

POPULATIONS OF SYMPATRIC SCULPINS, *COTTUS ALEUTICUS* AND *COTTUS ASPER*, IN FOUR ADJACENT SALMON-PRODUCING COASTAL STREAMS ON VANCOUVER ISLAND, B.C.

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ABSTRACT

General life history, distribution and abundance, age structure, and growth and survival are documented for sympatric populations of two cottid fishes. Stream obstructions may largely determine the distributional limits for both cottids with *Cottus aleuticus* penetrating farthest upstream. Biomass density and size of individual fish increased with distance upstream, largest individuals living at the upstream borders of their species ranges. Both sculpins were numerically most abundant in their lower ranges, reflecting the common estuarine origin of benthic young. From 69 to 74% of their combined biomass in the upper estuaries were *C. asper* while 75-100% was *C. aleuticus* in the upper stream zone. *Cottus asper* grew more rapidly and mortality rates were similar, but the oldest *C. aleuticus* was age 8 and 145 mm in length, compared with age 6 and 144 mm for *C. asper*. The length-weight relation was similar for both species. The community role of these sculpins is explored with primary focus on possible competition with the stream-dwelling salmonids, and recommendations are made which might lead to increased production of salmonid smolts to the sea.

As part of a general study of the fish community of Lymn Creek, populations of the sympatric sculpins, *Cottus aleuticus* and *C. asper*, were examined during 1968 with regard to population structure, annual growth and mortality, and general distribution and abundance in the system. In addition, three adjacent streams (Cabin, Chef, and Waterloo) were sampled in the fall of 1968 to provide a comparative basis for interpreting the findings at Lymn Creek. The present communication deals primarily with population characteristics of sculpins in relation to life history. Their role in the community, including possible competition with salmonids, is examined with a view of enhancing salmonid production.

THE STUDY AREA

The four streams studied are neighboring systems emptying into the Strait of Georgia on the east coast of Vancouver Island. They are small streams (drainage area <20 km², minimum summer flow <7 m³/min, Table 1), having similar gradients and streambed materials, but Cabin Creek is considerably smaller than the others. Their watersheds are forested at a similar stage

of second-growth conifers, primarily Douglas fir. Lymn and Waterloo creeks closely resemble each other, although the latter stream has fewer major obstructions (logjams) hindering the upstream migration of salmon. Lymn Creek differs from the other three streams in having a swampy sloughlike area resulting from beaver activities near the estuary. Both Lymn and Chef creeks course through some 200 m of intertidal meadow, but Cabin and Waterloo creeks empty directly onto the open beach. Extensive intertidal zones in all four streams result at low tide when nearly the entire zone is exposed to freshwater flow.

Unlike the other systems, Chef Creek is subject to flow extremes, rapid runoff during freshets and, during the late summer and early fall, intermittent flow and isolated pools in the lower reaches.

Cutthroat trout, *Salmo clarki*; coho salmon, *Oncorhynchus kisutch*; three-spined stickleback, *Gasterosteus aculeatus*; coastrange sculpin, *C. aleuticus*; and prickly sculpin, *C. asper*, reside in

TABLE 1.—Some physical characteristics of the four study streams.

Stream	Drainage area (km ²)	Average width ¹ (m)	Average gradient (%)	Minimum summer discharge (m ³ /min)
Cabin	2.3	1.5	1.2	0.5
Lymn	9.3	2.5	1.0	3.4
Waterloo	10.5	2.5	1.2	2.6
Chef	18.3	7.5	0.9	6.8

¹Within the sculpin zone.

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all four streams. Chef and Waterloo creeks also contain steelhead trout, *S. gairdneri*, and chum salmon, *O. keta*. Chum salmon occasionally spawn intertidally in Lymn Creek.

METHODS AND MATERIALS

Sampling the Populations

In Lymn Creek, sculpins were collected incidentally to salmonids from April to July 1968. A sampling schedule for cottids was initiated in August and terminated in December 1968. Chef, Cabin, and Waterloo creeks were sampled during September and October.

Fish were collected in the estuaries by seine at low tide. In the streams proper, collections were made with a 440-V DC fish shocker (Smith-Root Laboratories, Mark V³). In both environments, discrete sections of stream, usually 15- to 30-m sections, were sampled and all fish captured were removed.

Specimens were preserved in 5% Formalin. In the laboratory, total length was measured to the nearest millimeter and body weight to the nearest 10 mg. Otoliths were removed for age determination.

No attempts were made to quantify the relative or absolute efficiencies of the two sampling methods. The habitat seined lent itself to efficient seining, and it is considered that any increased capture efficiency or size-related sampling bias usually associated with electrical fishing devices was, at least in part, cancelled by the increased complexity of habitat typical of the stream proper and the concentration of the two youngest age-groups in the lower stream, including the estuaries. Increased stream flow and turbid water following the first significant rains in the late fall probably reduced the efficiency of both collecting methods to a considerable but unknown extent. Therefore, growth and survivorship estimates were based on data collected prior to the onset of the rainy season.

