Distribution, Growth, Condition, Origin and Associations of Juvenile Salmon in the Northern California Current

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ABSTRACT

Information is summarized on juvenile salmon distribution, size, condition, growth, stock origin, and species and environmental associations from the first year (June and August 2000) GLOBEC cruises with particular emphasis on differences related to the regions north and south of Cape Blanco off Southern Oregon. Juvenile salmon were found primarily in cooler water inside of the 200 m isobath. Juvenile salmon were more abundant during the August cruise compared to the June cruise and were distributed northward from Cape Blanco. The nekton assemblages differed significantly between cruises. June samples were dominated by juvenile rockfishes, rex sole, and sablefish, which were almost completely absent in August. The forage fish community during June was comprised of herring and whitebait smelt north of Cape Blanco and surf smelt south of Cape Blanco. The August fish community was dominated by sardines. Jack mackerel were abundant in August. Significant differences in growth and condition of juvenile salmon indicate different oceanographic environments north and south of Cape Blanco. The condition index was higher in juvenile yearling chinook salmon to the south of Cape Blanco whereas condition was higher in juvenile coho to the north. Genetic mixed stock analysis indicated that during June most of the chinook salmon in our sample originated from rivers along the central coast of Oregon. In August, chinook salmon sampled south of Cape Blanco were largely from southern Oregon and northern California while those north of Cape Blanco were from Central California. Distance offshore, surface temperature, and latitude were the main determinative factors in fish distribution.

INTRODUCTION

The U.S. GLOBEC project is a wide-scale, long-term research effort to examine the effects of global climate change on ocean ecosystems. The project objective is to understand how climate change and variability will translate into changes in the structure and dynamics of marine ecosystems and in fishery production. Many marine and anadromous fish stocks in the California Current region have been in severe decline since the 1977 ocean regime shift. In the Northeast Pacific, a major focus is on salmon condition, survival and production. Ocean salmon abundance is largely determined by survival of the juveniles in near-shore regions, and is affected by changes in the physical characteristics and in ecosystem food dynamics. To assess the condition and survival of juvenile salmonids, we measured growth rate, size variability, and bioenergetic condition as indicators of the relative quality of the marine habitat in different regions of the California Current. We also examined species and environmental associations of juvenile salmonids caught in two cruises of contrasting oceanographic conditions.

METHODS

The California Current region of the was sampled along 9 transect lines located between Newport, Oregon and Crescent City, California (Fig. 1) during June and August, 2000. An additional two fine scale sampling regions were located north and south of Cape Blanco. A total of 163 trawls were taken during this sampling period. Fish were collected using a 30 m X 18 m Nordic rope trawl (Fig. 2A&C). The cod end was emptied onto the deck of the boat and the catch was sorted and identified to lowest taxonomic category (Fig. 2B). For each salmonid sampled, fork length and weight were recorded (Fig. 2D). Hepatic tissue was excised and weighed along with the somatic weight of fish (eviscerated fish weight to the nearest 0.1g) in the laboratory (Fig. 2E, 3). Scale samples were taken for coho salmon and growth since ocean entry was measured (Fig. 4). The bioenergetic health of juvenile salmon was evaluated by assessing change in water content of muscle and liver to estimate dry tissue weight. Dry tissue weight is a surrogate for tissue lipid content. The freshwater origins of juvenile chinook and coho salmon and steelhead were studied using standard methods of genetic mixed stock analysis. Samples of eye, liver, heart, and skeletal muscle were extracted from frozen whole juvenile salmon and analyzed with horizontal starch-gel protein electrophoresis. Species assemblages were determined using Two-Way Indicator Species Analysis (TWINSPAN) and species-environmental relationships were explored using Detrended Correspondence Analysis (DCA) on relativised data.

