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T. E. Prinslow, C. J. Whitmus, J. J. Dawson,
N. J. Bax, B. P. Snyder, and E. O. Salo

FINAL REPORT

January to December 1979

This work was sponsored by the U.S. Department of the Navy

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FISHERIES RESEARCH INSTITUTE
College of Fisheries
University of Washington
Seattle, Washington 98195

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Submitted July 31, 1980

Robert L Burgner
Director

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ABSTRACT

Effects of Wharf Lighting on Outmigrating Juvenile Salmon

During 1976-1978 and 1979, the Fisheries Research Institute (FRI) of the University of Washington conducted a series of experiments to assess the effects of wharf lighting at the U.S. Naval Submarine Base-Bangor on outmigrating juvenile salmon in Hood Canal, Washington. Chum are the principal salmonid in Hood Canal, and pink the second most abundant. Previous studies reported that light may attract or repulse juvenile salmon depending on its quality (type and wavelength) and intensity. This report presents the results of the 1979 experiments and reviews those conducted during 1976 and 1978.

FRI studies focused on a 150-m-wide wharf which extends 180 m into the Canal; maximum depth below the wharf is 30 m. Three modes of wharf lighting were studied. Mode I termed "security lighting" provided 2-13 lux (11 lux ≅ 1 ft-c) at the water surface, and consisted of 150 W incandescent spotlamps emitting a white light, and 35 W low-pressure sodium vapor (SOX) lamps emitting a yellow light. Mode II, termed "partially operational lighting," provided 2-13 lux at surface around the perimeter of the wharf using Mode I fixtures, and ∿200 lux at surface in a 23-m wide berth in the offshore portion of the wharf; berth area fixtures were 1500 W quartz lamps emitting a white light. Mode III, termed "operational lighting," provided 2-66 lux at surface around the wharf perimeter using 250-500 W streetlamps (emitting an amber light) in addition to Mode I fixtures, and ∿400 lux at surface in the berth; 400 W and 1000 W metal halide lamps emitting a white light provided the additional berth lighting. The studies emphasized Mode I lighting; brief tests of modes II and III were conducted in 1978.

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

Mode I lighting (2-13 lux) did not affect salmonid catch, although we did observe salmonids congregating below the lights. Increased salmonid catch in the nearshore areas at the wharf appears to have been caused by some other stimulus, which we speculate was the presence of chum prey organisms characterizing this area. Perhaps salmon near the lights were drawn to them, but no large-scale aggregation of salmon in the wharf area resulting from Mode I lighting was detected.

Significantly greater light intensities (200-400 lux) of Mode II and Mode III conditions appeared to attract and delay chum (for 1-2 days from their normal migration timing). Because it is unlikely that any response to lights at night would carry over during the day, we speculate that the chum were initially attracted to the lights, but

remained because of food availability. Too few tests were run under these conditions to be conclusive.

Predation on outmigrating salmon in the wharf area was considered insignificant, as $< 4\%$ of the predators caught contained salmonid remains, and few of the predators implicated in consumption of salmonids (cutthroat trout and staghorn sculpin in Hood Canal) were present (total catch < 10 during February-July 1979; effort = 310 purse seine sets, 58 beach seine sets, and 35 townet sets). Thus any attraction to or delay at the wharf did not appear to harm the salmon. Mode I lighting also attracted juvenile herring and sand lance and their predator, dogfish. Catch of other predators on these fish--hake, resident chinook (blackmouth) and coho salmon, and sea-run cutthroat trout--did not increase with lighting.

Outmigrating salmon were also attracted to the unlighted wharf during the day, indicating the presence of food and shelter in shaded areas below the wharf.

ACKNOWLEDGMENTS

Many individuals have contributed to the success of the project. We wish to extend special thanks to Messrs. Leo Vasaitis, Donald Morris, and James Reeves from the OICC Trident Envrionmental Office. The U.S. Navy staff at Explosives Handling Wharf deserves credit for its cooperation.

Thanks are established to the field crew of Messrs. G. Maxwell, K. McDowell, J. DiCola, S. Newhauser, E. Kudera, S. Cramer, T. Wildebuer, and Ms. H. Buechner for their diligent work.

We wish to thank Prof. D. G. Chapman, University of Washington College of Fisheries, for his assistance in the design of the marine mortality study. Dr. T. M. Zaret, University of Washington Department of Zoology, had many helpful suggestions that contributed to the success of the study. Mrs. Dorothy Beall and the Fisheries Publications Center provided a great service in finalizing the manuscript.

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1.0 INTRODUCTION

by

Thomas E. Prinslow

Natural light is attenuated rapidly in water but the photic zone is a substantial portion of the habitat of most fishes and directly affects their physiology and behavior (Salo 1976, Hailman 1977). Ginetz and Larkin (1976) and Hobson (1979) report that light intensity influences feeding by predatory fish, as shown by the predators' periods of activity at dusk and dawn when prey fish defense mechanisms such as schooling (Shaw 1978) are least effective. The responses of certain fishes to light has been exploited by commercial fishermen who use powerful floodlights to attract herring, sardines, mackerel, and tuna to the netting area (Salo 1976). Japanese researchers use this technique to sample outmigrating juvenile chum salmon in estuaries (Chikara Ioka, personal communication).[1]

During 1976 the Fisheries Research Institute (FRI) of the University of Washington initiated studies of the effects of wharf lighting on juvenile salmon migrating out of Hood Canal, Washington (Fig. 1-1). Hood Canal, a fjord-like extension of northern Puget Sound, provides one of the most important passageways and nursery areas for chum salmon (*Oncorhynchus keta*) in Washington State, accounting for approximately a quarter of the state's total chum return (Fiscus 1969, Morrell 1974 as cited in Simenstad and Kinney 1978). FRI studies focused on the Explosives Handling Wharf (EHW), one of five wharf facilities at the U.S. Naval Submarine Base-Bangor on Hood Canal (Fig. 1-2) where proposed lighting was expected to illuminate a 5-km portion of the eastern shoreline of the Canal. Fisheries Research Institute investigated the possible effects of these lights on the outmigrating chum and pink (*O. gorbuscha*) salmon.[2] Attraction to the lighted wharf might benefit the salmon if feeding were enhanced (Simenstad and Kinney 1978), or might harm them if predation were enhanced by decreasing search area and increasing search time of the predators (Holling 1959; Iwamoto and Salo 1977; Gunsolus 1978; Sims, Bentley, and Johnsen 1977 and 1978; Fresh et al. 1979).

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[1] Chikara Ioka, Applied Research Scientist, Iwate Prefectural Fisheries Experimental Station, Iwate-ken Japan.

[2] Pink salmon migrate out of Hood Canal only during even years, while chum migrate annually.

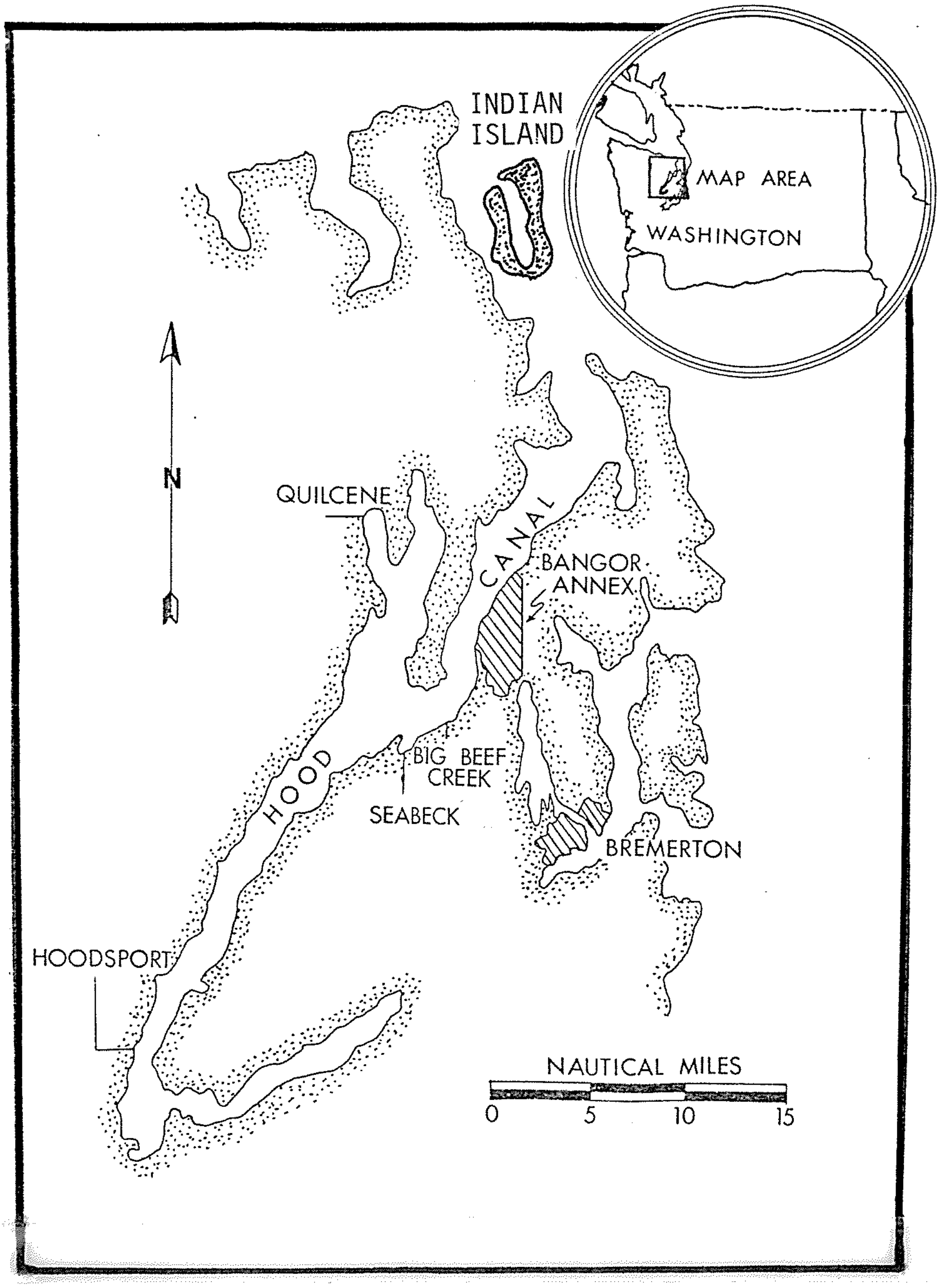

Fig. 1-1. Location of Hood Canal, Bangor Annex (U.S. Naval Submarine Base - Bangor), Big Beef Creek, Quilcene, and Hoodsport hatcheries.

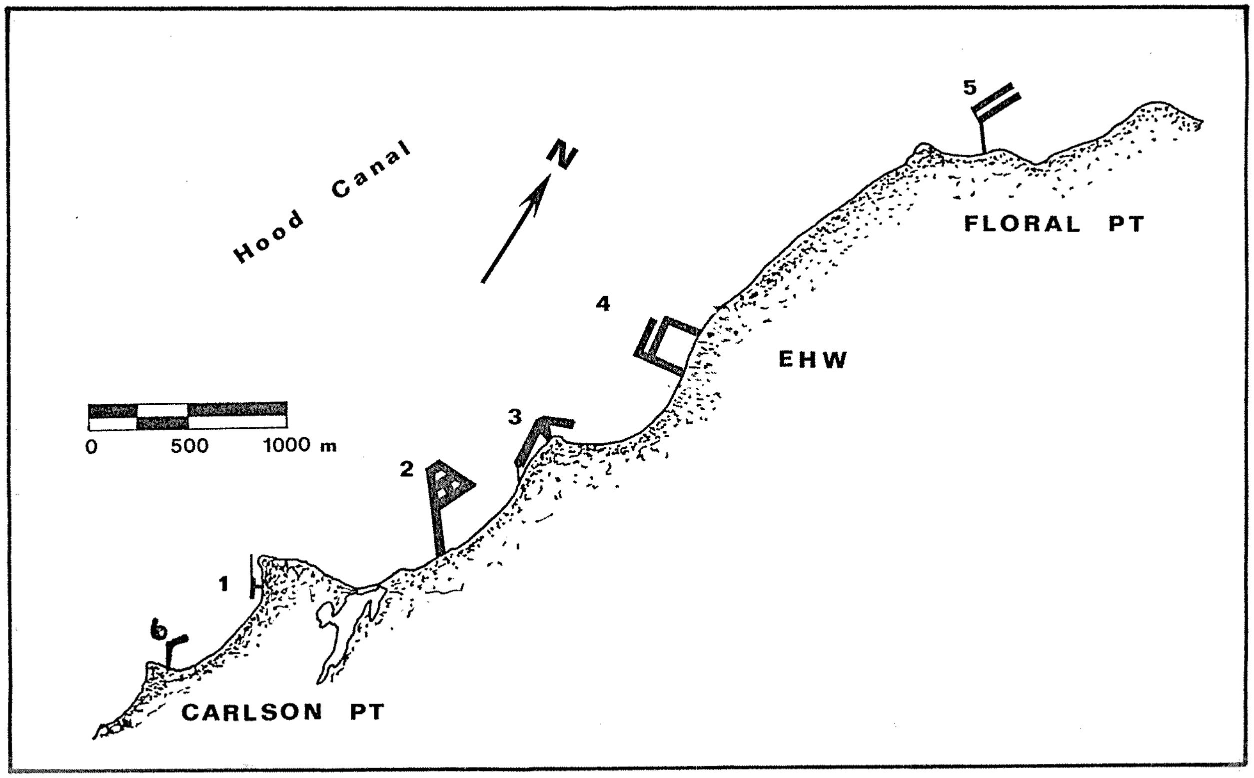

Fig. 1-2. Shoreline of Bangor Annex showing location of the Small Craft Wharf (1), Delta-Refit Pier (2), Marginal Wharf (3), Explosives Handling Wharf (4), and Magnetic Silencing Facility (Deperming Wharf) (5). The Service Pier (6) is under construction at Carlson Point.

The objectives and results of FRI wharf lighting studies during 1976-1979 are summarized in Table 1-1. The 1976 study (Salo, Salo, and Snyder 1977) alternately lighted and left dark the waters below a trestle of the EHW (Plate I). By observing fish aggregations with hydroacoustic monitors below the surface and visually from the trestle, they counted 30 times more fish with lights on than off. Tests were conducted after the peak of salmon outmigration, and because the fish were not sampled quantitatively, it was uncertain what proportion of the aggregated fish below the lights were salmon.

Tests at EHW during February, March, and April 1978 (Prinslow, Salo, and Snyder 1979 and Sec. 2.0, below) found attraction at night of outmigrating salmon to the nearshore area adjacent to EHW trestles where security lights produced ∿2-13 lux[3] at water's surface. Chum and pink outmigrants appeared to be attracted to the enclosed area of the wharf (see Plate I) during the night when this area was intensely lit (∿200 lux), as well as during the day when lights were off. Marked chum released at Big Beef Creek hatchery (Fig. 1-1) during February and March 1978 were attracted to the wharf area and appeared to remain for 1-2 days longer than marked chum released during February-March 1977 and 1979 (Whitmus and Olsen 1979, Salo et al. 1980, Sec. 3.0). Whether this was a response to the lights and/or to availability of chum prey organisms characterizing nearshore areas adjacent to the EHW (Simenstad and Kinney 1978) was unclear.

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. During preliminary tests in 1976 (Salo et al. 1977) spotlamps with colored glass lenses were substituted for spotlamps with colorless ("white") lenses located below the wharf trestles. White and yellow light were most attractive to fish in the area, and red least attractive. Because attracted species were not identified or enumerated, and because no attempt was made to measure the wavelengths and intensities of light produced from these colored spotlamps, it was unclear how different wavelengths of light affected outmigrating salmon.

1.1 OBJECTIVES

The objectives of the 1979 study were to estimate the:

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[3] 11 lux ≅ 1 ft-c; see 1.3 for a description of wharf lighting.

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

1976 Literature Review	1976 Simulation of Security Lights	1978 Tests of Partial Operational Lights	1979 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.

*The EHW was under construction during these experiments.

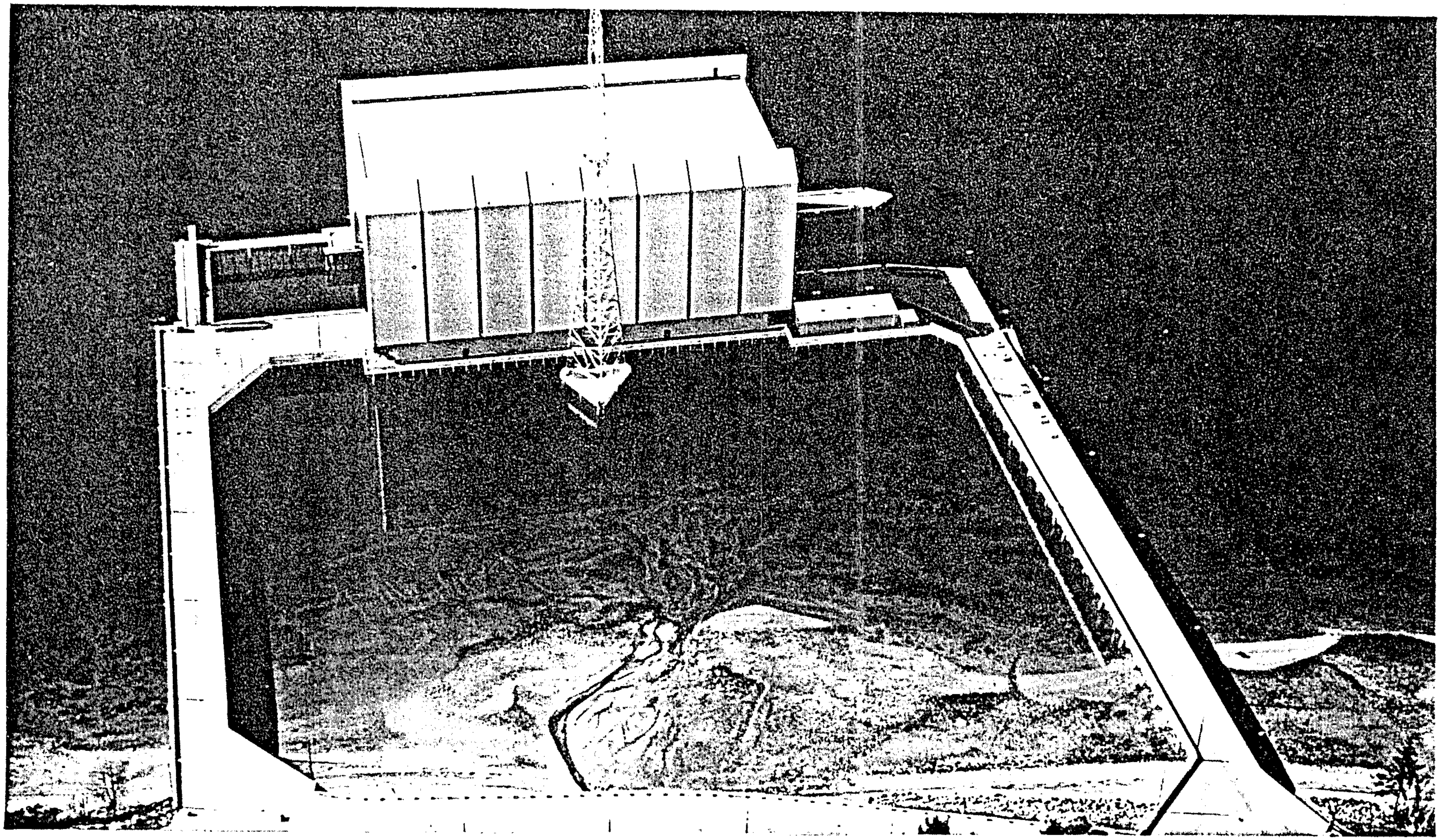

Plate I. Explosives Handling Wharf (EHW), U.S. Naval Submarine Base-Bangor, Hood Canal, Washington.

1) Effect of EHW security lights on the distribution and abundance of outmigrating chum salmon and their potential (piscine) predators[4] in the wharf area.

2) Predation rate on juvenile chum by means of stomach analyses of potential predators.

3) The relative attraction of juvenile chum and potential predators to different wavelengths (color) and intensities of light.

4) Survival of the chum smolts during their migration out of Hood Canal.

5) Residence time of chum at the wharf.

1.2 EXPERIMENTAL DESIGN

Changes over time in chum and potential piscine predator populations at EHW were estimated by sampling waters surrounding and enclosed by the wharf using purse seine, beach seine, townet (surface trawl), and hydroacoustic monitoring equipment. To assess the effect of security lighting, lights were turned on or off for set intervals (2-4 consecutive nights) during sampling (Table 1-2). Tests were conducted approximately two weeks per month from February through June 1979.

To estimate predation rates on chums, predators caught in the EHW area by the above methods were examined for chum remains.

To estimate the effects of wavelength and intensity on chum and potential predators, a specially-lighted test area was sampled with purse seine and hydroacoustic gear. Fish distribution and abundance in this area were compared with those in concurrently sampled, unlighted controls. Tests were conducted one week per month from March through June 1979 (Table 1-1).

To estimate survival and residence time, groups of hatchery-reared chum were marked, released, and tracked by capturing with beach seine and townet along the migration pathway, including the submarine base. Security lights were turned on and off for set intervals to test for effect on residence time. Tests were conducted one week per month from February through June 1979 (Table 1-1).

Section 2.0 of this report describes EHW security light and wavelength tests, including analysis of piscivorous predation in the EHW area. Section 3.0 describes mark-recapture tests estimating chum

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[4] *See* footnotes 1 and 2, Sec. 2.0.

Table 1-2. Schedule of predation and wavelength tests, February-June 1979.

Sample week No.	Dates	EHW lights	Tests/samples[1]	
1	2/5-8	Off	MR	
2	2/12-15	On	BS, TN, AC	
3	2/19-22	Off	BS, TN, AC	
4	2/26-3/1	On	AC	
5	3/5-8	On	MR, AC	
6	3/12-15	Off	BS, TN, AC, PS	
7	3/19-22	On	BS, TN, AC, PS	
8	3/26-30	Off	AC, WL, BS, TN	BS, TN
9	4/2-5	On	BS, TN, AC, PS	
10	4/9-12	On	MR, AC	
11	4/16-19	Off	BS, TN, AC, PS	
12	4/23-26	On	BS, TN, AC, PS	
13	4/30-5/3	Off	AC, WL, BS, TN	BS, TN
14	5/7-8	Off	MR, AC	
	5/9-10	On	Mr, AC	
15	5/14-15	Off	BS, TN, AC, PS	
	5/16-17	On	BS, TN, AC, PS	
16	5/21-22	Off	BS, TN, AC, PS	
	5/23-24	On	BS, TN, AC, PS	
17	5/28-29	Off	AC, WL, BS, TN	
	5/30	On	AC, WL, BS, TN	
	5/31	Off	AC, WL, BS, TN	
18	6/4-5	On	MR, AC	
	6/6-7	Off	MR, AC	
19	6/11-12	On	AC, WL, BS, TN	
	6/13-11	Off	AC, WL, BS, TN	
20	6/18-19	Off	BS, TN, AC, PS	
	6/20-21	On	BS, TN, AC, PS	

[1] BS: beach seining at EHW and other Base sites,
TN: townetting at EHW and other Base transects,
MR: mark-recapture experiments (incorporates BS & TN),
AC: acoustic monitoring,
PS: purse seining at EHW,
WL: wavelength tests (incorporates PS).

survival and residence time. Section 4.0 is devoted to hydroacoustic monitoring.

1.3 LIGHTING AT THE WHARF

Lighting at the EHW was divided into "security" and "operational" modes. In this report, the use of the words security and operational refer to these modes and are not used in a generic sense. Security lighting provides adequate illumination of areas underneath the wharf for visual inspection, and is composed of incandescent white spotlamps and low-pressure sodium (SOX) vapor lamps, the latter emitting a yellow light. During the test the configuration of and intensity of light varied around the pier. A detailed description appears in Sec. 2.2 and in Prinslow et al. (1979).

In 1979 the Navy changed the intensity of lighting significantly (from approximately 200 lux to 2-3 lux at surface). The effects of this change on fish behavior are discussed in Secs. 2.4 and 3.4 of this report.

Operational lighting provided illumination additional to security lighting of the deck areas of the trestles and the enclosed submarine berth, and was composed of sodium vapor and metal halide lamps producing approximately 200 times the intensity of 1979 security lighting (approximately 400 lux) at the water's surface (Prinslow et al. 1979).

The present study tested fish response, primarily to security lighting.

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2.0 PREDATION AT THE EXPLOSIVES HANDLING WHARF: ANALYSIS OF PURSE SEINE, BEACH SEINE, AND TOWNET SAMPLING FOR CHUM AND PREDATORS

by

Thomas E. Prinslow and Nicholas J. Bax

2.1 INTRODUCTION

The predation study proposed to determine whether:

1) The security lighting at the Explosives Handling Wharf (EHW) attracted potential piscine predators[1,2] of juvenile chum salmon (Oncorhynchus keta) to the wharf, leading to a higher density of predators at the "lit" versus "unlit" wharf (Objective 1).

2) The security lighting at EHW attracted juvenile chum salmon to the wharf, leading to a higher density of chum (prey) at the "lit" versus "unlit" wharf (Objective 2).

3) The immediate EHW area had a higher density of juvenile chum than other sites along the submarine base shoreline (Objective 3).

The study measured predation rate on juvenile chum by means of stomach analyses of potential predators and estimates of changes in predator abundance in the EHW area during outmigration. The relative attraction of juvenile chum and potential predators to different wavelengths (color) and intensities of light was also investigated.

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[1] Resident (blackmouth) chinook salmon (Oncorhynchus tschawytcha), coho salmon (O. kisutch), sea-run cutthroat trout (Salmo clarki clarki), dogfish (Squalus acanthus), hake (Merluccius productos), and sculpin (Cottids: Leptocottus, Enophrys, Myoxocephalus) (Simenstad and Kinney 1978, Fresh et al. 1979).

[2] No attempt was made to evaluate possible predation by birds, or any effect of EHW lights on such predation. Allen (1974) and Cooney et al. (1978) reported associations of birds such as cormorants and mergansers with schools of outmigrating juvenile salmon, but did not examine any birds for salmon remains in their guts.

2.2 MATERIALS AND METHODS

The following Sections, 2.2.1-2.2.3, describe EHW lighting tests. Wavelength tests are described in Sec. 2.2.4.

2.2.1 Test Area and Lighting Conditions

The EHW, located on the east shore of Submarine Base-Bangor on Hood Canal (Fig. 1-1), extends 180 m from shore to a depth of 30 m, and consists of four piling-supported trestles 10-20 m wide, to the south, west, and north (Plate I). The west side has two parallel trestles forming a 23 m-wide bay or slip (hereafter, the "sub bay") which opens to the north and is partially enclosed by a box-like building (Plate I).

Security lighting along the trestles during 1979 tests[3] consisted of incandescent white spotlamps and low-pressure sodium vapor (SOX) lamps, the latter emitting a yellow light. Combined, they produced an intensity of 8-14 lux (11 lux $\cong$ 1 ft-c) at surface (low tide, 0 ft). The southwest and northwest corners of the wharf, and the southern end of the sub bay (outside of the enclosure) were unlit. The enclosed area of the sub bay received incidental illumination from fluorescent lights located in a corridor 10 m above the eastern trestle of the sub bay. These lights produced an intensity of 2-3 lux at water surface; this illumination was also present when normal security lights (spotlamps and SOX lamps) were off. (*See* Appendix for configuration and location of individual lights.)

To assess any effect of EHW security lighting on outmigrating chum or potential predators, lights were turned on or off for set intervals (2-4 consecutive nights), and the area sampled for chum and predators. Nights with lights off were considered controls.

2.2.2 Sampling Technique

2.2.2.1 Fishing Method

The juvenile chum and their potential predators were sampled quantitatively by purse seine, beach seine, and townet (surface trawl), and qualitatively by hydroacoustics and visual observations (*see* Sec. 4.0 for acoustics and visual studies at EHW. The purse seine sampled principally the EHW area because of the vessel's slow running speed (3-4 km/hr).

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[3] "Security lighting" during 1978 tests (Prinslow et al. 1979) differed significantly from 1979 conditions (*see* Sec. 2.4.1).

The purse seine was selected for sampling predators because of success experienced in collecting predators, principally squawfish (Ptychocheilus oregonensis), on outmigrating juvenile chinook salmon and steelhead trout (Salmo gairdneri) in the Snake and Columbia rivers (Durkin and Park 1971; Johnsen and Sims 1973; Sims, Bentley, and Johnsen 1977 and 1978). The beach seine and townet have been used by the FRI of the University of Washington during 1975-1979 to sample outmigrating juvenile chum and pink salmon (O. gorbuscha) in Hood Canal (Schreiner et al. 1976 and 1977; Bax et al. 1978, 1979, and (1980). While the beach seine and townet do capture predators, they are shallow nets (see below) designed to capture principally juvenile salmon.

2.2.2.1.1 Net Designs and Deployment. The purse seine (Fig. 2-1)[4] measured 60 m long by 10 m deep with a 25% hang-in (i.e., in the water, the net hung to a depth 25% less than that obtained if the net were stretched out flat). The tapered bund end consisted of panels of 6-mm and 13-mm knotless nylon webbing. Along the bottom of the net ran a 3-mesh deep panel of 76-mm knotless nylon to facilitate spilling of water when the net was pursed and hauled aboard. This design captured small (< 3 cm) prey fish as well as larger (> 50 cm) predators. Detailed drawings of the net and its configuration during deployment appear in the Appendix.

The purse seine was deployed in offshore surface waters (10-30 m deep) from a 4.3 m x 7.3 m outboard-powered barge (Fig. 2-2) using a "round-haul" method whereby the seine skiff simply held position while the barge circled away from it (Fig. 2-3). The net's size and manner of deployment permits setting in confined areas (< 25 m diameter) including the EHW sub bay, and alongside wharf pilings. The net could be set and pursed in 3 min, and hauled aboard until the sample was trapped in the bunt end in another 3 min.

The 37-m floating beach seine consists of two 18 m wings of 3 cm mesh joined to a 0.6 m x 2.4 m x 2.3 m bag of 6 mm mesh. A solid-core lead line kept the seine on the bottom and prevented rolling in eelgrass beds. The seine is described fully in Schreiner (1977).

The beach seine was set parallel 30 m from shore from the bow of an outboard-powered 2.9 m skiff. Polypropylene lines 60 m long were used to retrieve the net. The net was hauled in by four persons toward shore at about 15 m/min. For the first 20 m the teams were 40 m apart and 10 m apart for the final 10 m.

The 15 m townet has a mouth opening of 3.1 m x 6.0 m and mesh sizes grading from 76 mm at the opening to 6 mm at the bag or cod end (see Schreiner 1977).

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[4] Modeled by Mr. J. Jerkovitch, National Marine Fisheries Service (NMFS), Seattle, after the net used by NMFS in the Snake and Columbia rivers studies.

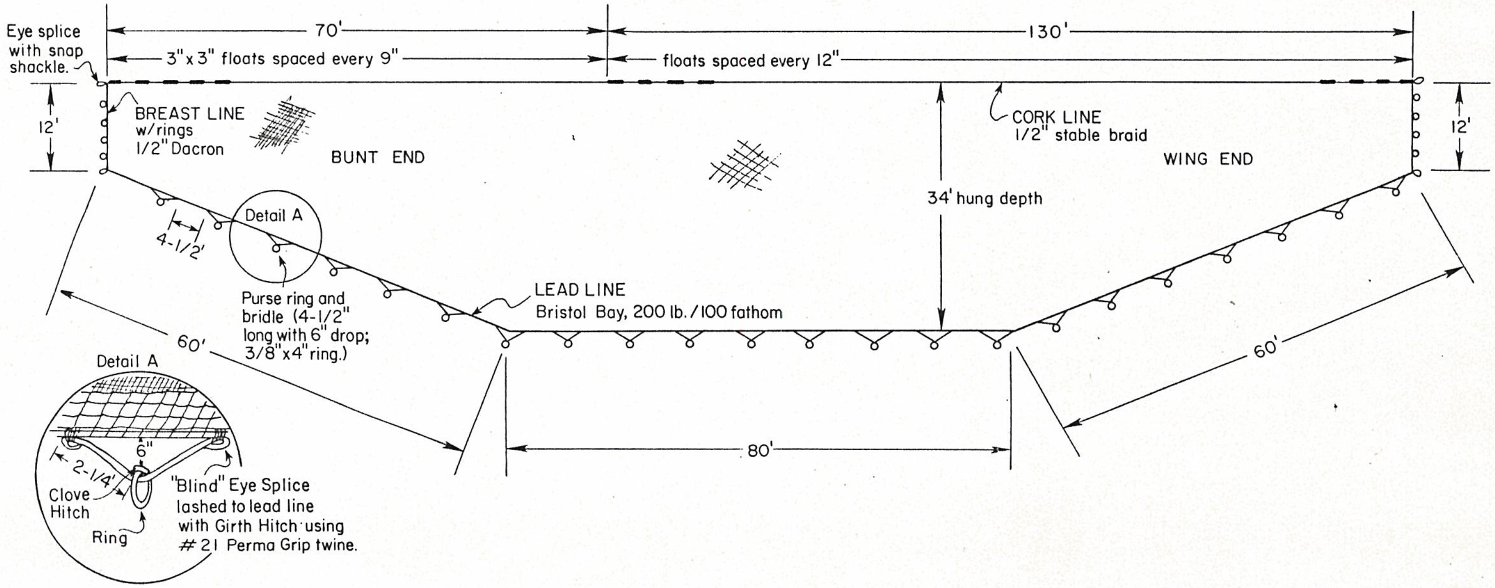

Fig. 2-1. Purse seine used during EHW lighting study, 1979. Bunt end consisted of two panels, one of 1/4-in mesh and one of 1/2-in mesh; the body and wing end consisted of 1-in mesh.