In the laboratory, breeding activity was followed by keeping adults allopatrically in 150-liter fiber glass tanks at ambient freshwater temperature with flow-through conditions, a rubble substrate, and normal photoperiod. Em-

bryological development and larval responses to salinity, illumination, current, and food were investigated. Egg masses of known age and their resulting larvae were kept in 3-liter glass jars filled with aerated fresh water or seawater; and mortality and feeding responses of larvae to microzooplankton were observed. The responses of larvae of known age and salinity history to overhead illumination and water currents were investigated in a Perspex test chamber.

Drift nets were set at several stations in Lymn Creek during the hatching period in the spring to document the timing and extent of the hatching period, upper limits of the spawning ground and characteristics of the fry moving seaward.

Population Estimates

Estimates of population size in Lymn, Cabin, and Waterloo creeks were attempted in the fall for both species of sculpin. Population estimates for Chef Creek were precluded by the large size of the stream, which prevented representative sampling across the stream at most stations. In the other three streams, catches from individual stations were assumed to be representative of that stream section, and population was calculated as follows:

$$N = \Sigma CD$$

where C = station catch (fish/meter of stream)
 where each station is representative
 of a larger stream section D
 D = stream section (in meters).

The estimated populations were distributed among the various age-classes so as to reflect the age-class composition of the station catches. Admittedly, these estimates are rather crudely derived yet they yielded fairly consistent trends in annual mortality, particularly for the Lymn Creek populations (see Results, Annual Growth, Mortality, and Length-Weight Relations). Attempts to apply mark and recapture techniques to the problem of population estimation proved fruitless due to extensive behavior changes in marked fish following their release. These changes (movement downstream or into the streambed) seriously affected their vulnerability to recapture and led to large scale overestimates of actual population size.

³Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Age Determination

Following dissection, otoliths were dried for several days and then immersed in a 50% solution of glycerin and water. Otolith structure was not clear when examination immediately followed removal of the otolith from the specimen. Otoliths of specimens preserved for more than 1 mo were partly decomposed by the preservative.

Whole otoliths were examined under a dissecting microscope by reflected light against a black background. In both species, the otolith had an opaque nucleus around which were arranged concentric, alternating hyaline and opaque bands extending to the margin. The opaque band reflected rapid summer growth and the hyaline band constituted the annulus. The first hyaline band around the nucleus was not considered an annulus but is assumed to reflect initial post-larval growth, perhaps prior to the onset of a benthic existence. The newly forming annulus was readily discernible in specimens collected in October and December.

Length-frequency histograms were found useful to identify the young of the year (age 0) and yearlings (age I).

RESULTS

General Life History

Both species of sculpins in these short coastal streams are "coastal" forms (McAllister and Lindsey 1960) which spawn during April and May. The prickly sculpin undergoes a downstream spawning migration in the early spring (Mason 1974a) and spawns in the estuary as reported previously by Krejsa (1967). The coast-range sculpin has been reported to make downstream migrations coincident with *C. asper* (Shapovalov and Taft 1954; Hunter 1959) but no such migration was recorded in Lynn Creek where *C. aleuticus* spawned in situ throughout its range in the stream as found in Alaskan streams by McLarney (1968).

The breeding males are territorial and court one or more females which deposit clusters of adhesive eggs on the underside of large rocks or debris forming the nest site. Following spawning, the females depart and the males guard the eggs until hatching. The newly hatched and transparent larvae begin swimming upon hatching and assume a pelagic life for some 30 days, grow-

ing from 5 mm at hatching to 12 mm in length before assuming a benthic existence.

In the laboratory at 10°-12°C, the eggs of both species were eyed at 9-10 days; the larvae were active at 15 days; and hatching occurred 19-20 days following fertilization. Hatching commenced in Lynn Creek on or before 11 May when water temperature reached 10°C. On this date, larvae began appearing in the driftnet catches and were taken for some 5 wk until 19 June.

From drift net catches of the larvae in Lynn Creek, coupled with laboratory studies on the reproduction of both species, we concluded that the eggs and larvae are euryhaline but survival and growth of cultured larvae are better in seawater. Feeding on microplankton commenced some 6-10 days following hatching of cultured larvae when the yolk was noticeably depleted and when most stream larvae were either in the estuary or, in the case of coast-range sculpin larvae, in the lower stream near the estuary. Since the average size of the latter larvae in drift samples from four stations located along 1,150 m of stream above the estuary equalled that of 6-day-old larvae in culture at similar temperatures, these larvae probably spend several days in the nest vicinity and in downstream transport following hatching.

