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SALMONID OUTMIGRATION STUDIES IN HOOD CANAL

by

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FINAL REPORT, PHASE V

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Director

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This project was made successful only by the long hours worked by the people associated with it. The 1979 field crew of Clifford Whitmus, Gary Maxwell, George Holman, Thomas Wildebuer, Sean Cramer, and Eddie Kudera deserve a special mention for their hard work and cheerful company on our 6.5 month, nocturnal sampling regime. Carol Sisley and Lila Stacey transcribed the initial text to a readable form. Dorothy Beall and staff were of great service in finalizing the manuscript.

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INTRODUCTION

The salmon outmigration studies were initiated in 1975 to monitor the effects of pier construction and operation on the migratory behavior of juvenile salmon along the U.S. Naval Submarine Base on the east shore of Hood Canal at Bangor Annex (Fig. 1). The shoreline construction area extends over a 5-km corridor which is a part of the annual migration route of four species of Pacific salmon and two species of anadromous trout. These salmonid species comprise both natural and hatchery stock. The chum salmon is the most abundant of the above species, and it is with this species that this report is primarily concerned.

Chum salmon stocks in Washington State are currently undergoing a massive enhancement, and Hood Canal is to be managed principally for the production of this species (Washington State Department of Fisheries 1979). Hood Canal accounts for about 25% of Washington State Department of Fisheries' (WDF) total chum return (Morrill, in Simenstad and Kinney 1978). Unfortunately, less is known about the biology of chum salmon than any of the Pacific salmon, and it is in the early marine life history that the information is most deficient (Merrell 1970; Allen 1974).

Extreme fluctuations in abundance have characterized chum populations, and it is thought that marine survival, especially in the first few weeks of marine residence, may be a major cause of these fluctuations (Bakkala 1970). The causes of this mortality are not well documented, but it is known that predation and environmental factors are of importance (Wickett 1958; Birman 1959). More evidence on the early marine mortality of the pink salmon than of the chum is documented, although some restraint must be used in extrapolating this data (Andrievskaya, in Bakkala 1970; Gallagher personal communication[1]). By assuming that chum and pink salmon suffered the same mortality rates and by comparing adult returns of these two species to Hooknose Creek, British Columbia, Parker (1962) estimated survival in the coastal juvenile stage as 5.4% compared with 56.6% in the pelagic stage and 93.0% in the coastal adult stage. Further experiments by Parker (1968) on Bella Coola pink salmon where the juveniles were marked at two points along their marine migration route and the percentage returns of marked adults compared, led Parker to the conclusion: "It is now possible to state that during the initial period of sea life <u>average</u> daily relative loss to the population was about 2-4% and during the following 410-day period <u>average</u> daily loss was about 0.4 to 0.8%." Parker cautions that these results are subject to some difficulties in interpretation due to the possibility of different exploitation (from fishing) of the two marked groups. Parker felt that the proposed mortalities could be due to predation by coho smolts on the pinks. Other studies by Blackbourn

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

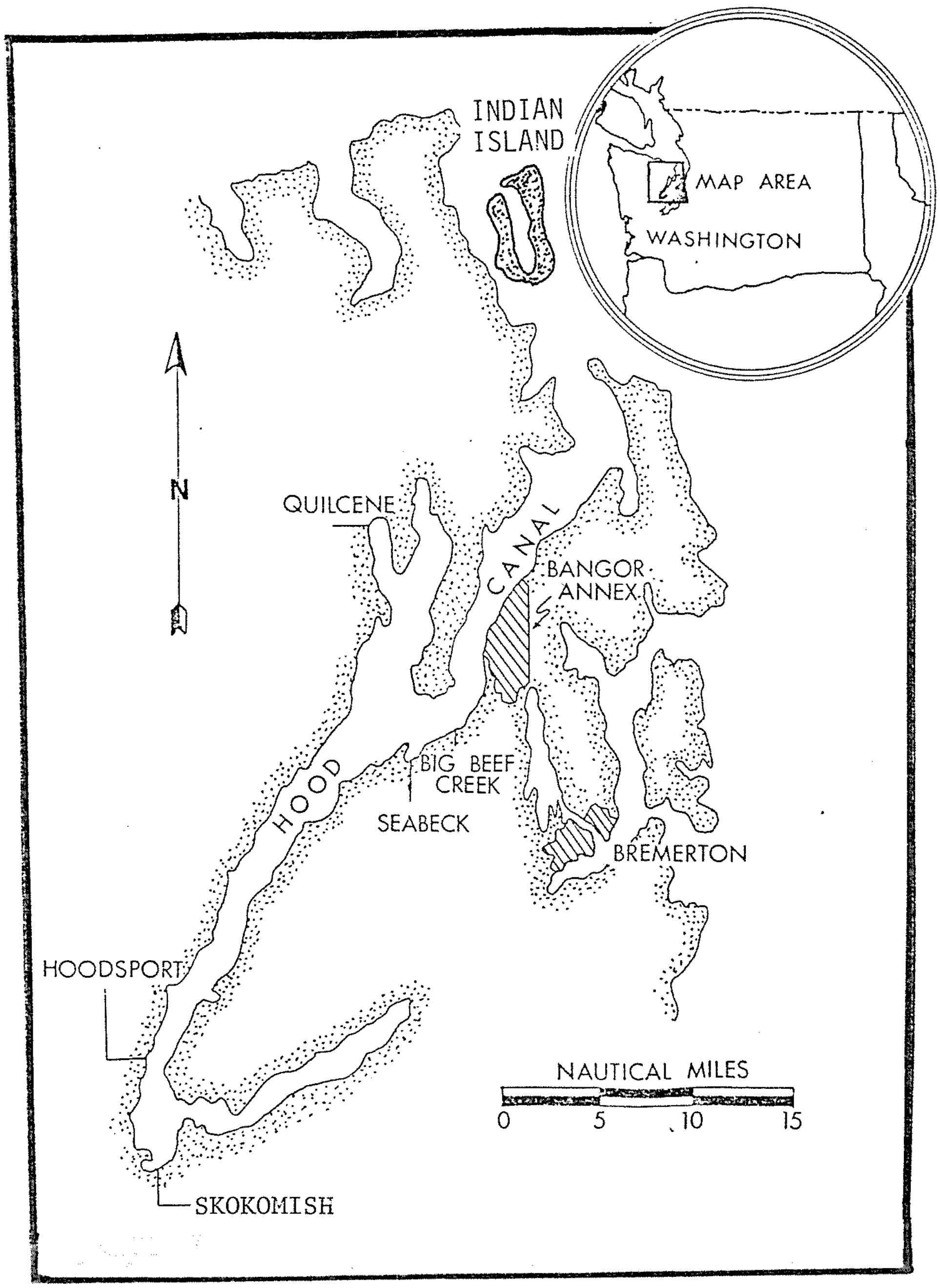

Fig. 1. Location of Bangor Annex in Hood Canal and the fish hatcheries at Big Beef Creek, Quilcene, Hoodsport, (Hood Canal hatchery) and on the Skokomish (Skokomish, George Adams and Hunter Springs hatcheries).

(1976) on Fraser River pinks have implicated environmental variables including river discharge, solar radiation, and the timing and initial size of pinks, as well as the catch-per-unit-effort (CPUE) of coho in the area. In fact, Blackbourn explained more than 90% of the variance in the survival of the pinks using groups of three of these factors. Gilhousen (1962), trying to explain Vernon's earlier work (Vernon 1958), where temperature was found to be the most important factor in explaining variations in survival of Fraser River pinks, suggested that higher temperatures led to the earlier offshore movement of the pinks and so increased the chances of predation on them. Gilhousen goes on to say that "conditions in the marine environment have been so variable that variations in fry abundance have had a secondary effect on total survival."

It is this extreme variability in marine survival of the economically important chum populations and the possible effects of construction and/or operational activities of the U.S. Naval Submarine Base that prompted this study. Earlier work by Heiser and Finn (1970) had shown buildups of migratory pink and chum juveniles at bulkheaded areas in Puget Sound. These juveniles later moved offshore, leading to an "observed increase in predation by coho salmon smolts and cutthroat trout," although no experiments were conducted to confirm this. Other authors have suggested that the movement away from the protective structures (vegetational or man-made) of the nearshore environment leads to an increased level of predation in salmon (Gilhousen 1962) and other species (Major 1977, Cooper and Crowder 1979, Hobson 1979). A factor studied closely in 1979, and described in detail in Prinslow et al. (1980), is the effect of the pier lighting on the migrating chum. It has been shown by Hoar et al. (1957) that lights attract chum salmon juveniles while in freshwater, and it is probable that this photopositivity continues in the marine environment (Gosho 1976; Salo 1976; Salo et al. 1977; Prinslow et al. 1979). Bakshtanskii (1970), studying the effects of the 24-hour illumination of the Arctic day on the predation of pink and red salmon, asserted that the predators (salmon, trout, and salmon juveniles in the river, cod and herring juveniles in the sea) do not lose contact with the schooling juveniles and are able to completely annihilate them. If the juvenile chum are forced offshore around the piers and away from the structural protection of the nearshore environment or are attracted to the pier lighting, it is possible that the predation upon them might be increased, due either to the decrease in shelter or to an increase in numbers of predators attracted to the piers or pier lighting.

This study and the pier lighting study mentioned above were concerned principally with the chum salmon juveniles routinely passing through the Bangor Annex shoreline. In addition, chum juveniles from Big Beef Creek hatchery were marked with fluorescent pigment and released from Big Beef Creek or at the Bangor Annex area to estimate their immediate marine mortality, migration patterns and reaction to the lighted piers. During the week of the marking studies each month the outmigration study crew worked on the mark-recapture project. The results of the marking studies are presented in Prinslow et al. (1980) and Salo et al. (1980).

The objectives of the 1979 outmigration study were:

1. To continue collecting baseline data on juvenile salmon migrating past the Bangor Annex, and to determine for each species their relative abundance, their origins (i.e., hatchery or stream), the timing of their migration, and their distribution.

2. To investigate the effects of the newly constructed shoreline facilities on the distribution of salmonids in the Bangor Annex area, and to compare this with previous years' data when large-scale waterfront construction was occurring. Emphasis in 1979 was on the effects of pier lighting at Explosives Handling Wharf (EHW), in particular its effect on the predator-prey relationships in the area.

3. To monitor some of the environmental variables to which the outmigrants were exposed. Variables measured were water temperature, weather, and tidal conditions. The variations in the CPUE with measured environmental variables were examined to explain gear avoidance or habitat preference.

4. To notify the U.S. Navy of any aberrant behavior of salmonids during the monitoring program, including that due to the wharves and trestles.

METHODS AND MATERIALS

Big Beef Creek, Fisheries Research Station of the College of Fisheries, University of Washington, was used as the base for field operations. The R/V Tenas, M/V Narwhal, and attendant skiffs used in the sampling operations were based at Seabeck.

Survey Area and Sampling Design

The area of Hood Canal sampled was bounded by the north and south boundaries of the Naval Submarine Base at Bangor Annex on the east shore and the area opposite this on the west shore (Fig. 1). Within this area sites were chosen such that contrasts could be made between sites affected and unaffected by the construction and operational activities of the base, and between sites on the east and the west shores (Fig. 2). Townet transects at varying distances from shore were used to assess the offshore distribution of the juveniles.

A floating beach seine and townet were used to assess the abundance of juvenile salmonids in the nearshore and offshore areas, respectively. Sampling transects with the surface townet were arranged to cover the majority of the offshore distribution of the juvenile salmonids as depicted in previous years (Bax et al. 1979). No attempt was made to estimate the midwater distribution of the juvenile salmonids, previous studies by Stober and Salo (1973) having shown that the majority of the juvenile chum (the species of principal concern) are to be expected in the top 3 m of the water column.

No surveys were conducted on the 1 week per month when mark-recapture experiments were in progress, although some of the incidental catch data during this week were used. All surveys were conducted at night so that any effects of pier lighting on the distribution of juvenile salmonids could be measured. In addition it has been found that nighttime sampling leads to lower variation in the catches when compared with daytime sampling, perhaps because the juveniles do not always school at night (Schreiner 1977, Bax et al. 1978).

Collection of Juveniles

The preliminary sampling of the nearshore environment in January was accomplished using a 10-m x 2-m beach seine with bag of 6-mm stretch mesh. With one man wearing waders, waist-deep in the water, and another on the shore, they seined a transect 30 m long and parallel to the shore. The maximum depth of the transect was 1.5 m.

In February when full-scale sampling began, a 37-m beach seine with 18-m, 3-cm stretch mesh wings and a 0.6-m x 2.4-m x 2.3-4 bag of 6-mm stretch mesh was used instead of the 10-m beach seine (Schreiner

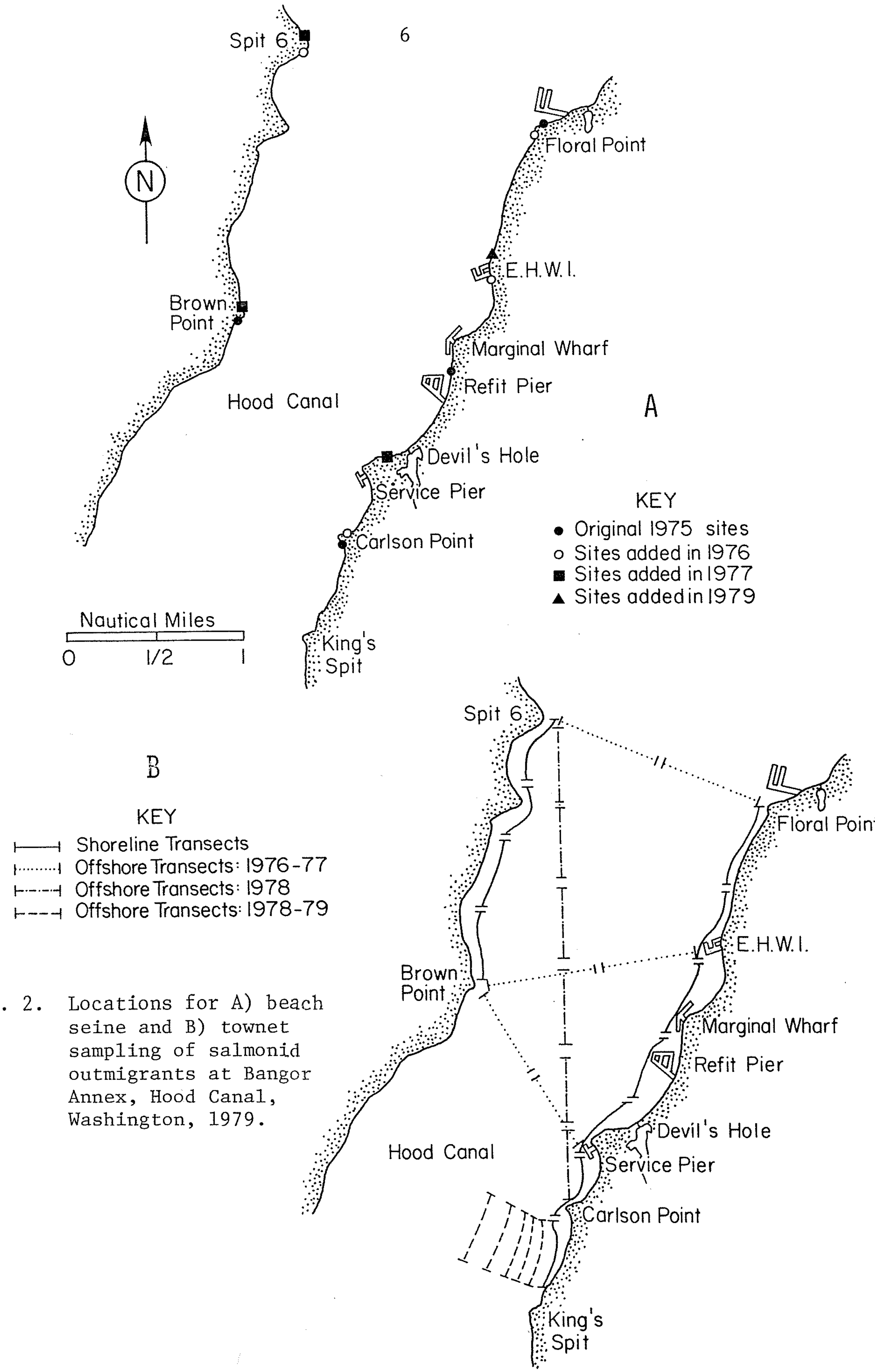

Fig. 2. Locations for A) beach seine and B) townet sampling of salmonid outmigrants at Bangor Annex, Hood Canal, Washington, 1979.