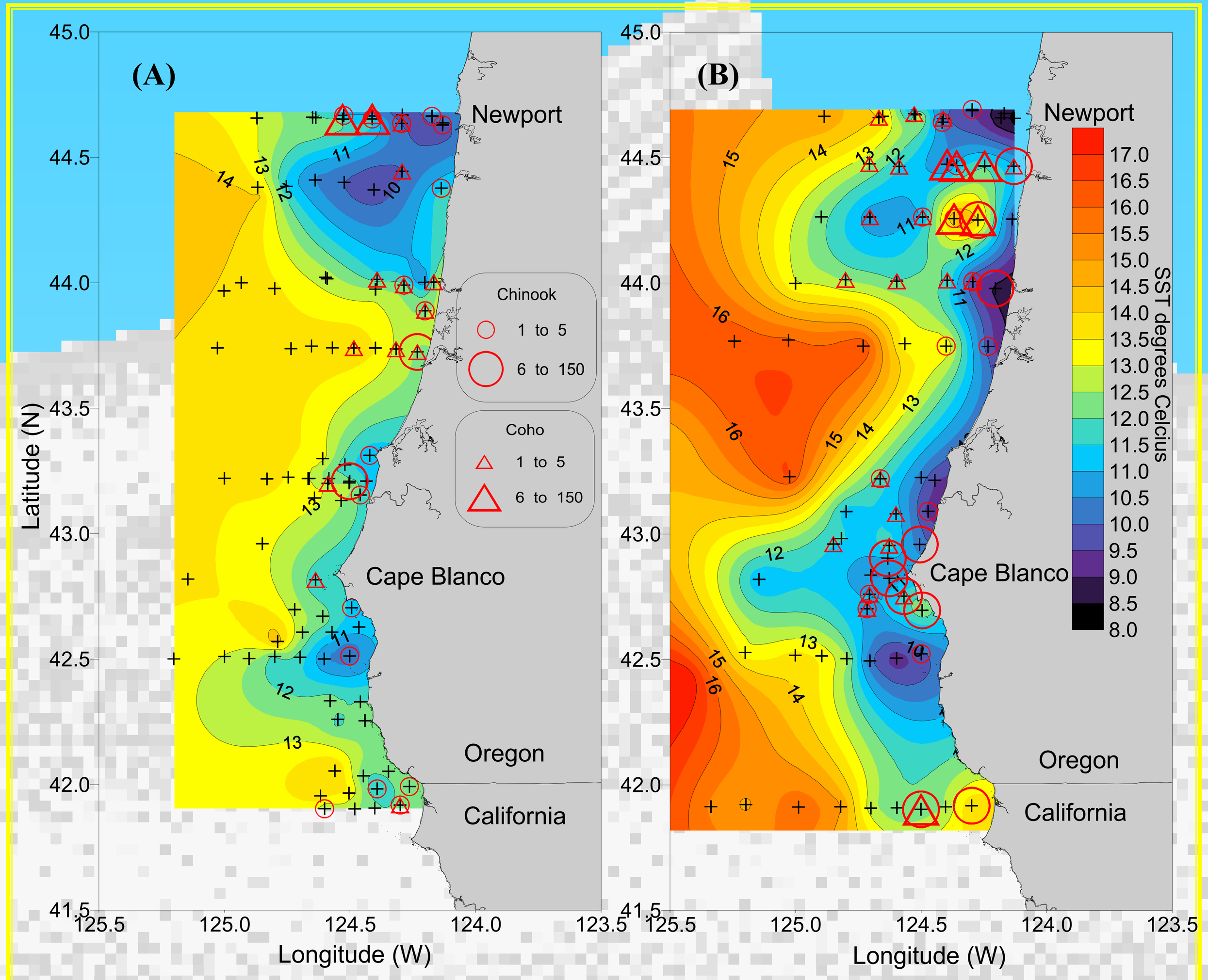


Fig. 1. Catch distribution for juvenile coho and chinook salmon for the (A) June and (B) August cruise overlaid on surface temperature contours. Plus signs are stations sampled where no salmon were caught.

