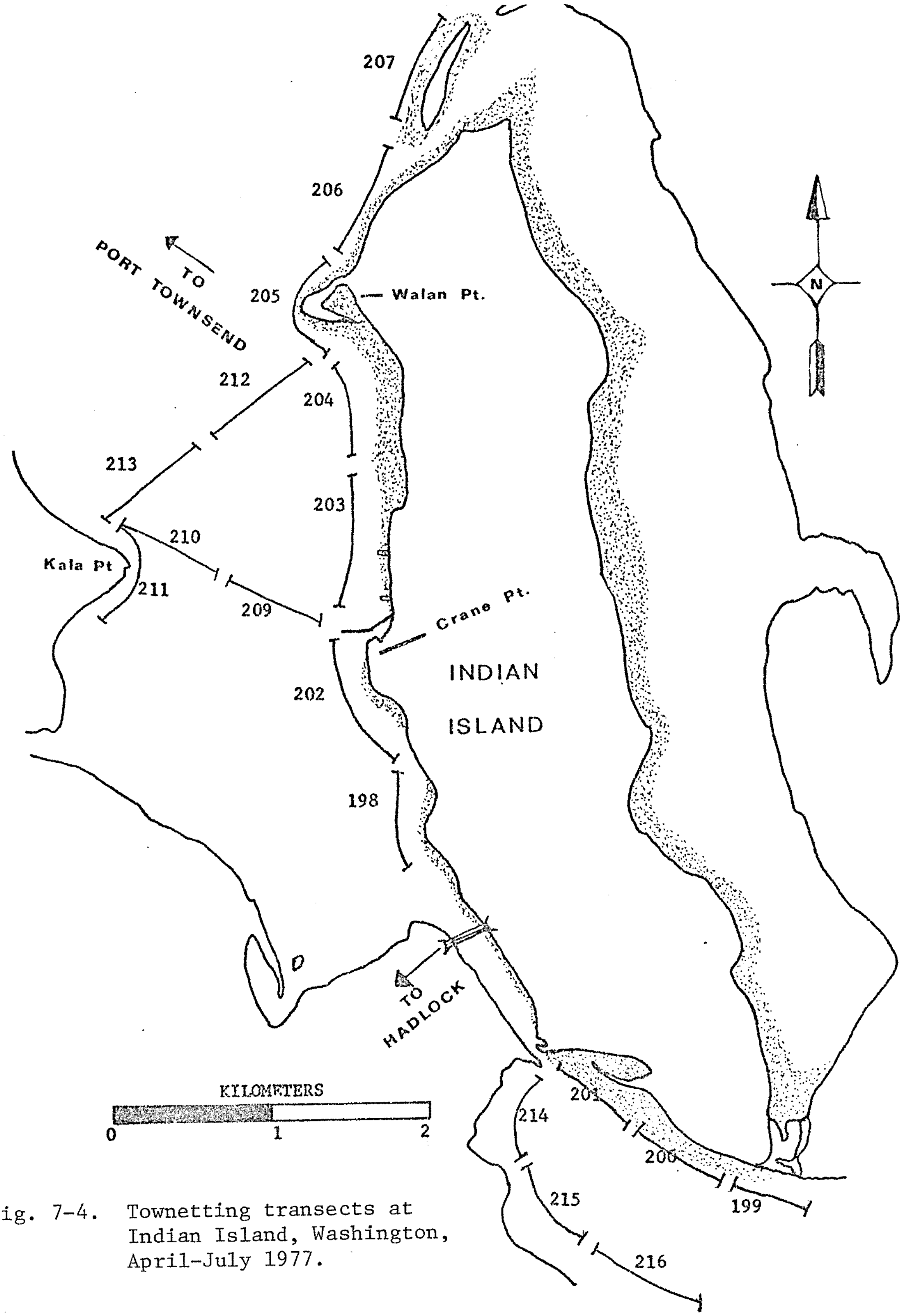

Fig. 7-4. Townetting transects at Indian Island, Washington, April-July 1977.

