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**Delayed high seas migration by chum salmon**

by


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**Abstract**

Young chum salmon were captured throughout the Strait of Georgia in a survey in October 1993 using beam trawls. The abundance of these chum salmon may represent a minimum of approximately 1% of the surviving production from this brood year, but the numbers appear to be large relative to estimates of abundance of chinook and coho salmon that remain in the strait. This indicates that chum salmon are an important part of the salmon community in the Strait of Georgia.

Daily growth increments in the otoliths of these chum salmon were examined to study growth and the timing of entry into salt water. Difficulties associated with the interpretation of the increments still exist, but it appears that the chum salmon in the October 1993 sample entered saltwater later in the downstream migration. The lengths of these chum salmon were only weakly related to the time of entry into salt water.

**Introduction**

The Strait of Georgia is one of the most important salmon rearing areas in the Pacific. Approximately 40% of the Pacific salmon smolts produced in British Columbia, enter the strait. Chum salmon are found in approximately 200 of the rivers and streams that drain directly or indirectly into the Strait. About 100 of these rivers are in the Fraser River drainage, which produces approximately 40% of chum salmon smolts that enter the strait. Chum salmon begin their migration into the Strait of Georgia from March to May, shortly after emergence from the gravel. In the Fraser River, 50% of the chum have entered the strait by the third week of April (Walters et al. 1978). By mid-May, chum smolts move from the very shallow marine areas to deeper water (Healey 1980). Healey (1980) and Phillips and Barraclough (1978) found that by August few chum were captured in the Strait of Georgia. The observations of Healey (1980) and Phillips and Barraclough (1978) provide most of the information that has been used to describe the early marine history of chum salmon stocks in southern British Columbia.

In this report, we show that chum salmon are still present in the Strait of Georgia in mid-October. We provide an approximate estimate of the number of chum in the strait at this time and relate this abundance to the number of chum produced from the same brood year entering the strait that would be expected to be alive in October. Using daily growth increments in otoliths we indicate when these chum salmon entered the strait.

We are reporting the results of the cruises that identify when chum salmon enter the Strait of Georgia and that show that some remain until October. The results from other cruises will be reported elsewhere.

## Methods

Surveys of juvenile Pacific salmon distribution and relative abundance were undertaken as part of a study of the carrying capacity of the Strait of Georgia. Juvenile salmon were captured using paired beam trawls (B. Hargreaves, Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C. pers. comm.), fished from either the *W. E. Ricker* or a chartered commercial vessel. The commercial vessel fished a 43.6 m long beam trawl with a 9.1 m x 9.1 m opening. Five mesh sizes ranged from 40.6 cm (stretched mesh) to 2.5 cm (knotless mesh) in the codend with a 1.5 cm knotless mesh liner. The beam trawl fished from the *W. E. Ricker* was similar in design, but with 7 mesh sizes and twice as long. Both beam trawls fished from the surface down to approximately 9 m, depending on fishing conditions.

The trawls were towed off the stern on each side of the vessel and fished continuously by retrieving the codend after approximately 60 minutes. Early in the year fishing was during the day. After July the nets were fished at night. The sampling areas were chosen to concentrate effort in areas where catches might be most variable, such as over a sloping bottom or in the Fraser River plume. Samples were collected throughout the Strait of Georgia including waters in the United States.

Chum salmon were weighed, measured, and otoliths taken. Scales were also sampled when available. Salmon caught in trawls frequently have lost their scales, making it difficult to collect useable material during routine sampling. One otolith from each fish was examined for daily growth increments using the procedures described in Zhang et al. (1994). The otolith was cleaned and mounted on a glass slide. The otolith was then ground on lapping film of 60 or

30μm until the primordia were revealed. The otolith was removed, turned over and mounted again. The otolith was polished until the microstructure was clearly visible.

