Marine distribution and origin of prerecruit chinook salmon, *Oncorhynchus tshawytscha*, in southeastern Alaska

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Abstract.—Chinook salmon, *Oncorhynchus tshawytscha*, <71 cm total length, are typically not retained in directed marine fisheries of southeastern Alaska because of size restrictions; consequently, little is known of the origin or temporal and spatial distribution of these prerecruits. To obtain such data, commercial power trollers were chartered to fish for small chinook salmon with small hooks and lures within the Alexander Archipelago (inside waters) and the adjacent coastal region (outside waters). During the 135-d study in February, May, and September 1986–87, a total of 5,838 prerecruit chinook salmon were caught, of which 539 contained coded-wire tags with information on stock origin. Age -.0 chinook salmon were caught in September during their first year at sea; they originated predominately from stream-type stocks of southeastern Alaska. Age -.1 chinook salmon in February and May were primarily from stream-type stocks of southeastern Alaska; however, by September most were from ocean-type stocks from British Columbia, Washington, and Oregon streams. Most age -.2 chinook salmon were from ocean-type stocks of southern origin. Average net marine migration rates of different chinook salmon age groups ranged from 0.1 to 6.9 km/d; the highest rates were for age 1.0 fish from Washington and Oregon. For coded-wire-tagged chinook salmon of the same ocean age group, growth rates of ocean-type fish were significantly ($P<0.05$) higher than growth rates of stream-type fish during most periods. Spatial distribution also differed by race: stream-type fish predominated in inside waters and ocean-type fish in outside waters. This study identifies the importance of marine waters of southeastern Alaska as a nursery area for an amalgam of prerecruit chinook salmon stocks originating between Oregon and southeastern Alaska, a range of 1,800 km.

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Alaskan and non-Alaskan stocks of chinook salmon, *Oncorhynchus tshawytscha*, are harvested in southeastern Alaska waters predominately in hook-and-line marine fisheries; however, owing to a minimum size restriction of 71-cm total length, limited information exists on the temporal and spatial occurrence of smaller fish (prerecruits). Many North American stocks of chinook salmon embark on extensive marine migrations along the eastern Pacific Rim (Mason, 1965; Hartt and Dell, 1986). Some migrate across international or state boundaries and are intercepted in fisheries along migration corridors or in distant nursery areas. Consequently, many chinook salmon stocks have been overexploited, and rebuilding depressed runs is a major concern identified in the 1985 U.S.-Canada Pacific Salmon Treaty (Pacific Salmon Commission, 1986). A better understanding of the marine life history and distribution of chinook salmon populations will contribute to the development of management policies that are needed to restore the depressed stocks.

Not all chinook salmon migrate long distances. Some stocks in Oregon, Washington, British Columbia, and southeastern Alaska apparently do not migrate northward to any great extent (Mason, 1965; Nicholas and Hankin[1]), and many remain in inside waters all or much of their marine life (Hartt and Dell, 1986).

Two distinct races of chinook salmon have been identified: stream-type and ocean-type ("sea-type") (Gilbert, 1914; Healey, 1983). Stream-type fish are found throughout the geographic range of the species, whereas ocean-type fish occur primarily from British Columbia to California (Major et al., 1978; Healey, 1983). Stream-type chinook salmon remain in fresh water for one or more years before migrating to an estuary, whereas ocean-type chinook salmon migrate directly to an estuary as newly emerged fry or after 2–3 months of freshwater residence (Healey, 1983; Taylor, 1990). Prior to ocean entry, stream-type chinook salmon have a brief estuarine residence (Healey, 1983; Fisher and Pearcy, 1990) in contrast to ocean-type chinook salmon, which may reside in estuaries for up to three months (Healey, 1980; Myers and Horton, 1982; Nicholas and Hankin[1]; Reimers[2]).

[1] Nicholas, J. W., and D. J. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: description of life histories and assessment of recent trends in run strengths. Info. Rep. 88-1, Oregon Dep. Fish Wildl., Fish. Div., Res. and Develop. Section, Portland, OR 97207, 359 p.

[2] Reimers, P. E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Oregon Fish Comm. Res. Rep. 4(2), Oregon Dep. Fish Wildl., Portland OR 97201, 43 p.

In marine waters of southeastern Alaska, chinook salmon occur throughout the year (Cobb, 1910) and are harvested principally in a commercial troll fishery. Origins of stocks in this fishery are diverse, as documented by marine tagging studies, coded-wire tag (CWT) recoveries, and scale pattern analyses (Parker and Kirkness, 1956; Clark et al., 1985; Van Alen, 1988; Kissner[3]; Funk[4]). Throughout the history of this fishery, ocean-type chinook salmon of non-Alaskan origin have been the major harvest component (Parker and Kirkness, 1956; Van Alen and Wood, 1983; Olsen, 1992). Surprisingly, relatively little is known of the early marine distribution of prerecruit ocean-type fish after the initial summer at sea (Healey and Groot, 1987). In particular, it is not known whether prerecruit chinook salmon of different age groups within Alaskan marine waters are primarily of Alaskan or non-Alaskan origin.

Southeastern Alaska stocks of chinook salmon, which are primarily stream-type (Van Alen et al., 1986), migrate through inside marine waters of southeastern Alaska before their first marine winter (Orsi et al., 1987). In the summer and fall after their first marine winter, some portion of these stocks are recovered in southeastern Alaska waters (Hubartt and Kissner, 1987), whereas others migrate offshore to the North Pacific Ocean (Dahlberg et al.[5]). To identify the temporal and spatial distribution of prerecruit chinook salmon stocks in southeastern Alaska waters, we used commercial salmon trollers with small hooks and lures to sample prerecruits during February 1987 and May and September 1986 and 1987.

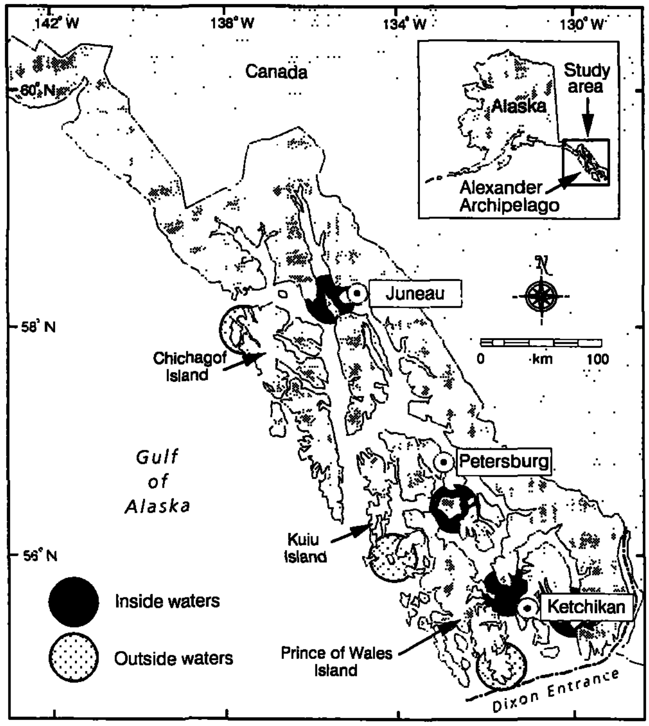

Figure 1

Inside and outside marine waters sampled in the northern, central, and southern regions of southeastern Alaska, 1986–87.

