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Seasonal Use by Fish of Nearshore Areas in an Urbanized Coastal Inlet in Southwestern British Columbia

Abstract

In this study, we examine the seasonal variation in fish assemblages at three nearshore marine sites on the north shore of outer Burrard Inlet, British Columbia. Monthly collections with beach seines were made to document changes in species abundance, fish size, and feeding activities over the period of one year. Collection sites represented the shallow sloping cobble beaches common to the Burrard Inlet area. Such beaches are frequently dyked, filled or dredged for port facilities during urban development. A total of 29 species were caught, including juvenile salmonids (*Oncorhynchus* spp.); chum salmon (*O. keta*) was the most abundant salmonid. Fish were caught throughout the year, but more individuals and species were present in the spring and summer than at other times. A size increase over time was noted for many of the species, and stomach analyses indicated that fish were feeding throughout the period they were present. Prey was planktonic or epibenthic and in general originated from marine sources. Outer Burrard Inlet functions as a temporary early marine residence and/or nursery region for many local fish despite local urbanization pressure from metropolitan Vancouver. The destruction or degradation of such areas can have harmful effects on fisheries resources.

Introduction

For over a century, estuaries and nearshore marine habitats of the northeastern Pacific coast have been subject to numerous environmental impacts due to industrial, commercial, and residential development. These areas are also important for foraging, predator avoidance, and physiological transition by various fish species, including Pacific salmon (*Oncorhynchus* spp.), particularly chum (*O. keta*) and chinook (*O. tshawytscha*) (Simenstad *et al.* 1982a, Levy and Northcote 1982). The Fraser River Estuary and adjacent Burrard Inlet support important fish resources, including Pacific salmon, Pacific herring (*Clupea harengus pallasi*), many groundfish species, shrimp, and crabs (Nelles 1978). Recently however, much of the habitat on which these species depend has been altered or lost to urbanization of greater Vancouver and fish stocks have declined (Harris 1978, Fedorenko and Shepherd 1984). Aquatic environments in the lower Fraser River region will continue to be subjected to development proposals which can affect both the physical habitat and water quality of the nearshore environment and adjacent streams.

Data on the use of these environments by fish is needed in order to assess and predict the effects of development on fisheries resources. A number of recent studies have examined fish assemblages and habitat use of the Fraser River estuary (Northcote *et al.* 1979, Greer *et al.* 1980, Gordon and Levings 1984), but only limited, and frequently unpublished information, is available regarding fish use of Burrard Inlet (Waters 1986).

In this study we examine the seasonal variation in fish assemblages at three nearshore sites on the north shore of the outer basin of Burrard Inlet. Sample sites chosen typify the shallow sloping beach habitat that composes most of the unaltered portion of the basin's shoreline. Our objective was to compose a resource inventory, including information on the numbers, species and sizes of fish, and to gather information on the source of food and degree of feeding activity of fish present in this habitat. Ultimately, we wish to describe the value of this habitat to our local fish stocks and identify the periods of highest sensitivity when fish migration rate and/or juvenile fish abundance is high (nursery periods). This information is required to establish guidelines for nearshore development.

Study Area

Burrard Inlet (49°18′N, 123°15′W) extends for about 31 km from its mouth at the Strait of Georgia to its head at Port Moody (Figure 1A). The following description is adapted from Thomson (1981). The inlet is divisible into inner and outer basins by a narrow body of water (First Narrows, Figure 1A). The outer basin, at its maximum, has