1977). The 37-m beach seine was used until the end of sampling in July. The seine was set from an outboard skiff 30 m from, and parallel to, the shore. Two men on a rope at either end of the seine pulled the net toward the shore as swiftly as possible without submerging the floats. At 10 m from the shore the wings of the net were pulled together, thus funnelling the catch into the bag. Each set took from 3 to 3 1/2 min from the start of laying out the net to the time that the bag was brought up onto the beach. Delays caused by catching the net on underwater obstructions or by exceptionally strong currents were noted on the data sheets. The seine was operated as a floating seine, a floating net having proven most effective for the nearshore collection of all juvenile chum salmon size classes (Schreiner 1977).

Offshore sampling was conducted using a surface trawl towed between two boats, the R/V Tenas, an 11.6-m vessel and the M/V Narwhal, a 7.9-m motor whaler. The mouth opening of the net measured 6.1 m wide by 3 m deep. Stretch mesh sizes ranged from 76 mm at the mouth to 5 mm at the bag (Schreiner 1977). The wings of the net were spread vertically by 3.75-cm diameter galvanized pipes, which were connected with a short nylon bridle to single warps leading to each vessel. The net was towed at between 1.5 and 2.0 knots with the tidal flow, but the speed was adjusted slightly during each tow, under different tide and weather conditions to keep the ends of the headrope just breaking the surface of the water. Tows were of 10-min duration, excepting one tow inside the EHW which was of a 2-min duration. At the end of each tow two crewmen in an outboard skiff pursed the cod-end of the net and removed all fish and debris. This technique allowed continuous sampling of the offshore transect pattern. It was arranged in 1979 that there was some distance between each transect when the net would be towed with the cod-end open. This procedure allowed the net to be cleared between tows and, more importantly, ensured that the individual transects covered the same area on each survey, regardless of tide, wind, or current conditions.

Processing of Samples

Salmonids caught in the beach seine were sorted and preserved immediately upon capture. Townet captures were transported to the deck of the R/V Tenas in 20-liter plastic buckets.

Subsamples of no greater than 100 chum were taken from each haul, and preserved immediately in 10% buffered seawater formalin. The remaining chum were counted and released. Other salmonids caught were measured (fork length) to the nearest 5 mm and released. Likely predators (salmonid and nonsalmonid), or subsamples of no more than five, were preserved. Large predators were injected in the stomach with a solution of formalin prior to bottling. The results of the predator stomach analysis are presented in Salo et al. (1980).

The preserved chum were retained for 7 days before weighing and measuring them. It was determined by prior experimentation that after this period individual variations in shrinkage and weight gain due to the preservation technique were minimized (Salo et al. 1980).

Environmental Data Collection

In 1979 water temperature, weather and sea conditions were the only measured environmental variables. As sampling was at night, water clarity and salinities (measured by a refractometer) could not be taken as had been done in previous years (Bax et al. 1978). Temperatures were taken at 1 m depth with a mercury glass thermometer after each beach seine set and after each tow. Weather and sea conditions were recorded at each site.

RESULTS AND DISCUSSION

Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) computed for each salmonid species was of the form:

$$CPUE = C_j/E_j$$

where C_j is the number of fish caught in the interval j and E_j is the effort during the same interval. One unit of effort was established as being a 10-min haul with the surface townet or one retrieval of the 37-m beach seine set 30 m from shore. The CPUE for the two gears were not equivalent quantitatively. The townet transect within the subbay of the EHW was of only 2-min duration. To compare the catches on this transect with other transects, the catches were multiplied by 5. As juveniles could often be seen ahead of the purseline at the end of a tow, i.e., yet to fall back into the cod-end, the multiplication factor of 5 might have resulted in an underestimate of relative population abundance, especially for the larger juveniles.

For data presentation, we arranged the CPUE over a week because daily sampling was inconsistent with regard to pier lighting conditions. Weekly sampling was consistent in this regard.

The CPUE data for chum salmon with both gears were found to be lognormally distributed. Consequently, a logarithmic transformation was used, where the dependent variable (D.V.):

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

Environmental Results

The water temperature at 1 m depth was measured upon completion of beach seine and townet hauls. The temperature was stable at about 8^{o}C until mid-March, when it started rising and continued rising throughout the sampling season (Fig. 3). Seasonal trends in salinity, dissolved oxygen, and water visibility were described for previous years by Bax et al. (1978), and Bax, Salo, and Snyder (1979).

Migration Periods and Peaks

Chum Salmon

Chum salmon juveniles were the predominant species of salmon captured in 1979. Similar trends were found on both shores and with both gear types, and they will be considered together.

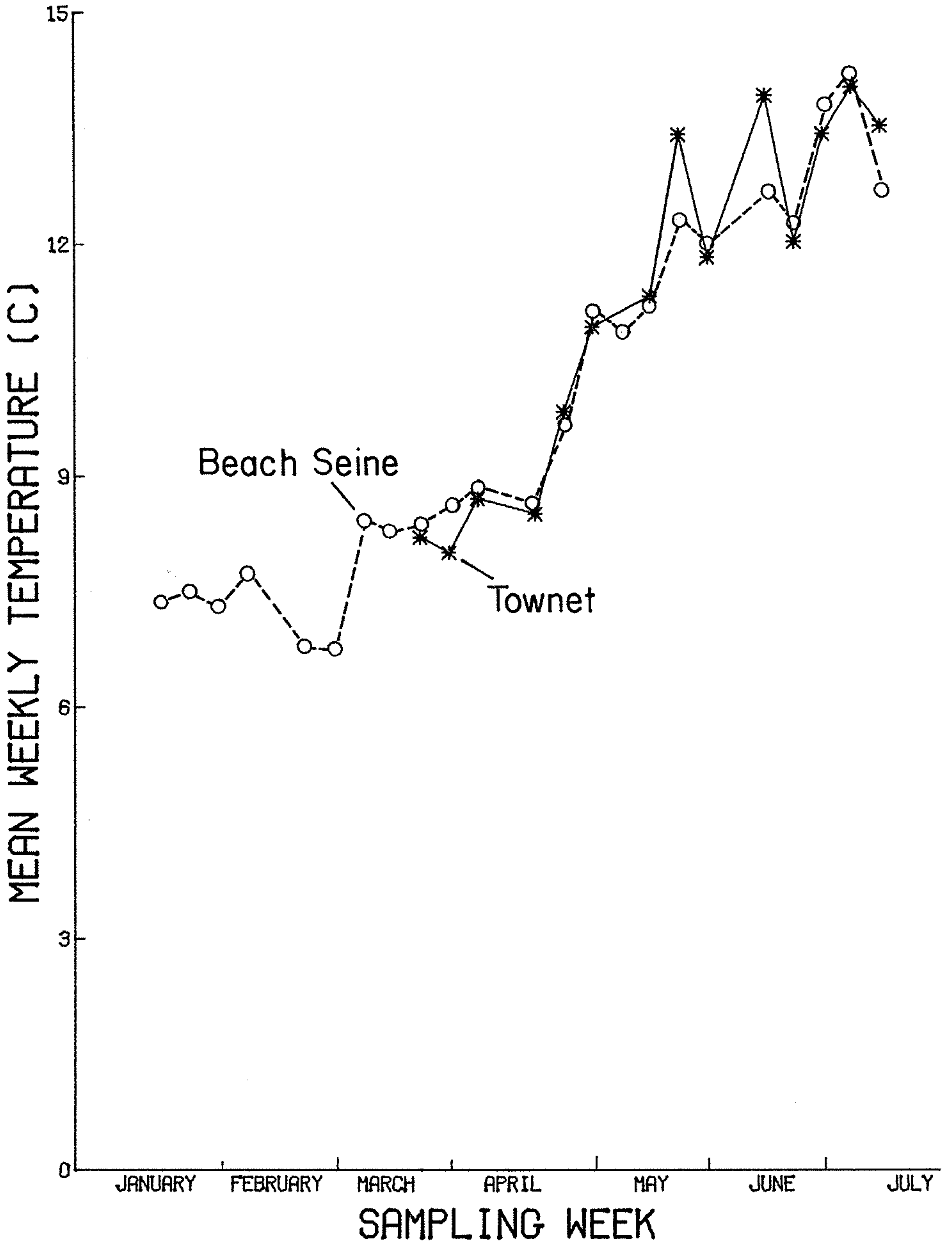

Fig. 3. Mean weekly water temperature at 1-m depth at sampling sites at Bangor Annex in 1979.

From early February to March, several small peaks in abundance occurred (Figs. 4 and 5). Subsequent to the initiation of hatchery releases, two larger peaks in mid-April and mid-June were noticed. Catches did not decline as rapidly, or to the same extent, following a peak in abundance on the east shore as they did on the west shore (Fig. 4). It is difficult to say whether this higher abundance is due to juveniles from subsequent and smaller hatchery releases utilizing predominantly the eastshore epibenthic zone during this period or due to the piers or pier lighting on the east shore concentrating the chum juveniles in the areas sampled by the beach seine creating an artificially high measure of abundance (Prinslow et al. 1979).

Coho Salmon

Coho salmon smolts were the second most abundant salmonid caught in 1979 (pink salmon do not regularly spawn in Hood Canal in even years). The coho smolts caught were checked for adipose fin clips. There was a minor peak of unclipped coho in mid-March and a large peak of both clipped and townet catches of unclipped coho in late May (Fig. 6 and 7). The first peak of clipped coho is thought to have originated from Big Beef Creek. The peak of clipped coho in late May was one week earlier for beach seine catches than for townet catches - 1 and 2 weeks after peak outmigration from Big Beef Creek, respectively (McComas, personal communication[2]). Townet catches of coho smolts decreased after this peak in late May, while beach seine catches continued to rise until the end of sampling in July.

Chinook Salmon

Very few chinook salmon smolts were caught until May (Fig. 8). There were two peaks in abundance - one in mid-May consisting mainly of beach seine captures, and one in early June comprising townet and beach seine captures. There was no evidence of the increasing abundance in July noticed in previous years (Bax et al. 1979). Hatchery release data data need to be examined before this can be explained.

Adult Salmon

As our sampling gear is designed for capturing juvenile salmon, few adult salmon are retained. No adult salmon were caught with the townet. Three adult coho and one adult chinook were caught with the beach seine.

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[2]R. Lynne McComas, Big Beef Creek Field Research Facility of the University of Washington, Seattle, Washington.

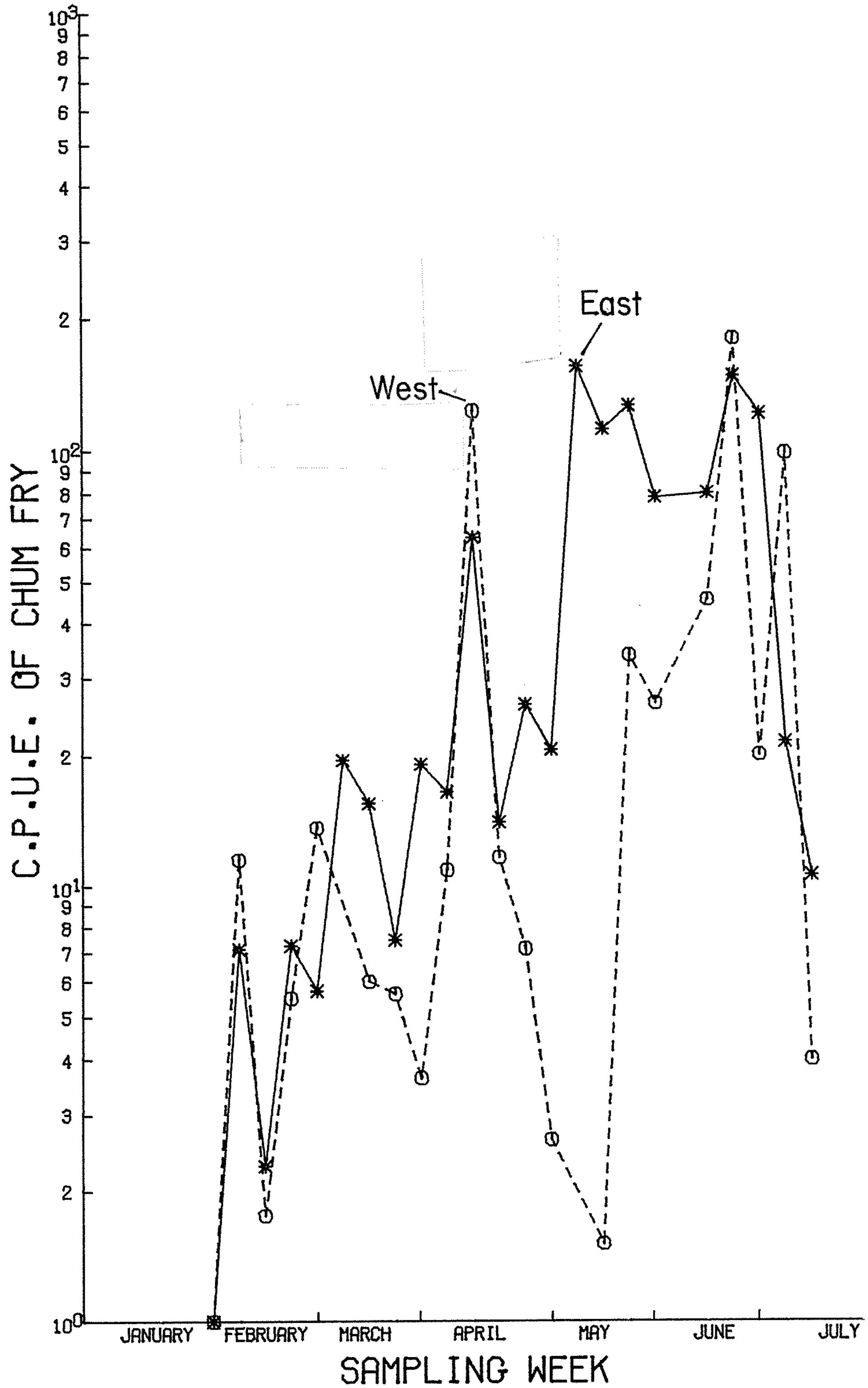

Fig. 4. Mean weekly CPUE of chum salmon juveniles at the East and West Shore beach seine sampling locations at Bangor Annex in 1979.