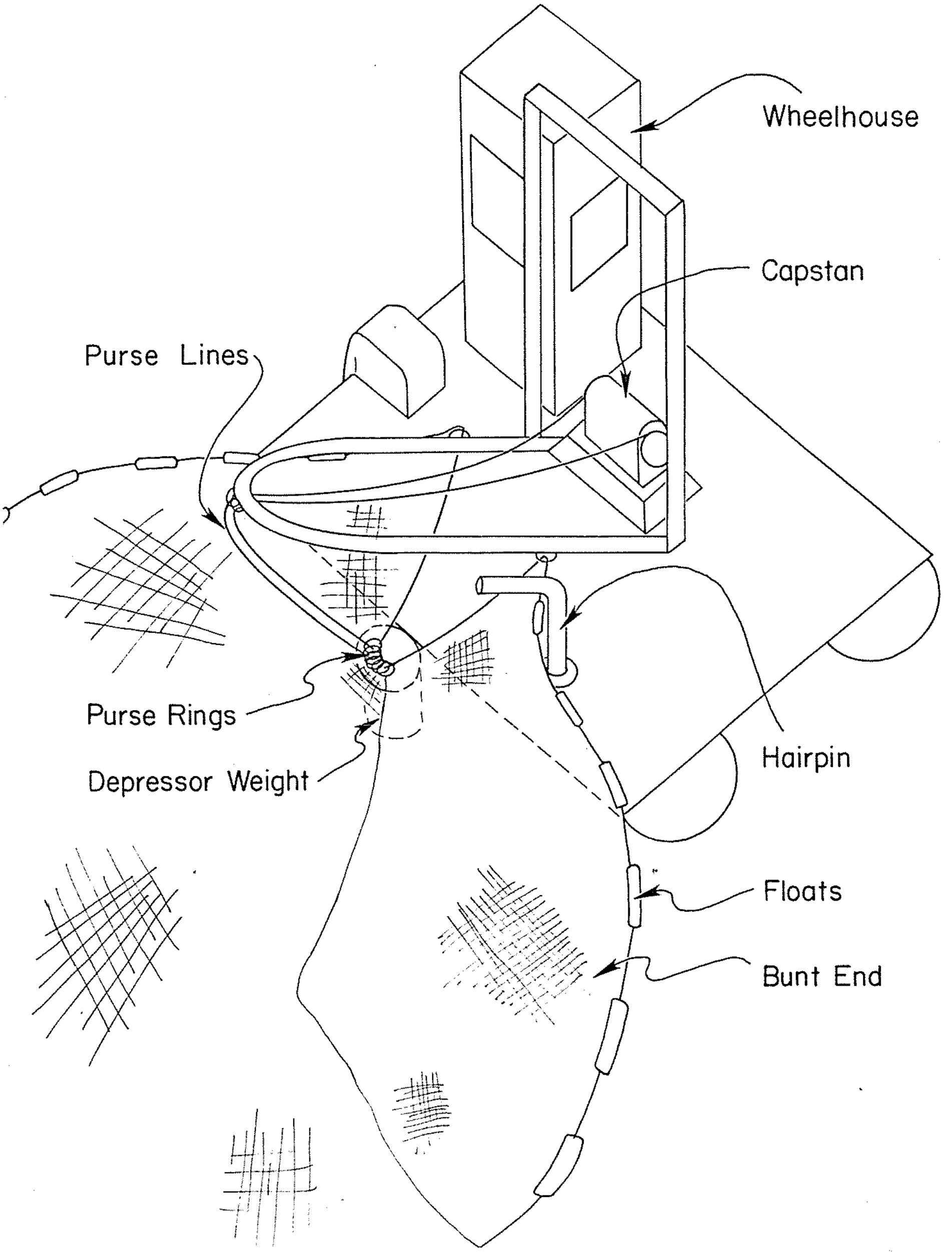

Fig. 2-2. Barge used to deploy purse seine.

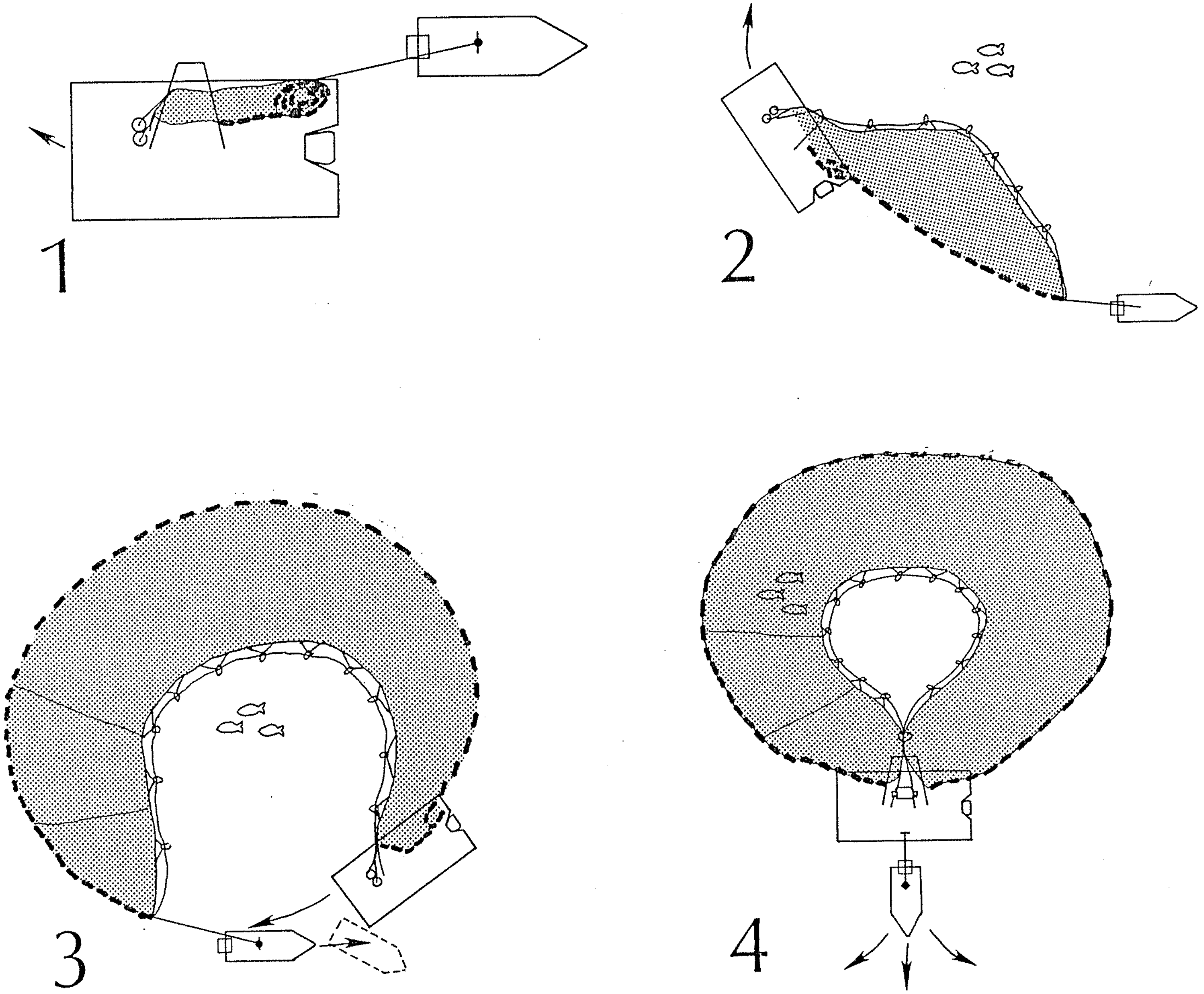

Fig. 2-3. Round-haul technique for deploying purse seine.

The townet was towed offshore between the 12 m R/V TENAS and a 5.5 m whaleboat in depths of 12-14 m. Vessel speed was constant with respect to the water, but due to differing tidal flows, linear distance covered varied; generally tow speed was approximately 3-4 km/hr. At 10-min intervals, personnel in a skiff pursed the cod end and emptied the catch.

2.2.2.1.2 Sampling Sites. To meet study objectives 1 and 2 (*see* Sec. 2.1), the EHW area was divided into eight purse seine sites (Fig. 2-4) to give two sampling areas on the south, west, and north sides of the pier, and two in the sub bay. Two sites for beach seining were established on the north and south sides of the wharf, and two townet transects in the sub bay and along the west side of the wharf were also sampled. The sub bay transect was a 2-min tow instead of the normal 10-min tow. To meet objective 3 (*see* Sec. 2.1), the remaining eastern shoreline of the Base was divided into six beach seine sites and five townet transects (Fig. 2-5).

The order in which purse seine sites were sampled depended on the direction of wind and currents. Generally sites 6 and 7 (Fig. 2-4) required sampling in still water, i.e., at high or low slack or about halfway between high and low slack. Sites 1 and 2 required still water or a southerly current; sites 5 and 8, still water or northerly current; sites 3 and 4, still water, northerly or southerly currents. Currents around EHW were produced by changing tides, and were quite variable during sampling periods. Thus, sites were fished on a random basis from night to night, with this exception: site 7 always followed site 6, and site 6 followed site 5 so that vessel movements would not disturb subsequent sites; the only access to the sub bay was from the north, site 5.

The order in which beach seine sites and townet transects were sampled also depended on currents. During ebb tide, sampling began at the south end of the Base and moved progressively north, while the reverse was true during flood tide. Unlike the purse seine, the townet could sample the sub bay at any time.

2.2.2.1.3 Catch-per-unit-of-effort (CPUE). In this report, the catch-per-unit-of-effort (CPUE) of any of the fishing methods is defined as the number of fish caught per set.

2.2.2.2 Analysis of Catch - Length, Weight, and Gut Contents

Juvenile salmon were transferred immediately after capture to 10% seawater formalin. Fork length (FL, nearest mm) and blotted wet weight (nearest 0.01 g) of the fish were measured 7 days after capture so that any changes due to preservation were stabilized (Parker 1963 and Appendix this report). Sets with CPUE >100 chum were subsampled, removing 100 juveniles, then counting and releasing the remainder.

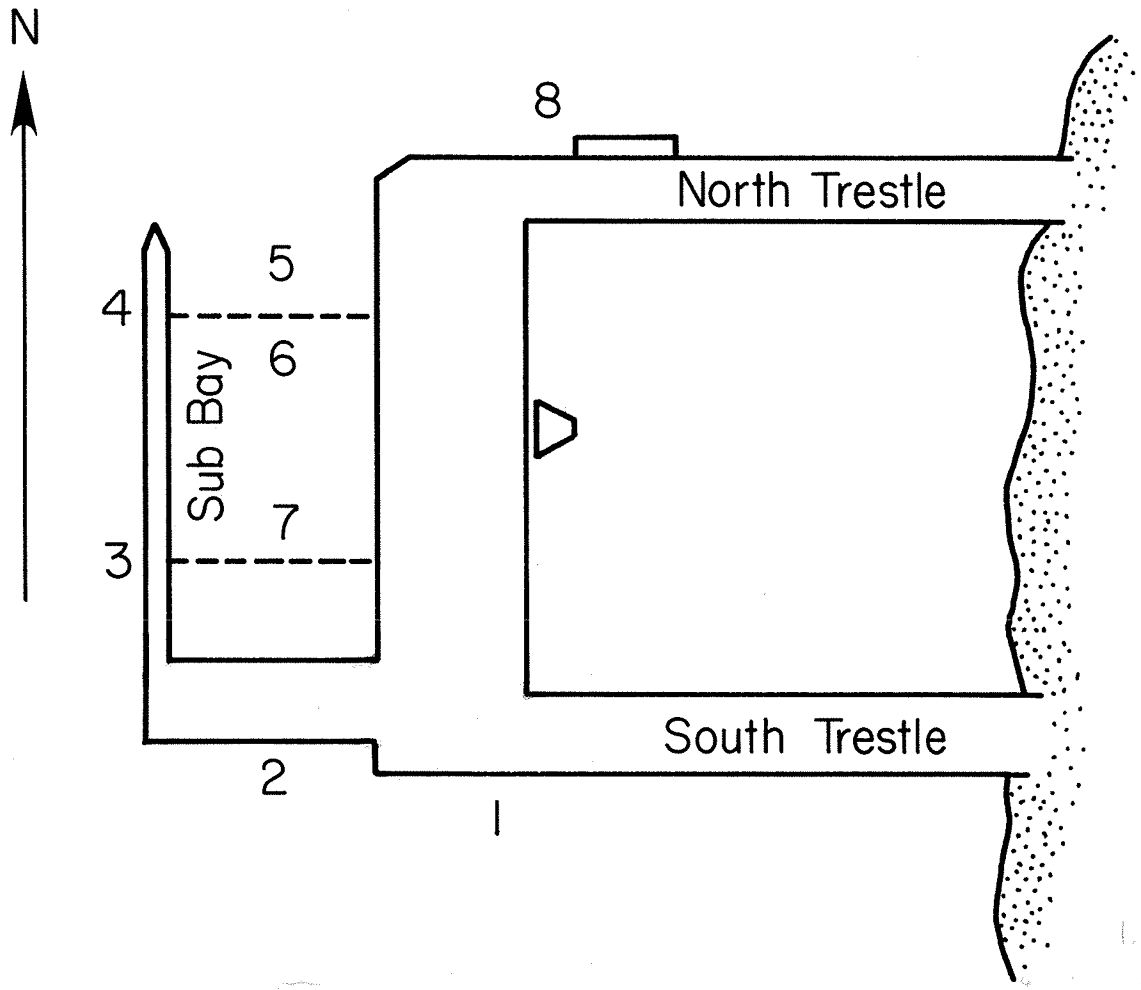

Fig. 2-4. Purse seine sampling sites at EHW.

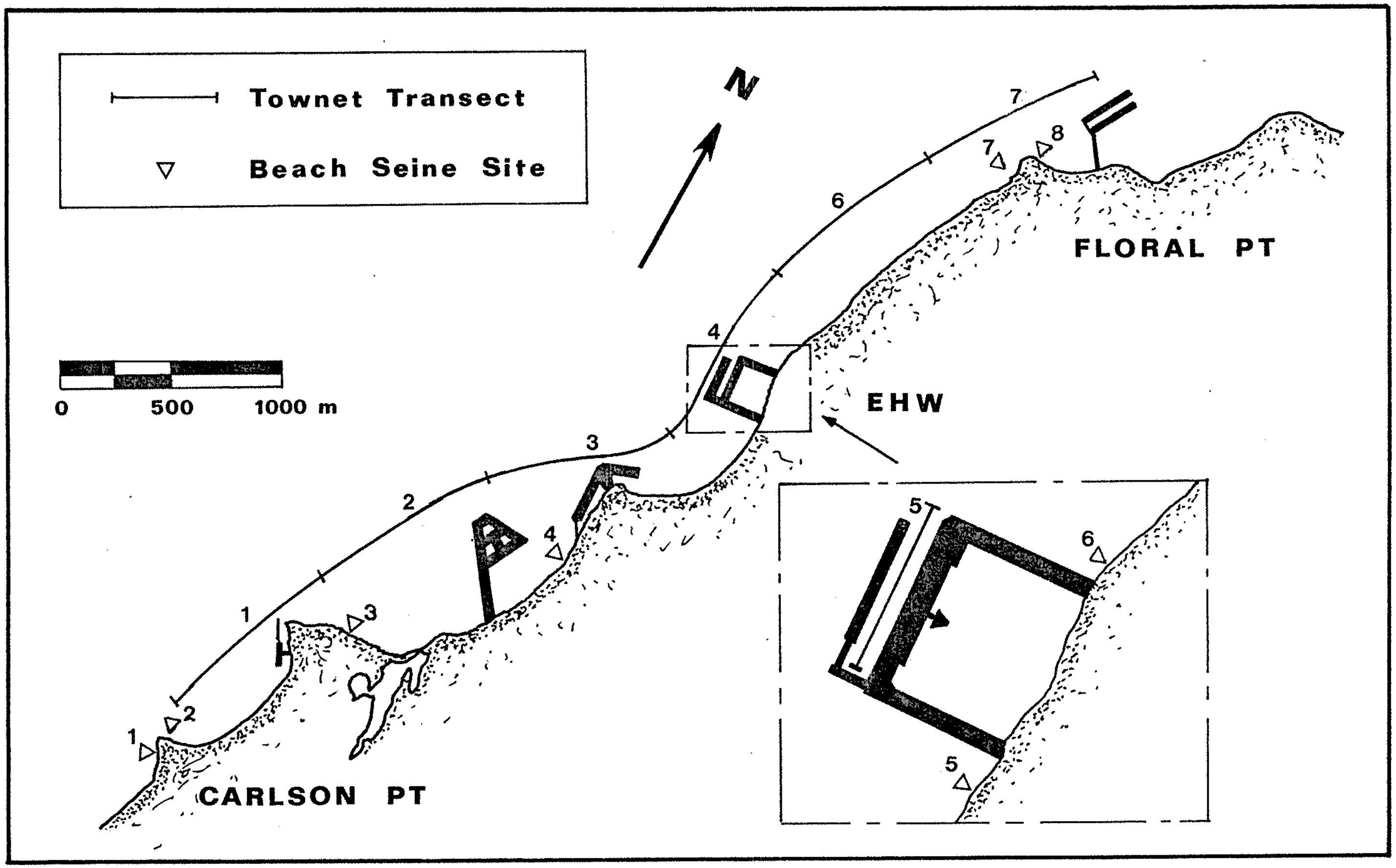

Fig. 2-5. Townet and beach seine sampling sites during EHW lighting study, 1979. Townet transect 4 is the "outside EHW" transect; transect 5 (inset) is the "inside EHW" transect.

Potential predators were examined immediately after capture for presence of juvenile salmon in the gut. While other gut contents were identified as well, it was beyond the scope of this study to quantify predation on nonsalmonids.

2.2.3 Sampling Schedule

Tests at EHW were conducted for three weeks out of each month from February through June 1979 (see Sec. 1.0, Table 1-1) and utilized beach seine and townet sampling for 3 weeks, and purse seine for 2 weeks. One of three weeks was for wavelength tests (see Sec. 2.2.4). During the fourth week of each month a mark-recapture experiment (see Sec. 3.0) used beach seine and townet to sample the Base shoreline including EHW.

Sampling began no earlier than 1 hr after sunset and terminated no later than 1 hr before sunrise. For "lights-on" sampling periods, security lights were turned on at least 1 hr before sampling, left on during the night, and turned off at dawn. For "lights-off" sampling, all wharf lights were extinguished at least 1 hr before sampling, except for office corridor lights located above the sub bay. During March and April, lights were on for one sampling week and off for the next, while during May and June they were on or off on alternate nights (Table 1-1). These changes were made to accommodate the large weekly variability in abundance of chum in the area (see below, Sec. 2.3.1 and Table 2-1).

2.2.4 Wavelength Tests

Wavelength experiments measured the attraction of chum and predators to 150 W, 110 VAC spotlamps with clear ("white"), yellow or green filters[5]. These were commercially available lamps similar to those used for EHW security lighting and not monochromatic lamps (e.g., those used in spectroscopy). Filters were of colored glass and did not produce a "pure" color as photographic quality gel filters would. Tests were conducted with these "impure" light sources as they were the only ones practical for replacement of existing security lamps should test results have warranted that action.

One week per month from March through June was devoted to wavelength tests. Experiments during March and April tested and refined apparatus and technique to continuously illuminate a target area while the purse seine was set around it. Attempts were made to acoustically

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[5] Colored lamps were 100 W; 150 W lamps were not available.

Table 2-1. Nightly variation in abundance of chum and other fish caught by purse seine in the EHW area.

Month	No. nights sampled	Total effort	Mean CPUE/month		Variation of nightly CPUE around mean, as coefficient of variation (%)	
			Chum	All fish	Chum	All fish
March	10	77	0.51	2.71	83	103
April	10	91	2.37	7.43	89	97
May	13	82	16.09	24.16	107	97
June	8	56	33.45	53.23	64	54

monitor the target area before and during illumination, and after the set. Lighting tests at EHW in 1976 (Salo et al. 1977) had successfully monitored a stationary target area, but had not successfully sampled that area to identify attracted targets.

The first procedure, used during March and April, had the lights attached to booms on the purse seine barge and acoustics boat. After 20 min with lights on, the net was set around the acoustics boat, with the boat backing out of the area just as the barge and seine skiff closed the net.

Concern that movement of the acoustics boat during seining might disrupt target fish prompted the construction of a 1.2 m x 1.2 m raft fitted with one spotlamp 1 m above the surface, a battery pack and inverter, and a dimmer switch (Fig. 2-6). The raft with the light on was set adrift for 30 min, then "captured" by the purse seine, i.e., the net was set, closed and pursed around the raft. During part of the drift period, the acoustics boat drifted alongside and monitored the target area, slowly pulling away 5 min before setting the net. This procedure freed the purse seine barge to do unlighted control sets nearby. Because the area illuminated by the raft ($\sim$15 m^2) was much smaller than that below the pier trestles, tests started with the spotlamp at full intensity of approximately 100 lux for 15 min, then reduced the intensity to approximately 2 lux ("security levels") for the duration of the test. May and June experiments used this procedure also.

2.3 RESULTS

2.3.1 Effect of EHW on Predators

Potential predators of outmigrating chum (2-8 cm FL) were considered to be any fish above 15 cm FL caught by purse seine, townet or beach seine.[6] This included resident chinook (blackmouth) and coho salmon, cutthroat trout, dogfish, hake, and sculpin. Table 2-2 summarizes monthly purse seine catch of these species in the EHW area. Over 90% of the catch was taken during May and June, particularly the June "lights off" period when 292 hake were captured in 15 sets. Hake and dogfish comprised 89% of the May-June predator catch.

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[6] Fresh et al. (1979) found that 10-15 cm FL salmonids preyed on outmigrating juvenile salmon; however, samples were taken directly off an estuary from which the juveniles were migrating, and it was unclear whether the juveniles had been ingested in the estuary or in open marine conditions.

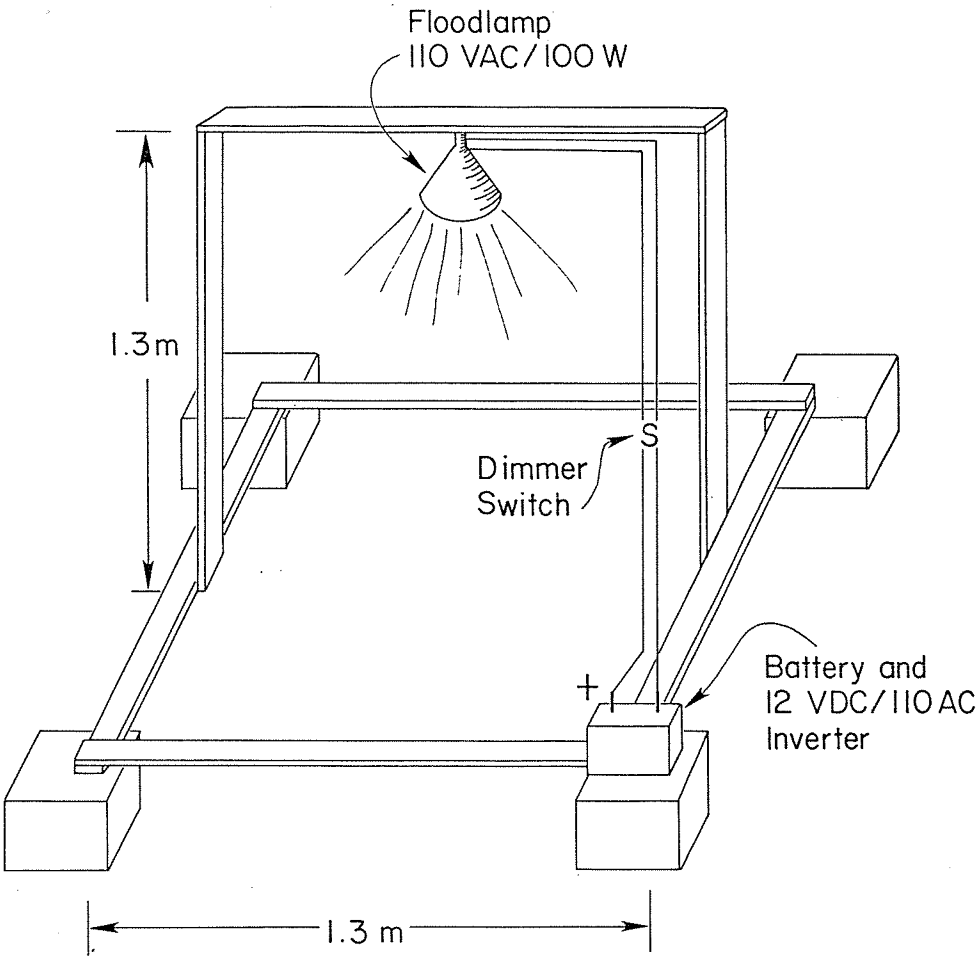

Fig. 2-6. Lighted raft used for wavelength tests.

Table 2-2. Summary of "potential predator" catch by purse seine at EHW during lighting study, March-June 1979.

Month	Lights at EHW	Effort (no. of sets)	Catch by species						Combined catch/light period		Monthly proportion of total combined catch (%)
			Chinook	Coho	Cutthroat	Dogfish	Hake	Sculpin	Catch	CPUE	
March	Off	11	1				1		2	.2	6.6
	On	33	26					1	27	.8	
April	Off	13	1						1	.1	2.3
	On	54	5					4	9	.2	
May	Off	21	1			7	31		39	1.9	15.4
	On	16				21	8		29	1.8	
June	Off	15	3	1		20	292		316	21.1	75.7
	On	16	2			2	11	2	17	1.1	
		179	39	1		50	343	7	440	—	100.0

The objective under consideration was determining whether security lighting (2-13 lux) at EHW attracted predators, leading to a higher density (CPUE) of predators at the "lit" versus "unlit" wharf; i.e., H_0: no difference in predator CPUE between "lights on" and "lights off" periods.

To test for effect of security lights, each month's sampling was considered separately because of the variability in species composition and abundance. Considering purse seine samples, first the homogeneity of catch among the eight sampling sites was tested using a Kruskal-Wallis (KW) ANOVA by ranks; if homogeneous, then the CPUEs from each sampling night were compared, again using the KW test. If there were significant differences among nights, a nonparametric analogue to the Student-Newman-Keuls (SNK) test (Zar 1974) determined which night(s) differed significantly from the others. Knowing which nights lights were on or off, we could then determine if the differences resulted from the lighting. Sampling nights were treated separately instead of as replicates because of the great variability from night to night of fish in the Bangor area (Table 2-1).

During March, 26 chinook and one sculpin were caught by purse seine at the lighted EHW (CPUE = 0.8 ± 0.2 SE), while only one chinook and one hake were caught when the wharf was not lighted (CPUE = 0.1 ± 0.1 SE), suggesting attraction of the chinook to the lights. The distribution of chinook catches at EHW was homogeneous, i.e., CPUE among sites during lighted and unlighted conditions did not differ significantly.

During April, five chinook and four sculpin were caught at the lighted EHW (CPUE = 0.2 ± 0.1 SE), while only one chinook was caught when the wharf was not lighted, suggesting attraction of both chinook and sculpin to the lights. Catch distribution was homogeneous.

Because of negligible catch during the "lights off" sampling periods in both March and April, the KW test was not performed.

The distribution of hake and dogfish catches at EHW during the May test (5/21-24) was homogeneous (Table 2-3); few chinook or sculpin were caught. Furthermore, predator CPUE during "lights on" nights did not differ significantly from the "lights off" night (Table 2-3), averaging 2.8 ± 0.8 SE.

As in May, the majority of predators caught during the June test (6/18-21) were hake and dogfish. The distribution of hake and dogfish catches at EHW was homogeneous (Table 2-3), but CPUEs were significantly smaller ($p < .05$) with the lights on than off (0.8 ± 0.2 versus 20.8 ± 9.0).

Table 2-3. Summary of statistical analyses of "potential predator" catch by purse seine at EHW during security lighting (2-13 lux at water's surface) tests, May-June 1979.

		Hypothesis (H_o)	Analytical Method	df	Result
May 1979	1.	No difference in CPUE among sampling sites.	Kruskal Wallis ANOVA by ranks	30	Do not reject H_o
	2.	No difference in CPUE among sampling nights.	Kruskal Wallis ANOVA by ranks	30	Do not reject H_o
June 1979	1.	No difference in CPUE among sampling sites.	Kruskal Wallis ANOVA by ranks	37	Do not reject H_o
	2.	No difference in CPUE among sampling nights.	Kruskal Wallis ANOVA by ranks	37	Reject H_o, $p < .05$
			(and because H_o rejected:) Student-Newman Keuls multiple comparison by ranks of nightly CPUE.	34[a]	"On" "On" "Off" "Off" $\underline{6/21 \quad 6/20}$ 6/19 6/18 Nights ranked from highest CPUE (on left) to lowest. Underscored nights indicate no significant difference at $\alpha = .05$.

[a] Data from site 1 not included because this site was not sampled on 6/18, and the test requires equal sample sizes.

Beach seine and townet catches of potential predators were too small to test for effects of EHW lights (Table 2-4).

2.3.2 Stomach Analyses of Predators

Subsamples of potential predators captured by purse seine, beach seine, and townet in the EHW area were examined immediately upon capture for presence of chum in the gut. From March through June a total of 125 potential predators was examined; one fish, a cutthroat trout captured by beach seine contained chum remains (Table 2-5). The predominant prey included juvenile herring and sand lances, euphausiids, worms, and shrimp. The size range of the herring (2-5 cm FL) was comparable to that of chum salmon captured concurrently, implying that the size of the chum did not preclude their consumption, i.e., in terms of gape of the predators. On the other hand, size of chum affects their swimming speed and thus their ability to avoid capture (Bams 1967).

2.3.3 Effect of EHW Lights on Chum

Chum salmon were the most abundant outmigrating juvenile salmonid caught in the Bangor area and the species of principal concern in this study. The objective was the determination of whether security lighting at EHW attracted outmigrating chum, leading to a higher density (CPUE) of chum (prey) at the "lit" versus "unlit" wharf, i.e., H_0:no difference in chum CPUE between "lights on" and "lights off" periods. Catches of chum by beach seine and townet were lognormally distributed with homogeneous variances, so logarithmic transformations were used in the parametric analyses of this data. Purse seine catches were not lognormally distributed, and nonparametric techniques were used in analysis.

(Note: Bax et al. (1980) present a detailed analysis of seasonal population dynamics of outmigrating chum for the whole Bangor area, while the following sections present information pertinent to EHW tests.)

2.3.3.1 Beach Seine Chum CPUE

To test the hypothesis, a variation of the analytical method described for purse seine predator CPUE was used. A ratio of the CPUE of chum at the north and south EHW sites to the CPUE at Floral Point was computed for samples from March through June 1979, and compared for the lit and unlit wharf, using a t-test. In this way daily fluctuations in overall numbers of chum would not affect results as they might with the purse seine data analysis. Additionally, if the lit wharf attracted chum, then the CPUE at Floral Point (the closest site to the north), might correspondingly decrease. Thus, the ratio would be a more

Table 2-4. Piscivorous predators[a] captured by beach seine and townet during security lighting (2-13 lux at water's surface) study, February-June 1979.

Gear[b]	Lighting at EHW	At EHW CPUE	(± S.E.)	effort	Remaining east shore sites at Bangor Base CPUE	(± S.E.)	effort
BS	On	.13	(.09)	38	.12	(.06)	76
	Off	.35	(.30)	20	.43	(.23)	40
TN	On	.56	(.38)	18	.80	(.55)	50
	Off	1.24	(1.17)	17	.72	(.53)	45

[a] Hake, dogfish, chinook, coho, cutthroat, sculpin.

[b] BS: beach seine; TN: townet.

Table 2-5. Stomach content analyses of piscivorous predators captured in the EHW area, March-June 1979.

Range in fork length (cm)	Chinook (Oncorhynchus tschawytcha) 16.0-58.6		Coho (Oncorhynchus kisutch) 19.6		Cutthroat (Salmo clarki) 26.0-40.0		Hake (Merluccius productus) 9.5-43.5		Dogfish (Squalus acanthus) 29.8-80.0		Cottids 20.9-25.5	
Stomach contents	A	B	A	B	A	B	A	B	A	B	A	B
Euphausiids	3	15					4	15	1	9		
Juvenile herring (Clupeia sp.)	5	25	1	-	1	50	15	58	4	36		
Juvenile sand lance (Ammodytes sp.)	1	5					17	65	5	45	2	67
Annelida	10	50										
Crustacea	5	25					1	4			2	67
Chum fry (Oncorhynchus keta)	0	0			1	50						
Unidentifiable	0	0							2	18		
No. empty	2 (9%)		0		0		4 (13%)		3 (21%)		3 (50%)	
No. feeding	20 (91%)		1 (100%)		2 (100%)		26 (87%)		11 (79%)		3 (50%)	
Total	22		1		2		30		14		6	

A = Incidence of feeding.
B = Percent occurrence in feeding fish.

sensitive measure of the attractivity of the lit wharf to chum. This method was not applicable to purse seine data as purse seine samples were taken only at EHW.

No differences were found between the ratio of catches at the lit and unlit wharf, i.e., there was no measurable effect of EHW security lighting on the CPUE of chum (Table 2-6).

2.3.3.2 Townet Chum CPUE

As with the beach seine data, to test for effect of lights on the distribution of chum, a ratio of the EHW "outside" transect CPUE to the Floral Point transect CPUE was formed. No differences were found between the catch at the lit and unlit wharf (Table 2-6).

2.3.3.3 Purse Seine Chum CPUE

From March 12 through June 21, 1979, 119 purse seine sets were made at the EHW with security lights on, and 60 sets with lights off. From March 12 through May 15, 88% of the sets caught fewer than five chum, too low to test for effect of light.

