Abstract.—Distribution and size during their first summer at sea were determined for juvenile salmon (*Oncorhynchus* spp.) caught in oceanic waters off northern British Columbia and Southeast Alaska, and in marine waters within the Alexander Archipelago of Southeast Alaska. More than 10,000 juvenile salmon were caught in 252 purse-seine sets during August 1983, July 1984, and August 1984. Distribution was patchy; juvenile salmon were highly aggregated, rather than dispersed randomly. Distribution and size of pink salmon (*O. gorbuscha*), sockeye salmon (*O. nerka*), and chum salmon (*O. keta*) were similar but differed from coho salmon (*O. kisutch*). Chinook salmon (*O. tshawytscha*) were excluded from most analyses because few were caught. Sizes were consistent with the concept that juvenile salmon in more northern and seaward locations had been at sea longer than those in more southern and inshore locations. Juvenile salmon migration up the Pacific coast did not peak in abundance off Southeast Alaska until August; movement from inside to outside waters was not complete by the end of August. The migration band of juvenile salmon in outside waters of Southeast Alaska extended beyond the continental shelf to at least 74 km offshore, twice the distance previously reported.

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Marine distribution and size of juvenile Pacific salmon in Southeast Alaska and northern British Columbia

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The general migratory movements of Pacific salmon (*Oncorhynchus* spp.) during their first year at sea have been described (Hartt and Dell, 1986), but little information is available on the seaward migration of juvenile salmon from the inside waters of Southeast Alaska into the Gulf of Alaska. Salmon moving seaward from streams inside Southeast Alaska pass first through the complex waterways of the Alexander Archipelago, the "inside waters" of Southeast Alaska. Upon entering the Gulf, these salmon either occupy outer coast inlets or move into exposed outside waters. Salmon entering exposed outside waters either migrate north along the coast or move progressively farther offshore (Hartt and Dell, 1986). Determining when and at what size juvenile salmon from Southeast Alaska utilize different habitats during their seaward migration to the Gulf may facilitate understanding the high mortality during their first few months at sea (Parker, 1968; Bax, 1983; Furnell and Brett, 1986).

Our goal was to ascertain the distribution and migration of juvenile Pacific salmon during their first summer at sea after they leave nearshore estuarine habitats. Specific objectives were 1) to determine relative distribution, abundance, and size of juvenile salmon in exposed outside waters, in protected waters adjacent to the outer coast, and in the inside waters of Southeast Alaska, and 2) to compare abundance and size of juvenile salmon in outside waters of Southeast Alaska and northern British Columbia.

Methods

Study area and time

The study area extended from Lituya Bay, Southeast Alaska, to the northern end of Vancouver Island, British Columbia (Fig. 1). Three major habitats were sampled: 1) outside waters (the North Pacific Ocean and Gulf of Alaska adjacent to the outer coast of Southeast Alaska and British Columbia); 2) outer coast inlets (protected waters along the outer coast of Southeast Alaska); and 3) inside waters (marine waters within the Alexander Archipelago). Southeast Alaska was further divided at lat. 56°N into a northern and southern region for some analyses. Fishing effort was concentrated in the northern region of Southeast Alaska (Fig. 1).

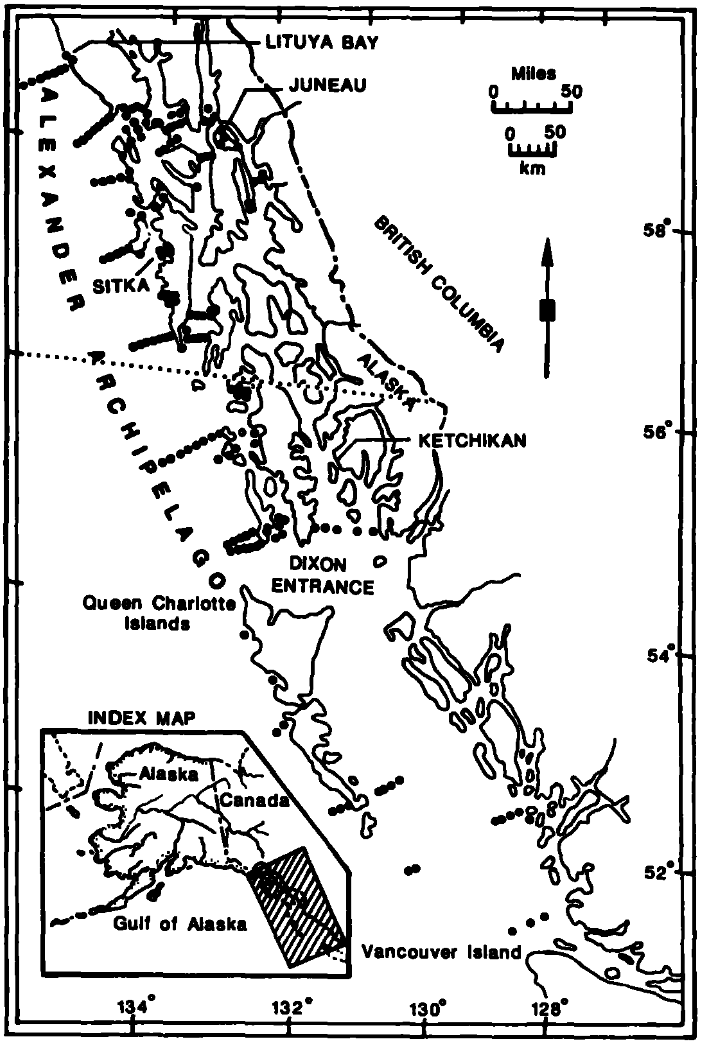

Figure 1
Locations seined in Southeast Alaska and British Columbia in 1983 and 1984. The delineation between northern and southern Southeast Alaska is indicated by the dotted line (running along 56°N lat.).