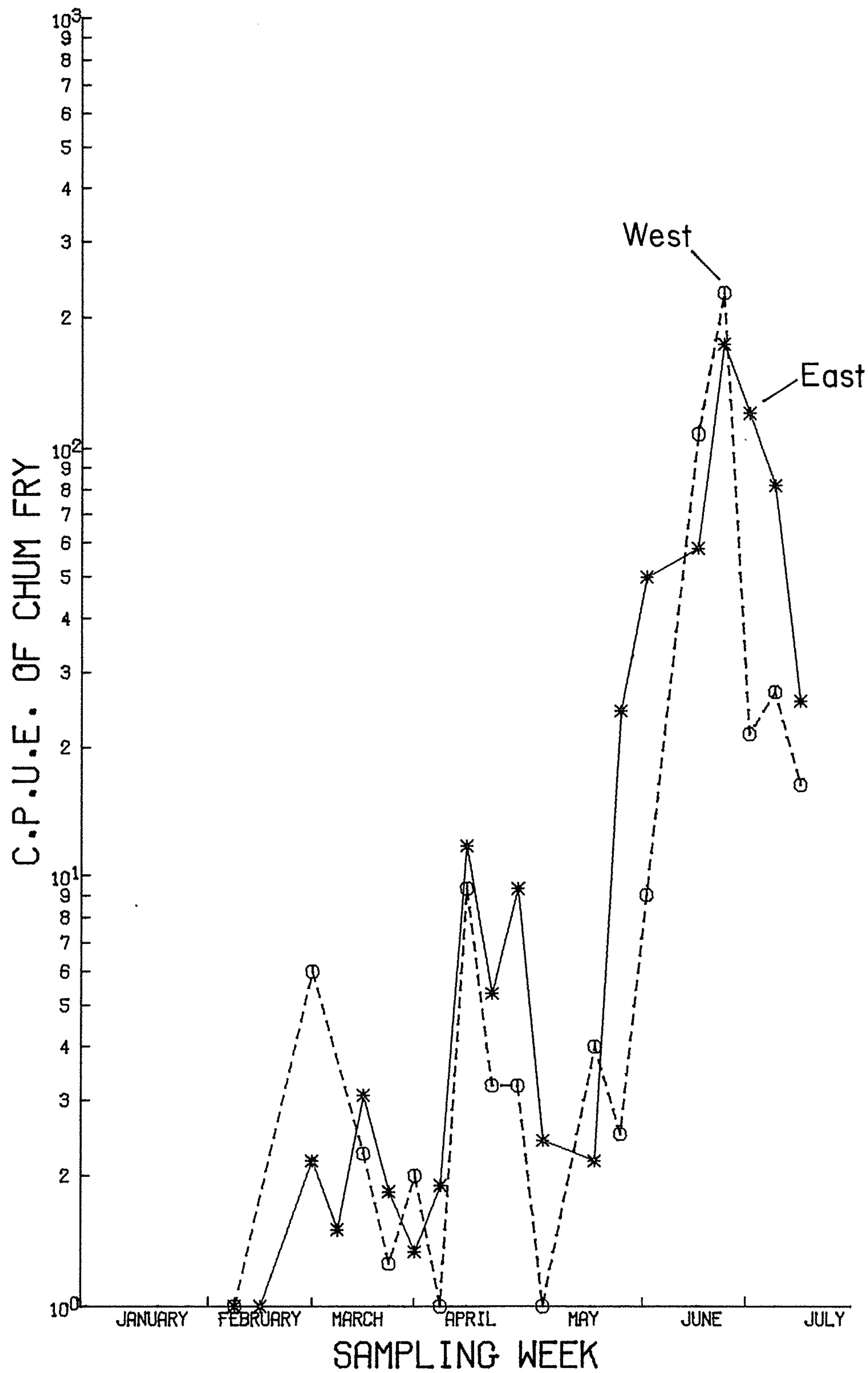

Fig. 5. Mean weekly CPUE of chum salmon juveniles at East and West Shore shoreline townet locations at Bangor Annex in 1979.

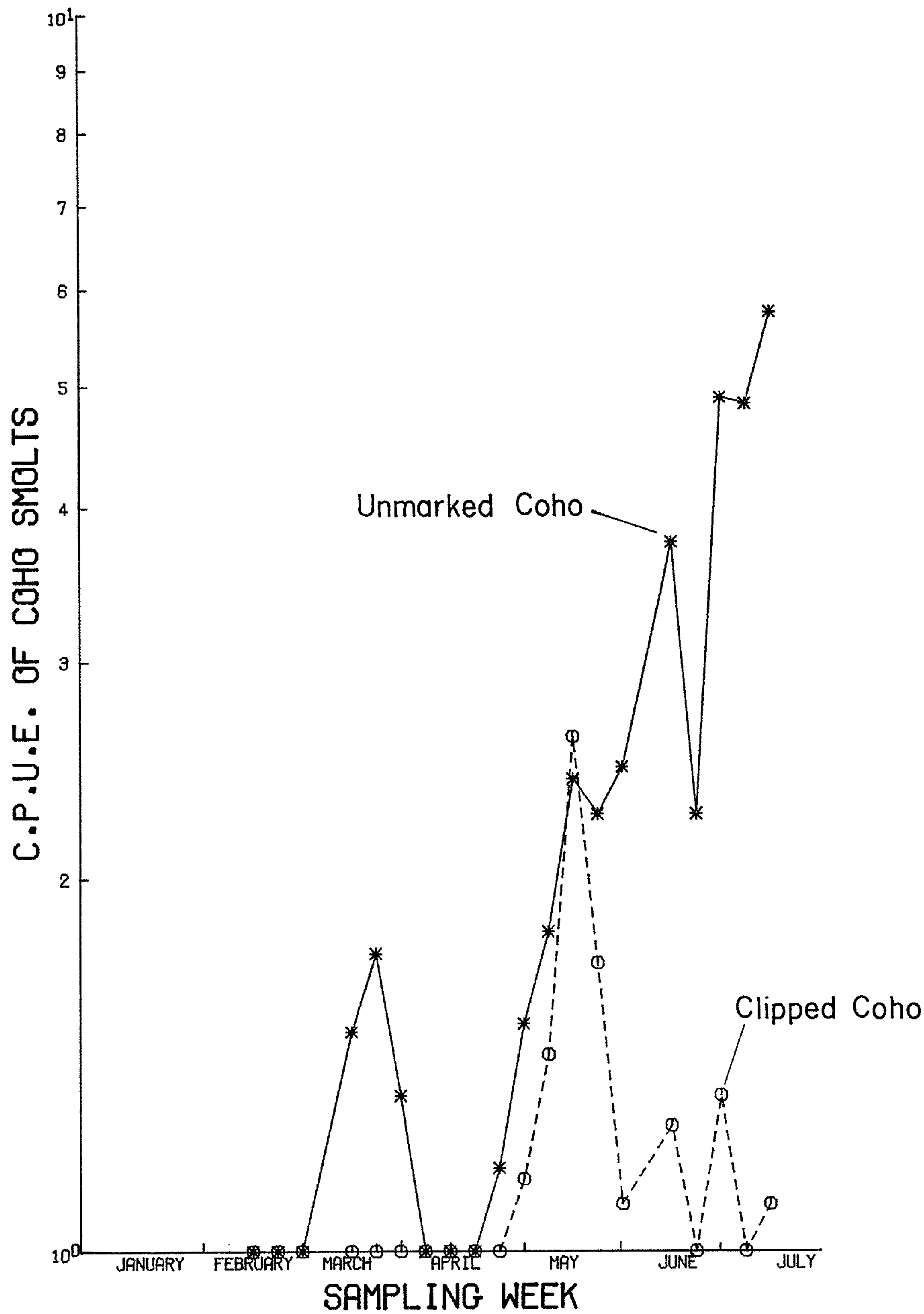

Fig. 6. Mean weekly CPUE of clipped and unclipped coho smolts at beach seine sampling locations at Bangor Annex in 1979.

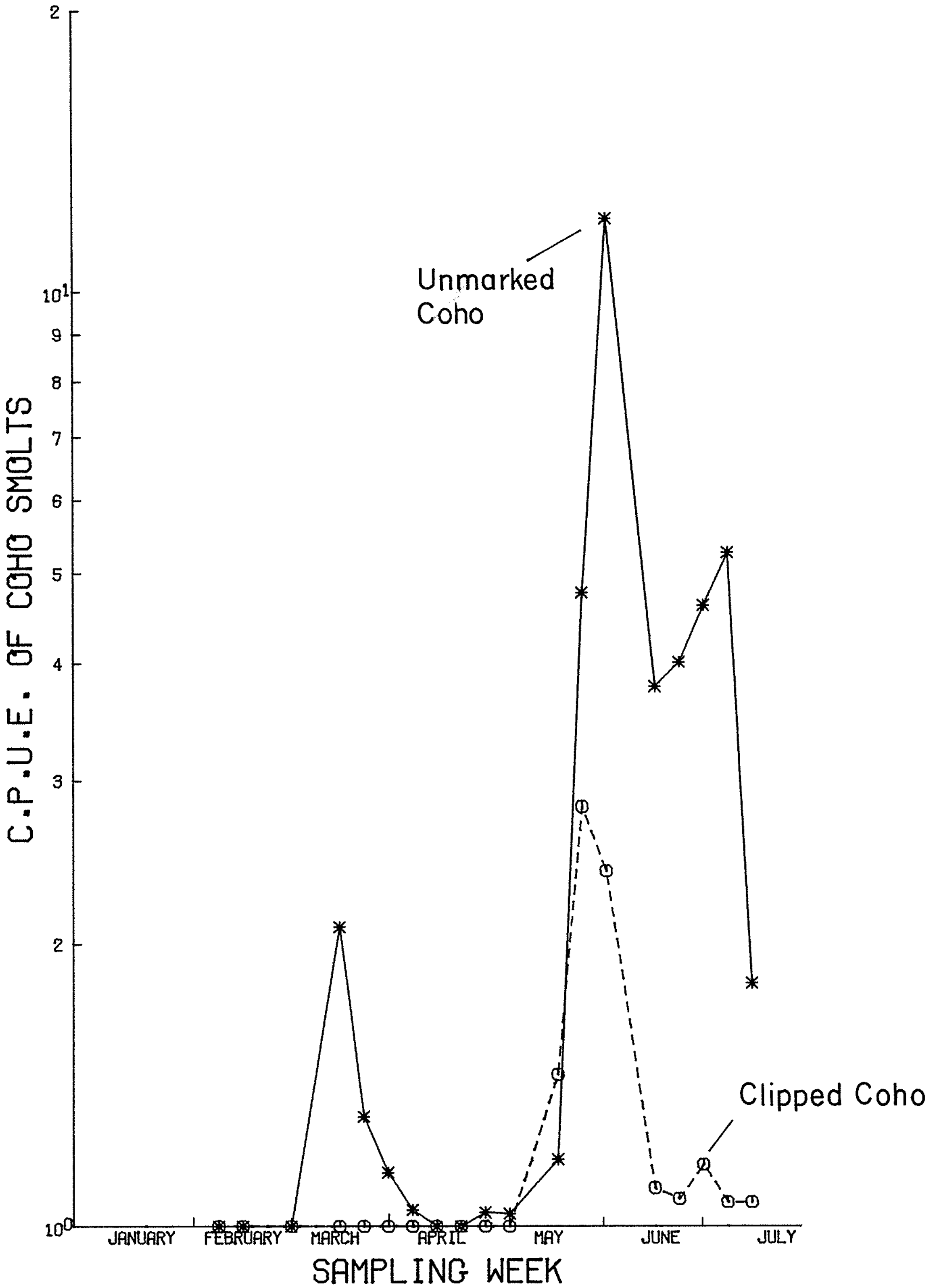

Fig. 7. Mean weekly CPUE of clipped and unclipped coho smolts at townet shoreline sampling locations at Bangor Annex in 1979.

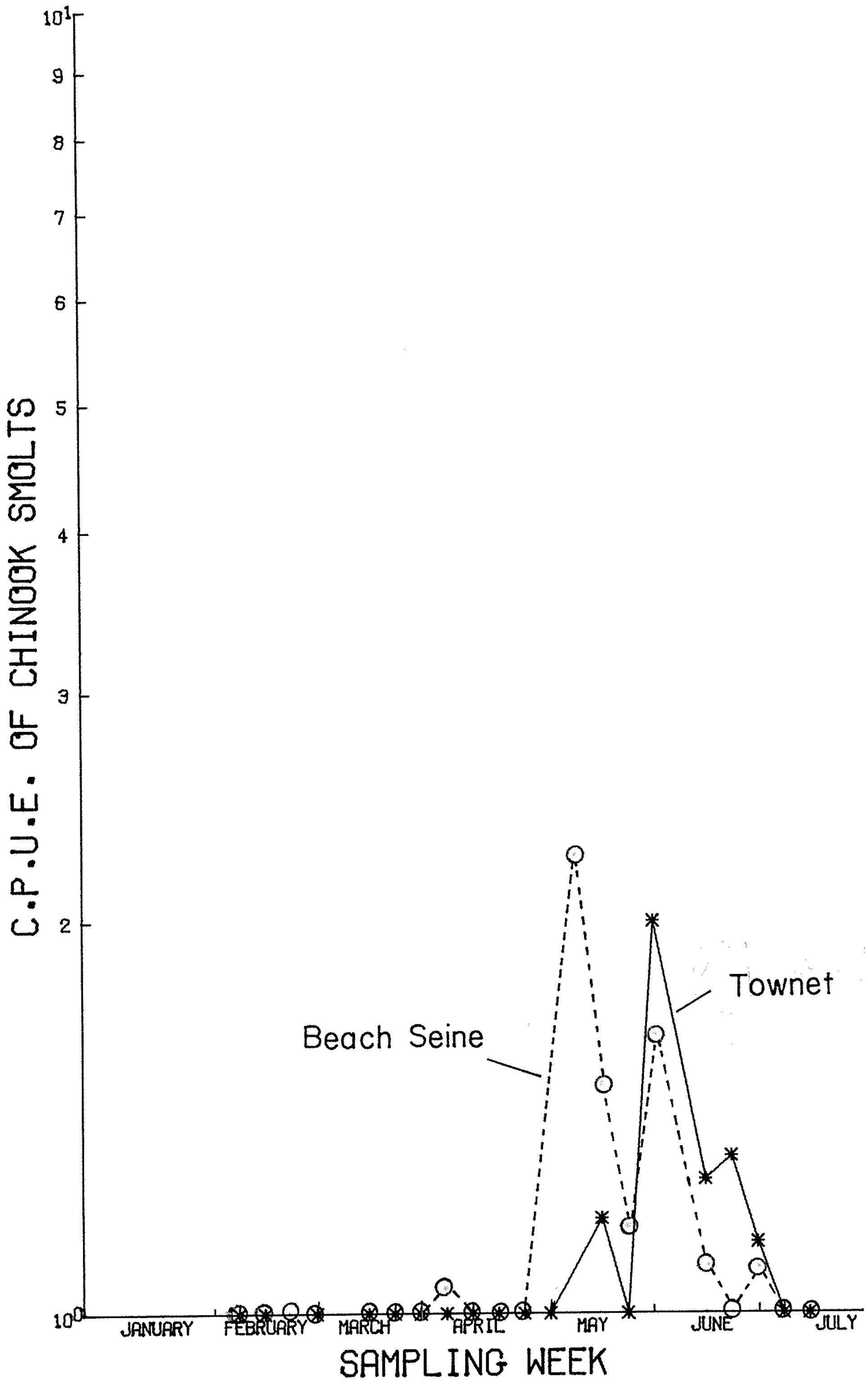

Fig. 8. Mean weekly CPUE of chinook smolts at beach seine and shoreline townet locations at Bangor Annex in 1979.

