Juvenile Salmon Residency in a Marsh Area of the Fraser River Estuary

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Large numbers of juvenile chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*) were present within tidal channels of a marsh area in the Fraser Estuary between March and June 1978. The tidal channels investigated dewatered at low tide, necessitating daily emigrations by juvenile salmon out of the channels. While pink fry emigrated from tidal channels at the early and middle stages of ebbing tides, most chum and chinook fry emigrated near the later stages of ebbing tides. Mark–recapture studies demonstrated that chinook and chum fry resided temporarily in the marsh prior to migrating into the Pacific Ocean and returned to the same channel on several tidal cycles. Pink fry were abundant in the channels, but appeared to be transient. Chinook and chum showed an increase in average length which was attributable to estuarine growth.

Key words: chinook salmon, chum salmon, pink salmon, juvenile residency, marsh tidal channel, Fraser Estuary, estuary growth

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Entre mars et juin 1978, il y avait un grand nombre de jeunes saumons chinook (*Oncorhynchus tschawytscha*), keta (*O. keta*) et roses (*O. gorbuscha*) dans des chenaux de marée des régions marécageuses de l'estuaire du fleuve Fraser. L'eau des chenaux de marée étudiées se retirant à marée basse, les jeunes saumons étaient forcés à émigrer quotidiennement hors de ces chenaux. Alors que les alevins de saumon rose quittaient les chenaux de marée au début ou au milieu du reflux, la plupart des alevins de saumons keta et chinook émigraient vers la fin du reflux. Des expériences de marquage et de recapture démontrèrent que les alevins de saumons chinook et keta résidaient temporairement dans la région marécageuse avant d'émigrer dans l'océan Pacifique et retournaient au même chenal pendant plusieurs cycles de marée. Les alevins de saumon rose étaient abondants dans les chenaux, mais semblaient n'y être que de passage. On a observé chez les saumons chinook et keta une augmentation de la longueur moyenne attribuable, semble-t-il, à la croissance estuarienne.

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ESTUARIES serve as nursery areas for the larvae and juveniles of commercially and recreationally important finfish and shellfish (Smith et al. 1966; Lauff 1967; Haedrich and Hall 1976). For anadromous species, estuaries can provide a transition zone wherein both juveniles and adults gradually adapt to environmental differences between freshwater and marine environments. Anadromous Pacific salmon (genus *Oncorhynchus*) are extremely abundant on both coasts of the North Pacific Ocean, and billions of juvenile salmon annually pass through estuaries on the Asian and North American Pacific coasts.

The Fraser River system in British Columbia supports some of the world's largest runs of Pacific salmon (Northcote 1974). Juveniles of two species of salmon, chum (*Oncorhynchus keta*) and chinook (*O. tshawytscha*), occur in the Fraser Estuary between March and July (Dunford 1975; Anon. 1978; Levy et al. 1979). Much of the original marsh area in the Fraser Estuary has been lost from dyking and subsequent development (Forrester et al. 1975). There is concern (Dorcey et al. 1978) that historical and present developments in the estuary have had negative impacts on Fraser salmon runs.

Information on the residency behavior of juveniles is required to evaluate the importance to salmon of Fraser and other marsh habitats. Both chum (Mason 1974; Healey 1979) and chinook salmon juveniles (Reimers 1973; Healey 1980) live temporarily in some estuarine areas along the Pacific coast prior to moving into the coastal marine environment. Species that are resident in estuaries for an extended period are potentially more sensitive to losses and changes in estuarine habitats than forms which utilize these areas merely for migratory passage. The prime objective of this study was to establish the relative length of residency by juvenile salmon in a major marsh of the Fraser estuary.