## Results

<u>Chum catches</u>

During the first cruise of 1993 (March 8-17) using the *W. E. Ricker*, no chum salmon were captured in 52 paired tows (104 sets). The next cruise in 1993 was from May 3-7, using the commercial charter vessel. A total of 171 chum salmon were caught in 32 paired sets (64 tows). Lengths of the chum salmon ranged from 37 mm to 103 mm with a mean length and standard deviation of 68 mm ± 13 mm (Fig 1A).

In 1994, the *W.E. Ricker* fished from April 12-16, in approximately the same areas as in March and May of 1993. A total of 45 chum salmon were captured in 44 paired sets (88 tows). The mean length and standard deviation was 47 mm ± 9 mm (Fig. 1B) and the smolts ranged from 23 mm to 68 mm. One large chum (127 mm) was captured in this cruise.

During October 5-15, 1993, 75 paired tows (150 sets) using the *W. E. Ricker*, captured 130 chum salmon. Catches of chum occurred throughout the survey area (Fig 2) with lengths ranging from 17 to 26 cm (Fig 1C) and a mean length and standard deviation of 221 mm ± 19 (Fig. 2).

<u>Chum abundance</u>

The surface area of the Strait of Georgia excluding islands is 6420 km$^2$, not including waters in the Strait of Juan de Fuca (Waldichuck 1957). In October, 64 sets were made in the strait, fishing a total distance of 356 km. Each net was 9.1 m wide, therefore, the two nets fished an area of 6.5 $km^2$. The catch of chum in the Strait of Georgia was 123, slightly less than the total catch which included Juan de Fuca Strait, thus the approximate number of chum salmon in the Strait of Georgia could be 122,000.

The 1992 chum salmon escapement to the Fraser River of approximately 682,000 would produce approximately 111 million smolts assuming an equal sex ratio, an average egg production of 3250, and an average egg to marine entry survival of 10% (Beacham and Starr 1982). The Fraser River produces approximately 40% of the chum salmon entering the Strait of Georgia, thus the total production in 1993 would be approximately 278 million smolts. By October there would be substantial marine mortality. Furnell and Brett (1986) estimated that for sockeye salmon 90% of the marine mortality occurred in the first 4 months, which is similar to an estimate of 90% by mid-September, modelled for Fraser River chum salmon (Walters et al 1978). The total marine mortality of chum salmon from Japanese hatcheries is approximately 98% (Salo 1991) and the total mortality of chum from the Fraser River from 1961 to 1974 averages about 98.8% (Beacham and Starr 1982). So, if we assume marine mortality by October is higher than 90%, or approximately 95%, and total smolt production from all rivers entering the strait is approximately 278 million, the number of chum surviving in October would be 14 million. The number of chum in the Strait of Georgia in October, would therefore represent about 1% of the surviving smolt production.

Daily otolith increments formed in salt water were counted and identified from the otoliths of 113 chum. In 87 of these we were able to obtain a complete count of the number of increments that formed in fresh water. Virtually all chum salmon otoliths had a check (an anomalous and irregular formation of several daily increments), just outside the otolith primordia. The position and appearance of this check was similar to a check, termed a first feeding check, that was shown to be associated with the onset of exogenous feeding for chinook salmon (Zhang et al. 1994). Daily growth increments in the chum otoliths that formed before the first feeding check were very faint. After the formation of the first feeding check, the daily growth increments appeared irregular and narrow. These irregular, narrow increments were considered to have formed in fresh water. These increments were followed by wider and more regular, daily growth increments. The point at which these wider increments became established was considered to be the transition from freshwater increments to those that formed in salt water.