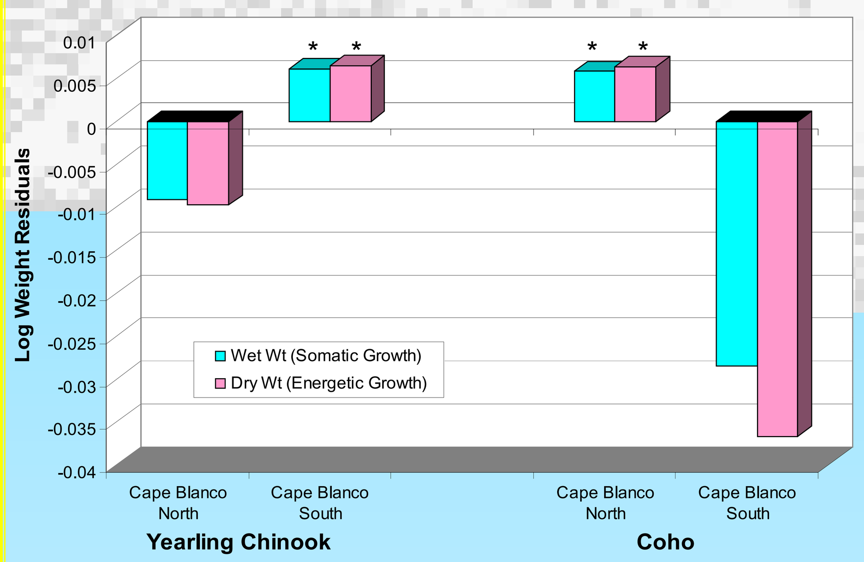


Fig. 6. Wet and dry weight residuals for yearling chinook and juvenile coho salmon collected North and South of Cape Blanco. Weight residuals are derived from the linear relationship between fork length and wet or dry weight (log-transformed data) of juvenile salmon captured in June and August. The asterisks indicate that all species/area pairs were significantly different from each other at p = 0.05.

RESULTS

Salmonids (mainly coho and chinook juveniles) made up a small proportion of the total catch (Fig. 5). The June catch was varied consisting mainly of smelts and juvenile rockfishes. The August catch was dominated (>75%) by sardines. The juvenile chinook were found close to shore in cooler water masses for both cruises whereas the juvenile coho were found mainly north of Cape Blanco and further offshore in warmer temperatures (Fig. 1).

Average instantaneous growth rates in weight were also higher for the coho juveniles caught in the August 2000 GLOBEC cruise (2.2 % and 2.7% body wt/day for the non-jack and jack fish, respectively) than for the fish caught in the September 1998, 1999 and 2000 BPA cruises (1.6%, 1.8% and 1.7 % body wt/d, respectively; Table 1). Growth (measured either as somatic or energetic growth) of yearling chinook and coho salmon in the regions north and south of Cape Blanco were different. Yearling chinook salmon weighed significantly more for a given length in the region south of Cape Blanco, whereas coho salmon weighed more if captured north of Cape Blanco (Fig. 6). Although stock composition in the two regions could account for some differences, the growth responses likely reflect habitat specific features in these regions that benefit salmon.

Allozyme data were collected from samples of 280 chinook salmon, 104 coho salmon, and 58 steelhead trout. Genetic mixed stock analysis indicated that chinook salmon in June were predominately (60%) from rivers and hatcheries along the mid Oregon coast, an area immediately north of Cape Blanco (Fig. 7). In August, chinook salmon were largely from rivers that enter the sea south of Cape Blanco. Genetic estimates of coho salmon indicated that most fish originated from coastal Oregon rivers north of Cape Blanco (48%) and from the Columbia River (14%), though a substantial proportion (38%) of coho salmon were from coastal rivers south of Cape Blanco.