During the remaining test in May (5/21-24), the distribution of chum catch among the eight sites was homogeneous (Table 2-7). Furthermore, "lights on" CPUEs did not differ significantly from "lights off" CPUE (Table 2-7), averaging 11.7 ± 2.4 SE for the period (Table 2-8).

The distribution of chum catch at EHW during the June test (6/18-21) was homogeneous (Table 2-7), but there was a significant difference ($p < .01$) in CPUEs among the four nights (Tables 2-7 and 2-8). The lowest CPUE was on June 19 when lights were off, and the highest CPUE was on June 21 when lights were on; however, CPUEs during the other "lights on" night (6/20) did not differ significantly from the "lights off" nights (6/18-19).

These results are difficult to interpret, and may reflect the limitations of our sampling methods: there may be some threshold density of chum necessary for our methods to detect a "significant" effect of EHW lights, i.e., $\text{CPUE}_{\text{on}} \neq \text{CPUE}_{\text{off}}$ at $\alpha = .05$. If the June 21 CPUE (72.2, Table 2-8) had resulted from a wave or pulse of chum passing through the areas and was unrelated to the lights, we would have expected chum CPUEs at other sites in the Bangor area to show the same proportional increase. Unfortunately, equipment malfunction on June 18 prevented beach seining, so we had no basis for comparison with beach seine catch from June 21; however, townet data from June 19 and June 20 were available. Townet chum CPUE increased from an average 31 on June 19 to 90 on June 20 in the EHW area, but decreased from 17 on June 19 to 8 on June 20 at the remaining transects. Purse seine chum CPUE also increased threefold, from 11.8 on June 19 to 31.2 on June 20,

Table 2-6. Comparison of the ratio of CPUE at EHW/CPUE at Floral Point for chum salmon smolts during lit and unlit conditions (security lighting, 2-13 lux at water's surface), February-July 1979.

Groups	t-statistic	df	Significance (one-tailed)
a) Beach seine			
Lit Unlit	0.1348	24	> 0.25
b) Townet: inside EHW			
Lit Unlit	0.9035	12	0.10 < p < 0.25
c) Townet: outside EHW			
Lit Unlit	0.1557	10	> 0.25

Table 2-7. Summary of statistical analyses of chum catch by purse seine at EHW during security lighting (2-13 lux at water's surface) tests, May-June 1979.

	Hypothesis (H_o)	Analytical Method	df	Result
May 1979	1. No difference in CPUE among sampling sites.	Kruskal Wallis ANOVA by ranks	30	Do not reject H_o
	2. No difference in CPUE among sampling nights.	Kruskal Wallis ANOVA by ranks	30	Do not reject H_o
June 1979	1. No difference in CPUE among sampling sites.	Kruskal Wallis ANOVA by ranks	37	Do not reject H_o
	2. No difference in CPUE among sampling nights.	Kruskal Wallis ANOVA by ranks (and because H_o rejected:)	37	Reject H_o, $p < .01$
		Student-Newman-Keuls multiple comparison by ranks of nightly CPUE	34[a]	"On" 6/21 "Off" 6/18 "On" 6/20 "Off" 6/19 Nights ranked from highest CPUE (on left) to lowest. Underscored nights indicate no significant difference at $\alpha = .05$.

[a] Data from site 1 not included because this site was not sampled on 6/18, and the test requires equal sample sizes.

Table 2-8. Summary of chum CPUE by purse seine at EHW. A. May 21, 23-24; B. June 18-21, 1979.

A.

Catch[a] site at EHW	5/21 "Off"	5/23 "On"[b]	5/24 "On"
1	0	0	1
2	0	3	4
3	7	0	27
4	16	0	12
5	14	11	30
6	20	3	33
7	29	7	21
8	2	36	4

$\bar{x}$ ± SE: 11.7 ± 2.4

B.

Catch[a] site at EHW	Catch			
	6/18 "Off"	6/19 "Off"	6/20 "On"	6/21 "On"
1	—	13	3	106
2	21	11	4	32
3	8	30	13	110
4	5	6	17	171
5	19	9	57	19
6	90	17	114	63
7	90	3	32	55
8	26	5	10	38
$\bar{x}$ ± S.E.:	37.0 ± 14.0	11.8 ± 13.4	31.2 ± 13.4	74.2 ± 18.1

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[a] *See* Fig. 2-4 for location.

[b] Security lights (2-13 lux at water's surface) "on."

which suggests that security lighting was responsible for increased numbers of chum in the EHW area during both June 20 and June 21, but that our statistical method (the KW ANOVA and nonparametric SNK tests) was too limited to detect this effect on June 20 (see Zar (1974) for a discussion of the sensitivity of these tests).

2.3.4 Effect of EHW (Irrespective of Lighting) on Chum

The objective here was determining whether the immediate EHW area had a higher density (CPUE) of chum than other sites along the submarine base shoreline. This effect was noted during past outmigrations (Schreiner 1977, Bax et al. 1978, Bax et al. 1979). Beach seine and townet data were used in the analysis.

2.3.4.1 Beach Seine

Chum CPUE data from the sites at north and south EHW were combined and compared to the remaining east shore sites using a t-test. It was found that the CPUE of chum at EHW was higher than at other sites (Table 2-9).

2.3.4.2 Townet

The two transects at EHW, one inside the sub bay and one alongside the wharf, were individually compared with the remaining east shore sites at Bangor. Because the transect inside the wharf was only of 2-min duration, its CPUE was increased by a factor of 5 to compare with the standard 10-min tows. It was found that while the CPUE of chum inside the wharf was higher than other east shore locations, the CPUE outside the wharf showed no difference from the mean east shore CPUE (Table 2-9).

2.3.5 Wavelength Experiments

Test results were analyzed by the Wilcoxon paired sample technique (cf., Zar 1974). The number of successful tests with white and yellow light was minimal for this technique. Additional tests were foiled by wind and/or currents. Therefore results of the wavelength experiments should be considered tentative. Actual catch data are presented in the Appendix, and the results summarized below.

2.3.5.1 Preliminary Tests

Tests during March and April developed the raft technique described in Sec. 2.2.2. The first raft tests conducted May 1-2 with

Table 2-9. Comparison of the CPUE of chum smolts at EHW and the remaining east shore sites at Bangor Annex, February-July 1979.

Groups	t-statistic	df	Significance (one-tailed)
a) Beach seine			
North and south EHW East shore	3.394	373	< 0.005
b) Townet			
Outside EHW East shore	0.967	265	$0.10 < p < 0.25$
Inside EHW East shore	4.314	394	< 0.0005

white and yellow-colored spotlamps were inconclusive because there were too few fish in the area: total catch in five sets was only four fish, none of them chum. The same problem occurred May 16-17.

2.3.5.2 Test Catch of Chum

Tests conducted May 29 with yellow light captured 55 chum in three lighted sets with the raft, and 127 chum in concurrent control sets. Additional yellow-light tests conducted June 13 captured 11 chum in three lighted sets and 16 chum in controls. These differences were not statistically significant ($p = 0.2$).

Tests conducted June 11-12 with white light captured 141 chum in five lighted sets compared to 54 chum in controls, but these differences were not statistically significant ($p = 0.2$).

Tests conducted June 14 with green light were inconclusive: strong wind and current prevented repeated attempts with the raft. Only two test sets were completed capturing 52 chum, while control sets captured 15 chum.

2.3.5.3 Test Catch of Predators

Tests with white and yellow light showed no consistent differences ($p > 0.2$) in catch of hake or dogfish with either color, compared with controls. Catch of other predators was too small to test.

2.3.6 Population Dynamics of Chum in the EHW Area Based on Purse Seine Sampling

2.3.6.1 Temporal Distribution

Four peak-migration periods were evident from purse seine catches (Table 2-10) - mid-April (4/16-19), early May (5/7-10), late May (5/28-31), and mid-June (6/18-21). These periods coincided with those indicated by townet data (Fig. 2-7). The main peak at late May (CPUE = 61.6) was corroborated by beach seine data (Fig. 2-8) as equipment malfunction prevented townetting during this period.

The multiple CPUE peaks reflect movement of hatchery-released chum (Fig. 2-9) (Schreiner 1977, Fresh et al. 1979).

Differences in magnitude of CPUE between townet and purse seine are evident in Fig. 2-7 and may reflect either area or volume of water sampled by each gear, or differences in the efficiency of capturing fish. Purse seine chum CPUE was generally less than townet (average

Table 2-10. Summary of purse seine chum data: CPUE, effort, fork length (mean ± SE and range).

Sample		Catch			Fork Length (mm)			
Date	Area[a]	CPUE	(± SE)	Effort	Mean	(± SE)	n	Range
3/12-15	EHW	.54	(.29)	11	39.5	(1.8)	6	35-50
3/19-23	EHW	.42	(.30)	33	40.0	(.7)	22	36-42
3/26-30	WL	1.14	(.49)	7	40.8	(.6)	8	38-43
4/2-5	EHW	1.36	(.59)	22	42.2	(1.7)	22	36-68
4/9-12				NOT ATTEMPTED				
4/16-19	EHW	6.31[b]	(2.35)	13	45.8	(.6)	82	34-65
4/23-26	EHW	3.06	(.82)	32	57.4	(.8)	93	40-83
4/30-5/3	WL	1.11	(.99)	9	64.3	(1.4)	9	60-73
5/7-10	MR	61.60[b]	(51.15)	5		NOT ATTEMPTED		
5/14-17	EHW	0	(-)	13				
5/21-24	EHW	11.67	(2.44)	24	83.5	(.4)	278	50-112
5/28-31	VL	29.87[b]	(5.19)	24	90.3	(.1)	717	43-121
6/4-7				NOT ATTEMPTED				
6/11-14	WL	17.04	(3.71)	22	88.9	(.8)	363	57-138
6/18-21	EHW	38.01[b]	(7.58)	31	77.5	(.5)	698	44-135

[a] EHW: eight purse seine sites; <u>see</u> Fig. 2-4,
WL: sets made between EHW and Floral Point; see Fig. 1-2,
MR: sets made at EHW, but not at standard purse seine sites, for mark-recapture experiment,
VL: sets made between EHW and Floral Point for vessel light tests for net avoidance; <u>see</u> Sec. 2.4.1.1.

[b] Peak migration periods.

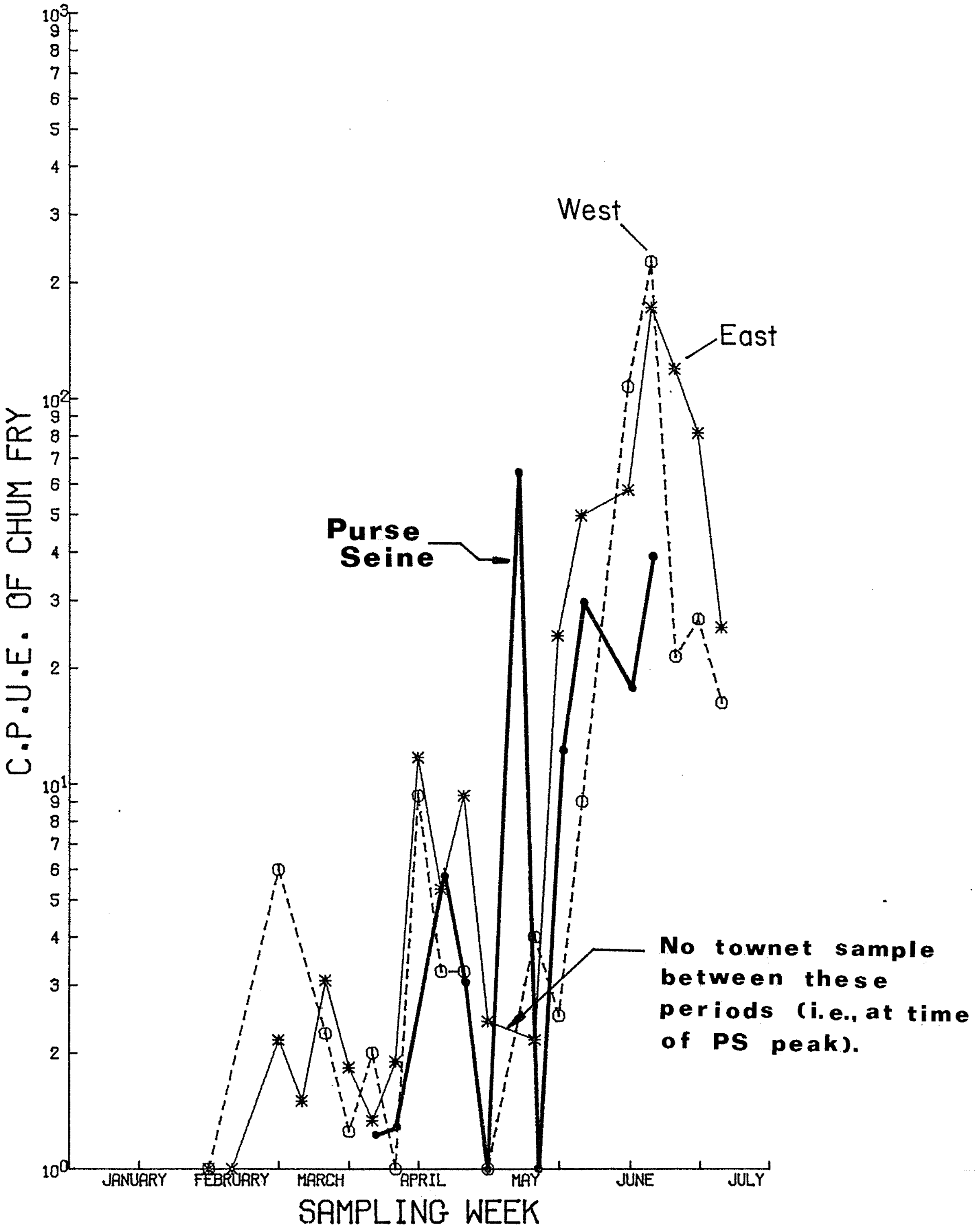

Fig. 2-7. Comparison of purse seine with townet chum catch-per-unit-effort (CPUE) at Bangor (superimposed on townet data from Bax et al. 1980).

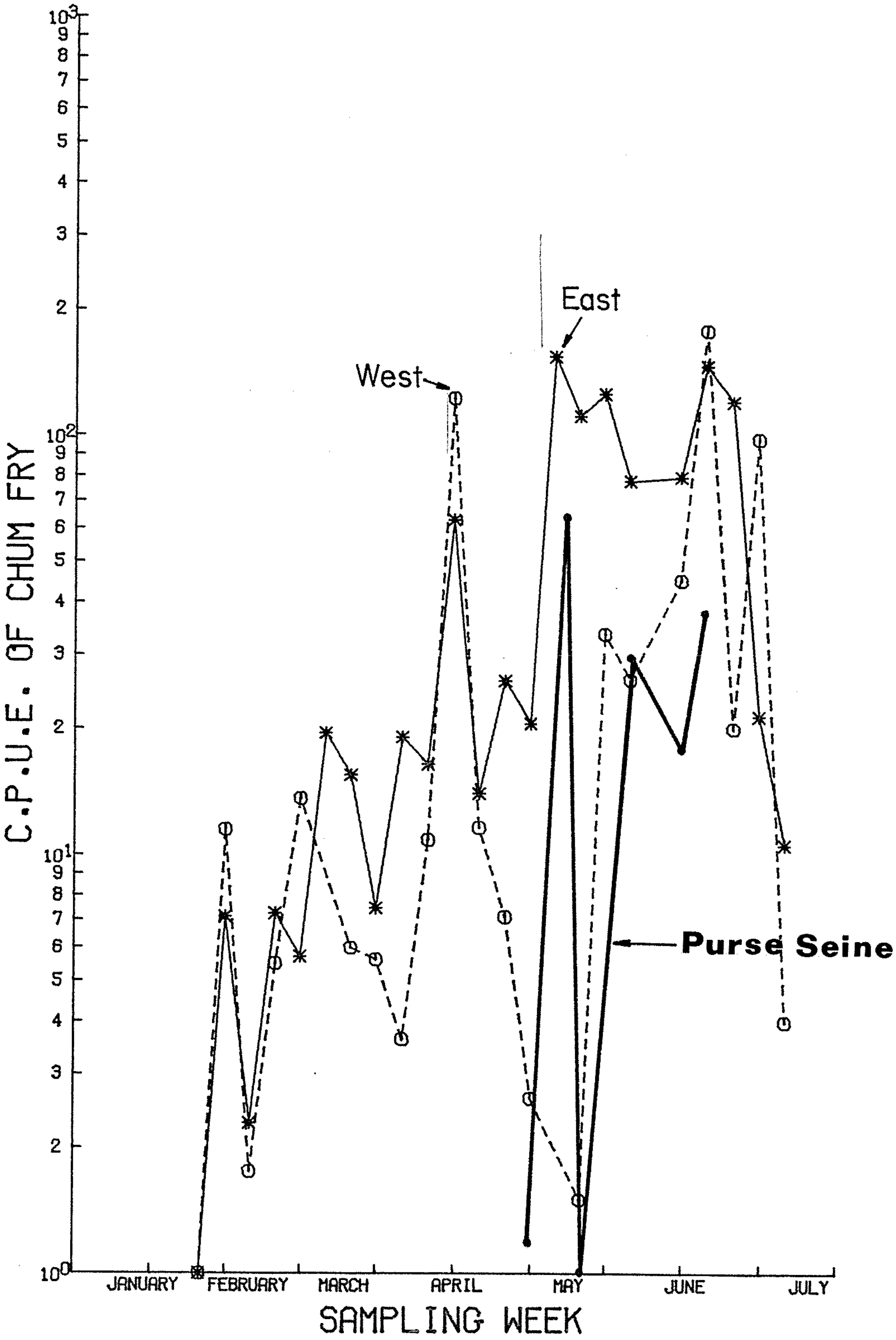

Fig. 2-8. Comparison of purse seine with beach seine chum catch-per-unit-effort (CPUE) at Bangor (superimposed on beach seine data from Bax et al. 1980).

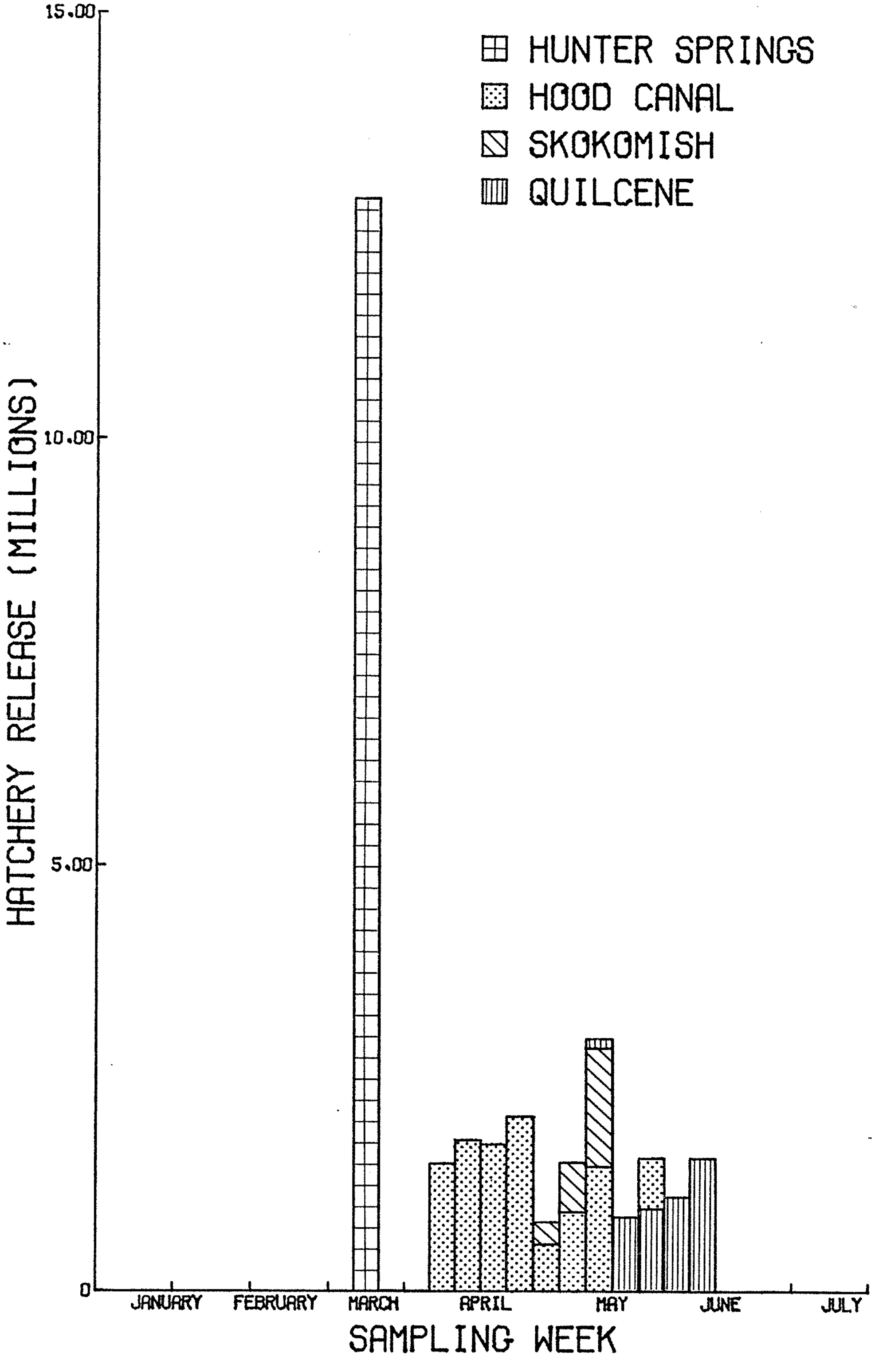

Fig. 2-9. Releases of chum juveniles into Hood Canal from the Hunter Springs, Hood Canal (Hoodsport), Skokomish, and Quilcene fish hatcheries, 1979 (reproduced from Bax et al. 1980).

36% of townet CPUE, April-June, Table 2-11). Each purse seine set sampled an area and volume of approximately 300 m^2 and 3,000 m^3, respectively, while values for the townet were approximately 3,800 m^2 and 11,400 m^3, respectively. Numerous researchers (Schreiner 1977, Fresh et al. 1979, Heiser and Finn 1970, Parker 1965) suggest that CPUE of chum is area-related. Thus we would expect purse seine chum CPUE to reflect the lesser area of the purse seine relative to the townet (300 m^2/3,800 m^2 or 8%). In fact, purse seine CPUE averaged 36% of townet CPUE, suggesting greater efficiency in capturing juvenile chum. The greater effectiveness of the purse seine in capturing predators (cf., Tables 2-2 and 2-4, average CPUE townet = 0.7, purse seine = 3.4) evidently resulted from greater efficiency as well, since both area and volume of the purse seine are less than those of the townet. It appears, then, that in waters of comparable fish density, purse seine CPUE would exceed townet CPUE; however, during the same time period, the townet is capable of sampling a larger area than the purse seine, i.e., the entire Base shoreline versus 2-3 sites at EHW.

2.3.6.2 Spatial Distribution

The purse seine sampled the area midway between Marginal Wharf and the EHW on the south, midway between EHW and Floral Point on the north, and offshore (west) in depths of 10-30 m. The townet sampled an offshore zone on the east side of the Canal extending from Carlson Point to Floral Point (Fig. 1-2). Data from this east shore zone are compared with purse seine data in this section.

Abundance patterns of chum indicated by purse seine for the EHW area were comparable to those indicated by townet for the whole east shore of the Base (Fig. 2-7). This suggests that the EHW did not attract and delay chum migrating offshore through this area; however, a more subtle effect is described below.

2.3.6.3 Size of Chum Populations

Chum caught in the EHW area by purse seine and along the Base shoreline as a whole by townet were of comparable size (fork length) (Fig. 2-10), indicating that both gear types sampled the same populations of chum, and that, overall, the EHW did not affect outmigrants in a size-selective manner. However, during June 18-21, significantly smaller chum were caught in the sub bay by purse seine than at other EHW sites (Table 2-12); this phenomenon was not evident during May, nor in townet sampling of the EHW area. The presence of greater numbers of smaller chum in the sub bay may indicate offshore movement (to pass around the wharf) of chum normally traveling nearshore. Bax et al. (1980) and Salo et al. (1980) present evidence of such movement at the Delta Pier as well. On the other hand, the purse seine data may simply reflect that currents were negligible in the sub bay during sampling

Table 2-11. Comparison of purse seine with townet CPUE of chum, April-June 1979 (TN data from Fig. 2-7).

Date	Townet CPUE (TN)	Purse seine CPUE (PS)	Difference (TN - PS)	% of CPUE (PS/TN x 100)
4/16-19	5.3	6.3	+ 1.0	(119)[a]
4/23-26	9.0	3.1	- 5.9	34
4/30-5/3	2.3	1.1	- 1.2	48
5/14-17	2.0	0	- 2.0	0
5/21-24	23	12	- 11	52
5/28-31	47	30	- 17	64
6/11-14	53	17	- 36	32
6/18-21	160	39	- 121	24
			Ave.	36[a]

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[a] The only time purse seine CPUE exceeded townet CPUE was 4/16-19. If the value from this period ("119") is included in the average "% CPUE" computation (lower right), then that average changes from "36" to "47".

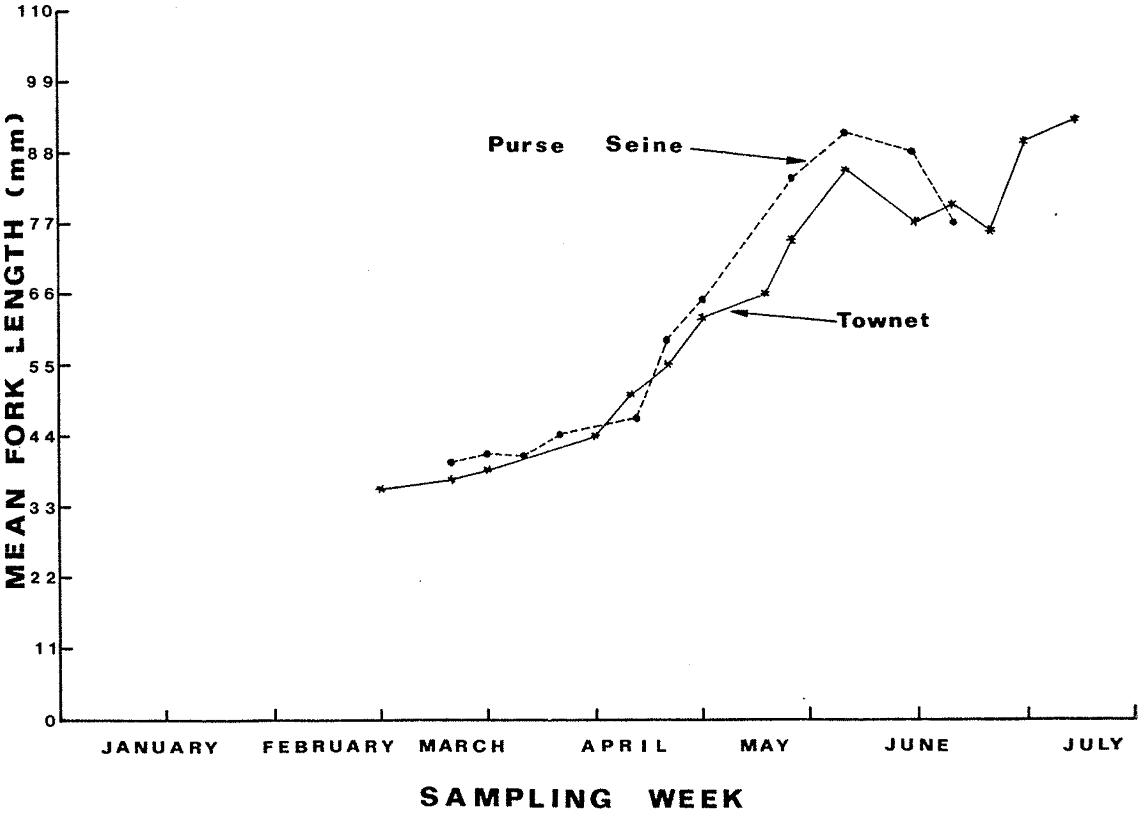

Fig. 2-10. Comparison of mean fork length of chum caught by purse seine and townet at Bangor (superimposed on data from Bax et al. 1980).

Table 2-12. Difference in fork length (cm) of chum caught by purse seine at EHW, June 18-21, 1979: summary of results of ANOVA and SNK multiple comparison among means.

A. ANOVA

H_o: no difference in mean length among 8 sampling sites at EHW, 6/18-21/79.

Source of variation	d/f	MS	F	
Among	7	21.099	12.86	$p << .001$
Within	690	1.640		

Conclusion: reject H_o

B. SNK multiple comparison among site means

Sites (ranked by magnitude of means)

Location:	Sub bay		N. EHW		W. EHW	S. EHW		W. EHW
Site No.[a]:	6	7	5	8	3	1	2	4
F.L.	7.168	7.895	7.931	7.959	8.130	8.159	8.272	8.330

Underlined means do not differ significantly ($\alpha = .05$)

Conclusion: chum caught in sub bay significantly smaller than those caught at remaining sites

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[a] See Fig. 2-4.

(*see* Sec. 2.2.2.1.2), and smaller fish were not "pushed" out of the area as they might have been at other sites sampled in stronger currents. Allen (1974) and Fresh et al. (1979) suggest that chum seek refuge from current by moving inshore.

2.4 DISCUSSION

2.4.1 Effects of Lighting on Chum

The results of the net sampling phase of this study contradict those of the acoustic monitoring and visual observation phase (*see* Sec. 4.0) with respect to effect of security lighting on the distribution and abundance of chum in the EHW area: *catch* of chum was not consistently affected by the lights, but chum and other species were *observed* to aggregate below the lights. This suggests that security lights attracted chum, but that chum in lighted areas either avoided capture, or the effect on chum was localized to areas partially or totally inaccessible to the nets (*see* Sec. 2.4.1.2).

2.4.1.1 Net Avoidance

It is generally accepted that fish will try to avoid nets they can see. Avoidance may involve not only visual detection of the net itself, but also of the fishing vessels which, in a lighted area, cast a large "predator-like" shadow. Thus, fish in the EHW area might have better avoided the seines and townet when EHW lights were on than off, so that "lights on" catch values might have underestimated population densities.

Fish use their lateral line systems to detect pressure waves from the net, the vessel′s hull and noise, and may respond by avoiding the net. Hypothetically, such avoidance in this study would have equal probability of occurring in both "lights on" and "off" situations, and thus would not affect estimates of light effect.

Nets were dyed blue-green to minimize detection of the net itself. No method was available to eliminate shadows cast by the vessels.

Tests for light-mediated avoidance of the nets focused on the purse seine because it was the most frequently used net in the lighted area. We: 1) visually observed surface waters ahead of the vessel; 2) acoustically monitored the sample area during sets; and 3) conducted a series of sets away from the EHW, alternately turning on the vessel lights illuminating the area where the net was being laid out for one set, and immediately afterwards making another set ∿300 m away with lights off. Conducting a similar test series at EHW and turning the pier lights on and off, while offering the advantage of actual lighting-netting conditions, was not feasible since acoustic monitoring demonstrated that the pier lights affected fish distribution in a large area, and the time needed for distributions to stabilize (i.e., reflecting the lighting conditions as opposed to the *changing* conditions) was too long (∿1 hr) to allow adequate replicates (>10 sets).

Visual observations of purse seining in the sub bay showed that nearsurface (<2 m depth) chum (3-7 cm FL) tended to scatter laterally but not sound when the vessels, particularly the barge, moved through the set. Since the set was clockwise, chum scattering to the left of the barge escaped capture; however, chum scattering to the right were corralled by the net. These qualitative observations did not provide any index of the proportion of available chum which escaped.

Acoustic monitoring of the purse seining, using a transducer placed prior to the set directly below the seined area, did not detect any fish sounding to avoid the net (Fig. 2-11). However, during normal sampling, adult herring were occasionally found gilled near the bottom of the net, suggesting sounding. Large (>7 cm) outmigrating salmonids are reported to sound to escape predators (Cooney et al. 1978).

Vessel light tests found no significant difference in CPUE of chum, chinook (>15 cm), hake, or dogfish from seven pairs of "on/off" sets.

Unfortunately the vessel light tests did not duplicate actual pier lighting: surface intensities (2-5 lux) were comparable to EHW security light intensities, but the area illuminated (∿6 m^2) was significantly less. Moreover, pier-lighted paired sets were impractical, and acoustic monitoring and visual observations could not quantify avoidance. Consequently, we may have underestimated any effect of EHW lights, both in the present study of security lighting and in 1978, when the more intense operational lights appeared to attract juvenile chum and pink salmon (Prinslow et al. 1979).

2.4.1.2 Localized Effect of Security Lights

An alternate hypothesis to net avoidance is that the effect of security lights on chum was localized to an area partially or totally inaccessible to the nets. The width of the vessels restricted netting to areas >3 m from the wharf. The circular purse seine sets sampled a zone ∿5-15 m from the wharf (width of vessel = 5 m, diameter of set ≃10 m); the townet swept a zone ∿5-11 m from the wharf (*see* Plate II; width of vessel = 3 m, width of net = 6 m); and the beach seine sampled a zone ∿3-27 m from the wharf (width of vessel = 2 m, diameter of set ≃24 m). Security light intensities decreased ∿50% at surface, and 100% at 2 m depth at a distance of 10-15 m from the wharf. Thus in the areas sampled by net, security light intensities were significantly less than in nearby areas adjacent to the trestles and inaccessible to the nets. That chum were observed in these (lighted) "near-trestle" areas in 1978 and 1979 but catch was not consistently affected by the lights, supports the hypothesis of localized effect of security lights.