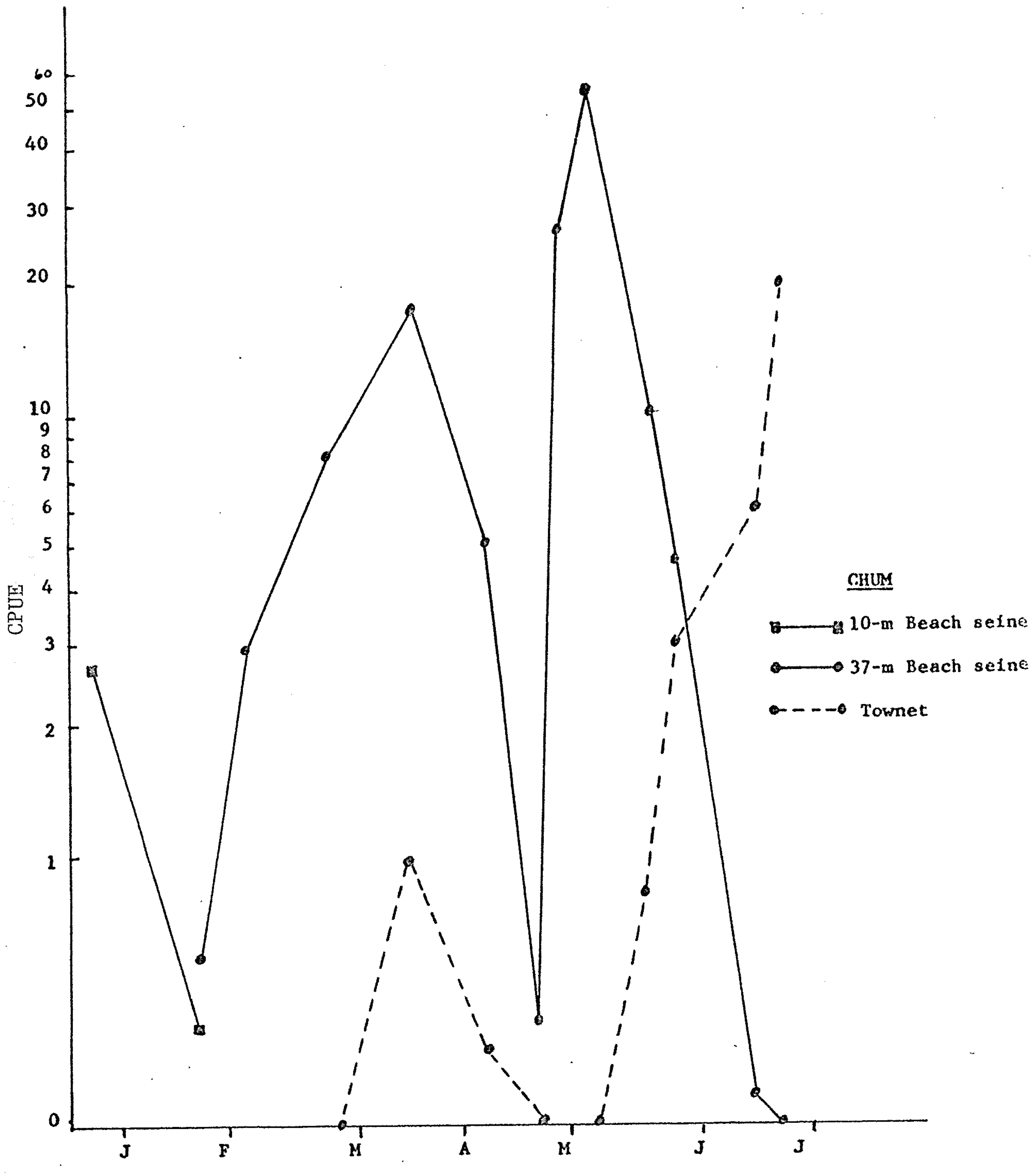

Fig. 7-5. Catch per unit effort (CPUE) of chum salmon at Indian Island, Washington, 1977 (time scale approximate).