The June TWINSPAN analyses differentiated the inshore and offshore taxa at the first division, and a north-south separation in the second division (Fig. 8A&C). The inshore southern assemblage (Group A) consisted of subyearling chinook salmon and several forage species including market squid, Pacific herring, surf smelt and whitebait smelt. The inshore northern assemblage (B) consisted of juvenile chinook and coho salmon, lingcod, and wolfeels. The offshore southern assemblage (C) was made up of juvenile steelhead trout and sablefish while the offshore northern assemblage (D) contained juvenile rex sole, juvenile sanddabs, darkblotched and yellowtail rockfishes (Fig. 8A). The August nekton community was differentiated into inshore and offshore assemblages and northern and southern assemblages by the TWINSPAN divisions one and two, respectively (Fig. 8B&D). The northern inshore assemblage (Group A) consisted of both juvenile and adult coho salmon, subyearling chinook salmon and smelt juveniles. An inshore southern group (B) was comprised of yearling chinook salmon, surf smelt, medusafish and wolfeel. An offshore northern grouping (C) was made up of northern anchovy and juvenile steelhead trout and rex sole. An offshore southern assemblage (D) was made up of highly migratory species such as adult chub and jack mackerel, Pacific sardine, blue shark, and Pacific saury (Fig. 8).

The species scores from the DCA showed a large range of values for the first three axes in June (Fig. 9A). The first axis was highly negatively correlated with distance offshore. The second and third axes were moderately correlated with latitude and neuston biomass, respectively (Fig. 9A). In August, the first axis was negatively related to temperature (Fig. 9B). The second axis was related to latitude of sampling while the third axis was weakly related to distance offshore.