We sampled in Southeast Alaska during three periods: 6 August–3 September 1983 (hereafter designated August 1983), 9–24 July 1984, and 1–30 August 1984. Sampling in British Columbia was conducted 1–6 July 1984.

Survey stations in outside waters were located along transects perpendicular to shore (Fig. 1). The nearshore station of each transect was as close to land as net depth and safety permitted. Stations were usually sampled progressively offshore at 5.6 km (3 nautical miles [nmi]) intervals in 1983 and at 9.3 km (5 nmi) intervals in 1984. Sampling generally did not extend beyond 37 km offshore except in Southeast Alaska in August 1984, when transects extended as far as 74 km offshore. Distances are rounded to the nearest 1 km in the text.

In large passages in the inside waters, sets were often made along transects near the entrance to outside waters (Fig. 1). Multiple sets were also made in clusters in the larger inlets.

Gear

Stations were sampled with table and drum seines as described by Browning (1980). The 28-m NOAA RV *John N. Cobb* fished a table seine in August 1983 and August 1984; the 24-m FV *Bering Sea* fished a drum seine in July 1984. Sets were made at predetermined locations without reference to visual or instrument sightings of fish. All sets were round hauls: the net was set in a semi-circle, held open 3–5 minutes, closed, pursed, and retrieved by means of a hydraulic power block (table seine) or a hydraulic roller (drum seine). Only catches from effective seine sets are listed (Table 1).

Although the seines differed in size, mesh, and area enclosed, the two nets were assumed to be comparable in their ability to capture juvenile salmon. The table seine was 455 m long; depth tapered from 37 m in the wing to 11 m in the bunt; web sizes (stretch mesh) were 89 mm and 57 mm in the wing, and 25 mm in the bunt. The drum seine was 503 m long, 46 m deep, and had 32-mm mesh in the wing, and 25 mm in the bunt. Depths fished were assumed to be adequate for sampling juvenile pink (*O. gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), and coho (*O. kisutch*) salmon, which usually occupy the upper 10 m of the water (Manzer, 1964; Godfrey et al., 1975; Hartt, 1975). To compensate for the larger surface area enclosed by the drum seine (20,150 m^2) compared to the table seine (16,467 m^2), drum seine catches (July 1984) were reduced during analyses by 18.3% to standardize the catch per unit of effort (CPUE). This standardization caused the July 1984 catches reported to be sometimes less than the number of fish measured for size that period.

Catch processing and analysis

The catch was processed aboard ship and in the Auke Bay Laboratory. The number of juvenile salmon captured in each set was counted if the catch was small (i.e., <100 fish) or estimated gravimetrically if the catch was large. Up to 100 salmon from each set were preserved in 10% formalin in seawater

Table 1

Number of juvenile salmonids caught by species, period, and habitat. All seining occurred in Southeast Alaska (SE AK) except in July 1984 when the outside waters of British Columbia (B.C.) were also sampled.

Period	Habitat	Number of sets	Number of fish caught					
			Pink[1]	Chum[2]	Sockeye[3]	Coho[4]	Chinook[5]	All species
August 1983	Inside waters	54	2,011	385	178	201	3	2,778
	Outer coast inlet	27	680	85	0	23	1	789
	Outside waters	8	20	2	9	27	0	58
	Subtotal	89	2,711	472	187	251	4	3,625
July 1984	Inside waters	18	91	16	17	197	19	340
	Outer coast inlet	14	10	2	0	24	0	36
	Outside waters							
	B.C.	21	573	189	581	33	5	1,381
	SE AK	33	181	34	109	28	1	353
	Subtotal	86	855	241	707	282	25	2,110
August 1984	Inside waters	37	1,850	163	23	375	23	2,434
	Outer coast inlet	4	0	12	0	3	0	15
	Outside waters							
	≤37 km seaward	26	866	152	171	128	5	1,322
	>37 km seaward	10	522	63	119	26	0	730
	Subtotal	77	3,238	390	313	532	28	4,501
All	Inside waters	109	3,952	564	218	773	45	5,552
	Outer coast inlet	45	690	99	0	50	1	840
	Outside waters	98	2,162	440	989	242	11	3,844
	Total	252	6,804	1,103	1,207	1,065	57	10,236

[1] *Oncorhynchus gorbuscha.*
[2] *O. keta.*
[3] *O. nerka.*
[4] *O. kisutch.*
[5] *O. tshawytscha.*

for later species identification and size measurements (fork length [FL] to nearest mm). If more than 100 juvenile salmon were captured in a set, the excess fish were released alive.

Graphs (Chambers et al., 1983) and exploratory data analysis (Tukey, 1977) were used to present catch data because the data had a nonnormal distribution with values clumped at zero (many seine sets did not capture juvenile salmon). Transformations of catch data were ineffective in making the distribution more symmetrical. Quantile plots (Chambers et al., 1983), which show individual catches from smallest to largest, were used to describe the statistical distribution of catches of each species. Chinook salmon (*O. tshawytscha*) were excluded from the remaining analyses because few were caught. Morisita's Index of Aggregation (Morisita, 1959; Poole, 1974) was used to test whether each salmon species was randomly dispersed or aggregated in marine waters of Southeast Alaska.

Morisita's index is defined as

$$I_\delta = \frac{\sum_{i=1}^{N} n_i (n_i - 1)}{n(n-1)} N,$$

where N is the number of samples, n_i is the number of individuals in the ith sample, and n is the total number of individuals in all samples. The significance of I_δ is tested with the F test described by Poole (1974). Spearman's rho (ρ) correlation test (Daniel, 1978) was used to measure association between each possible pairing of the four main species caught (pink, chum, sockeye, and coho salmon).