Materials and Methods

The study area was on Woodward Island (49°6′N, 123°8′W) within the Ladner marsh–island complex of the

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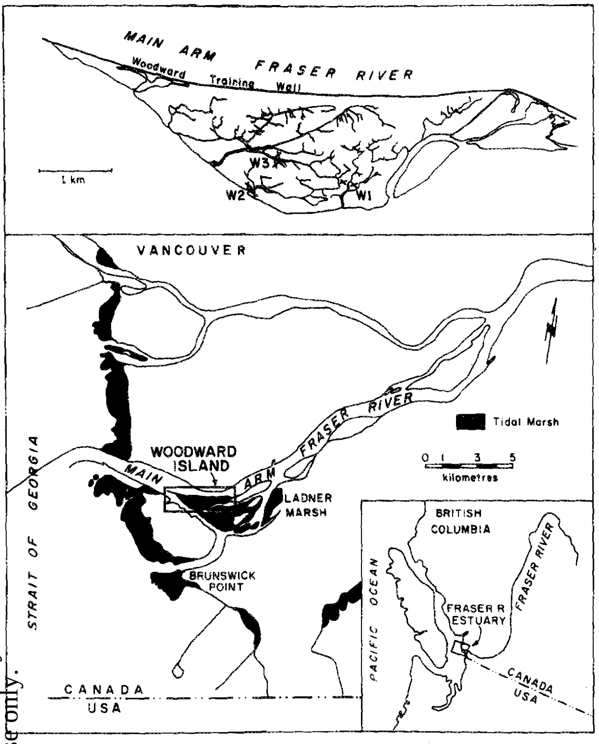

FIG. 1. Location of sampling sites in tidal channels on Woodward Island within the Fraser River Estuary.

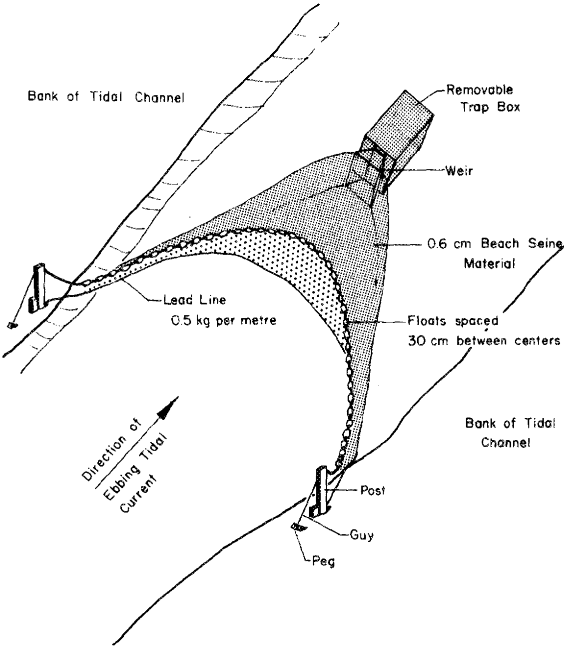

FIG. 2. Intertidal trap net designed to sample fish utilizing tidal channels on Woodward Island.

Fraser River Estuary (Fig. 1). Woodward Island is an intertidal marsh of ~128 ha and has a plant community dominated by the sedge, *Carex lyngbyei* (Kistritz and Yesaki 1979). As a result of variation in Fraser River discharge (commonly approaching 8 000 $m^3 s^{-1}$ in peak freshet periods between May and July, but falling to 700 $m^3 s^{-1}$ in winter months), marsh areas in the vicinity of Woodward Island are dominated by freshwater or by brackish water at different times of the year (Kistritz 1978). Highest salinities on Woodward Island (10‰) occur during low Fraser River flows in winter months. During March–July 1978, the period of investigation, salinities on Woodward Island ranged between 3‰ in March and 0‰ during the latter 4 mo (Westwater Research Centre, unpublished data).

Three tidal channels on Woodward Island (Fig. 1) served as sampling sites. Tidal channels are dendritic waterways which extend into, and drain, marsh areas. They may be up to several hundred metres in length, tapering from a mouth several to tens of metres wide into narrow terminal branches, often less than 1 m in width. Other predominant fish habitats surrounding Woodward Island are referred to as sloughs (Dunford 1975) and encompass a subtidal habitat immediately adjacent to marsh areas. Slough habitats are open-ended, exposed to the flow of the Fraser River at all tide levels. Because tidal channels undergo dewatering on low tides, fish move out of the channels and into sloughs as the tide ebbs, and reenter the tidal channels on a successive flood tide.