Within several hours of hatching, larvae of both species swam to the water surface and maintained themselves vertically immediately beneath the surface film by steady swimming movements. This behavior was sustained through the 25 days of culture in both fresh water and seawater. Tests on 5-day-old and older larvae showed that they were positively rheotactic at velocities greater than 1 cm/s and swam actively against the current in short bouts of rapid swimming.

Post-spawned *C. asper* remained in the estuary of Lynn Creek throughout the summer and early fall. Their return to upstream areas may coincide with the spawning runs of salmon that commence in October (Mason 1974a). The offspring of both species remain in the estuarine zone until the early summer of the following year when they proceed to invade upstream areas.

Distribution and Relative Abundance

Both sculpin populations were limited to the lower reaches and estuaries of all four streams, with coast-range sculpins distributed farthest up-

stream. The prickly sculpin was not found more than about 1 km upstream from high tide mark where the stream gradient did not exceed 1.5%, whereas the coastrange sculpin penetrated upstream some 1.6-2.7 km from high tide mark in a range of stream gradients not exceeding 6%. In Cabin Creek, the smallest stream, the same general difference between the two species in longitudinal distribution prevailed, but the distances involved were reduced by a factor of 10.

The upstream distributional limits of both species in all four streams are indicated in Figure 1.

Habitat segregation was evident in cohabitated stream areas, large *C. asper* occupying the deepest locations in pools, under log jams and undercut banks. Intermediate-sized *C. asper* and large *C. aleuticus* were also found at these sites but at shallower depths. Riffle and glide areas were mainly occupied by small and medium-sized *C. aleuticus*.

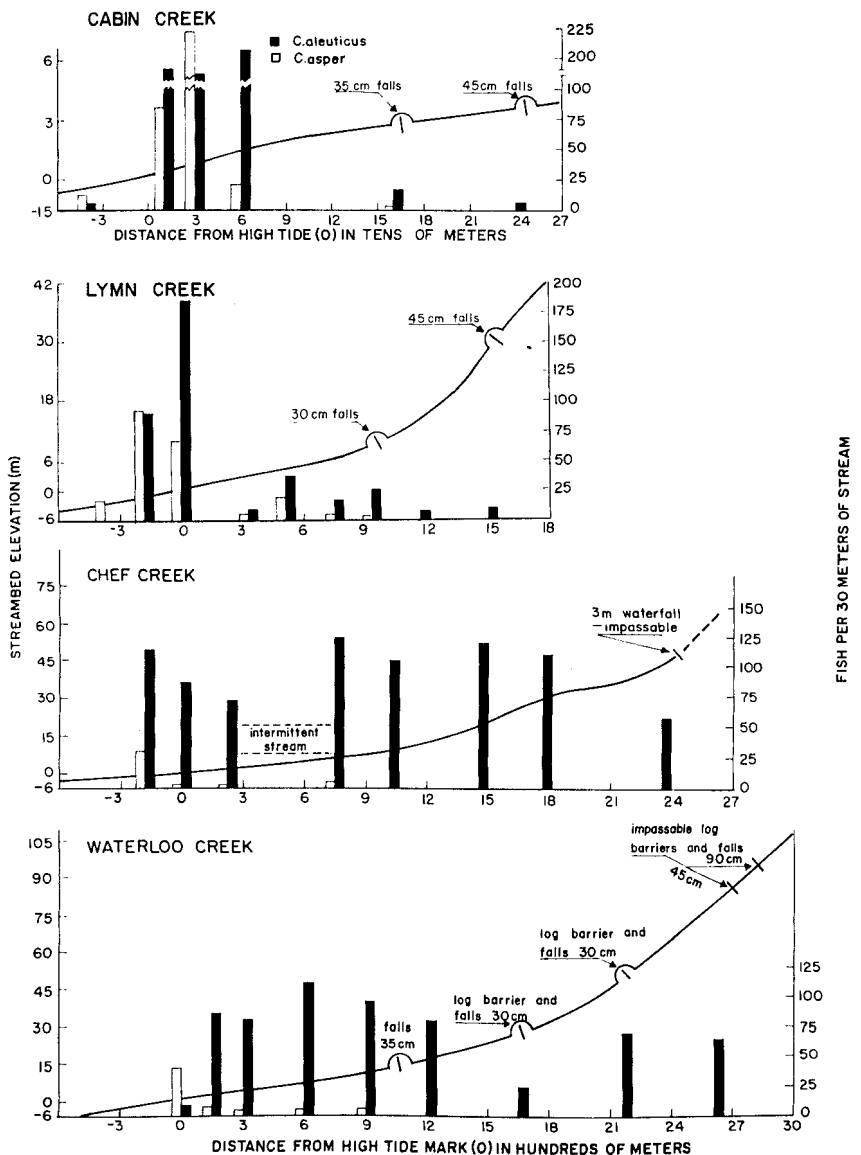


FIGURE 1.—Autumnal distribution and abundance of *Cottus aleuticus* and *C. asper* in relation to stream profile and streambed obstructions. High time mark (0) is a reference benchmark determined by the highest spring tide.