The number of freshwater daily increments ranged from 12 to 37 with a mean and standard deviation of 23 ± 6 (Fig. 3A). The number of saltwater increments ranged from 99 to 169 with a mean and standard deviation of 136 ± 15 (Fig. 3B). The saltwater daily increment count indicated that daily increment formation in salt water occurred from April 28 to July 3, with most beginning from mid-May to mid-June (Fig. 4). The largest number of otoliths had saltwater increments beginning at the end of May. The number of saltwater and freshwater increments was weakly related to the length of the fish in October (Fig 3A, $r^2 = 0.03$; Fig 3B, $r^2 = 0.05$). A comparison of the lengths of salmon in October (Fig. 5), grouped by periods of entry indicated that the mean size in an early entry group (May 8-14, N=16, 215 mm ± 24 mm), the most numerous group (May 22-31, N=28, 219 mm ± 21 mm), and late group (June 8-14, N=16, 218 mm ± 18 mm), were not significantly different ($p > 0.1$).

## Discussion

The existence of young chum salmon throughout the Strait of Georgia in October indicates that some remain in the strait longer than previously thought. Chum salmon were reported in purse-seine catches in the Gulf Islands in October 1976 (Healey 1978, Healey 1980), but the distribution throughout the Strait was not determined. Chum salmon probably left the strait between October 1993 and April 1994 as only one larger chum was captured in the April 1994 sample. The number that remained in the strait in October 1993 appears small relative to those that migrated offshore but, depending on the abundance of other salmon, they may or may not be an important component of the Pacific salmon community in the strait at this time.

Coho and chinook salmon are the more commonly known salmon residents in the Strait of Georgia. The average total catch of coho from 1988 to 1990 was approximately 925,000 fish and the average total wild escapement was 170,000 for this period. Thus the average number of coho smolts may be approximately 1.1 million if most of the marine mortality of coho has occurred by mid-October. Because coho may move into the strait at the time of the fishery, the actual average number of coho rearing in the strait may be smaller than 1.1 million. The abundance of chum in October may be equivalent to approximately one tenth of this estimated average number of coho smolts.

Total catches of chinook salmon were lower than coho for this same period, averaging approximately 167,000 fish, while escapements over the same period averaged about 126,000 fish. The average abundance of young chinook in the strait could be about 300,000 from a brood year, assuming most of the marine mortality is over by October. There is more than one brood year rearing in the strait and some chinook caught in the strait may have reared in other areas, indicating that any estimate of abundance of young chinook can only be approximate. Nevertheless, it is unlikely that the number of young chinook salmon present in the strait in October exceeds that of coho. On average, therefore, the chinook abundance may be less than one half the coho abundance. The abundance of chum salmon in October, therefore, may be about 25 -33% of the abundance of chinook salmon.

We could apply our method of estimating chum abundance to estimate the abundance of chinook and coho during the October 1994 survey. The October 1993 catches of 437 coho would indicate an abundance of 427,000 and the catches of 263 chinook would indicate an abundance of 257,000. Using these numbers, the catches of chum are equivalent to approximately one-quarter the coho abundance and one-half the chinook abundance. The trawl estimates of abundance may be lower than the estimates based on catch and escapement because the trawls fish only from the surface to approximately 9.1 m. Thus our gear may not sample the entire depth distribution of coho and chinook and probably does not catch and retain all salmon in the path of the net opening. If this is true, the estimates of chum may also be correspondingly low. This indicates that an estimate of 122,000 chum is a minimum estimate of abundance. We believe that the relative abundance of chum should be compared to coho and chinook abundance using the estimates from trawl catches. Although these estimates are only approximate, they suggest that chum salmon were an important component of the Pacific salmon community in the Strait of Georgia in October 1993 relative to the abundance of coho and chinook salmon.

The presence of young chum salmon in the Strait of Georgia late in the year may indicate that they occur in other coastal waters at this time. If these other areas are large, then the percentages of the brood year rearing in these waters may be higher than in the Strait of Georgia.

The average number of daily increments (23) estimated to have formed in fresh water indicates that it would take approximately 23 days for the fry from the October sample to enter the ocean. In the Fraser River, chum move downstream from February to June (Todd 1966). In recent years the majority of chum migrate from mid-March to the end of April (Beacham and Starr 1982). If the estimates of the time in fresh water are approximately correct, then the chum salmon in the October sample emerged from the gravel from late-March to early June, consistent with the observations of Todd (1966).