Methods

Sampling areas and times

Southeastern Alaska comprises the mainland coast and a large island group, the Alexander Archipelago, which covers about 100,000 km^2 (Fig. 1). Marine waters throughout this island group are a network of estuaries, fjords, and straits that lead into the Gulf of Alaska or Dixon Entrance. We sampled chinook salmon in "inside" and "outside" marine waters of the northern, central, and southern regions of the archipelago (Fig. 1). We defined "inside" waters as those within the Alexander Archipelago, typically adjacent to mainland southeastern Alaska, and "outside" waters as the coastal waters exposed to the Gulf of Alaska or Dixon Entrance near the outer coasts of Chichagof, Kuiu, and Prince of Wales Islands. Our selection criteria for sampling areas and times were influenced by the geographical localities of the major fishing ports in southeastern Alaska and by the availability of commercial trolling vessels during three off-season fishing periods separated by about four months.

We sampled chinook salmon from 11.0–16.2-m chartered commercial power troll vessels during May and September 1986 and February, May, and September 1987 for a total of 1,156 h of fishing effort over a 135-d period (Table 1). The vessels were operated by experienced commercial salmon trollers, accompanied by fishery biologists. Inside and outside waters were typically sampled in each region and season; however, the central region was sampled only in September 1986, and inclement weather precluded sampling the outside waters of the southern region in February 1987 (Table 1).

[3] Kissner, P. D. 1977. A study of chinook salmon in Southeast Alaska. Alaska Dep. Fish Game, Sport Fish Div. Completion Rep., Vol. 18, Project F-9-8, Study AFS-41-5, Juneau, AK, 63 p.

[4] Funk, F. 1981. Analysis of southeastern Alaska troll fisheries data. Final Report, Contract 79-4, North Pacific Fishery Management Council Document 17. Alaska Dep. Fish and Game, Juneau, 103 p. + appendix.

[5] Dahlberg, M., S. Fowler, N. Maloney, and R. Heintz. 1991. Incidence of coded-wire tagged salmonids in commercial and research catches in the North Pacific Ocean and Bering Sea, 1990–1991. (INPFC [International North Pacific Fisheries Commission] Doc.), Auke Bay Laboratory, Alaska Fish. Sci. Cent., NMFS, NOAA, 11305 Glacier Hwy., Juneau, AK 99801-8626, 17 p.

Table 1

Hours of sampling effort for chinook salmon, *Oncorhynchus tshawytscha*, in inside and outside marine waters of southeastern Alaska over a 135-d period in February, May, and September 1986–87.

	February		May		September	
Region	Inside waters	Outside waters	Inside waters	Outside waters	Inside waters	Outside waters
1986						
Southern	—	—	—	—	79	40
Central	—	—	—	—	68	69
Northern	—	—	121	47	63	45
1987						
Southern	106	—	128	19	118	12
Northern	50	43	84	64	—	—
Total	156	43	333	130	328	166

Trolling gear

We fished with reduced-size replicates of commercial trolling gear. These small hooks and lures have proven more selective than standard commercial trolling gear in catching smaller sizes and younger age groups of chinook salmon (Orsi, 1987). The hooks were single Mustad no. 9510X3S, size 2/0, barbed, gap 1.6 cm, throat 2.0 cm. All lures used were 6.0-cm hootchies (plastic imitation squid) fished behind 9 × 28-cm flashers at 0.5–1.5 m/s and typically at 7.3-m depth intervals (7.3 m, 14.6 m, 21.9 m, 29.3 m, and 36.6 m). Five flasher and hootchie combinations were used concurrently on each of four trolling lines weighted with 13.6–22.7-kg lead "cannonballs." Areas where the bottom depth was shallower than 37 m were not sampled. Additional information on trolling methods or gear is given in Browning (1980) and Orsi et al. (1987).

To test whether the catch and size distribution of the youngest age group of chinook salmon in our study were representative of the population, we compared the catch and length of prerecruit chinook salmon caught on our standard small gear versus the catch and length of prerecruit salmon caught on smaller hooks (Mustad no. 9321, size 6, gap 0.7 cm, throat 1.0 cm) and hootchies (4.0 cm). We tested this for two days during September 1987 in inside waters of the southern region, where chinook salmon are known to occur during their first summer at sea. Equal numbers of each gear size and color were used on opposing vessel sides at equivalent depths; sides of the vessel were alternated each day. A chi-square (χ^2) test was used to test for significant differences ($P<0.05$) in catch between gear sizes, and a one-tailed t-test was used to test for significant differences ($P<0.05$) in the mean fork length of chinook salmon caught between gear sizes.

Fish processing

Chinook salmon were sampled while immobilized in an electric basket (Orsi and Short, 1987). While in the basket and lifted from the water, fish were identified, measured from tip of snout to fork of tail (to the nearest cm), tagged with a 6.4-cm-long Floy anchor tag (to ensure that fish had not already been caught), and sampled for scales from the preferred area (INPFC, 1957). All chinook salmon were released after tagging, except adipose-clipped fish under the Alaska minimum size limit (66 cm fork length [FL]=71 cm total length; Reed, 1972), which were retained to recover previously implanted CWT's (Jefferts et al., 1963). Sex and weight (to the nearest 0.1 kg) were recorded for all retained CWT chinook salmon.

Because field identification between chinook salmon and coho salmon, *O. kisutch,* in their first ocean year is sometimes difficult, salmon identifications during the charters in September were confirmed later by a scale reader. Identifications that did not correspond to the determinations of species by the scale reader were reexamined and reassigned as appropriate. Salmon with CWT's were also used to corroborate species identifications.

Scale, age, and sex analysis

Scales of chinook salmon were aged according to the methods of Van Alen and Wood (1983) and designated with the nomenclature of Koo (1962). The end of the calendar year was used as a break point for ocean-age assignment. For example, a 1984-brood-year chinook salmon that entered saltwater in 1986 was designated to be age 1.0 until 31 December 1986 and age 1.1 from 1 January to 31 December 1987.[6] Distinguishable ocean-winter annuli were present in scales taken from fish in February.

Data on age -.3 chinook salmon were not presented because few were caught; the hooks used in this study

[6] Numeral preceding the decimal point denotes the number of freshwater winters and the numeral following the decimal point denotes the number of marine winters. A dash before the decimal point indicates freshwater ages of 0 and 1.

tend to bend or straighten when large fish strike (Orsi, 1987). The data were also limited because we did not retain CWT fish >66 cm FL, which are typically age -.3 fish (Wright et al., 1972).

Scale and CWT ages, when available for the same fish, were used to compare age-determination techniques each season. Although freshwater and marine age can be misinterpreted from reported CWT release information, we assumed that the release year reported for CWT chinook salmon (Johnson and Longwill[7]) was also the year of seawater entry unless specified otherwise. We rejected age determinations based on scale analysis for fish in time periods or regions where they were unlikely to occur and were not substantiated by CWT recoveries; examples of this were age 0.0 fish in September in the northern and central regions, age -.0 fish in February and May and age 0.1 fish in February and May in the northern region.