In upstream areas devoid of *C. asper*, the large coastrange sculpins were found in habitats which were usually occupied downstream by large prickly sculpins. Although the subyearlings of both species were found in riffle habitats of the intertidal zone, some habitat segregation was evident since prickly sculpins tended to concentrate in riffle areas where water depth increased and velocity lessened.

The upstream movement of both sculpins is clearly hindered by minor obstructions in the stream, and their respective upstream distributional limits are marked by similar but different obstructions. These obstructions were usually small log jams involving minor waterfalls although in Chef Creek *C. aleuticus* was stopped by a high waterfall (3-4 m) plunging over bedrock. Obstructions resulting in differences in water level greater than 30 cm were impassable for *C. asper* while differences greater than 45 cm were necessary to prevent upstream movement of

C. aleuticus. The limiting structures in Lymn Creek are shown in Figure 2.

The upstream limits of both species of sculpin bore a general association with stream gradient, since both stream gradient and frequency of log jams increase with distance upstream, as do streambed disjunctions causing higher falls (Figure 1).

Both species were distributed downstream into the intertidal zone but to dissimilar extent. For *C. aleuticus*, the downstream limit was the upper edge of the barnacle zone (station 0 minus 250 m, Figure 1) while *C. asper* was not collected below the upper edge of the oyster zone (station 0 minus 400 m).

Both sculpins were most abundant in the lower parts of their ranges (Figure 1) although the data for *C. aleuticus* in Chef Creek are inconclusive, possibly due to upstream movement of fish from the region of intermittent flow although such movement was not observed. Skewed distribution is most pronounced in populations of the two smaller streams, Cabin and Lymn creeks, and in large part is due to inequitable distribution of the age-classes. The subyearling sculpins were found to inhabit a narrow zone about the high tide mark, within which the two species showed extensive overlap (Figure 3). The relative contributions of subyearlings to total catches were rather low in Chef and Waterloo creeks, suggesting poor reproductive success or poor recruitment in 1968. This aspect will be dealt with again in a subsequent section.

Neither species of sculpin undertook any obvious seasonal movements in Lymn Creek during the period from August to December (Figure 4), although the large catches of age I+ prickly

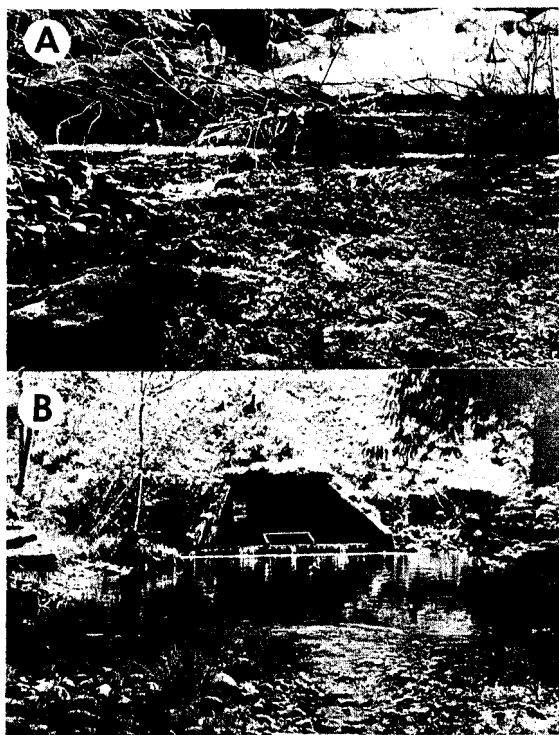


FIGURE 2.—Stream obstructions delimiting the upstream distribution of sculpins in Lymn Creek. A. 45-cm waterfall caused by a large cedar log which blocks the upstream movement of *Cottus aleuticus*. B. 30-cm waterfall at the concrete culvert under Trans-Canada Highway 1, which blocks the upstream movement of *C. asper*.

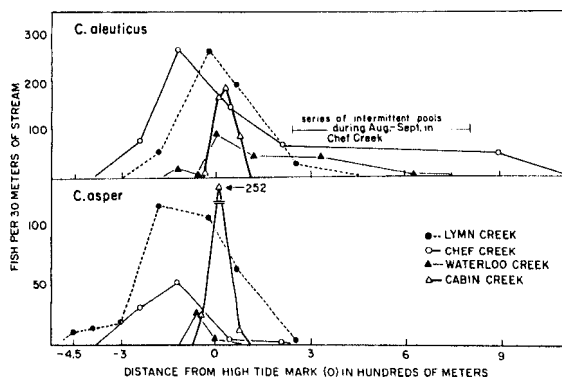


FIGURE 3.—Autumnal distribution and abundance of sub-yearling sculpins.