A large beach seine was used as an intertidal trap (Cain and Dean 1976) to capture fish utilizing tidal channels. The trap net (0.6-cm mesh, 2.4 m deep) was stretched across a tidal channel at a high slack tide, preceding a steep tidal drop, and fastened to stakes set into the bank of the channel (Fig. 2). As the tide ebbed, most of the fish population in the channel upstream from the trap net either entered the trap or was retained in a small pool behind the net. When the channel was nearly dewatered, all the fish that had not entered the trap were concentrated into a small section of the net, and together with those from the trap, transferred into a 20-L cooler. The catch was either kept alive in 64-L plastic pails until enumerated or else immediately preserved in a 10% Formalin solution.

The removable trap box (Fig. 2) permitted investigation of the timing of fish emigrations from tidal channels on ebbing tides. The trap box was emptied hourly. After the tide had dropped to a level where about a 0.5-m depth of water remained in a pool of the tidal channel immediately upstream from the trap net, the net was pursed and the fish in front of the net were captured.

To mark juvenile salmon for mark–recapture studies, fine fluorescent grit was applied with an air gun at 5.6 kg/cm^2 pressure (Healey et al. 1976). Fish were held in a pen for 1 d prior to being marked. About 200 fish were placed on a 3-mm plastic mesh screen rack (25 × 40 cm) and then into a bath of MS-222 anesthetic. Once the fish were motionless, the rack was placed on a table and the grit sprayed from a distance of about 40 cm. The racks containing the fish were then rinsed to get rid of excess grit, and the fish allowed to recover in oxygenated 64-L pails. Groups of fish were marked with different colors of fluorescent grit so that several release groups were distinguishable. Marked fish were held for 1 d prior to being released, as it was during the initial period after marking that mortality was thought to occur (Healey et al. 1976).

TABLE 1. Gear efficiency of intertidal fish traps for capturing juvenile salmon in three tidal channels on Woodward Island during 1978.

	Sampling site			
	W1	W2	W3	All sites
Chinook				
No. of tests	2	3	2	7
Average	46%	68%	70%	62%
Range	25–66%	50–74%	60–79%	25–79%
Scaling factor	2.17	1.47	1.43	1.61
Chum				
No. of tests	2	4	2	8
Average	37%	44%	55%	45%
Range	12–62%	28–59%	14–66%	12–66%
Scaling factor	2.70	2.27	1.82	2.22
Pink				
No. of tests	2	2	1	5
Average	37%	42%	86%	49%
Range	19–54%	26–48%	—	19–86%
Scaling factor	2.70	2.38	1.16	2.05

To recover marked individuals, fish were checked for fluorescent grit marks by inspection under an ultraviolet (uv) light source. About 50 live fish were first placed on 3-mm mesh racks (identical with the marking racks) in an anesthetic (MS-222) bath. As soon as the fish were motionless, the rack was lifted out of the bath and passed under the uv light. Both sides of the fish were inspected for marks by flipping the rack over onto an identical rack and passing it under the uv light a second time.

Two types of mark–recapture studies were conducted: gear efficiency assessments and residency determinations. Gear efficiency assessments (Kjelson and Colby 1977) were designed to determine the proportion of the fish population in the tidal channel that was sampled by the gear used. After setting the nets and waiting for the tide to recede to the tops of the sedge plants lining the channel banks, a known number (~100) of marked fish of a given species was introduced into the tidal channel about 200 m upstream from the traps. Recovery rates of marked fish were used to estimate gear efficiency factors (the inverse of the average recovery rates) and to scale the catch data to corrected density data. Estimates of the areas of the tidal channels upstream from the sampling sites (W1 = 4227 m^2, W2 = 24 192 m^2, W3 = 6745 m^2) were obtained by planimetry off Fraser River Delta Series Maps 72-24T (Department of Lands, Forests, and Water Resources, Government of British Columbia) and used to express the fish catch data on an areal basis.

