Juvenile Salmon Utilization of Rejuvenated Tidal Channels in the Squamish Estuary, British Columbia

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JUVENILE SALMON UTILIZATION OF REJUVENATED TIDAL CHANNELS IN THE SQUAMISH ESTUARY, BRITISH COLUMBIA

by

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ABSTRACT

Ryall, P. and C. D. Levings. 1987. Juvenile salmon utilization of rejuvenated tidal channels in the Squamish estuary, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1904: 23 p.

In 1984, a 600 m long channel was excavated through disrupted habitat at the Squamish River estuary in order to reconnect natural tidal channels blocked by port construction. Tidal access was increased about 87% during spring tides. Juvenile coho (Oncorhynchus kisutch) and chum (O. keta) and a variety of non-salmonids used the channel and the reconnected habitat. Catches of coho in beach seines were comparable to or greater than those at reference habitats. Residence time of coho introduced to the restored area was about 10 d and 3 d in the middle and end of the outmigration, respectively. Coho fry from the reconnected channels fed on adult insects and stomach contents as a percent of body weight were similar to natural sites. Chum fry catches and residency estimates at the reconnected channels were also comparable to or greater than those at reference habitats.

RESUME

Ryall, P. and C. D. Levings. 1987. Juvenile salmon utilization of rejuvenated tidal channels in the Squamish estuary, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1904: 23 p.

En 1984, on a creusé un chenal de 600 m de longueur à travers un habitat perturbé de l'estuaire de la rivière Squamish afin de raccorder les chenaux naturels de marée bloqués par la construction du port. Pendant les marées de vive eau, la mer a pénétré 87% plus loin. Les saumons coho (Oncorhynchus kisutch) et kéta (O. keta) juvéniles ainsi qu'une variété de poissons autres que des salmonidés ont utilisé le chenal et l'habitat nouvellement disponible. Les prises de coho à l'aide de sennes de rivage étaient semblables ou supérieures à celles obtenues dans des habitat étalons. Au milieu et à la fin de la dévalaison, le saumon coho est resté environ 10 j et 3 j respectivement dans cet habitat rétabli. Les alevins do coho présents dans ces chenaux ont consommé des insectes adultes; leurs contenus stomacaux exprimés en pourcentage du poids corporel étaient semblables à ceux de cohos vivant dans des habitats naturels. Les prises d'alevins de kéta et les estimations de leur séjour dans les chenaux remis en état étaient aussi semblables ou supérieures à celles observées dans des habitats étalons.

INTRODUCTION

The Squamish River estuary, located 50 km north of Vancouver, B.C. was the location of a habitat restoration program to reactivate a channel that had limited access to the ocean. The channel is located on the northern portion of the Squamish River's central delta (see station 1; Fig. 1). This network of channels was blocked from the influences of tidal cycles by the deposition of dredge spoil in 1972, during the construction of a river training dyke and channel stabilization work on the Squamish River (Levings 1980). Before reactivation there was a minor tidal connection (Fig. 1) to the central basin that flushed water into the right branch of the rejuvenated channel (A; Fig. 1) at tide heights of 4.1 m and greater (estimated by extrapolations from tide book[1]). Examination of the Canadian Tide and Current Tables (1984) from May 1 to Aug. 31, 1984 reveals that the tides higher than 4.1 m occur only 26% of the time. Prior to excavation tidal flucuations of up to 4.8 m were required to bring water into the left channel (B; Fig. 1). Tide heights greater than 4.8 m from May 1 to Aug. 31, 1984 are not recorded in the Canadian Tide and Current Tables (1984). Therefore, prior to excavation fish species had limited access to the right channel (A) and no access to the left branch (B).

On June 13-15, 1984, a 2.0 m wide by 600 m long channel was excavated with a backhoe, connecting the blocked channel to a channel currently open to lower tidal fluxes and the Central Basin (Figs. 1). The floor of the channel was excavated to about 1 m below the local elevations, enabling tides of approximately 3.5 m to flood the rejuvenated channels. Over the period June 15 to August 30, 1984, this represented an 87% increase in the number of high tides that would reach into the rejuvenated area (i.e., 27 tides without channelizing; 139 tides with channelizing) via the excavated channel. The reactivation of the blocked channel, therefore, made accessible an additional 1100 m of pools and waterways for the rearing juvenile salmonids. In addition, it is now possible to connect the reactivated channel to other tidal channels in the central delta (C; Fig. 1).

The importance of estuarine habitats for rearing juvenile salmonids has been documented by numerous authors (e.g. Congleton and Smith 1976; Healey 1979, 1980; Sibert 1979). During the time period juvenile salmonids reside in estuarine habitat they feed, increase in size considerably, and then move into the marine environment. There is evidence that estuary resident chinook (<u>Oncorhynchus tshawytscha</u>) of the Sixes River, Oregon had a higher survival rate than non-residents (Reimers 1983). Salmon which resided in the estuary as juveniles contributed a larger proportion of the returning adult population. Estuaries are also possibly utilized for seawater acclimation (Dorcey et al. 1978).

The purpose of the present study was to document the restoration of

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[1]The tidal height required to flush water into the rejuvenated channel (A; Fig. 1) was measured by noting the time of water entry during a tidal cycle (Sept. 22, 1984) and calculating the intermediate tide height from the Canadian Tide and Current Tables (1984).

the channel and to document the utilization of the rejuvenated channel by juvenile salmonids as compared to other tidal channels in the delta.