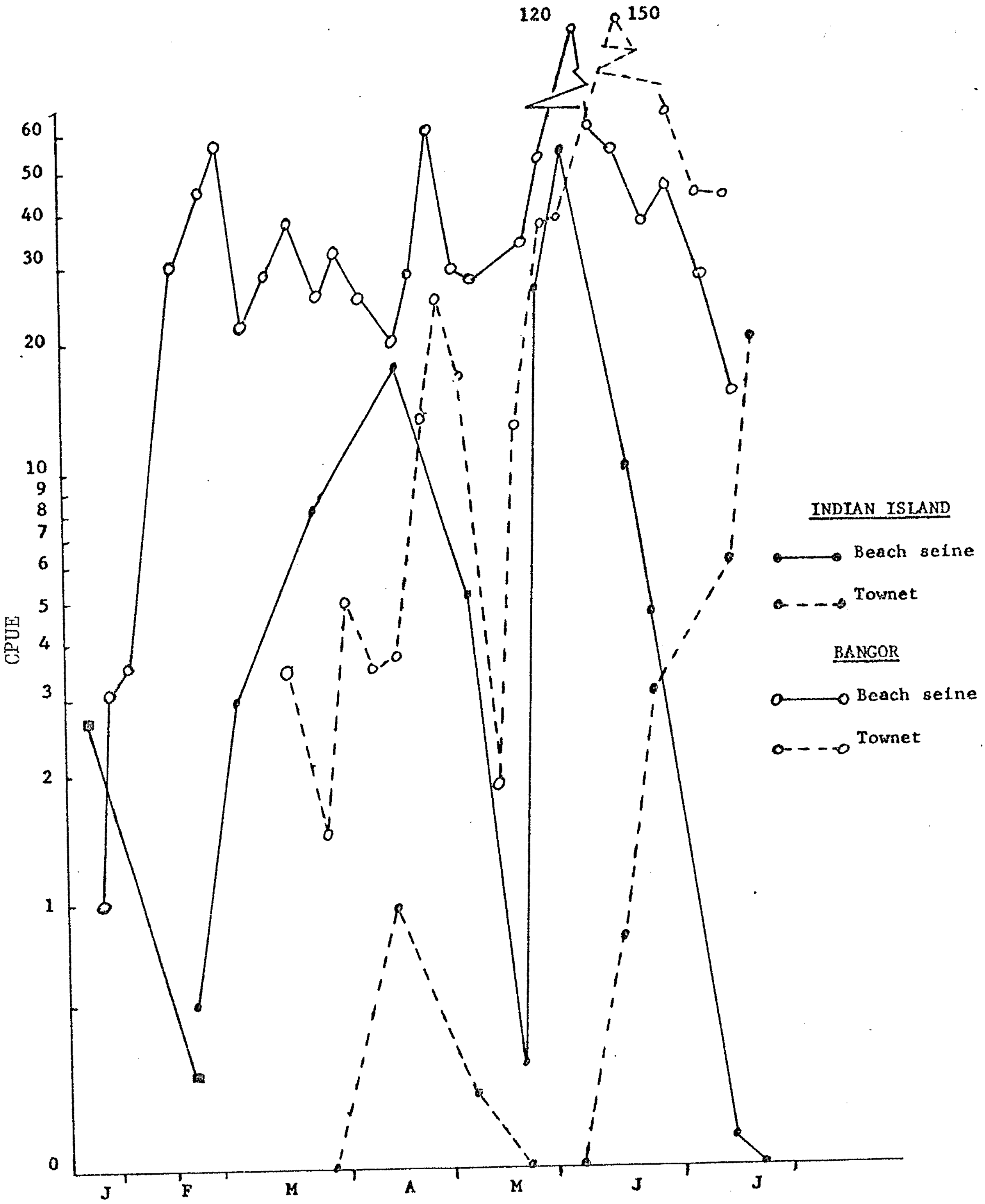

Fig. 7-6. Catch per unit effort (CPUE) of chum salmon, Indian Island vs. Bangor, January-July 1977 (time scale approximate).

It is uncertain how many of the chum caught near Indian Island originated from Hood Canal hatcheries and spawning areas, as opposed to sources in Puget Sound. At least some Hood Canal chum reach the Straits of Juan de Fuca by passing Indian Island because a total of six marked chum (Table 7-1) were recaptured near Indian Island from releases at Hoodsport hatchery and Bangor (experimental releases by Whitmus and Olsen [1979]; see also Section 3.1.2). Sampling effort was inadequate to estimate what proportion of the 20+ million salmonid outmigrants in Hood Canal take this route.

Major construction work (pile driving) at Walan Point was conducted throughout the study period, but did not affect chum catch-per-unit-effort (CPUE) (Table 7-2).

7.4 CONCLUSIONS

1. Juvenile chum (*Oncorhychus keta*) were the most abundant salmonid in the Indian Island pier construction.

2. Nearshore chum catch peaked in mid-April and early-June, while offshore catch was increasing at the termination of sampling in mid-July.