Gear efficiency assessments were conducted with juvenile chinook, chum, and pink salmon (*O. gorbuscha*) in three tidal channels (W1–W3) between April and June 1978 (Table 1). Recaptures of marked chinook, chum, and pink fry were lowest in W1; consequently, scaling factors were highest at this site. There were consistent species differences in recapture rates. Chinook fry recaptures were higher than pink and chum fry recaptures during gear efficiency assessments, the one exception being a higher recapture rate of one group of marked pink fry in W3 (Table 1). On average, 62% of the marked chinook fry but only 45 and 49% of the marked chum

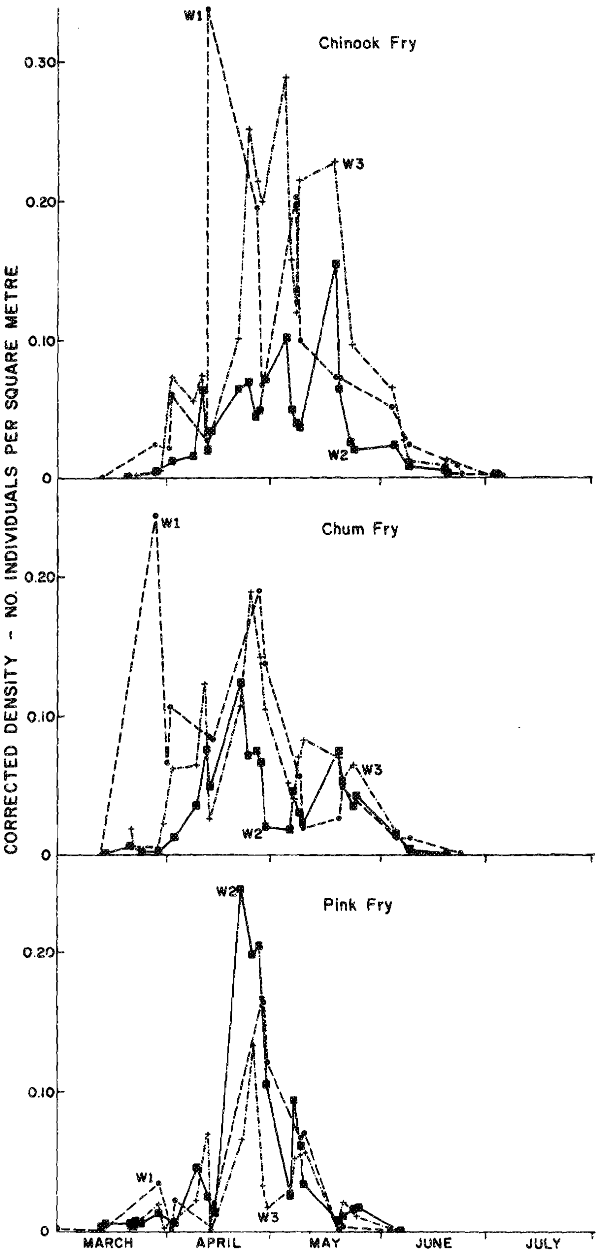

FIG. 3. Density of juvenile salmon in three Woodward Island tidal channels (W1–W3) during 1978. All numbers adjusted for gear efficiency (see Table 1) and tidal channel area.

and pink fry were recaptured during gear efficiency estimates. Leakage of fish around the traps, stranding of fish in pools upstream of the sampling site, and selective predation on marked fish may have affected the gear efficiency of the intertidal trap nets.

Three short-term mark–recapture studies were designed to measure residency of young salmon in the study areas. Groups of marked fish were released into tidal channel W2 on three occasions during May 1978. Between 1 and 7 d

TABLE 2. Results of mark–recapture studies on juvenile salmon conducted on Woodward Island during 1978.

Date of release	Stage of tide	Release period (d)	Recapture date	Species	No. released at W2	No. recaps. in W1	No. recaps. in W2	No. recaps. in W3	Total No. recaps.	[a]Scaled % recap.
May 7	Flood	1	May 8	Chinook	697	6	249	10	265	56
				Chum	238	—	40	2	42	40
				Pink	401	2	2	—	4	2
May 21	Flood	2	May 23	Chinook	351		17	3	20	8
				Chum	193	Not done	5	1	6	7
				Pink	50		4	—	4	19
May 12	Ebb	7	May 19	Chinook	625	—	43	20	63	15
				Chum	171	—	3	—	3	4
				Pink	262	—	—	—	—	—

$^{a}\left\{\left[\sum_{i=1}^{n} (\text{No. recaps. in tidal channel } (i) \times \text{gear efficiency scaling factor in tidal channel } (i))\right] \Big/ \text{Total no. marks released at W2}\right\}$ where n is the number of tidal channels sampled.