Most of the fish in the October sample began forming saltwater increments from mid-May to early June. Walters et al. (1978) estimated a mean time of entry into saltwater of April 20 ± 6d, thus the chum salmon in the October sample may have entered salt water later than average. There may have been a lag between the time they entered the estuary and the formation of the first marine daily increments. If a lag occurs, it is unlikely to be longer than a few days. Thus we suspect that chum that remained in the strait entered salt water later in the migration.

One surprising result of the daily increment analysis was the weak relationship between the number of saltwater increments and fish length, indicating that chum salmon entering saltwater earlier were not necessarily longer than those that entered later. One possible explanation is that because chum may then spend up to about 1 month in the estuary or shallow nearshore areas before moving into deeper waters (Sibert et al. 1977) and the chum in the inshore, shallow nursery areas grow slower than those that move into deeper waters (Healey 1980), the chum in the October 1993 sample that were in salt water the longest may have spent a longer period in the nursery areas.

Additional work is required to verify that the daily increment analysis accurately identifies the time of entry into salt water and the time spent in salt water. However, this preliminary study indicates that the increment counts probably are reliable and provide a useful method of studying the early marine biology of chum salmon.

**Figure Legends**

Figure 1. Length frequency of chum caught in the (A) May 3 to 7, 1993 survey, (B) April 12 to 16, 1994 survey, and (C) October 5 to 15, 1993 survey. The 13 cm chum in the April 12 to 16 survey was not included in the average lengths of the smaller chum.

Figure 2. Location and number of chum salmon caught in the October 5 to 15, 1993 survey.

Figure 3. The relationship between (A) the number of freshwater daily increments and length of chum salmon in October 1993 ($r^2 = 0.03$), and (B) the number of saltwater daily increments and length of chum salmon in October 1993 ($r^2$ - 0.05).

Figure 4. Numbers of chum salmon in the October 1993 sample and the date of their estimated entry into saltwater. The data are organized by 4 periods each month with the last period being slightly longer.

Figure 5. A comparison of the lengths of chum in the October 1993 sample that entered the ocean in an early (May 8-14), mid- (May 22-31), and late period (June 8-14).

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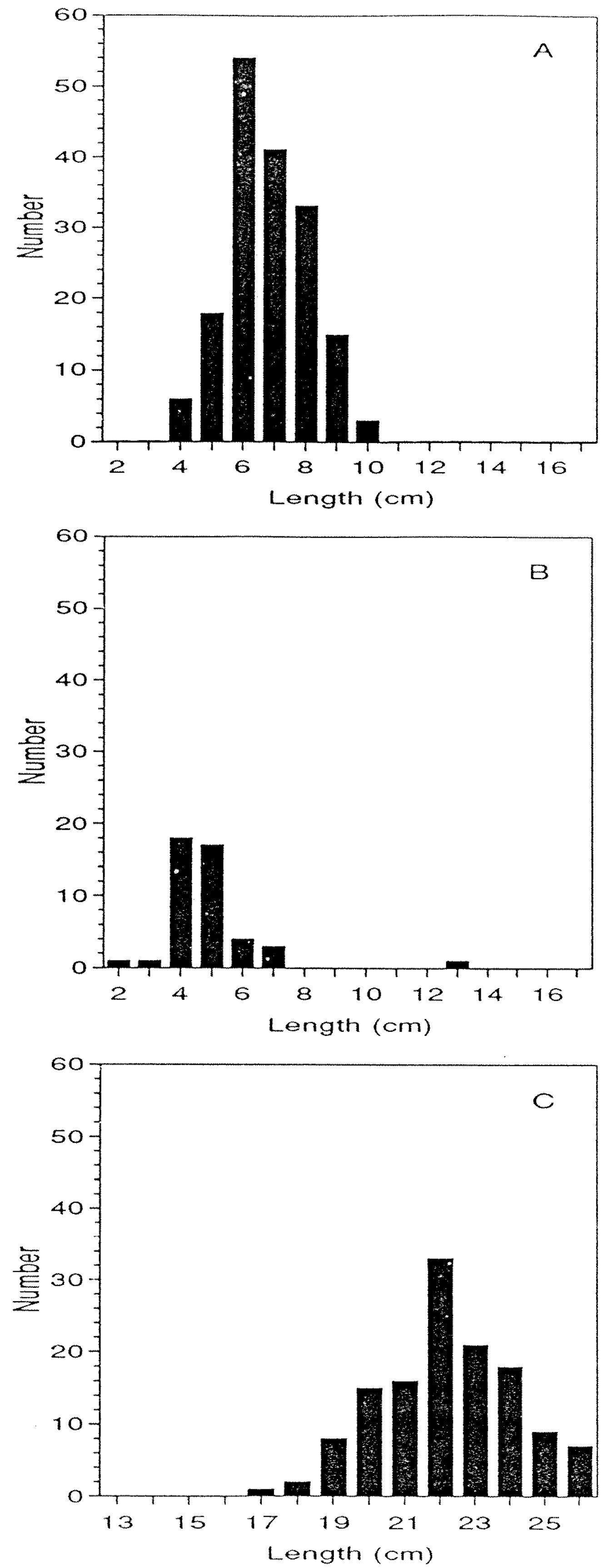