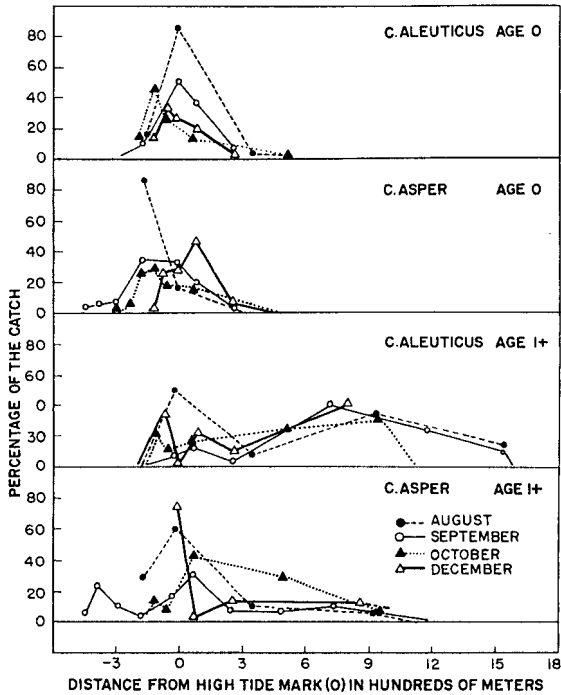


FIGURE 4.—Relative distribution of subyearling and older (I+) sculpins in Lymn Creek during the period August-December.

sculpins made at the head of tide in December suggest the return upstream of individuals which made the downstream migration in the previous spring.

In general, size of fish increased with distance upstream, the largest individuals of both species living at the upstream border of their respective ranges (Figures 5-7); however, subyearling and yearling sculpins of both species tended to be larger both upstream and downstream from the head of tide.

Age Structure

Age structure of populations of both species in Lymn, Chef, and Waterloo creeks was determined by reading the otoliths. Only the first two age-classes could be identified from length frequency histograms (Figures 5-7), and these modes agreed with the otolith readings. The Lymn Creek populations were aged from three successive monthly samples (August-October) that indicated similar lengths within age-groups for this time interval (Tables 2, 3). Slight length increases for a given age-group reflected detectable growth.

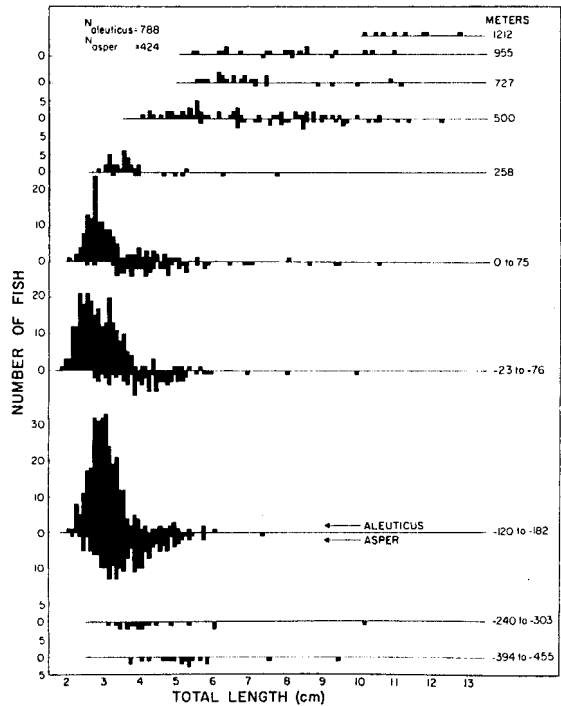


FIGURE 5.—Length-frequency histograms for sculpin populations in Lymn Creek from collections made in September and October. Sampling stations are identified as distances upstream or downstream (-) from high tide mark (0) in meters.

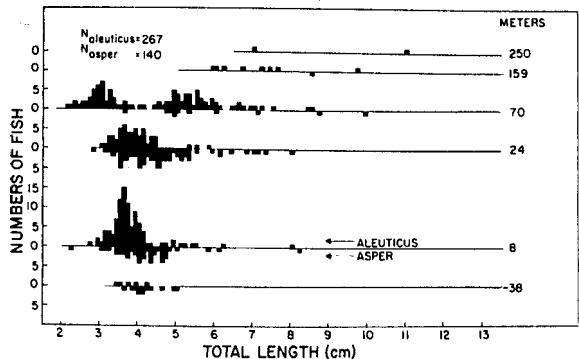


FIGURE 6.—Length-frequency histograms for sculpin populations in Cabin Creek from collections made in September and October. Sampling stations are identified as distances upstream or downstream (-) from high tide mark (0) in meters.

