NPAFC

Doc. No. 200

Rev. No. ______

The relationship between time of ocean entry and residence in the Strait of Georgia for three chinook salmon rearing types

by

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submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

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October 1995

This paper may be cited in the following manner:
Beamish, R. J. and Z. Zhang. 1996. The relationship between time of ocean entry and residence in the Strait of Georgia for three chinook salmon rearing types. (NPAFC Doc. No.___). 18 p. Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, B.C. Canada. V9R 5K6

Abstract

Daily growth increments were used to estimate the date of ocean entry of hatchery, wild ocean and wild stream type chinook life history and rearing types. The mean date of ocean entry for ocean age 0 juveniles that resided in the Strait of Georgia later in the year, was late May to mid-June and was surprisingly similar among the life history and rearing types. The wild ocean life history type had the greatest diversity in ocean entry times, with a relatively large number entering in late June and July, after most hatchery fish had entered salt water. In the November sample, hatchery fish were most abundant, followed by wild stream type, then followed by wild ocean type.

Introduction

Wild chinook salmon (*Oncorhynchus tshawytscha)* enter the ocean in their first year after hatching (ocean type) or one or even two years later (stream type), (Healey 1991). The actual date that the young enter the ocean varies among stocks and among years with most entering the ocean between April and the end of June. However, some chinook enter later in the year and some may migrate to sea almost anytime during the year (Healey 1983). Recently, hatchery-reared chinook salmon have appeared as a prominent rearing and life history type, representing at least 50% of the smolts that enter the Strait of Georgia each year (Beamish et al. 1995). Most of these hatchery reared chinook are released from the hatcheries between about mid-April to mid-June.

In this study, we are attempting to understand the factors that affect the carrying capacity for chinook salmon in a semi-enclosed marine ecosystem. The Strait of Georgia has always been one of the most important recreational fishing areas in Canada, particularly for chinook salmon. There was a precipitous decline in abundance in the early 1980s that was associated with the 1976-1977 climate-ocean regime shift (Beamish et al. 1995). Despite an intensive effort to restore the levels of catch to pre-1977 levels, the stocks have not rebuilt. In this project we are attempting to determine what changes in the Strait of Georgia ecosystem were associated with the decline in marine survival of chinook. Here we report our preliminary findings on the relationship between the timing of entry into salt water and the residence of juvenile chinook in the Strait of Georgia at the end of their first ocean year.

Methods

In 1995, we carried out a series of surveys in the Strait of Georgia, using beam trawls and rope trawls to capture young salmon. Chinook salmon were measured, the otoliths removed and stomach contents analyzed. Unfortunately the gear caused large scale losses, thus it was difficult to collect preferred scales routinely. The otoliths were used to determine the rearing type (Zhang et al. 1995) and the daily growth increment pattern was used to identify the approximate date of entry into salt water. Otoliths were prepared using the procedures described in Zhang et al. (1995). The date of ocean entry was determined by counting the number of daily increments that formed in the ocean and subtracting this number of days from the capture date. Daily growth increments formed in the ocean were wider and more prominent than freshwater daily growth increments and the area of persistent change was considered to be the time of ocean entry. The actual entry into salt water may not be an abrupt change from freshwater to saltwater environments, resulting in a transition in the appearance of the zones with the mid point in the transition pattern considered to be the date of entry. The interpretation has not been validated, but we did compare determinations of the date of ocean entry with tagged hatchery fish whose date of release from the hatchery was known.

Results

A total of 48 juveniles were examined that were reared in the hatcheries and had a coded wire tag (CWT) when captured in the Strait of Georgia in 1995. The difference between the estimated date of ocean entry and the average date of release from the hatchery was compared for each of the sampling periods (Fig. 1). The average difference for all samples was 10.1 days (sd 10.9). This release date is earlier than the date of ocean entry as smolts spend a variable amount of time in fresh water after release. Also, the first few days in salt water may not produce distinct ocean type growth increments. Hatchery release dates are usually ranges of dates requiring the selection of the mid-point as the date of hatchery release. Thus it would be expected that there is a difference between the release date and the date of ocean entry and an average difference of 10.1 days is an indication that the otolith increments may provide reliable estimates of the date of entry into the ocean.

In 1995, we conducted surveys in the Strait of Georgia throughout the year, with the September 11-22 and November 6-18 cruises being the latest in the year. The mean dates of ocean entry for these two cruises and the chinook life history and rearing types are listed in table 1. In general, all of the samples in these two cruises, had an average date of ocean entry about mid-June. The mean time of entry was particularly consistent for the November sample, varying by only a few days for the various life history types. As might be expected, the larger standard deviation for wild juveniles than for hatchery juveniles indicates that wild smolts enter the ocean over a longer period.

In the September sample, the samples of wild stream type fish, entered the ocean at the same time as the early hatchery releases (Fig. 2). The hatchery releases in 1995 also had a pattern that could be separated into an early and late release period (Fig. 3). The wild ocean fish in this sample entered about mid-July and were considerably smaller in length than the other life history types (Fig. 4). By mid-November, the wild ocean fish that entered the ocean in mid-July were not as dominant and the mean entry date reflected the dominance of wild stream type fish that entered earlier (Fig. 5). In the November sample, the mean size of hatchery fish was smaller than the wild juveniles (Fig. 6) and the mean size of the wild stream type fish was larger than the wild ocean type.

A comparison of the mean entry date for the five sampling periods (Fig. 7) indicates a trend towards later ocean entry of fish that are resident later in the year. The trend is most obvious for wild stream type. The wild ocean fish mean date of entry was influenced by the entry of smolts later in June and in early July (Fig. 7). Hatchery fish did not show much of a change after the May 23-30 sample. The frequency distributions of entry dates (Fig. 8, 9, 10) show the range in entry dates for the various life history types. For hatchery fish (Fig. 8) the earliest sample, in May, was taken before all fish were released (Fig. 3). Subsequent samples identified a small increase in the date of entry for fish captured later in the year, but the range in entry dates remained quite constant. The distributions of the date of entry for wild stream-type (Fig. 9) changed only for the last sample, possibly indicating the movement of fish out of the strait rather than the mortality of the wild-stream type fish that entered earlier. The range in ocean entry dates is more restricted than the other types, showing both the tendency of this life history type to enter salt water early and over a shorter period. The greatest variation occurred for the ocean type fish (Fig. 10). This life history type entered salt water from at least early April through to early August in our samples. The fish resident in November represented a composite of this complex ocean migration pattern with broad representation from the range of ocean entry dates.