We used χ^2 tests to examine differences in the proportion of male and female CWT chinook salmon by ocean-age group for each period. In September, all three ocean-age groups were present (i.e. age -.0, -.1, and -.2), whereas in February and May, data were available for only the age -.1 and -.2 ocean-age groups.

Length analysis

Box-and-whisker plots (Tukey, 1977) were performed for length ranges of each age group of chinook salmon within each region and time stratum to ensure accurate ageing and length representation. Values over 1.5 times the inner quartile range (IQR) were examined to identify extreme cases in length within a given age group that may have resulted from errors (by misinterpreting scale position on a scale card or by transposing age values). After extreme values had been examined and age or length reassigned as appropriate, box-and-whisker plots were reconstructed and values >3.0 times the IQR were eliminated from the database unless substantiated by CWT fish. The eliminated values constituted less than 0.5% of the data.

To demonstrate temporal and regional differences in length-frequency distributions of chinook salmon, length data were plotted for the three sequential sampling periods (September 1986, February 1987, and May 1987) from fish in inside and outside waters (when possible) in the northern and southern regions. All age groups were pooled in each length-frequency distribution.

To demonstrate seasonal size structure, fork lengths of ocean- and stream-type chinook salmon were plotted by age group and period. Fork-length data were pooled across regions, years, and waters.

Stock composition

Coded-wire tag recoveries from chinook salmon and the expanded number of fish represented by each tag code were used to determine stock composition. Expanded numbers represent the total number of fish represented by a CWT, based on the proportion of tagged fish in a release group. Origin of chinook salmon stocks represented by CWT's were pooled into three geographic groups: southeastern Alaska, British Columbia, and Washington or Oregon. Washington and Oregon stocks were combined because most recoveries from these regions originated from the Columbia River basin.

Catch per unit of effort (CPUE) was used with CWT recoveries to determine the spatial and temporal distribution of stock groups. To determine CPUE, expanded numbers for a particular age and stock group of chinook salmon were divided by the number of hours fished. This CPUE was computed separately for inside and outside waters and pooled across regions. For examining spatial distribution of individual age groups of ocean- and stream-type fish in inside and outside waters, CPUE was plotted against age for each stock group. For examining seasonal distribution, CPUE was plotted against ocean age and season for each stock group.

Migration and growth

Net migration rates for each CWT chinook salmon were calculated by dividing the hypothetical "straight line" marine distance traveled between release and recovery points by the number of days since release. Because of limited information on precise freshwater release sites for many CWT fish, freshwater distance was not included in the determination of migration distance. Direction of travel of each fish from its marine entrance point to its recovery locality was recorded to the nearest 45° directional interval (e.g. N=337.6°–22.5°, NE = 22.6°–67.5°, etc.).

Growth rates were compared between ocean- and stream-type CWT chinook salmon recovered during seven seasonal periods after release: age -.0 fish in September; age -.1 fish in February, May, and September; and age -.2 fish in February, May, and September. Specific growth rates, G, were determined for CWT chinook salmon by dividing the difference

[7] Johnson, J. K., and J. R. Longwill. 1988. Pacific salmonid coded wire tag releases through 1987. Regional Mark Processing Center, Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 S.W. First Ave., Portland, OR 97201-5346, 228 p.

of the natural logarithms of the recovery weight and of the release weight by the change in time (Weatherley and Rogers, 1978). Because of limited samples of CWT fish, growth rates for ocean- or stream-type fish were pooled between years, regions, waters, and stock groups for each growth period. Ocean- and stream-type fish in each growth period were then tested for significant differences ($P<0.05$) in growth rates with t-tests.

Results

Gear selectivity

For the 2-d gear comparison conducted in inside waters of the southern Alaska region in September 1987, both sizes of hooks and lures caught similar numbers and mean fork lengths of age -.0 chinook salmon. In this comparison, 68 age -.0 chinook salmon were caught on our "standard" small gear and 59 on the smaller gear; numbers caught did not differ significantly (χ^2, $P > 0.10$) by gear size. Mean fork length (27.6 cm) of age -.0 chinook salmon caught on "standard" small gear also did not differ significantly from mean fork length (27.0 cm) of fish caught on smaller gear (t-test, $P=0.36$). However, age -.0 chinook salmon caught on the "standard" small gear were larger (range, 22–37 cm FL) than those caught on the smaller gear (range, 15–34 cm FL).

Age, length, and sex composition

Of the 539 CWT chinook salmon sampled, 486 had scales that could be aged. Agreement between scale- and CWT-age was highest in September (95%) and lowest in February (79%); overall agreement was 90% (Table 2). The most common disagreement of age designations was the assignment of ocean-type chinook salmon (as determined by CWT's) as stream-type. Of the 51 disagreements in chinook salmon age determinations, 43 (84%) were ocean-type fish assigned stream-type designations; some of these disagreements may have been a result of fish that were released as ocean-type but that overwintered in freshwater, and therefore bore a "stream-type" scale pattern.

Age data for 5,838 chinook salmon were obtained from scales and CWT's in all sampling periods and regions in 1986–87 (Table 3). CWT's were represented in 36 of the 39 age-group–time-period strata. Age -.0 chinook salmon were caught only during September, and most were stream type (age 1.0); only a few ocean-type (age 0.0) chinook salmon were caught, all in the southern region. In February and May, age -.1 chinook salmon were primarily stream type (age 1.1); a few ocean-type fish (age 0.1) were caught only in the southern region. In September, however, both stream- and ocean-type age -.1 chinook salmon were caught in all regions. Age -.2 chinook salmon of the ensuing year were also a mixture of ocean- (age 0.2) and stream-type (age 1.2) fish in each season and region. Only four age -.3 CWT chinook salmon were recovered and all were ocean type (age 0.3).

Chinook salmon were larger and older in the northern than in the southern region in each sampling period (Fig. 2; Table 3). Length modes of chinook salmon within each region generally increased between September and May. The proportion of small fish (<30 cm FL) was highest in inside waters of both regions in September.

Mean length of chinook salmon increased with each successive period; and for each ocean-age group, stream-type fish were consistently longer than ocean-type fish for each period (Fig. 3). Differences in mean length of ocean- and stream-type chinook salmon

Table 2

Percent accuracy of scale reading (in parentheses) based on coded-wire–tag (CWT) age determinations of chinook salmon, *Oncorhynchus tshawytscha*, during February, May, and September 1986–87. n = number of fish.

CWT age	February n	February (%)	May n	May (%)	September n	September (%)	Total n	Total (%)
0.0	—	—	—	—	1	(100)	1	(100)
0.1	1	(0)	7	(0)	48	(81)	56	(70)
0.2	19	(16)	23	(60)	9	(89)	51	(49)
1.0	—	—	—	—	152	(100)	152	(100)
1.1	64	(98)	90	(97)	31	(94)	185	(95)
1.2	3	(100)	36	(97)	2	(50)	41	(95)
Total	87	(79)	156	(87)	243	(95)	486	(90)

Table 3

Number of chinook salmon, *Oncorhynchus tshawytscha*, of different age groups (based on scale samples and coded-wire tags) caught in marine waters of the northern, central, and southern regions of southeastern Alaska during February, May, and September 1986–87. The number of coded-wire tags recovered is shown in parentheses.