Both sculpins showed differences in age structure in the three streams (Tables 2, 3). There were eight age-classes of *C. aleuticus* in Lymn Creek but only five in Chef and Waterloo creeks. For *C. asper* there were six age-classes in Lymn and Waterloo creeks but only four in Chef Creek.

Lymn Creek contained older fish of both species but *C. aleuticus* lived longer than did *C. asper*.

Distribution of Biomass

The autumnal distribution of biomass by stream zone was derived from population estimates and length-weight data for both species of sculpin in Lymn, Waterloo, and Cabin creeks (Table 4). Density of sculpin biomass (grams per square meter) was lowest in the estuaries and increased upstream. *Cottus aleuticus* showed the greatest increase in biomass density with increased distance upstream, particularly when proceeding from the estuary upstream into the lower stream zone. About 69-94% of sculpin biomass in the estuaries was *C. asper*, whereas about 60-100% of sculpin biomass were *C. aleuticus* in the upper zones whose downstream boundaries were marked by the first significant streambed obstruction. Species biomass in the

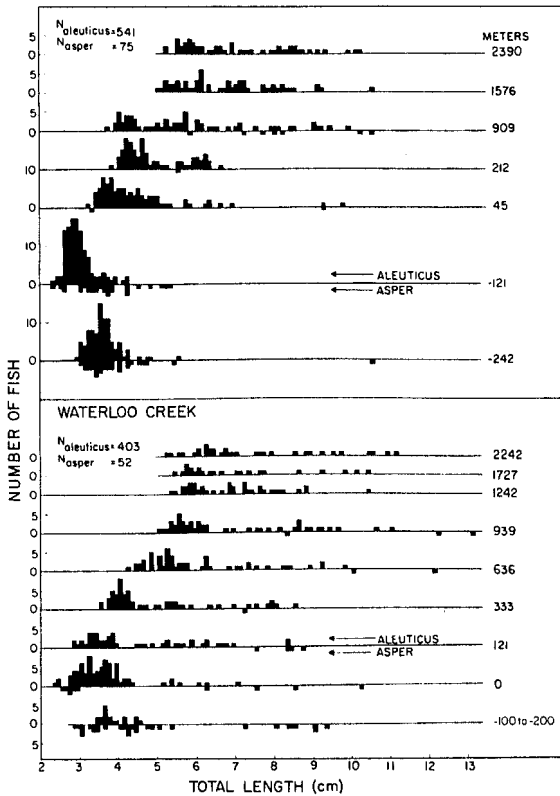


FIGURE 7.—Length-frequency histograms for sculpin populations in Chef and Waterloo creeks from collections made in September and October. Sampling stations are identified as distances upstream or downstream (-) from a high tide mark (0) in meters.

TABLE 2.—Age distributions of *Cottus aleuticus* in successive 5-mm intervals of total length, sexes combined. Number in parentheses indicates total number of fish when not all fish in the length interval were aged.

Total length (mm)	Lymn Creek												Chef Creek					Waterloo Creek					
	August				September				October				September-October					October					
	0	I	II	III	IV	V	VI	VII	0	I	II	III	IV	0	I	II	III	IV	0	I	II	III	IV
14.5-19.4							(7)						(4)										
19.5-24.4							12(83)						3(65)										2
24.5-29.4							5(73)						6(75)										5
29.5-34.4							3(50)						10(80)										13
34.5-39.4							8(15)						6(40)										17
39.5-44.4							9						21										13
44.5-49.4							40						1										17
49.5-54.4							37						3										2
54.5-59.4							25						10										14
59.5-64.4							6						6										15
64.5-69.4							1						2										15
69.5-74.4							8						3										1
74.5-79.4							4						5										2
79.5-84.4							6						1										3
84.5-89.4							4						1										4
89.5-94.4							1						3										1
94.5-99.4							5						2										3
99.5-104.4							1						3										1
104.5-109.4							4						1										2
109.5-114.4							1						2										1
114.5-119.4							2						1										2
119.5-124.4							1						2										1
124.5-129.4							1						1										1
129.5-134.4							1						1										1
134.5-139.4							2						1										3
139.5-144.4							1						1										3
144.5-149.4							1						1										1
Total fish	240	116	25	16	4	5	1	1	288	25	12	4	6	426	40	19	7	2	347	140	40	14	1

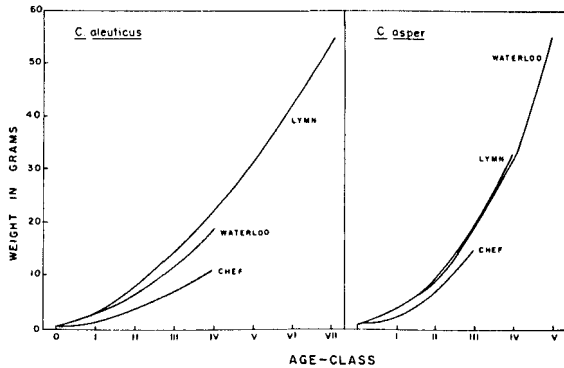


FIGURE 8.—Annual growth rates (weight) of *Cottus aleuticus* and *C. asper* in Lymn, Chef, and Waterloo creeks.

population, which was first sampled in early April, was most rapid during the spring and early summer and nearly completed by mid-August. The largest coastrange sculpin captured was 145 mm in length and 8 yr old while the largest prickly sculpin was 144 mm in length and 6 yr old.