3. The recapture of six marked chum from Hood Canal hatcheries indicates that some Hood Canal salmonids take this passageway in their seaward migration, but sampling effort was inadequate to estimate what proportion do so.

4. No effect of pile driving at the pier construction site on chum catch was detected.

7.5 LITERATURE CITED

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Gerke, R. J., and V. W. Kaczynski, 1972. Food of juvenile pink and chum salmon in Puget Sound, Washington. Washington State Dep. Fish., Tech. Rep. 10. 27 pp.

Table 7-1. Spray-marked chum released into Hood Canal and recovered at Indian Island, Washington, 1977.

Release site	Date released	Time	Number released	Color (mark)	Length (Mean) mm	Recovery date	Number collected	Length (mm)	Migration duration[4]
B.B.C.[1]	February 21	PM	50,206	Red	48.3				
B.B.C.	21	PM	20,492	Yellow	56.5				
Bangor[2]	21	AM	3,000	Blue	-	March 1	1	46 mm	8 days
B.B.C.	March 20	-	27,000	Red	57				
			7,000	Green	53				
B.B.C.	27		63,550	Orange	55				
B.B.C.	April 16		20,000	Orange	38				
	17		22,000	Blue	38				
	18		20,000	Green	38				
Hoodsport[3]	20		256,000	Red	-	May 6	4		16 days
Hoodsport	June 5		400,000	Orange	-	June 17	1	80 mm	12 days

[1] Big Beef Creek, University of Washington.

[2] Bangor Annex, University of Washington.
[3] Hoodsport Hatchery, State of Washington.
[4] Note: Indian Island to Bangor - 27 km,
to B.B.C. - 37 km,
to Hoodsport - 67 km.

Table 7-2. CPUE per day near Walan Point versus number of pilings driven at pier site, Indian Island, Washington, 1977.

Date	Number of piles driven	Transects			Station		Daily total
		204	205	206	123	127	
January 20	3	-	-	-	0	0	0
February 17	15	-	-	-	1/0[1]	0/1	2
March 1	0	-	-	-	3	9	12
April 1	0	0	0/0[2]	0/0	0	0	0
15	12	0/0	0	0	0	0	0
May 6	0	-	0/0	0/0	0	0	0
20	3	-	0	0	0	-	0
27	0	-	-	-	0	-	0
28	No data	-	-	-	-	29	29
June 2	2	0/0	0	0	-	0	0
3	2	-	0	0	-	-	0
16	8	-	0	0	-	27	27
17	3	0/0	0	0	9	-	9
24	No data	0/3	0/10	1	11	-	25
July 14	16	8/14	0/5	0	0	0	27
15	10	2/4	5	0	0	0	11
21	16	0	9	0/4	0	0	13

[1] Two values per day for beach seine means 10m first, 37m second.

[2] Two values per day for townet means transect was sampled twice.

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8.0 RECOMMENDATIONS

8.1 OPERATIONAL PROCEDURES

1. Operational lighting (30-40 ft-c; *see* Sec. 5.0) should be minimized and directed toward pier and trestle work areas as much as practicable.

2. Security lighting (0.2-0.4 ft-c), when required, is recommended for all waterfront structures.

3. Pollution containment equipment should be located at Bangor to handle routine spillage.

4. Speed of support service vessels should be minimuzed within 500 m of shore because of potential turbulence from vessel wakes in the littoral areas.

8.2 CONTINUED MONITORING

Because chum salmon generally have a 3-4-year marine residence before returning to spawn, additional information on the outmigrants which were monitored as juveniles from 1977 onward, will not start to become available until Fall 1980. By Fall 1983, outmigrants monitored during 1975-1979 will have returned and at that time any unusual variations in the returns may be evident. It is recommended that the evaluation of outmigrations be continued.[1]

1. Outmigration studies should be continued from 1980 through one year after construction is completed during the peak period (April- June) to determine if the apparent loss of chums as they migrate past Bangor is real (*see* Sec. 3.0). We recommend weekly beach seine sampling at Carlson, Marginal Wharf, EHW, Floral, Brown, and Spit 6, and townetting along these shoreline areas (*see* Sec. 3.0). These sites have been sampled since 1975 and would serve as index areas for future assessment.

2. Shoreline biological studies by the Naval Undersea Center should be continued until completion of shoreline construction, particularly to monitor the eelgrass areas (*see* Sec. 6.0).

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[1] We do not wish to imply that any monitoring beyond 1979 is an obligation of the Navy.