Cutthroat Trout

Coastal cutthroat trout adults and juveniles were caught throughout the sampling season (Fig. 9). Only 3 juveniles were caught with the townet and 22 juveniles and 22 adults with the beach seine.

Factors Affecting Catch-Per-Unit-Effort

Site Preference

To investigate any effects of the construction and operation of Naval facilities on the migrating chum juveniles a comparison was made between the catches at different sampling locations in the area. The distribution of the juveniles was compared with previous years' data and any anomalies or trends found.

Data collected with the 37-m beach seine from February to July and with the surface townet from April to July were used to compare CPUE of chum juveniles between sampling sites. For earlier dates, recaptures from both the 37-m beach seine and the townet were too few for statistical analysis. For both gear types, data from all sites were entered into a fixed effects analysis of variance, where the logarithmically transformed catch data were the dependent variable, and sampling location and sampling week were the independent variables. Additionally, *a priori* t-tests were run to find differences in east/west shore distribution and the effects of the EHW on east shore distribution.

Nearshore. Significant differences in CPUE were found amongst the beach seine locations (Table 1a). Only one site, north Spit 6, was found to be significantly different (in this case lower) from all other sites when tested with a Student-Newman-Keuls (SNK) multiple comparison procedure. North Spit 6, a site with a steep, exposed beach, has consistently had a lower CPUE than the other beach seine sites in previous years. On the east shore the sampling locations at Floral Point, north of the major base facilities, had a CPUE lower than all other east shore sites except for south Carlson Point. The decreasing catches north of the major base facilities from 1976 to 1979 relative to the east shore mean have been discussed in Salo et al. (1980). The decline cannot be explained by either an increased offshore movement of the juvenile chum or their crossing over to the west shore. The *a priori* t-test showed that the CPUE at north and south EHW was higher than the east shore in general (Table 1b). From these data and that of the multiple comparison, it appears that the east shore sites close to the major base facilities had a CPUE higher than those farther away. The high catches at Devil's Hole and the EHW may be explained by the extensive littoral zone in these areas. Other studies have shown an attraction of young chum salmon to sheltered nursery areas during their first 2-4 weeks in the marine environment (Allen 1974; Cooney et al. 1978). The high CPUE at South Marginal Wharf, which has a limited littoral zone shows that this is not the only factor operating. Another hypothesis is that the chum

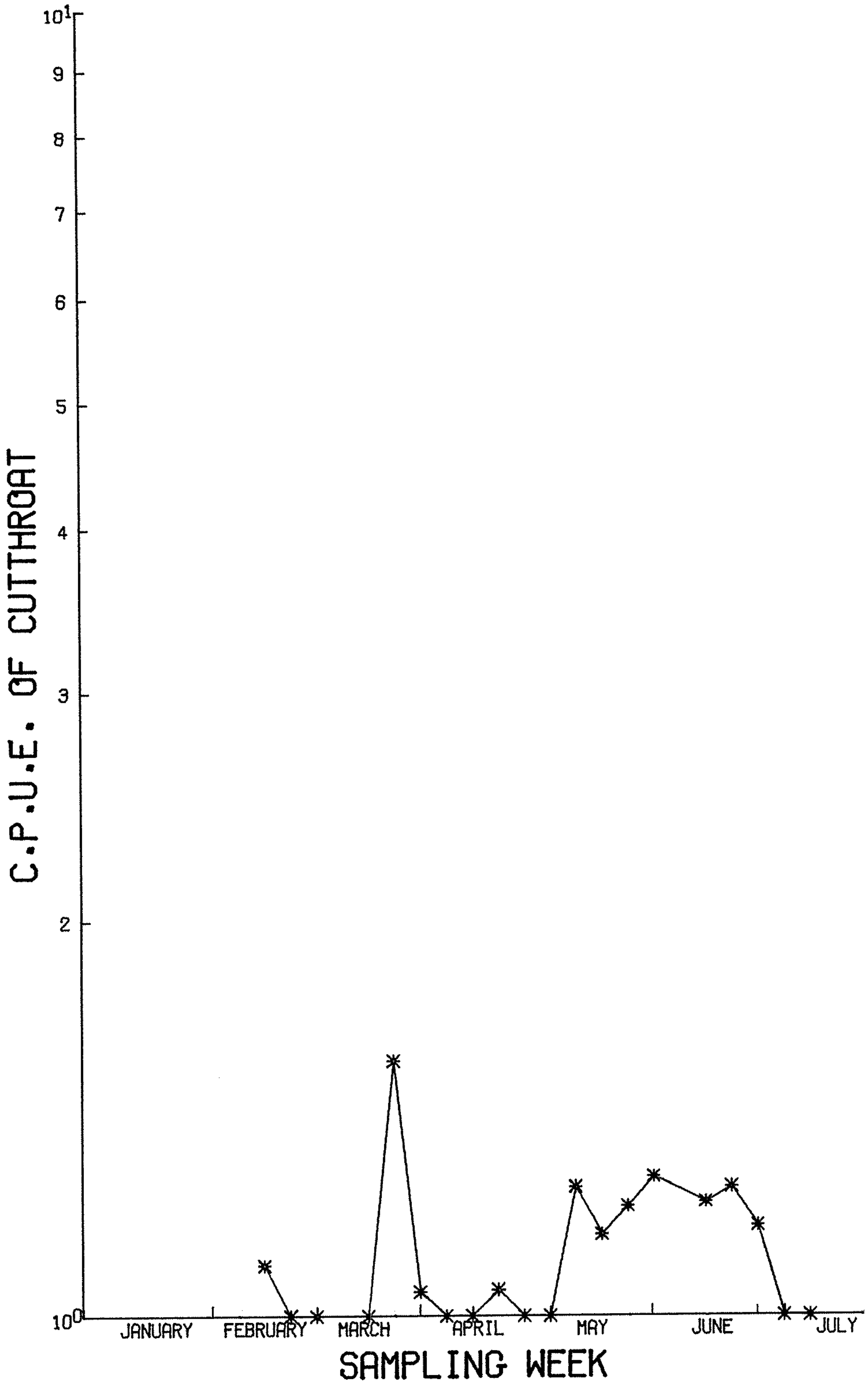

Fig. 9. Mean weekly CPUE of juvenile and adult cutthroat trout at beach seine locations at Bangor Annex in 1979.

Table 1. Analysis and variance (a) and t-tests (b) to show differences in the CPUE of chum fry between beach seine locations at Bangor Annex, 1979.

(a) ANOVA SUMMARY TABLE

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance of F
Total	206.994	378	.548		
Cells	102.791	32	3.212	16.016	<<.001
Location	29.869	11	2.715	13.538	<<.001
Week	69.411	21	3.305	16.480	<<.001
Interaction	75.923	205	.370	1.847	<.001
Error	178.714	237	.754	3.760	

Significant Groups in Multiple Comparison*

Location	$\bar{x}$	Groups			
N. E.H.W.	1.5488	│			
Devil's Hole	1.3251	│			
S. Marginal Wharf	1.2881	│	│		
S. E.H.W.	1.2849	│	│		
N. Carlson	1.2461	│	│		
S. Carlson	1.0102		│	│	
S. Brown	.9766		│	│	
N. Brown	.9107			│	
S. Floral	.8557			│	
N. Floral	.7701			│	
S. Spit 6	.7293			│	
N. Spit 6	.4767				│

(b) *A priori* t-tests

	Groups	T statistic	Degrees of freedom	T probability
(i)	N. and S. E.H.W. vs East Shore	-3.394	373	<<.001
(ii)	East Shore vs West Shore	5.170	373	<<.001

*Locations which are not significantly different from each other at the 5% significance level are encompassed by the same line.

juveniles would be attracted to the piers which might serve a protection from predation as they "limit the maneuverability and avenues of approach for all species of predators" (Major 1977). The lack of a pier in the close vicinity of the Devil's Hole area means that protection from predation is also not the sole factor operating on site selection. It is most probable that a complex of factors is operating on the site preferences of the juvenile chum salmon. As Matthews and Hill (1979) stated:

> "The influence of any variable upon habitat selection depends upon the entire milieu of conditions at a particular time and organisms seldom select habitat in response to single factors."

The *a priori* t-tests showed that the nearshore CPUE was higher on the east than on the west shore (Table 1b). From 1975 to 1978 there was no significant difference between beach seine catches on the east and west shores, although the vast majority of chum juveniles entering Hood Canal come from hatcheries and rivers on the west shore (Salo et al. 1980). The cause of the higher beach seine catches on the east shore than on the west shore in 1979 is uncertain. It cannot be entirely explained by diel variations, as the nighttime catches in 1977 do not show a difference between shores (Bax et al. 1978). It is not due to the additional east shore beach site in 1979 - North EHW which had the highest CPUE of all beach seine sites - as this site was excluded from the analysis. Possibly the changes on the east shore since 1977 - construction of degaussing wharf, lights operational at EHW and the Refit Pier - caused this change in distribution, but we have no direct evidence for this.

The higher catch on the east shore in 1979 is unlikely to be caused by a redistribution of juveniles from the west shore to the east shore in the vicinity of Bangor Annex. Our offshore distribution data show few juveniles being found in the middle of the Canal; additionally data from the 1977 Hoodsport mark-recapture study (Whitmus and Olsen 1979) show an immediate crossing to the east shore by approximately half of the juveniles. Differences in the length-weight relationships and differences in peaks of abundance between the juveniles caught on the east and the west shores at Bangor Annex suggest that the juveniles on the two shores remain distinct after an initial crossing soon after release from the hatcheries. Therefore, the higher catch on the east shore in 1979 is most likely due to a localized redistribution of the juveniles at night on the east shore perhaps caused by pier lighting, leading to an increased probability of their capture with the beach seine. Schreiner (1977) speculated that the high spring runoff in Hood Canal may result in salinity gradients from the east to the west shore to which the juveniles could respond. Thus, east-west distribution may also be a function of environmental variables.

Offshore. The CPUE of chum was higher on the east than the west shore, as has been found in all previous years. The implications of this are discussed above. Significant differences were found in the CPUE at different locations (Table 2a). The transect inside the EHW had a higher CPUE than any other east shore transect. The attraction of the pier may be partly due to its structural protection from predators (Major 1977), or to the always present low level lighting (Prinslow et al. 1980). The catch at the Service Pier was higher than the remaining east shore locations, an effect perhaps mediated by the pier and/or its lighting and its proximity to shore. The remaining east shoreline transects were not different from one another. The importance of these observations in regard to forced offshore movement of the chum juveniles is discussed later in this section.

There was a decline in the abundance of chum with increasing distance from shore in the Carlson Spit area unaffected by wharves (Fig. 10). The decline was highly significant (Table 2b), the first transect (75 m from shore) having a higher catch than the remaining five transects.

The similarity in the offshore distribution of the chum between 1978 and 1979 (Bax et al. 1979) is surprising in one regard: the data in 1978 were collected during the day, while the 1979 data were collected at night. There is no indication of the nocturnal offshore movement suggested in 1977 by the smaller daytime beach seine catches as compared with the nighttime catches (Bax et al. 1978). It is possible that the juveniles utilizing the epibenthic habitat during the day do move offshore at night but only into the area within 100 m of shore. The juveniles utilizing the pelagic zone do not appear to move farther offshore at night.

As discussed previously, the catch of chum juveniles with the townet did not decrease around the perimeter of the piers, although these transects were far enough from shore (up to 400 m) that a decrease was to be expected. The catch was higher for the transect inside EHW than for all other transects. Thus, we conclude that there was an offshore movement of the juvenile chum around the piers and also a buildup of juveniles inside the perimeter of the one wharf studied, perhaps due to lights. Before it can be accepted that this response of offshore movement may lead to increased predation on chum - as suggested by Gilhousen (1962) and Heiser and Finn (1970) for nearshore migrants - it must be shown that those chum captured around the wharves came, at least in part, from the nearshore zone.

The chum caught in the nearshore zone with the beach seine have a mean size smaller than those caught simultaneously with the townet in the pelagic zone (Fig. 11). After this initial increase in size with increasing distance from shore, there is no further increase until over 300 m from shore when again there is an increase in mean size (Table 3a). The townet transects along the east shore vary from 75 m from shore, on unobstructed shorelines, to 400 m from shore around the Refit Pier.

Table 2. Analysis of variance to show differences in CPUE of chum fry with the surface townet between (a) all transects and (b) the parallel transects from April to July 1979.

a)

Shoreline transects 1979
ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance of F
Total	166.932	280	.596		
Cells	122.826	26	4.724	25.996	<<.001
Location	26.669	15	1.778	9.754	<<.001
Week	99.200	11	9.108	49.626	<<.001
Error	18.172	100	.182		
Interaction	25.933	154	.168	.927	.667

Significant groups in multiple comparison*

Location	$\bar{x}$	Groups 1	Groups 2	Groups 3	Groups 4
Inside EHW	1.9496	|			
Service Pier	1.5258		|		
S. Carlson Pt. (75 m)	1.3107		|	|	
S. Carlson Pt. (125 m)	1.1397			|	|
Marginal Wharf	1.1331			|	|
S. Carlson Pt. (160 m)	1.0322			|	|
Outside EHW	.9759			|	|
Spit 6 — Spit 5	.9671			|	|
S. Floral Pt.	.9567			|	|
Spit 5 — Spit 4	.9343			|	|
S. Carlson Pt. (225 m)	.9318			|	|
S. Carlson Pt. (300 m)	.9303			|	|
Spit 4 — Brown Pt.	.8749			|	|
S. Carlson Pt. (550 m)	.8136				|
Delta Pier	.8117				|
Spit 4	.7343				|

b)

Parallel tows 1979
ANOVA summary table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	16,355.894	95			
Location	4,651.578	5	930.316	7.15	p < .0005
Error	11,704.317	90	130.048		

Significant groups in multiple comparison*

Distance from shore (m)	75	125	160	300	225	550
$\bar{x}$	36.74	26.41	23.83	19.47	17.50	16.09
Groups 1	|					
Groups 2		|	|	|	|	|

*Locations which are not significantly different from each other at the 5% significance level are encompassed by the same line.