METHODS

STUDY AREA

The study area was on the central delta (est. 64 ha) of the Squamish River estuary (Fig. 1). The southern portion of the central delta is an intertidal marsh with a plant community dominated by the sedge, *Carex lyngbyei*. The northern portion of the central delta is above highwater datum and is dominated by true grasses (*Deschampia* spp.), shrubs, and trees, such as Red Alder (*Alnus rubra*). As a result of variation in runoff, peaking at about 700 $m^3 \bullet s^{-1}$ (daily discharge) in May and decreasing to about to about 60 $m^3 \bullet s^{-1}$ in winter, the marsh areas of the Central Delta are characterized by freshwater in summer (2 ‰) and brackish water in winter (16 ‰) (Levings 1980). The marsh areas of the Central Delta are characterized by dendritic waterways which drain the marsh area. They can be up to 1200 m in length tapering from a mouth of 12 m wide into narrow terminal branches <50 cm width. The tidal channels undergo dewatering during the low tides. Consequently, the majority of the fish move out of the channels into the sloughs and other areas of the estuary. The fish reenter the tidal channels on the following tidal flood.

SALMON SAMPLING METHODS

Three tidal channels on the central delta served as sampling sites (Fig. 1): station 1 (rejuvenated channel); station 2 (excavated channel); station 3 (existing tidal channel).

A beach seine, 7 m by 2 m and 0.6 cm stretched mesh, was used to capture fish utilizing the tidal channels. Seine haul lengths were standardized at approximately 20 m. However, where required due to differences in width and depth of the channel the haul length varied so as to sample a similar volume of water each time. Five replicate seine hauls were generally made at each sampling location. Samples of juvenile salmonids were taken and fixed in 10% formalin. About once a week, samples were taken from June 30 to August 15, 1984 and from March 1 to April 29, 1985.

Mark - Recapture Experiments

Juvenile coho used for residency determination were obtained from the Tenderfoot Creek Hatchery (mean length 64 mm), and marked by the removal of either their right or left pelvic fin. Fish to be marked were immersed in water with MS-222 anesthetic; once motionless they were dip-netted out of the bucket onto a 3 mm mesh net. The fish were then marked and held in a tank at the hatchery for at least 24 hours prior to being released, since it is during the initial period after marking when most mortality is thought to occur (Healey et al. 1977). The marked salmon were released into the rejuvenated tidal channel on two occasions; on July 4 (N=230) and on July 24 (N=115). The length of residence of the marked coho in the tidal channel was estimated by the method of Healey (1979).

$$D_{(i)} = \Sigma d_{(i)} \bullet R_{(i)} / \Sigma R_{(i)}$$

$$T = D_1 - D_2$$

where

$D_{(i)}$ is the weighted mean release or recapture date for each release series
$R_{(i)}$ is the number of fish released or recaptured, expressed as a catch per unit effort, on day $d_{(i)}$
$d_{(i)}$ is the Julian day of release or recapture
D_1 and D_2 is the mean release and recapture dates respectively for a marked cohort
T is the average residence time in days.

The preceeding estimate assumes that sampling effort and efficiency are constant during the period of sampling. More important is the fact that the above calculation includes the confounding influences of mortality and emigration to other unsampled areas of the marsh. Consequently, the calculated residence time will be a minimum estimate. In addition, as mean size of the hatchery fish was larger than the mean size of wild coho present in the estuary, the estimate of residence time may be biased to shorter residency.

Residence time was calculated during 2 separate occasions and estimates of the cumulative proportion of the coho outmigration accrued to various dates were calculated from Levy and Levings' (1978) estimates of seasonal change in abundance. Using Levy and Levings' (1978) results in seasonal change of coho abundance was probably valid because comparisons between their observations and the present studies for the same time period (i.e., July-August) showed a similar pattern.

Stomach Content Analysis

Preserved fish were rinsed in fresh water, blotted dry, and measured to the nearest millimeter. Preserved weights were measured and then converted to dry weight using a conversion factor of 0.2. Gut contents between the esophagus and the junction of the pyloric caecae with the intestine were examined using a stereomicroscope. The prey items were partitioned into six major food categories; adult insects, insect pupae, insect larvae, Eogammarus confervicolus, Corophium spinicorne, and Gnorimosphaeroma spp. The stomach contents of a group of juvenile fish were dried at 65°C for 24 h. The dry stomach contents are expressed as a percentage of dry body weight.

RESULTS

FISH OCCURRENCE

The occurrence of fish species within the three tidal channel sampling locations from June 30 to August 15, 1984 and from March 1 to April 29, 1985 is tabulated in Tables 1 and 2. In 1984, coho were recorded at each of the three sites until August. On August 3 they were caught at stations 1 and 2, and on August 11 and 15 only at station 1. In 1985 chum were first recorded on March 16 at station 1 and thereafter at all three sites. Staghorn sculpins, *Leptocottus armatus*, were present at all sites. However, they occurred in highest numbers at station 3. Threespine stickleback, *Gasterosteus aculeatus*, occurred at all three stations throughout the sampling period as well. The highest concentration of these fish were recorded at station 1. Starry flounder, *Platichthys stellatus*, occurred sporadically throughout the sampling period, with the maximum number occurring at stations 2 and 3. Chinook salmon were found at two sampling periods (June 30 and July 3, 1984) and only at station 3.

BEACH SEINE CATCHES OF COHO JUVENILES

The mean number of coho salmon juveniles caught in beach seine hauls at stations 1, 2, and 3 are shown in Figure 2. There was a peak abundance of juvenile coho on July 6 (6 fish per set) at stations 2 and 3, while peak abundance at station 1 (24 fish per set) did not occur until July 17. Mean number caught per beach seine haul at each of the sampling stations, as tested by a two-way analysis of variance, differed significantly with regards to location ($F=53.4$; $p<0.0001$), sampling date ($F=4.5$; $p<0.0001$), and there was a significant interaction effect between sampling location and date ($F=4.0$; $p<0.0001$). Duncans multiple range test indicated that the catches of juvenile coho salmon at stations 2 and 3 were less than at station 1 ($p<0.05$).