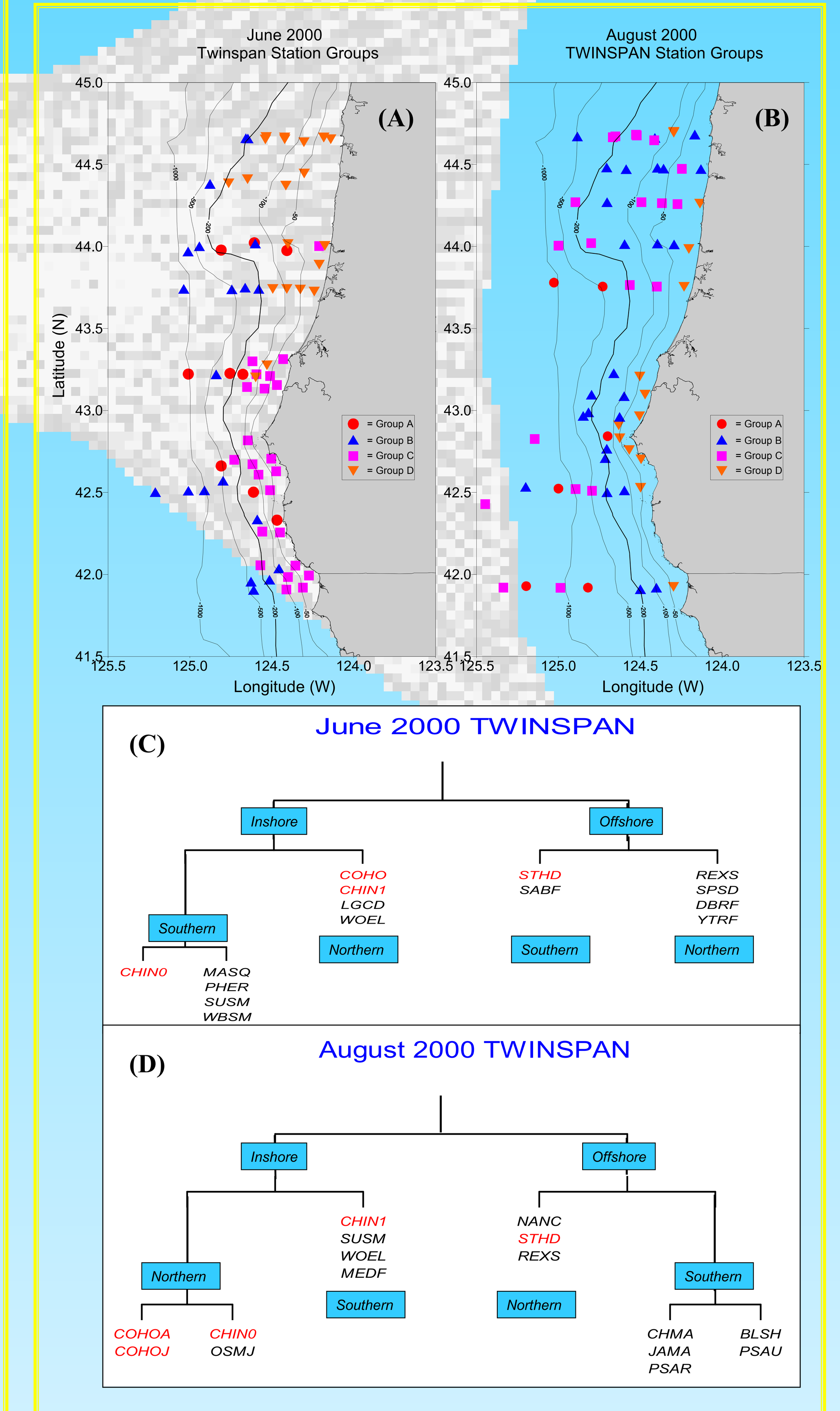


Fig. 8. TWINSPAN assemblage distribution and composition by cruise. (A) June station groups (B) August station groups (C) June species groups, (D) August species groups.