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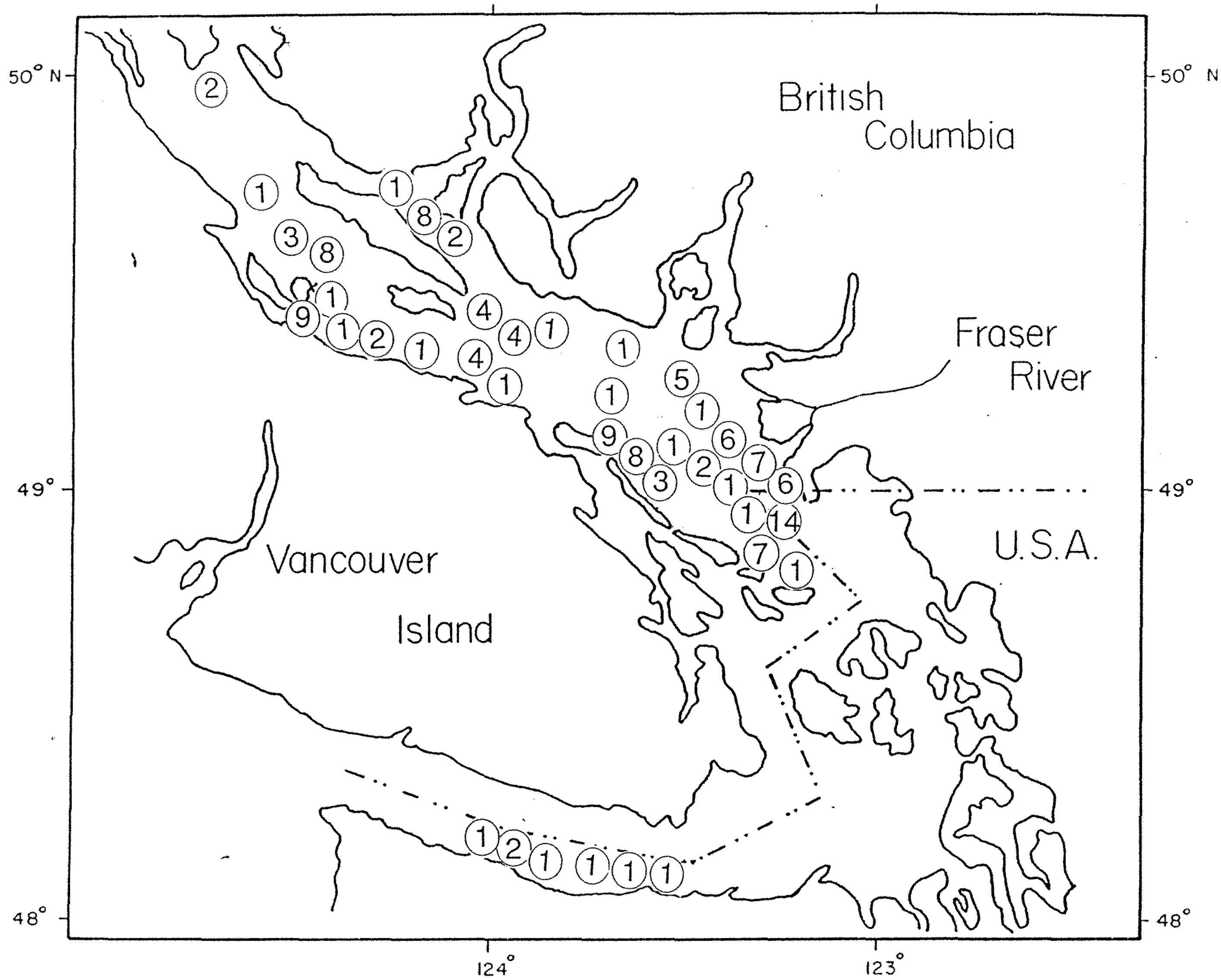