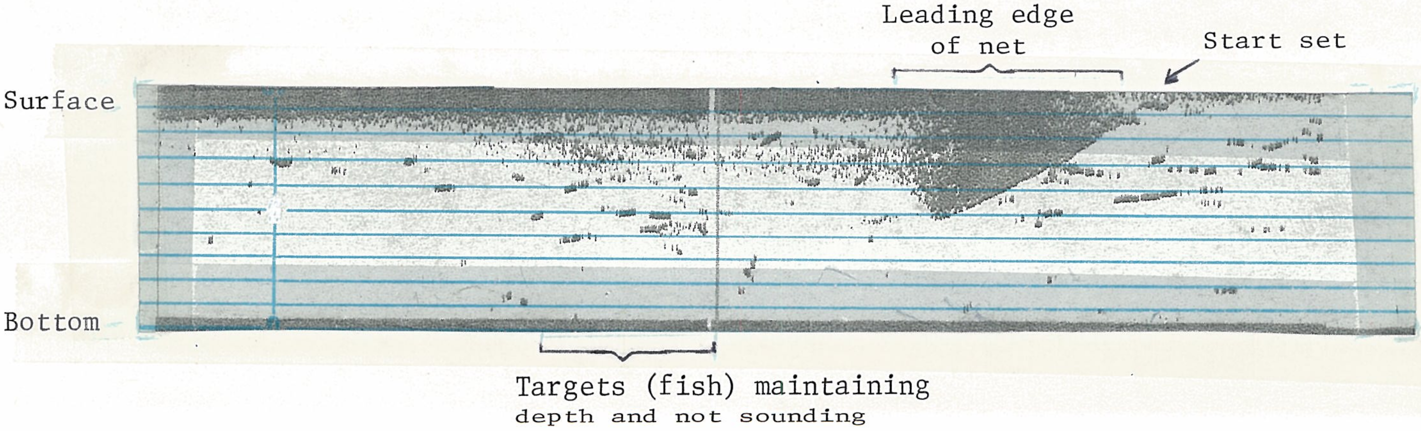

Fig. 2-11. Upward-looking acoustic monitoring of purse seining. Each horizontal line is 1 fathom (∿2 m) depth. Elapsed time during strip ∿2 min. (Note: Read strip chart from right to left.)

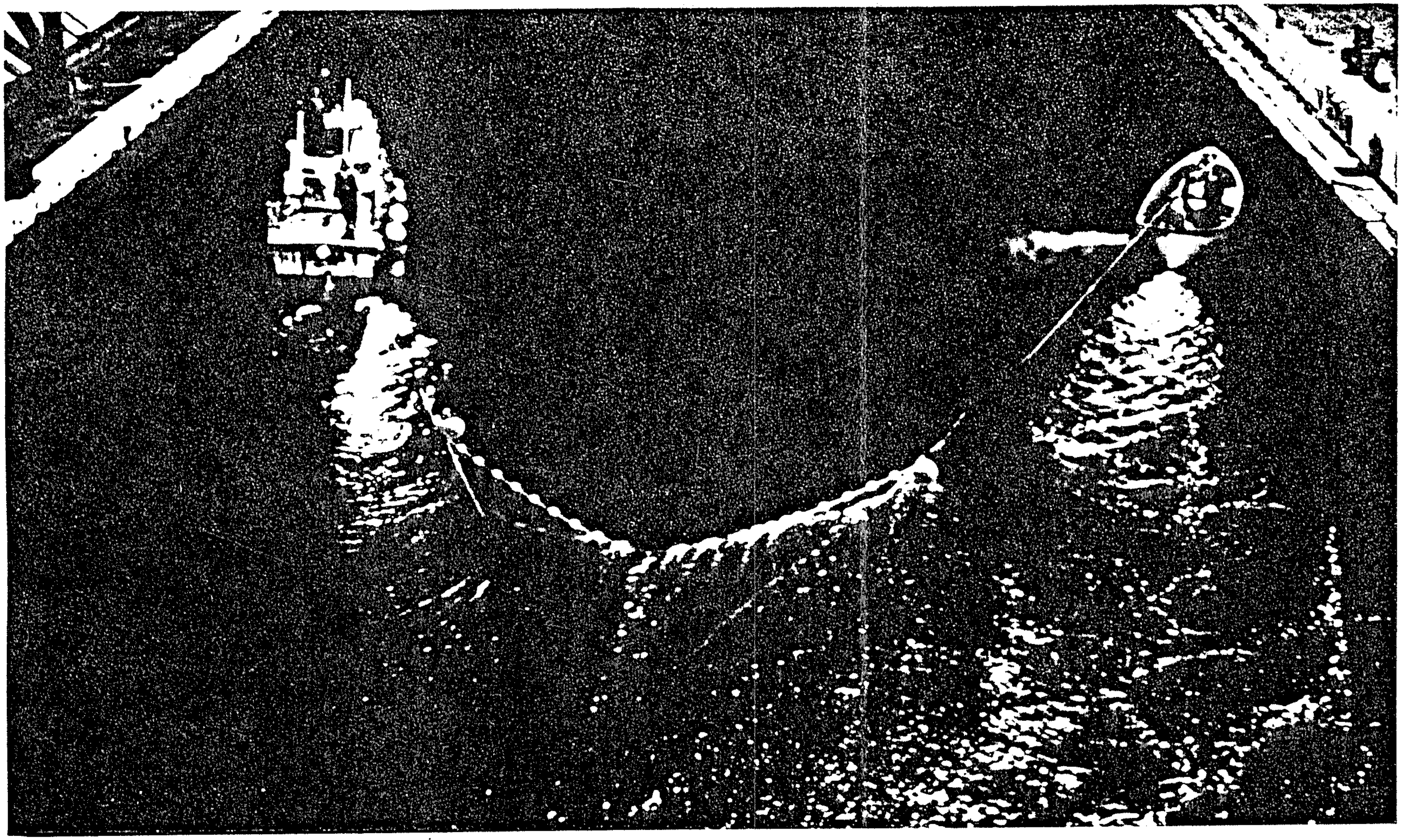

Plate II. Townetting at night in EHW submarine berth, Bangor, Hood Canal, Washington.

Irrespective of lighting, chum catch at EHW during 1979 significantly exceeded catch from other sampling areas on the submarine base shoreline, suggesting that chum were attracted to the wharf, perhaps for food or for protection.

These results appear to contradict those of the 1978 study (Prinslow et al. 1979), which found increased catch of chum in the nearshore area adjacent to trestles with security lights on, and apparent attraction to the sub bay which was more intensely lighted (∿200 lux), but not to the wharf itself (i.e., with lights off).

Three hypotheses to account for this are:

1) the wharf and/or light stimuli differed between 1978 and 1979 causing the different responses; or

2) the outmigrating salmon behaved differently to the wharf and light stimuli between 1978 and 1979, i.e., some other environmental factor(s) affected the fish resulting in the different responses; or

3) the short-term tests in 1978 were inadequate to describe the behavior of chum around the wharf.

We know that the lighting scheme changed, being 100 times less intense in the sub bay area in 1979, which could account for attraction to this area when lighted in 1978, but not in 1979. Furthermore, the sub bay during 1979 tests received identical illumination when lights were "off" as "on" (about 2-3 lux at surface). Since salmon respond to light intensities of 10^{-3} lux (Brett and Groot 1963), attraction of offshore-moving chum to the "wharf" at night in 1979 may in fact have been attraction to lights.

This does not explain increased abundance of chum near shore at EHW relative to other nearshore areas at Bangor, since with the security lights off, illumination from office lights in the sub bay was >100 m away. On a seasonal basis, the nearshore area at EHW has historically produced greater catches of outmigrating chum than elsewhere at Bangor (Schreiner 1977, Bax et al. 1979). We speculate that chum prey organisms characterizing this area (Simenstad and Kinney 1978) elicited this response, and that, in view of the results of the intensive 1979 tests, the increased nearshore chum catch at EHW in March 1978 was also a response to food availability rather than security lights. That chum catch in this area during the 3-night "lights off" test in April 1978 was not greater than other nearshore areas at Bangor probably does not contradict the "food availabililty" hypothesis but simply reflects the high variation in weekly chum catch at any Bangor site.

Finally, there may be other factors causing a yearly change in chum behavior, e.g., the presence of pink salmon smolts (Gallagher 1980), temperature (Gilhousen 1962), or other environmental variables (Blackbourn 1976).

We conclude that 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. We speculate that chum prey organisms characterizing this area (Simenstad and Kinney 1978) elicited this response, and that, in view of the results of the intensive 1979 tests, the increased nearshore chum catch at EHW in March 1978 was also a response to food availability rather than security lights. That chum catch in this area during the 3-night "lights off" test in April 1978 was not greater than other nearshore areas at Bangor probably does not contradict the "food availability" hypothesis but simply reflects the high variation in weekly chum catch at any Bangor site.

2.4.1.3 Operational Lighting

Explosives Handling Wharf 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 2-13 lux at the water surface, while operational lighting provides 2-66 lux below the pier trestles and 340-420 lux in the submarine berth. This intensity more than doubles that tested in 1978 which appeared to attract 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 (Tables 2-13A and D) suggested a strong attraction to operational lights. Similar operational lighting exists at the Delta Pier (see Fig. 1-2) and will be used at the Service Pier presently under construction at Carlson Point.

Thus when the Base is in operation during outmigration, the lights will probably attract the salmon to a degree dependent on intensity. Although mark-recapture experiments (Sec. 3.0) suggest that there will be no lingering effect, it is uncertain what impact additional wharves and frequency of use of operational lighting might have on outmigrating salmon. Furthermore, gathering evidence (Parker 1965, 1971; Gunsolus 1978; Gallagher 1980) implicates the first week of marine existence of juvenile salmon as critical to their survival. Chum salmon from Hood Canal hatcheries pass the Base during this period in March-May outmigrations and might be most sensitive to any perturbations resulting from the wharves and lighting. This question deserves future study.

Table 2-13. Summary of "operational lighting" test data, 1979.

A. Purse Seine

Date	Lights	CPUE (± S.E.)	Effort	Range	Compare
6/19	Operational (sub bay only)	187 (—)	1	—	$.05 < p < .1^{*}$
6/21[a]	Security	74.2 (18.1)	8	19 - 171	
6/18[a]	Off	20.8 (9.2)	10	3 - 101	$p < .01^{\dagger}$

* $t = 2.064$, $df = 7$ $.05 < p < .1$
† $H/D = 11.363$, $df = 3.27$ $.001 < p < .01$

B. Townet

Date	Action	Result
6/20	Operational lights turned on for 1/2 hr and sub bay sampled	Lights turned on < 1 hr before dawn, CPUE small (8), but "security light" tow on same night only caught 9; therefore uncertain whether adequate no. fish available to test.

C. Beach Seine — not attempted.

D. Acoustic

Date	Action	Result
	Operational lights turned on after security lights on for 2 hr.	1. On echogram, schooling fish left area. 2. Visual observations, chums aggregated in 1000's at surface (zone not detected in echogram).

[a] For a conservative estimate of effect of "operational" lights on chum CPUE, 6/18 and 6/21 were chosen because CPUE's on these nights were greater than 6/19 and 6/20.

2.4.2 Effects of Lighting on Predators

Predator CPUE was significantly less with security lights on than off, perhaps because the EHW lights helped predators detect and avoid the net.

Alternatively, EHW security lights may have elicited a "daylight behavior" in the predators: Hobson (1979) and Major (1977) describe an inactive period for predators in tropical waters during daylight, when light intensities were high (about 10^4-10^5 lux, Salo 1976)[7], which was followed by an active period at dusk (10^1 lux, Major 1977). Another inactive period followed when complete darkness had fallen (10^{-3} lux, Salo 1976).[8] Dawn brought a brief resurgence of activity. Ginetz and Larkin (1976) also demonstrated an inverse relationship between light intensity (5-30 lux) and predation rate by rainbow trout (Salmo gairdneri) on migrant sockeye fry. Hobson (1979) suggested that defense mechanisms of schooling fish accounted for this behavior: bright light reflected off the many fish in the school, confusing the predator. As light dimmed, this defense became less effective, until at dusk the predators attacked. Complete darkness helped to obscure and protect the prey.

If reduced CPUE of predators with EHW lights "on" indicated avoidance, predation might be reduced there. However, EHW lights would also produce a moving but "permanent dusk" transition zone at varying distances from the pier where predator activity might increase. This study did not investigate this possibility.

While chum salmon are facultative schoolers and may participate in diurnal light-mediated cycles (Schreiner 1977), predation on outmigrating chum in the pelagic zones near the EHW was insignificant. Simenstad and Kinney (1978) drew the same conclusion for outmigrating salmonids in Hood Canal generally, although their sample size was small. The principal piscivores in the EHW area (by catch data) were hake and dogfish. Studies of other areas show these opportunists to exert insignificant predation pressure on chums (Hickling 1927, Tillman 1968, Jones and Geen 1977). The only incident of predation we found on chum was from a cutthroat trout, but the total catch was only two in the EHW area from February through July 1979. Simenstad and Kinney (1978) and Specht (1979) reported that chum comprise an insignificant fraction of the diet of sea-run cutthroat, at least in the marine environment. Although the chum may not have been preyed on heavily, the opposite was true for juvenile herring and sand lance (Table 2-5; and Hickling 1927, Tillman 1968, and Jones and Geen 1977).

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[7] Light intensities not specified by authors; approximate values estimated from Salo (1976).

[8] Ibid.

Operation of waterfront facilities at Bangor will illuminate a 5-km-long zone from Carlson Pt. to north of Floral Pt. on the eastern shoreline of the Canal (Fig. 1-2). It is unknown how this would affect hake, dogfish, herring, and sand lance populations. Jones and Geen (1977) note that:

> "Preliminary analyses suggest that dogfish consume over five times the current annual commercial catch of herring (in British Columbia waters)..."

2.5 CONCLUSIONS

1. Security lighting at EHW (2-13 lux) is an attractive stimulus to which outmigrating chum salmon may respond; any effect appears to be temporary and localized to within 5-10 m of the wharf.

2. The EHW area, irrespective of lighting, attracts chum salmon, perhaps to adjacent eelgrass beds abundant in chum prey.

3. Predation on chum by piscivores in the pelagic zone at EHW was insignificant. The piscivores included adult salmon, trout, hake, sculpin, and dogfish.

4. Bangor base waterfront lighting may affect other fisheries in Hood Canal, e.g., herring.

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3.0 MARK-RECAPTURE EXPERIMENTS

by

Clifford J. Whitmus

3.1 INTRODUCTION

The objectives of the mark-recapture studies were to determine:

1) estimates of early marine mortality,
2) residency and attraction around piers,
3) migration patterns, and
4) growth rates.

3.2 MATERIALS AND METHODS

3.2.1 Marking

Chum salmon from the Big Beef Creek hatchery were marked with fluorescent pigment to monitor their migratory behavior past the security lighting at the Explosives Handling Wharf (EHW). Chums ranging from 48 mm to 54 mm were marked by forcing fluorescent pigment particles through the epidermis and into the dermis by using a small sand-blasting gun and compressed air. The pigment is a biologically inert polystyrene pigment that is not readily excited by daylight but will fluoresce under ultraviolet. For a complete description of marking procedure see Whitmus and Olsen (1979).

Mortalities were enumerated 48 hr after marking. A subsample was evaluated for mark retention prior to release.

3.2.2 Releases

We released groups of marked fish from the Big Beef Creek estuary and from a site 300 m south of EHW.

Releases from the Big Beef Creek estuary were after dark on an high outgoing tide. Fish released south of EHW were held in salt-water pens for 48 hr before being released after dark. The fish were transported to Bangor in a 400 gal tank aboard the R/V TENAS or by truck.

3.2.3 Sampling

We used simultaneous beach seining and townetting to monitor the migration of marked fish out of Hood Canal. Sampling began the day after release from Big Beef Creek and continued daily until the distribution could no longer be defined. Transects were monitored from Misery Point to Foulweather Bluff (Figs. 3-1 and 3-2).

We sampled immediately after an EHW release with beach seine and townet from south of EHW to north of EHW. Each sampling round took 1.5 to 3.5 hr depending on the range of the sampling. Two to four sampling rounds could be completed per night. In addition to beach seining and townetting, we used hydroacoustic sampling to monitor the dispersion of the released fish.

Immediately after capture, the fish were brought to the R/V TENAS for analysis. Fish were anesthetized with Tricane Methane Sulfonate (TMS), placed under black light, and examined for pigment. For a description of the light source see Whitmus and Olsen (1979).

3.2.4 Early Marine Mortality

Estimates of the early marine mortality of juvenile chum salmon in Hood Canal, where other populations may be entering the samples, were based on subsequent releases of new marks at standardized intervals. It was then possible to estimate the survival over time between the introduction of new marks. An initial group of marked smolts was released from Big Beef Creek and allowed to emigrate. Subsequent groups of chums were released at 48 and 96 hr at the peak of the initial group′s distribution in Hood Canal as detected by beach seining and townetting. The procedure is:

	t_0	t_1	t_2	t_3	. . . .
Population	N_0	N_1	N_2	N_3	. . . .
Marks added	M_0	M_1	M_2	M_3	. . . .
Sample taken		n_1	n_2	n_3	. . . .
Mark recaptures		m_{01}	m_{02}	m_{03}	. . . .
			m_{12}	m_{13}	. . . .
				m_{23}	. . . .

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

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

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

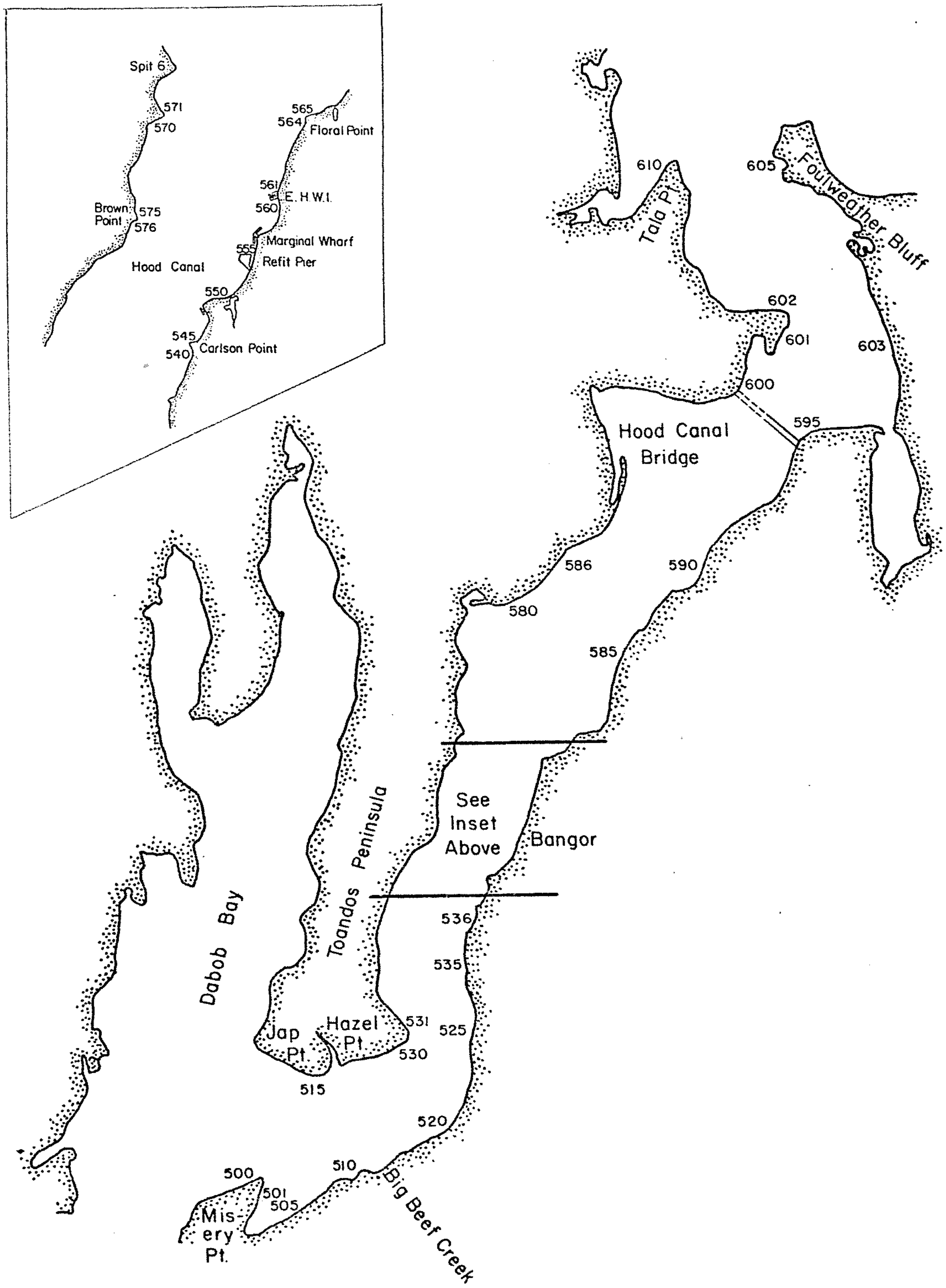

Fig. 3-1. Beach seine sites during mark-recapture experiments with chum salmon, Hood Canal, 1979.

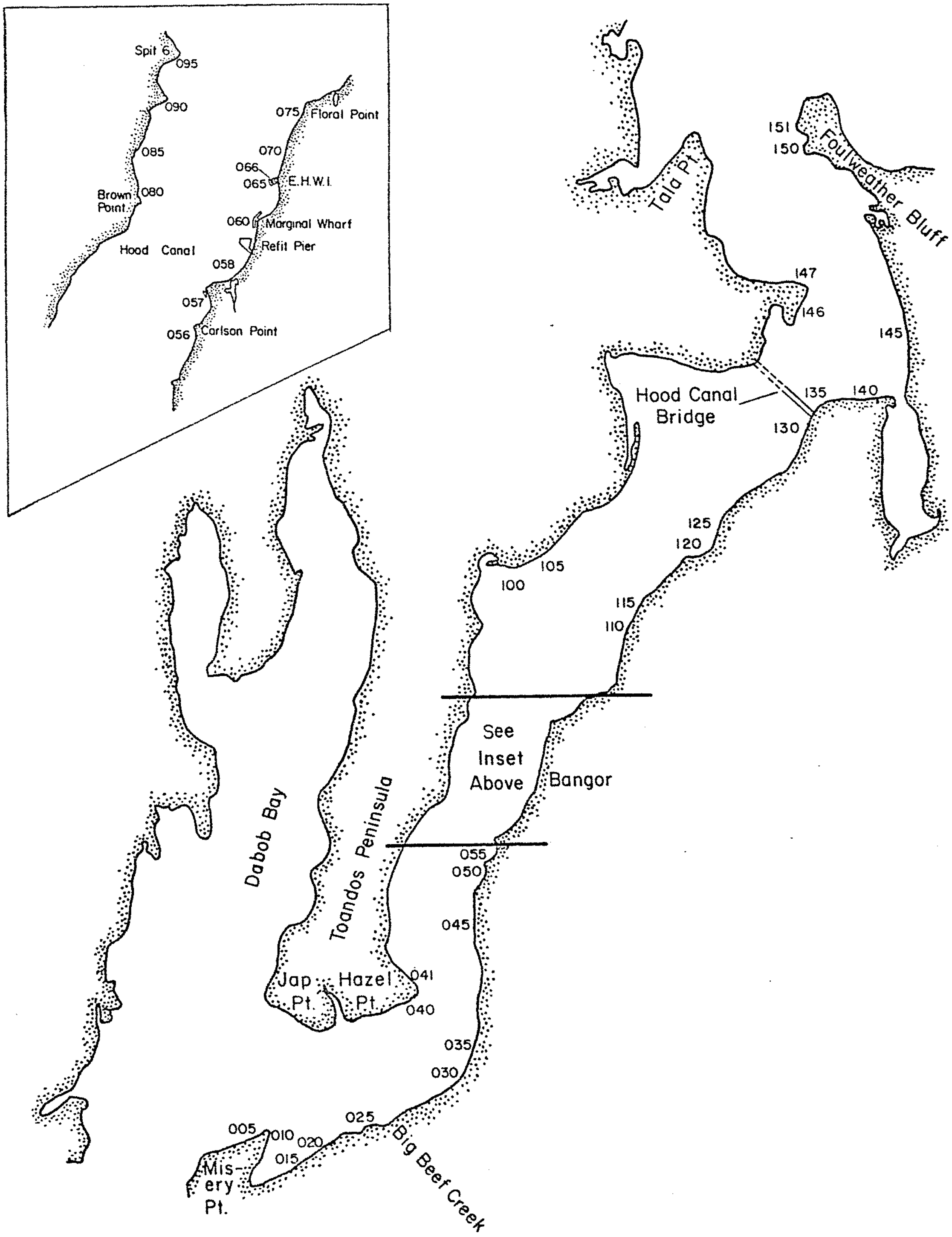

Fig. 3-2. Townet transect locations during mark-recapture experiments with chum salmon, Hood Canal, 1979.

Then $$S_0 = \frac{m_{02}'}{m_{12}'} \quad X \quad \frac{M'}{M_0}$$

Relative error of the estimate of S_0 is approximately:

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

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

3.2.5 Growth

Marked fish recaptures were stored in 10% buffered saltwater formalin for 7 days before length-weight analysis. It was found there was less variability in length and weight after 7 days than any time prior to that (Appendix III). Individual lengths and weights were taken for all marked fish. A daily growth rate was then computed.

3.3 RESULTS AND DISCUSSION

3.3.1 Migratory Behavior

The releases from Big Beef Creek and from south EHW are summarized in Table 3-1.

3.3.1.1 February

On February 4, we released 57,600 chum fry (mean fork length (MFL) 52 mm, mean weight (MW) 1.2 g), marked with orange pigment, at 2100 hr from Big Beef Creek. These fish had a 94% mark retention with less than 1% marking mortality for an effective release size of 53,600. Sampling began February 5, and continued through February 8 (see Table 3-2 and Figs. 3-3 and 3-4).

For the mortality estimate, we released 20,000 (effective release 18,600) chum fry (MFL 52 mm, MW 1.2 g) marked with red pigment at 2230 February 6, 300 m south of EHW. Sampling on the following days failed to find any peak of marked fish. For this reason we abandoned the remaining mortality estimate release.

Table 3-1. Summary of marked fish releases from Big Beef Creek Hatchery, February through June.

	Big Beef release				Hood Canal release					
Month	Date	Number	Color	Size	Date	Location	Number	Color	Size	Lights
February	4 Feb.	57,600	Orange	52 mm, 1.2 g	6 Feb.	300 m S of EHW	20,000	Red	52 mm, 1.2 g	On
					14 Feb.	300 m S of EHW	3,900	Green	52 mm, 1.2 g	On
March	4 Mar.	82,100	Red	52 mm, 1.1 g	7 Mar.	300 m S of EHW	36,800	Blue-Green	52 mm, 1.2 g	On
					8 Mar.	300 m S of EHW	20,000	Orange	52 mm, 1.2 g	On
April	8 Apr.	66,000	Orange-Green	48 mm, 0.8 g	10 Apr.	300 m S of EHW	18,000	Red	48 mm, 0.8 g	On
May					7 May	300 m S of EHW	16,000	Orange	54 mm, 1.4 g	Off
					9 May	300 m S of EHW	16,000	Red	54 mm, 1.4 g	On
June	3 June	76,000	Red-Green	51 mm, 1.1 g						

Table 3-2. Date, gear, area sampled, time sampled and peak distribution(s) of marked chum released February 4, 1979 from Big Beef Creek.

Date	Gear	Area Sampled (Site No.*)	Time Sampled	Peak Distribution(s) (Site No.*)
Feb. 5	BS	500-564	1030-1620	501,531,560 (*see* Fig. 3-3)
Feb. 5	TN	005-065	1127-1626	010,025,050,041 (*see* Fig. 3-3)
Feb. 6	BS	500-595	1145-1955	545,580 (*see* Fig. 3-4)
Feb. 6	TN	005-135	1132-1959	065 (*see* Fig. 3-4)
Feb. 7	BS	545-605	1225-1625	None
Feb. 7	TN	056-151	1208-1956	None
Feb. 8	TN	060-115	1236-1333	None

*Cf Figs. 3-1 and 3-2.

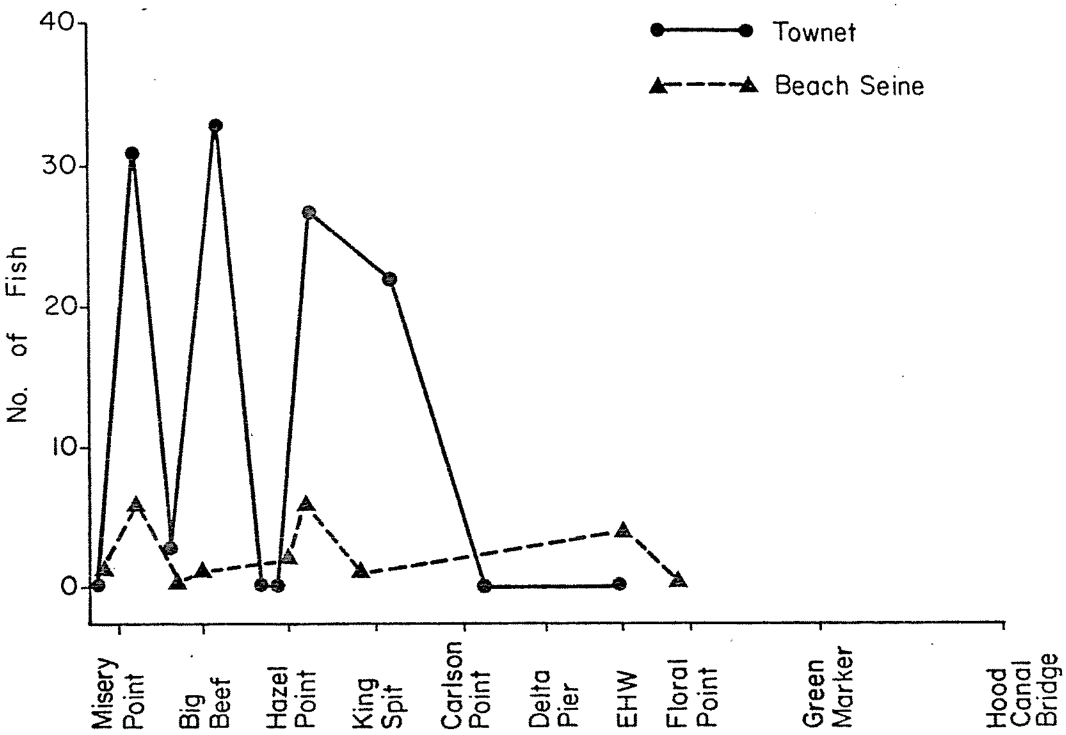

Fig. 3-3. February 5, 1979 beach seine and townet captures of marked chum released February 4, 1979 from Big Beef Creek.

Fig. 3-4. February 6, 1979 beach seine and townet captures of marked chum released February 4, 1979 from Big Beef Creek.

To test for the effect of EHW lights on residence time, we released the remaining group (effective release 3,900; MFL 52 mm, MW 1.2 g) marked with green pigment. At 2100, February 14 on an ebb tide, 300 m south of EHW with security lighting on, simultaneous beach seining and townetting began at 2130 hrs February 14 and continued until 0700, February 15. We completed four sampling rounds between Delta Pier and Floral Point. No sampling took place from 2400-0400 because of equipment breakdown. The beach seine caught six marked fish while the townet captured 135 (Fig. 3-5).

As shown in Fig. 3-5, the recoveries of marked fry decreased over time indicating the fry moved out of the area. In all sampling rounds we captured more marked fish at EHW than any other site which may indicate some degree of attraction to EHW.

3.3.1.2 March

On March 4, we released 82,000 chum fry (MFL 52 mm, MW 1.1 g) from Big Beef Creek at 2200 hr. The fish, marked with red pigment, had a 93% mark retention and less than 1% marking mortality (effective release 75,600).

We sampled March 5 and March 6 with no marked fish being caught March 6 (Table 3-3 and Fig. 3-6). Since we could not find a peak of marked fish, our planned releases of the two subsequent 48 and 96 hr mortality estimate groups were abandoned. We released the remaining marked fish at EHW in two groups.

On March 7 at 2100 hr, 40,000 fry (MFL 52 mm, MW 1.1 g) marked with blue and green pigment (effective release size 36,800) were released on a flood tide 300 m south of EHW with security lighting on. Beach seining was conducted from 2200 March 7 to 0130 March 8 between South Marginal Wharf and north of EHW. Townetting took place from 2145 to 2300 March 7 and 0300 to 0530 March 8 between the Service Pier and north of Floral Point (breakdown of equipment between 2300 and 0300). Beach seining captured few marks at any site except South EHW where 330 were caught in two sets within 2 hr after release. The fish began to spread out immediately after release, moving both north and south of the release point. It appears that the initial peak of the distribution was located at EHW, but moved northward over time (Fig. 3-7).