For comparisons, catch data were split into cells by 1) species, 2) habitat (outside waters, outer coast inlets, and inside waters), 3) region (northern Southeast Alaska, southern Southeast Alaska, and British Columbia), and 4) time period (August 1983, July 1984, and August 1984). CPUE was used as an index of abundance; frequency of occurrence (FO) was used as a measure of presence of juvenile salmon.

Five null hypotheses were tested during fish length analyses of the four species. The first four hypotheses stated that size of a species did not differ for fish from 1) outside and inside waters, 2) outside waters >37 km offshore and ≤37 km offshore, 3) northern and southern waters, and 4) July and August of 1984. The alternate hypotheses stated that fish were larger in 1) outside than inside waters, 2) outside waters >37 km offshore than outside waters ≤37 km offshore, 3) northern than southern waters, and 4) August than July of 1984. The fifth hypothesis stated that length did not differ among species caught within each period.

A number of one-tailed, two-sample t-tests were conducted under null hypotheses 1–4. Only cells that varied in one dimension were directly compared. (For example, under the hypothesis that mean sizes of fish from northern and southern waters did not differ, the mean lengths of pink salmon in the inside waters of northern and southern Southeast Alaska in August 1983 could be compared because the difference between these two cells was in only one dimension—north versus south.) Each possible pairwise comparison under one of the hypotheses was treated as a separate, single, and independent test, and all comparisons were equally weighted. No t-tests could be conducted if one cell had only one fish length. For the overall probability statement, the following statistic was used (Winer, 1971):

$$\chi^2 = 2\sum u_i, \text{ where } u_i = -\ln P_i.$$

Under the hypothesis that the observed probabilities were a random sample from a population of probabilities having a mean of 0.50, the χ^2 statistic has a sampling distribution which is approximated by the χ^2 distribution having $2k$ degrees of freedom, where k is the number of comparisons (Winer, 1971).

For size hypothesis 5 (no difference in mean fork length among salmon species), ANOVA was applied by pooling observations for each species from all habitats and regions. In effect, the pooled species length distribution is a weighted sum of the component distributions represented by the individual samples. Mean lengths of different species were compared separately for each period. If the overall F-test was significant, all possible species comparisons within a period were tested with two-tailed t-tests. Experimentwise error was controlled at α = 0.05 by adjusting the critical value for each t-test to α = 0.0085, by using the Dunn-Sidak method (Sokal and Rohlf, 1981).

Results

Total catch

Over 10,000 juvenile Pacific salmon were captured in 252 seine sets during the three sampling periods (Table 1). The catch consisted of 66% pink salmon, 11% chum salmon, 12% sockeye salmon, 10% coho salmon, and 1% chinook salmon. Pink salmon were the most abundant species (CPUE=27), with 6,804 caught. Chinook salmon were the least abundant species (CPUE=0.23), with only 57 caught.

Statistical distribution of catch

Catch distribution of juvenile salmon was extremely patchy. None were caught in 22% of the sets; more than half were captured in 5% of the sets. Plotting catch abundance against quantiles illustrated that the underlying statistical distribution for each species was clustered around zero (Fig. 2). Chinook salmon had the lowest FO in catches (12%), followed by sockeye salmon (32%), chum salmon (39%), pink salmon (45%), and coho salmon (54%). Coho salmon (median catch=1) was the only species with a median catch >0.

Juvenile salmon had highly aggregated distributions. Morisita's Index of Aggregation (I_δ) was significantly (P<0.001) greater than 1, indicating all species had aggregated distributions in each habitat and for all habitats pooled (Table 2).

Species associations

Pink, chum, and sockeye salmon catches were closely associated with each other. Catches of pink, chum, and sockeye salmon were positively and significantly (P<0.05) correlated (Table 3). In contrast, coho salmon abundance was not correlated with that of other salmon (Table 3).

Abundance

By habitat In Southeast Alaska and British Columbia combined, pink salmon were the most abundant species in each habitat (Table 1). The total pink salmon catch exceeded the catch of each of the other species by six times or more.

In Southeast Alaska, the CPUE of juvenile pink, chum, coho, and chinook salmon was greater in inside waters than in outside waters (Fig. 3), whereas sockeye salmon were more abundant in outside waters than inside waters (Fig. 3). For each species, the lowest CPUE and FO were in the outer coast inlets; sockeye salmon were never captured in an outer coast inlet (Fig. 3). The FO of pink, chum, and sockeye salmon was higher in outside than inside waters; the opposite was true for coho salmon (Fig. 3).