Canadian hatcheries releasing chinook into the Strait of Georgia, released fish from mid-April to mid-June (Fig. 3). As noted earlier, the release date may be an average over a range and does not reflect the time needed for the smolts to migrate from fresh water into the ocean. The schedule in 1995 resulted in about 65% of the smolts being released before May 26, resulting in a large release at the end of May. The effects of this release schedule can be seen in the July and September samples, but is absent by November. The average entry date of mid-June of the juveniles resident late in the year (November), indicates that a high percentage of the hatchery fish that entered earlier probably were no longer resident in the strait. If the difference of about 10.1 days between release date and our estimate of ocean entry date can be applied, then it is the end of May and early June hatchery releases that are most common in our samples. The dominance of these later entry hatchery fish in the resident population late in November was confirmed using CWT juveniles caught in the 1995 and 1994 surveys late in the year (Table 2). Of the 63 CWT juveniles captured in the late samples in 1994 and 1995, approximately 2/3 were released about May 28 or later and 1/3 were released in June.

The chinook in the sports catch of hatchery fish with CWT's, in 1995, had a release or ocean entry pattern (Fig. 11) more similar to the pattern of hatchery releases in 1995 (Fig. 3). The fish in the 1995 catch entered salt water several years earlier and we will have to wait to find out how the 1995 ocean age 0 fish are distributed in the catches.

Discussion

The pattern of daily growth increments in the otoliths of chinook salmon appears to be useful to study the timing of ocean entry in relation to marine survival and residence in a particular ecosystem. The comparison of estimates of date of entry with the known release dates from hatcheries indicated that the estimated date of ocean entry was almost exclusively after the release date and an average of about 10.1 days after the release date for these CWT smolts. The time to enter salt water and the time required for the wider, more prominent saltwater increments to form was not determined, but an estimate of an average of about 10.1 days appears possible. The observations that fish resident in the Strait of Georgia late in the year, were fish that entered later in the migration into salt water was consistent with the known release dates of hatchery fish with CWT's that were caught later in the year. Thus, even though the determinations have not been validated, the interpretations of freshwater and saltwater increments and the estimates of dates of entry appear reasonable. As with all ageing techniques, the interpretations need to be validated to ensure that one increment forms each day in salt water and to determine when the first saltwater increments first form after ocean entry.

A surprising observation was the virtual identical mean date of ocean entry for the hatchery, wild ocean, and wild stream types in the November sample. The interpretation of these results is not clear for all life history and rearing types. For wild stream types, it was clear that the fish that entered the ocean later, were more abundant later in the year. For the hatchery ocean type, there was very little change, suggesting that the mean date of entry was the mean date of fish found later in the year. Wild ocean fish from a range of entry times were resident in November and the mean entry date may represent a composite of changes that occur for these stocks once they enter the ocean.

In general, stream type fish entered the ocean earlier than the other rearing types as described by Healey (1991) and others, but stream type fish were twice as abundant as the ocean type later in the year, contrary to the popular opinion. The ocean type wild fish entered salt water throughout the spring and summer, with a relatively large number entering in late June and July.

As with all Pacific salmon, marine mortality rates are high with most mortality believed to occur within the first few months in salt water. Beamish et al. (1992) and Beamish and Neville (1995) concluded that, spiny dogfish and river lamprey predation was a major source of mortality of chinook in the Strait of Georgia. Both these predators would tend to feed on smolts that enter earlier in the year. Spiny dogfish, for example, moved into the shallow nearshore areas at the Big Qualicum hatchery in mid-May, just prior to the release of chinook. River lamprey that feed on coho and chinook, mainly in June and July (Beamish and Neville 1995) attack the larger fish that have been in salt water longer. Therefore, there is some evidence that indicates there could be an increased mortality for smolts that enter earlier in the year. However, it is also possible that the chinook entering earlier in the year tend not to reside in the strait later in the year.

This is the first report of the effect of ocean entry dates on chinook abundance in the Strait of Georgia carrying capacity study. As with other studies of this type, it is necessary to continue the observations before attempting to conclude what is "normal" behaviour. This may be particularly true for chinook which have the greatest diversity of natural life history types of all Pacific salmon, that have become even more complex with the additions of large numbers of a hatchery reared type. Presumably the diversity of life history types and the time of ocean entry in some way ensures the overall survival and optimal usage of a particular marine carrying capacity. If this is true, we might expect that the average dates of marine entry of the ocean age 0 juveniles in the Strait of Georgia will vary as the ecosystem changes. It would be useful to know if the carrying capacity for all rearing types combined can be altered by adjusting release dates or if the diversity in ocean entry times ensures that the carrying capacity is optimized. Recognizing our warning to ourselves to be cautious about interpretations at this stage of the study, it is still tempting to note that the great diversity of behaviour of chinook salmon may reflect the diversity of sources of marine mortality. In 1995, the optimal period for marine survival may account for the particular mixture of life history types we observed in November. In other years, there may be other optimal dates and the relative proportions of life history types may change accordingly.

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Table 1. Mean dates of ocean entry (± sd).

	Total	Hatchery	Total Wild	Wild-Stream	Wild-Ocean
Sept. 11 - 22	June 20 ± 24.6 (n=305)	June 8 ± 16.1 (n=119)	June 28 ± 26 (n=186)	May 26 ± 14.4 (n=52)	June 10 ± 16.5 (n=134)
Nov. 6 - 18	June 13 ± 20.6 (n=180)	June 12 ± 13.3 (n=108)	June 13 ± 28.3 (n=72)	June 14 ± 28 (n=49)	June 12 ± 29.6 (n=23)

Table 2. Hatchery release dates and the number of juveniles in the samples with a CWT that were released on these dates.