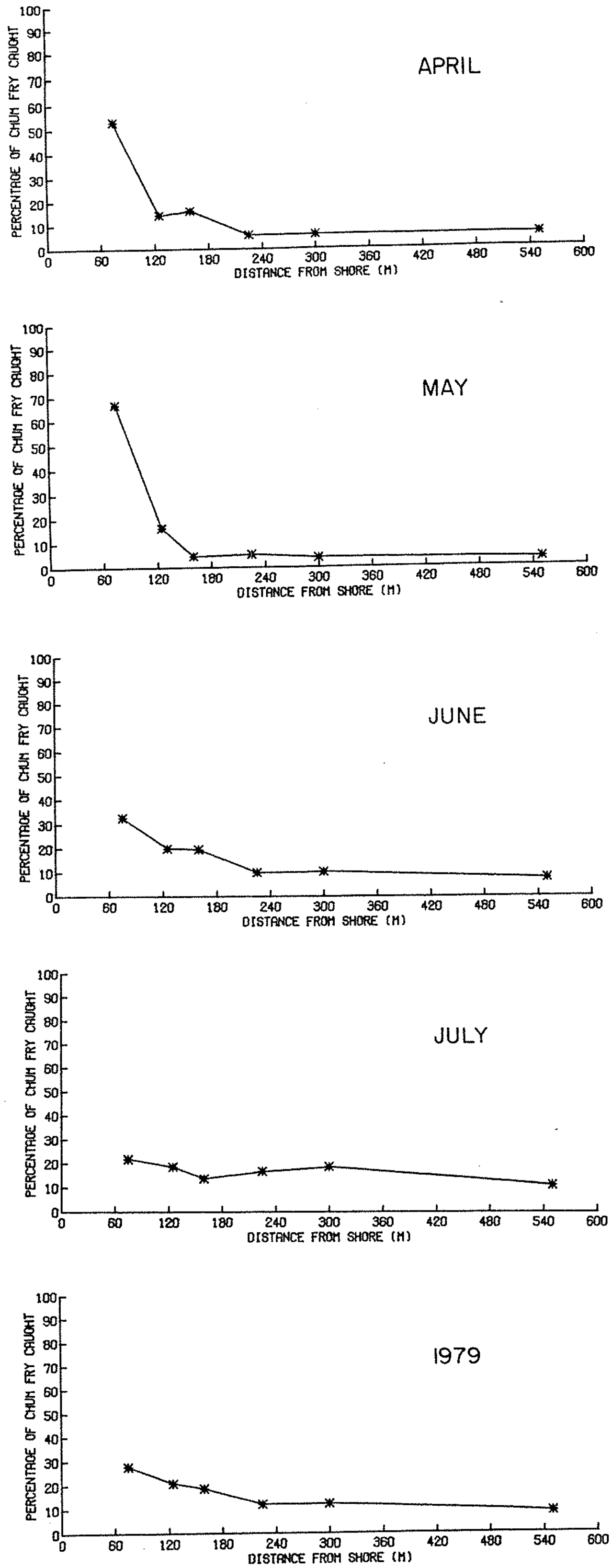

Fig. 10. Effect of distance from shore on the CPUE of juvenile chum on parallel townet transects in 1979.

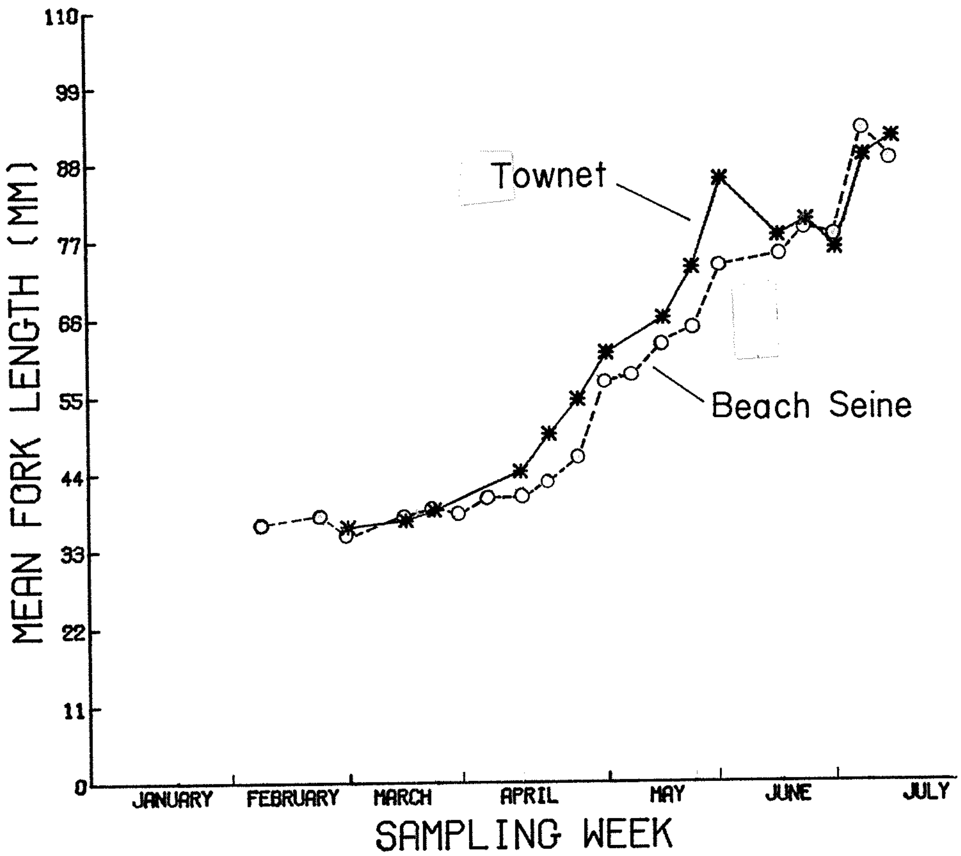

Fig. 11. Comparison of the mean length of chum juveniles caught with the beach seine and the townet in 1979.

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

a) Parallel Transects

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	656041.019	2402			
Cells	142769.519	8	17847.190	84.378	<<.001
Location	2733.035	5	546.607	2.584	.025
Week	140572.781	3	46857.594	221.546	<<.001
Two-way interaction	10106.339	15	673.756	3.186	<.001
Error	503165.161	2379	211.503		

Significant groups in multiple comparison*

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

b) Shoreline Transects

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance
Total	632975.244	2912			
Cells	78030.182	9	8760.020	47.583	<<.001
Location	25235.069	6	4205.845	23.082	<<.001
Week	61149.630	3	20383.210	111.867	<<.001
Two-way interaction	29087.982	17	1711.058	9.391	<.001
Error	525857.080	2886	182.210		

Significant groups in multiple comparisons*

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

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

Along these transects the mean size would be expected to be constant or increasing slightly offshore around the piers. A two-way analysis of variance, with the lengths of chum fry as the dependent variable and sampling transect and week as the independent variables (Table 3b) was run using only weeks with catches of at least 25 chum juveniles per transect. Two distinct groups of transects were distinguishable. The three transects at the south of the base, from King's Spit to the Refit Pier, had a larger mean size of chum than the four transects at the north of the base from Marginal Wharf to Floral Point. Length frequency distributions of the catches showed the decrease in the mean size at the north of the base to be due to an increased number of smaller fish, while the range of sizes remained the same. An example of these data for July 4 is given in Figs. 12 and 13. This decrease in mean size was still evident at Floral Point after the major wharves had been passed. Apparently some chum in the nearshore environment moved offshore when they encountered shoreline structures and did not pass through the trestles. Although at the EHW in 1979, we found no significant predation (Salo et al. 1980), such an offshore movement would be expected to increase the availability of the juveniles to predators.

Environmental Variables

The effect of environmental factors - tidal direction, tide height, water temperature (recorded as the deviation from the weekly mean temperature for all sampling sites), sea state (measured on the Beaufort scale), wind direction, weather conditions (measured on a scale from 0 to 6 corresponding to clear and sunny, through hail and snow), and the time of year (sampling week) - on the catches of chum juveniles with the townet and with the beach seine was investigated. Data from February to July were used in the analyses. The beach seine and townet data were treated separately, as it was thought that environmental factors might affect the efficiency of these gears or affect the chum juveniles in the areas sampled by these gears differently.

Initially, the effect of tidal direction, a nominal variable, was tested by a t-test. No significant differences in CPUE were found for the townet data (Table 4). For the beach seine data it appeared that tidal direction influenced catches at sites with a northern exposure but not at sites with a southern exposure. Tidal direction on catches have not been consistent over the 5-year study. No effects were found on 1978 catches (Bax et al. 1979), while in 1977 there appeared to be a strong influence of tidal direction on catch, although the data needs to be reexamined to account for diel sampling variation (Bax et al. 1978). The 1979 beach seine data were separated by tide stage before entry into the multiple regression analyses.

A backward elimination procedure was used in these regressions. This procedure enters all variables into the equation on the first step, and then removes variables one at a time until the best regression fit

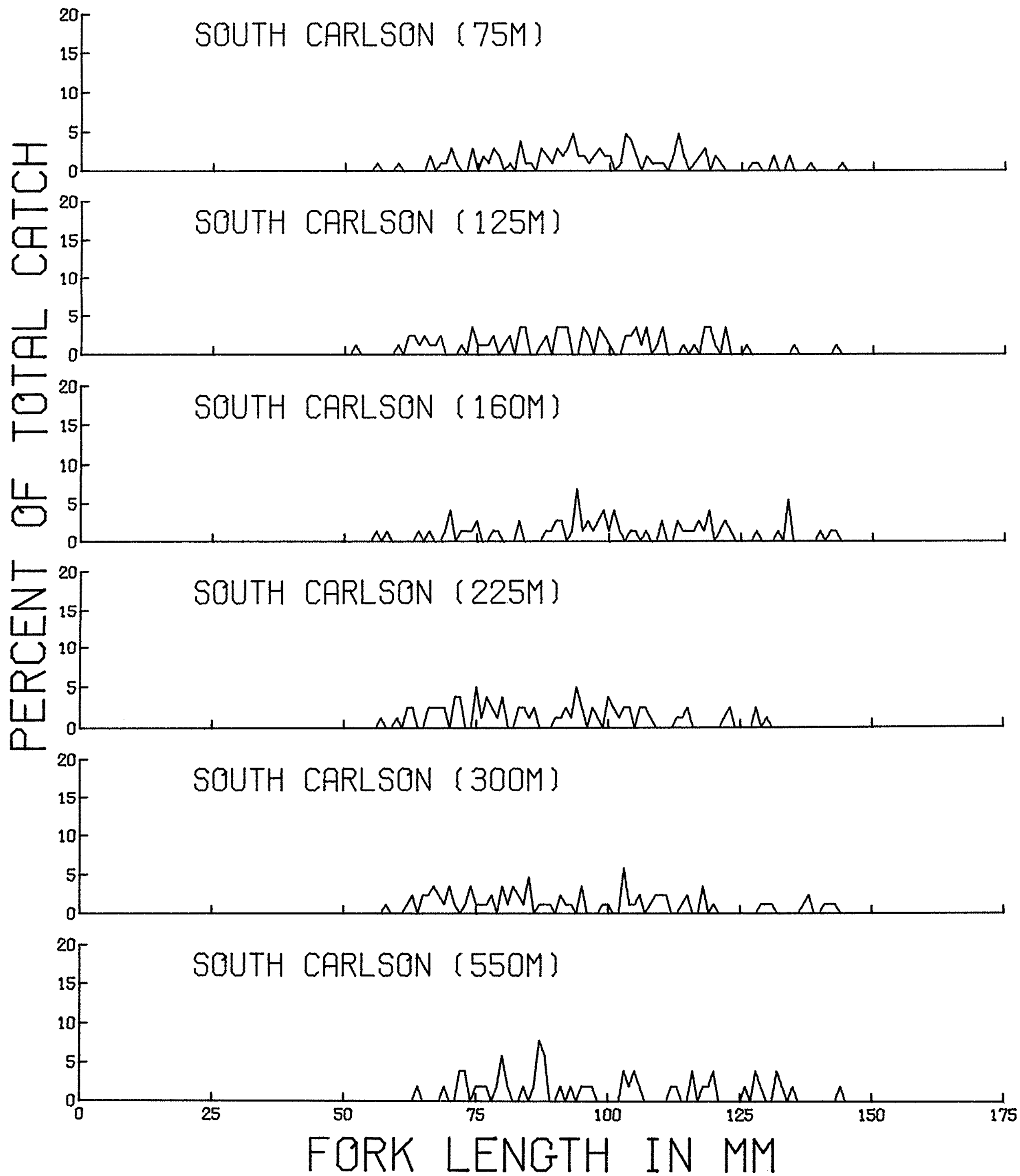

Fig. 12. Percent length frequency distribution of juvenile chums caught with the surface townet at varying distances from shore on July 4, 1979.

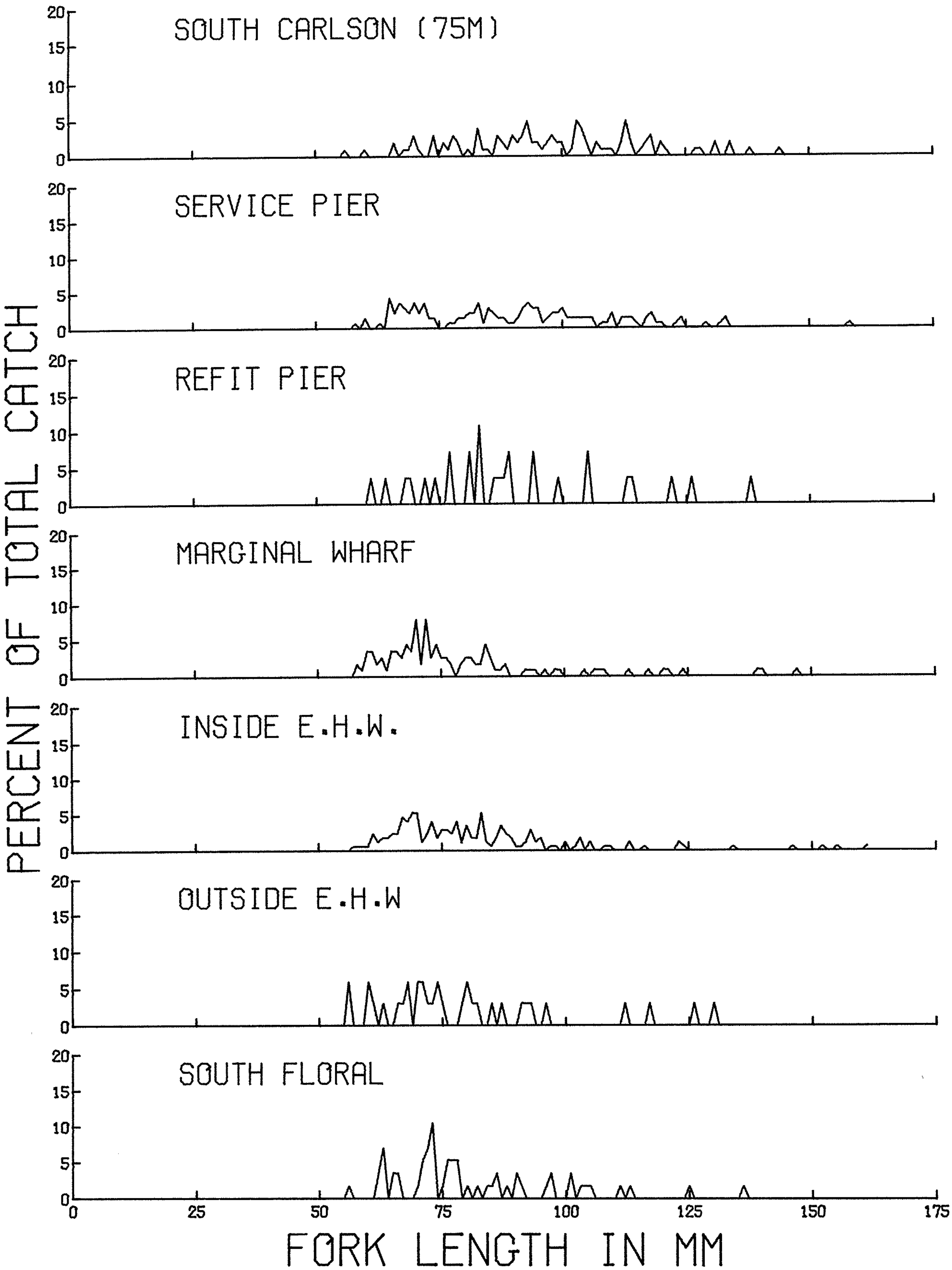

Fig. 13. Percent length frequency distribution of juvenile chums caught with the surface townet along the Bangor Annex shoreline on July 4, 1979.