Month and Region	Year	Age -.0 0.0	Age -.0 1.0	Age -.1 0.1	Age -.1 1.1	Age -.2 0.2	Age -.2 1.2	Total
February								
Northern	1987	—	—	—	20	62	86	168
		—	—	—	(0)	(4)	(1)	(5)
Southern	1987	—	—	8	520	62	50	640
				(1)	(69)	(17)	(3)	(90)
May								
Northern	1986	—	—	—	88	114	149	351
		—	—	—	(13)	(10)	(17)	(40)
Northern	1987	—	—	—	162	92	254	508
		—	—	—	(7)	(9)	(18)	(34)
Southern	1987	—	—	110	639	39	69	857
		—	—	(8)	(83)	(7)	(1)	(99)
September								
Northern	1986	—	38	318	114	30	17	517
		—	(0)	(19)	(7)	(2)	(1)	(29)
Central	1986	—	112	141	157	42	10	462
		—	(7)	(10)	(8)	(1)	(1)	(27)
Southern	1986	2	450	149	64	14	1	680
		(1)	(32)	(9)	(14)	(2)	(0)	(58)
Southern	1987	21	1,283	168	126	45	12	1,655
		(1)	(125)	(14)	(11)	(5)	(1)	(157)
Total		23	1,883	894	1,890	500	648	5,838
		(2)	(164)	(61)	(212)	(57)	(43)	(539)

were not as great among age -.2 fish as among younger fish, especially in September. Some age -.2 fish were probably not caught effectively then, owing to the small gear used; therefore the lengths of age -.2 chinook salmon in September did not extend far above one standard deviation from the mean (Fig. 3). Conversely, the lengths of age 0.0 chinook salmon caught in September, which did not extend far below one standard deviation from the mean, suggest that fish <15 cm FL were too small for our gear or were absent.

The overall sex ratio of the 539 CWT chinook salmon was nearly equal to 1.0, namely 275 males to 264 females. There were, however, significant differences in proportion of males by ocean-age group in September (χ^2, P<0.01) and May (χ^2, P=0.05) but not in February (χ^2, P=0.75). Percentage of males for each ocean age by season were as follows: September, age -.0 (57%), age -.1 (41%), and age -.2 (23%); May, age -.1 (56%) and age -.2 (40%); and February, age -.1 (56%) and age -.2 (52%). Of the CWT chinook salmon examined, most were immature; only a few age -.1 and -.2 males sampled in May were qualitatively assessed as maturing on the basis of coloration, shape, or enlarged gonads.

Origin and distribution

According to CWT recoveries, prerecruit chinook salmon in southeastern Alaska were from 74 stocks originating from Oregon to the northern region of southeastern Alaska, a range of 1,800 km (Table 4; Table 5).

Most stream-type chinook salmon of Alaska origin were caught in inside waters, whereas ocean-type fish of non-Alaska origin were slightly more abundant in outside than in inside waters (Fig. 4; Table 6). Most age -.0 stream-type chinook salmon from Alaska and British Columbia stocks were caught in inside waters, whereas those from Washington and Oregon stocks were caught in both inside and outside waters (Fig. 4; Table 6). Only two CWT age -.0 ocean-type chinook salmon were sampled; both were experimental hatchery releases from Alaska stocks caught in inside waters. Age -.1 and -.2 stream-type chinook salmon were mainly from Alaska stocks and were caught at a higher rate in inside waters than

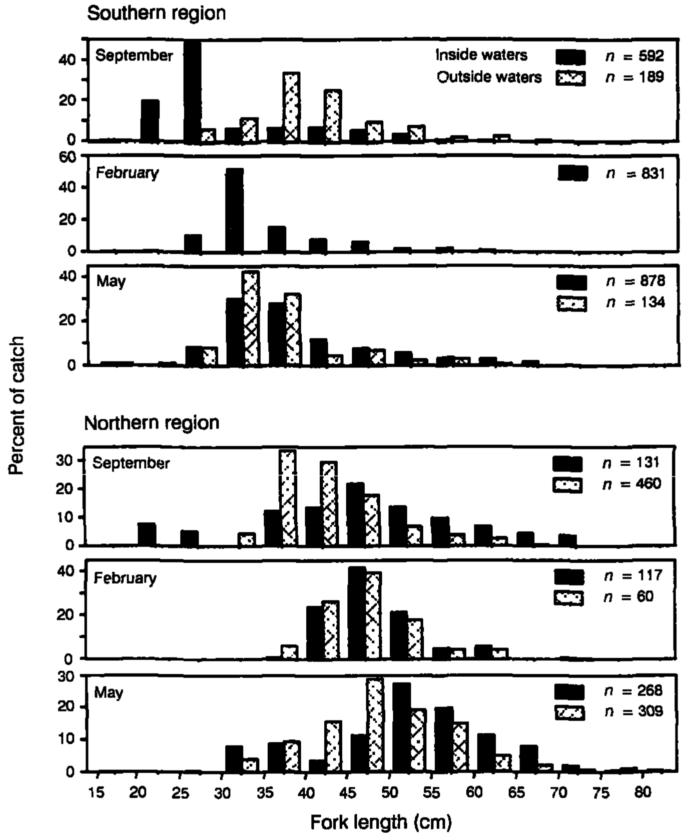

Figure 2

Length structure of chinook salmon, *Oncorhynchus tshawytscha*, sampled in inside and outside marine waters of the southern and northern regions of southeastern Alaska, September 1986 and February and May 1987.

Table 4

Major release localities of 539 coded-wire–tagged (CWT) chinook salmon, *Oncorhynchus tshawytscha*, recovered in marine waters of southeastern Alaska, February, May, and September 1986–87.

	CWT age at recovery						
Release locality	0.0	0.1	0.2	1.0	1.1	1.2	Total
Southeastern Alaska	2	4	—	127	204	40	377
Northern British Columbia	—	16	10	14	4	—	44
East coast Vancouver Island	—	12	14	—	—	—	26
West coast Vancouver Island	—	5	8	—	—	—	13
Fraser River drainage	—	2	—	—	—	—	2
Puget Sound	—	—	—	—	1	—	1
Strait of Juan de Fuca	—	—	1	—	—	—	1
Coastal Washington	—	8	12	—	—	—	20
Columbia River drainage	—	7	6	23	3	3	42
Coastal Oregon	—	7	6	—	—	—	13
Total	2	61	57	164	212	43	539

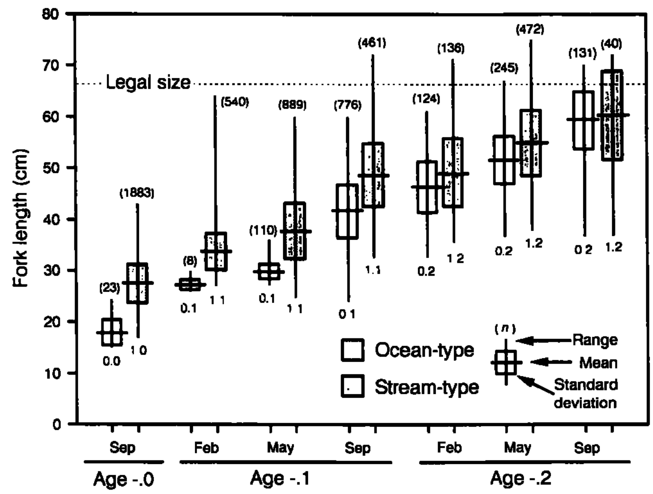

Figure 3

Length at age for ocean- and stream-type chinook salmon, *Oncorhynchus tshawytscha*, sampled in marine waters of southeastern Alaska during February 1987, May 1986–87, and September 1986–87. Sample sizes are in parentheses.

in outside waters; conversely, age -.1 and -.2 ocean-type fish were almost exclusively from British Columbia, Washington, or Oregon stocks and were caught at a slightly higher rate in outside waters (Fig. 4).