		Nov. 95	Sept. 95	Sept. 94
April	3	1	1	-
	8	-	-	-
	13	-	-	2
	18	-	-	-
	23	-	-	-
	28	-	-	-
May	3	1	-	-
	8	-	-	1
	13	1	-	1
	18	-	-	1
	23	4	2	4
	28	2	1	20
June	2	-		2
	7	1	2	2
	12	-	-	6
	17	-	-	8
	22	-	-	-
	27	-	-	-
July	2	-	-	-
Total		10	6	47

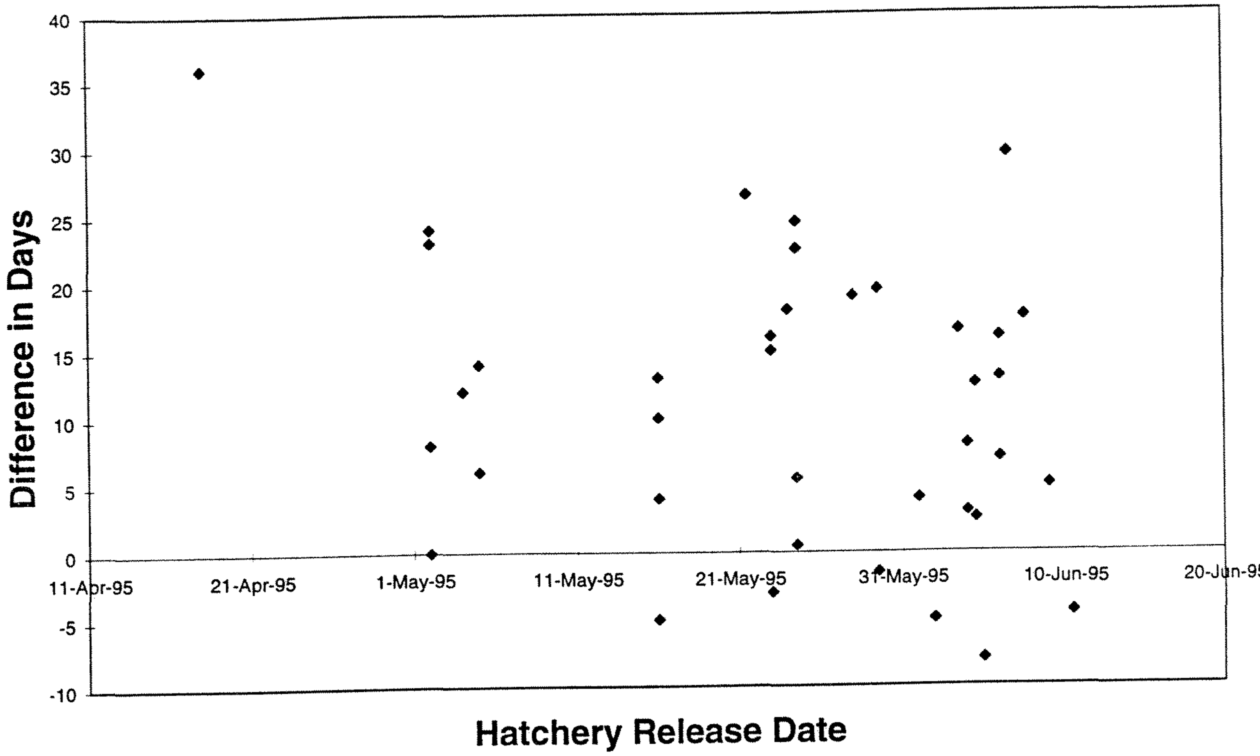

Fig. 1. Difference between the date of release from a hatchery and the estimated date of entry into the ocean for CWT fish captured throughout the study. If the hatchery release date was identified as a range, the mid-point in the range was used. Thus, some of the negative differences may result from the uncertainty of the exact date of ocean entry.

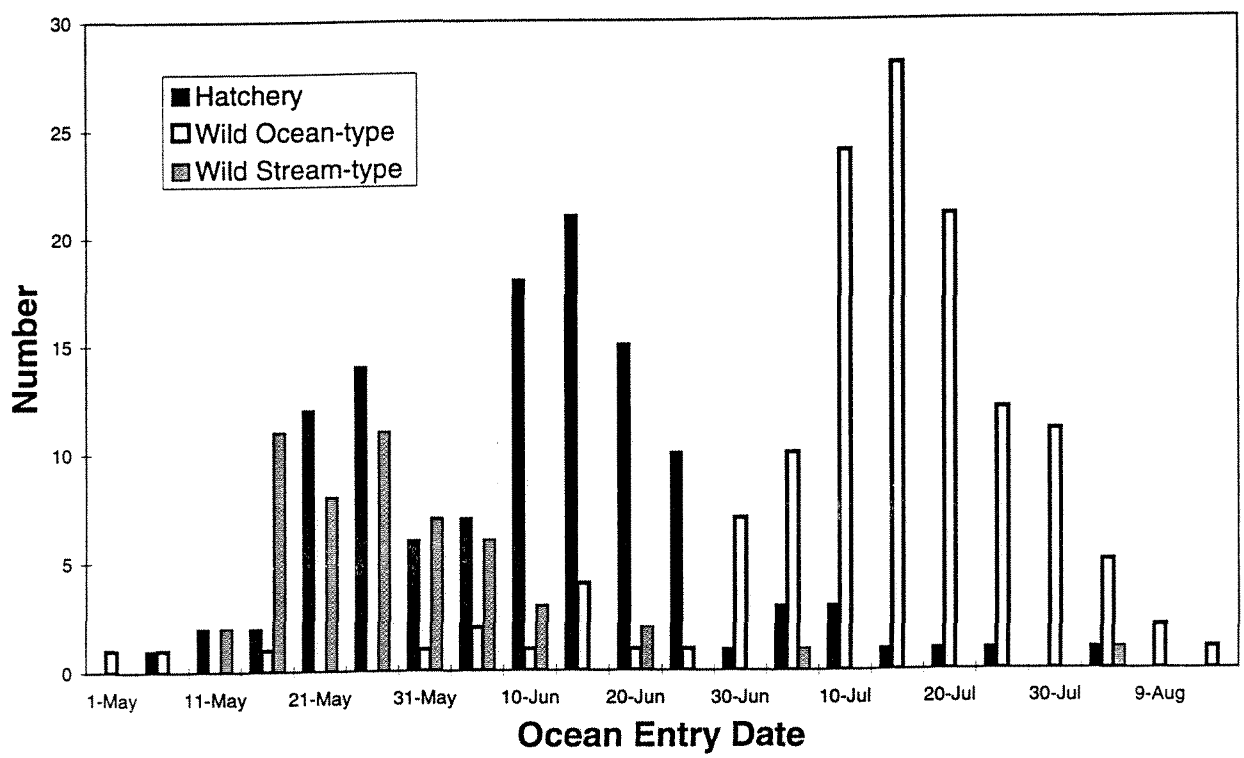

Fig. 2. Ocean entry dates for hatchery reared, wild ocean and wild stream life history type for chinook sampled from September 11-22, 1995.