Table 4. Analysis of tidal effects on the CPUE of chum fry caught in 1979.

Variable	Number of cases	Mean	T-statistic	Significance
		Surface townet		
Ebb	192	.753	- .75	.453
Flood	139	.815		
		Beach seine — northern exposure		
Ebb	59	.995	2.69	.008
Flood	54	.618		
		Beach seine — southern exposure		
Ebb	58	.703	-1.26	.211
Flood	53	.860		

is found. This procedure has less theoretical deficiencies than the forward inclusion method (Mantel, in Zar 1974). The exception to this was the sampling week which was always the last variable to be eliminated, if necessary, to prevent seasonal trends in CPUE affecting the choice of variables.

The variable explaining most of the variability in CPUE trends was sampling week. The other variables remaining in the equations are tide height and weather conditions (Table 5). There has been little consistency from year to year in the apparent effect of environmental variables on catch data.

Chum salmon juveniles have been shown in other studies to respond to changing environmental conditions such as temperature (Bessey 1972), salinity (Houston 1957, Baggerman 1960, McInerney 1964), photoperiod (Hoar et al. 1957, Kobayashi 1960, McDonald 1960, Kobayashi and Sasaki 1965) under laboratory conditions but, there is little evidence available in the literature on any effect of environmental variables on the distribution of chum juveniles under natural conditions, with the exception of photoperiod. It must also be considered whether any change in catch correlated with an environmental variable is due to a change in the distribution, a change in the catchability of the chum, or alternatively, due to a change in the gear efficiency of the net. As Reynolds (1977) suggests:

> "where netting . . . is used in fish sampling studies an artifact might be introduced by a possible effect of temperature on . . . ability to escape from an area being netted."

Variables such as weather conditions, sea state, or light could be adversely affecting the catch efficiency of the net, leading to significant relationships between catch and environmental variables. More detailed analysis of the 5 years of data may show some consistent factors. Tidal effects especially require further investigation which will be reported in Bax (Ph.D. Dissertation in preparation).

Effects of Low-Level Pier Lighting at EHW

The effects of the low-level pier lighting at EHW on the distribution of chum was studied in 1979 (see Prinslow et al. 1980 for details). Briefly, a ratio of the catches of chum at EHW with the catches at Floral Point was formed. This eliminated the effect of weekly variations in juvenile abundance from the data. The ratio when no low-level lighting was present was then compared with the ratio when low-level lighting was present to find any increase in abundance at EHW associated with the low-level lighting. No increase was found in either the beach seine or townet catches (Table 6).

Table 5. Linear regression equations describing the effect of measured environmental variables on the CPUE of chum fry in 1979.

Variable in equation	Partial regression coefficient	F	Significance of F	Constant	Overall R^2	Overall F	Overall significance
			Surface townet				
Week	.740	350.205	<< .001				
Tide height	.022	4.170	<< .042	- 1.295	.569	122.682	<< .001
Wind	.032	2.605	.108				
			Beach seine — ebb tide				
Week	.471	26.435	<< .001				
Weather	- .177	3.441	.066	.558	.258	16.107	<< .001
Tide height	.086	1.678	.197				
			Beach seine — flood tide				
Week	.527	41.941	<< .001				
Sea state	- .208	2.499	.117	.344	.359	20.716	<< .001
Tide height	.140	6.247	.014				

Table 6. Comparison of the ratio of CPUE at EHW to CPUE at Floral Point for chum salmon fry during lit and unlit conditions, February to 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

Hatchery Influence

Chum Salmon. In 1979 the nearshore and offshore abundance of chum juveniles on the east and west sides of Hood Canal underwent similar changes and so will be dealt with together.

After early peaks in abundance, attributable to natural production, two major peaks in abundance were observed, in mid-April and from mid-May to early July (Figs. 4 and 5). With the exception of an early, and relatively large release from the Hunter Springs hatchery, hatchery releases in 1979 were fairly uniform from mid-April to late June (Fig. 14). This makes analysis of the speed of migration of individual releases difficult. The first of the two major peaks occurred 1 week after the first hatchery release from the Hood Canal hatchery and 4 weeks after the large early release from the Hunter Springs hatchery. Previous years' data (Bax et al. 1978; Bax et al. 1979) and mark-recapture data in 1979 (Salo et al. 1980) make it appear unlikely that the migration speed of the chum juveniles would be slow enough so early in the season for the peak to have resulted from the Hunter Springs release. While the Hunter Springs chum were smaller at time of release than the remaining hatchery-reared chum released into Hood Canal in 1979, they were no smaller than chum released at the same time in previous years, so we would not expect their size to have caused such a large change in migration speed. At the same time, the Hood Canal hatchery releases which were from 1.5-2.0 million/week for four consecutive weeks do not explain the dramatic rise in abundance over only 1 week. The lack of a large increase in abundance of chum juveniles at Bangor Annex in the first 2 weeks following the release of 12.8 million juveniles from Hunter Springs hatchery suggests that the behavior of those juveniles was abnormal as manifested by changed migration timing and/or disproportionately high early marine mortality.

At the end of the sampling season the abundance of chum juveniles dropped 2 weeks after the final releases of chum fry from the Quilcene hatchery.

Coho Salmon. The peaks in abundance of coho salmon smolts at Bangor Annex can often be related to hatchery releases and the outmigration of adipose fin-clipped smolts from Big Beef Creek and other streams in Hood Canal.

After a small increase in abundance in mid-March before hatchery releases, abundance increased again in late April as indicated by catches in the beach seine for the nearshore zone and in mid-May as indicated by the townet catches further offshore (Figs. 6 and 7). This increase followed hatchery releases from the Hood Canal, Quilcene, and George Adams fish hatcheries (Appendix Table 1). At the same time the abundance of Big Beef Creek smolts (thought to comprise the initial peak of fin-clipped smolts) increased, peaking one and two weeks after peak outmigration from Big Beef Creek in the beach seine and townet catches,

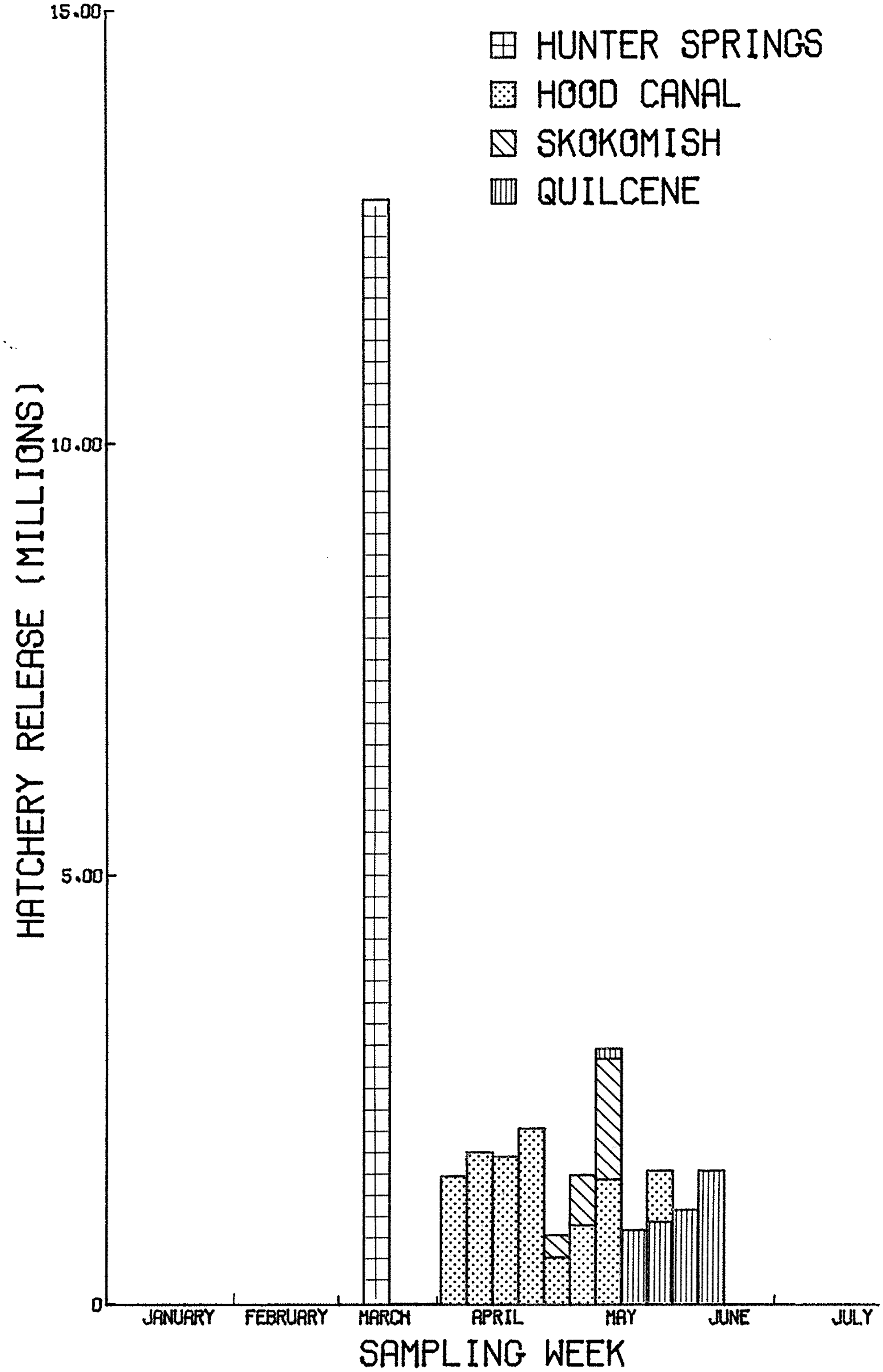

Fig. 14. Releases of chum juveniles into Hood Canal from the Hunter Springs, Hood Canal, Skokomish, and Quilcene fish hatcheries, 1979.

respectively (Appendix Table 2). The majority of the Big Beef Creek smolts passed through the Bangor Annex area rapidly as evinced by the transitory increase in abundance there.

The first peak of unclipped coho smolts in the offshore area, thought to be of hatchery origin, was in early June two weeks after a large release from the George Adams fish hatchery. Abundance in the nearshore zone peaked one week later. The second major peak, in early July in the offshore area, followed one week after a release from the Hood Canal fish hatchery. Nearshore abundance had yet to peak again at the end of sampling in mid-July.

There is yearly variation in the migration speed of the coho smolts migrating from Big Beef Creek. In 1977, peak abundance of Big Beef Creek coho at Bangor Annex followed one week after peak outmigration from Big Beef Creek (Bax et al. 1978). In 1978 the delay increased to three weeks (Bax et al. 1979), and in 1979 decreased back down to 1-2 weeks, as mentioned above. The slower migration speed in 1978 was not restricted to the coho smolts from Big Beef Creek. Data from mark-recapture studies on Big Beef Creek hatchery-reared chum salmon showed that their migration speed was slower in 1978 than in 1977 or 1979 (Table 7, data from Salo et al. 1980). As yet we do not know the cause of these annual variations in migration speed common to Big Beef Creek chum and coho. Furthermore, we do not know whether to attribute the changes to yearly fluctuations of unknown cause or to an odd/even (or other) yearly cycle effect. Closer examination of the 1976 catch data in relation to hatchery releases may answer the latter question for chum. Similar annual changes in migratory behavior have been observed for chum salmon in Prince William Sound (Cooney, personal communication)[3], although the data were confounded because the measurements were of different stocks in the two years studied.

Chinook Salmon. The number of chinook salmon smolts caught was not high, despite large hatchery releases. This may have been due to gear avoidance by these larger fish, or differing migration strategies between the salmonid species. Miller et al. (1977) found that whereas a floating beach seine was most effective for chum, a sinking seine was most effective for chinook.

The three peaks in the catches, early to mid-May, late May and mid-June (Fig. 8) reflected hatchery releases from the Hood Canal and George Adams fish hatcheries occurring from 2-5 weeks before the peaks in catches at Bangor (Appendix Table 1). The releases from the Quilcene fish hatchery in late June to early July may not have been fully detected because sampling ceased shortly thereafter. Some of the variation in time taken to reach the Bangor Annex from time of release may be

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[3]R. Ted Cooney, Institute of Marine Science, University of Alaska, Fairbanks, Alaska, 99701.

Table 7. Migration speed (km/day) of juvenile chum salmon released into Hood Canal from Big Beef Creek during the first 3 days. (Data from Salo et al. 1980).

	1977	1978	1979
February	12	4	9
March	14	4	14
April	—	—	7
May	9*	—	—
June	4*	—	4

*Released from Hoodsport.

explained by the size of the smolts. The first group, which took 4-5 weeks to reach Bangor Annex, were 223/lb when released and were intercepted chiefly with the beach seine. The second group was 100/lb when released from the Hood Canal hatchery and took only two weeks to reach the sampling area, where they were intercepted with both beach seine and townet. The third group may have been comprised of both George Adams and Quilcene releases so the above interpretation is not possible.

Length-Weight Data

Length Data

The length data in 1979 were found to be normally distributed with homogenous variances and thus suitable for parametric statistical testing. Due to the number of data records involved, weekly mean lengths at each site for each gear were used in the majority of analyses. To test the specific hypothesis of the offshore movement by nearshore-oriented juveniles, length frequency data from days of high fish abundance were analyzed. The results of this analysis have been presented previously under "Site Preference - Offshore" in this report.