The pattern of juvenile coho salmon residence in the Squamish estuary in the present study appears to concur with Levy and Levings' (1978) findings for the same sampling period. However, since it was not possible to sample earlier in June it is not known whether there were two peaks of juvenile coho abundance, one in June and the other in July, as found by Levy and Levings (1978).

SIZES OF JUVENILE COHO

The change in mean fork length of wild juvenile coho salmon from July 3 to August 15 is shown in Figure 3. By July 24, the mean size of coho at each site ranged between 41 and 50 mm. Coho at station three were recorded until mid-August when they averaged 57 mm in length. A 2-way analysis of variance was conducted to test for changes in mean size of juvenile coho salmon between sampling station and sampling date. Station 3 was not included in the analysis due to small sample size. It was determined that there was no significant change in mean size from July 6 to July 24, but there was a significant increase from July 3 to July 6 ($p<0.05$). The mean size of fish at station 1 was significantly larger than those found at station 2 ($F=13.8$; $p<0.01$). There was no systematic increase in mean size of juvenile salmon from July 6 to July 24, during the period of highest recruitment to the tide channels, as estimated by the increase in the catch per unit effort over this time period. However, later in the season, July 24 to August 15, at station 1 there was a systematic increase in mean size of the juvenile coho residing there ($p<0.05$). At this time the catch per unit effort was declining (Fig. 2).

RESIDENCE TIME OF HATCHERY JUVENILE COHO

Estimates of the residence time of juvenile coho salmon are shown in Table 3. The data indicate that juvenile coho salmon resided longer at station 1 (est. 10 d) during the early part of the outmigration than did juvenile coho later on (3 d).

STOMACH CONTENT ANALYSES

Coho fry consumed mostly insect prey with epibenthic crustaceans such as amphipods and isopods less important dietary items.

Stomach contents of wild juvenile coho averaged 1.8-4.1% of body weight at station 1, 2.5-3.03% at station 2, and 1.1-3.7% at station 3 (Table 4). Stations 1 and 3 exhibited a decrease in average stomach contents on July 17 and July 6, respectively, which coincides with the maximum density of juvenile coho salmon in each of those locations. At station 2 average stomach weight stayed fairly constant throughout the sampling period. At station 1, stomach contents showed a slight increase on July 25 and thereafter were approximately the same until August 15.

The stomach content of marked hatchery coho averaged 0-3.76% of body weight (Table 5). The lower values were recorded when the marked hatchery coho were recaptured 2-3 days after release. However, marked hatchery coho recaptured after 10 days had comparable stomach contents, expressed as percent of body weight, to the wild coho. The marked hatchery coho also showed a decline in stomach contents during peak coho abundance.

BEACH SEINE CATCHES OF CHUM FRY

The mean number of chum fry caught in beach seine hauls at stations 1, 2, and 3 is shown in Figure 4. There was a peak in abundance of juvenile chum on April 15 at all 3 stations. Mean catch per set at station 1 was much higher than at the other two sites (est. 190 vs 30 to 80 fish per set) (Fig. 4). Mean number caught per beach seine haul at each of the sampling stations, as tested by an analysis of variance, differed significantly with regards to location ($F=4.2$; $p<0.05$) and sampling time ($F=4.8$; $p<0.01$). A Duncan's Multiple Range test demonstrated that the density of juvenile chum salmon at stations 2 and 3 was less than that at station 1 ($p<0.05$).

SIZES OF CHUM FRY

The change in mean fork length of wild juvenile chum salmon from April 1 to April 29, 1985 is shown in Figure 5. From mid to late April, mean length of chum fry was approximately 37 to 39 mm at all three sites. The absence of any systematic increase in mean size was probably due to the continuous recruitment to the tide channel population. This hypothesis is supported by the fact that the standard error of fork length measurements is greatest when catch per unit effort is at a maximum (April 15).

DISCUSSION

Juvenile coho salmon were captured in the rejuvenated tidal channel (station 1), immediately after its completion, and the highest catch per unit effort of juvenile coho salmon was recorded at this site. The pattern of catch per unit effort for chum salmon at the 3 sampling sites was the same as that observed for juvenile coho, that is greatest at station 1 and no significant difference between stations 2 and 3. This indicates that the rejuvenated channel habitat was a useful habitat for juvenile salmon.

Unfortunately, it was not possible to collect data prior to the excavation of the ditch. However, as mentioned in the introduction, prior to the construction of the ditch high tides of 4.1 m were required before any fish from the central delta could enter channel B. Therefore, while juvenile salmonids had the potential to enter the channels A in the past, their movement to and from the central delta was restricted. Now the juvenile salmonids can exit and enter at lower heights and can avoid being trapped for extended periods.

Physiographic characteristics of the rejuvenated channel may explain partly why larger catches were found there compared the other stations sampled. Levy and Northcote (1981) relate 22 tidal channel characteristics to juvenile salmon abundance using factor and multiple regression analysis. The multiple regression analysis determined that the most important variable for chinook and chum fry are areas of low elevation refuge, i.e. tide pools. The rejuvenated tide channel is unique from other tide channels in the area, in that no part of it dewaters at low tide, due to a sill at the southern portion of the channel were it connects to the excavated channel. Consequently, the juvenile coho and chum salmon are not forced to vacate the rejuvenated tidal channel at low tide as they are at stations 2 and 3.

The rejuvenated tidal channel is also characterized by partially submerged logs, a channel bottom with an aquatic vascular plant community, overhanging vegetation, and low velocity water movement. These characteristics are the preferred habitat of stream dwelling coho fry (Hartman 1965; Ruggles 1966). The spatial requirements for coho inhabiting estuaries are similar to those of their stream-dwelling siblings (Hartman 1965). Coho fry do not undergo a change in habitat requirements when they move from streams to estuaries in the spring and summer (Tschaplinski 1982).