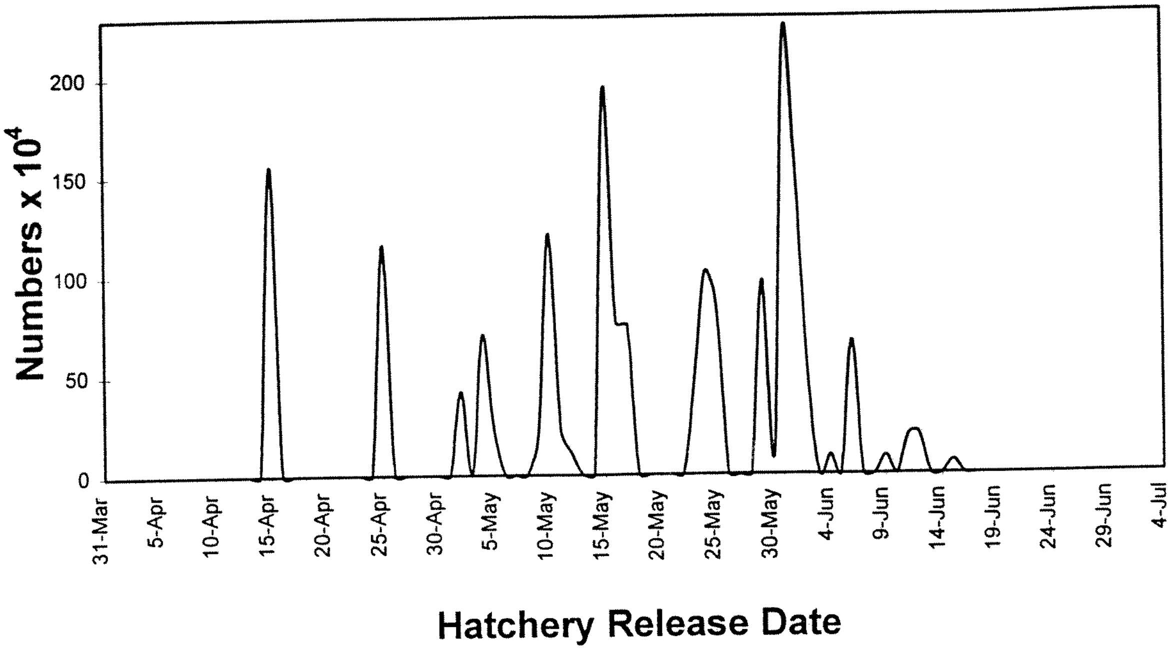

Fig. 3. Release dates from Canadian hatcheries producing chinook salmon that entered the Strait of Georgia in 1995.

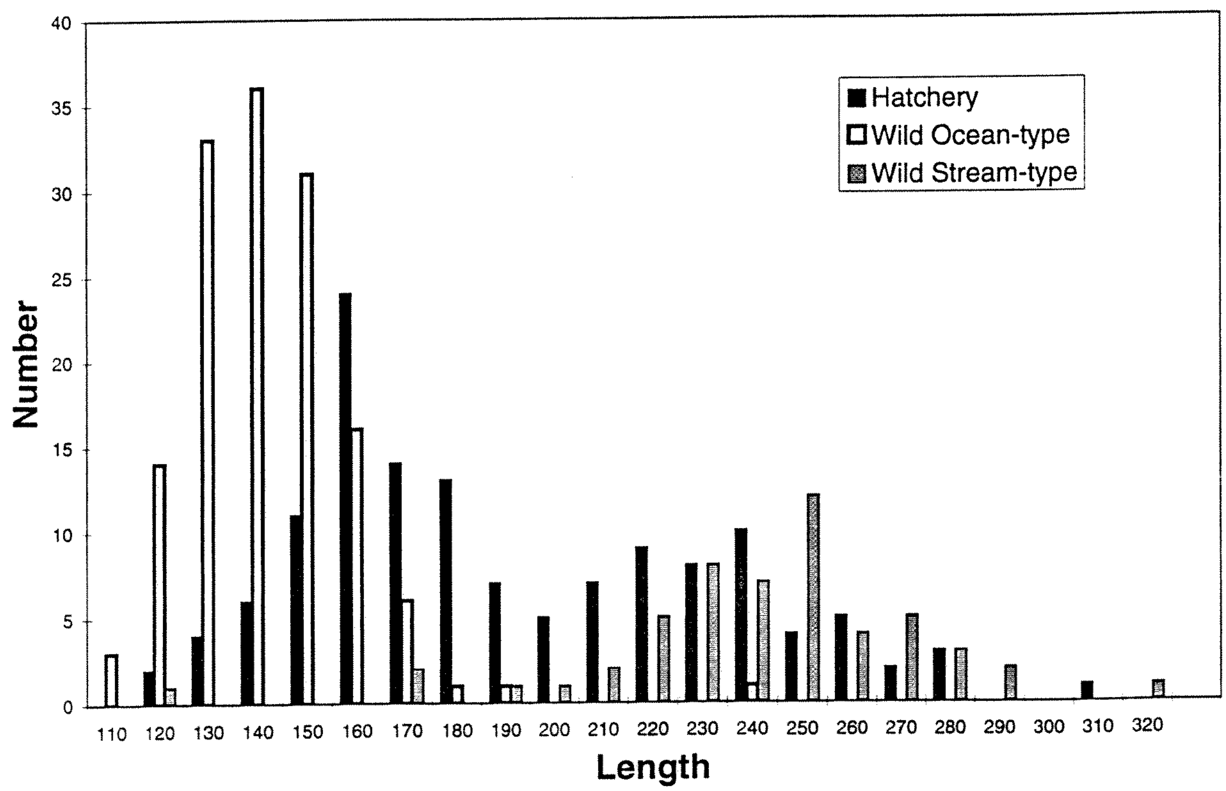

Fig. 4. Fork lengths (mm) of the rearing and life history types, sampled from September 11-22, 1995. Hatchery (mean 187.6, sd 41.4, n=135), wild ocean (mean 137.7, sd 16.3, n=142), wild stream type (mean 263.8, sd 37.8, n=54).