Chum Salmon. The mean length of chum salmon juveniles caught with the beach seine and townet started rising from 35-40 mm in early April as hatchery-reared juveniles first started arriving at Bangor (Fig. 11). By the end of the season, in July, the juveniles mean length was about 90 mm. Overall, the mean size of townet-caught chum was higher than that of beach-seine-caught chum ($.02 < p < .05$); although at the beginning and end of the sampling season their mean lengths were similar.

The higher overall mean length of chum juveniles caught offshore with the townet than those caught in the nearshore zone with the beach seine agrees with data from previous studies. Most authors have found a distinct size range at which chum fry move offshore. Allen (1974) found a "definite movement offshore" when the juveniles were approximately 75 mm. Sano and Kobayashi (1952) found that offshore movement occurred when the juveniles were between 70 and 100 mm, and Sano (1966) found juveniles in a different area not moving offshore until 100-120 mm in length. This offshore movement has sometimes been recorded as accompanying a distinct change in maximum size of prey organisms taken by the chum as they moved offshore at 50-60 mm in length (Okada and Taniguchi 1972). Other authors have found definite behavioral changes, the juveniles responding to danger by diving deeper offshore instead of scattering across the surface as they had in the nursery areas (Cooney et al. 1978). In contrast to this distinct offshore movement, the movement offshore in Hood Canal as seen in this study and by Gerke and Kaczynski (1972) is a gradual process occurring at no distinct size range or time of year, although few chum are caught offshore until early May, when a dramatic change in food selection to pelagic prey organisms occurs.

After this time many of the chum juveniles caught with the beach seine have been feeding on pelagic organisms. It has been suggested (Salo et al. 1980) that the pelagially feeding juveniles might return to the nearshore area for its structural protection from predators. The lack of a distinct size at which juveniles move offshore may be due to the predominance of hatchery juveniles in Hood Canal. The hatcheries release juveniles of a larger initial size on entry into salt water as the season progresses, and if the offshore movement is dependent upon the time spent in the nearshore zone, as well as size, then it would be expected that the mean size at which offshore movement occurs would increase correspondingly as the season advances.

The weekly mean length of chum caught at individual locations was determined to find any effects of locality on fish size. A two-way fixed effects analysis of variance with the independent variables, sampling week and sampling location was run so that any locality effects would be examined independent of time of year. For the beach seine samples, of all sites sampled, three - south Carlson and south and north Floral Points - had higher mean lengths than at the remaining sites (Table 8 and Fig. 15). Additionally, juveniles of a smaller mean length were caught at west shore sites than at comparable sites on the east shore.

The trend for juveniles larger than the overall mean size to be caught at the sites on the exposed spits on the east shore has not been noticed in previous years; however, the converse, that is, juveniles of a smaller size than the overall mean being found in the sheltered "nursery" areas at Devil's Hole and at EHW, was noticed in 1978 (Bax et al. 1979). The nocturnal sampling shedule may have also effected this trend. It would be informative to reanalyze the 1977 length data separately for night and daytime sampling.

The difference in juvenile characteristics - length, condition factor, and time of arrival at the Bangor Annex area - between chum sampled on east and west shores has been noticed in previous years. It has been suggested (Salo et al. 1980) that the east and west shore groups are distinct from early on in their outmigration from Hood Canal, even though the majority enter Hood Canal from hatcheries and rivers on the west shore and some cross over before reaching Bangor Annex. Whitmus and Olsen (1979) found that approximately half of the marked juveniles released from the Hood Canal fish hatchery in 1977 crossed immediately to the east shore.

The mean length of chum caught with the townet did not vary between locations when the whole season's data were considered. As discussed above, when individual days' data were examined differences were found with an increase in mean size at more than 300 m from shore and a decrease in mean size offshore around the piers and wharves of the Base (Table 3). The different results from the two methods of analysis reflect that a large number of zero catches entered into the former

Table 8. A comparison of the weekly mean lengths of chum fry caught with the beach seine at different locations in Hood Canal, Washington, 1979.

Source of variation	Sum of squares	Degrees of freedom	Mean square	f	Significance
Total	65197.016	161			
Cells	61566.582	30	2052.219	74.052	< .001
Location	1105.853	11	100.532	3.628	< .001
Week	58704.401	19	3089.705	111.488	< .001
Error	3630.434	131	27.713		

Significant groups in multiple comparisons*

Location	$\bar{x}$	Groups		
S. Carlson	68.96	│		
N. Floral	66.04	│		
S. Floral	65.57	│		
Devil's Hole	60.76		│	
N. Carlson	60.69		│	
S. EHW	59.94		│	│
S. Marginal	59.90		│	│
S. Spit 6	58.58		│	│
N. Brown	58.40		│	│
N. Spit 6	56.34		│	│
S. Brown	55.50		│	│
N. EHW	54.82			│

*Locations not significantly different from each other (p = .05) are covered by the same line.

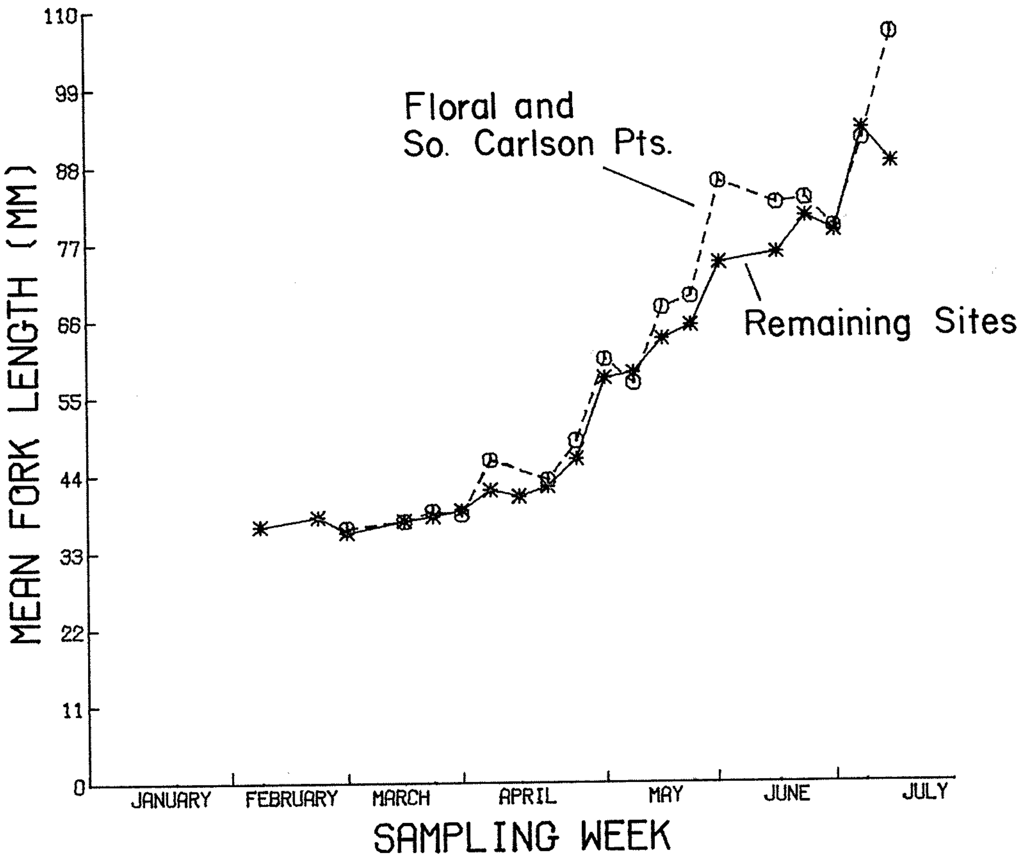

Fig. 15. Comparison of the mean length of chum fry caught at Floral Point and South Carlson Point with the remaining beach seine locations at Bangor Annex in 1979.

analysis, as often no fish were caught on many of the transects. Additionally, the method does not take the sample size of the catch into account, leading to a disproportionate contribution to the overall data from small samples and far fewer degrees of freedom than would be present if the data from the individual fish were used.

Coho Salmon. There were insufficient length data on coho smolts to analyze location effects, so only overall trends will be discussed.

The same trends were apparent in beach seine and townet catches (Fig. 16). The mean length dropped from about 150 mm in early April to less than 100 mm by early July. The decreasing size of captured coho smolts over the sampling season cannot be explained by any change in the size of smolts released from the hatcheries (Appendix Table 1). It is possible that it reflects the natural outmigration of coho smolts from the rivers of Hood Canal. For example, at Big Beef Creek, the largest smolts migrate down the river first (Appendix Table 2); however, there is no subsequent increase near the end of the outmigration as is also seen at Big Beef Creek.

The similarity of size of coho smolts caught with the beach seine and with the townet (Fig. 16) contrasts with the higher mean length of townet-caught chum as compared with beach seine-caught chum (Fig. 11). This similarity in mean length is in spite of the difference in migration timing found between the coho smolts caught with the beach seine and townet (Figs. 6 and 7). These data may be somewhat compromised by the size of the coho smolts approaching the upper range of size selectivity of the townet, of which we have no estimate.

Chinook Salmon. Length data on chinook salmon smolts are limited to overall weekly trends. The size of the chinook smolts rose from 75 mm in late May to 90-115 mm by early July (Fig. 17). Such an increase in size was not found with the hatchery releases over the same period of time (Appendix Table 1), so may indicate growth in the marine environment.

Condition Factor

Length and weight data were used to compute the condition factor of the smolts according to the equation

$$\text{Condition Factor of 5-mm increment group} = \frac{\sum_{i=1}^{n} \frac{\text{Mean weight 5mm increment group}}{(\text{Length}_i)^3}}{n} \times 10^5$$

The mean condition factors for each 5-mm increment size class, at each location, for each week, were computed and used in the analyses.

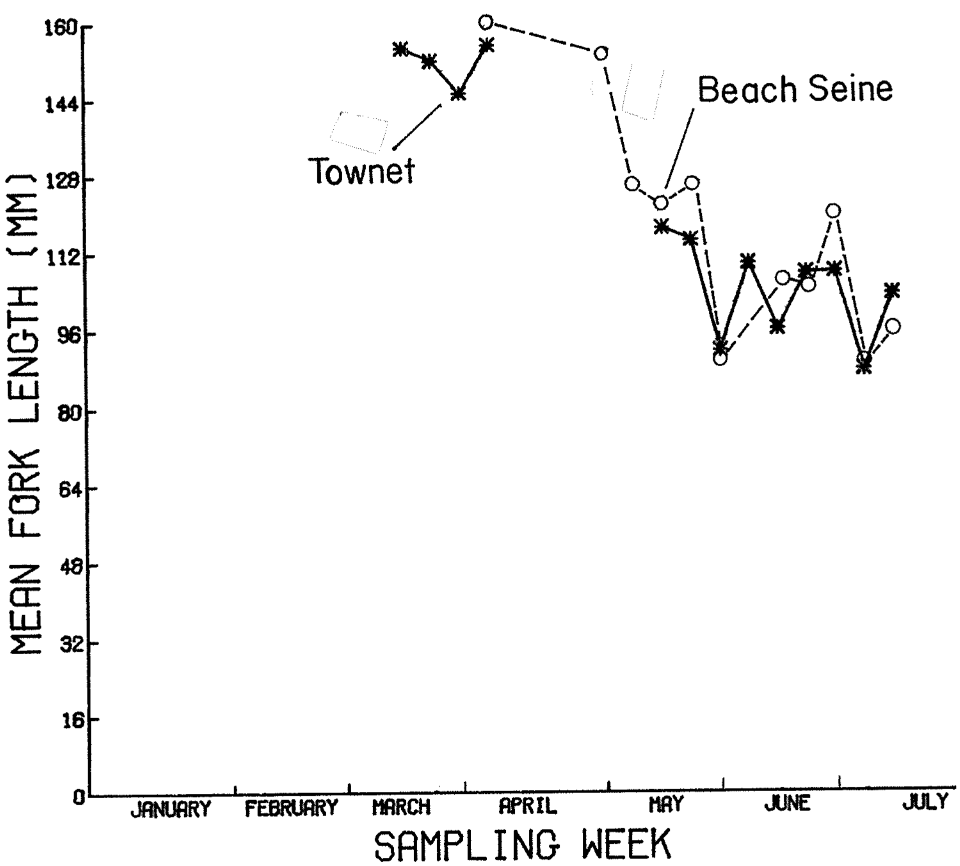

Fig. 16. Comparison of the mean length of coho smolts caught with the beach seine and the townet in 1979.

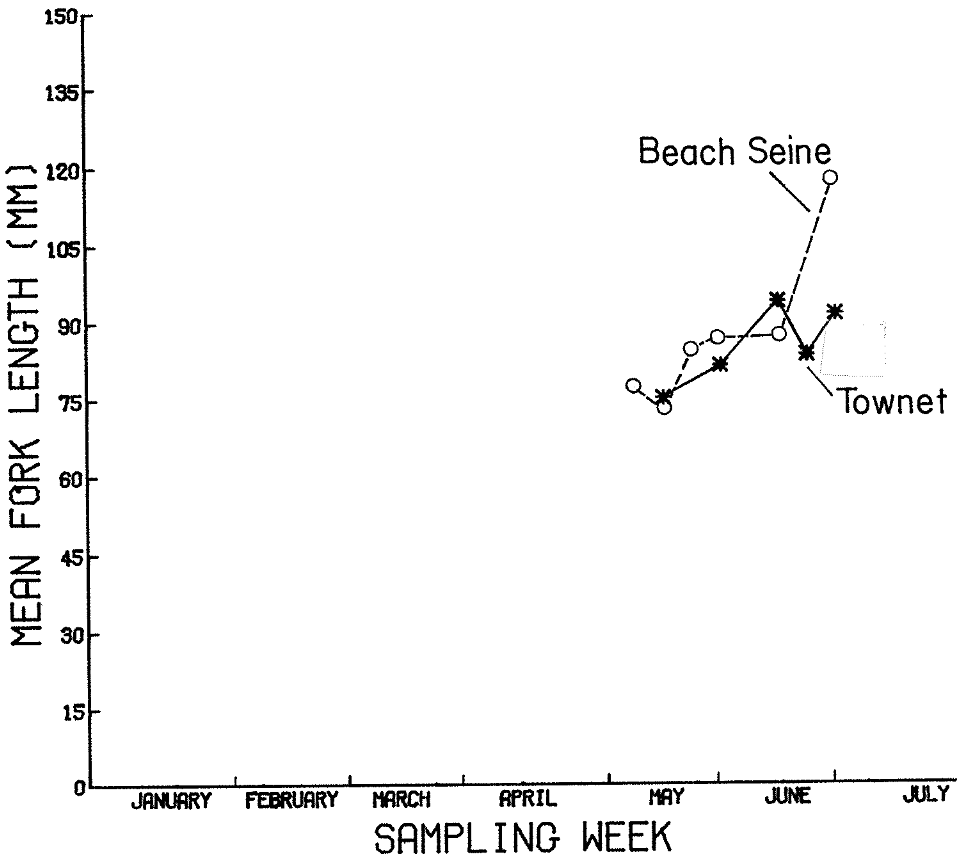

Fig. 17. Comparison of the mean length of chinook smolts caught with the beach seine and the townet in 1979.