Length-weight linear regressions based on logged data were calculated for both species in the three largest streams (Table 6) and compared by analysis of variance. The length-weight relation was similar for both species in all three streams except for the coastrange sculpin in Chef Creek, which was considerably lighter per unit length than in the other two systems ($F_{2, 2737} = 77.5$). Slow annual growth and a lower slope (b) may reflect poorer feeding conditions or associated population stress during the late summer when the flow in a 500- to 600-m section of this stream becomes intermittent.

Estimates of average annual mortality for both species of sculpins in Lymn, Cabin, and Chef creeks ranged between 58 and 75%, the differences between species and streams depicted in Figure 9 being statistically non-significant. Although similar for both sculpins, mortality in Waterloo Creek was considerably lower than in the other three streams 38-40%. No estimate of

annual mortality was attempted for *C. asper* in Chef Creek due to the small population present.

Despite close agreement to the linear function of the majority of point estimates, some points for young and old age-classes deviated considerably and are taken to indicate poor survival, low recruitment of subyearlings from the estuary in some years, or inadequate sampling. For example, poor survival of age I of *C. asper* is indicated for Lymn, Waterloo, and Cabin creeks (Figure 9). Similarly, age 0 of both species were poorly represented in Waterloo Creek, as were age 0 in Chef Creek, despite intensive sampling in the downstream areas in which they were distributed. In Chef Creek, age IV of *C. aleuticus* was very poorly represented, suggesting either a sudden extensive mortality or inadequate sampling effort in the larger pools upstream where these fish reside.

DISCUSSION

The ecological importance of cottid fishes in the simple fish communities of these coastal streams remains essentially unknown but the present findings appear to be timely in view of the resurging interest in enhancing the natural production of anadromous stream salmonids. Previous

TABLE 6.—Length-weight regression parameters ($\log y = a + bx$) for *Cottus aleuticus* and *C. asper* in three streams on Vancouver Island, B.C.

Parameter	<i>C. aleuticus</i>			<i>C. asper</i>		
	Lymn	Chef	Waterloo	Lymn	Chef	Waterloo
N	1,565	767	397	1,225	73	49
a	-5.312	-5.001	-5.297	-5.268	-5.143	-5.363
b	3.237	3.041	3.224	3.203	3.122	3.259
r	0.993	0.994	0.996	0.992	0.997	0.998
$S_{y \cdot x}$	0.0096	0.0122	0.0136	0.0115	0.0308	0.0268

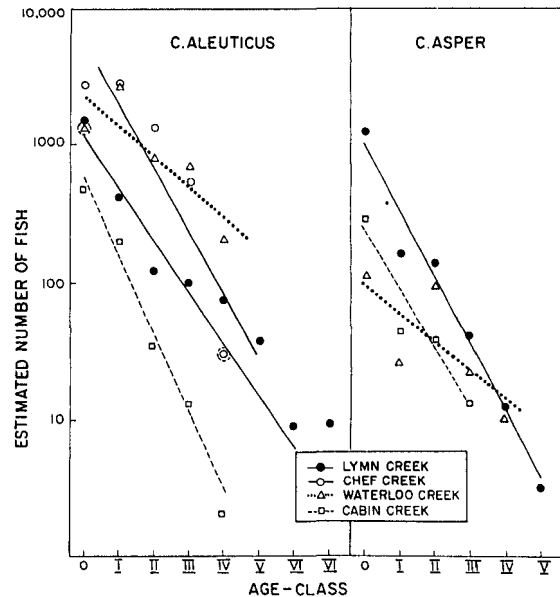


FIGURE 9.—Declining numbers with increasing age within sympatric populations of *Cottus aleuticus* and *C. asper* in four streams. Straight lines describe least-square regressions of best fit.

studies on *C. aleuticus* and *C. asper*, which are widely distributed and commonly abundant in coastal streams from California to Alaska, have emphasized their potentially destructive role as predators on the eggs and fry of salmon and trout (Shapovalov and Taft 1954; Hunter 1959; McLarney 1967). Conversely, it has been generally shown that sculpins in streams of the North Temperate Zone prey incidentally on salmon and trout, but sculpins do share a common source of food—the benthic invertebrate community.