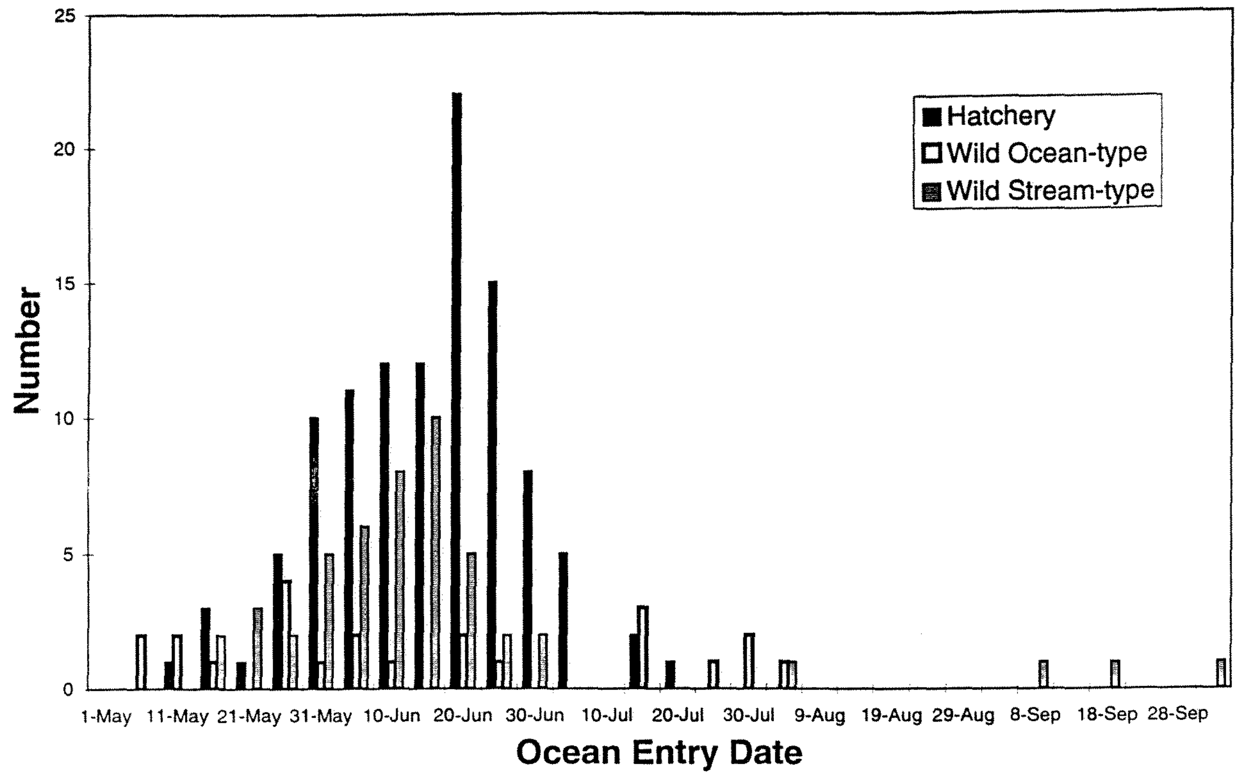

Fig. 5. Ocean entry dates for hatchery-reared, wild ocean and wild stream life history types for chinook sampled from November 6-18, 1995.