The CPUE of chinook salmon originating from each geographic region changed seasonally for each ocean-age group (Fig. 5). Age -.0 chinook salmon, which were caught only in September, were mainly of Alaska origin. All age -.1 chinook salmon in February were of Alaska origin except a few fish from British Columbia in inside waters (Fig. 5; Table 6). Among age -.1 fish caught in May, increasing numbers of fish from non-Alaska stocks were present; however, most of the fish were still of Alaska origin (Fig. 5). By September, an influx of age -.1 chinook salmon from British Columbia, Washington, or Oregon occurred, whereas the catches of age -.1 fish of Alaska origin diminished (Fig. 5). Most age -.2 chinook salmon were also from non-Alaska stocks for all periods.

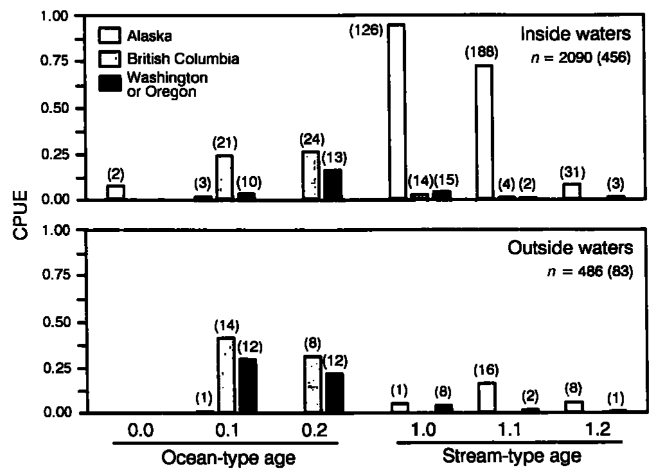

Figure 4

Catch rate by age and origin of ocean- and stream-type chinook salmon, *Oncorhynchus tshawytscha*, in inside and outside marine waters of southeastern Alaska, 1986–87. Catch rate is based on the expanded numbers of coded-wire–tagged fish caught per hour. Actual numbers of coded-wire–tagged fish are shown in parentheses.

Migration and growth

Assessment of migration direction and rates of the CWT chinook salmon was based on the origin and age of the stock group (Table 7). Stocks originating from British Columbia and Washington or Oregon generally traveled NW or N to reach our sampling localities, whereas stocks originating from within southeastern Alaska had no apparent directional tendency. Average net migration rates ranged from 0.1 to 6.9 km/d (Table 7). A decrease in average migration rates with increasing age occurred for all stock groups of ocean- and stream-type fish.

Table 5

Origin and age of 539 coded-wire–tagged chinook salmon, *Oncorhynchus tshawytscha*, recovered in marine waters of southeastern Alaska, February, May, and September 1986–87.

Origin		Number of chinook salmon					
		Age (yr)					
Locality	Latitude	0.0	0.1	0.2	1.0	1.1	1.2
Southeastern Alaska							
Speel Arm	58°04'N	—	—	—	—	3	3
Kasnyku Bay	57°13'N	—	—	—	—	2	3
Medvejie	57°01'N	—	—	—	—	4	1
Crystal Creek	56°53'N	—	—	—	—	—	2
Ohmer Creek	56°46'N	—	—	—	—	—	1
Osprey Lake	56°24'N	—	—	—	—	—	1
Little Port Walter	56°23'N	—	—	—	—	11	19
Earl West Cove	56°18'N	—	—	—	1	—	—
Unuk River	56°05'N	—	—	—	—	1	—
Chickamin River	55°47'N	—	—	—	2	4	—
Neets Bay	55°46'N	1	—	—	15	24	7
Carroll Inlet	55°39'N	1	1	—	63	67	—
Thomas Basin	55°21'N	—	3	—	—	—	—
Ketchikan Creek	55°21'N	—	—	—	6	23	—
Herring Cove	55°20'N	—	—	—	4	58	3
Whitman Lake	55°20'N	—	—	—	31	—	—
Tamgas Creek	55°01'N	—	—	—	5	7	—
Southeastern Alaska total		2	4	0	127	204	40
British Columbia							
Babine River	55°41'N	—	—	—	9	4	—
Upper Bulkley River	55°15'N	—	—	—	1	—	—
Hadenchild Creek	54°56'N	—	—	—	3	—	—
Cedar River	54°50'N	—	—	1	—	—	—
Copper River	54°32'N	—	—	2	—	—	—
Kitsumkalum River	54°31'N	—	3	—	—	—	—
Deep Creek	54°30'N	—	—	—	1	—	—
Hirsch Creek	54°05'N	—	4	—	—	—	—
Skeena River	54°01'N	—	2	2	—	—	—
Kitimat River	54°00'N	—	4	3	—	—	—
Kildala River	53°48'N	—	—	1	—	—	—
Snootli River	52°23'N	—	2	—	—	—	—
Atnarko River	52°22'N	—	1	—	—	—	—
Wannock River	51°40'N	—	—	1	—	—	—
Marble River	50°32'N	—	2	2	—	—	—
Tenderfoot Lake	50°25'N	—	1	—	—	—	-
Birkenhead River	50°19'N	—	1	—	—	—	—
Campbell Transit	50°02'N	—	—	2	—	—	—
Deepwater Bay	50°02'N	—	1	—	—	—	—
Quinsam River	50°02'N	—	6	8	—	—	—
Puntledge River	49°42'N	—	4	3	—	—	—
Big Qualicum	49°24'N	—	—	1	—	—	—
Little Qualicum	49°22'N	—	1	—	—	—	—
Robertson Creek	49°19'N	—	3	3	—	—	—
Thornton Creek	48°58'N	—	—	2	—	—	—
Nitinat River	48°40'N	—	—	1	—	—	—
British Columbia total		0	35	32	14	4	0
Washington or Oregon							
Kendall Creek	48°54'N	—	—	—	—	1	—
Elwha River	48°06'N	—	—	1	—	—	—
Soleduck River	48°03'N	—	3	2	—	—	—

Table 5 (continued)