The aquatic plant cover could also be utilized by the amphipod, <u>E. confervicolus</u>, which is a food item of juvenile salmon. The sediment of the rejuvenated channel is composed of a soft fine mud which is conducive to the growth of <u>Corophium</u> spp. (Meadows 1964; Chang and Levings 1976), another gammarid consumed by juvenile salmonids. An unfavourable characteristic of the rejuvenated channel is warming during periods of low tide. The water temperature in the rejuvenated channel reached 22°C (July 25, 1984) on a warm day. However, there were pools of cooler deep water in channel B that the juvenile salmon can use until the following high tide.

Other evidence that suggests the rejuvenated channel is a favourable rearing habitat is provided by the average weight of coho stomach contents as compared to station 2 in the excavated channel and station 3 in an existing tidal channel. The highest average weight of coho stomach contents was found for salmon captured in the rejuvenated channel, when weighted by the density of juvenile coho present at each sampling location. Consequently, it appears that the rejuvenated tidal channel could not only support more juvenile coho salmon fry, but may provide better food resources as compared to the other two areas studied. With more food available the juvenile salmon might attain larger sizes. This is important, as numerous studies have demonstrated the correlation between larger size as smolts and increased percent age survival to adults (Foerster 1954; Ricker 1962).

Food may be limiting during certain periods at all three sampling stations as evidenced by the drop in stomach content weight when juvenile coho were most abundant. A decrease in availability in food may explain the decrease in mean residence time from 10.1 days during the earlier part of the season to 3.1 days after 90% of the juvenile coho outmigration occurred. Alternatively, the decrease in stomach content weight could, for example, be explained by an increase in water temperature and thus faster digestion (Healey 1980).

Chum stomach weight content are in the same range as those observed by Healey (1979) for chum sampled in the Nanaimo estuary during 1975 and 1976. Healey (1979) also observed a decline in stomach content weight during peak periods of fry density.

The apparent lack of growth of the juvenile coho during certain sampling periods was probably due to recruitment of smaller fish into the estuary at those time periods. For example, at stations 1 and 2 from July 6 to July 24 there was no apparent growth and this time period coincided with maximum immigration of juvenile coho to the tidal channels. However, at station 1 after July 24, there was substantial growth in the coho fry which was when the recruitment of coho fry to the tidal channels was declining. Healey (1979) showed similar findings for chum fry growth; however, growth of marked chum fry was about 6% per day in the Nanaimo estuary.

It is interesting to note that the size of juvenile coho observed in the present study are much smaller than those recorded by Levy and Levings (1978) at Squamish, but they sampled the deeper main channel habitats that perhaps were not used by fry. Levy and Levings (1978) observed coho juveniles ranging from 80 to 130 mm during July and August in 1978; while in this study coho juveniles ranged from 32 to 55 mm for the same time period. Levy and Levings' (1978) juvenile coho would be classified as smolts while the present studies are fry. This would indicate that the coho juveniles in 1984 resided for a short time in streams prior to emigrating to the estuary, while the coho juveniles observed by Levy and Levings (1978) spent one year residing in streams prior to emigrating to the estuary. Alternatively the coho smolts that Levy and Levings (1978) observed may have overwintered in the lower river or shallow parts of the estuary, including tidal channels. The movement of coho fry into the Squamish estuary from tributary streams has not been documented in detail. Argue and Armstrong (1977) found coho fry moved from two tributaries (Tenderfoot Creek and Little Stawamus River) in early to mid-May, but our data suggest the fry out migration may be prolonged into late June, indicating considerable year-to-year variation in the time when the fry reach the estuary. Investigators such as Mason (1969) and Mason and Chapman (1965) maintain that young fry are dispersed downstream as an outcome of intraspecific competition for food and space and may not survive. Dill (1978) found coho residing in streams to be territorial and that they aggressively defend their feeding space. Therefore, coho unable to secure a territory may be displaced downstream to find food and suitable habitat. However, Tschaplinski (1982) found no evidence to support the density dependent hypothesis as the cause for early emigration of coho fry downstream from Carnation Creek, B.C., nor any evidence to suggest these coho are competively inferior. In fact, Tschaplinski (1982) presented data demonstrating that estuary reared fry have a faster growth rate and higher survival than their stream dwelling counterparts. Coho fry at the Yakoun River estuary in northern B.C. also appeared to grow well and were present in brackish water in spring and summer (Stockner and Levings 1982).

Chum fry showed a slight increase in mean size during April 1985. The greatest increase in mean size appeared to be at station 1, followed by stations 2 and 3. The absence of any significant increase in size with season was probably due to the continuous recruitment of new fry to the tidal channel population. This result concurs with Healey's (1979) findings for chum in the Nanaimo estuary. Healey (1979) found residency periods ranging from 0 to 18.5 days for chum at Nanaimo and indicated that chum fry from the early part of the run spent considerably longer in the estuary than fry from the latter part of the run. In the Fraser River estuary the longest recorded residence time for marked juvenile chum was 11 days (Levy and Northcote 1982). The pattern of juvenile chum residence in the Squamish estuary in the present study concurs with Levy and Levings (1978) findings for the same sampling period.

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Table 1. Occurrence of fish in 1984 at the three sampling locations in the Squamish River estuary.