The second group, 20,000 marked orange (effective release 18,400), was released at 2000 hr March 8, 300 m south of EHW on a flood tide, with security lighting on. Monitoring by beach seine was conducted from 2020-2215 hr March 8 between South Marginal Wharf and South Floral Point. Townetting took place from 2045 March 8 to 0130 March 9 between the Service Pier and Floral Point. The distribution of these fish was similar to that of March 7. The peak of the distribution of the fish during the second townet sampling round (2305-0130) appeared to be farther south than that of March 7 (Fig. 3-8). This may have been caused

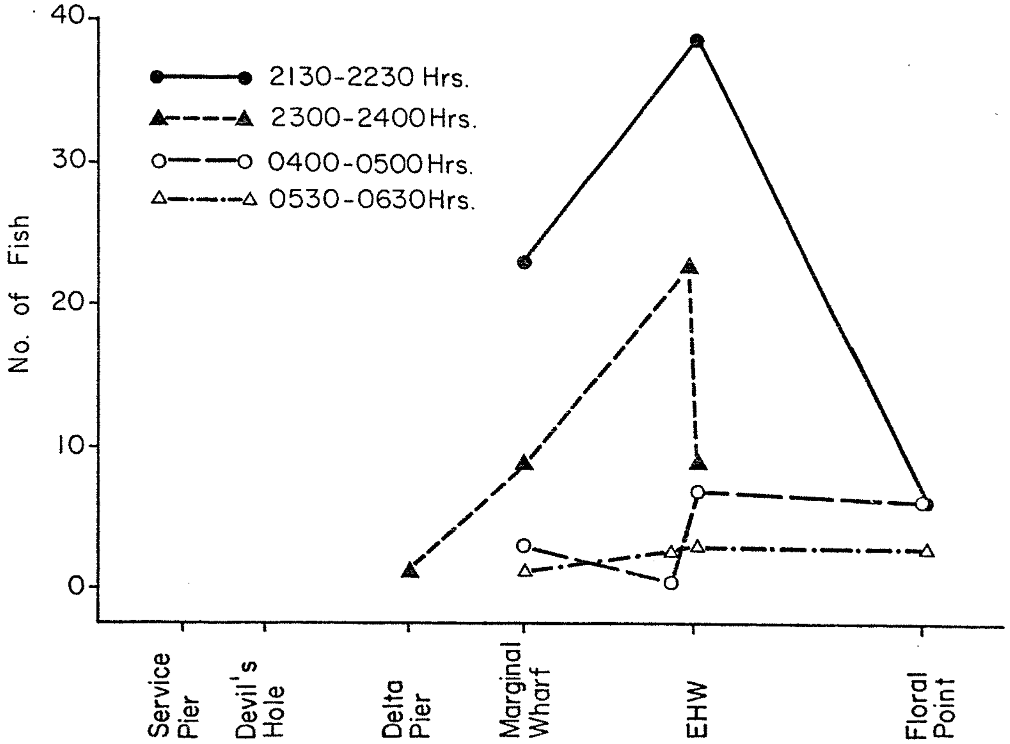

Fig. 3-5. February 14 and 15, 1979 townet captures of marked chum released 300 m south of EHW at 2050 hr, February 14, 1979.

Table 3-3. Date, gear, area sampled, time sampled and peak distribution(s) of marked chum released March 4, 1979 from Big Beef Creek.

Date	Gear	Area Sampled (Site No.*)	Time Sampled	Peak Distribution(s) (Site No.*)
Mar. 5	BS	500-565	1155-1620	520,575 (_see_ Fig. 3-6)
Mar. 5	TN	005-075	1215-1646	075 (_see_ Fig. 3-6)
Mar. 6	BS	500-605	1110-1540	None
Mar. 6	TN	005-151	1055-1545	None

*Cf Figs. 3-1 and 3-2.

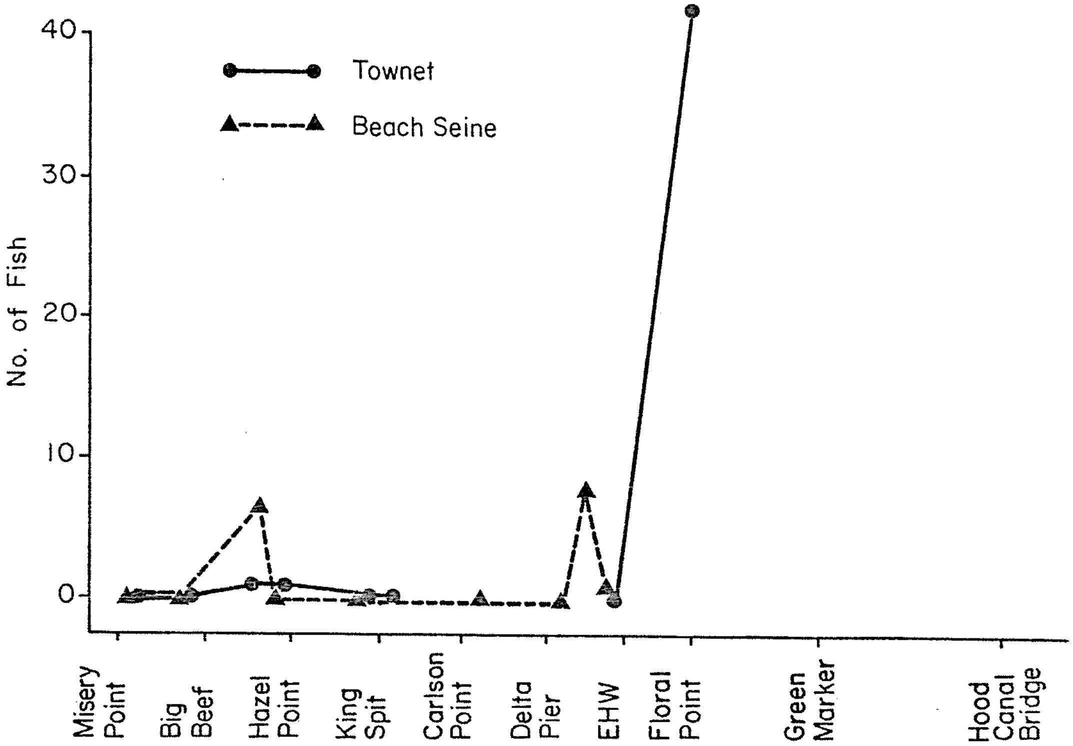

Fig. 3-6. March 5, 1979 beach seine and townet captures of marked chum released March 4, 1979 from Big Beef Creek.

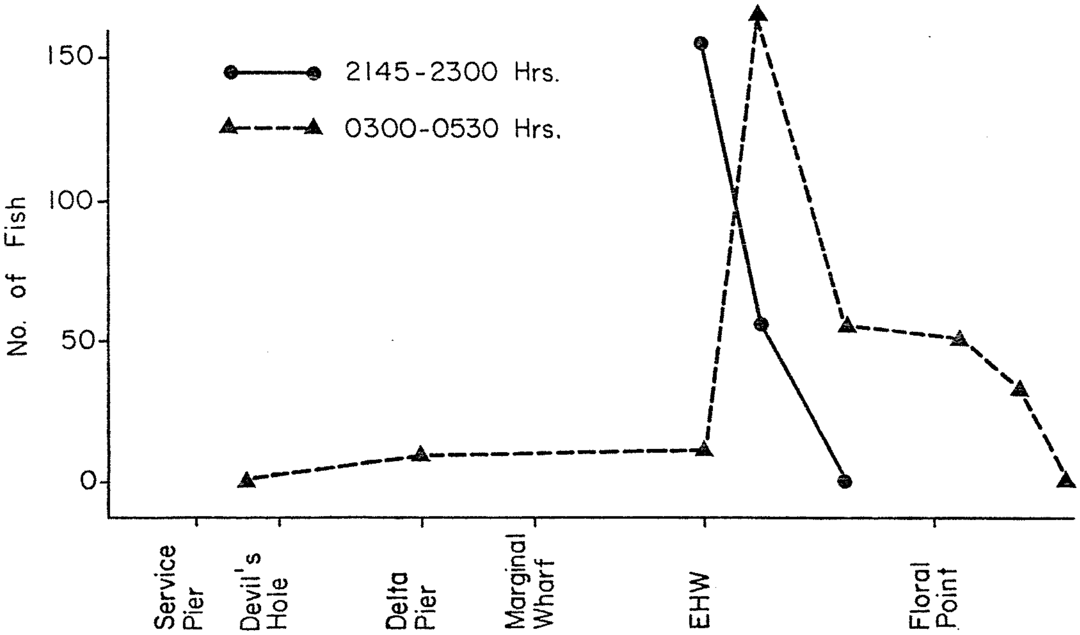

Fig. 3-7. March 7 and 8, 1979 townet captures of marked chum released 300 m south of EHW at 2100 hr, March 7, 1979.

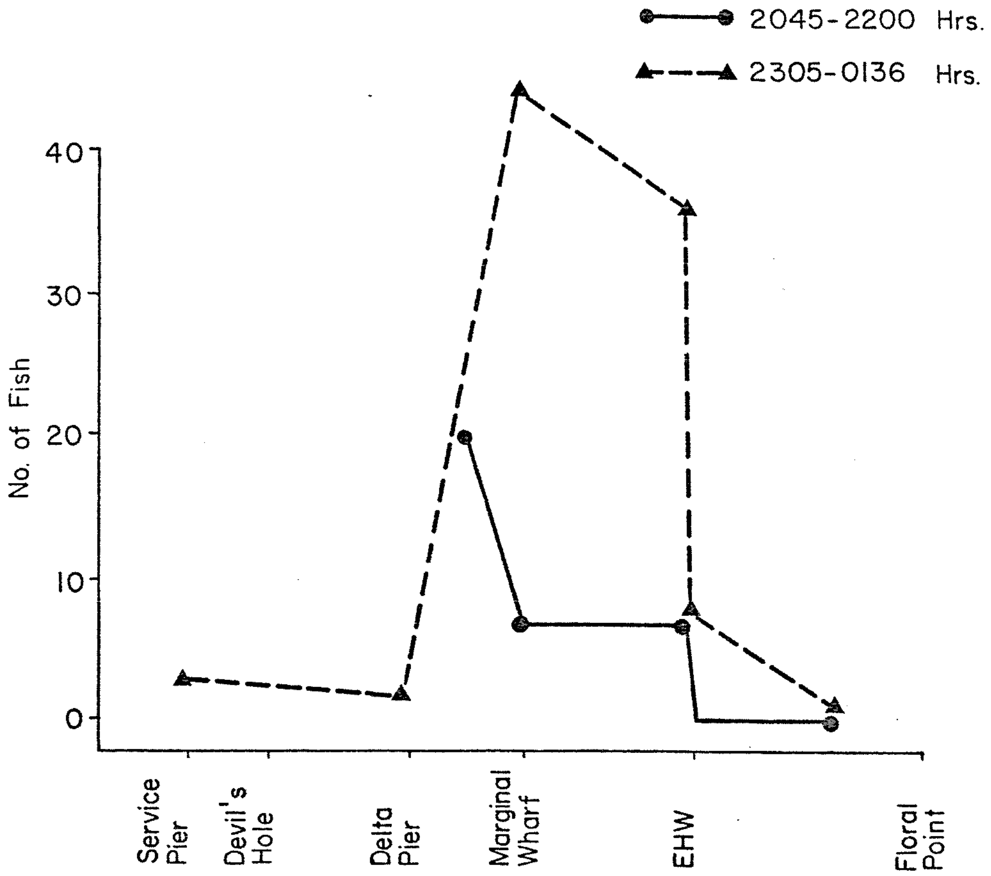

Fig. 3-8. March 8 and 9, 1979 townet captures of marked chum released 300 m south of EHW at 2000 hr, March 8, 1979.

by a ship docking at Marginal Wharf, resulting in all the dock lights being turned on. This may have caused some attraction to the south.

3.3.1.3 April

On April 8, 66,000 chum fry (MFL 48 mm, MW 0.8 g) marked orange and green (58,800 and 7,800, respectively) were released from the Big Beef Creek estuary at 2200 hr. Mark retention was approximately 91% with less than 1% marking mortality (effective release 60,600).

We sampled April 9 and 10 with the mortality experiment being abandoned because of insufficient captures of marked chum (Table 3-4 and Fig. 3-9). The remaining fish were released at EHW in two groups.

The first group of 18,000 (effective release 16,400) marked red was released at 2200 hr April 10, 300 m south of EHW with security lighting on. Beach seining and townetting were conducted immediately after the release from Marginal Wharf to Floral Point (Fig. 3-10). Sampling was conducted for only 1 hr and during this time the peak coincided with the release point. The second group of marked fish was to be released April 12, but strong winds caused the survey to be postponed. During the storm, the fish (held in pens at Marginal Wharf) suffered approximately a 70% mortality. The fish were released the next day, in poor condition, as stormy weather persisted.

3.3.1.4 May

During April the fish being reared for the May release contracted bacterial gill disease causing approximately a 65% mortality. This eliminated a release from Big Beef. The remaining 32,000 fry were released at EHW.

Two groups of 16,000 chum fry each (MFL 54 mm, MW 1.4 g) were marked with orange and red pigment. There was 91% mark retention with less than 1% marking mortality (effective releases 14,400 each). The orange group was transferred to floating pens at South EHW on May 5 and the red were moved May 7. After 48 hr in saltwater both groups had approximately 3,000 mortalities which were probably latent mortalities due to bacterial gill disease.

At 2300 hr May 7, with security lighting off, the orange group was released from holding pens 300 m south of EHW. Sampling by beach seine and townet began immediately following the release and continued through 0530 hr May 8. Three sampling rounds were conducted from Devil's Hole to Floral Point (Fig. 3-11 and Fig. 3-12). Marked fish around EHW were characterized by two distributions. The townet showed that offshore chum dissipated from the EHW-Marginal Wharf area and moved both north and south. The beach seine showed that nearshore fish moved both north and south but that the peak of the distribution remained at EHW, although total numbers declined. On May 8, security

Table 3-4. Date, gear, area sampled, time sampled and peak distribution(s) of marked chum released April 8, 1979 from Big Beef Creek.

Date	Gear	Area Sampled (Site No.[*])	Time Sampled	Peak Distribution(s) (Site No.[*])
April 9	BS	500-600	1025-1850	520,564 (*see* Fig. 3-9)
April 9	TN	005-115	1034-1748	030,041 (*see* Fig. 3-9)
April 10	BS	520-565	1150-1905	535
April 10	TN	030-075	1234-1754	090

[*] Cf Figs. 3-1 and 3-2.

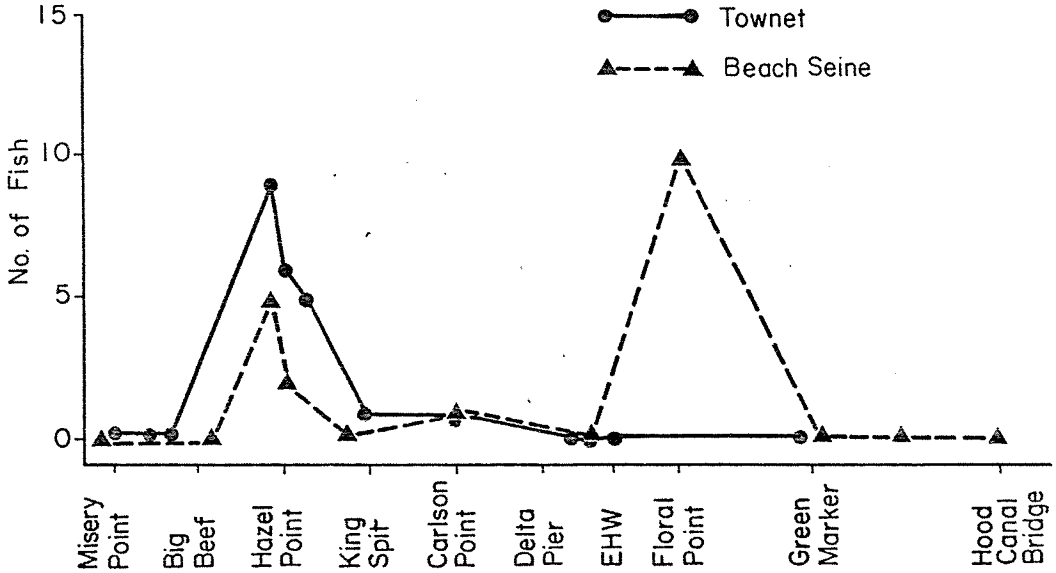

Fig. 3-9. April 9, 1979 beach seine and townet captures of marked chum released April 8, 1979 from Big Beef Creek.

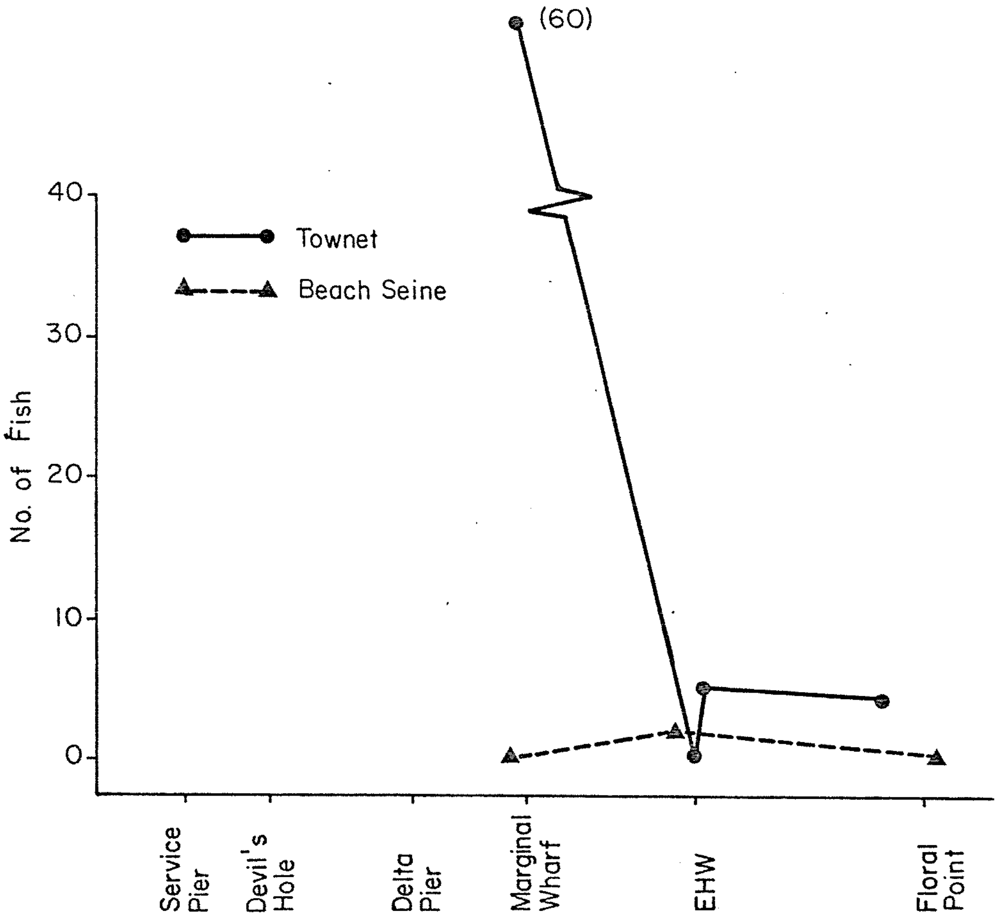

Fig. 3-10. April 10, 1979 beach seine and townet captures of marked chum released April 10, 1979, 300 m south of EHW.

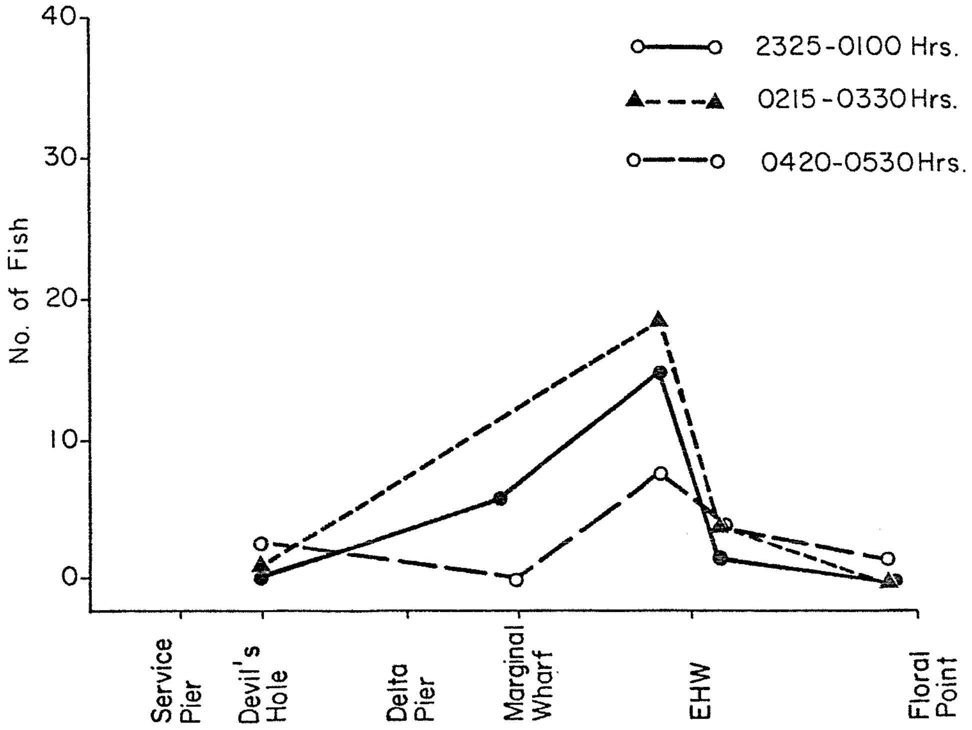

Fig. 3-11. May 7 and 8, 1979 beach seine captures of marked chum released May 7, 1979, 300 m south of EHW.

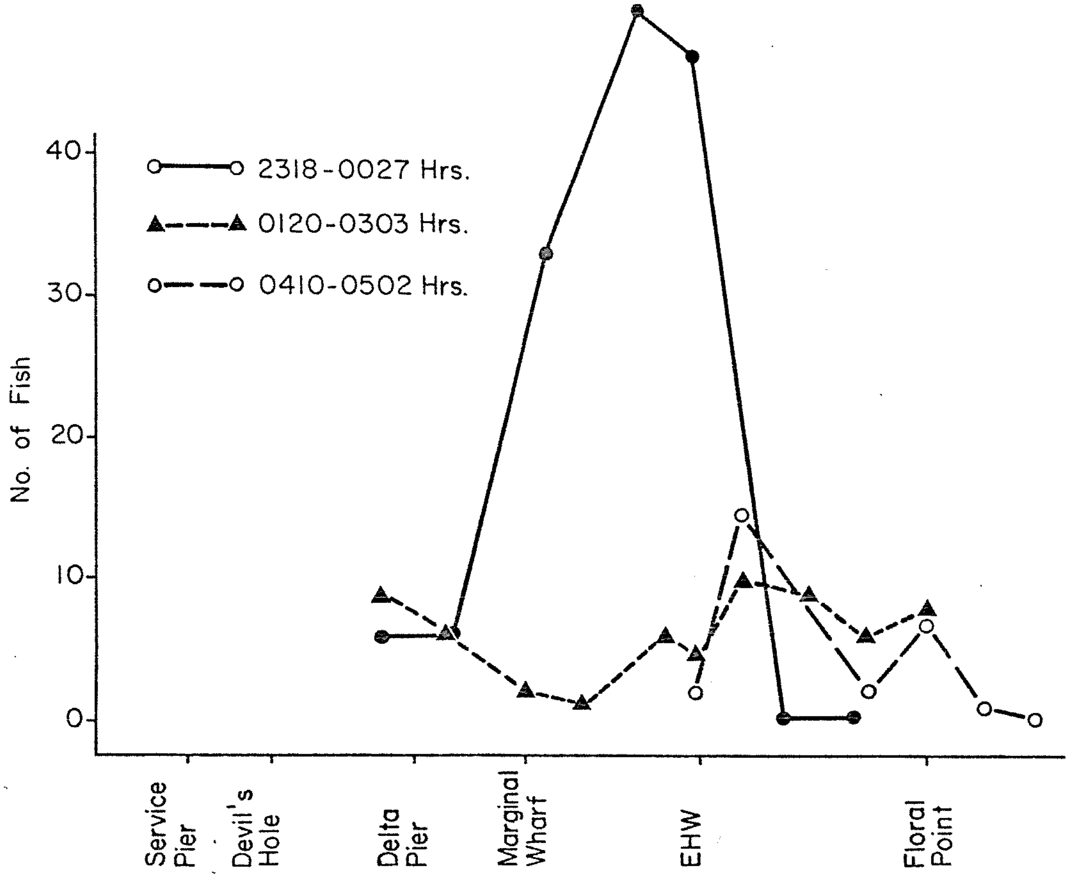

Fig. 3-12. May 7 and 8, 1979 townet captures of marked chum released May 7, 1979, 300 m south of EHW.

lighting off, beach seining and purse seining were conducted for 2 hr. The beach seine caught 6 marked fish (1 Carlson, 2 Devil's, and 3 EHW), and the purse seine caught none.

The group of "red" fish was released at 2100 hr May 9, with security lighting on, 300 m south of EHW. Three sampling rounds of beach seining and townetting were made from Carlson Point to Floral Point (Fig. 3-13 and Fig. 3-14). The distribution of fish was very similar to that of the fish released with the security lighting off. Both the nearshore and offshore fish exhibited the same patterns of distribution as the fish released May 7 (Fig. 3-11 and Fig. 3-12). Sampling on May 10 security lighting on was conducted with the beach seine. Twelve orange and fourteen red marks were found between Carlson Point and Floral Point.

3.3.1.5 Problems Encountered

Marked juvenile chum salmon released from Big Beef Creek were to be used to evaluate any attraction to security lighting at EHW and to estimate early marine survival. Early season releases (February, March, and April) migrated out of Hood Canal in as little as 3 days after release form Big Beef Creek. With this rapid emigration, marked chum fry were not in the sampling area long enough to draw any conclusions about light attraction and mortality. This necessitated the redesigning of the study. Groups of marked fish to be used for the 48 hr and 96 hr mortality estimate releases were instead released south of EHW. This may have helped to determine the light attractiveness of EHW to juvenile chum but all the releases in February, March, and April were made with security lights on. There were no releases during February, March, and April with lights off, therefore there were no control releases.

May releases at EHW were designed so that the effects of both lighting regimes (on and off) could be examined over a short period of time (2 days). The conclusions drawn from the data were not tested statistically because sample sizes were small.

A criticism of the releasing of the fish at EHW is the "disorientation" upon release. This disorientation is characterized by the fish spreading north and south of the release point. This behavior is not the same as fish naturally migrating out of Hood Canal in that they would not experience this "disorientation" upon reaching EHW. This aberrant migratory behavior may influence the response of the fish to light.

Consequently, all inferences must be made with some degree of reservation. It is more likely the case that although behaviorally altered, response of "disoriented" fish to the two lighting regimes is the same as with "natural" fish.

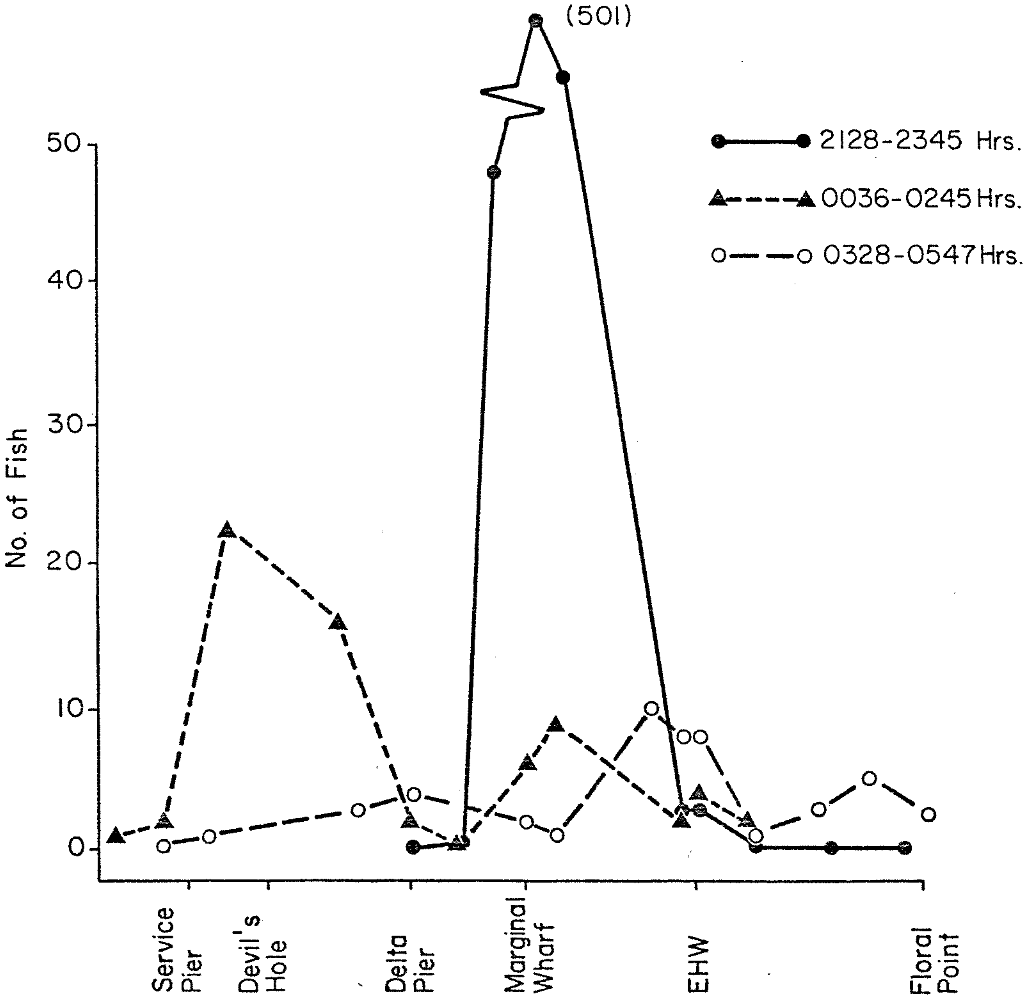

Fig. 3-13. May 9 and 10, 1979 townet captures of marked chum released May 9, 1979, 300 m south of EHW.

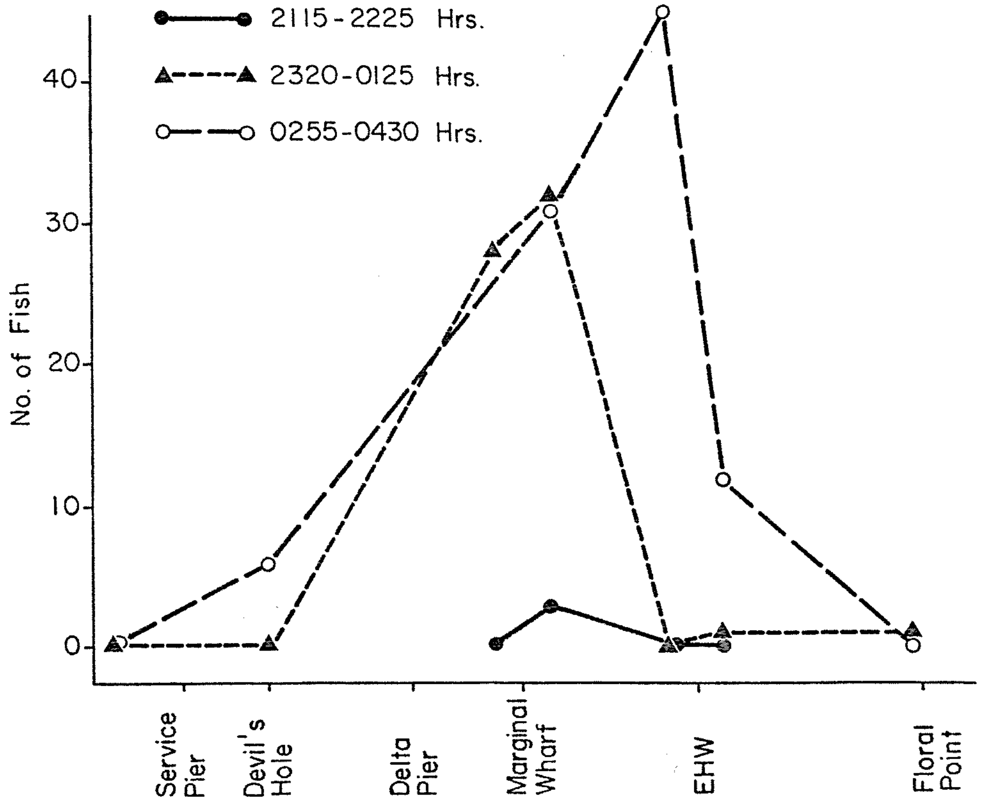

Fig. 3-14. May 9 and 10, 1979 beach seine captures of marked chum released May 9, 1979, 300 m south of EHW.

3.3.1.6 June

We released approximately 76,000 chum fry (MFL 51 mm, MW 1.1 g) from Big Beef Creek estuary on June 3. The fish, marked with red (56,000) and green (20,000) pigment, had 93% mark retention and less than 1% marking mortality (effecting release 70,000).

We sampled by simultaneous beach seine and townet June 4, 5, 6, and 7 (Table 3-5, Figs. 3-15, 3-16, 3-17, and 3-18). The fish appeared to spread out and move out of Hood Canal in groups. Figures 3-17 and 3-18 indicate that by day 4 after release the major portion of the release had not moved past Bangor Annex. The June release moved more slowly than releases in February, March, and April, which moved past Bangor and possibly out of Hood Canal by day 3 after release.

During the first week after release in June, no monitoring was done at EHW at night, after which normal beach seine, townet, and purse seine operations resumed. For the June release, there were 4 nights of sampling with security lights on and 3 with lights off for beach seining, and 3 nights of lights on and 5 nights of lights off for townetting.

Marked fish captured by beach seine and townet at EHW from the June release with lights on and off are summarized in Table 3-6. Captures from the EHW beach seine sites (North EHW and South EHW) were combined whereas those from the townet sites (inside and outside EHW) were not. The numbers of marked fish recaptures at other sites along Bangor Annex are shown in Tables 3-7 and 3-8. Purse seining was conducted for 2 nights with lights on and 2 nights with lights off. The lights on and off marked fish catch-per-unit-effort (CPUE) for the purse seine, grouped by sites with equivalent light intensities, are shown in Table 3-9.

To test if observed differences in beach seine and townet CPUE, with lights on and off, were statistically significant, we used the following ratio: the CPUE of marked fish at EHW sites with lights on (CPUE, EHW, ON) to the CPUE of marked fish at EHW sites with lights off (CPUE, EHW, OFF) plus the CPUE of marked fish at all east shore Bangor Annex sites (CPUE, Bangor, East).

$$\frac{(\text{CPUE, EHW, ON})}{(\text{CPUE, EHW, OFF}) + (\text{CPUE, Bangor, East})}$$

The ratio of marks adjusted for daily variations in catch and removed this bias from the results. The data were normalized by use of the arcsine transformation using Anscombe's correction factor. We compared beach seine catches by using the t-test. Townetting inside and outside of EHW was compared by using the Mann-Whitney test because of nonhomoscedasticity of the townet variances. An analysis of variance

Table 3-5. Date, gear, area sampled, time sampled and peak distribution(s) of marked chum released June 3, 1979 from Big Beef Creek.