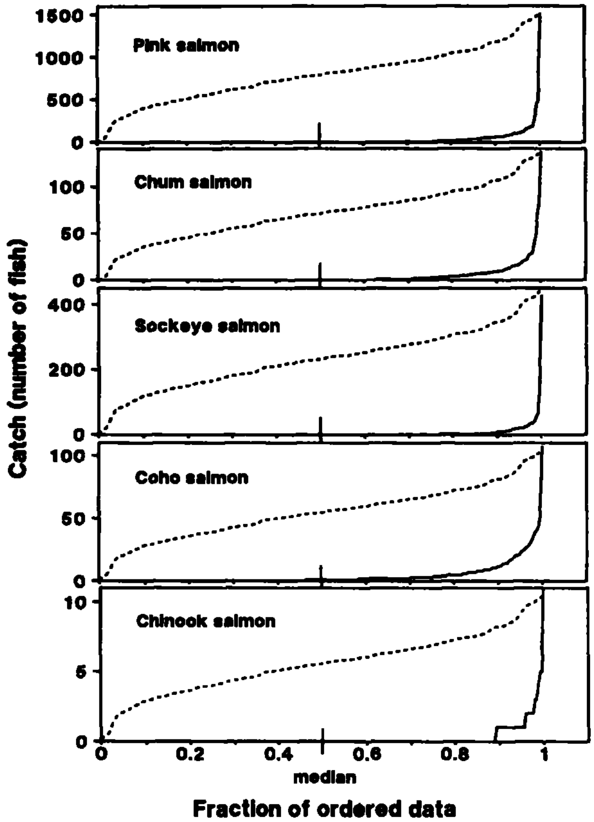

Figure 2

Quantile plots of abundance of the five species of juvenile Pacific salmon (pink, *Oncorhynchus gorbuscha*; chum, *O. keta*; sockeye, *O. nerka*; coho, *O. kisutch*; chinook, *O. tshawytscha*) caught in 252 purse-seine sets in Southeast Alaska in 1983 and 1984 and in British Columbia in 1984. The ranked catches are from the smallest (0) to largest (1) on the X axis. A theoretical normal distribution is indicated by the dotted lines.

By distance offshore in outside waters Distribution of juvenile salmon varied by distance offshore. Substantial numbers of fish were captured up to the maximum distance fished offshore (74 km, Fig. 4A). At intervals offshore, abundance and presence of each species is shown by the 3RSSH smoothed (Tukey, 1977) natural logarithms (ln) of CPUE (Fig. 4B) and smoothed FO (Fig. 4C) respectively. Highest ln CPUE of pink and chum salmon was near the center of the distance fished offshore (Fig. 4B). The transformed CPUE of sockeye salmon, the least abundant species nearshore (Fig. 4B), was greatest 37–74 km offshore, indicating they may have been abundant beyond 74 km. The ln CPUE of coho salmon suggests it was the least abundant species beyond 56 km (Fig. 4B).

Table 2

Morisita's Index of Aggregation (I_δ) and the associated F-value for seine catches of juvenile pink, chum, sockeye, and coho salmon taken in individual habitats (inside waters, outer coast inlets, outside waters) and all these habitats pooled in Southeast Alaska in August 1983, July and August 1984. Dashes indicate no fish captured.

Salmon species	Habitat	I_δ	F
Pink[1]	Inside waters	20.0	695.7*
	Outer coast inlet	10.7	153.0*
	Outside waters	3.6	54.9*
	All habitats pooled	18.5	474.5*
Chum[2]	Inside waters	13.6	66.6*
	Outer coast inlet	9.0	18.7*
	Outside waters	5.4	15.3*
	All habitats pooled	12.7	47.6*
Sockeye[3]	Inside waters	11.8	22.7*
	Outer coast inlets	—	—
	Outside waters	15.1	23.2*
	All habitats pooled	9.5	24.2*
Coho[4]	Inside waters	4.4	25.1*
	Outer coast inlets	2.9	3.1*
	Outside waters	7.8	19.5*
	All habitats pooled	6.2	24.3*

* F-value is significant for $P < 0.001$.
[1] *Oncorhynchus gorbuscha*.
[2] *O. keta*
[3] *O. nerka*.
[4] *O. kisutch*.

Table 3

Spearman's rank correlation coefficient (ρ) test of pair rankings of juvenile salmon species catches taken during 252 separate sets in Southeast Alaska and British Columbia.

Comparison of species of salmon	Correlation between species pair rankings (ρ)
Pink[1]/Chum[2]	+0.75*
Pink/Sockeye[3]	+0.68*
Pink/Coho[4]	+0.14
Chum/Sockeye	+0.55*
Chum/Coho	+0.13
Sockeye/Coho	+0.11

* Significant association at $P < 0.05$, with rejection criteria adjusted for multiple comparisons.
[1] *Oncorhynchus gorbuscha*.
[2] *O. keta*.
[3] *O. nerka*.
[4] *O. kisutch*.