Sampling station	Staghorn sculpin	Starry flounder	Threespine stickleback	Prickly sculpin	Coho salmon	Chinook salmon
June 30						
1	+		+		+	
2	+		+		+	
3	+	+	+		+	+
July 3						
1	+	+	+		+	
2	+	+	+		+	
3	+		+		+	+
July 6						
1	+	+	+		+	
2	+		+		+	
3	+		+		+	
July 13						
1	+	+	+		+	
2	+		+		+	
3	+	+	+		+	
July 17						
1	+	+	+	+	+	
2	+	+	+	+	+	
3	+	+	+	+	+	
July 25						
1	+		+		+	
2	+	+	+		+	
3	+		+			
July 26						
1	+	+	+		+	
2	+		+		+	
3	+		+		+	
August 1						
1	+		+		+	
2	+		+		+	
3	+		+			
August 11						
1	+		+		+	
2	+		+			
3	+		+			
August 15						
1	+		+	+	+	
2	+		+			
3	+		+	+		

Table 2. Occurrence of fish in 1985 at the three sampling locations in the Squamish estuary.

Sampling station	Staghorn sculpin	Starry flounder	Threespine stickleback	Prickly sculpin	Chum salmon
March 2					
1			+		
2					
3	+	+		+	
March 9					
1			+		
2	+		+		
3	+				
March 16					
1			+		+
2	+	+	+		
3	+		+	+	
April 1					
1	+		+		+
2	+		+		+
3	+		+		+
April 15					
1	+		+		+
2	+	+	+		+
3	+		+		+
April 18					
1	+		+		+
2	+		+		+
3	+	+	+		+
April 29					
1	+		+		+
2	+	+	+		+
3	+		+		+

Table 3. Estimated residency of coho juveniles in the Squamish estuary in July 1984. Timing data from Levy and Levings (1978) were used to compute cumulative percentages.

Date	Cumulative Percentage of outmigration	Residence time in days
July 4	58%	10.1
July 24	90%	3.1

Table 4. Mean stomach contents of wild coho as a percentage of body weight. n = number of juveniles sampled.

	Station sampling location					
Date	n	1	n	2	n	3
July 3	10	2.6	10	2.5	3	3.7
July 6	10	4.1	10	3.0	6	1.1
July 13	10	1.7	10	2.8		-
July 17	10	1.8	10	2.7	10	2.2
July 25	10	2.3		-		-
July 26	10	2.1	4	2.6	4	1.8
August 1	10	2.2		-		-
August 11	10	1.8		-		-
August 15	7	2.0		-		-

Table 5. Stomach contents (mean percentage of body weight) of hatchery coho released and recaptured at station 1, Squamish River estuary.

Days from release	n	Stomach content (% body weight)
2	5	0.0
3	9	1.0
10	3	3.8
14	3	2.0
22	5	2.1