3. Additional food habit studies are needed at EHW during security and operational lighting modes to determine response of salmon prey organisms (plankton) to the lights. These might also be used to further define the responses of salmon to the lights (*see* Secs. 5.0 and 6.0). Also, the communities of fishes among the wharf pilings should be described.

APPENDICES

APPENDIX I

PURSE SEINE SPECIFICATIONS

Hung dimensions: 200' x 30' (stretch measure approx. 250' x 40' with 25% hang-in)

Bunt end: 1/4" stretch knotless nylon (kn) 800 meshes deep (md), joined to 1/2" stretch kn. Bunt end taper: 2 bar, 1 mesh. Breast lines 12' long with 4 equally spaced rings.

Body of net of 1" stretch kn 600 meshes deep.
Wing of 1" stretch kn, same taper and breast line as bunt end.
3" stretch mesh panel along lead line, 3 meshes deep.

Cork line: Samson stable brand, 1/2". Hang tight. Use 3 x 3 floats every foot, every 9" on bunt end.

Lead line: Bristol Bay 200 lb/100 fathom.

Ring Bridle: 4 1/2' finished length, with eye splice ends, clove hitch around ring. Lash eyes to lead line. Use 3/8 x 4 rings. Space ring bridles 4 1/2' from end of lead line, then every 4 1/2' thereafter, with 6" drop per bridle.

Purse Line: same as cork line, with eye splices in ends and middle; fit ends with figure 8 shackles.

Netting specs:

1/4": 02 thrd 12 lb 800 md, 255,900 sq m/lb
1/2": 1 1/2 thrd 15 lb 800 md, 110,800 sq m/lb
twine: lash with 15 thrd perma grip
1": 4 or 5 thd, 15 lb 200 md.
3": 5 thd, 15 lb, 3 md.

APPENDIX II: Changes in Length and Weight of Chum Salmon Fry at 1- and 7-days after Preservation in 10% Buffered Saltwater Formalin.

by Michael McDowell

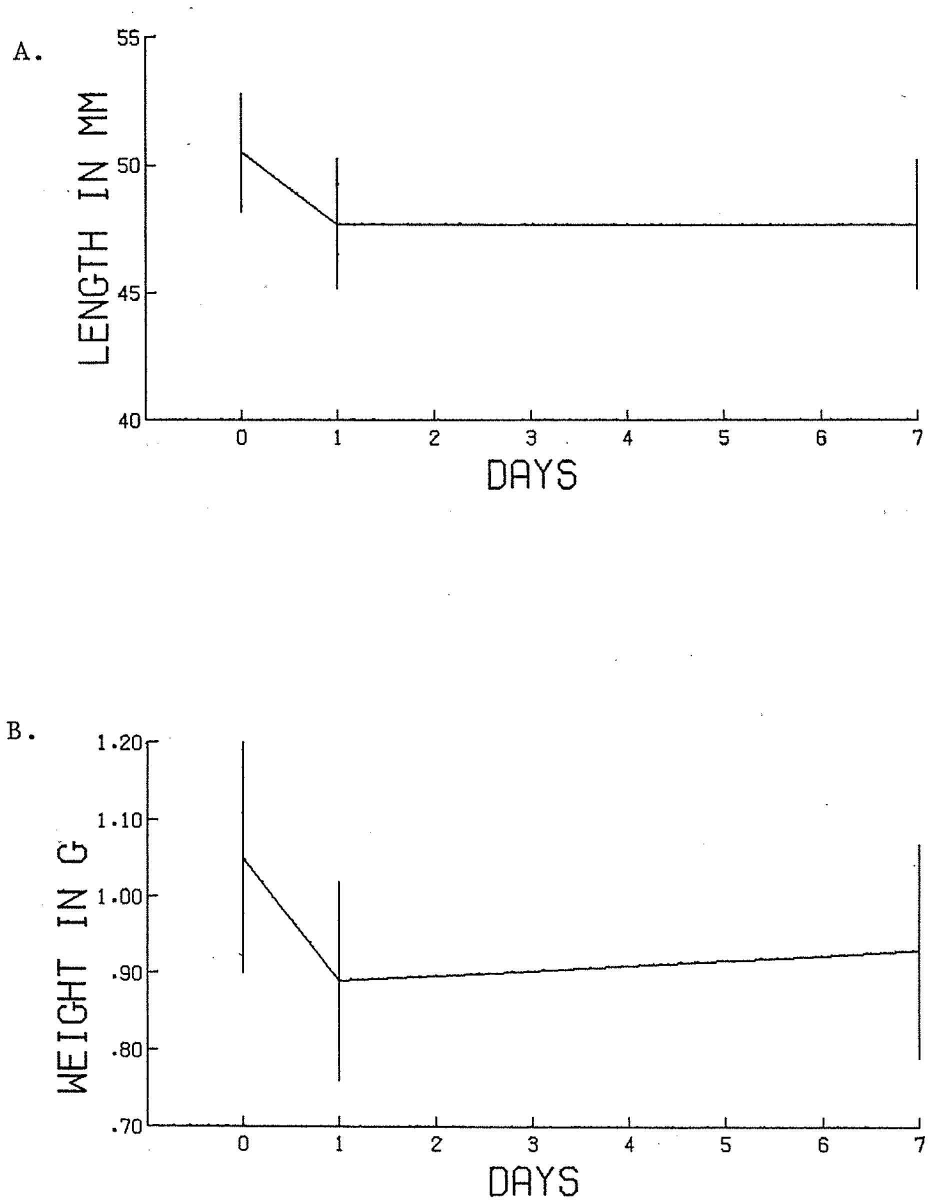
The nighttime sampling schedule of 1979 outmigration and lighting studies brought with it several logistical problems not encountered in previous years. One of these problems involved the handling of the salmon fry collected for the outmigration and lighting studies. In the years preceding 1979 the length/weight from the fry was taken from a particular day's catch immediately upon return from the day's sampling. This procedure became impractical with the night sampling regime. It was proposed to hold the samples for some period to allow them to be worked up in the evening before the night's sampling began. Therefore, it became important to determine what would be the best period of time for holding the samples.