Date	Gear	Area Sampled (Site No.*)	Time Sampled	Peak Distribution(s) (Site No.*)
June 4	BS	500-565	1430-1915	520 (*see* Fig. 3-15)
June 4	TN	005-075	1425-1946	025,030 (*see* Fig. 3-16)
June 5	BS	500-595	1415-2130	575,505,520,535 (*see* Fig. 3-15)
June 5	TN	005-125	1437-2116	None (*see* Fig. 3-16)
June 6	BS	505-600	1355-2010	540,570 (*see* Fig. 3-17)
June 6	TN	025-151	1403-2037	045 (*see* Fig. 3-18)
June 7	BS	520-595	1415-1930	520,535,590 (*see* Fig. 3-17)
June 7	TN	030-135	1431-1958	None (*see* Fig. 3-18)

*Cf Figs. 3-1 and 3-2.

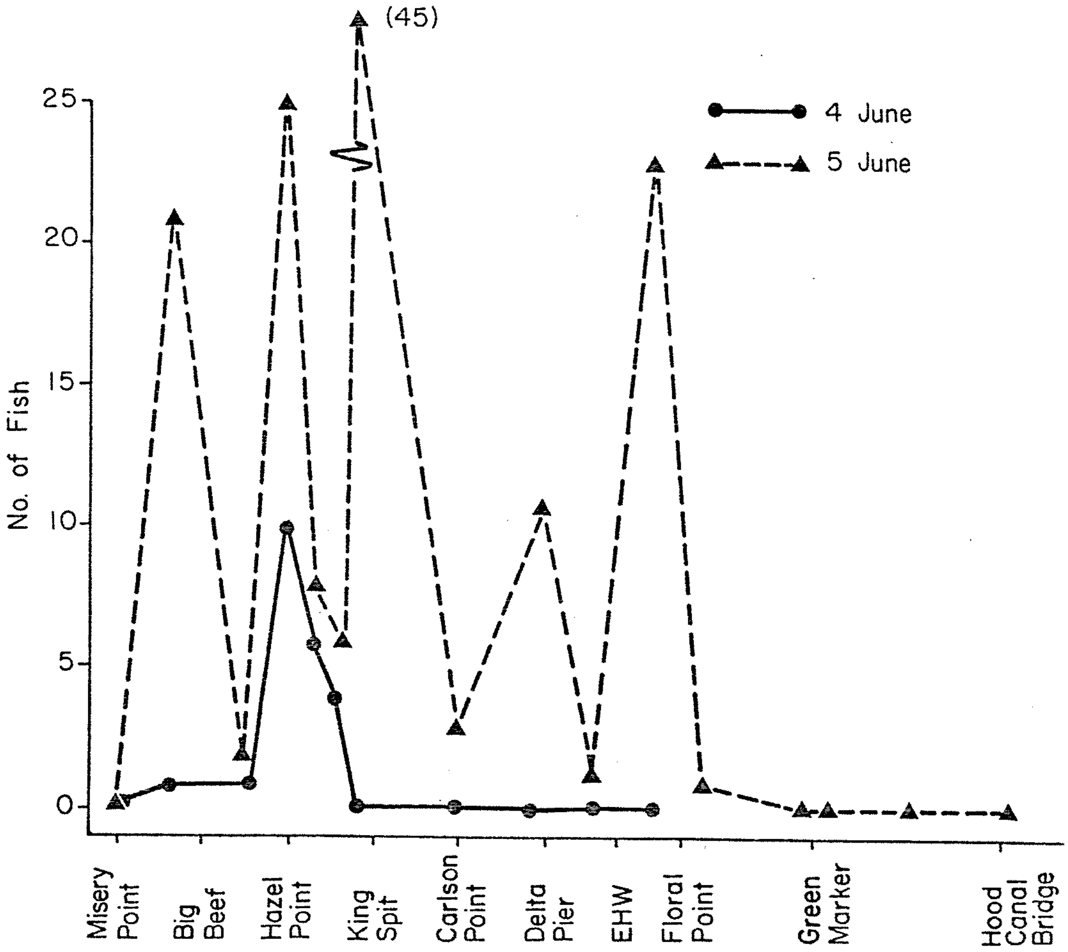

Fig. 3-15. June 4-5, 1979 beach seine captures of marked chum released June 3, 1979 from Big Beef Creek.

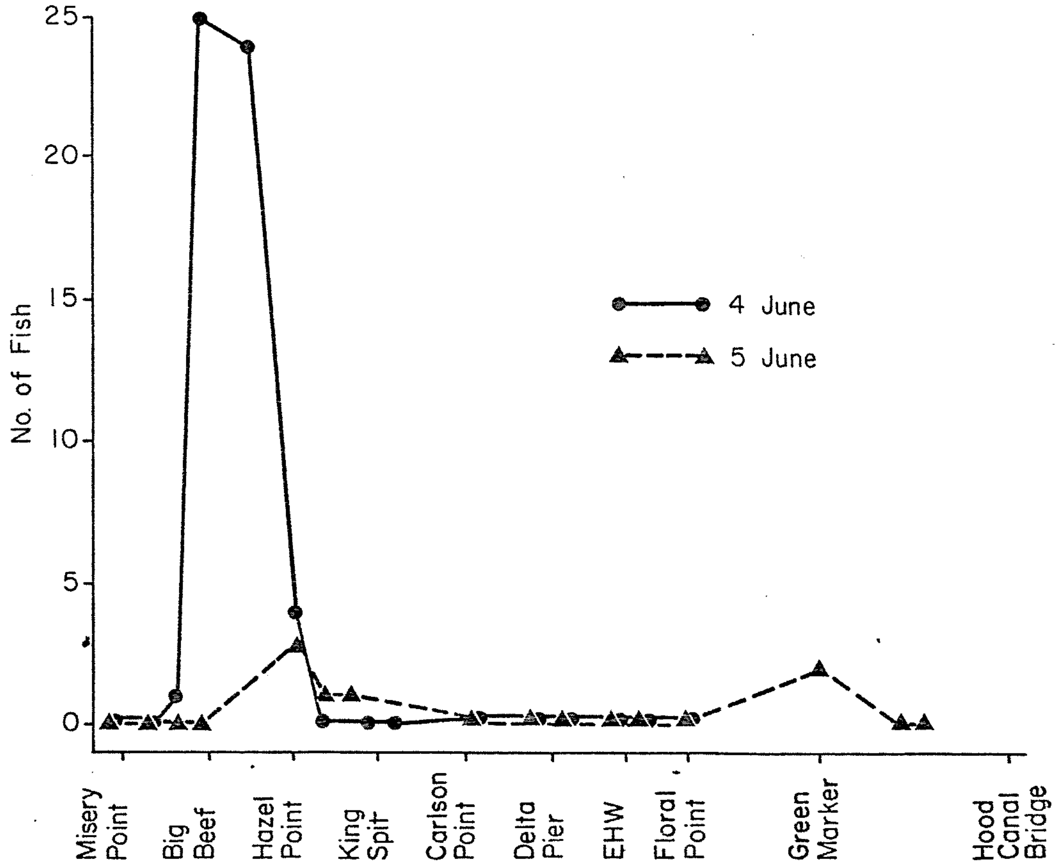

Fig. 3-16. June 4-5, 1979 townet captures of marked chum released June 3, 1979 from Big Beef Creek.

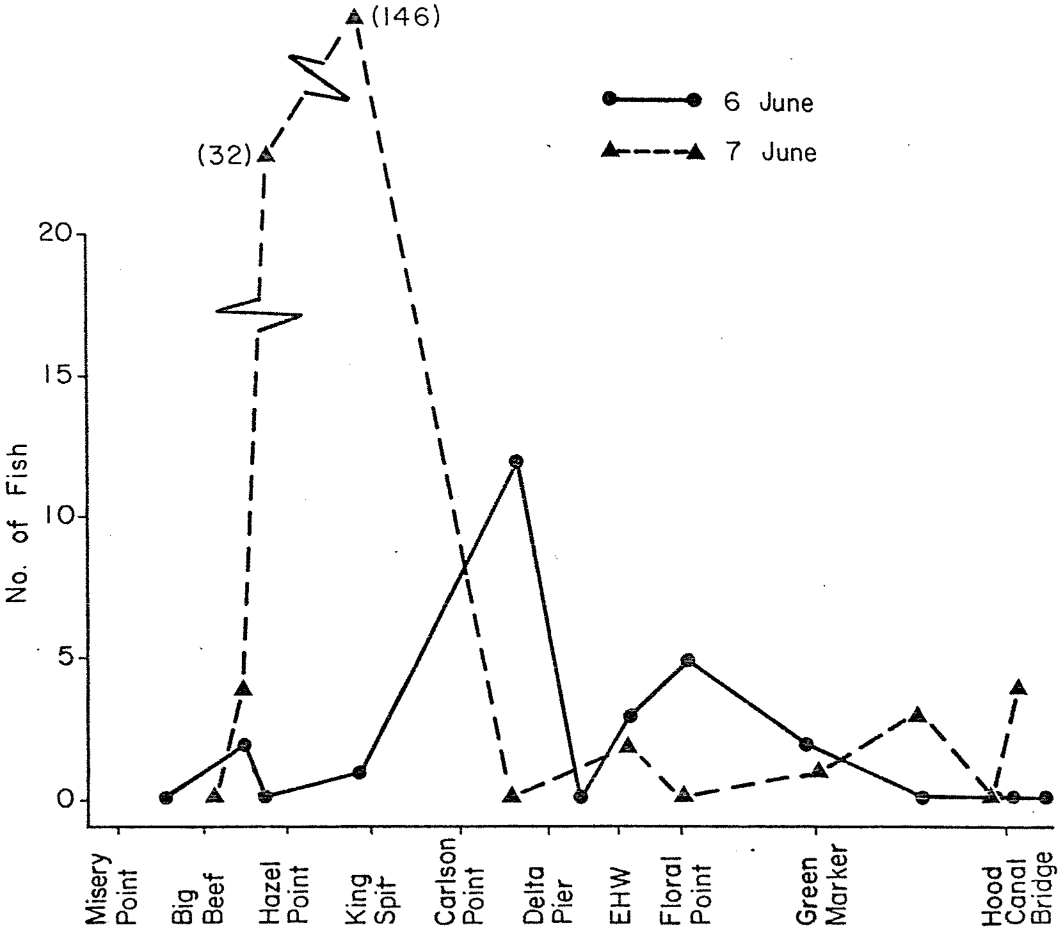

Fig. 3-17. June 6-7, 1979 beach seine captures of marked chum released June 3, 1979 from Big Beef Creek.

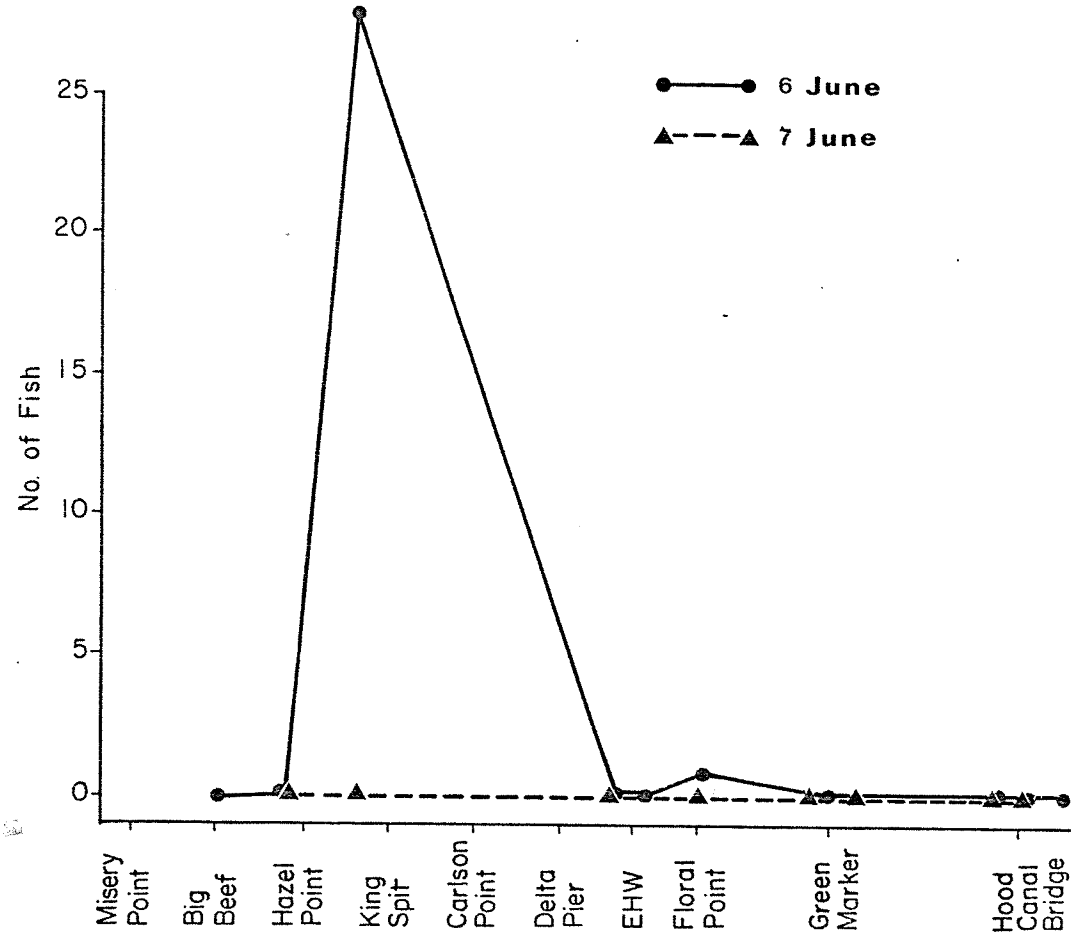

Fig. 3-18. June 6-7, 1979 townet captures of marked chum released June 3, 1979 from Big Beef Creek.

Table 3-6. CPUE of beach seine at Bangor Annex sites for marked chum fry released from Big Beef Creek, June 3, 1979.

	Lights On								Lights Off					
	Date								Date					
	11 June		14 June		21 June		25 June		28 June		2 July		11 July	
Location	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch
Carlson	2	1	2	2	2	0	2	0	2	1	2	0	2	0
Devil's	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Marginal	1	0	1	0	1	0	1	0	1	2	1	0	1	0
Floral	2	0	2	0	2	0	2	2	2	0	2	0	2	0
Spit 6	2	0	2	1	2	1	2	0	2	0	2	0	2	0
Brown	2	3	2	11	2	4	2	1	2	1	2	0	2	0

CPUE 0.7

CPUE 0.1

Table 3-7. CPUE of beach seine and townet at EHW for marked chum fry released from Big Beef Creek, June 3, 1979.

	Lights On						Lights Off					
	Beach Seine		Townet Inside		Townet Outside		Beach Seine		Townet Inside		Townet Outside	
Date	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch
11 June	2	2										
12 June			1	0	1	0						
13 June									1	0	1	0
14 June	2	0										
19 June									1	1	1	0
20 June			1	3	1	2						
21 June	2	0										
25 June	2	2										
26 June			-	-	1	0						
27 June									-	-	1	0
28 June							2	1				
2 July							2	0				
3 July									1	0	1	0
10 July									1	0	1	0
11 July							2	0				
	CPUE 0.5		CPUE 0.7		CPUE 0.7		CPUE 0.2		CPUE 0.5		CPUE 0.0	

Table 3-8. CPUE of townet at Bangor Annex sites for marked chum fry released from Big Beef Creek, June 3, 1979.

	Lights On						Lights Off									
	Date						Date									
	12 June		20 June		26 June		13 June		19 June		27 June		3 July		10 July	
Location	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch
Carlson	6	3	6	0	6	2	6	2	6	1	6	0	6	0	6	0
Service	1	1	1	1	1	2	1	0	1	2	1	1	1	0	1	0
Delta	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	1
Marginal	1	0	1	1	1	3	1	1	1	0	1	0	1	0	1	0
Floral	1	0	1	0	1	2	1	1	1	0	1	0	1	0	1	0
Spit 6	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Spit 5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Spit 4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Brown	1	0	1	0	1	1	1	0	1	0	1	0	1	0	1	0
	CPUE 0.4						CPUE 0.3									

Table 3-9. CPUE of purse seine at EHW of marked chum fry released from Big Beef Creek on June 3, 1979, grouped by sites with equivalent light intensities.

	Lights Off						Lights On							
	Sites						Sites							
	1,2,3,4,8		6,7		5		2,3,4,8		6,7		5		1	
Date	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch	Sets	Catch
18 June	4	0	2	7	1	0								
19 June	5	2	3	2	1	0								
20 June							4	1	2	8	1	2	1	0
21 June							4	1	2	6	1	0	1	0
	CPUE 0.2		CPUE 1.8		CPUE 0		CPUE 0.3		CPUE 3.5		CPUE 1.0		CPUE 0	

by ranks (Kruskal-Wallis test) was performed on marked purse seine captures.

In all tests the null hypothesis (there is no significant effect of lights) could not be rejected (Tables 3-10 and 3-11).

To test if there was any significant effect of site on pooled (lights on and off) purse seine marked captures, we used a Kruskal-Wallis test. The results showed a significant site effect. A SNK multiple comparison showed that Site 6 (*see* Fig. 2-4) differed significantly in catch from other EHW sites (Tables 3-11 and 3-12). No significant difference was found when testing site with lighting regime (Table 3-11).

To test if there was a significantly higher CPUE of marked fish at EHW than any other east shore Bangor Annex Site, a Kruskal-Wallis test was used. It was found that EHW did not significantly attract marked chums irrespective of lights (Table 3-13).

It appears that there was no measurable delay (residence) of marked fish at EHW. Fish from February, March, and April releases migrated out of Hood Canal very rapidly and showed no residence or higher CPUE at other than other Bangor sites. The June release was characterized by marked fish being in the Bangor Annex area as long as 3 weeks after release. Although marked fish were being caught at EHW, the last capture was on June 28, whereas the last marked fish capture at other Bangor Annex sites was July 10, indicating no residence preference for EHW.

3.3.2 Mortality Estimates

A mortality estimate was made only for the February release of marked fish. Beach seine data were excluded because of unequal effort between shores and few captures of marked fish. The estimate was made using townet data from east shore transects, where sampling effort was concentrated. West shore townetting was not used directly in the mortality estimate but used to account for any marked fish which had left the east shore sampling area (i.e., had crossed to the west shore). It was assumed that 1) the movement of marks to the west was a continuing process and would be better represented by catches on day 2; and 2) the rate of loss to the west shore was then calculated to be 38%. The data are summarized in Table 3-14. From these data the survival estimate was 0.44 ± 0.59 (95% confidence interval). Although this estimation must be regarded with some degree of caution because of the small numbers of captures, it indicates that juvenile chum salmon may experience early marine mortality of a magnitude similar to that Parker (1965) measured for pink salmon.

Table 3-10. Comparison of beach seine and townet CPUE with lights on and off at EHW using the t-test or Mann-Whitney test.

Groups	Statistic	Significance
Beach Seine Lit vs Unlit	$t = 0.8865$ $df = 5$	$0.1 < P < 0.25$
Townet (inside) Lit vs Unlit	$U = 6.5$ $n_1 = 3 \quad n_2 = 5$	$P < 0.1$
Townet (outside) Lit vs Unlit	$U = 9.5$ $n_1 = 3 \quad n_2 = 5$	$P < 0.1$

Table 3-11. Kruskal-Wallis test of marked chum salmon captured at EHW, June 18, 19, 20, and 21.

Groups	Statistic	Significance
Purse seine-effect of sampling day	$H_c = 2.2313$ $df = 3$	$0.50 < P < 0.75$
Purse seine-effect of sampling site excluding Site 1 (pooled)	$H_c = 16.2387$ $df = 6$	$0.01 < P < 0.025$
Purse seine-effect of sampling site excluding Site 1, lights off	$H_c = 8.978$ $df = 6$	$0.10 < P < 0.25$
Purse seine-effect of sampling site excluding Site 1, lights on	$H_c = 10.014$ $df = 6$	$0.10 < P < 0.25$

Table 3-12. SNK nonparametric multiple comparison of purse seine sites for June 18, 19, 20, and 21, excluding Site 1.

Rank	1	2	3	4	5	6
Site	2&4	8	4	3	7	6

B vs A	q	q 0.05, ∞, p	
6 vs 1	4.596	4.030	
6 vs 2	4.564	3.858	
6 vs 3	5.251	3.633	$\underline{2\&4\ \ 8\ \ 4\ \ 3\ \ 7}\ \ \underline{6}$
6 vs 4	5.963	3.314	
6 vs 5	4.899	2.772	
5 vs 1	3.465	3.858	

Table 3-13. Kruskal-Wallis test of marked chum salmon captured on east shore transects - effect of site, July 10-12, 1979.

Groups	Statistic	Significance
Beach seine	$H_c = 4.843$ $df = 4$	$0.25 < P < 0.50$
Townet (inside)	$H_c = 1.617$ $df = 5$	$0.75 < P < 0.90$
Townet (outside)	$H_c = 6.534$ $df = 5$	$0.25 < P < 0.50$

Table 3-14. Mark-recapture data for February 1979, early marine mortality estimate.

Date	Marks M_0	Added M_1	Recaptures M_{01}	 M_{02}	 M_{03}	 M_{12}
4 Feb	34570	-	-	-	-	-
5 Feb	-	-	137	-	-	-
6 Feb	-	18800	-	71	-	-
7 Feb	-	-	-	-	4	5

3.3.2.1 Size Selective Mortality

An important cause of mortality of juvenile salmonids in the natural environment is predation. Parker (1971) found that predators selected the smaller fry. Larger fry are less susceptible to predation because they are better able to escape and/or survive the initial attack by the predator (Walker 1974). Hiyama et al. (1972) found that smaller fry experience a higher mortality than larger ones. This higher mortality was probably due to predation.

We used the June release was used to determine if there was any size selective mortality. The greatest daily CPUE of marked fish occurred during the first 4 days after release. Day 1 length frequency of marked fish, captured in the beach seine, was used to predict the length frequency of fish captured in the beach seine on day 4 compensating for growth. If no size selective mortality took place then the predicted length frequency for day 4 should be the same as the observed. By using the log-likelihood ratio goodness of fit we compared the expected length frequency on day 4 to the observed. At $X^2_{0.05(5)}$ and G = 21.903 the null hypothesis must be rejected ($p<.001$): there is a difference in length frequency. This implies that mortality over the first 4 days of marine existence is size selective.

Observed length frequencies of marked chum on day 4 after release and expected length frequency on day 4 were plotted to determine where the difference in length frequency occurs. A linear regression of these frequencies gives a visual representation of where this difference occurs (interpreted as the point where the two linear regression lines cross (Fig. 3-19)). From Fig. 3-19, it appears that there are more smaller fish and fewer larger ones being captured than expected. This could be due to one or more of the following:

1. There is a size selective mortality for the larger fish, although this would contradict the literature.
2. The beach seine was size selective for smaller fry.
3. The larger fry had moved offshore and were no longer available for sampling by beach seine.

If there is size selectivity of the gear, this could mask any size selective mortality and, therefore, these results must be regarded with caution.

3.3.3 Growth

The June release of marked fish was the only group that was available for a long enough period of time to estimate growth rate. Over a 25 day period, 339 recaptured marked fish were retained for length-weight analysis.

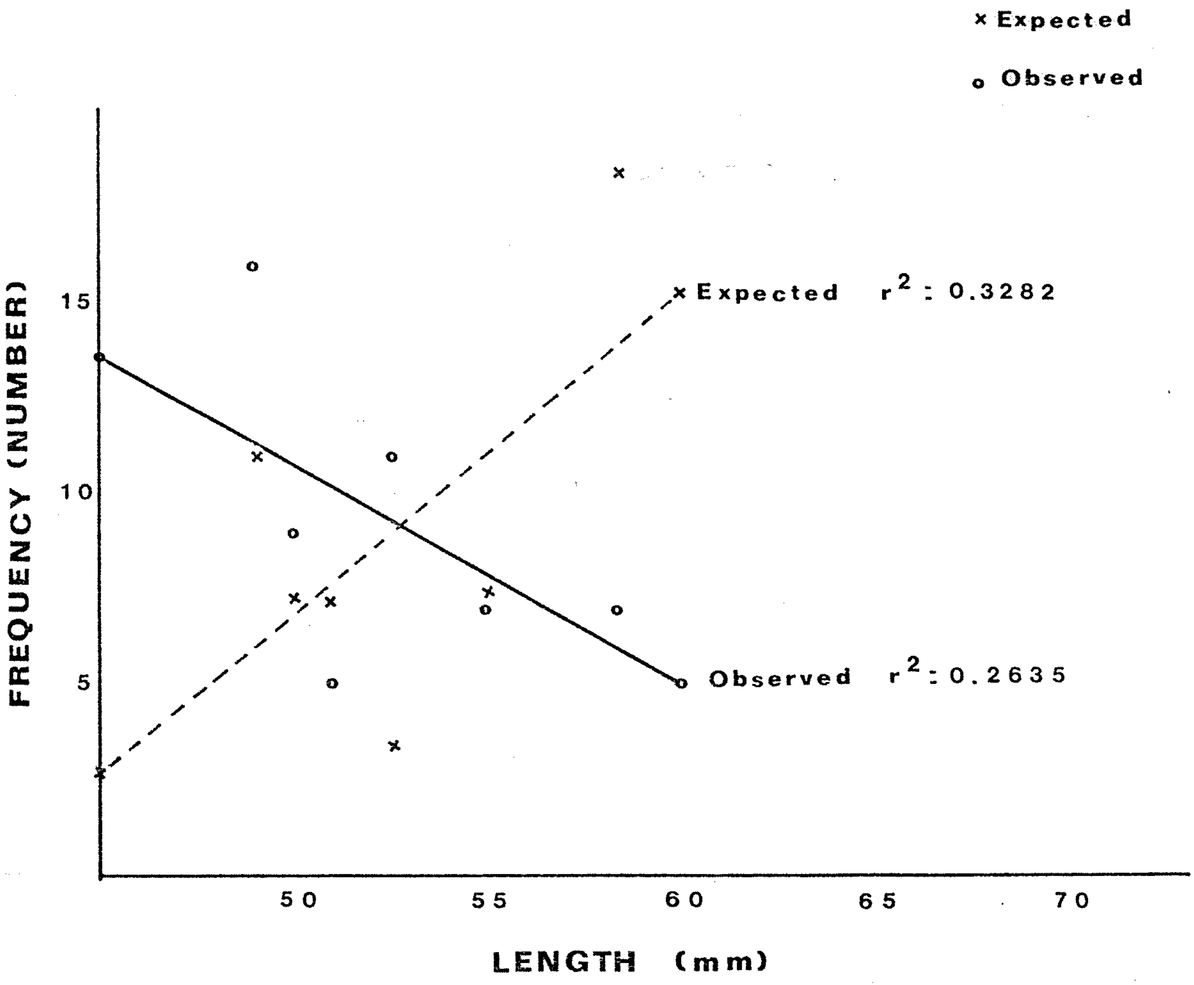

Fig. 3-19. Observed length frequencies of marked chum on day 4 after release and expected length frequencies on day 4 (calculated from day 1 values); chum released from Big Beef Creek and captured by beach seine.

Ricker (1975) states that over short periods of time an exponential curve may be used to express growth. An exponential curve was fitted by regressing log weight on day, yielding the following regression formula:

$$\text{Log } y = -0.63077 \times 10^{-2} + 0.2820 \times 10^{-1}(t)$$

where y = weight in grams and t = days after release.

The growth in percent body weight per day can be determined by calculating (using the regression formula) weights on any 2 consecutive days (e.g. 1 + 2, 2 + 3,...). The percent body weight gain/day is then calculated from these calculated weights. From these computations, daily growth rate over the 25 day period from 4-28 June, was 6.7% body wt/day. This appears to be comparable to what has been previously reported for chum salmon (Healy 1979, Whitmus and Olson 1979). A linear regression of condition factor on day showed an increase in condition factor of 25.7% over the same 25 day period. The estimate of growth may be biased by:

1) Sampling gear being size selective causing either an over- or underestimation.
2) Size selective mortality may have caused an overestimation.
3) The larger fish in the population may have migrated out of Hood Canal causing an underestimation.

Fry of comparable size reared in freshwater, fed an excess diet of Oregon Moist Pellets (17% body wt/day), grew at a rate of 3.9% body wt/day. During the 25 day period, condition factor increased by 6.8% (Schroder, in press).

This disparity in growth rates may be a function of many factors. Ricker (1975) stated that there are several growth stanzas during a fish's life. The one beginning when a fish enters saltwater is characterized by a sudden change in growth rate. Once entering saltwater, the fry have a greater choice of temperatures for habitat selection. This may tend to maximize the fish's digestive efficiency (Brett 1971). Also the food available in the natural environment may be more nutritious than hatchery diets and fry may feed during all hours, compared to daylight feeding hours in hatcheries.

3.4 CONCLUSIONS

1) More marked fish were caught in the EHW sub bay than any other EHW site.
2) EHW security lights did not affect the migratory behavior of marked fish.
3) Marked fish show no significant attraction to the EHW irrespective of lighting.

4) Marked fish showed no measurable residence at EHW during 1979 tests.

5) Marked fish released from Big Beef Creek in February, March, and April moved very rapidly out of Hood Canal in as little as 3 days after release.

6) Mark-recapture tests in February estimated a 44% ± 59% (95% confidence interval) survival of juvenile chum salmon in their first 4 days of marine existence.

7) Fish released in June from Big Beef Creek grew at a rate of 6.7% body wt/day for a 25 day period while condition factor increased 25.7%.

3.5 LITERATURE CITED

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4.0 HYDROACOUSTIC SURVEYS

by

James J. Dawson and Bruce P. Snyder

4.1 INTRODUCTION

Hydroacoustic survey techniques have been shown to be a useful tool in describing the distribution and behavior of fishes as related to site-specific investigations. Advantages of hydroacoustic techniques include nondestructive surveying, minimal effect on fish behavior, and efficiency of cost, manpower, and field time. Specific advantages for studies adjacent to the Explosives Handling Wharf (EHW) include capability of sampling from near surface to the bottom, use in conjunction with net sampling and lighting experiments, and efficiency as a broader scale survey tool. Disadvantages include lack of species identification; interference from pilings, nets, tidal disturbances, and sea state; and inability to adequately sample the near surface populations when used in a down-looking mode.

Objectives of using hydroacoustic surveys in the studies at the EHW included: 1) determination of the seasonal and diel variations in distribution and abundance of fish (in the EHW area); and 2) observation of effects of EHW lighting on migratory chum salmon.

The hydroacoustic system used in this study had a 1.5 m dead zone at the surface from which no data were received. As a result, positive identification of the species being observed by the echo sounder was not possible. Spotlight observations at the surface were routinely made simultaneously with the acoustic surveys. As these two techniques looked at different sections of the water column, extrapolation of identified species at the surface to those seen below by the echo sounder usually could not be justified. Therefore, the results of acoustic monitoring are predominantly concerned with fish whose distributions and behavior under differing lighting regimes give indications of their identification (i.e., fish exhibiting schooling behavior).

*Note: In this section the term "school" is used in a general (generic) sense, not in the scientific sense.

4.2 MATERIALS AND METHODS

The hydroacoustic equipment used in this study is identical to the principal system used by the Marine Acoustics group in the University of Washington's Sea Grant program (Thorne 1972). Briefly, the system uses a commercially manufactured Ross 200A echo sounder. The echo sounder has been modified by inclusion of inner calibration and electronic output circuits. The electronic output is changed from 105 kHz, the operating frequency of the echo sounder, to 5 kHz for recording of selected portions on magnetic tape. An echogram or stripchart is also produced continuously during operation of the Ross system. The system transmits about 1000 W of power through an 8° full-angle transducer.

The method of deployment of the Ross transducer is depicted in Plate III. The transducer was suspended from a pivot point at the center of the inner tube float to minimize effects of wave action and to fix the transducer depth. The inner tube float was suspended from a boom mounted on the front of the 4 m acoustics boat and towed 3 m in front of the bow. Transecting speed of 1-2 knots was maintained as constant as possible given wind and tidal conditions. This configuration was adopted to minimize abnormal fish behavior due to presence of the boat and motor.

4.2.1 Standardized EHW Transects

A standardized series of transects associated with the EHW structure was chosen early in the study (Fig. 4-1). A primary consideration in choosing these transects was to survey as close to the EHW trestles and pilings as possible without interference from pilings. Transects 7-9 were located beyond 100 m from the EHW to minimize light effects.

4.2.2 Net Sampling

The hydroacoustic equipment was used in conjunction with the purse seine and townet sampling. In down-looking mode, the transducer was suspended from the inner tube float and placed over a spot selected for experimental illumination or over an area of fish density observed on the echo sounder. The purse seine was then set around the area of interest and the inner tube float was withdrawn just before the ends of the seine net closed. An additional technique required the acoustics boat to locate a suitable concentration of fish and mark its position with a small lighted free floating buoy. The seine crew would then immediately set around the buoy. The transducer was also lowered to the bottom looking upward to monitor a purse seine site before and during the set.

The acoustic system was used with the townet operation by driving the acoustic boat between the townet boats or adjacent to one. Later techniques used a rope to tow just the transducer between the tow boats. It was towed at the surface looking down or towed 10 m below the surface looking up.