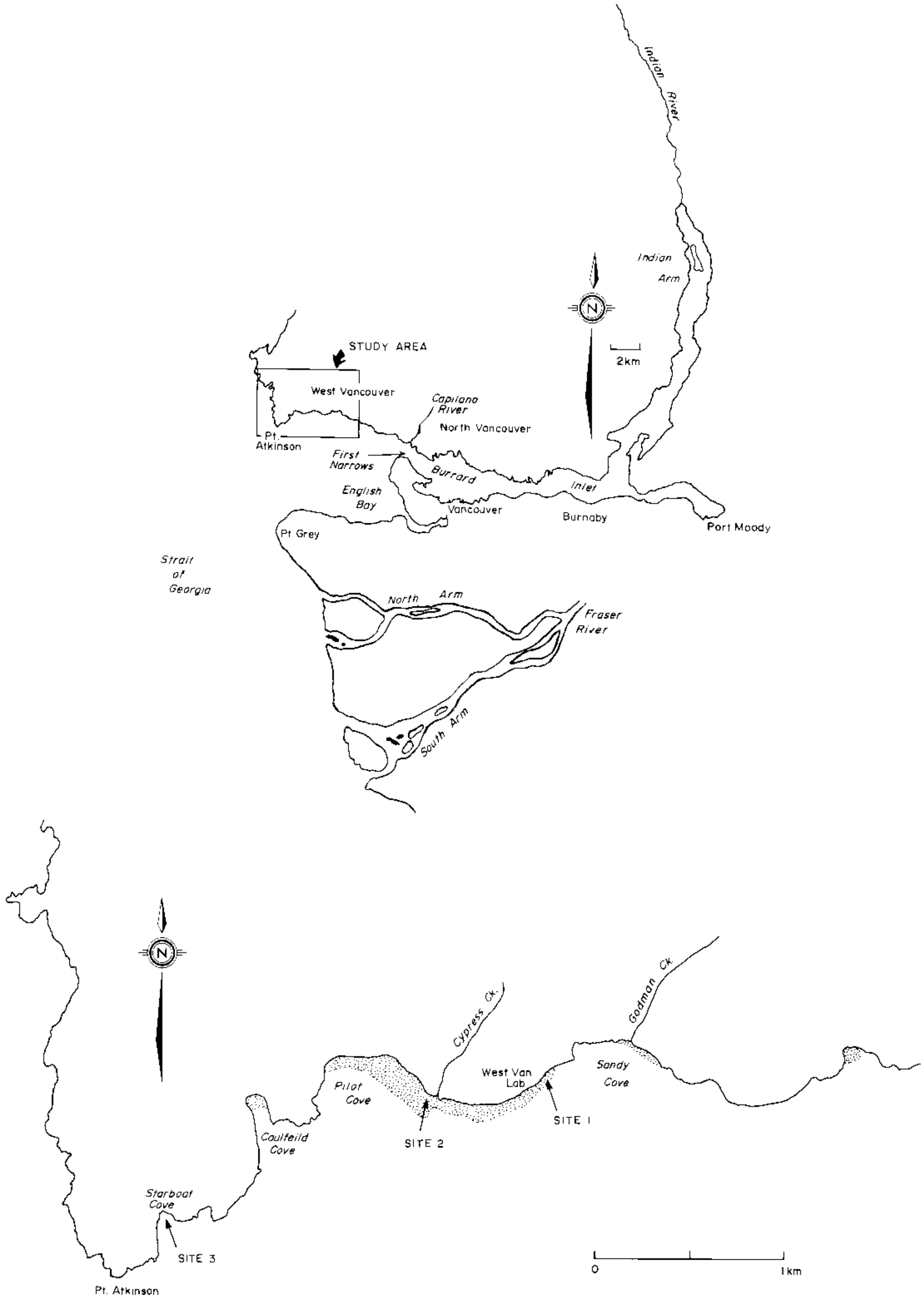

Figure 1. Map of Burrard Inlet and Indian Arm (1A), with sample site locations indicated (1B).

a width of 7 km and extends for about 9 km from Point Atkinson east to the First Narrows. It is bordered by residential areas of Vancouver on the south and West Vancouver on the north. The inner basin is up to 3.5 km wide and extends east from the First Narrows through the highly industrialized and commercialized areas of Vancouver Harbour. Indian Arm extends north for 22 km from near the head of Burrard Inlet in a largely undeveloped area.

The outer basin of Burrard Inlet receives most of its fresh water from the North Arm of the Fraser River, which discharges into the Strait of Georgia 7 km to the south. The peak runoff period for the Fraser River is from May to July. The main direct freshwater input to the outer basin of Burrard Inlet is the Capilano River, which discharges to the north shore of the outer basin about 6 km east of the study area.

The three sites sampled in this study were located on the north shore of the outer basin between Point Atkinson and Sandy Cove (Figure 1B). The adjacent land use is predominantly residential.

Fish Resources of Burrard Inlet

Salmon spawning has been observed in 16 streams flowing into Burrard Inlet (Farwell *et al.* 1987). Between 1981 and 1985, the number of adult salmon returning to these streams (including hatchery returns) averaged 1,200 chinook, 26,000 chum, 32,000 coho (*O. kisutch*), 25,600 pink (*O. gorbuscha*), and 13 sockeye salmon (*O. nerka*). The majority of the chinook (74%) and coho (65%) were hatchery salmon returning to the Capilano River, while most of the chum (97%) and pink (96%) salmon were naturally spawned fish returning to the Indian River. Pink salmon do not return to these streams in even numbered years. Annual steelhead (*O. mykiss*) returns to Burrard Inlet streams averaged 840 during 1981-1983, including some hatchery production (Department of Fisheries and Oceans, unpublished data).

In 1983 the Capilano River Hatchery released 522,000 yearling coho (average weight 15.2 g), and 798,000 underyearling chinook salmon (average weight 8.2 g). Thirty-two percent of both species of fish were marked with a coded wire nose tag and an adipose fin clip. The juvenile coho salmon were released on June 1. The juvenile chinook salmon were released on June 8 to 10 (Capilano hatchery staff, personal communication). Additional juvenile salmonids immigrate into Burrard Inlet and Vancouver Harbour in the spring, from the Fraser River system and possibly from Puget Sound and Vancouver Island streams (Nelles 1978; Conlin, unpublished report).

Few fish surveys have been done in Burrard Inlet, and those that have provide limited interpretation and are restricted to the summer months. They describe the Inlet as having a diverse and abundant assemblage of fish species. Purse and beach seines, and hydroacoustic surveys by Nelles (1978) estimated 1000-2000 tons of Pacific herring (0+) in Vancouver Harbour in late August 1973. Subtidal bottom trawl surveys commonly catch English sole (*Pleuronectes vetulus*), rex sole (*Ernex zachirus*), flathead sole (*Hippoglossoides elasodon*) and hybrid sole (*Inopsetta ischra*) (Thomas and Goyette 1987). Levings (1973) identified 37 fish species, most of which were juvenile flatfish, suggesting that shallow areas in Burrard Inlet may act as nursery grounds.

Methods

Sampling Sites Characteristics

Three sites along the north shore of Burrard Inlet were sampled (Figure 1B). Site one was an exposed gravel beach located adjacent to the pilings, docks and rip-rap associated with the West Vancouver Federal Laboratory of the Canadian Department of Fisheries and Oceans. Site two was near the midpoint of a two km gravel beach that was exposed to S.E. swells. Cypress Creek, a small stream that supports a small run of coho salmon (average annual return of seven from 1981-1985; Farwell *et al.* 1987), enters the Inlet immediately to the east of this sampling site. Site three was a sheltered gravel beach located at the head of a small cove near Point Atkinson within a region of rocky headlands at the mouth of Burrard Inlet. It was the only site that could be seined efficiently within these headlands.

Surface water temperatures during sampling ranged from 8-9°C in winter (February, March, November) to about 16-17°C in summer & June-September, Figure 2). Salinity was not measured in this study. Despite the proximity of site two to a small creek, none of the sampling sites received large freshwater runoff from the adjacent land. Surface salinities in the vicinity of our study area range from approximately 20‰) in summer to approximately 25‰ in winter (Thomson 1981).