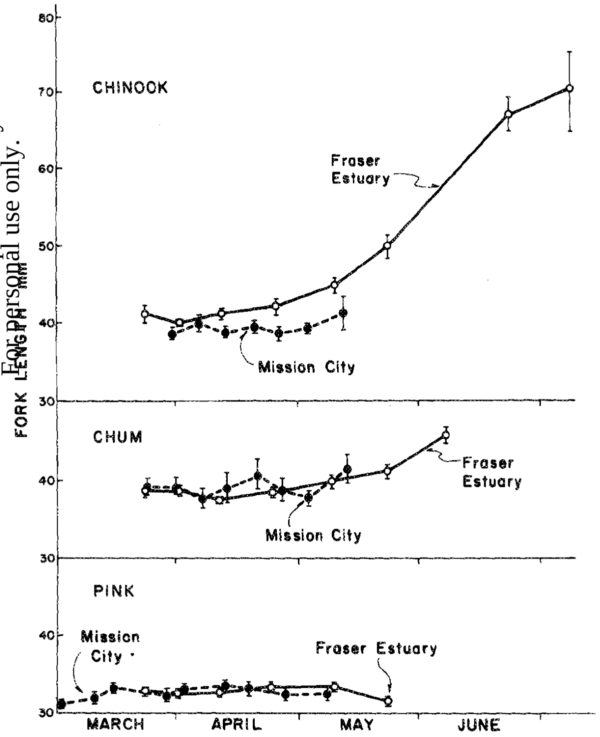

FIG. 4. Seasonal change in average juvenile salmon fork length ± 95% confidence limits during 1978 at W1 on Woodward Island (Fraser River Estuary) and at Mission City, B.C., 100 km upstream from the Fraser Estuary.

after the release of marked fish, the tidal channels were sampled and the fish inspected for marks. Additional marked fish were recovered when fish caught in subsequent sampling operations were inspected under uv light.

Results

Corrected density data for chinook, chum, and pink salmon (Fig. 3) illustrate the seasonal pattern of juvenile salmon occurrence in Woodward Island tidal channels. Between March and May, juvenile chinook, chum and pink salmon were numerically dominant in the tidal channel fish community on Woodward Island (Levy et al. 1979). Juvenile coho salmon (*O. kisutch*) (yearling smolts) and juvenile sockeye salmon (*O. nerka*) (underyearling fry and yearling smolts) also occurred in the tidal channels, but in relatively low numbers. The most abundant salmonid (juvenile chinook) reached an average density of 0.18 individuals per square metre in early May (Fig. 3). The other two abundant salmonids, pink and chum, reached average densities of 0.16 and 0.14 individuals per square metre, respectively, in late April.

Recaptures of marked salmon fry (Table 2) provided evidence for temporary residency and for different residency times of pink, chum, and chinook fry in the vicinity of Woodward Island. Most of the recaptured fish were chinook fry (Table 2). Relatively few pink fry were recaptured, with the exception of four marked individuals following the May 21–23 release. Chum fry recapture rates (scaled percent) were intermediate between those for pink and chinook fry. Recaptures of marked fry during routine sampling operations that followed these studies indicated that chinook fry had a relatively long residence in the marsh. Virtually all incidental recaptures of marked fish were chinook fry. Recoveries of marked fish from the May 12 release group, in addition to the May 19 recaptures shown in Table 2, occurred on the following sampling dates:

	May 20	May 23	May 24	June 6
W1	—	Not sampled	Not sampled	—
W2	5 chinook	1 chum	—	1 chinook
W3	5 chinook	3 chinook	1 chinook	—

Recoveries of marked fish from the May 21 release group, in addition to the May 23 recaptures (Table 2), also occurred on June 19 (one chinook fry in W3) and June 20 (one chinook fry in W3). The longest recorded residence times for marked chinook, chum, and pink fry were 30, 11, and 2 d, respectively.