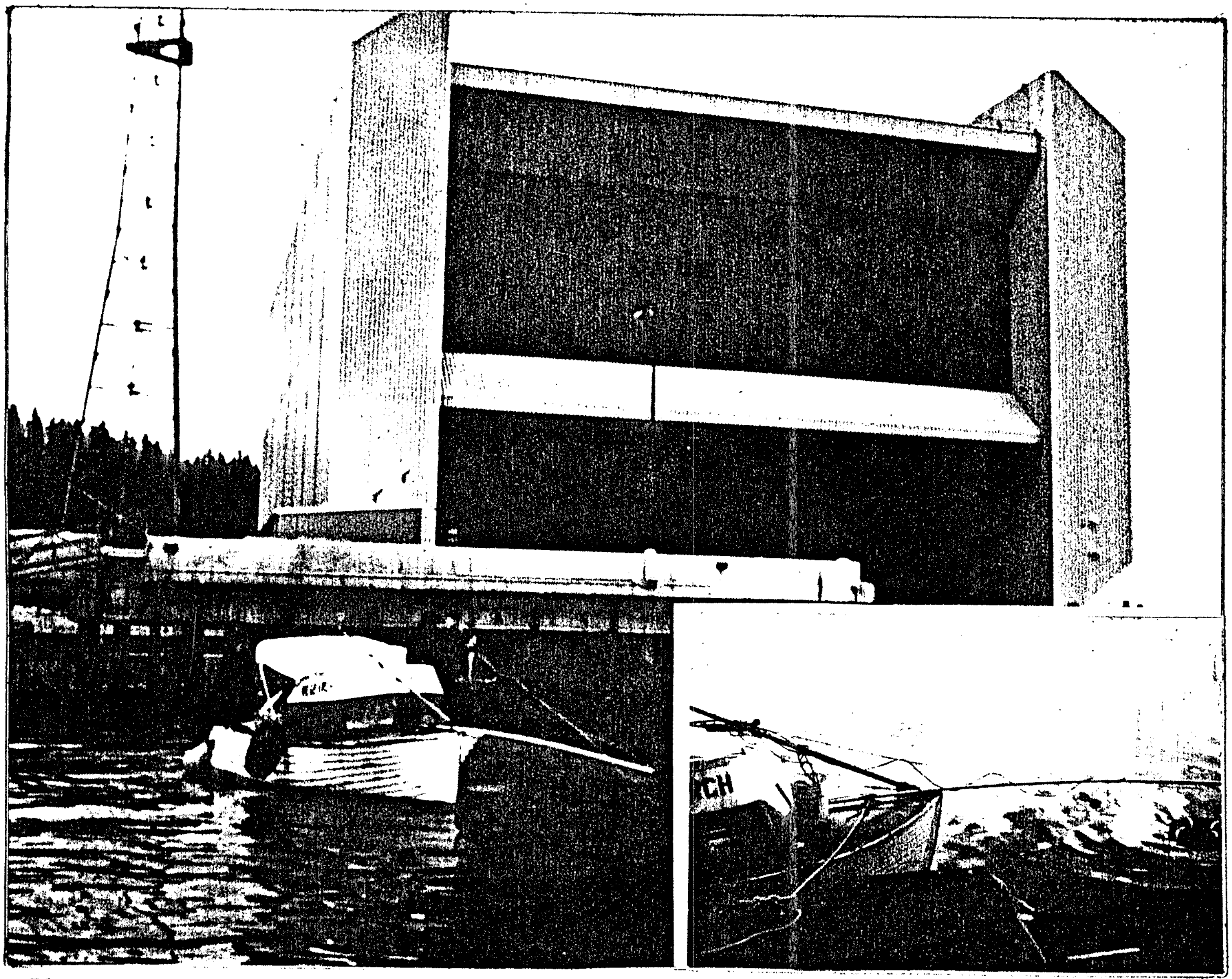

Plate III. Deployment of transducer for hydroacoustic surveys around the Explosive Handling Wharf at Bangor on Hood Canal, 1979.

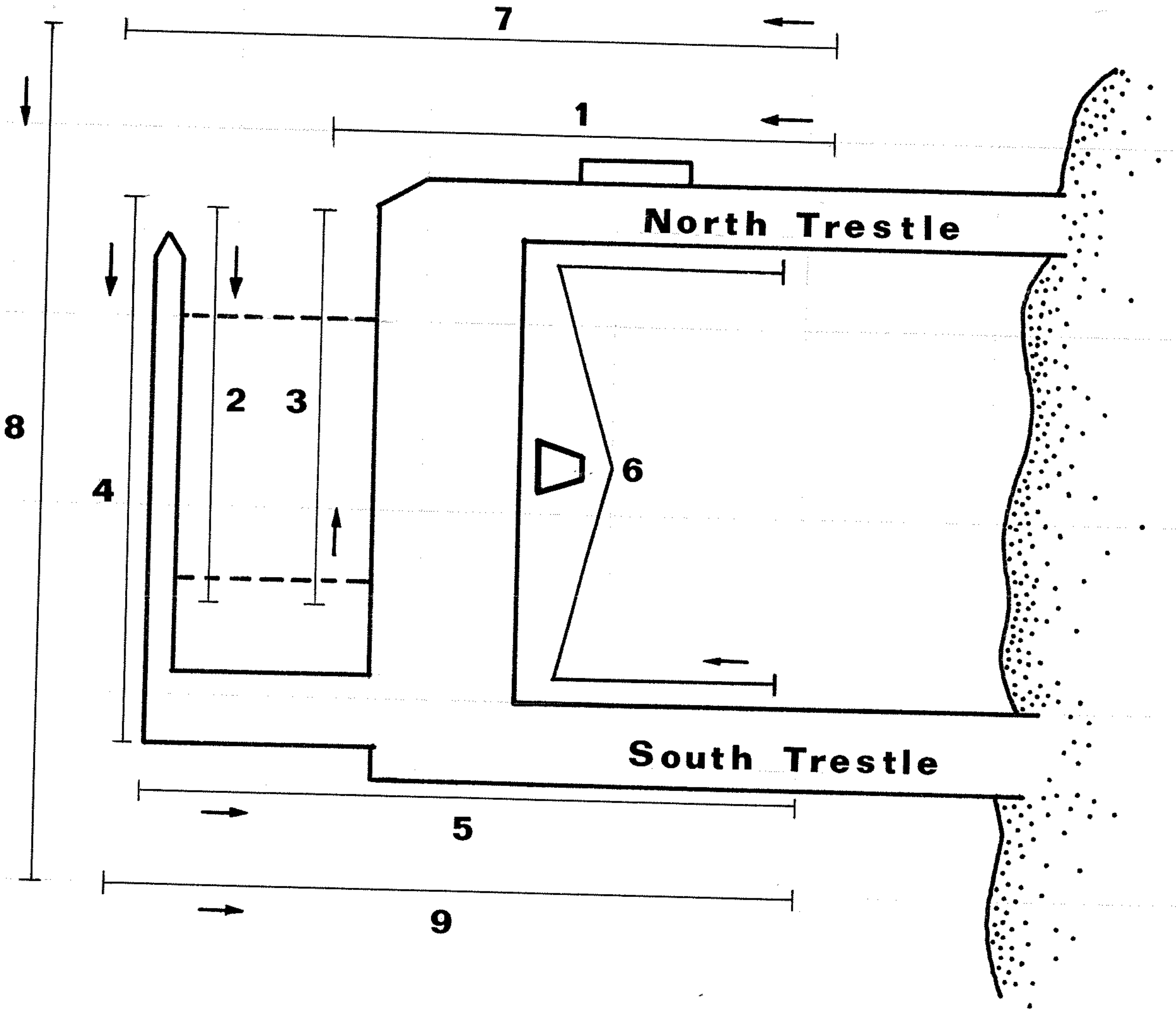

Fig. 4-1. Acoustic monitoring transects at EHW during 1979 lighting study (for wharf lighting configurations, see Appendix).

4.3 RESULTS AND DISCUSSION

4.3.1 Fish Distribution

Distribution of fish about the EHW was analyzed by comparing acoustically determined densities between transects. No consistent bias of densities to the north or south was observed. On May 20, large extremely dense schools of sand lance were located inshore close to the bottom (Fig. 4-2). During May surveys, higher nearshore densities were observed in the daytime which were dispersed at dusk to offshore areas around the EHW (Fig. 4-3). By mid-June, a similar pattern was exhibited by herring fry (Fig. 4-4). The identity of the sand lance and herring fry groups was determined by visual observation using the spotlight and confirmed by large catches in the purse seine and townet. Throughout the study period, solitary fish were seen rising off the bottom at dusk and moving in from deeper water. These fish or targets appeared larger on the echogram than those seen inshore (Fig. 4-5).

4.3.2 Acoustic Measurements of EHW Lighting Effects

The most pronounced effects of the EHW lights on fish were observed when schooling fishes were in the EHW area. Normally, the dense sand lance schools observed in early May dispersed at dusk; however, when EHW security lights were on, these fish accumulated under the nearshore SOX lamps and reformed into schools (Fig. 4-6). These schools extended to the surface and were visually identified as sand lance. In late June when the sand lance had left the area, herring fry were observed accumulating under the SOX and white incandescent lights (Fig. 4-7). These fish were identified by visual observation and net sampling.

Several other fishes in the region showed sensitivity to light. Adult herring which had moved into the study area (Fig. 4-8) apparently seek an optimal light threshold. Lowering the intensity of an incandescent test lamp drew them closer while raising the intensity caused them to move away. These adults will likely be attracted to a region of optimal intensity around the EHW, the position of which will be affected by water transparency and sea state. Another group of fish of unknown species was observed coming off the bottom at dusk. These fish exhibit sensitivity to light in their diel behavior as they move inshore and mix with the near-surface fish. Their response to the EHW security lighting is clearly seen (Fig. 4-9) in their avoidance of the SOX lamps on the west side. This behavior pattern correlates with descriptions in the literature (Hickling 1927, Tillman 1971) and purse seine catch (Sec.2.0) of hake (*Merluccius productus*).

The acoustic surveys indicated that the light conditions inside the sub bay and near the stairways were often attractive to fish. Both sand lance and herring fry formed near-surface layers under the fluorescent lights located in the EHW offices and stairwells (intensity = 2 lux).

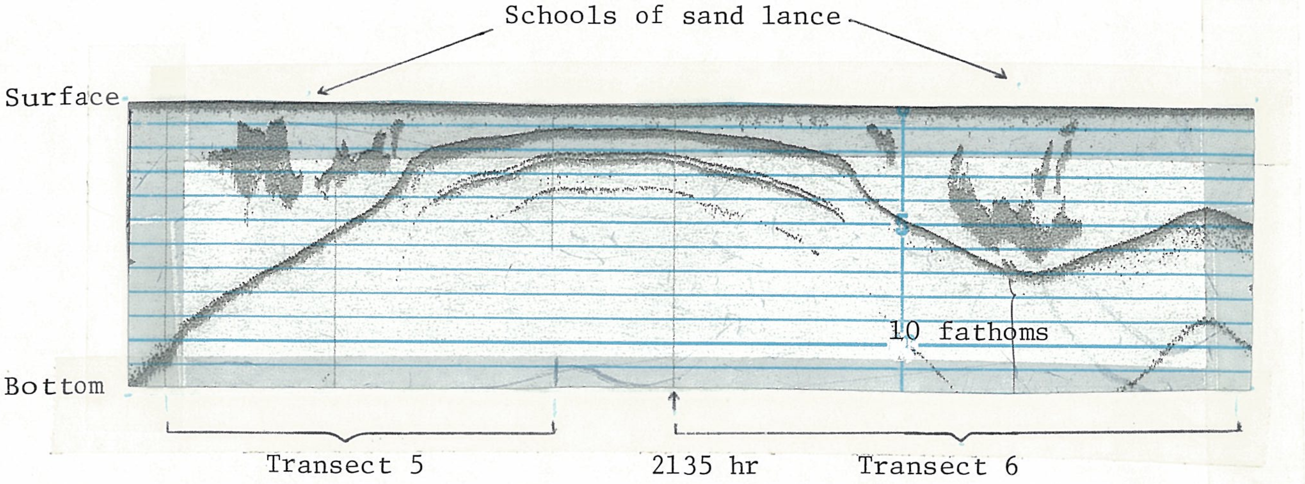

Fig. 4-2. Large sand lance schools near shore during daylight on transects 5 and 6 at the EHW, May 30, 1979.

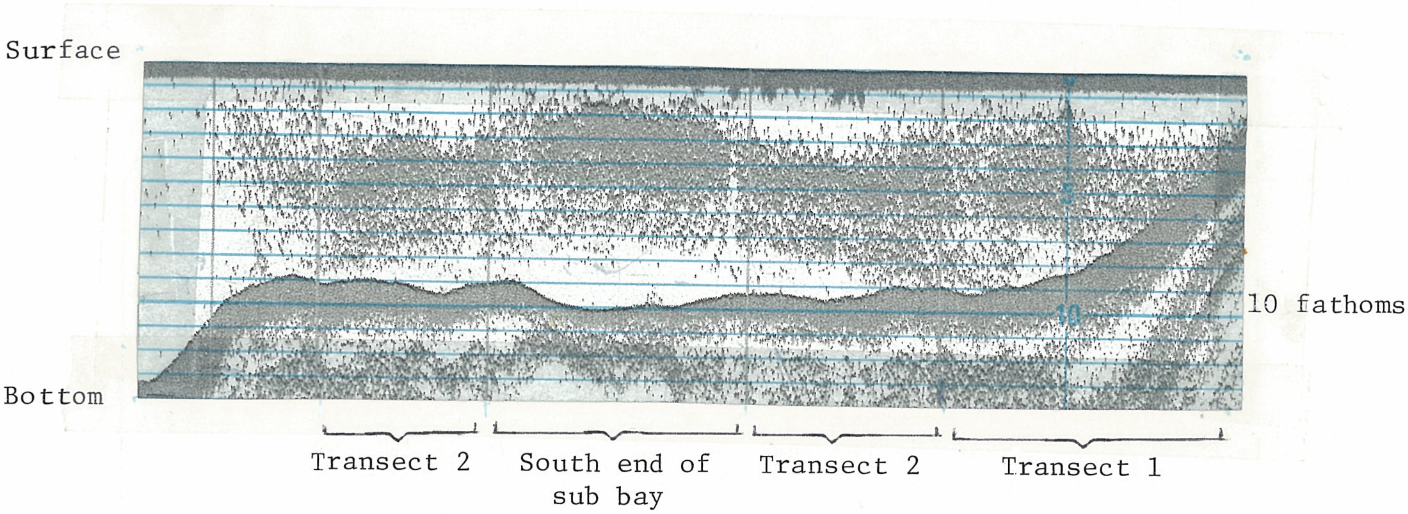

Fig. 4-3. Nearshore fish schools that had moved offshore and dispersed throughout the EHW area after dark during May 1979.

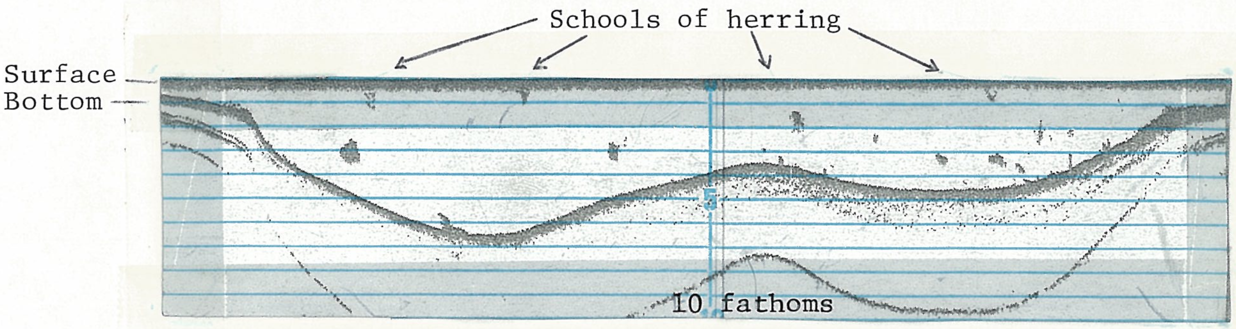

Fig. 4-4. Juvenile herring schools on transect 6 at the EHW on June 21, 1979.

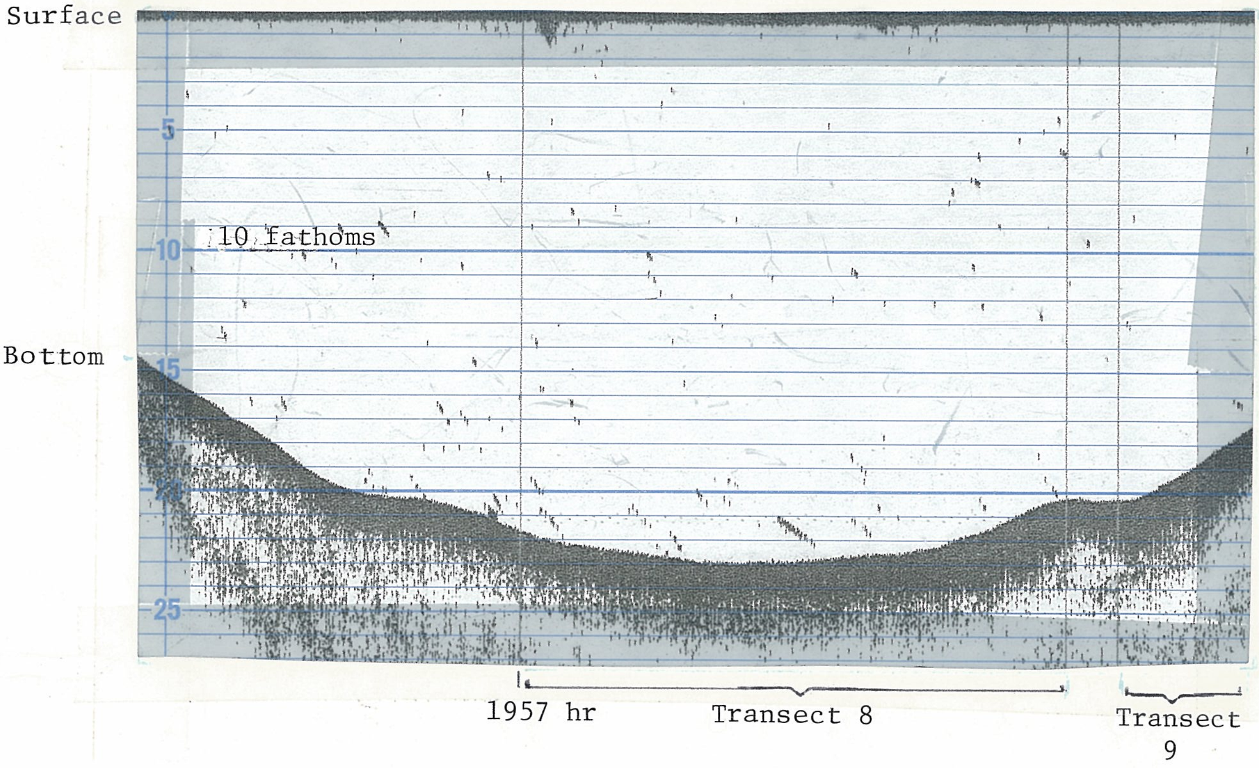

Fig. 4-5. Large fish rising off the bottom at dusk on transect 8, 250 m from EHW, March 21, 1979.

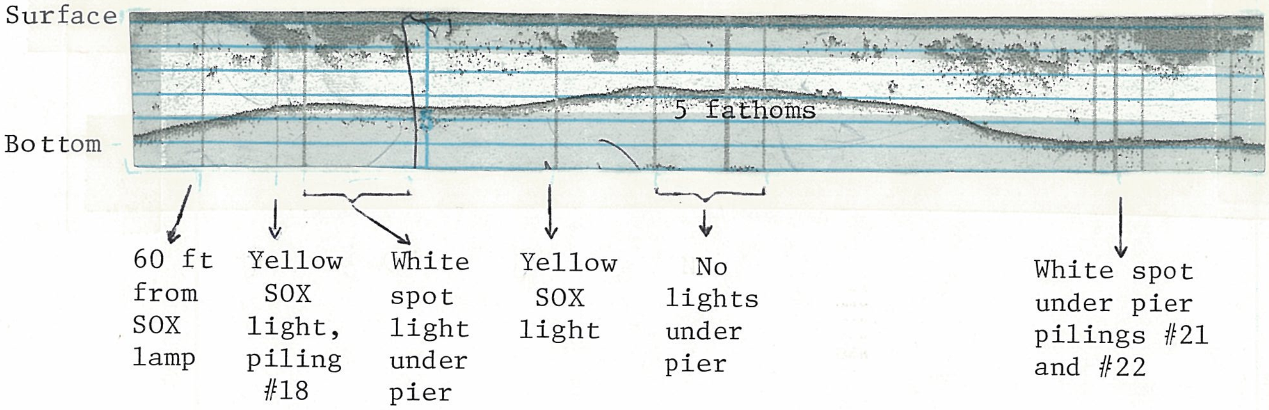

Fig. 4-6. Schooling fish located under yellow SOX and white lights in the nearshore area on transect 5 at EHW on May 23, 1979.

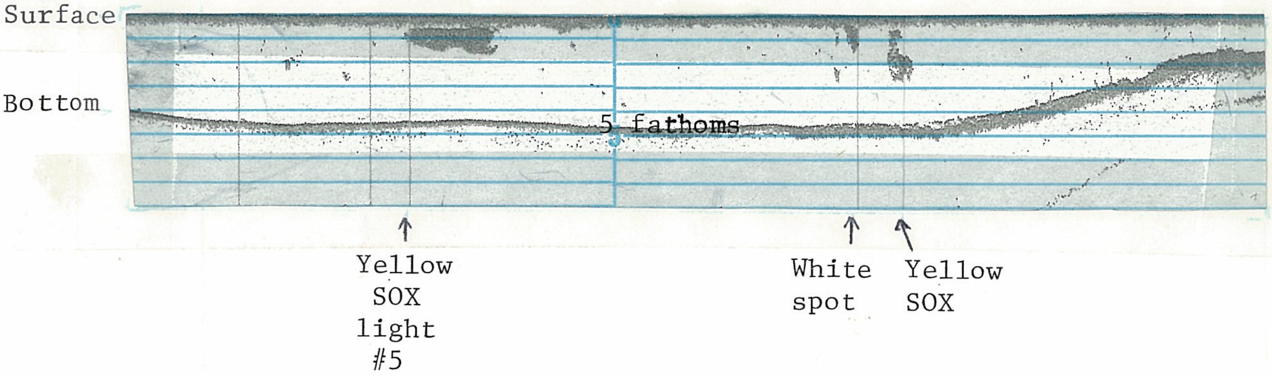

Fig. 4-7. Juvenile herring schools directly under yellow SOX and white incandescent lights on transect 5 at EHW on June 20, 1979.

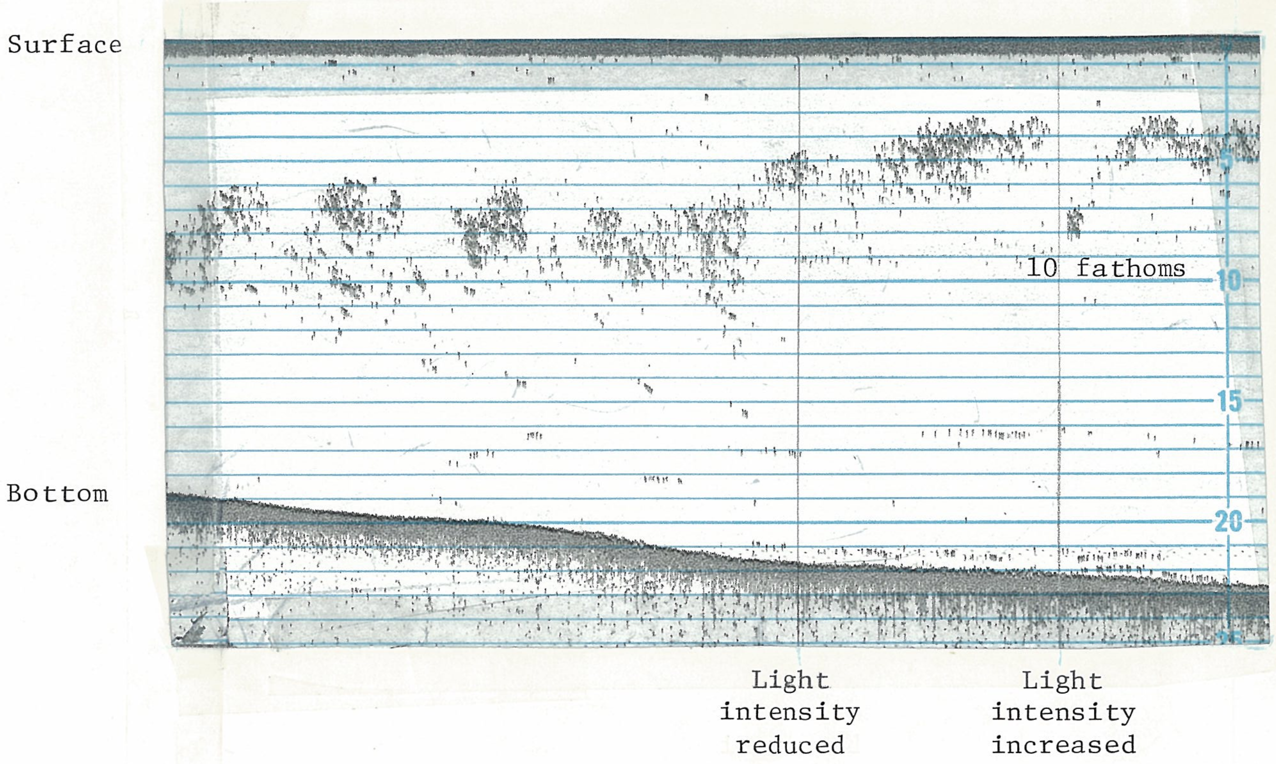

Fig. 4-8. Adult herring schools attracted to a white light offshore on transect 8 near the EHW on May 2, 1979.

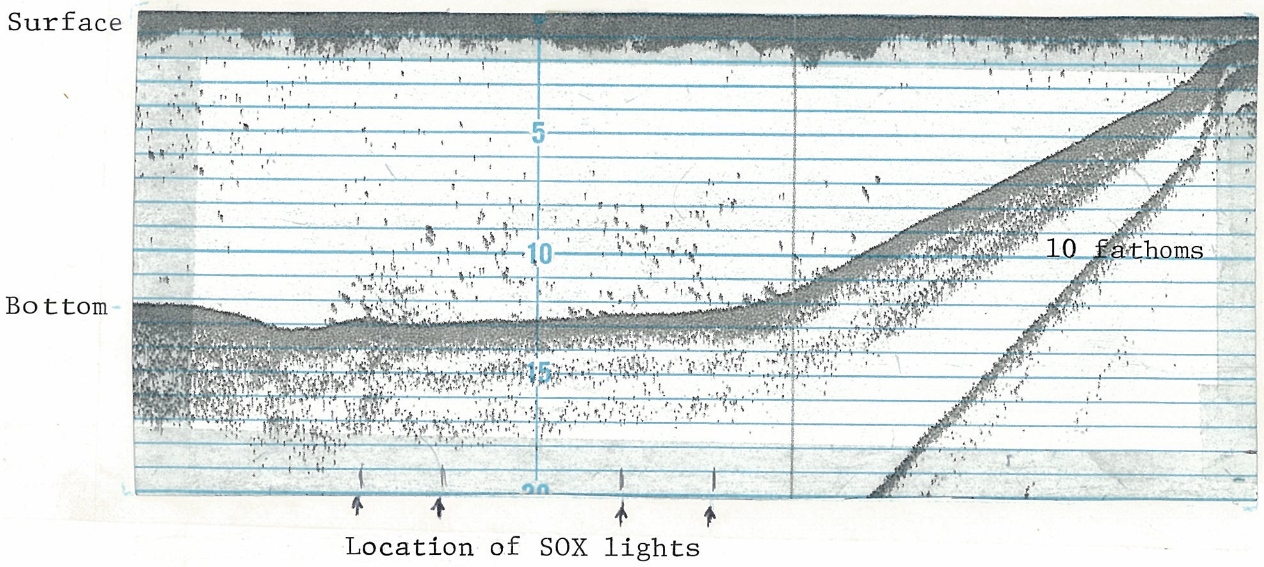

Fig. 4-9. Fish attracted to yellow SOX lights on transect 4 at 10 fathoms next to EHW on April 25, 1979.

Under operational light conditions inside the sub bay (~400 lux) this layer assumed a typical daytime distribution of near-surface dense schools (Fig. 4-10).

Visual observations with the spotlight also illuminated many solitary chum. Densities of chum in the influence of EHW security lighting (2-13 lux) were higher than densities of chum along the outer darker transects. Many chum were seen in the sub bay area with the security lights on or off, since this area was illuminated during "off" as well as "on" conditions (see Sec. 2.0). The spotlight indicated many chum swimming near the surface solitarily or in small aggregates when the operational lights were on.

The spotlight showed many dogfish swimming among the groups of smaller fishes at night. Large masses of nereid worms were seen by the spotlight in the sub bay and occasionally under a SOX lamp during security lighting.

4.3.3 Miscellaneous Light Effects

On March 7, the acoustics equipment was used to monitor the movement of marked chum smolts (see Sec. 3.0) before and after release 200 m south of the EHW. Acoustic surveys prior to release showed very few targets in the water column at the release site. After release, all of the chums immediately formed small schools and scattered in all directions including sounding to the bottom (Fig. 4-11). Subsequently, fish were seen moving randomly both north and south along the shore. One concentration of chum was observed visually and acoustically under the lights at Marginal Wharf. These lights are white sodium halide flood lamps producing ~15 lux at surface. However, a greater concentration was located adjacent to the EHW, in the influence of its security lights, based on echogram data collected after release and spotlight observations. Due to high numbers of chum observed, these fish were assumed to be the same fish just released.

4.3.4 Acoustic Monitoring/Net Sampling

The hydroacoustic gear was used to monitor areas being sampled by both the purse seine and the townet. Approximately 20 purse seine sets and 45 townet transects were examined for correlation with catch. Townet transects monitored by a down-looking transducer showed essentially no correlation between number of targets and catch, most likely due to low sampling volume of the echo sounder at the transducer (i.e., near the surface). Tows using an up-looking transducer at 10-m depth increased the sampling volume of the echo sounder, but too few of these tows were completed to establish a correlation between catch and number of targets viewed acoustically.

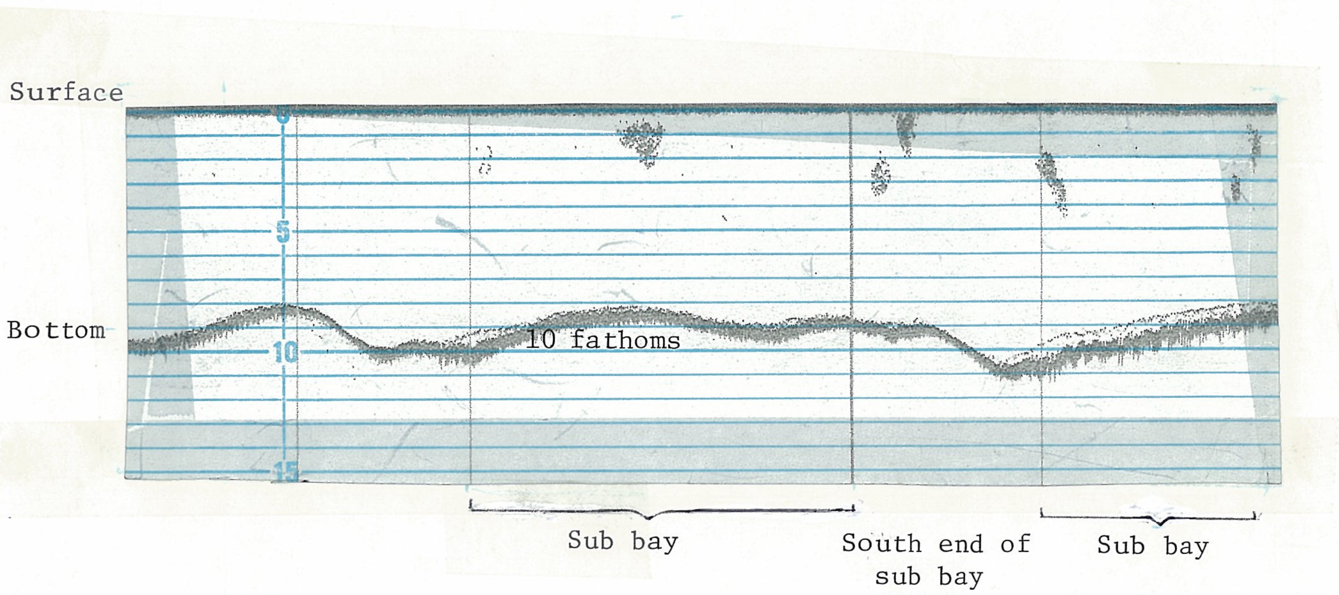

Fig. 4-10. Herring schools at surface in sub bay of EHW with operational lights "on," June 14, 1979.