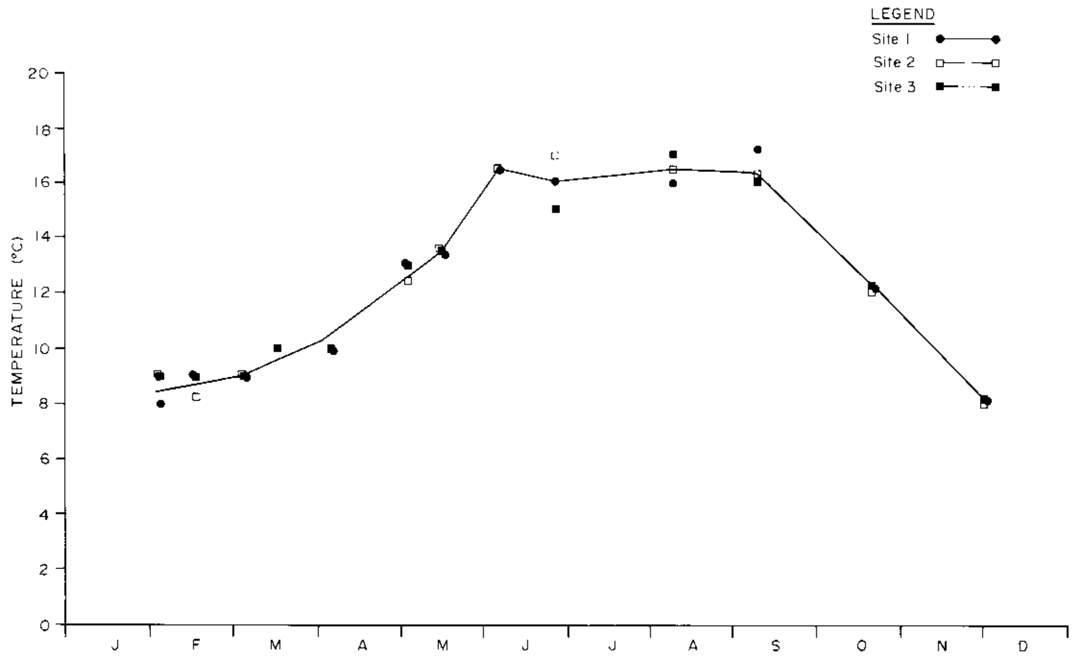

Figure 2. Surface water temperatures at sample sites during sampling times in 1983. Line is fit through all points by eye.

Sampling Methods

Fish were sampled using a 13.8 m beach seine with 4.6 m wings (10 mm stretched mesh), a 4.6 m bunt (5 mm stretched mesh), and a 3.0 m depth. The net was fitted with a 15 m towing line attached to each wing, with which it was pulled off the beach using an outboard powered 5 m inflatable boat. Once the net was approximately 10 m offshore and parallel to the beach it was immediately hauled in. With this method we were able to consistently sample an area of approximately 100 m^2. Sampling was done at intermediate tide levels (2.0-3.5 m), and usually in the early afternoon.

Thirteen sampling trips were undertaken between 4 February and 30 November 1983. Two replicate beach seine sets were made adjacent to each other at each site. A total of 76 sets were made during the study. Due to adverse weather conditions, Site three was not sampled during the 7 June trip.

At each site, fish were removed from the net and counted into buckets filled with seawater. Lengths of all species of fish were recorded. Subsamples (n = 20-30) were used to estimate lengths when catch size of a species exceeded 50 individuals. Fork lengths were used if species had indented caudal fins. Otherwise, maximum total lengths were used. Subsamples, to a maximum of 10 individuals of each species caught, were preserved immediately in 10% formalin. Stomachs of the larger fish were injected with formalin using a needle and syringe.

Catch per unit effort (CPUE) was estimated as the average catch per seine haul at each site, during each sampling time. The nine of the most common species of fish were selected for length-frequency distribution and stomach content analyses (species chosen are listed in Table 1). Comparisons of lengths among sites were made for each of the nine species of fish using analysis of covariance (ANCOVA, SAS Proc GLM 1985), which also tested and corrected for the temporal variation in fish length (covariate). Tests for homogeneity of variance and linearity between the dependent and independent variables were made before each statistical test and the data were transformed, if necessary.

Stomach contents were removed in the laboratory, rinsed to remove formalin and preserved in 70% ethanol. Contents of the nine common predator species were identified to family or order, counted and the entire contents of the stomach

TABLE 1. Species list, in order of total abundance, indicating presence (+) or absence (−) at each sampling time with data from all sites combined. Sites at which each species was captured (a = all 3 sites) and the total number caught during the whole study are listed. Nine species were selected for length-frequency and stomach content analyses*, two were selected for stomach content weight comparisons′.

	Sample Date														
Month:	02	02	03	03	04	05	05	06	06	08	09	10	11		
Day:	04	17	04	17	05	03	16	07	27	09	09	20	30	Site	Total Catch (n)
Pacific sand lance*′	−	−	+	−	−	+	+	+	+	−	−	−	−	a	1952
Chum salmon*′	−	−	+	+	−	+	+	+	+	+	−	−	−	a	1185
Threespine stickle-back*	+	+	−	+	−	+	+	+	+	+	+	+	−	a	587
Chinook salmon*	−	−	−	−	−	+	+	+	+	+	+	−	−	a	58
English sole*	−	−	+	+	+	+	+	−	−	+	−	+	+	a	49
Speckled sanddab*	−	−	+	+	+	+	+	+	+	+	+	+	+	a	36
Bay pipefish	−	−	−	−	−	+	+	−	+	+	+	−	−	a	35
Starry flounder*	+	−	+	+	+	+	+	+	+	+	+	+	+	a	33
Tidepool sculpin*	+	−	+	−	−	+	+	−	+	+	+	−	−	a	28
Pacific staghorn sculpin	−	−	−	+	+	+	+	+	+	+	+	+	−	a	24
Kelp greenling	−	−	−	−	−	+	+	+	+	+	+	−	−	a	15
Coho salmon*	−	−	−	−	−	−	+	+	−	−	−	−	−	1,2	15
Tube-snout	−	−	+	−	−	−	−	−	+	+	−	−	−	2,3	15
Surf smelt	−	−	+	−	−	−	+	−	−	−	+	+	−	1,2	10
Buffalo sculpin	−	−	−	+	+	+	+	+	−	−	−	−	−	1,2	8
Pile perch	−	−	−	−	−	−	−	+	−	+	−	−	−	2,3	6
Steelhead	−	−	−	−	−	−	+	+	−	−	−	−	−	2	5
Sharpnose sculpin	+	+	−	−	−	−	−	−	−	−	−	−	+	1,2	5
Pacific tomcod	−	−	−	−	−	+	+	−	−	−	−	−	−	3	5
Shiner perch	−	−	−	−	+	−	−	+	−	−	+	−	−	1,2	4
Penpoint gunnel	−	−	−	−	−	−	+	−	−	+	+	−	−	3	3
Crescent gunnel	−	−	−	−	+	+	−	−	−	+	−	−	−	2,3	3
Sockeye salmon	−	−	−	−	−	−	+	−	−	−	−	−	−	1	2
Pacific herring	−	−	−	−	−	−	−	+	+	−	−	−	−	1	2
Rock sole	−	−	+	−	−	+	−	−	−	−	−	−	−	1	2
Dover sole	−	−	−	−	−	−	−	−	+	−	−	−	−	2	1
Butter sole	−	−	−	−	−	+	−	−	−	−	−	−	−	3	1
Eulachon	−	−	+	−	−	−	−	−	−	−	−	−	−	1	1
Northern anchovy	−	−	−	−	−	+	−	−	−	−	−	−	−	3	1

weighed on a top-loading, 2-decimal-place balance. Principal Components Analysis (PCA, SAS Proc Factor 1985) was used to identify the prey categories that occurred in large numbers and to identify those categories that differed in abundance among collection dates and predator species.