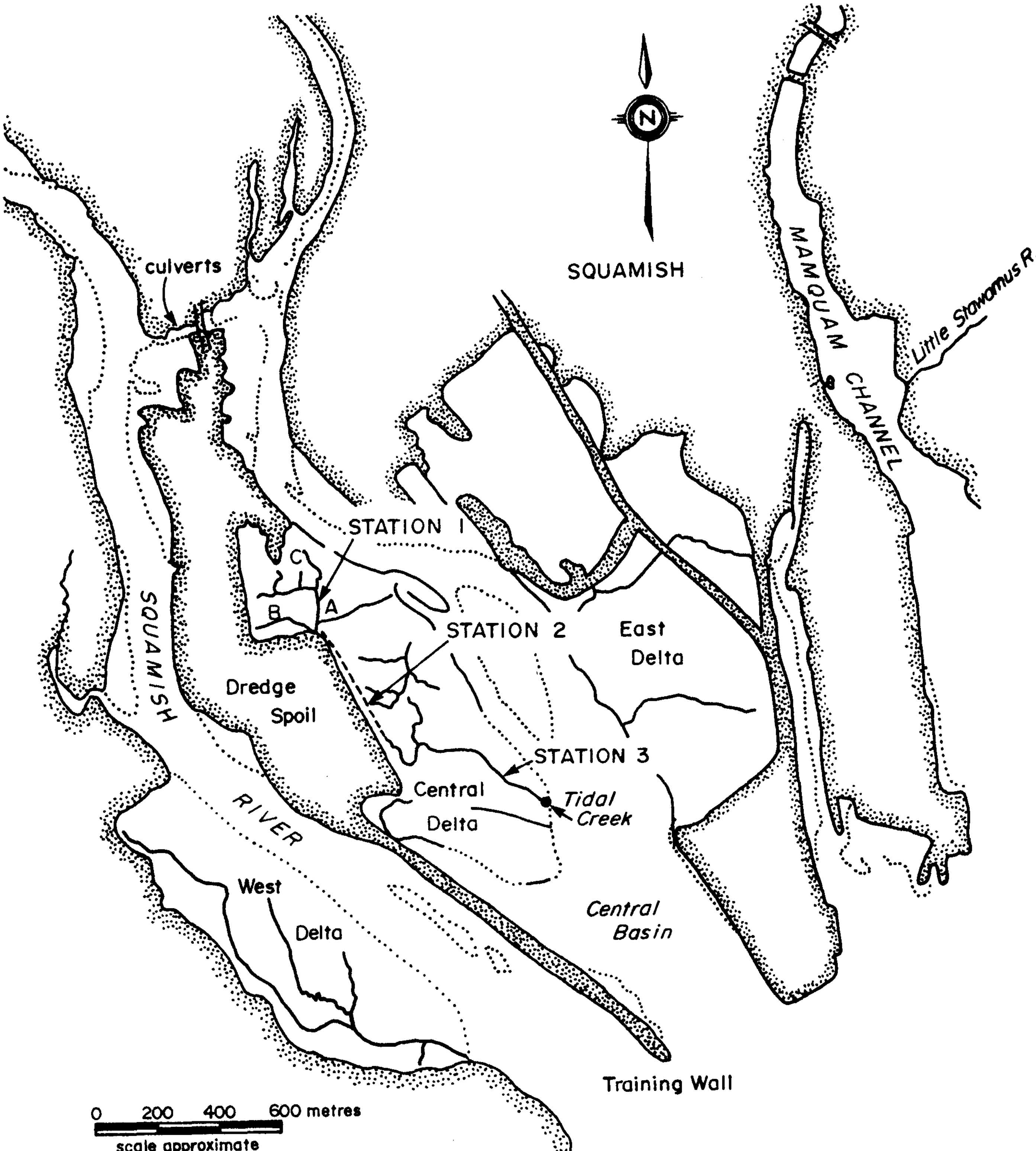

Fig. 1. Location of study areas and sampling locations at the Squamish estuary. The dotted line on the immediate east side of the dredge spoil indicates the location of the ditch constructed to reconnect the network of channels near Station 1.

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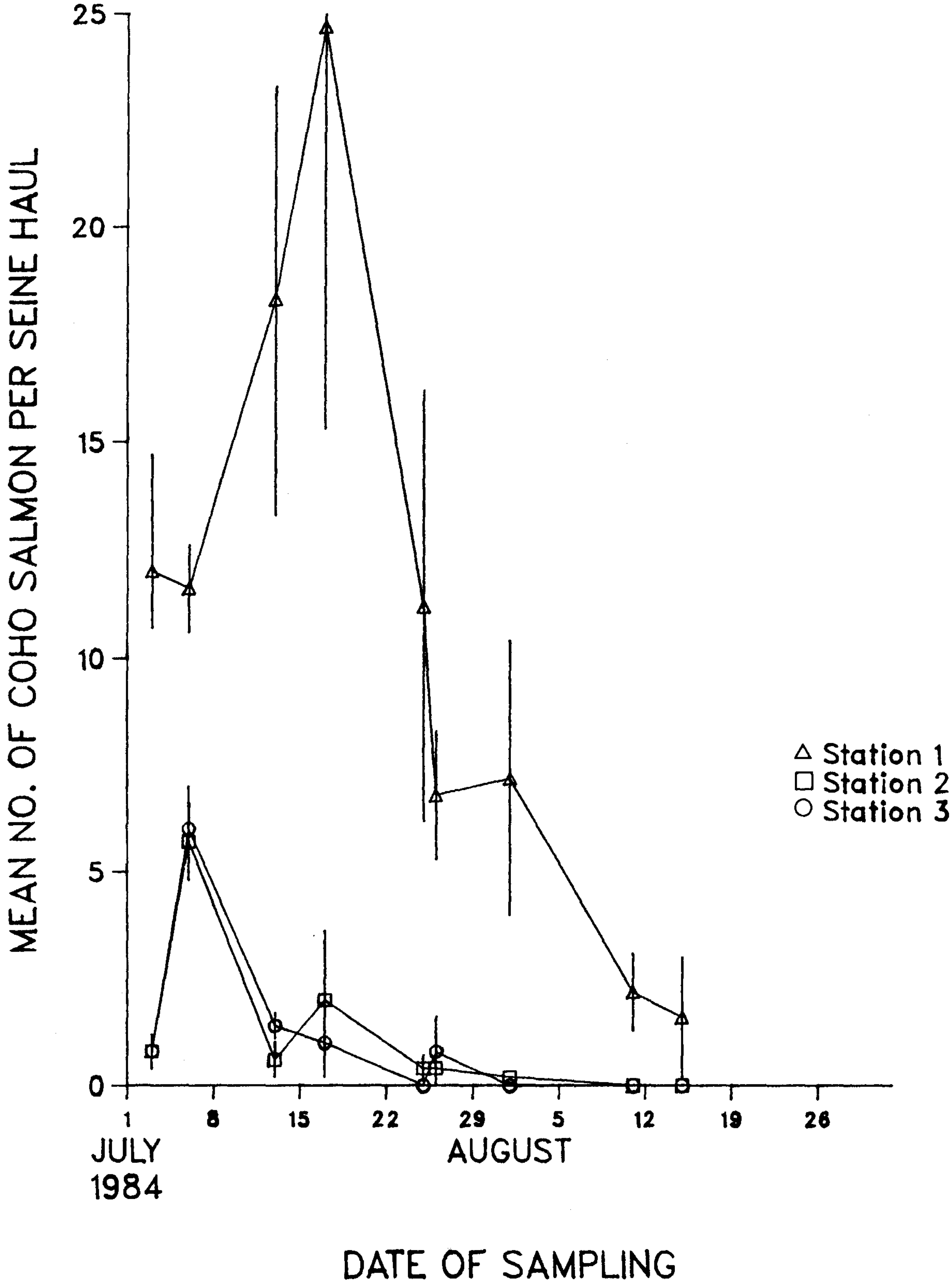

Fig. 2. Mean number of juvenile coho per beach seine haul at three stations in the Squamish estuary, July and August 1984. Vertical bars indicate standard error.