Origin		Number of chinook salmon					
		Age (yr)					
Locality	Latitude	0.0	0.1	0.2	1.0	1.1	1.2
Washington or Oregon (continued)							
Wells Channel	47°55'N	—	—	—	2	—	—
Rocky Reach	47°32'N	—	—	—	5	—	—
Cook Creek	47°30'N	—	1	5	—	—	—
Fork Creek	46°33'N	—	—	2	—	—	—
Cowlitz River	46°31'N	—	—	1	—	—	—
N. Nemah River	46°30'N	—	1	1	—	—	—
Hanford	46°30'N	—	1	—	—	—	—
Naselle River	46°23'N	—	3	2	—	—	—
W. Fork Grays River	46°23'N	—	1	—	—	—	—
Columbia River	46°20'N	—	1	2	—	—	1
Lyons Ferry	46°15'N	—	—	—	4	—	—
N. Fork Lewis River	45°54'N	—	—	1	—	—	—
Wind River	45°51'N	—	—	—	1	—	—
Umitilla River	45°50'N	—	1	—	2	—	—
Spring Creek	45°42'N	—	—	1	—	—	—
Bonneville Dam	45°39'N	—	—	—	3	—	—
Washougal River	45°39'N	—	1	1	—	—	—
Tanner Creek	45°38'N	—	1	—	—	2	—
Trask River	45°25'N	—	1	2	—	—	—
Clackamas River	45°20'N	—	—	—	1	—	1
N. Santiam River	44°40'N	—	—	—	—	—	1
Yaquina Bay	44°37'N	—	2	—	—	—	—
Newport offshore	44°37'N	—	1	—	—	—	—
Deschutes River	44°36'N	—	—	—	2	—	—
McKenzie River	44°07'N	—	1	—	2	1	—
Willamette River	43°55'N	—	—	—	1	—	—
Coos Bay	43°20'N	—	—	2	—	—	—
Elk River	42°45'N	—	3	2	—	—	—
Washington or Oregon total		0	22	25	23	4	3

Growth rates were significantly higher (t-test, $P<0.05$) for ocean- than for stream-type CWT chinook salmon in four of the seven growth periods examined (Fig. 6). Sample sizes of certain age groups of fish in the three growth periods with no statistical significance were extremely limited (4 or less), although ocean-type chinook salmon in those cases also had higher growth rates than had stream-type fish. Mean growth rates generally declined as age increased and season progressed for ocean-type (2.35, 1.54, 1.20, 0.97, 0.71, 0.74, and 0.69% body wt/d) and stream-type (1.85, 0.99, 0.88, 0.78, 0.63, 0.64, and 0.58% body wt/d) chinook salmon (Fig. 6).

Discussion

This study has described the initial marine occurrence and distribution of ocean-type chinook salmon of non-Alaska origin in marine waters of southeastern Alaska. During earlier research on prerecruit chinook salmon in the central and northern regions of southeastern Alaska in May and September, Orsi et al. (1987) caught age 0.1 chinook salmon of non-Alaska origin in September, but not earlier. In our study, we caught age 0.1 non-Alaskan stocks of chinook salmon in the southern region in February, May, and September (Table 6). Consistent with Orsi et al. (1987), we also found an influx of non-Alaska age 0.1 chinook salmon by September in the central and northern regions (Table 6). We found age 0.2 chinook salmon of non-Alaska origin throughout marine waters of southeastern Alaska each season. Age 0.2 chinook salmon reach the minimum harvest size limit in the southeastern Alaska troll fishery in June and July (Olsen, 1992), and age 0.3 fish are the predominant harvest component (Van Alen and Olsen, 1986; Van Alen et al., 1986, 1987). Thus, non-

Table 6

Catch per hour of numbers represented by coded-wire–tagged (CWT) age groups of chinook salmon, *Oncorhynchus tshawytscha*, of southeastern Alaska (AK), British Columbia (BC), and Washington or Oregon (WO) origin recovered in inside and outside marine waters of the northern, central, and southern regions of southeastern Alaska in February, May, and September 1986–87. The actual number of CWT's is shown in parentheses.

	Inside waters						Outside waters					
Region	0.0	1.0	0.1	1.1	0.2	1.2	0.0	1.0	0.1	1.1	0.2	1.2
Southeastern Alaska origin												
February												
Northern	—	—	—	—	—	—	—	—	—	—	—	—
Southern	—	—	—	2.46	—	0.08	—	—	—	—	—	—
	—	—	—	(67)	—	(3)	—	—	—	—	—	—
May												
Northern	—	—	—	0.06	—	0.20	—	—	—	0.08	—	0.15
	—	—	—	(12)	—	(24)	—	—	—	(7)	—	(8)
Southern	—	—	0.03	1.96	—	0.01	—	—	0.09	0.98	—	—
	—	—	(2)	(78)	—	(1)	—	—	(1)	(2)	—	—
September												
Northern	—	—	—	0.08	—	0.09	—	—	—	0.35	—	—
	—	—	—	(2)	—	(1)	—	—	—	(4)	—	—
Central	—	0.87	—	0.43	—	0.05	—	—	—	—	—	—
	—	(4)	—	(8)	—	(1)	—	—	—	—	—	—
Southern	0.29	3.60	0.02	0.16	—	0.01	—	0.28	—	0.14	—	—
	(2)	(122)	(1)	(21)	—	(1)	—	(1)	—	(3)	—	—
AK total	(2)	(126)	(3)	(188)	—	(31)	—	(1)	(1)	(16)	—	(8)
British Columbia origin												
February												
Northern	—	—	—	—	0.87	—	—	—	—	—	0.57	—
	—	—	—	—	(2)	—	—	—	—	—	(2)	—
Southern	—	—	0.01	0.02	0.75	—	—	—	—	—	—	—
	—	—	(1)	(2)	(15)	—	—	—	—	—	—	—
May												
Northern	—	—	—	—	0.03	—	—	—	—	—	0.65	—
	—	—	—	—	(3)	—	—	—	—	—	(6)	—
Southern	—	—	0.25	0.02	0.52	—	—	—	—	—	—	—
	—	—	(4)	(2)	(3)	—	—	—	—	—	—	—
September												
Northern	—	—	0.89	—	—	—	—	—	1.87	—	—	—
	—	—	(3)	—	—	—	—	—	(6)	—	—	—
Central	—	—	0.36	—	—	—	—	—	0.59	—	—	—
	—	—	(1)	—	—	—	—	—	(6)	—	—	—
Southern	—	0.08	0.45	—	0.07	—	—	—	0.11	—	—	—
	—	(14)	(12)	—	(1)	—	—	—	(2)	—	—	—
BC total	—	(14)	(21)	(4)	(24)	—	—	—	(14)	—	(8)	—
Washington or Oregon origin												
February												
Northern	—	—	—	—	—	0.02	—	—	—	—	—	—
	—	—	—	—	—	(1)	—	—	—	—	—	—
Southern	—	—	—	—	0.02	—	—	—	—	—	—	—
	—	—	—	—	(2)	—	—	—	—	—	—	—
May												
Northern	—	—	—	—	0.04	0.02	—	—	—	0.02	0.47	0.01
	—	—	—	—	(1)	(2)	—	—	—	(1)	(9)	(1)
Southern	—	—	0.01	0.01	0.15	—	—	—	—	—	0.05	—
	—	—	(1)	(1)	(3)	—	—	—	—	—	(1)	—
September												
Northern	—	—	—	—	0.19	—	—	—	1.56	0.05	0.09	—
	—	—	—	—	(1)	—	—	—	(10)	(1)	(1)	—