The stomach content weights of chum salmon and Pacific sand lance (*Ammodytes hexapterus*) were used to estimate the level of feeding activity by these species, during each collection date at each site. Other species were not collected in sufficient numbers to allow comparisons (Table 1). Content weights were compared using an ANCOVA which also tested and corrected for the effect that growth-induced increase in fish weight (covariate) had on stomach content weight. Data transformation was not necessary. Beach seine collection times each day were kept consistent to minimize the potential confounding effects caused by diel variation in stomach content composition and weight.

Results

Species Presence

A total of 29 fish species were caught during this study (Table 1). Pacific sand lance, chum salmon, and threespine stickleback were by far the most abundant species, composing 91% of the total catch. The ten most abundant species were caught at all three sites. The difference in species composition among sites were mainly due to the presence or absence of the least abundant species. The numbers of individuals (particularly the rarer species) were insufficient to determine if there were significant differences in species composition among sites. Unless otherwise stated, in all further analyses the data from all three sites were combined.

Five species of juvenile salmon and trout were caught. Chum salmon were by far the most abundant, followed by chinook salmon. One of the 15 coho salmon caught had been tagged, indicating hatchery origin (note that most hatchery-reared coho and chinook salmon juveniles do not receive tags). This fish was caught on 16 May. The coded-wire nose tag indicated it was one of 20,000 coho that had been released inadvertently from the Capilano hatchery during a flood on 9 March 1983. Two sockeye salmon and five steelhead were also caught.

Seasonal Abundance Changes

Only a few species, such as threespine stickleback (*Gasterosteus aculeatus*), English sole, speckled sanddab (*Citharichthys stigmaeus*), starry flounder (*Platichthys stellatus*), tidepool sculpin (*Oligocottus maculosus*) and Pacific staghorn sculpin (*Leptocottus armatus*), were present throughout most of the year (Table 1). Species richness showed a seasonal trend at all sites, with more species being caught during spring (particularly at sites 2 and 3) and early summer (site 1) (Figure 3). Site 1 had greater species abundance than the other sites during most of the late fall and winter collections. Total fish abundance also showed a seasonal trend, with more individuals being present in spring and summer (Figure 4).

Chum salmon were caught in March and from May to August, with greatest abundance in May-June at a density of approximately 1.5 individuals/m² (Figure 4). Chinook salmon were

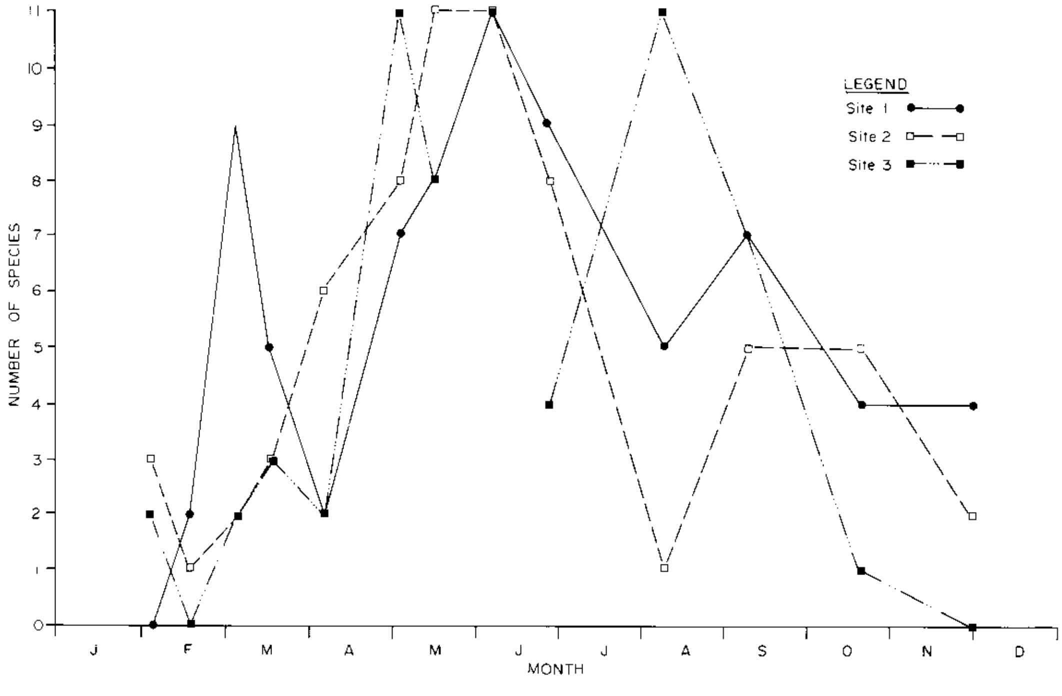

Figure 3. Number of species caught at each sample site in 1983.