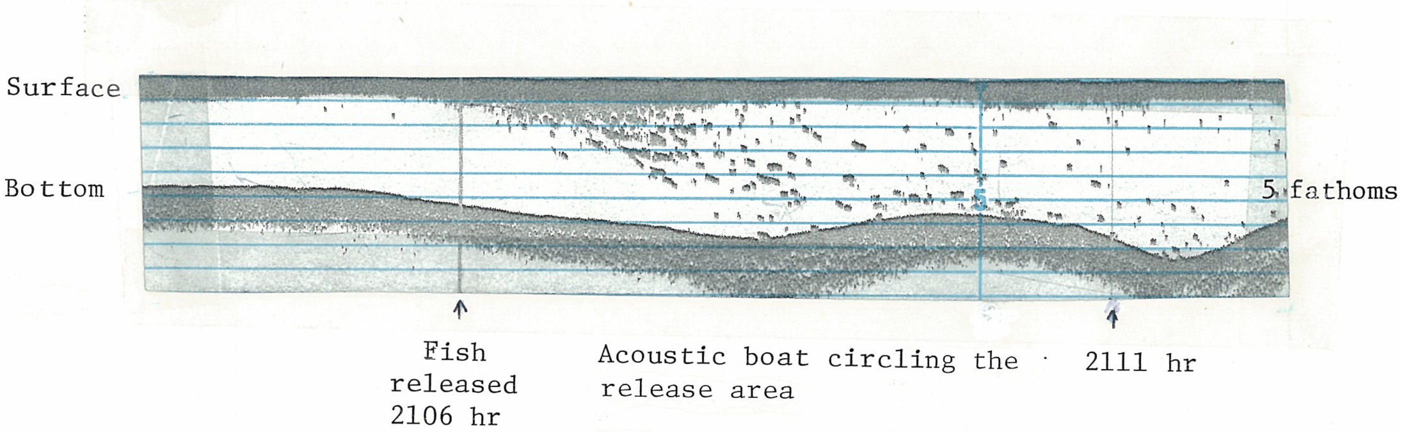

Fig. 4-11. Release of 20,000 chum salmon from a floating net pen at 2106 hr, 300 m south of the EHW on April 10, 1979.

The acoustic system was used in conjunction with the purse seine either to locate and mark a fish concentration to be sampled or to monitor a standard sampling site. Due to drifting of the lighted marker buoy placed over the fish by the acoustic boat, the purse seine often was not able to set over the exact area marked. As a result, correlations between purse seine catches and acoustic observations were poor. The acoustic transducer was located on the bottom to monitor standard purse seine sampling sites before and during the set. Although numbers of fish indicated by the two techniques varied, the echo sounder did not detect any vertical avoidance of the seine by the fish.

4.4 CONCLUSIONS

4.4.1 Fish Distribution

1. On a seasonal basis, fish did not concentrate north or south of the EHW study area.

2. Inshore fish densities from February through April are higher in the day and in general disperse outward at dusk.

3. Schooling fishes in May and June inhabit the shallows around the EHW in dense schools. These schools break up at dusk, forming near-surface layers that disperse outward.

4. At dusk, solitary larger fish move up off the bottom from depths below 20 m. These fish move up and inshore, mingling with the fish that were in the shallow inshore region during daylight.

4.4.2 Lighting Effects

1. Schooling fish such as sand lance and herring fry form dense schools under the SOX and incandescent security lamps on the EHW (2-13 lux).

2. The fluorescent tube lamps in the EHW office windows and doorways above the sub bay (2-3 lux) concentrate sand lance, herring and nereid worms at the sub bay surface. Spotlight surveys indicate that these lights also attract chum to the sub bay surface.

3. Several fish groups near the EHW have shown a sensitivity to light. Adult herring seek out a preferred light level, and would likely inhabit a region around the EHW in which this light intensity existed. Some fish species that rise off the

bottom at dusk and move inshore at night are inhibited by the light levels present under security lighting.

4. Use of operational or missle-loading lights in the sub bay (~400 lux at surface) causes immediate schooling behavior in herring and other schooling fish that may be in or near the sub bay. Substantial numbers of chum were attracted to the surface or from surrounding areas by these light intensities.

4.4.3 Net Sampling/Acoustics

1. Simultaneous acoustic monitoring in down-looking mode and townet fishing indicate that many chum are near the surface and cannot be seen by the echo sounder.

2. Acoustic monitoring in up-looking mode indicates that fish do not sound at the approach of the purse seine or townet.

3. Visual observations during daytime acoustic transecting showed no significant avoidance of the transducer by near-surface fish. The angles of the traces on the echogram showed no consistent sounding of deeper fish which would indicate avoidance in a downward direction.

4. Chum released at night by dumping or without acclimation to the area formed small tight schools throughout the water column apparently due to dumping stress. These schools dispersed within one hour of release and rose to the surface, as they were no longer seen by the echo sounder but identified by visual observations.

4.5 LITERATURE CITED

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Thorne, R. E. 1972. Hydroacoustic assessment of limnetic-feeding fishes. Pages 317-322 *in* J. F. Franklin, L. J. Dempster, R. H. Waring, eds. Proc. - Research on coniferous forest ecosystems - a symposium. USDA, Forest Serv., Portland, OR.

Tillman, M. F. 1968. Tentative recommendations for management of the coastal fishery for Pacific hake, *Merluccius productus* (Ayres), based on a simulation study of the effects of fishing upon a virgin population. M.S. Thesis, Univ. Washington, Seattle.

APPENDIX I

PURSE SEINE SPECIFICATIONS.

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.

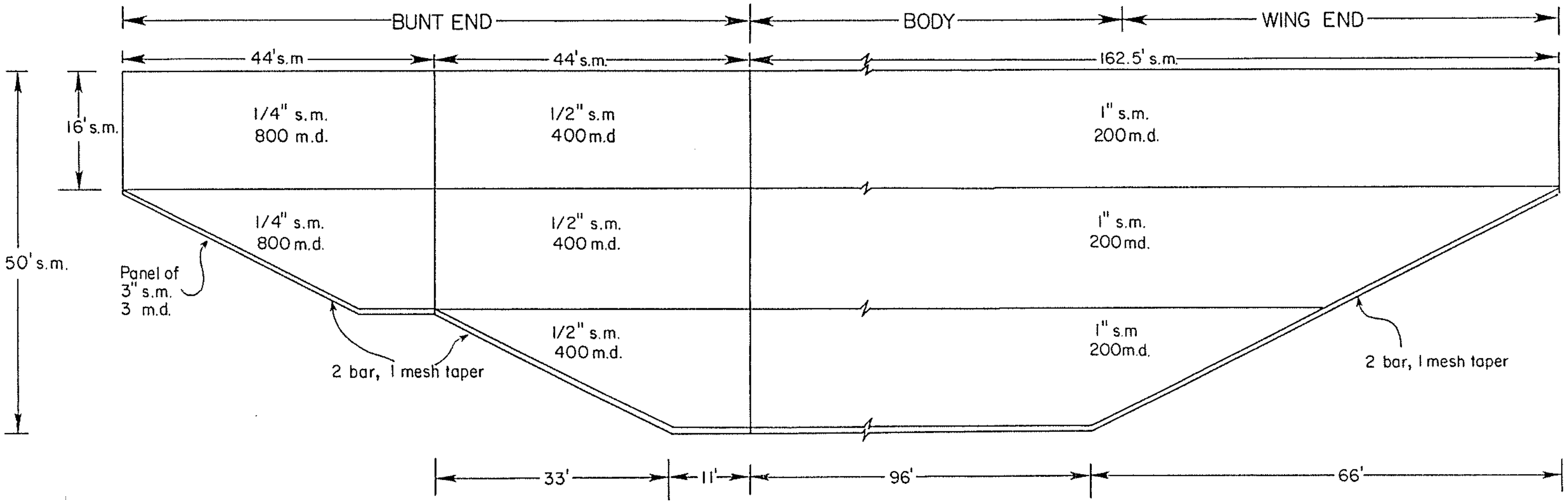
Lead line: Bristol Bay 200 lb/100 fathom.

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.

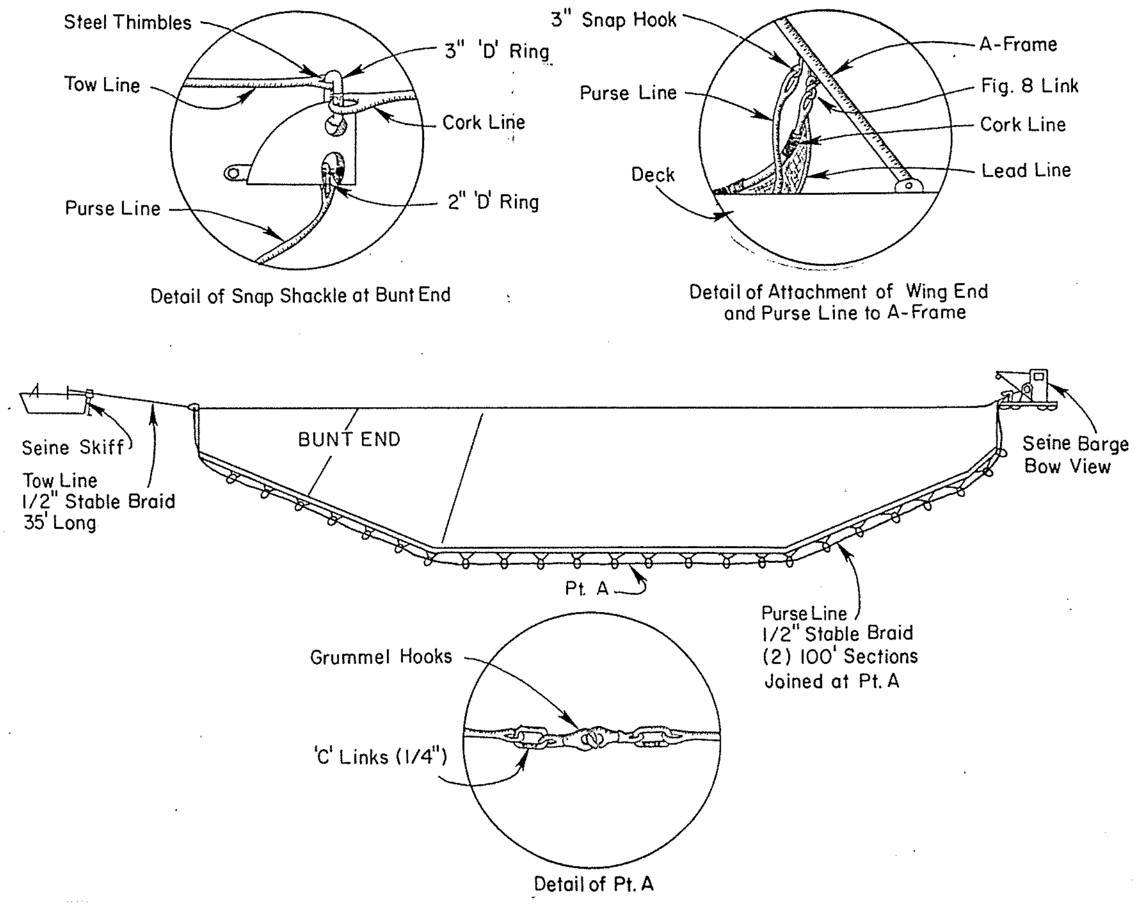
Purse Line: same as cork line, with eye splices in ends and middle; fit ends with figure 8 shackles.

Netting specs:

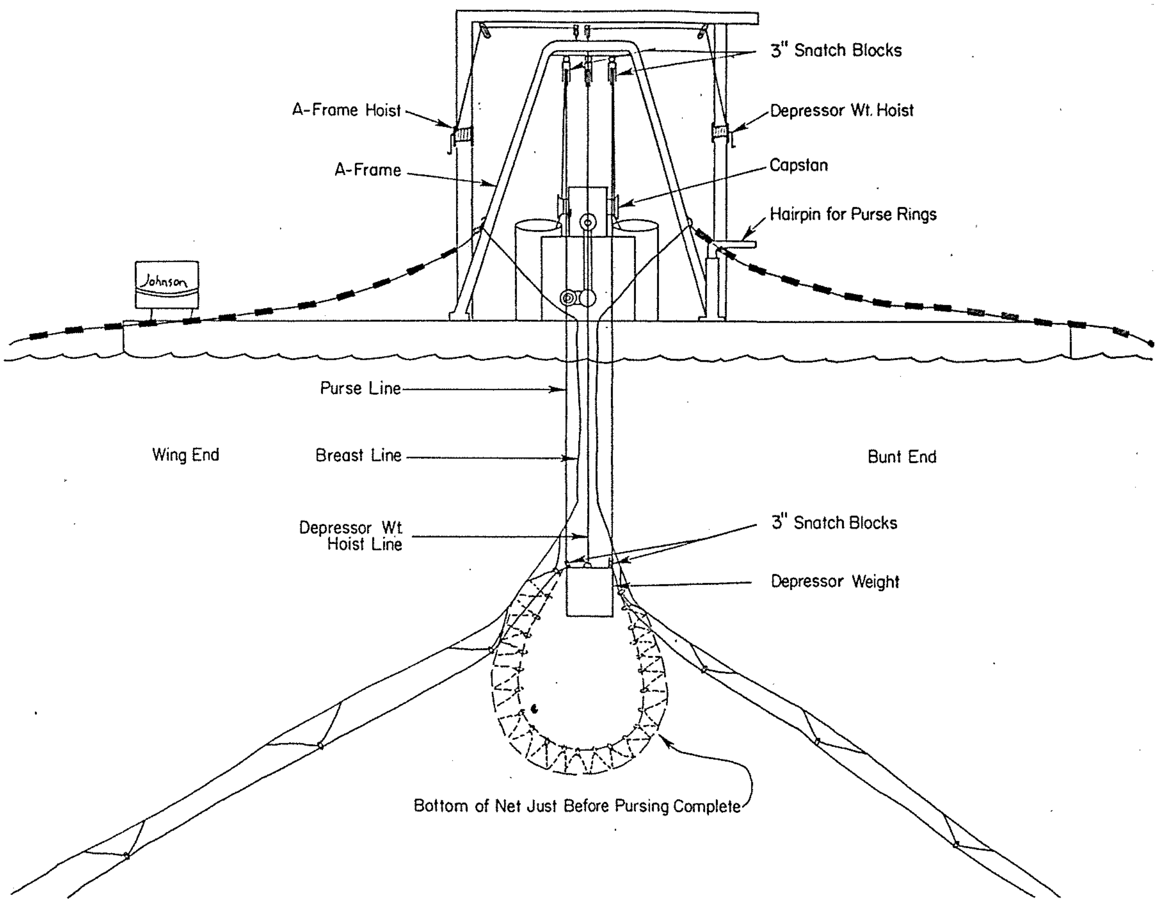
1/4": 02 thrd 12 lb 800 md, 255,900 sq m/lb
1/2": 1 1/2 thrd 15 lb 800 md, 110,800 sq m/lb
twine: lash with 15 thrd perma grip
1": 4 or 5 thd, 15 lb 200 md.
3": 5 thd, 15 lb, 3 md.



Appendix I - Fig. 1. Construction diagram of purse seine used during EHW lighting study, 1979. (Term definitions: "s.m." = stretch measure or mesh; "m.d." = meshes deep.)



Appendix I - Fig. 2. Details of hardware and lay out for purse seine used during EHW lighting study, 1979.



Appendix I - Fig. 3. Depressor weight and hoist systems used with the purse seine used during the EHW lighting study, 1979.

APPENDIX II

CHANGES IN LENGTH AND WEIGHT OF CHUM SALMON FRY AT 1- AND 7-DAYS AFTER PRESERVATION IN 10% BUFFERED SALTWATER FORMALIN.

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

by K. Michael McDowell

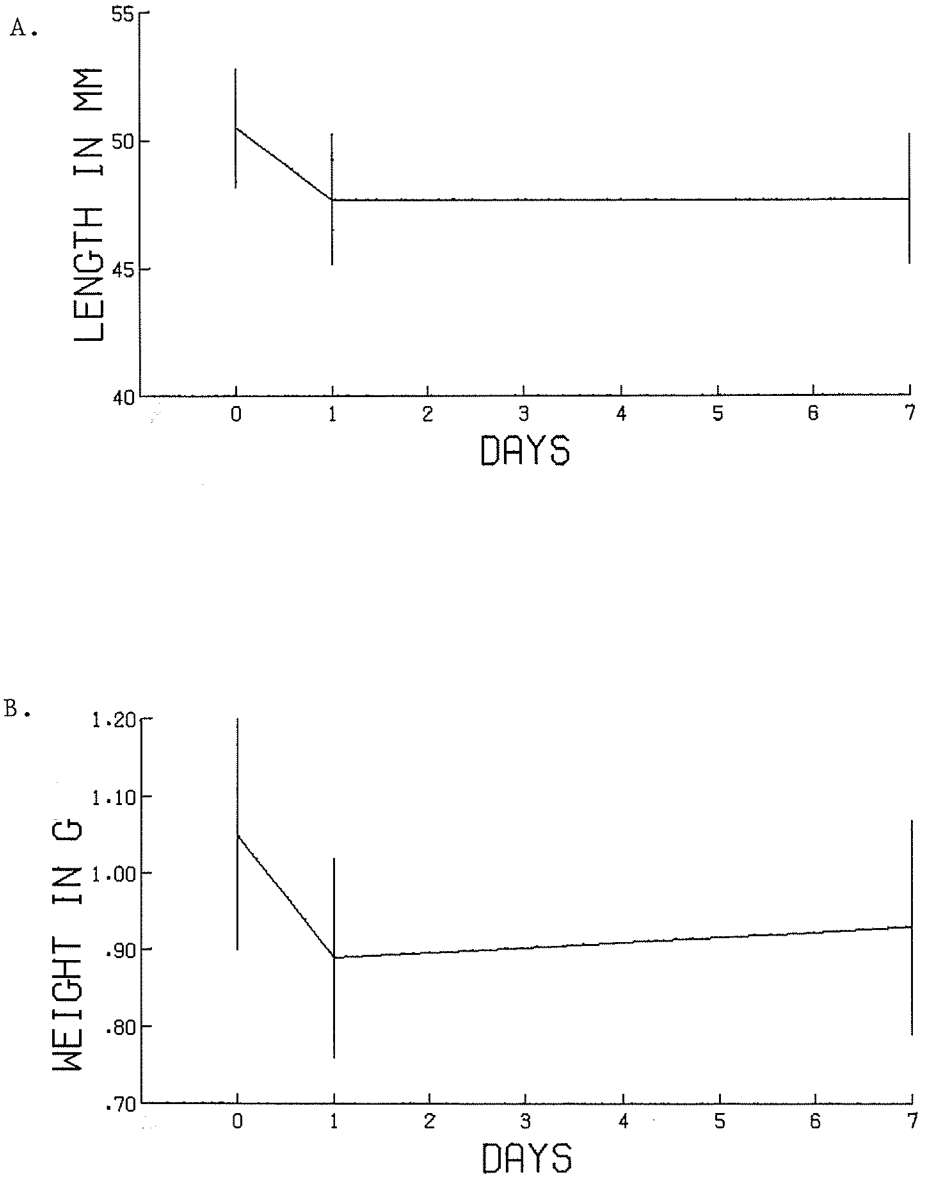
The nighttime sampling schedule of 1979 outmigration and lighting studies brought with it several logistical problems not encountered in previous years. One of these problems involved the handling of the salmon fry collected for the outmigration and lighting studies. In the years preceding 1979 the length/weight 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 II - 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.

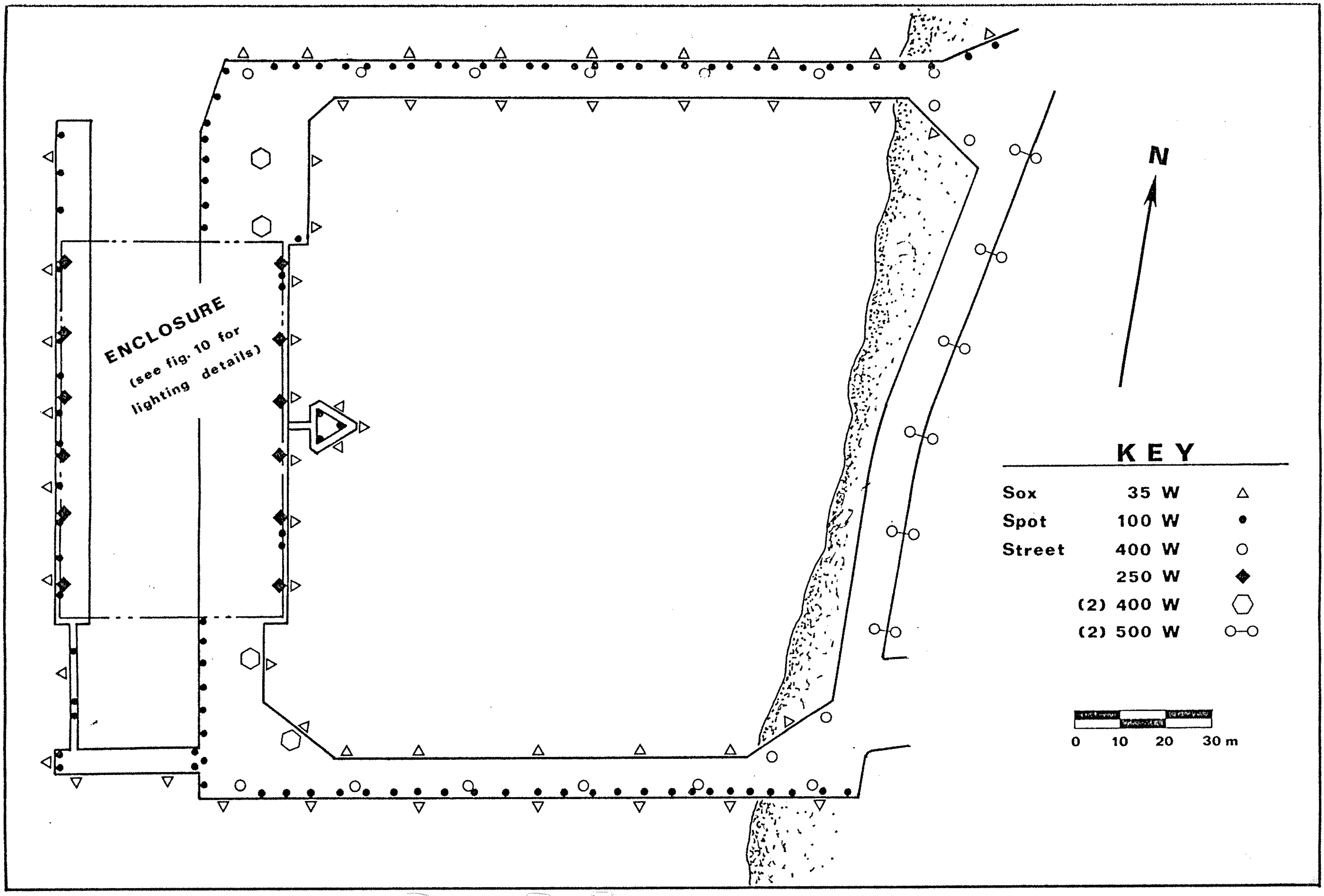
APPENDIX III

Summary of wavelength test catch data,
May-June 1979.

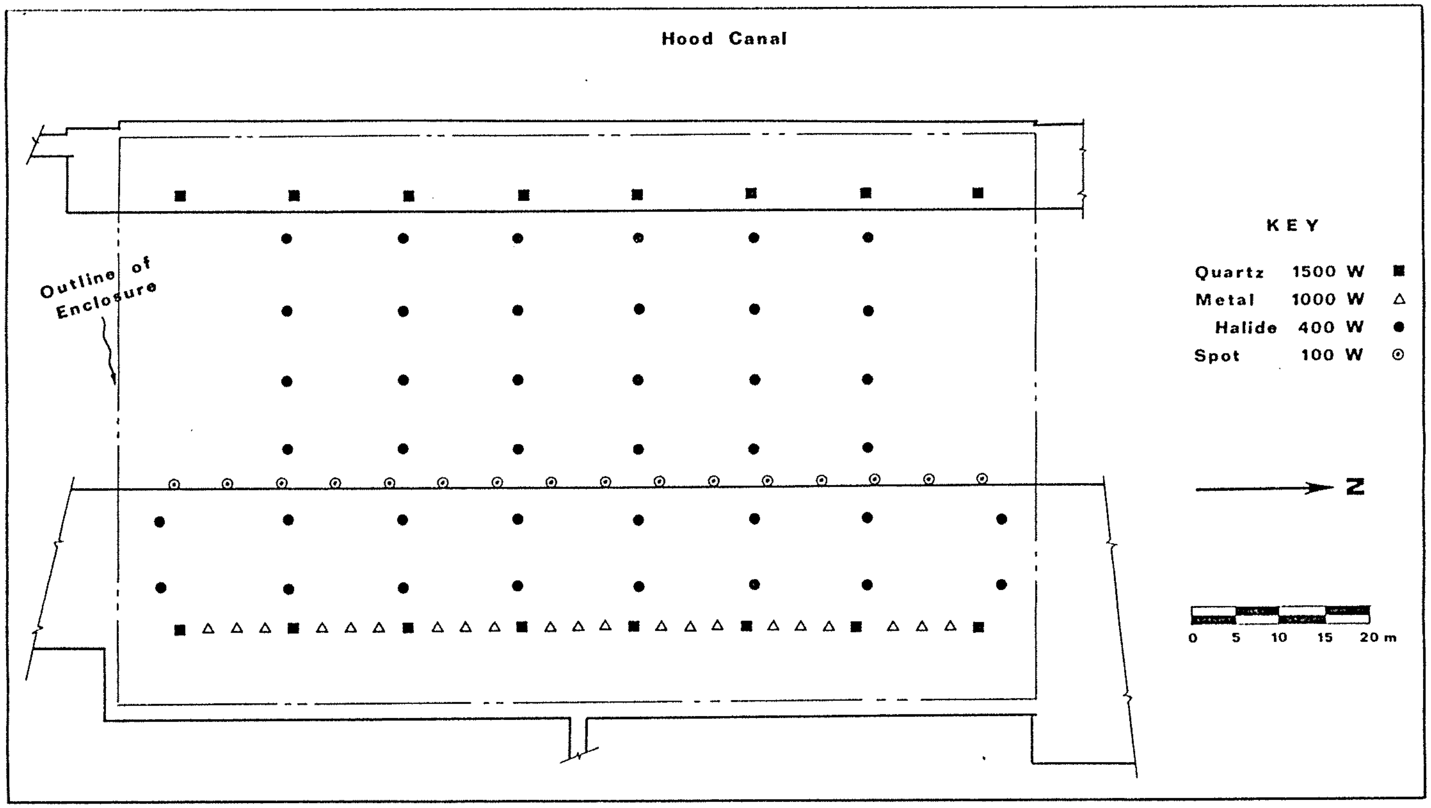
Wavelength (color)	Date	Catch in lighted (L) and control (C) sets									
		Chum		Chinook		Coho		Hake		Dogfish	
		L	C	L	C	L	C	L	C	L	C
WHITE	MAY	1	--	0	--	0	--	0	--	0	--
		0	1	0	0	0	3	0	0	0	2
		0	0	0	0	0	0	0	0	0	1
	JUNE	43	10	1	0	4	0	5	1	2	0
		36	19	2	1	4	1	10	17	9	61
		47	6	3	0	2	2	0	4	4	0
		1	7	0	1	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

APPENDIX IV

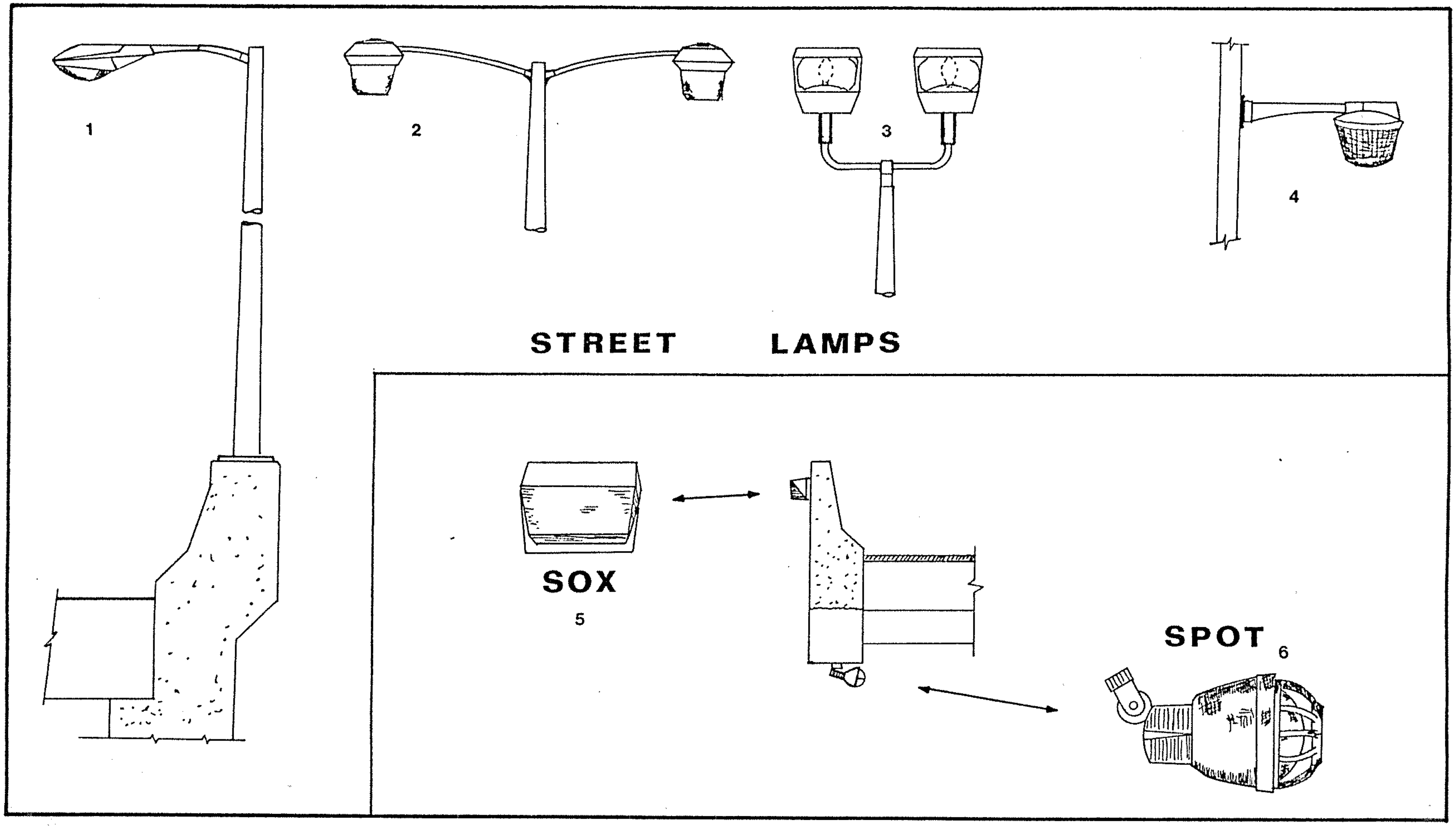
FIGURES - POSITIONS OF LIGHTS AND TYPES OF LAMPS AT EHW.



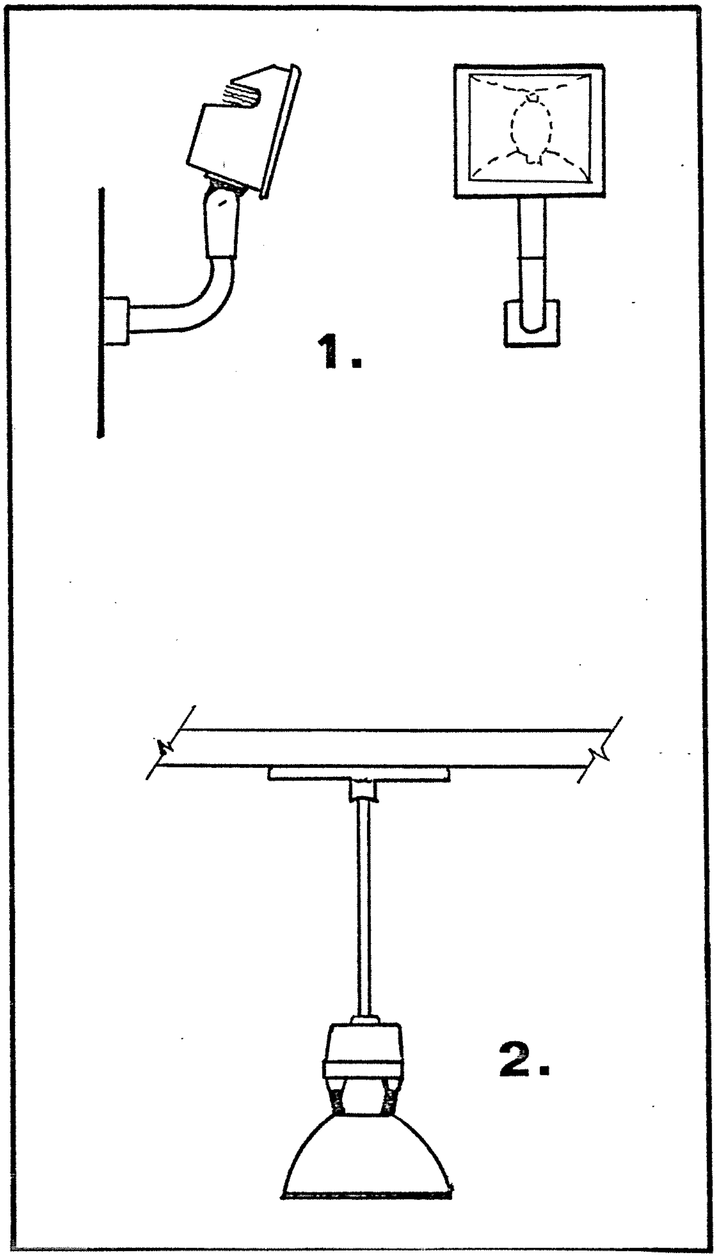
Appendix IV - Fig. 1. Positions of lights at EHW.



Appendix IV - Fig. 2. Positions of lights in enclosed area (submarine berth) of EHW.



Appendix IV - Fig. 3. Types of lamps used at EHW; street lamps: (1) one 400-W high pressure sodium, (2) two 500-W incandescent, (3) two 400-W high pressure sodium, (4) one 250-W sodium vapor; sox lamp, (5) one 35-W low pressure sodium; spot lamp, (6) one 150-W incandescent.



Appendix IV - Fig. 4. Types of lamps used in enclosed area (submarine berth) of EHW; (1) one 1000-W metal halide or one 1500-W quartz; (2) one 400-W metal halide.