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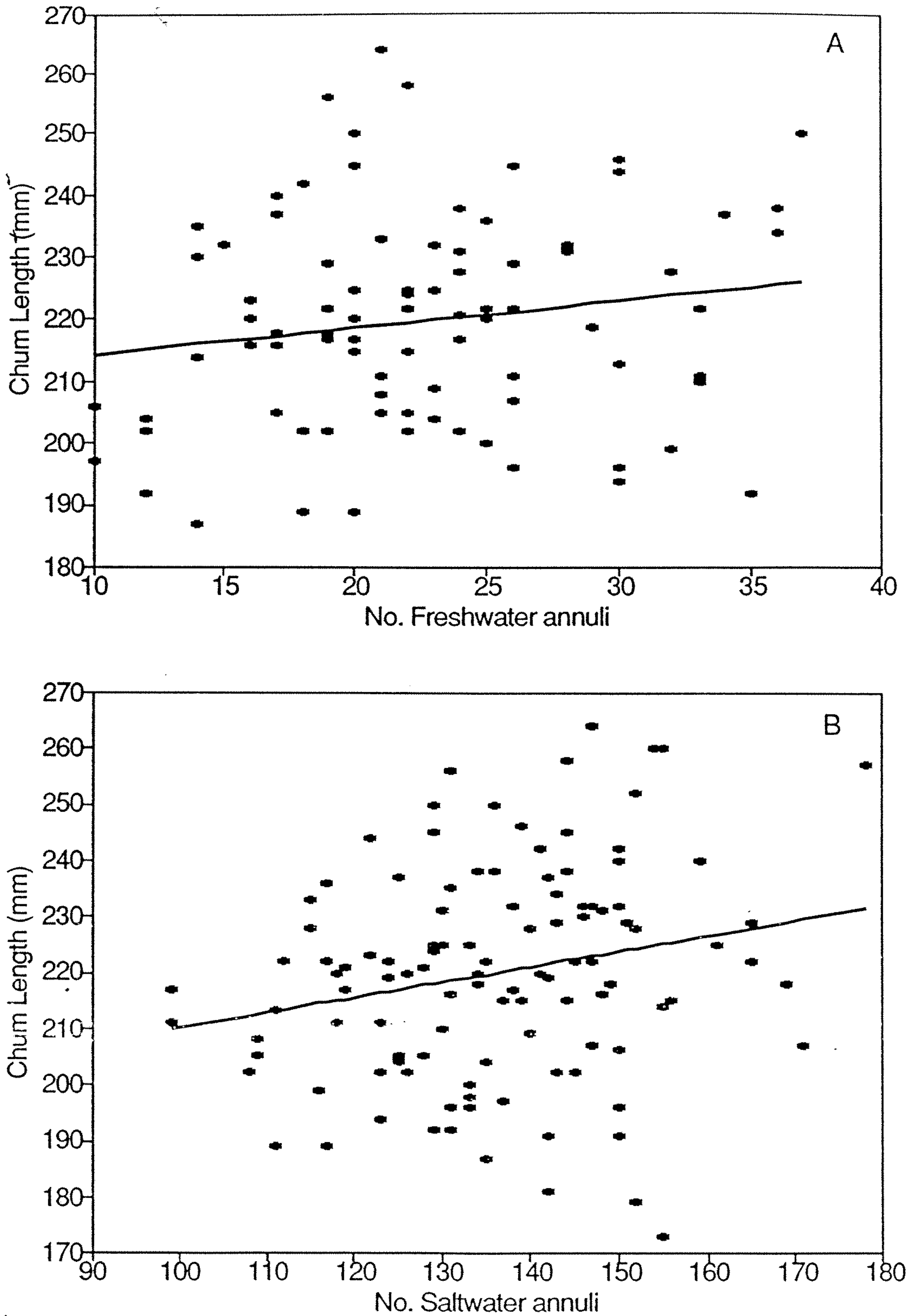