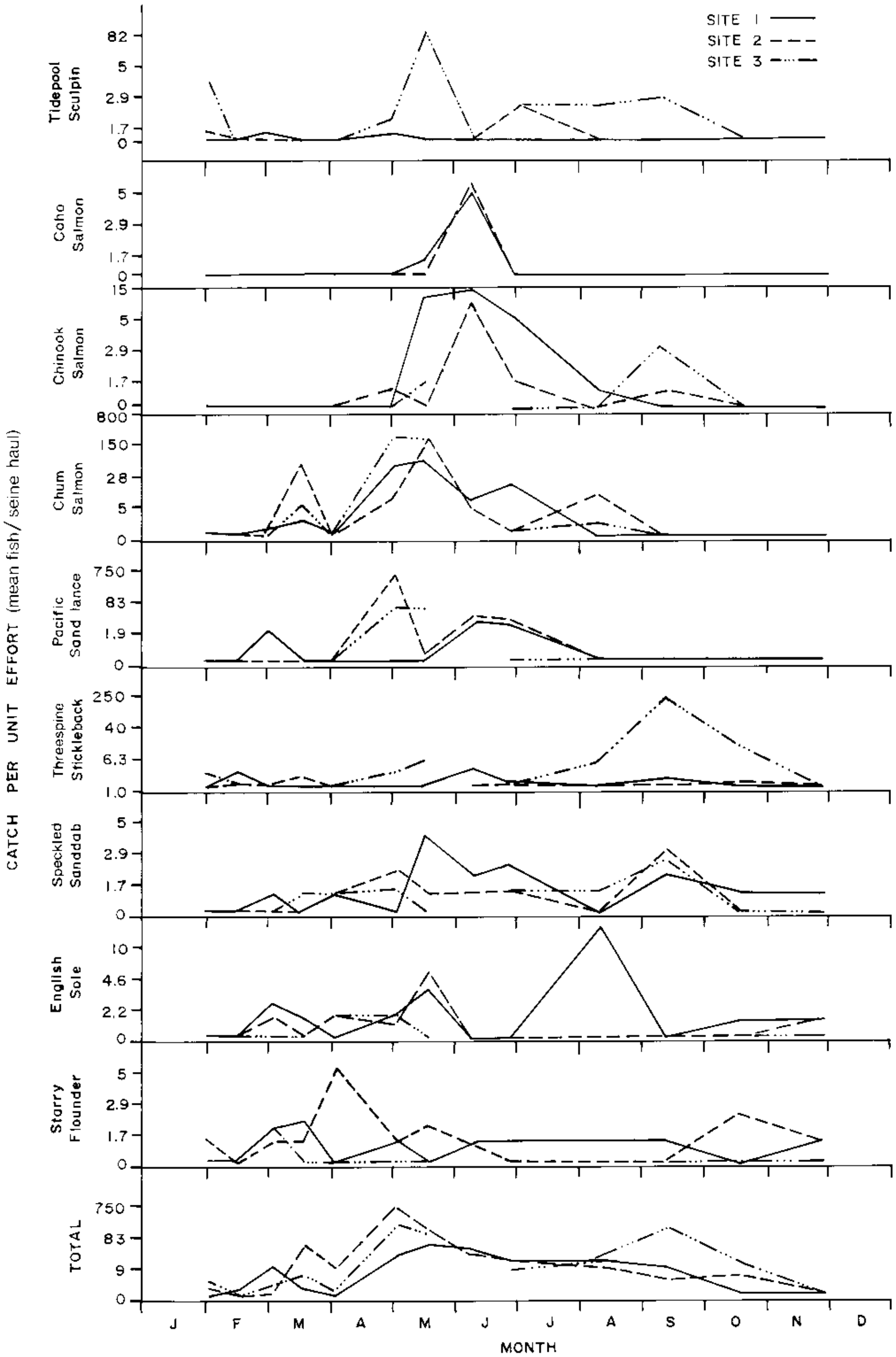

Figure 4. Abundance (catch per unit effort) over time for selected fish species. Each set sampled approximately 100 m^2 area. Vertical axis is on a logarithmic scale. Site 3 was not sampled on 7 June due to inclement weather.

caught from May to September with a peak density of approximately 0.1 individuals/m^2 in May and June. Numbers were relatively low in August and September. Coho salmon were caught only on 16 May and 7 June. Sockeye salmon were caught only on 16 May and steelhead were caught in May and June (data not shown).

Pacific sand lance were caught from March to the end of June only, with the highest abundance in early May at a density of approximately 7.5 individuals/m^2 (Figure 4). This may be an underestimate as sand lance are able to burrow in the sand and potentially avoid capture. Threespine stickleback were caught in relatively low numbers throughout most of the year, with one very large sample in September at Site 3. Seasonal abundance trends for other common species are also shown in Figure 4.

Length-Frequency Distributions

For each of the nine common species, the size of fish captured did not differ among sites during each collection trip ($P > 0.05$). However, meaningful spatial or temporal comparisons of lengths of some fish species are limited by small catch sizes at some sites and times. After combining catches from all sites, and limiting further analysis to the four most common species, variation in length-frequency distributions were detectable ($P < 0.05$), and three of the four species showed temporal trends (chum, sand lance, stickleback; Figure 5). The beach seine may not have been effective at catching small fish, particularly post-larval stages.

The first chum salmon appeared in our samples in March at a length of 31-37 mm (Figure 5). Size increased over time until June, reaching a mean size of 52-55 mm. During this period, the mean length increased at a rate of 0.20 mm$\bullet$d^{-1}. Chinook salmon first appeared in May as smolts (70-120 mm), but measurements of those caught each month into the fall showed no increase in mean size. Pacific sand lance ranged in size from 25 to 135 mm. The larger sand lance (80-135 mm) were captured from March to May. In May, a second, smaller age class appeared (25-30 mm). Individuals in subsequent collections increased in mean size until June when the fish were nearly the size of those captured in March. The smallest threespine sticklebacks were caught in August (10-25 mm) and mean size increased through the fall. The mean size of the sticklebacks also increased through the spring with the capture of the largest individuals in May.

The other species of salmon captured ranged in size from 60-120 mm for coho, 89-97 mm for sockeye and 134-284 mm for steelhead (data not shown). The tagged coho salmon caught on May 16 was 111 mm in length. Only immature individuals of the four species of sole, tomcod, eulachon, and northern anchovy were caught. Size ranges of other species were: English sole 17-67 mm, speckled sanddab 19-117 mm, Starry flounder 21-430 mm (all but one exceeding 50 mm) and tidepool sculpin 16-94 mm.

Stomach Content Analyses

Thirty-one prey groups were identified in the stomachs of the nine common predator species. Based on the variable loadings on the first three factors of the PCA (describing 94% of the variation in the data matrix), eight prey groups were sufficient to characterize the feeding habits of the predators (Table 2). Food eaten by the fish was either planktonic (e.g., crustacean larvae, calanoid copepods, and Oikopleura sp.) or epibenthic (e.g., harpacticoid copepods, amphipods, and cumaceans). Most of the food items resided naturally in marine or estuarine habitats. However, some food items did originate from freshwater sources (e.g., some species of cladocerans). We do not know whether the cladocerans in the diets were consumed during the salmonids' migration from freshwater habitats or were flushed to marine regions before being consumed.

Copepods consumed by chum salmon, tidepool sculpin, and the three species of flatfish were almost exclusively harpacticoids, whereas sand lance and threespine stickleback consumed both calanoid and harpacticoid copepods. Amphipods were consumed by most species during most sampling times (Table 2). Other prey species (e.g., crustacean and decapod larvae, and cumaceans) varied in importance depending on the predator species. Further prey composition comparisons among species were hampered by the small numbers of stomachs examined. The eight coho salmon examined had empty stomachs and very few food items were found in larval fishes' stomachs (e.g., sand lance captured in May).