The periods of 24 hr and 7 days, from the time of being caught, were suggested. A study was undertaken to determine what effects storage would have and at which time it would be best to look at the samples. The fry used for this study were taken from a group of fish being reared for our mark-release program.

Thirty fish were taken in a random sample from a group of approximately 120,000 in one of our rearing ponds. This number was chosen because it had been shown to be a sufficient sample in the determination of KD condition factors in salmon fry in previous years. These fish were put down individually using MS 222. Length and weight were taken on each fish. The fish were then placed in individual numbered vials containing 10% buffered saltwater formalin. After 24 hr each fish was removed from its vial, patted dry, weighed and measured for length and placed back into its vial. This procedure was repeated after 7 days.

The data clearly show a drop in mean length and mean weight of the preserved fry over the first 24 hr (Appendix Figs. 1A and 1B). In the ensuing 6 days the mean length did not change, while the mean weight increased. The standard deviation of the length and weight distributions did not change appreciably over time.

After examination of all these data, it was decided that 7 days after being caught would provide us with the most stable situation. Therefore, all samples when taken in the field were placed live into 10% buffered saltwater formalin. These samples were then worked up 7 days later. This schedule was followed throughout the sampling season.



Appendix Fig. 1. Change in A) length and B) weight over a period of 7 days of chum salmon fry preserved in formalin. Expressed as the mean ± one standard deviation.

APPENDIX III

Summary of Wavelength test catch data
May - June 1979.

Wavelength (color)	Date	Catch in lighted (L) and control (C) sets									
		Chum		Chinook		Coho		Hake		Dogfish	
		L	C	L	C	L	C	L	C	L	C
WHITE	MAY	1	--	0	--	0	--	0	--	0	--
		0	1	0	0	0	3	0	0	0	2
		0	0	0	0	0	0	0	0	0	1
	JUNE	43	10	1	0	4	0	5	1	2	0
		36	19	2	1	4	1	10	17	9	61
		47	6	3	0	2	2	0	4	4	0
		1	7	0	1	0	0	0	1	1	1
		14	11	0	3	0	0	0	1	1	0
YELLOW	MAY	13	25	0	0	2	0	1	0	0	0
		35	95	3	0	4	1	9	1	6	0
		7	7	0	0	5	2	1	2	0	1
	JUNE	8	4	0	0	0	0	0	0	0	11
		2	8	0	0	0	0	0	1	1	1
		1	4	0	1	2	0	0	0	0	0
GREEN	JUNE	48	14	5	1	0	0	0	2	0	0
		4	1	0	1	1	0	0	0	0	0