Preserved fry were measured to the nearest 0.1-mm fork-length and compared with those obtained in a 4 × 4 floating fry trap (Conlin and Tutty 1979) which was operated by the Department of Fisheries and Oceans, Vancouver, B.C., between early March and late May 1978 at Mission City, B.C., 100 km upstream of the Fraser Estuary. There is evidence for growth of juvenile chum and chinook salmon in the Fraser Estuary (Fig. 4). The chum and chinook fry samples from Mission City ranged between 37.5–40.9 mm and 38.2–39.4 mm in average fork length, respectively, during March–May. Chum and chinook fry obtained on Woodward Island were similar in length to those at Mission City until early May and thereafter increased in size reaching average lengths of 46.2 mm for chum in early June and 70.5 mm for chinook during early July. Pink fry trapped on Woodward Island were similar in fork length to specimens obtained at Mission City throughout their occurrence in the marsh (Fig. 4) and did not increase in length during this period.

The emigration sequence of juvenile salmon from tidal channels was studied on four sampling dates. Consistent patterns of movement of pink, chum, and chinook fry were observed. Pink salmon was the first species to emigrate from the tidal channel during its dewatering phase (Fig. 5). Large numbers were caught during the middle draining period 2 and 3 h after high tide. Very few juvenile chum and chinook salmon were caught during ebbing tides; most were captured near the end of the dewatering phase of the channel at low tide. Similar patterns of emigration were observed throughout April and May 1978.

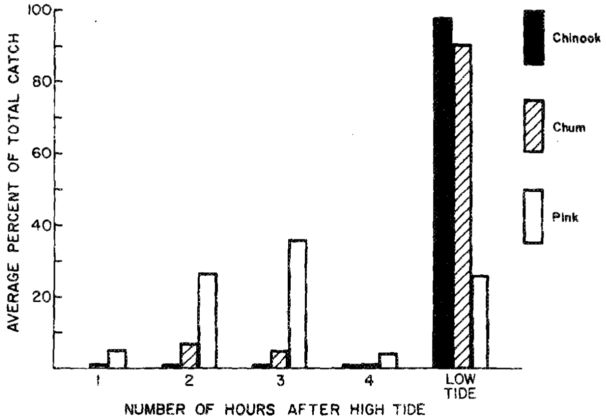

FIG. 5. Percentage of juvenile salmon in trap catches between high and low tide in W3 averaged for four sampling dates during May of 1978.

Discussion

The anadromous progeny of Fraser salmon must pass through the lower Fraser River and estuary at some point during their juvenile existence. Results from this study provide the first evidence that two species of juvenile salmon, chum and chinook can reside in Fraser Estuary marshes prior to entering the marine environment. Chinook was the species which resided in Woodward Island tidal channels for the longest period during May 1978. During mark–recapture experiments, the recapture frequencies probably underestimated the number of marked chinook fry resident on Woodward Island. Only three tidal channels were sampled (representing about 25% of the total tidal channel area on Woodward Island), providing a limited opportunity to recapture marked individuals. Recaptures of marked fry indicated that chinook are capable of month-long residency periods in the vicinity of Woodward Island.

Our results suggest that the increase in average fork length demonstrated by the estuary chinook population represents estuarine growth. The habit of juvenile chinook salmon to remain in tidal channels during the early stages of the ebbing tide probably represents a mechanism for maintaining a position close to the mouths of tidal channels at low tide and avoiding being flushed downstream by tidal and river currents. This behavior allows resident fry to feed on the rich crustacean and insect food resources of the marsh tidal channels (Levy and Northcote 1981) and is conducive to estuarine growth. The largest chinook fry captured on Woodward Island were close to 70 mm in fork length by July, also indicating long marsh residency. Similar observations have been made in the Nanaimo Estuary (Healey 1980) where it was estimated that individual chinooks spent an average of 25 d rearing and emigrated after reaching a fork length of 70 mm.