Table 6 (continued)

Region	Inside waters						Outside waters					
	0.0	1.0	0.1	1.1	0.2	1.2	0.0	1.0	0.1	1.1	0.2	1.2
Washington or Oregon origin (continued)												
Central	—	—	0.07	—	0.18	—	—	0.07	—	—	—	—
	—	—	(3)	—	(1)	—	—	(3)	—	—	—	—
Southern	—	0.15	0.08	0.01	0.37	—	—	0.14	0.11	—	0.18	—
	—	(15)	(6)	(1)	(5)	—	—	(5)	(2)	—	(1)	—
WO total	—	(15)	(10)	(2)	(13)	(3)	—	(8)	(12)	(2)	(12)	(1)
Total	(2)	(155)	(34)	(194)	(37)	(34)	—	(9)	(27)	(18)	(20)	(9)

Alaska ocean-type chinook salmon of age 0.1 begin to arrive in the marine waters of southern region of southeastern Alaska in February and May, and by September, non-Alaska chinook salmon age 0.1, as well as those 0.2 and 0.3, are distributed throughout the marine waters of southeastern Alaska.

The temporal and spatial distribution of stream-type chinook salmon in southeastern Alaska appears more complex than that of ocean-type stocks. We found that age 1.0 chinook salmon in September originated from southeastern Alaska, British Columbia, Washington, and Oregon. Age 1.0 stocks from southeastern Alaska were almost exclusively found in inside waters of the southern and central regions; Orsi et al. (1987) also identified age 1.0 fish from these stocks in the northern region. Age 1.0 stocks from British Columbia were found exclusively in inside waters of the southern region. Age 1.0 chinook salmon from Washington and Oregon stocks were recovered in both inside and outside waters of the southern region and in outside waters of the central region. These recoveries corroborate the external tagging studies of Hartt and Dell (1986). Healey (1983, 1991) reported that the residence of stream-type chinook salmon in estuaries and sheltered coastal waters is generally brief and that fish move offshore during their first summer at sea, in contrast to ocean-type fish, which remain in sheltered coastal waters. Our data support his hypothesis with respect to stream-type chinook salmon from Washington and Oregon. However, our recoveries of Alaska and British Columbia stream-type chinook salmon in inside waters during September, and during the ensuing year in February and May, suggest a more protracted residence or limited marine migration for portions of stocks from these regions.

The limited marine migration of some Alaska stream-type stocks of chinook salmon could have a genetic basis. Although Alaska stocks of chinook salmon are almost exclusively stream-type, electrophoretic evidence suggests that southeastern Alaska stocks are genetically intermediate between stream-type stocks of western Alaska and ocean- and stream-type stocks of the Pacific Northwest (Gharrett et al., 1987). Therefore, following the Wisconsinan glacial age, some southeastern Alaska drainages were probably colonized by ocean-type stocks. These fish may have selected a stream-type freshwater life history trait as a result of low "growth opportunity" in northern lati-

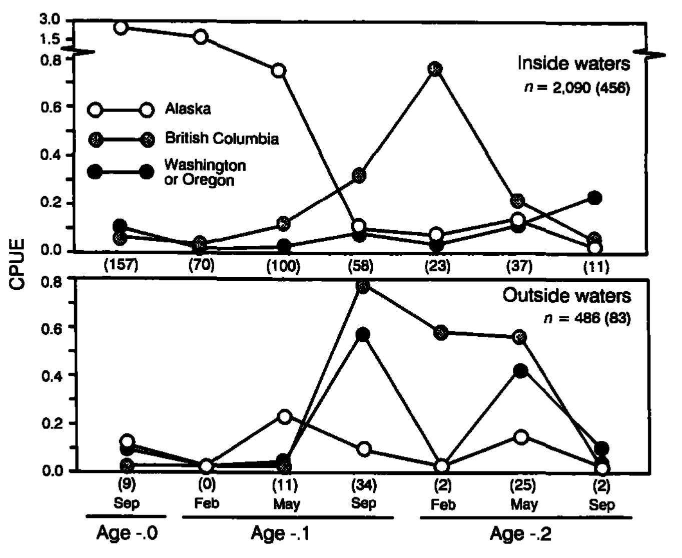

Figure 5

Catch rate of chinook salmon, *Oncorhynchus tshawytscha*, by ocean age and season in inside and outside marine waters of southeastern Alaska, 1986–87. Catch rate is based on the expanded numbers of coded-wire–tagged fish caught per hour. Actual numbers of coded-wire–tagged fish are shown in parentheses.

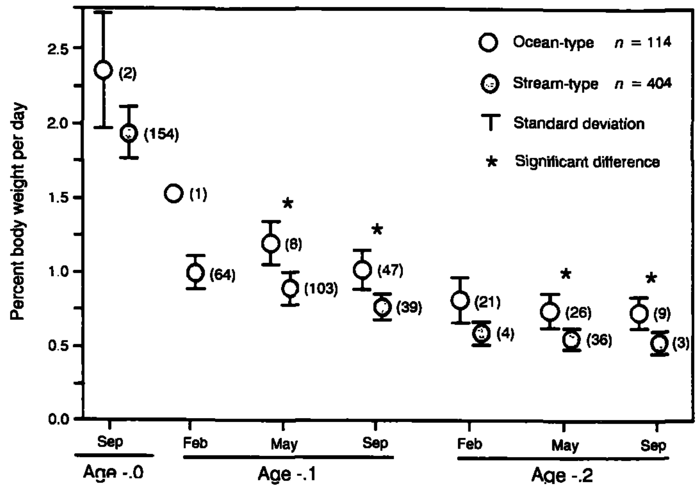

Figure 6

Growth rates of ocean- and stream-type chinook salmon, *Oncorhynchus tshawytscha*, by ocean age and season in marine waters of southeastern Alaska, 1986–87. Mean growth rates are based on coded-wire–tag recoveries shown in parentheses. Significant differences ($P<0.05$) in growth rates between ocean- and stream-type chinook salmon were denoted by an asterisk.

Table 7

Migration rate and direction of coded-wire–tagged ocean- and stream-type chinook salmon, *Oncorhynchus tshawytscha*, recovered in inside and outside marine waters of the northern, central, and southern regions of southeastern Alaska in February, May, and September 1986–87. Stock group designations: AK = Southeastern Alaska, BC = British Columbia, and WO = Washington or Oregon. *n* = number of fish.