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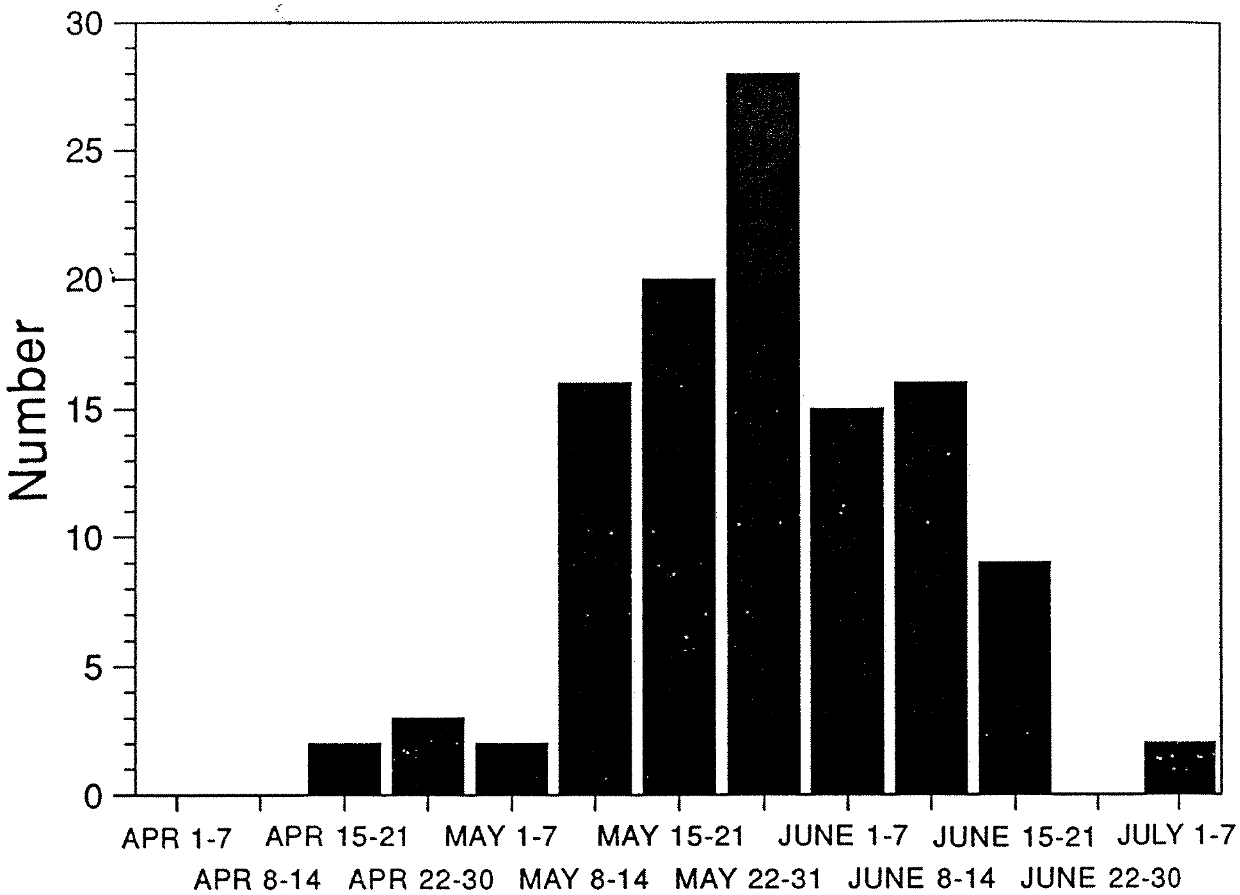