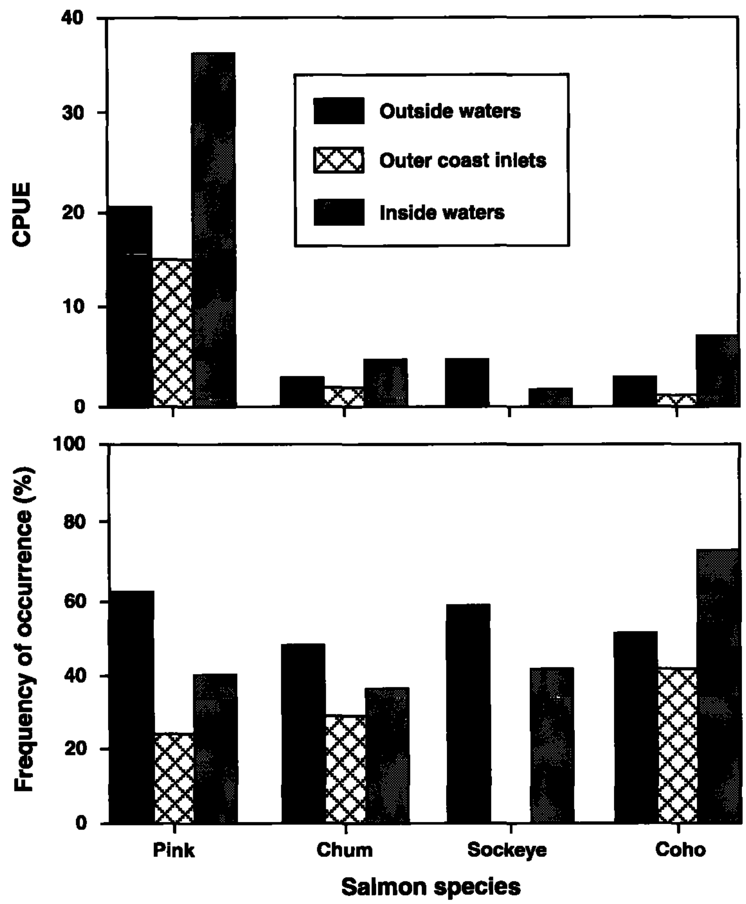

Figure 3

Catch per unit of effort (CPUE) and frequency of occurrence of juvenile salmonids (pink, *Oncorhynchus gorbuscha*; chum, *O. keta*; sockeye, *O. nerka*; coho, *O. kisutch*; in outside waters (77 sets), outer coast inlets (45 sets), and inside waters (109 sets) in Southeast Alaska in 1983 and 1984 combined.

Pink and chum salmon FO was lowest nearshore, then increased and stabilized mid-distance offshore, around 37 km (Fig. 4C). Pink salmon were caught in all sets beyond 37 km and had the highest FO of all species; sockeye salmon FO remained constant 2–74 km offshore. Coho salmon FO was the highest nearshore (2 km) of all species, then the FO stabilized at 37 km and beyond (Fig. 4C).

By sampling period Abundance of juvenile salmon in Southeast Alaska increased from July (CPUE=11) to August (CPUE=58) 1984 for all species. Summed over all habitats, pink, chum, sockeye, and coho salmon had higher FO's and abundance in August than in July. In outside waters, CPUE of each species increased two to seven times from July to August 1984, with juvenile pink salmon showing the largest increase (Fig. 5). In inside waters, CPUE of pink and chum salmon increased 10 and 5 times respectively from July to August, whereas CPUE's of sockeye and coho salmon remained constant (Fig. 5). For all four species, FO increased in outside waters but decreased in inside waters from July to August 1984 (Fig. 5). The low number of sets (four) made in outer coast inlets of Southeast Alaska in August 1984 precluded seasonal comparisons of CPUE or FO for this habitat.

Size

Juvenile salmon were larger in outside waters than in inside waters. Thirteen matched pairs of size samples could be compared under the hypothesis that size did not vary between outside and inside waters; the fish were larger in the outside water in all comparisons (Table 4, χ^2=133.66, df=26, P<0.005) and the null hypothesis was rejected.

Juvenile salmon in outside waters were larger farther seaward. Of the eight possible matched pairs of samples compared under the hypothesis that size was not different between outside waters >37 km offshore and ≤37 km offshore, the juvenile salmon were larger >37 km seaward in all comparisons (Table 4, χ^2=67.44, df=16, P<0.005).

Juvenile salmon in northern waters were larger than those in southern waters. The fish were larger in the northward locations than southward locations in 18 of 23 possible paired size comparisons (Table 4, χ^2=214.76, df=46, $P \leq 0.005$).

Juvenile salmon were larger in August than in July. Of the matched size samples compared under the hypothesis that size was not different between August and July of 1984, fish in August were larger than in July in 10 of 12 comparisons (Table 4, χ^2=145.36, df=24, P<0.005).

The sizes between the different species of juvenile Pacific salmon differed significantly (P<0.05) (Table 5). Coho salmon juveniles were significantly larger than other species in each sampling period; mean length of coho salmon was always at least 40% greater than in other species, whereas pink, chum, and sockeye salmon were within 9% of each other. Juvenile sockeye salmon were significantly larger than pink salmon in each sampling period and were significantly larger than chum salmon in 1984. In both July and August 1984, pink and chum salmon did not differ in size, and in August 1983 chum and sockeye salmon did not differ in size.

Discussion

Fish distribution

Each species of juvenile salmon was highly aggregated rather than dispersed randomly. In contrast to our results, Hartt and Dell (1986) seldom observed zero catches and therefore concluded that juvenile salmon in the ocean were evenly dispersed. Several differences between our study and theirs may explain the differing conclusions. Seines used by Hartt and Dell were longer than ours and were held open for 30 minutes instead of 3–5 minutes. Our catches may be more of a point estimate or instantaneous picture of fish abundance, whereas their seines were more likely to intercept at least part of a juvenile salmon school. More importantly, Hartt and Dell did not separate juvenile salmon by species when considering their distribution.