We were unable to find significant spatial or temporal variation in the amount of food consumed by chum salmon or sand lance ($p > 0.05$).

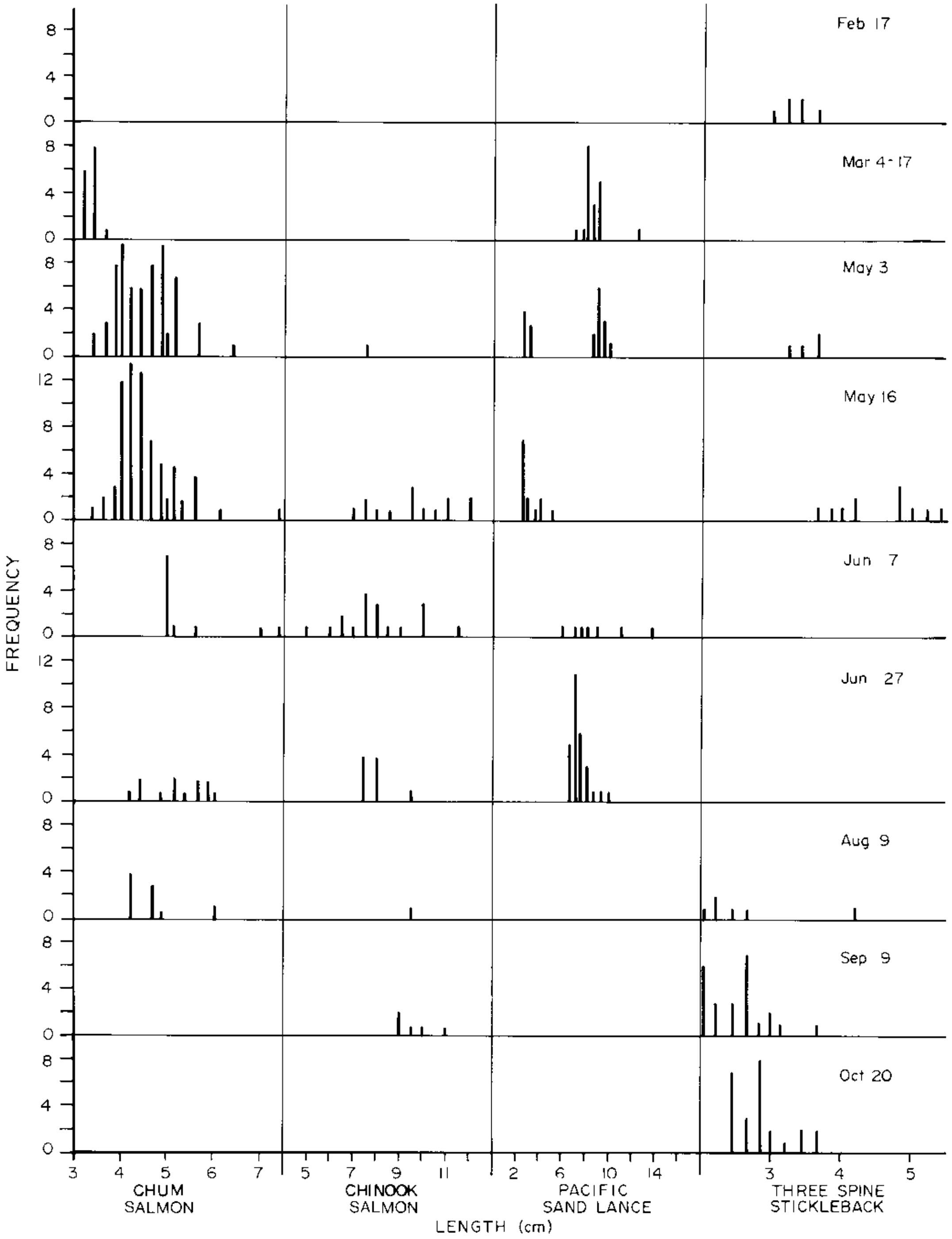

Figure 5. Length-frequency distributions for selected fish species. Fork length measurements were used.

TABLE 2. Counts per fish of major prey groups of the nine most common predators in the littoral zone of outer Burrard Inlet. Prey groups determined by Principal Components Analysis.

Predator	Chum salmon				Chinook salmon			Coho salmon	Pacific sand lance			Threespine stickle-back	
Month	Mar.	May	June	Aug	May	June	Aug-Sep	June	Mar	May	June	Feb	May
Copepods	10.4	136.8	0	2.2	0	0.3	0	0	199.0	0	6.7	35.0	8.4
Cladocerans	0	1.9	152.2	0.4	0	0	0	0	0	0	48.3	0	7.1
Other crustacean larvae	0	1.7	0	0	0	0	0	0	0.2	0	0.4	0	114.4
Amphipods	1.0	7.5	1.5	13.5	0	1.1	2.0	0	0.7	0	1.0	0.8	9.1
Decapod larvae	0.6	0	0.5	0	0	4.3	1.0	0	85.2	0	0.3	0	0
Cumaceans	4.0	0.2	18.3	14.9	0	27.1	0	0	0.5	0	0.1	0	0
Cirripedia larvae	0	3.4	0	0	0	0	0	0	0	0	0	0.8	6.3
Oikopleura sp.	0	6.3	0	0	0	0	0	0	2.2	0	0.1	2.3	13.9
Sample size	5	43	4	8	1	7	2	8	4	14	16	4	7

TABLE 2. (cont'd)

Predator	Tidepool sculpin					Starry flounder			English sole			Speckled sanddab			
Month	Feb	Mar	May	June	Sep	Feb	Apr	May	Apr	May	Nov	Apr	May	June	Sep
Copepods	0.2	16.0	0	0.5	0	0	0.6	0	400.0	101.6	2.0	0	0	0	2.0
Cladocerans	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0
Other crustacean larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipods	2.6	2.0	61.0	1.5	1.0	1.0	10.2	7.0	0	3.4	1.0	13.0	7.8	0	28.2
Decapod larvae	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Cumacean	0	0	0	0	0	0	0.8	0	5.0	2.6	1.0	0	0.6	0	0.2
Cirripedia larvae	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oikopleura sp.	2.3	0	0	0	0	0	0	0	0	0	0	0	1.6	4.0	0
Sample size	5	1	4	2	1	1	5	2	1	10	1	1	5	3	5

However, larger fish did consume larger meals (as expressed by the covariate stomach content weight; $p < 0.05$) and, for chum in particular, as size increased with time (Figure 5), larger food items became more common in their diet. For example, copepod consumption was greatest early in the year (March-May) and declined with increased consumption of larger prey species such as amphipods and cumaceans (Table 2). However, seasonal variation in the type of food available may also have had an effect on diet.