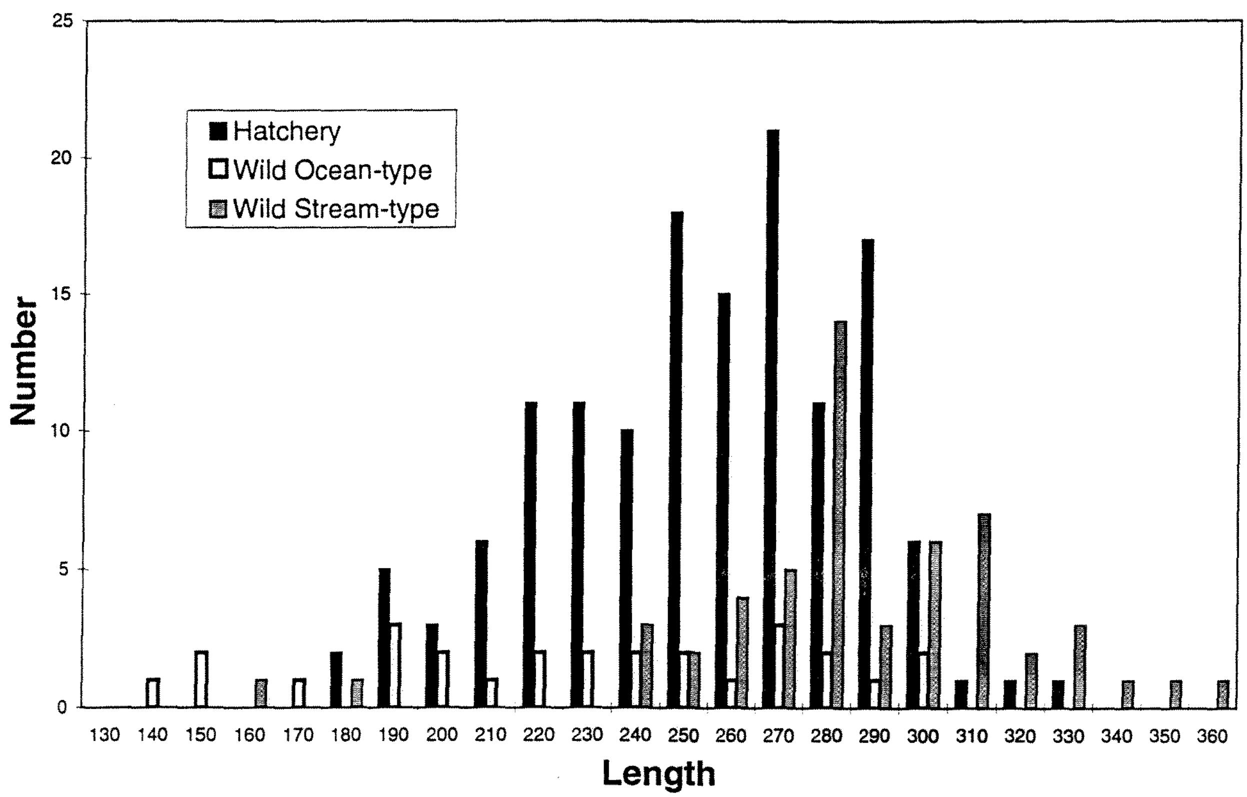

Fig. 6. Fork lengths (mm) of the rearing and life history types, sampled from November 6-18, 1995. Hatchery (mean 250.4, sd 30.8, n = 139), wild ocean (mean 224.8, sd 48.9, n = 27), wild stream type (mean 280.5, sd 35.7, n = 54).

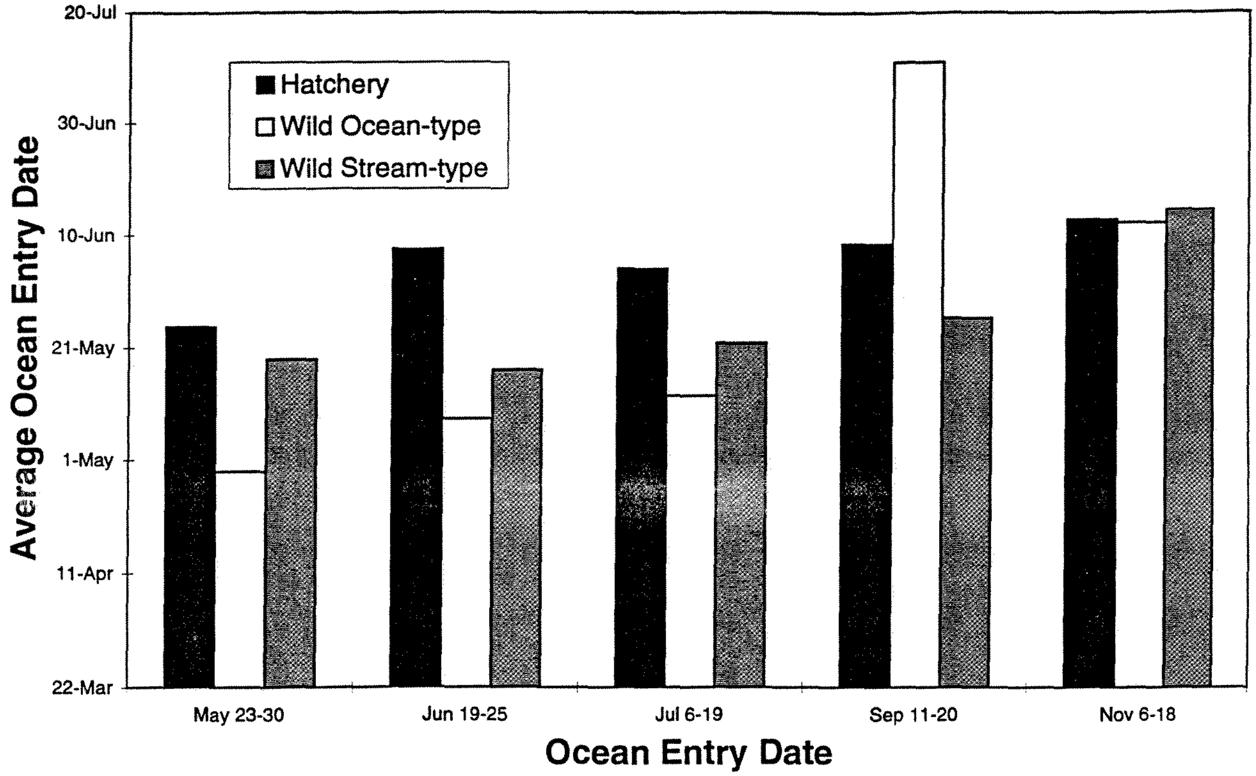

Fig. 7. Changes in the mean ocean entry dates for the three life history and rearing types, for all cruises in 1995.