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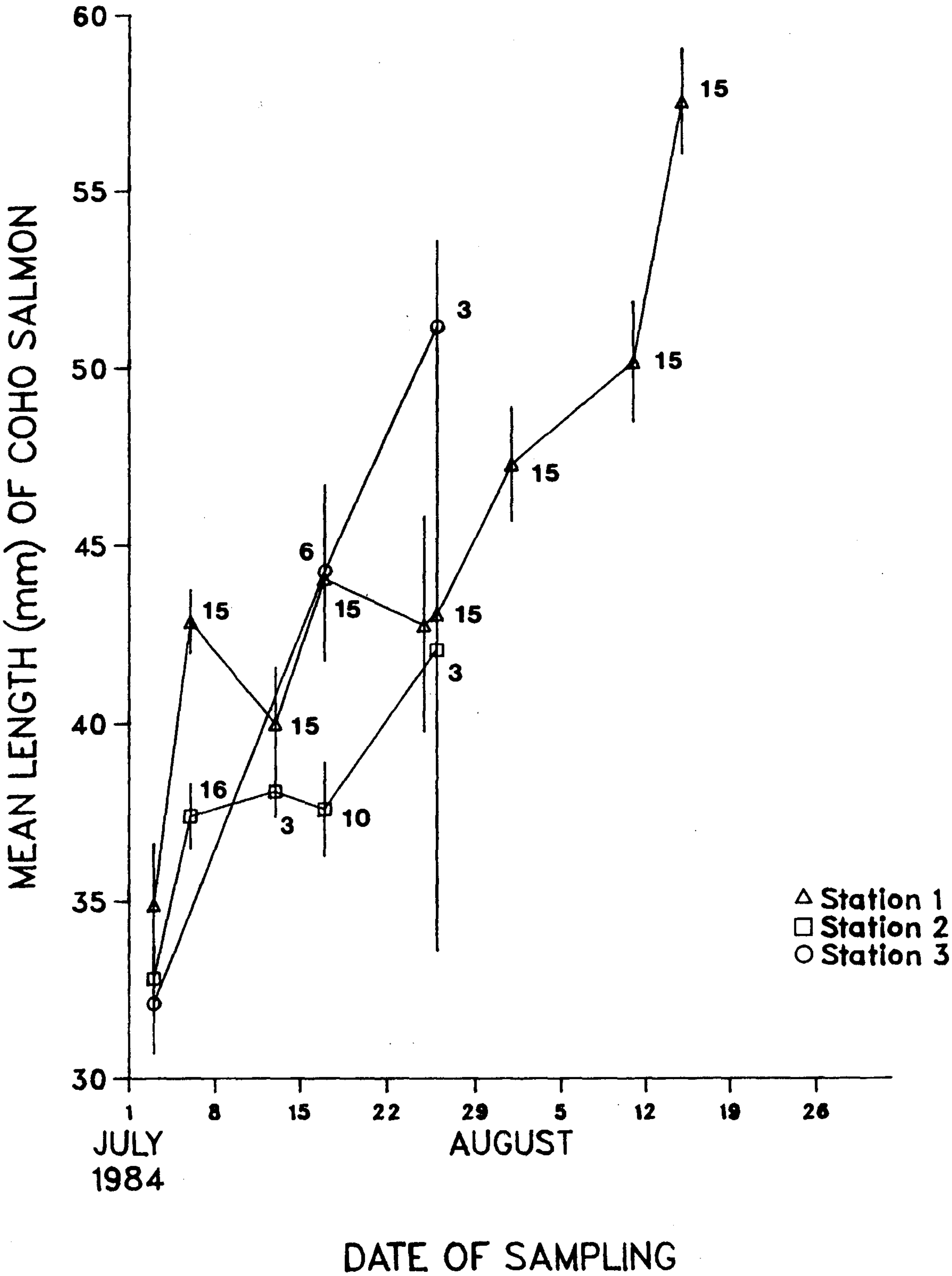

Fig. 3. Mean fork length of juvenile coho at three stations in the Squamish estuary July and August 1984. Number of fish measured is indicated in brackets beside symbols. Vertical bars indicate standard error.

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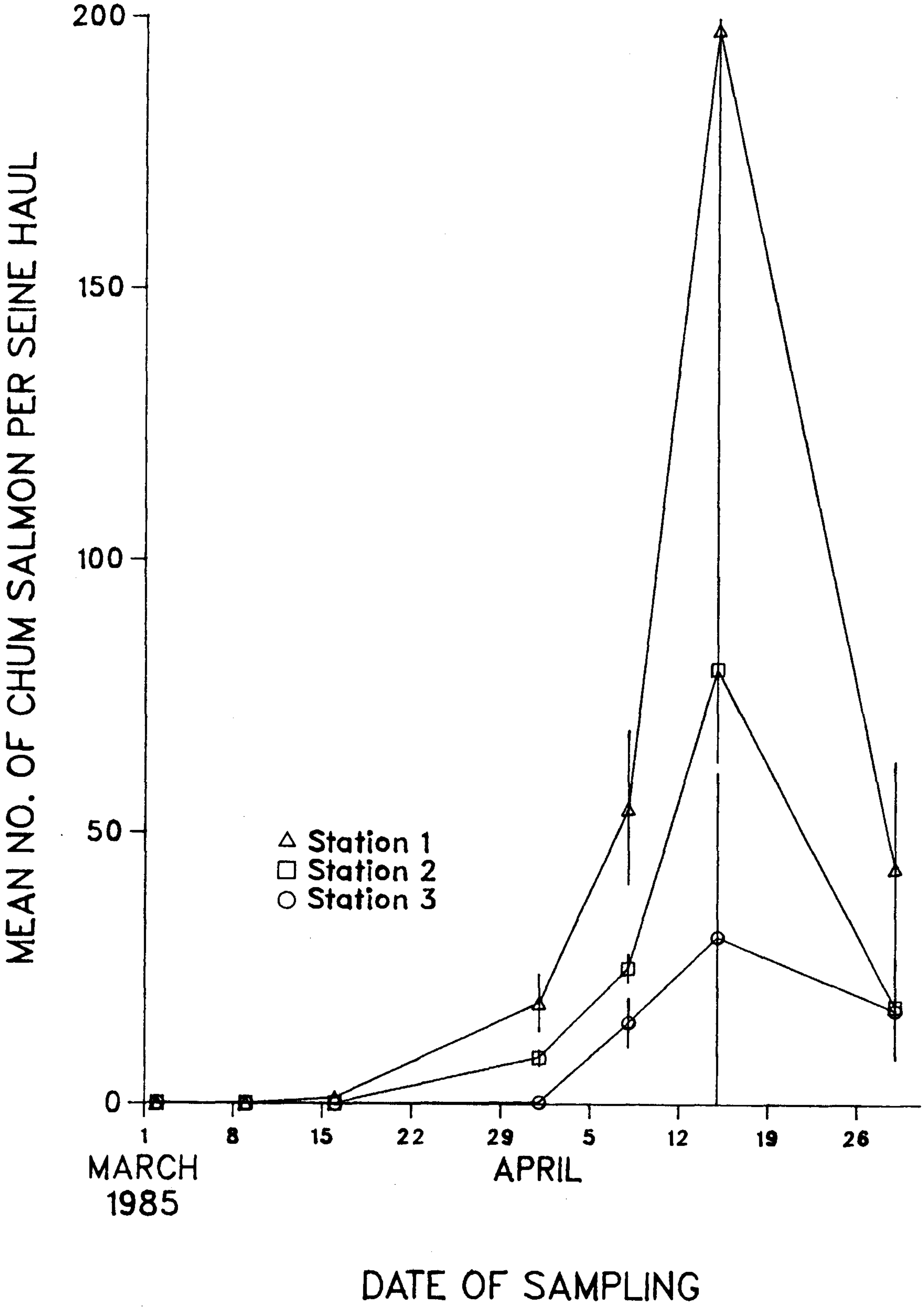