The use of this length-weight relationship to describe a fish's condition assumes that the heavier the fish at a given length, the "better" its condition. The difficulties in this assumption as discussed by Abbasov and Polyakov (1978) are that the condition factor describes not only differences in the immediate life history of the fish, but also racial and age characteristics, degree of fullness of intestines, state of gonads, and other features. In our particular instance differences in the "condition" of the fish that we hope to attribute to local habitat differences or preferences may be confounded by differences in racial origins, size or hatchery rearing techniques. The use of the three-way analysis of variance in these analyses takes into account some of the above problems of racial origins, rearing practices, and size differences, by standardizing condition factor with regard to length and week before analyzing location effects.

In use of this (Fulton's) condition factor the exponent in the equation is fixed at 3. This is most likely not the true case (Schreiner 1977); however, the difficulties in defining standard conditions and thus obtaining the exact exponent required for the allometric condition factor are severe. Ricker (1975, p. 209) does state, however, that:

> "Fultons' condition factor can also be used to compare fish of approximately the same length no matter what the value of b (the exponent)."

<u>Chum Salmon</u>. As the data from the townet and the beach seine showed the same trends, they will be considered together.

No sampling location had a significant effect on the condition factor of fish sampled by either gear (Table 9). For both gears there was an increase in condition factor of chum over the sampling season and an increase with size at any one time (Table 9 and Figs. 18 and 19).

Results of the conditions factor analysis have been varible over the duration of this study. In all years there has been an increase in condition factor over the season, although in 1977 there was a drop at the end of the season. The change in condition factor with size at any one point in the season was noted in 1978, but in the opposite direction. The increasing condition factor as the season progresses suggests that conditions are better for chum growth later in the season. Such an increase in condition factor was not found for chum juveniles held in freshwater at Big Beef Creek (Whitmus, personal communication[4]).

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[4]Cliff J. Whitmus, Big Beef Creek Field Research Facility of the University of Washington, Seattle, Washington.

Table 9. Effect of sampling location, sampling week, and mean size on the condition factor of chum fry caught at Bangor Annex, Hood Canal, 1979.

a) Beach seine

ANOVA Summary Table

Source of variation	Sum of squares	Degress of freedom	Mean square	f	Significance
Total	29.852	1171			
Cells	7.033	49	.144	7.057	.001
Location	.321	11	.029	1.436	.151
Week	2.983	19	.157	7.719	.001
Size group	.810	19	.043	2.097	.004
Error	22.819	1122	.020		

b) Townet

ANOVA Summary Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	f	Significance
Total	19.074	1125			
Cells	3.911	49	.080	5.665	.001
Location	.292	15	.019	1.382	.148
Week	.827	9	.092	6.520	.001
Size group	1.712	25	.068	4.860	.001
Error	15.162	1076	.014		

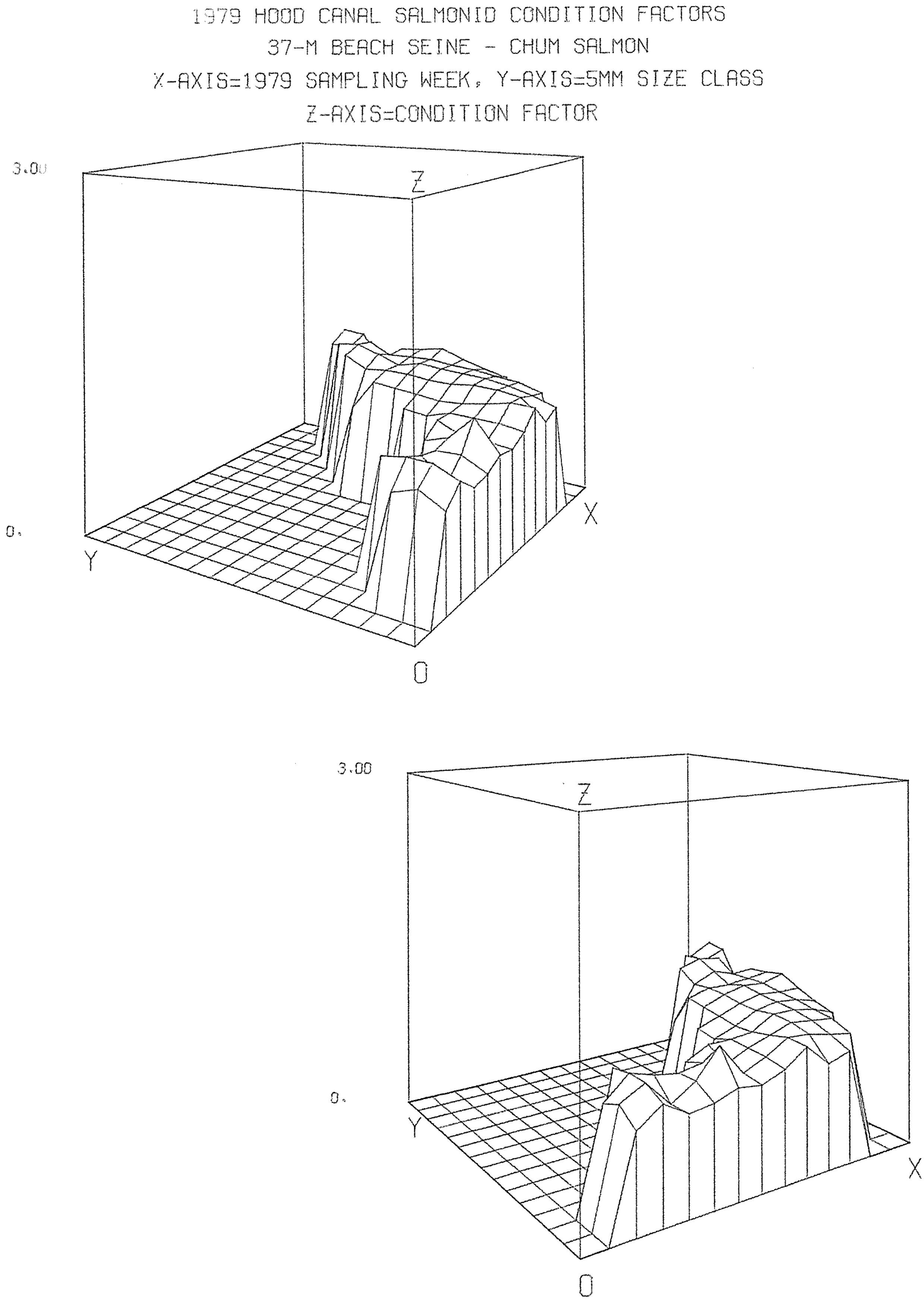

Fig. 18. Three-dimensional plot to show the effect of sampling week and fork length on the condition factor of chums caught with the beach seine at Bangor Annex from January to July 1979 (data are computed on biweekly means).

SURFACE TOWNET - CHUM SALMON
1979 HOOD CANAL SALMONID CONDITION FACTORS
X-AXIS=1979 SAMPLING WEEK, Y-AXIS=5MM SIZE CLASS
Z-AXIS=CONDITION FACTOR

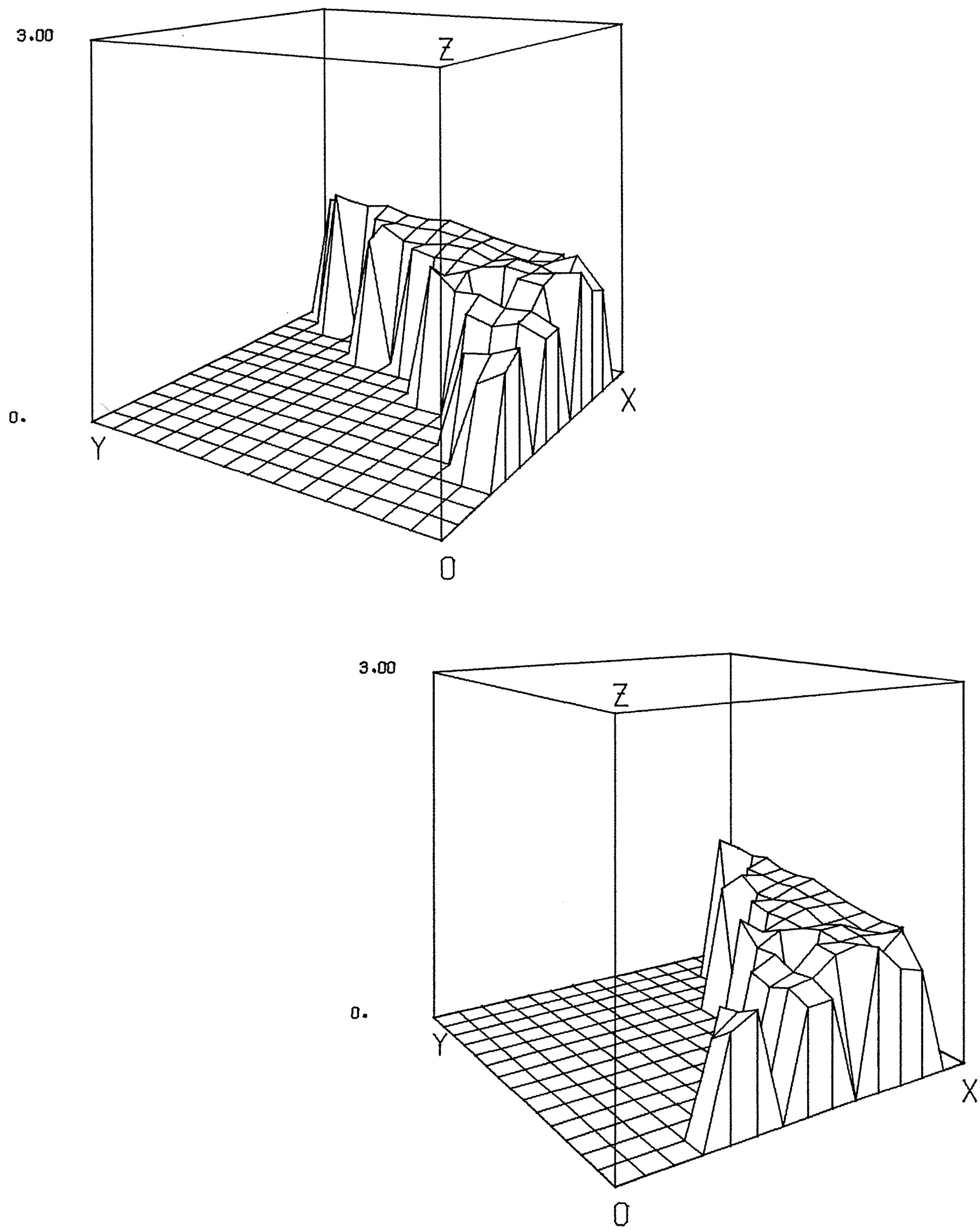

Fig. 19. Three-dimensional plot to show the effect of sampling week and fork length on the condition factor of chums caught with the townet at Bangor Annex from January to July 1979 (data are computed on biweekly means).

SUMMARY

1. Juvenile salmonids were monitored as they migrated along the Bangor shoreline on Hood Canal, site of the construction of four pier facilities for the U.S. Navy's Submarine Base. Floating beach seines were used from January through July and a surface townet from February through July in 1979, as the fifth season of a five-year program.

2. Chum salmon juveniles were the predominant salmonid species captured with peak catches in mid-April and mid-June. Additionally, there were consistently high catches with the beach seine on the east shore from April to June. These peak catches were thought to consist of juveniles of principally hatchery origin.

3. Coho salmon smolts were the second most abundant salmonid captured, with a peak in late May. After this time catches with the townet decreased, while beach seine catches continued to increase until the end of the sampling period.

4. Few chinook salmon smolts were caught until May. There were two peaks in recaptures, mid-May and early June, the earlier one being noticed mainly in beach seine sampling, the later one by both gear types.

5. Significant differences in CPUE of chum juveniles between sites were identified by beach seine. Sites near the wharves, especially EHW, had higher catch than sites at the north, and perhaps at the south of the Base. The extensive littoral zones at EHW and Devil's Hole may have also increased catches in these areas. Beach seine catches were higher on the east than the west shore, whereas from 1975 to 1978 no difference was identified, which may be due to the constructed wharves and new security lighting systems.

6. For the townet sampling, it was found that the transect inside EHW had a higher catch than all the others, and the transect past the Service Pier was second. In the absence of piers, catches decrease rapidly with increasing distance from shore. The large catches offshore around the piers suggest forced offshore migration by the juvenile chum, the smaller of which come from the more protected nearshore environment.

7. The effect of environmental factors, tidal direction, tide height, water temperature, sea state, wind direction, weather condition and sampling week on the CPUE of chum juveniles was examined. Sampling week explained a large amount of the variation in catches. Tide height and weather conditions showed a significant relationship with chum catches, but explained only a small amount of the variation.

8. A yearly variation in the migration speed of coho salmon smolts from Big Beef Creek was noted. This paralleled the variations found for chum juveniles over the same 3-year period, with migration speed slower in 1978 than in 1977 or 1979.

9. Larger chum juveniles were caught with the townet than with the beach seine. The size of the juveniles caught in the pelagic zone did not increase further until more than 300 m from shore. Larger juveniles were caught with the beach seine at the more exposed sites than at the sheltered sites. The difference in length-weight characteristics of the juveniles caught on the east versus the west shore supports the hypothesis of little intermixing of the juveniles between the two shores, after an initial dispersal.

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Appendix Table 1. Releases of coho and chinook salmon smolts from Quilcene, Hood Canal, and George Adams fish hatcheries into Hood Canal, 1979.

Quilcene Fish Hatchery (USFWS)				Hood Canal Fish Hatchery (WDF)				George Adams Fish Hatchery (WDF)			
Date of release	Fish* species	Number released	Fish/1b	Date of release	Fish* species	Number released	Fish/1b	Date of release	Fish* species	Number released	Fish/1b
March 25	Coho	209,000	810	Feb. 22	S/FCS	302,003	13	May 14	Coho	936,051	30
April 22	Coho	172,700	19-480	April 12	FCS	49,952	223	May 30	FCS	185,399	120
May 6	Coho	406,000	20	May 18	FCS	1,574,000	100				
May 20	Coho	24,611	18	June 29	Coho	477,990	15				
June 24	FCS	659,147	98								
July 1	FCS	557,710	97								

*FCS - Fall chinook salmon
S/FCS - Spring and fall chinook salmon

Appendix Table 2. Weekly release of fin-clipped coho smolts from the Big Beef Creek wild outmigration into Hood Canal, Washington, 1979.*

Week	Total tag release	Mean length of tag release (mm)
Prior to April 15	0	
April 16 - 22	0	
April 23 - 29	2,049	125
April 30 - May 6	9,150	110
May 7 - 13	10,050	102
May 14 - 20	6,852	99
May 21 - 27	3,389	99
May 28 - June 3	913	104
June 4 - 10	250	110
June 11 - 17	70	112
Total released	41,723	

*Data from R. Lynne McComas, University of Washington, and David Siler, Washington State Department of Fisheries, Olympia, Washington.