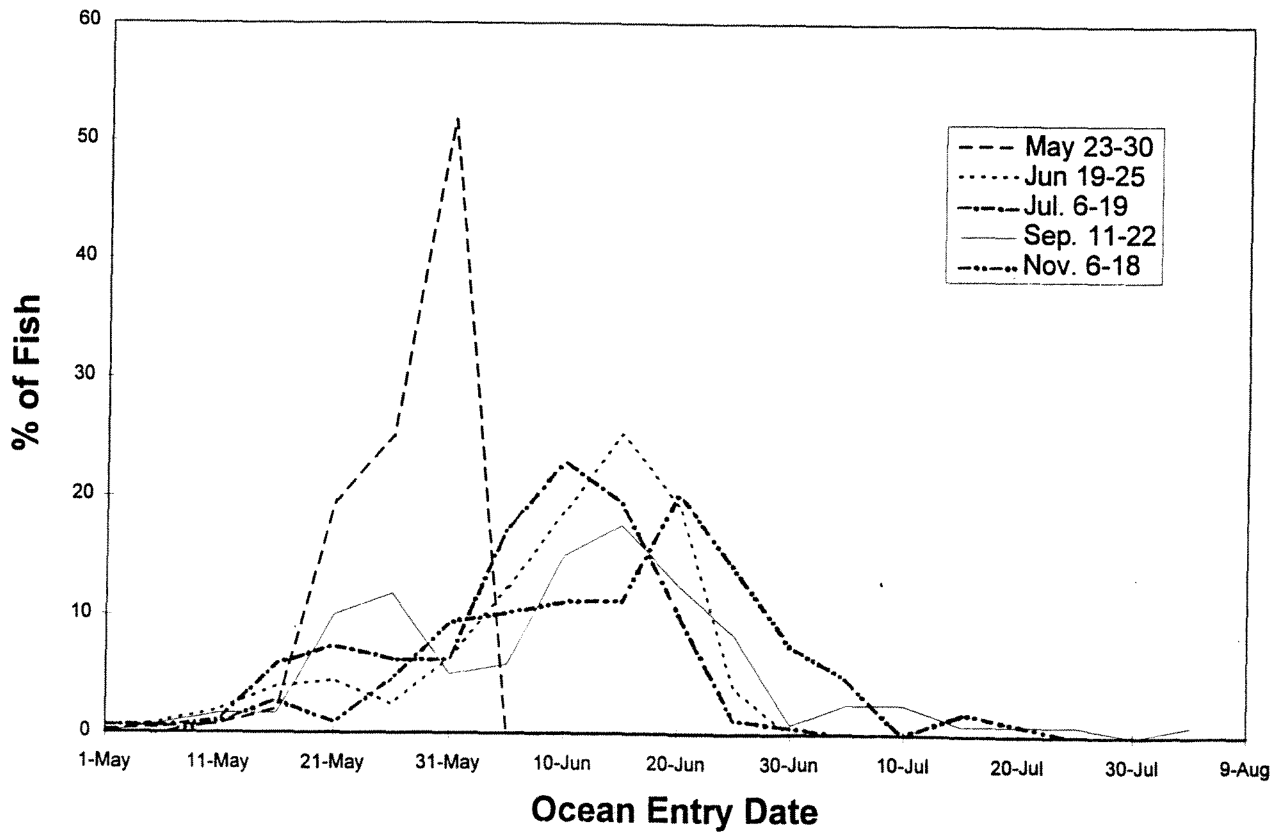

Fig. 8. Percentage of fish for each ocean entry date, for hatchery-reared chinook in all samples from the 5 cruises in 1995.

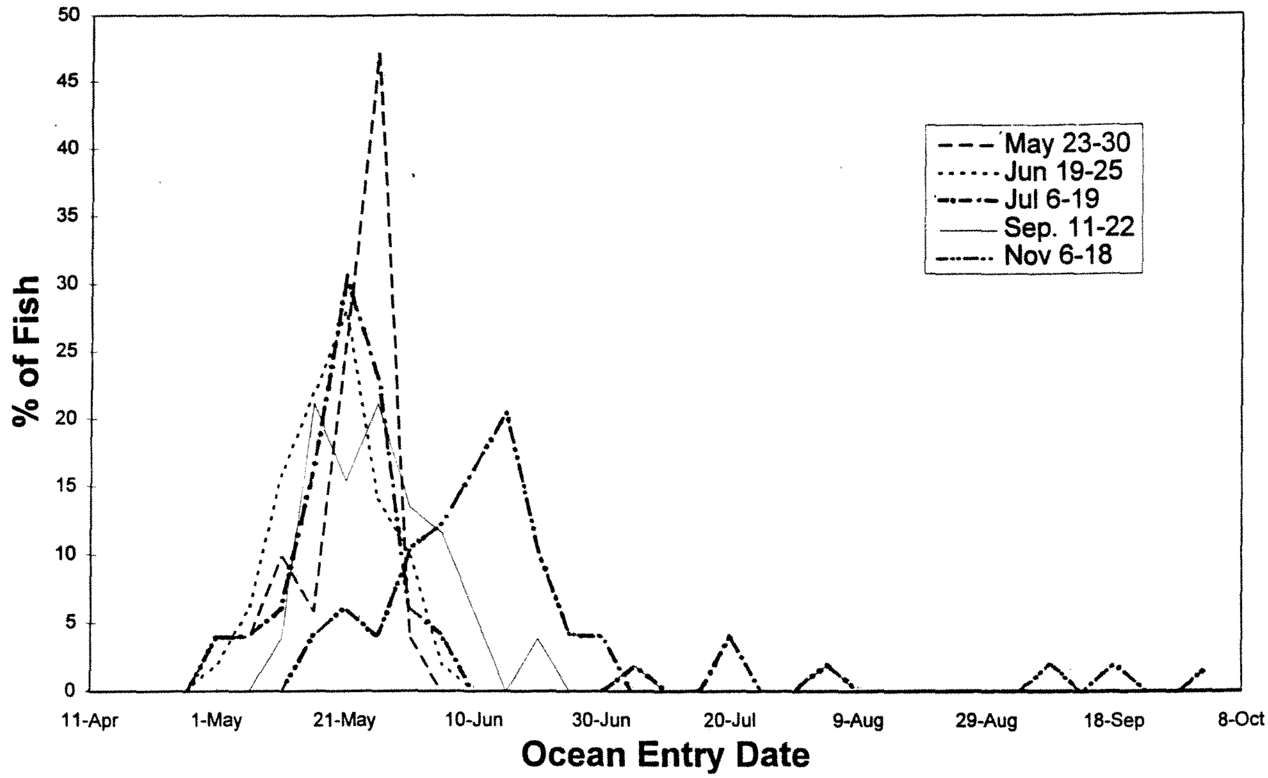

Fig. 9. Percentage of fish for each ocean entry date, for wild stream chinook in all samples from the 5 cruises in 1995.