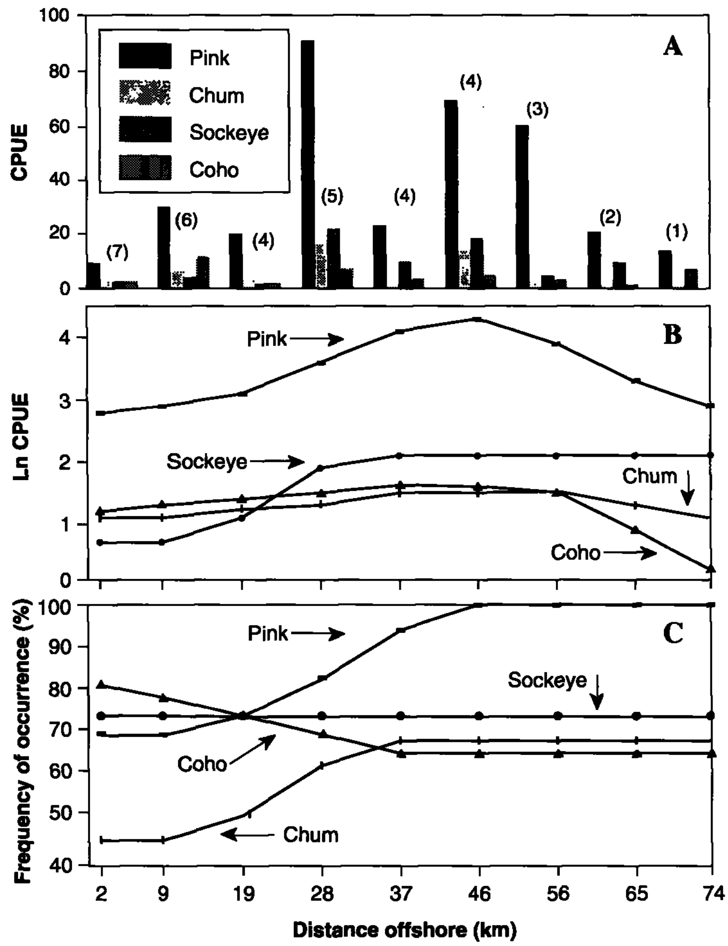

Figure 4

Abundance of juvenile salmonids (pink, *Oncorhynchus gorbuscha*; chum, *O. keta*; sockeye, *O. nerka*; coho, *O. kisutch*) by distance offshore in the outside waters of Southeast Alaska in August 1984 (36 sets). Abundance is shown in terms of (**A**) catch per unit of effort (CPUE), (**B**) the smoothed natural logarithm of CPUE, and (**C**) the smoothed frequency of occurrence of the catches; number of sets is in parentheses. All distances are rounded to the nearest kilometer. Actual distance between intervals (except the first) is 9.3 km.

Species associations

Juvenile pink, chum, and sockeye salmon were generally closely associated with each other in their distribution. The distribution of these species, however, differed from the distribution of coho salmon, a result consistent with the conclusions of Hartt and Dell (1986) and Waddell et al. (1989). In the inside waters and outer coast inlets, we found that pink, chum, and sockeye salmon had a lower FO than coho salmon, indicating that those species were more highly aggregated and sparsely distributed than coho salmon. Paszkowski and Olla (1985) found that behavior patterns of juvenile coho salmon promoted dispersion, not aggregation. The utilization of similar areas in this study by juvenile pink, chum, and sockeye salmon correlates with the high degree of diet overlap observed between these species; in contrast, juvenile coho salmon showed little diet overlap with the other species.[1] Healey (1991) reported that juvenile pink, chum, and sockeye salmon in British Columbia were also aggregated.

Migration

The migration of juvenile salmon off Southeast Alaska (Hartt and Dell, 1986) consists of two components: 1) fish migrating north from the Pacific Northwest and British Columbia, and 2) fish from Southeast Alaska migrating from inside to outside waters.

[1] J. H. Landingham, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801–8626, pers. commun. Jan. 1992.

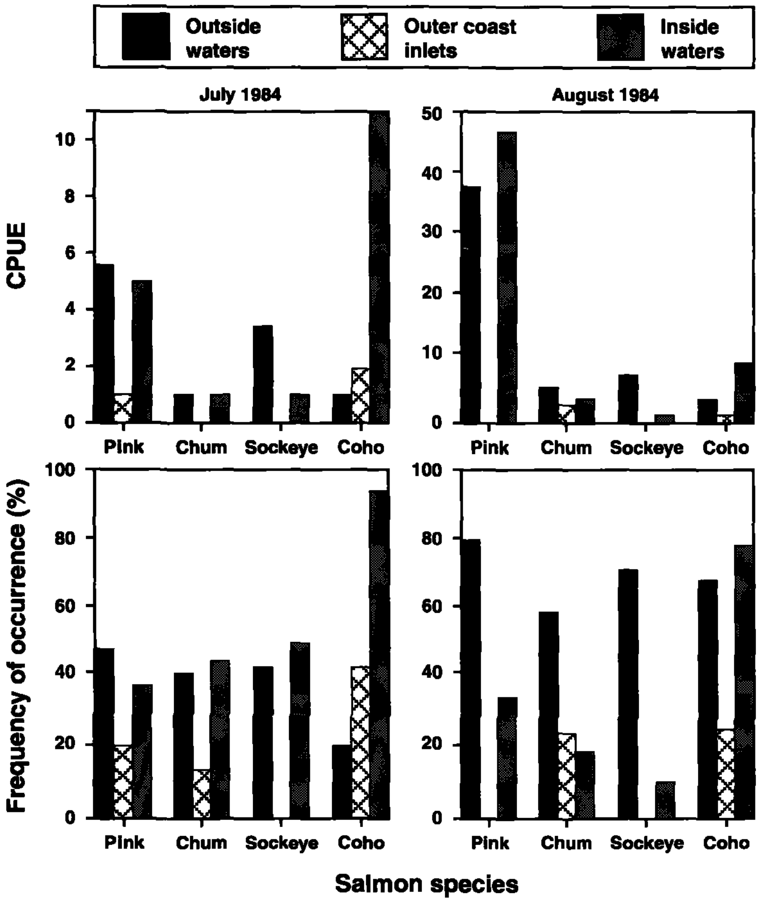

Figure 5

Catch per unit of effort (CPUE) and frequency of occurrence of juvenile salmonids (pink, *Oncorhynchus gorbuscha*; chum, *O. keta*; sockeye, *O. nerka*; coho, *O. kisutch*) in the outside waters (69 sets), outer coast inlets (18 sets), and inside waters (55 sets) in Southeast Alaska in July and August 1984. Note change in scale of CPUE from July to August 1984.

Juvenile salmon migrations along the Pacific coast in 1984 did not peak off Southeast Alaska until, at earliest, August. In July, CPUE's were much higher in the outside waters of British Columbia than in Southeast Alaska. By August, CPUE of juvenile salmon in outside waters of Southeast Alaska had increased fivefold, and FO had increased for each species. Hartt and Dell (1986) observed that juvenile salmon abundance peaked in August in outside waters of Southeast Alaska.