Discussion

Our study clearly shows use of nearshore marine habitat by fish in outer Burrard Inlet. These sites were used by salmon and other fish species, particularly during the spring and summer when both species abundance and total fish abundance were greatest. Similar trends found by Gordon and Levings (1984) in the Fraser River estuary were correlated to the increased temperatures at this time of year. The 29 species of fish identified in Burrard

Inlet in this study were among the 37 species identified by Greer *et al.* (1980) and the 57 identified by Gordon and Levings (1984), at the mouth of the Fraser River estuary. Inshore fish populations in estuaries around the world typically have modest species diversity with a dominance of the total number of individuals by a few species (Haedrich 1983). Most of the non-salmonid species are of no commercial importance, except for Pacific herring and eulachon (which were rare in our samples) and English sole. However, many of these species, such as Pacific sand lance, starry flounder, kelp greenling (*Hexagrammos decagrammus*), and surf smelt (*Hypomesus pretiosus pretiosus*) are important in the diets of juvenile salmon (Hart 1973) and sea birds (Hay *et al.* 1989).

For the juvenile stages of salmon, sand lance, pile perch and many species of flatfish, the study sites served as a transit area, where temporarily, feeding and other activities associated with rearing (e.g., predator avoidance) likely occur. Juvenile wild and hatchery coho and chinook salmon and steelhead produced in Burrard Inlet streams must pass through Burrard Inlet during their seaward migrations. Juvenile salmon produced in the Fraser River are also known to enter outer Burrard Inlet (K. Conlin unpublished data). Subsequently, the salmon will move offshore (Healey 1980, 1982) and many of the flatfish species will move to deeper water (Ketchen 1956; Hart 1973).

Other species are present in shallow nearshore areas for a substantial period of the year. These were frequently small species such as speckled sanddab, threespine stickleback, sculpins, gunnels and pipefish. Further study of the residence times of individuals of each species is required in order to determine which species remain nearshore for their entire lives. Threespine sticklebacks and Pacific staghorn sculpin are found throughout the year on tidal banks at the mouth of the Fraser River (Gordon and Levings 1984). Presumably, nearshore habitats provide feeding opportunities and protection from predation. However, nearshore populations of prey fishes in midwinter, albeit in lower numbers than in warmer months, may provide an essential food source for birds overwintering in the Strait of Georgia (Vermeer 1983).

Our samples include immature individuals of many species that were also captured as adults. Immature individuals of starry flounder, sand lance, and tidepool sculpins were captured in the spring and early summer, suggesting that the adults of these species, that were captured in the winter or early spring, were in nearshore waters to spawn (Hay *et al.* 1989). These patterns are consistent with observations of starry flounder on Roberts Bank (Gordon and Levings 1984) and the spawning times reported by Hart (1973). A species closely related to the tidepool sculpin (sharpnose sculpin, *Clinocottus acuticeps*) has been observed spawning in Vancouver Harbour from January through April (Marliave 1981). The immature stages of threespine sticklebacks and speckled sanddabs in Burrard Inlet and threespine sticklebacks at the mouth of the Fraser River (Gordon and Levings 1984) occur in mid summer, suggesting that they spawn during the spring in the Vancouver area. Threespine sticklebacks are reported to spawn from April to September (Scott and Crossman 1973), and may have two spawning peaks (April-May and late August), in marine water near Vancouver (Dr. D. McPhail, University of British Columbia, personal communication).

Juvenile pink salmon were not caught in our study because spawning runs in southern British Columbia generally occur in odd-numbered years, with the downstream juvenile migrations in the following even-numbered years. We would expect significant numbers of juvenile pink salmon in our study area during the spring of even-numbered years (Heard 1991).

The scarcity of juvenile sockeye salmon in our study was expected because adult sockeye escapements to Burrard Inlet streams are very low. The few that we caught during this study may have come from the Fraser River. Juvenile sockeye do not utilize the nearshore marine environment to a great extent (Healey 1980, 1982). Few are found in the littoral zones at the mouth of the Fraser River despite a large sockeye salmon outmigration each spring (Levy and Northcote 1982, Gordon and Levings 1984). Steelhead were also scarce in our study. There are relatively low escapements of steelhead to Burrard Inlet streams, and they may not use nearshore areas for transit to offshore habitats. Increased sampling in different regions is needed to evaluate the importance of Burrard Inlet to steelhead.

Only a small number of juvenile coho salmon were caught in this study, and only in May and June, despite the large numbers that are produced in Burrard Inlet streams (both from natural spawning and hatcheries). While coho salmon fry have been shown to prolong residence in inner estuarine regions during spring and summer (Tschaplinski 1988), other studies, such as Healey (1980) in the outer Nanaimo River estuary, McCabe *et al.* (1983) in the Columbia estuary and Levy and Northcote (1982) in the Fraser River estuary, have shown that juvenile coho salmon fry and smolts (1+) do not utilize outer estuaries and nearshore marine areas (such as our study area) to a great extent. Coho tagged and released from the Capilano Hatchery were not recaptured six days later during our first sampling trip. They may have remained in the Capilano estuary, or more likely moved offshore, out of reach of our nets. In 1979, Conlin (P. communication) caught several juvenile coho salmon, with Capilano Hatchery tags, at two sites within our study area. However, he found that captures of tagged coho salmon at sites throughout Burrard Inlet dropped off very quickly two to three days after their release from the hatchery. A more intensive sampling schedule may be required to document habitat used by coho and the timing of their outmigration.

In our study, chinook salmon first appeared as 60+ mm smolts in May and were present until September (110+ mm), although numbers were relatively low in August and September. Peak densities in May and June were lower than those reported in Fraser River tidal channels by Levy and Northcote (1982) (0.10 vs. 0.18 individuals/m^2, using different sampling methods). Similar size ranges and residency periods were observed in shallow marine locations adjacent to the Campbell River estuary (Levings *et al.* 1986), in the outer estuary of the Nanaimo River (Healey 1982) and in the Columbia River estuary (McCabe *et al.* 1983). Chinook salmon in the outer estuary of the Yaquina River estuary, Oregon, are abundant from June to September, although lower numbers were caught through October and November (Myers and Horton 1982).