Stock group	Age	*n*	Average migration: km	Days out	Rate km/d	Migration direction: N	NE	E	SE	S	SW	W	NW
Ocean-type													
AK	0.0	2	41	95	0.4	—	—	—	—	1	1	—	—
AK	0.1	4	37	345	0.1	—	—	1	1	—	1	1	—
AK	0.2	—	—	—	—	—	—	—	—	—	—	—	—
BC	0.0	—	—	—	—	—	—	—	—	—	—	—	—
BC	0.1	35	653	446	1.5	—	—	—	—	—	—	2	33
BC	0.2	32	741	642	1.2	—	—	—	—	—	—	—	32
WO	0.0	—	—	—	—	—	—	—	—	—	—	—	—
WO	0.1	22	1,430	397	3.6	6	—	—	—	—	—	—	16
WO	0.2	25	1,325	686	1.9	—	—	—	—	—	—	—	25
Stream-type													
AK	1.0	127	39	120	0.3	3	1	15	17	38	14	24	15
AK	1.1	204	64	354	0.2	9	4	19	37	70	15	17	33
AK	1.2	40	176	734	0.2	19	0	1	1	1	2	3	13
BC	1.0	14	183	197	0.9	—	—	—	—	—	—	—	14
BC	1.1	4	175	349	0.5	—	—	—	—	—	—	1	3
BC	1.2	—	—	—	—	—	—	—	—	—	—	—	—
WO	1.0	23	1,153	168	6.9	10	—	—	—	—	—	—	13
WO	1.1	4	1,354	486	2.8	—	—	—	—	—	—	—	4
WO	1.2	3	1,546	729	2.1	—	—	—	—	—	—	—	3

tudes owing to temperature and photoperiod regimes (Taylor, 1990) but retained the early ocean-distribution pattern characteristic of their ocean-type lineage.

Differences in length and spatial occurrence of prerecruit ocean- and stream-type chinook salmon in our study were similar to those found later in the commercial troll fishery of southeastern Alaska. Our stream-type chinook salmon were larger and more prevalent in inside waters than were ocean-type chinook salmon of the same ocean-age group. In the southeastern Alaska troll fishery, stream-type chinook salmon are also larger than ocean-type chinook salmon of the same ocean-age group (Van Alen and Wood, 1983; Van Alen et al., 1987), and ocean-type chinook salmon are generally more prevalent than stream-type chinook salmon in outside waters (Van Alen and Olsen, 1986; Van Alen et al., 1987).

Prerecruit chinook salmon were older and larger in the northern regions. Age data from the commercial troll fishery of southeastern Alaska similarly reveal that chinook salmon are older in northern regions (Van Alen and Olsen, 1986; Van Alen et al., 1987). In British Columbia, Healey (1986) found that age 0.2 and age 0.3 troll-caught chinook salmon dominated the catch, that larger age 0.3 fish were more common in northern and central regions, and that smaller age 0.2 fish were more common farther south off Vancouver Island. Age 0.2 chinook salmon also dominate the catch in the Strait of Georgia (Argue et al., 1977; Carter et al., 1986) and off the Washington coast (Wright et al., 1972). However, increased harvest of age 0.2 fish southward is also a reflection of lower minimum-size limits in these fisheries.

The 15–43 cm FL range of our troll-caught age -.0 chinook salmon during September in Alaska is consistent with other studies. Hartt and Dell (1986) reported a 16–36 cm FL range for age -.0 chinook salmon caught with small-mesh purse seines fished in the northeastern Gulf of Alaska from July to October. In another seine study, Fisher and Pearcy (1995) reported a 9–32 cm FL range for age -.0 chinook in shelf waters off the Oregon and Washington coasts from May to September. Of the smaller chinook salmon captured, Fisher and Pearcy (1995) found that chinook salmon <15 cm FL were most abundant in July and August and that chinook salmon <13 cm FL (primarily age 0.0 fish) were closely associated with the warm, low-salinity waters of the Columbia River plume. Moreover, Miller et al. (1983) hypothesized that offshore movement of chinook salmon is size dependent because few chinook salmon <13 cm FL are found in waters >30 m. Our gear test with smaller hooks and lures did indicate a lower length range for age -.0 fish sampled, but fish <15 cm FL were not encountered. Therefore, the absence of fish <15 cm FL in our study may have been a function of the deeper water (>37 m) that we sampled or of our later sampling time (September) when small age -.0 fish were unavailable. In contrast to the seine sampling, the greater upper length range for this age group caught on troll gear may be attributed to seine avoidance by larger chinook salmon. Chinook salmon occur deeper as they increase in length (Orsi and Wertheimer, 1995). Consequently, troll sampling may provide a more representative sample of larger age -.0 chinook salmon within this age group if larger fish were deeper than the seine nets.

Fishery size limits and gear selectivity can influence length distributions. The 66-cm-FL Alaska size limit for chinook salmon had little effect on the length distribution of the age -.0 or -.1 chinook salmon sampled in our study, because the range of length for these age groups seldom exceeded the size limit. However, the range of length for age -.2 chinook salmon usually exceeded the size limit. In the southeastern Alaska troll fishery, Van Alen and Wood (1983) have shown that the percent contribution of age -.2 chinook salmon increases during summer. Therefore, many larger age -.2 chinook salmon may have been removed by the troll fishery before we sampled in September. Healey (1986) reported that the average length of age 0.2 chinook salmon in the British Columbia troll fishery remained relatively constant over the fishing season and attributed this constancy to new recruits growing to legal size. Selectivity by trolling gear also influences length distribution; Orsi (1987) reported significantly more age-.2 chinook salmon caught in September–October on standard commercial gear than on small trolling gear. Other studies also document that large chinook salmon are generally caught with large trolling gear, such as plugs (e.g. Milne, 1955; Boydstun, 1972; Orsi et al., 1993). Thus, fishery size limits and removals, as well as gear selectivity, affected the length structure of age -.2 chinook salmon in our study.

Mean fork length of stream-type chinook salmon was consistently greater than that of ocean-type fish of the same ocean-age group, but this difference was less pronounced as ocean age increased. The greater mean fork length of age -.0 stream-type fish is a function of greater freshwater age and an earlier time of ocean entry. However, mean fork length of age -.2 ocean- and stream-type fish were nearly equivalent in September. Although Healey (1991) reported that rates of growth were similar between ocean- and stream-type fish during their ocean life, we found significantly higher growth rates for ocean-type fish. The higher growth rates for ocean-type fish in our study may explain why mean fork length of ocean- and stream-type fish converged as ocean age increased.

Average net migration rates decreased with increasing age for all stock groups of ocean- and stream-type chinook salmon. This decreased migration rate for older fish may be a consequence of residency in the sampling area or of interception of fish during a circuitous return migration. Highest migration rates were for age 1.0 fish from Washington and Oregon (6.9 km/d). Fisher and Pearcy (1995) reported that age 1.0 chinook salmon (75 km up the Columbia River) migrated at an average net rate of 4.1 km/d to ocean capture locations off Washington and Oregon. Our higher average net migration rates for age 1.0 chinook salmon from Washington and Oregon may have been a function of our capture locality, which would favor recoveries of fish from these stocks that had migrated northward most rapidly.

This study identifies the marine waters of southeastern Alaska as an important nursery area for an amalgam of prerecruit chinook salmon stocks originating from Oregon to Alaska. Stream-type stocks from southeastern Alaska and northern British Columbia typically use inside waters during their first year at sea; at the same time stream-type stocks of Washington and Oregon use both inside and outside waters. Ocean-type stocks from British Columbia, Washington, and Oregon first appear in marine waters of southeastern Alaska after their first winter at sea and use waters throughout the region during their second and third years at sea. Although our study on prerecruit chinook salmon has contributed to our understanding of the temporal and spatial occurrence of this species in southeastern Alaska, additional studies of prerecruits in this region are needed to further identify migration routes, distribution patterns, and residency time of specific stock groups.

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