In Southeast Alaska, juvenile sockeye salmon probably begin their ocean migration to the Gulf of Alaska before juvenile pink and chum salmon, based on two observations from our study. First, the sockeye salmon did not occur in protected waters along the outer coast of Southeast Alaska like the other species: no sockeye salmon were captured in an outer coast inlet. Second, sockeye salmon was the only species with a higher CPUE in outside waters than in inside waters. This higher abundance outside, coupled with low abundance in inside waters in July and August, is consistent with the conclusion that sockeye salmon commence their ocean migration before pink or chum salmon (Straty, 1981; Healey, 1982).

The migration of pink salmon from the inside waters of Southeast Alaska lasts until at least September. Martin (1966) concluded that late July and early August were the peak periods of juvenile pink salmon migration from the inside waters. However, our data show that pink salmon abundance in inside waters increased from July to August and that pink salmon were more abundant in inside waters than outside waters in August, thus indicating that migration out of the inside waters was not complete in August. The seasonal migration of juvenile chum salmon out of Southeast Alaska could not be determined from the abundance data of this study. The migration of juvenile pink, chum, and sockeye salmon out of the inside waters in September and later has not been studied.

The offshore migration of coho salmon in Southeast Alaska is more complex. CPUE and FO of coho salmon in inside waters remained relatively constant for July and August. Coho salmon was the only species with both a higher CPUE and FO in inside waters than in outside waters in August. These data suggest extensive residency in inside waters for a substantial portion of coho salmon juveniles in Southeast Alaska. Other researchers have found that some juvenile coho salmon remain in the eastern Pacific Ocean inside waters until late fall (Healey, 1984; Hartt and Dell, 1986; Orsi et al., 1987). Winter residency of juvenile coho in inside waters of Southeast Alaska is apparently rare.[2] Hartt and Dell (1986) and Pearcy and Fisher (1990) also found coho salmon offshore as early as May or June; Hartt and Dell (1986) noted that juvenile coho salmon migrated seaward earlier than the other salmon species, presumably because of their larger

[2] J. A. Orsi, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801–8626, pers. commun. Jan. 1992.

Table 4

Fork length (FL) of juvenile salmonids sampled by period, habitat, north (N) or south (S) region, and distances offshore in outside waters of Southeast Alaska in 1983 and 1984 and outside waters of British Columbia (B.C.) in 1984. Values are mean ± standard error, with number of samples in parenthesis. In brackets under the values are the specific paired size comparisons used in the null hypothesis testing of sizes by: northern vs. southern waters (A1, A2, ..., A23); outside vs. inside waters (B1, B2, ..., B13); August vs. July 1984 (C1, C2, ..., C12); and outside waters >37 km offshore vs. outside waters <37 km offshore (D1, D2, ..., D8). Dashes indicate no fish caught.

		FL of salmon (mm)			
Period	Habitat (region)	Pink[1]	Chum[2]	Sockeye[3]	Coho[4]
Aug 83	Inside (N)	169 ± 0.8 (890) [A1]	180 ± 1.8 (199) [A2]	163 ± 2.7 (74)	233 ± 1.8 (136) [A3]
	Inside (S)	121 ± 1.9 (10) [A1, B1]	139 ± 4.6 (18) [A2, B2]	—	227 ± 11.9 (5) [A3, B3]
	Outer coast inlet (N)	—	166 ± 4.9 (4) [A4]	—	221 ± 6.3 (11) [A5]
	Outer coast inlet (S)	124 ± 0.5 (404)	133 ± 1.5 (76) [A4]	—	217 ± 7.9 (11) [A5]
	Outside (S)	153 ± 3.6 (19) [B1]	141 ± 13.5 (2) [B2]	152 ± 2.6 (9)	234 ± 3.6 (25) [B3]
July 84	Inside (N)	121 ± 1.7 (94) [A6, B4, C1]	112 ± 5.2 (19) [B5, C2]	136 ± 5.9 (20) [B6, C3]	193 ± 2.0 (206) [A7, B7, C4]
	Inside (S)	132 ± 1.2 (3) [A6, B8]	135 ± 0 (1)	—	202 ± 7.8 (3) [A7, B9]
	Outer coast inlet (N)	105 ± 10.9 (4)	139 ± 0 (1)	—	177 ± 3.6 (27)
	Outside (N)	135 ± 0.8 (207) [A8, A9, B4, C5]	133 ± 2.3 (38) [A10, A11, B5, C6]	151 ± 2.1 (111) [A12, A13, B6, C7]	220 ± 4.5 (26) [A14, A15, B7, C8]
	Outside (S)	134 ± 4.6 (10) [A8, A16, B8, C9]	161 ± 18.5 (2) [A10, A17, C10]	157 ± 2.6 (19) [A12, A18, C11]	224 ± 7.5 (8) [A14, A19, B9, C12]
	Outside (B.C.)	128 ± 1.0 (126) [A9, A16]	132 ± 1.5 (46) [A11, A17]	128 ± 0.9 (197) [A13, A18]	129 ± 10.3 (7) [A15, A19]
Aug 84	Inside (N)	143 ± 1.0 (358) [B10, C1]	125 ± 1.2 (118) [B11, C2]	157 ± 2.1 (18) [B12, C3]	234 ± 1.9 (168) [B13, C4]
	Outer coast inlet (S)	—	132 ± 6.1 (12)	—	246 ± 12.2 (3)
	Outside (N)	144 ± 0.6 (730) [A20, B10, C5]	160 ± 2.0 (93) [A21, B11, C6]	159 ± 1.5 (75) [A22, B12, C7]	267 ± 5.6 (33) [A23, B13, C8]
	≤37 km	143 ± 0.8 (457) [D1]	157 ± 2.2 (73) [D2]	156 ± 1.7 (52) [D3]	266 ± 6.5 (28) [D4]
	>37 km	146 ± 1.0 (273) [D1]	169 ± 4.1 (20) [D2]	165 ± 2.8 (23) [D3]	274 ± 2.3 (5) [D4]
	Outside (S)	139 ± 1.0 (373) [A20, C9]	144 ± 2.1 (66) [A21, C10]	149 ± 0.9 (141) [A22, C11]	265 ± 3.3 (37) [A23, C12]
	≤37 km	135 ± 1.2 (243) [D5]	144 ± 2.7 (38) [D6]	148 ± 1.0 (103) [D7]	263 ± 3.3 (35) [D8]
	>37 km	144 ± 1.4 (130) [D5]	145 ± 3.5 (28) [D6]	152 ± 1.5 (38) [D7]	291 ± 15.0 (2) [D8]