On the tidal banks at the mouth of the Fraser River, juvenile chinook salmon were first captured in March or April (Gordon and Levings 1984) with peak abundance in May (Conlin *et al.* 1982). Allowing for estuarine residency times of up to 30 days (Levy and Northcote 1982), these fish, and chinook salmon from other nearby systems, could conceivably begin to appear in the adjacent littoral zones of Burrard Inlet in May. The absence of tagged chinook salmon in our study indicates that few, if any, Capilano Hatchery chinook were present when we sampled. However, in Conlin's unpublished study in 1979, tagged juvenile chinook salmon from the Capilano Hatchery were captured at two sites within our study area. Hatchery releases occurred 17-62 d before we began sampling and thus we may have been too late to sample the peak outmigration of these fish from Burrard Inlet. Alternatively, they may have attained a sufficient size to have moved to deeper water, beyond the reach of our nets. Juvenile chinook salmon captured by purse seine off the mouth of the Fraser River had begun to move to deeper water at a length of 50-55 mm; 10 mm longer than those captured by beach seine in shallower water (Levings 1982).

By far the most abundant of the juvenile salmonid species in our study was the chum salmon, present from March to August. There were two peaks in abundance (March and May) during which the density of chum salmon at our sites exceeded that recorded in tidal channels in the lower Fraser River estuary (0.14 vs. <0.60 individuals/m^2, Levy and Northcote 1982, using a different sampling method). While the two peaks in abundance may be due to sampling variability, they may also reflect different outmigration strategies. A similar pattern in abundance was found by Healey (1982) in the outer estuary of the Nanaimo River. The initial peak in March in our samples may represent juveniles that dispersed seaward immediately after reaching the river mouths (Mar-Apr. in the Fraser River, Levy and Northcote 1982, Gordon and Levings 1984), while the later, larger peak beginning in May may represent juveniles that have reared in estuaries prior to migrating to marine areas. Levy and Northcote (1982) have recorded chum remaining in an estuarine tidal channel complex for up to 11 days. The main peaks in abundance of chum salmon in the outer Fraser and Nanaimo River estuaries and in shallow marine locations in the Gulf Islands (southern Georgia Strait) were also found to occur in May-June (Healey 1980, 1982, Gordon and Levings 1984).

There was a general increase in mean size of juvenile chum in our samples from March (when they first appeared in samples) until early June. We do not know if this was due entirely to growth, since we have no information on the residence times of individual fish at the study sites, although stomach analyses indicated that chum we captured were feeding during the period they were present. The lack of size increase in later samples is probably due to emigration of larger fish to sublittoral and eventually offshore areas.

Emigration from estuarine and marine nearshore areas by chum and chinook salmon is likely related to size (Levings 1982), and possibly abundance, occurring at approximately 5.0-6.0 cm and 12.0-17.0 cm by chum and chinook salmon respectively (Myers and Horton 1982, McCabe *et al.* 1983). During periods of peak fish abundance in areas, when potential competition for limited food resources is highest, offshore movement may be related to availability of preferred prey organisms. Levings (1982) found juvenile Fraser River chinook salmon to feed selectively on the larger items available in the water column. Simenstad and Salo (1982b) suggested the presence of large pelagic copepods in sublittoral areas may explain offshore movement of chum salmon in the Hood Canal, Washington State. However, studies by Gerrath (1963), Stockner and Cliff (1979) and unpublished observations of zooplankton population growth by staff of the West Vancouver Laboratory found that zooplankton abundance in outer Burrard Inlet was highest in spring and summer. As the period of greatest fish abundance occurs when food resources are greatest, competition is unlikely to be the main force driving emigration from nearshore areas.

Stomach content analyses in our study indicated that most fish were feeding throughout the period during which they were caught. Meal weight and size of individual prey items increased as the season progressed and the fish grew. This was also observed by Karpenko (1982). Small sample sizes of most fish species and lack of residency time information prevents us from making firm conclusions regarding interspecific diet overlap or the importance of nearshore zones for feeding and growth. However, based on the species of prey identified, it is apparent that a variety of habitats act as a source of food for fish captured in littoral zones. Epibenthic habitats support harpacticoid copepods, cumaceans, and amphipods that are found in the diets of a number of fish species captured in this study, including chum salmon. Other investigators report similar findings (Healey 1979, 1982, Bailey *et al.* 1975, Simenstad and Salo 1982). Food of planktonic origin, commonly found in the diets of sand lance and other species, may have been produced in Burrard Inlet or drifted with tidal currents from other Strait of Georgia locations. Freshwater habitats are also important, providing cladocera and insects found in the stomachs of fish in nearshore habitats. Insects are more important in diets of fish captured at the mouth of the Fraser River than those captured in our study (Levings 1982).

The study area is located within the metropolitan Vancouver area. The land adjacent to the study sites is a residential area, which is not subject to the more disruptive effects of industries and port facilities located in the inner basin of Burrard Inlet. Nevertheless, waterfront residential areas are subject to development pressures that could alter the nearshore fisheries habitat. Such alterations, including filling of shallow areas, dredging, building of shoreline protection works and construction of marinas, boat launching ramps, seawalls and foreshore parks, can decrease the ability of these areas to support fish. In addition to the threat of physical habitat alteration, nearshore marine areas and creeks adjacent to urban areas are subject to increased threats from pollution, both from land sources and from ships.

This study has shown that nearshore marine areas, such as our sampling sites, are utilized by salmon and other fish species despite urbanization of the adjacent land. While salmon and most other species occupy these areas most heavily in the spring and summer, other species of fish are present throughout the year. These sites serve as nursery areas for the juvenile stages of many fish species, while some species spend their entire lives in these nearshore zones. Most fish that use this zone as a nursery area are likely produced in Burrard Inlet or nearby streams. However, the outer Burrard Inlet region also has some importance as a rearing area for Fraser River salmon stocks, possibly including some of the sockeye, chinook and coho salmon captured during this study (Conlin, unpublished report). While salmon were the only abundant species that were commercially important, other species present may be important to support the salmon's food web and ecosystem. The destruction or degradation of such areas can therefore have significant harmful effects on fisheries resources.

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