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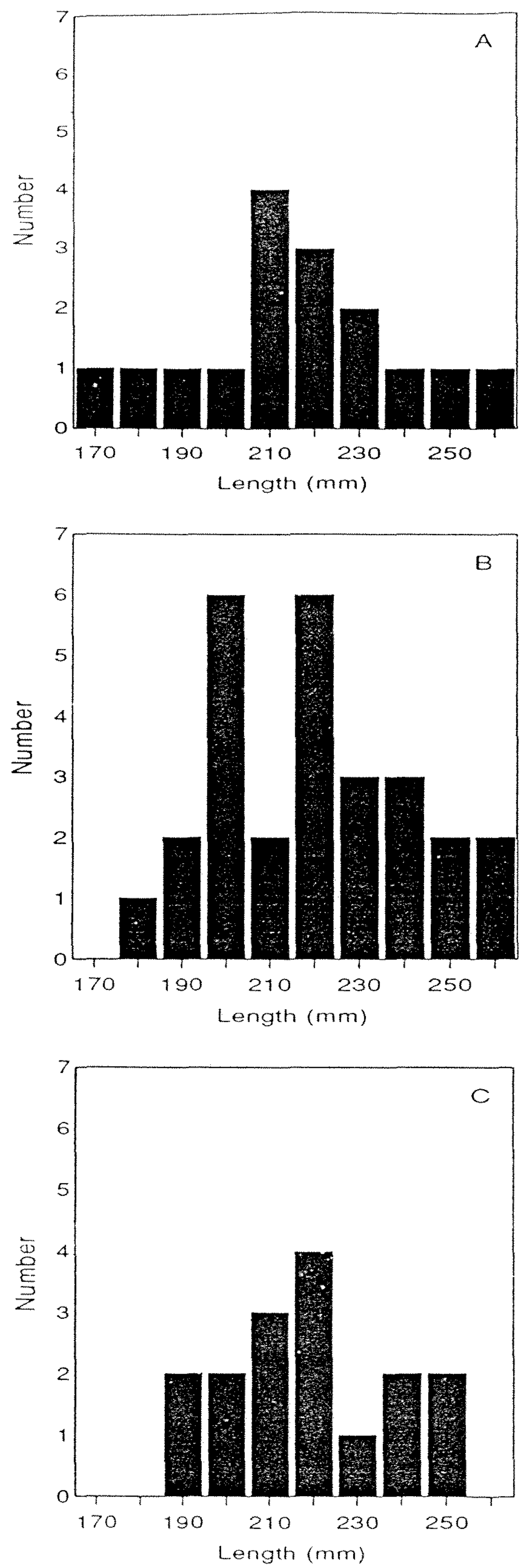


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