[1] *Oncorhynchus gorbuscha.*
[2] *O. keta.*
[3] *O. nerka.*
[4] *O. kisutch.*

size. An early component of coho salmon juveniles could have moved offshore in June, prior to our sampling effort. More extensive sampling from late spring through fall is required to define the timing of migrations of coho salmon in the waters of Southeast Alaska.

The sizes of juvenile salmon we captured support the findings of Hartt and Dell (1986) that fish in more northern locations have been at sea longer than those in southern locations. Hartt and Dell (1986) observed a general increase in mean length of juvenile salmon from south to north in the outside waters from Washington to Southeast Alaska. In the coastal waters off Oregon and Washington, larger, presumably older, juvenile coho salmon were found farther north (Pearcy and Fisher, 1988). Assuming they were similar in size on entering the sea, the smaller fish in the southerly locations are recent arrivals from nearby production areas, whereas the larger fish in the northerly locations have been at sea longer and probably migrated from more southerly production areas (Hartt and Dell, 1986). Our studies also reveal juvenile salmon in Southeast Alaska were larger in the outside waters than inside waters and farther offshore in the outside waters than closer to shore. The progression of juvenile salmon migrations over a season may be size-dependent (Healey, 1982, 1984), and certain phases of migration may depend on fish reaching a threshold size. According to Hartt and Dell (1986), the offshore migration into the Gulf of Alaska of juvenile pink, chum, and sockeye salmon does not begin until September or October when fish are 180–230 mm or greater in mean FL. However, our findings show that these species are found offshore earlier (in August) and at a much smaller size (145–170 mm mean FL).

Width of migration band

Juvenile Pacific salmon typically migrate in nearshore waters during their first few months at sea (Straty, 1981); however, the width of this migration band varies regionally (Straty and Jaenicke, 1984; Hartt and Dell, 1986). Juvenile salmon concentrated within 37 km of shore along the broad continental shelf (<183 m deep) off Oregon and Washington (Miller et al., 1983; Pearcy and Fisher, 1990). Hartt and Dell (1986) concluded that the band of juvenile salmon was within 37 km of shore off Southeast Alaska where the continental shelf is narrow, but that the band widened in the northern Gulf of Alaska where the shelf is wider.

Our results indicate that the coastal band of migrating juveniles can be much wider than 37 km and that the offshore migration beyond 37 km may begin as early as August. Catches of juvenile salmon 74 km offshore—the maximum distance we fished offshore—and the catch distributions indicate that some juvenile salmon (pink, chum, and sockeye) may have been abundant even farther seaward. Two-thirds of the juvenile salmon captured in outside waters in August 1984 were beyond the continental shelf.

The width of the migration band is probably influenced by the Alaska Coastal Current—a dominant feature in the circulation of Gulf of Alaska coastal waters. This freshwater-driven current begins along the British Columbia coast and flows north then west within 20 km of shore into the Bering Sea (Royer, 1984). The strength of this current is affected by local precipitation, wind, air temperature, and other meteorological conditions. Millions of juvenile salmon migrate through the current every year en route to more oceanic waters. Cooney (1984) theorized that the current represents a critical early-feeding habitat in the summer and early fall. In modeling the early-ocean limitations of Pacific salmon production, Wal-

Table 5

Comparison of mean fork lengths (FL) of juvenile salmonids caught in the marine waters (all habitats pooled) of Southeast Alaska and northern British Columbia in 1983–84. Sample size = *n*; standard deviation of the size in mm = s. The hypothesis was that there were no size differences between species during the same period. The rejection criteria were adjusted for multiple comparisons so that experimental error did not exceed $\alpha = 0.05$. Species having the same letter in a column were not significantly different by size.

Salmon species	August 1983 *n*	mean FL (mm)	s	July 1984 *n*	mean FL (mm)	s	August 1984 *n*	mean FL (mm)	s
Pink[1]	1,323	155[c]	29	444	130[c]	14	1,461	142[c]	18
Chum[2]	299	165[b]	31	108	129[c]	17	289	141[c]	22
Sockeye[3]	83	162[b]	23	347	138[b]	20	234	153[b]	12
Coho[4]	188	232[a]	22	277	193[a]	30	241	253[a]	20

[a] *Oncorhynchus gorbuscha.*
[b] *O. keta.*
[c] *O. nerka.*
[d] *O. kisutch.*

ters et al. (1978) noted that production predictions were critically sensitive to the width of the coastal band within which salmon migrate during their first summer at sea. We recommend additional sampling be conducted from June through September to better document 1) the width of the coastal band of juvenile salmon migrations through the summer and 2) the timing of offshore migrations beyond 37 km from the outer coast.

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