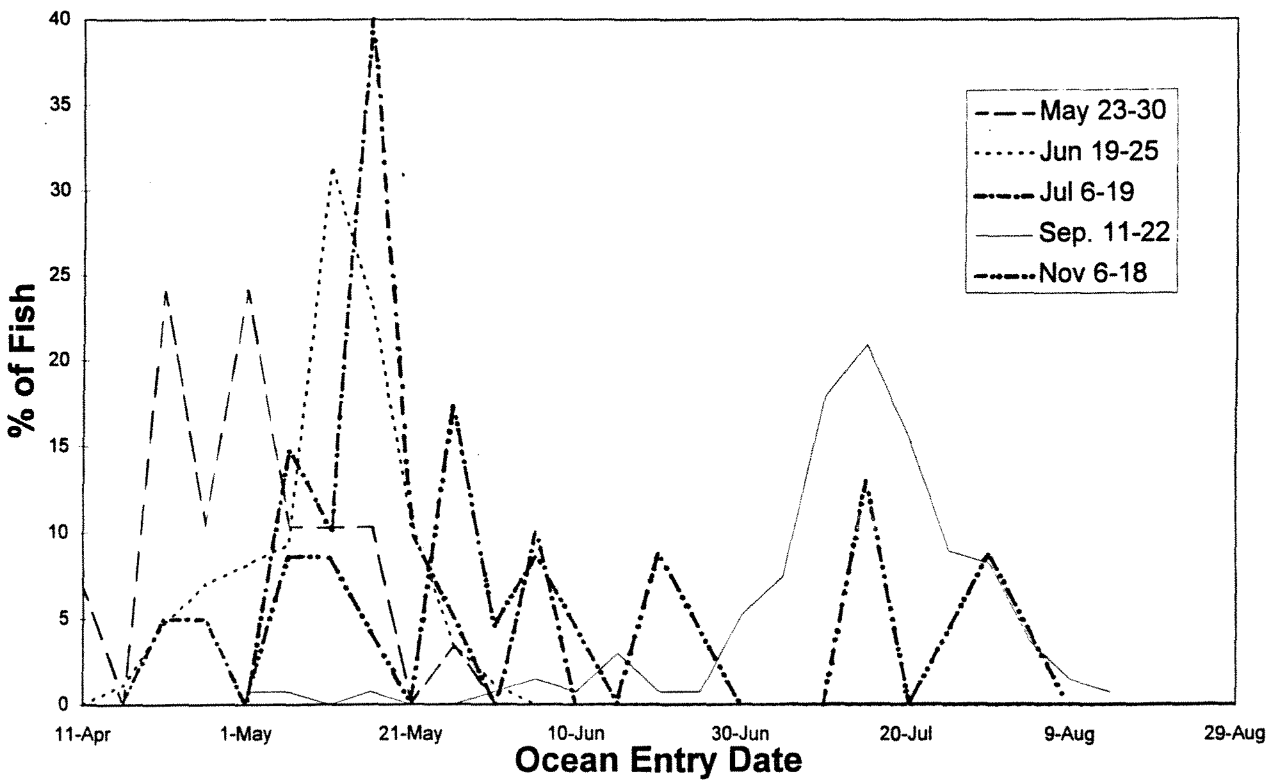

Fig. 10. Percentage of fish for each ocean entry date, for wild ocean chinook in all samples from the 5 cruises in 1995.

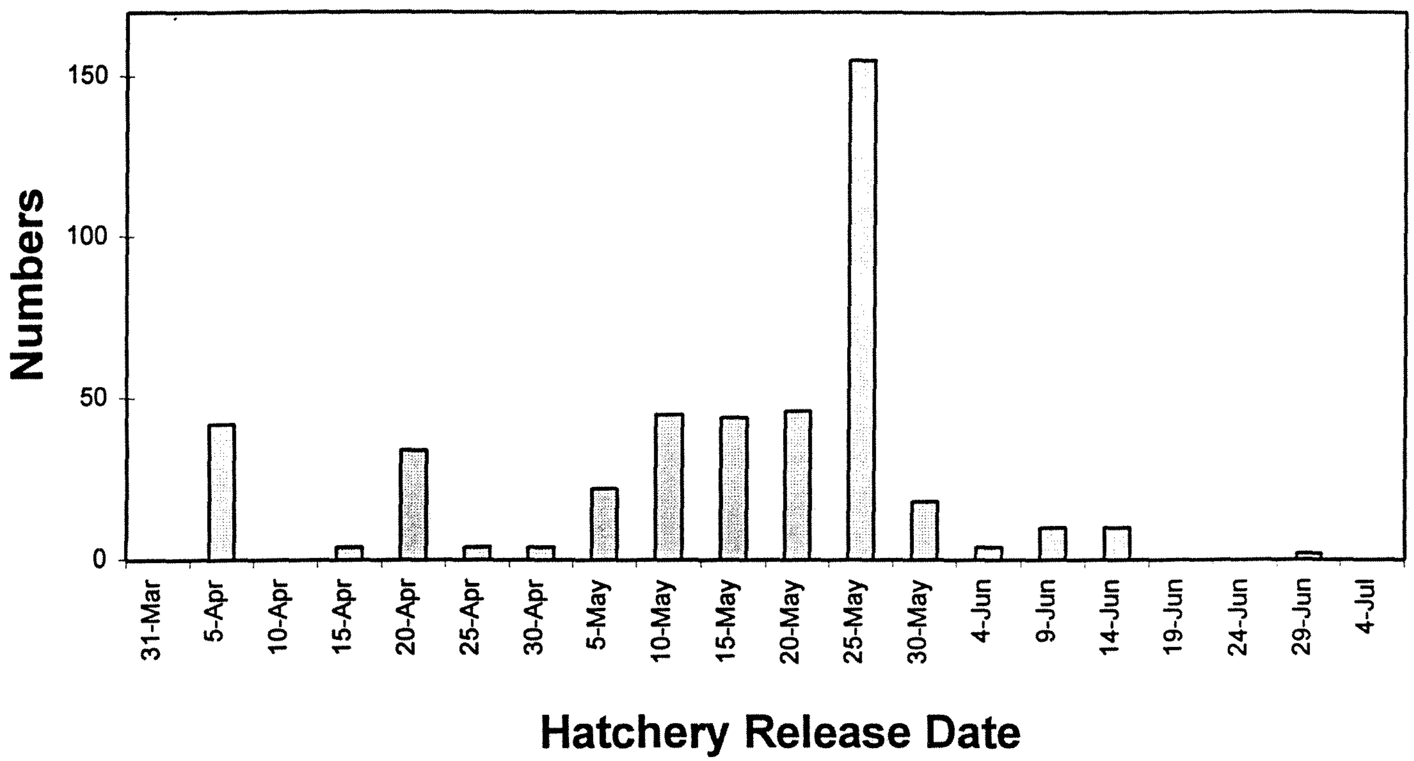

Fig. 11. Hatchery release dates for chinook salmon, with CWT's, caught in the sports fishery in the Strait of Georgia in 1995.