In contrast with the resident chinook fry, pink fry in Woodward Island tidal channels were transient and only a few were recaptured during mark–recapture studies.The length data indicate no increase in mean size between March and May. Juvenile chum salmon demonstrated a tidal channel residence of intermediate duration between that of pink and chinook fry. A slight increase in mean size was realized by the population and a number of marked chum fry were recaptured during mark–recapture studies. Juvenile chum residency times in the Nanaimo Estuary varied between 0 and 18 d during two field seasons of mark–recapture studies in 1975 and 1976 (Healey 1979).

Although juvenile chinook salmon are relatively less abundant than pink or chum (by an order of magnitude) as downstream migrants in the Lower Fraser River (Department of Fisheries and Oceans, Vancouver, B.C., unpublished data), because of their strong tendency to reside in estuary marsh habitats, they in fact reach higher densities in tidal channels than do the other two species. In late April and early May 1978, the maximum corrected density of chinook, chum, and pink fry in Woodward Island tidal channels was 0.18, 0.14, and 0.16 individuals/m^2, respectively (average values for the three tidal channels sampled). The tendency for chinooks to reside in the tidal channels for a relatively long period resulted in this species concentrating on Woodward Island and becoming the predominant salmonid in the marsh. Pink and chum fry, although much more abundant at Mission City, reared in the marsh for relatively short periods and were not concentrated in the tidal channels of Woodward Island to the same extent as chinook fry.

A difference in the degree to which marshes are utilized as rearing habitats by juveniles may contribute to segregation of the five species of *Oncorhynchus* present in the Fraser River system. Although millions of adult sockeye salmon annually spawn in the Fraser River system, most sockeye fry utilize lakes as juvenile rearing areas (Northcote 1974), and only few are present in tidal channel marsh habitats. The progeny of

Fraser coho spawners mostly use streams as juvenile rearing habitats and are only occasionally captured in marsh tidal channels. Pink fry, although abundant in the tidal channels in even-numbered years, migrate quickly through the marsh and into the Strait of Georgia. The two species that overlap in the marsh to the greatest extent are chum and chinook. This overlap is reduced through differences in migration timing, with chum preceding chinook in the marsh, and through different marsh residency periods, with chum spending a relatively short time in the marsh, when compared with chinook.

Along the Pacific coast of North America, chinook salmon range from the Ventura River in California north to the Chukchi Sea in Alaska, and major spawning populations of chinook salmon occur in large Pacific rivers and their tributaries (Mason 1965). Juvenile chinook have been found in the following large river estuaries: the Sacramento River Delta (Kjelson et al. 1981), the Columbia River Estuary (Johnsen and Sims 1973), the Fraser River Estuary (this study), and the Skeena River Estuary (Hoos 1975). Additionally, estuarine rearing of juvenile chinook salmon has been documented in two relatively small coastal river systems including the Sixes River Estuary, Oregon (Reimers 1973), and the Nanaimo River Estuary, B.C. (Healey 1980). Other chinook rivers having well-developed marshes and/or estuaries likely support populations of resident chinook juveniles in the estuary for part of the year.

The utilization of rearing habitats both in freshwater (Tutty and Yole 1978) and in the estuary can benefit specific chinook runs. The habit of juveniles to concentrate and rear in estuaries, as well as in river tributaries, serves to extend the area of available juvenile rearing habitat. Estuary characteristics of high productivity and intermediate salinity (Odum 1971) may promote the survival of estuary residents. Furthermore, the chinook that rear in freshwater may benefit from reduced competition for space and food resources, if indeed these are limiting, by having a component of the population emigrate to the estuary soon after emergence from the gravel. The overall productivity of a chinook population (number of smolts entering the marine environment) is probably higher for river systems having well-developed estuaries with marshes which serve as additional juvenile rearing areas than in systems without such a habitat.

Scale analysis of adult Sixes River (Oregon) chinook salmon enabled Reimers (1973) to quantify the contribution of five different chinook life history types to the adult population for the 1965 brood year. The most common type was chinook which had remained in freshwater for about 3 mo, and then reared in the Sixes River Estuary for an additional 3 mo. Approximately 90% of the successfully returning adults showed estuarine circuli in the 1st year of scale growth. Some stocks of Fraser River chum and especially chinook salmon may well realize a similar enhancement of survival following a period of juvenile residency in the marshes of the Fraser Estuary.

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