The probable importance of interspecific competition in general, and for food in particular, in such streams where the several species of fishes consume in common a wide variety of food organisms has been readily acknowledged (Hartley 1948; Maitland 1965; Mann and Orr 1969) but continues to defy quantitative analysis. The overlapping summer foods of juvenile coho salmon, cutthroat trout, and coastrange sculpins in Cabin Creek (Table 7) clearly show the possibility of competition for food in the present study streams. Numerically, Ephemeroptera and Diptera were important in all three diets but most important in the coho salmon diet, while Trichoptera were most important in the trout and sculpin diets. The sculpins showed the least varied diet as Ephemeroptera, Diptera, and Trichoptera composed nearly 95% of the food items consumed. Dietary differences can be related to behavioral differences in feeding and habitat response. The

sculpins were abundant in all habitats but ate few foods of surface origin, being crepuscular grazers on the benthos. The trout were principally riffle-dwellers and grazed the benthos (both trout and sculpins ate large numbers of Trichoptera larvae) but exploited the invertebrate drift to a lesser extent than did the coho salmon, which preferred the pool and glide habitats of low current velocity. Despite this behavioral diversity, niche differentiation remains poorly developed in the Eltonian sense discussed by Weatherley (1963) who proposed that the niche be defined as "...the nutritional role of the animal in its ecosystem..."

Recent experiments have clearly illustrated that populations of juvenile coho salmon in these streams are limited by their food supply during the summer months (Mason 1974b, 1974c). Rates of growth, survival and emigration were amenable to manipulation by varying population density and food availability. Thus, in that young coho salmon share a common food supply with both trout and sculpins, the likelihood of food competition is strongly suspected.

Since direct documentation of competition among stream fishes in natural environments continues to elude us, the inferential definition of competition proposed by Maitland (1965) appears to have greater utility than the *modus operandi* definition of Larkin (1956), "...the demand, typically at the same time, of more than one organism, for the same resources of the environment in excess of immediate supply." Maitland (1965) suggested that competition occurs "...when the presence of more than one species causes the average total biomass (standing crop) of one of them to be less than it would be if that species were existing alone—species which are directly parasitic or predatory on one another being excepted."

Fish biomass in small coastal streams of Vancouver Island usually ranges between 7 and 10 g/m² in midsummer (unpubl. data). Of this 3-6 g/m² (50-80%) consists of sculpins (*C. asper* and *C. aleuticus*) in the first several kilometers above the estuarine zone. Studies by Brocksen et al. (1968) have shown that, within the carrying capacity of laboratory streams producing natural drift foods, production of cutthroat trout was determined by the biomass ratio of trout and sculpin, *C. perplexus*, at time of stocking, whereas sculpin production remained independent of trout biomass. These results were obtained over a

TABLE 7.—The percentage composition by frequency of occurrence (O) and number (N) of the midsummer (June-July) foods eaten by juvenile coho salmon, cutthroat trout, and coastrange sculpins in Cabin Creek. Based on 30 fish of each species collected simultaneously.

Food category	Coho		Trout		Sculpin	
	%O	%N	%O	%N	%O	%N
Oligochaeta	10.0	1.2	—	—	—	—
Diplopoda	—	—	40.0	6.2	—	—
Collembola	23.3	4.1	—	—	—	—
Ephemeroptera	46.7	17.4	30.0	9.2	60.0	30.3
Plecoptera	16.7	4.1	20.0	3.1	3.3	<1
Hemiptera	20.0	3.3	10.0	1.5	—	—
Coleoptera						
Adults	30.0	6.2	30.0	4.6	3.3	<1
Larvae	13.3	1.7	—	—	—	—
Trichoptera	10.0	2.1	40.0	26.2	56.6	44.9
Lepidoptera ¹	3.3	<1	50.0	9.2	6.7	2.8
Diptera						
Adults	70.0	28.5	20.0	7.7	—	—
Larvae	26.7	20.7	43.4	15.4	33.3	18.3
Hymenoptera ¹	10.0	1.2	20.0	3.1	—	—
Araneida	36.7	6.6	10.0	1.5	—	—
Acarina	6.7	1.7	23.3	10.8	3.3	1.8
Gasteropoda	3.3	<1	—	—	—	—

¹Refers to adult stage, all categories of Insecta are larval stages unless noted otherwise.

range of species biomass levels commensurate with those encountered in nature and suggest that the availability of drift foods for the trout was determined by the intensity of grazing by sculpins on the stream benthos.

From the present study, the restricted ability of both species of sculpins to surmount obstacles in the streambed, coupled with the life history features of planktonic young and downstream spawning migrations, lend themselves to the potential development of a management strategy for enhancing the production of salmonid smolts to the sea. If the findings of Brocksen et al. (1968) can be corroborated in stream simulator systems more closely approximating the natural environment, studies on the locomotory ability of these sculpins relative to the performance of their communal salmonids could provide the design criteria for physical barriers to be located on test streams at suitable sites above the influence of high tide.

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