Fig. 4. Mean number of juvenile chum fry per beach seine haul at three stations in the Squamish estuary, March and April 1985. Vertical bars indicate standard error.

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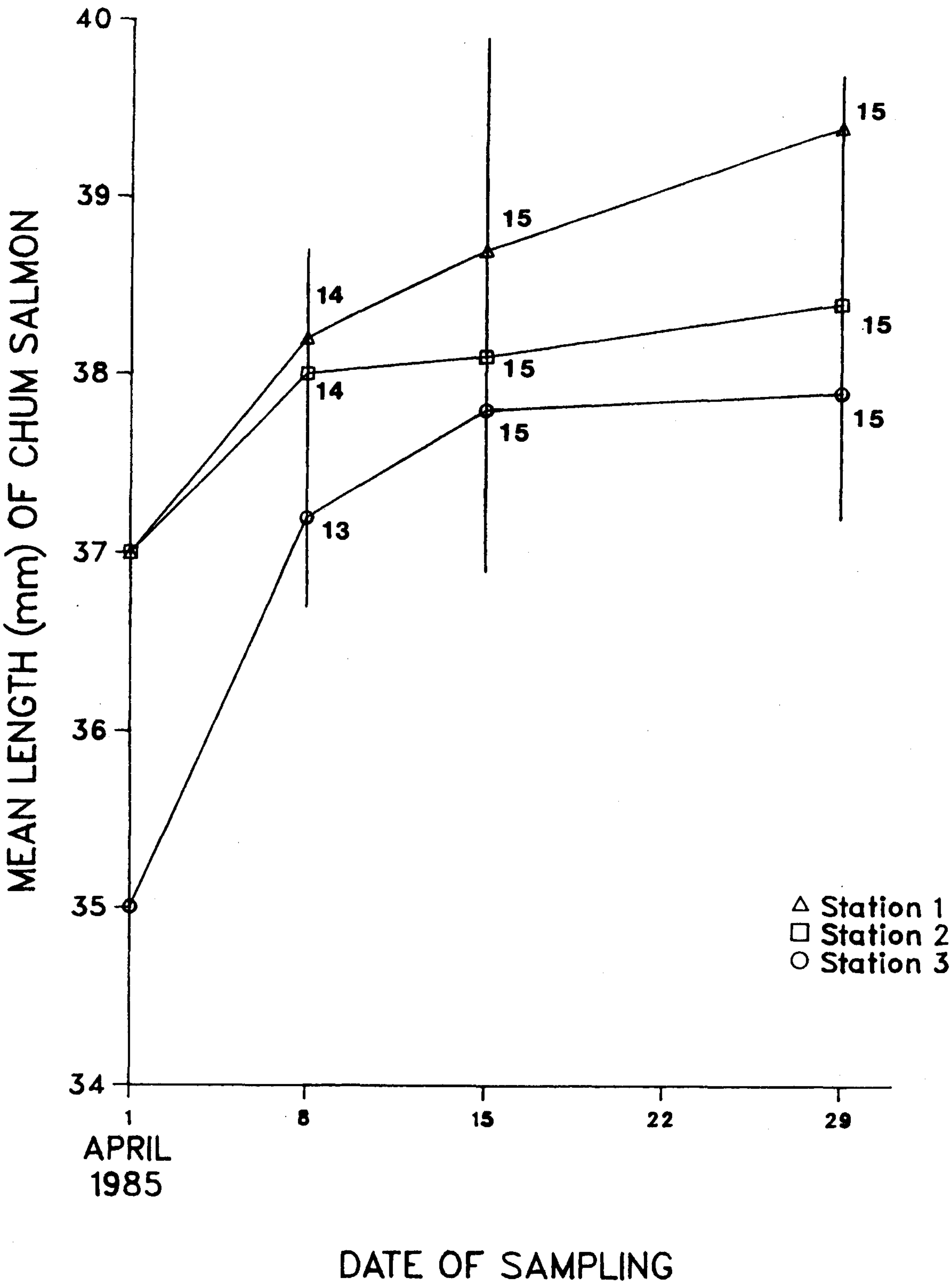

Fig. 5. Mean fork length of chum fry at three stations at the Squamish estuary, April 1985. Number of fish measured is indicated by numbers beside symbols.