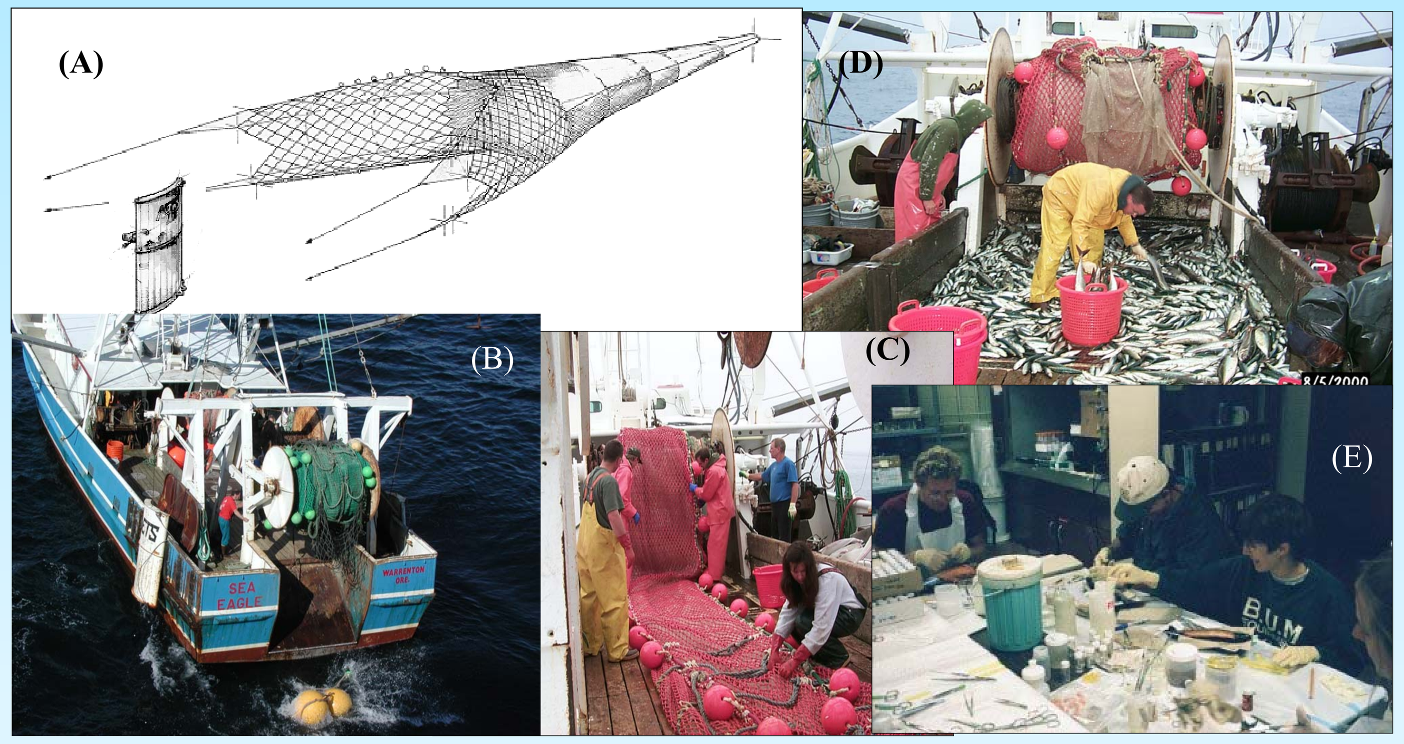


Fig. 2. A) Drawing of trawl net. B) The commercial fishing vessel used. C) Trawl net being brought back onto deck. D) Sorting fish onboard. E) Lab necropsies of juvenile salmon.

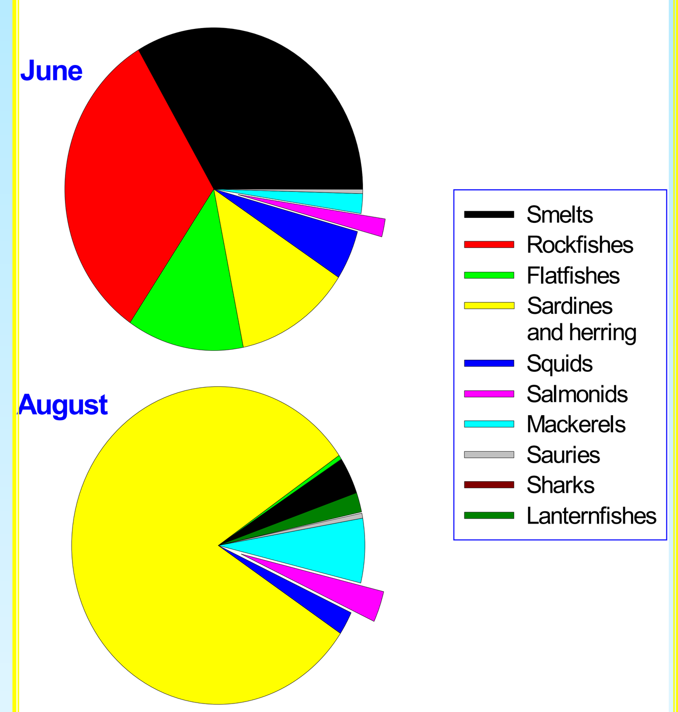


Fig. 5. Catch composition by major taxonomic groups for each cruise. The slice for salmonids is expanded out.

Table 1. Mean weights at OE back-calculated from scales and instantaneous rates of growth in weight while in the ocean (G) for coho caught during the 1998-2000 BPA cruises and the 2000 GLOBEC cruises. In August 2000, growth statistics for fish with enlarged testes ("jacks") were calculated separately from the other fish. When calculating growth rate an ocean entry date of May 15 was assumed.

Cruise	n	Back-calc. Wt. at O E (g) mean (s.d.)	G: ln(Wt. at capture)-ln(Wt. at OE) / days in ocean mean (s.d.)
May 1999	14	40.6 (7.9)	0.023 (0.039)
May 2000	79	39.4 (10.8)	0.020 (0.024)
June 1998	6	30.1 (17.5)	0.013 (0.016)
June 1999	198	40.6 (13.6)	0.018 (0.011)
June 2000	96	42.4 (12.5)	0.012 (0.009)
GLOBEC June 2000	11	45.5 (26.8)	0.020 (0.015)
GLOBEC Aug 2000 *non-jacks*	15	59.8 (21.3)	0.022 (0.005)
GLOBEC Aug 2000 *jacks*	19	67.6 (29.2)	0.027 (0.005)
Sept. 1998	12	47.1 (17.0)	0.016 (0.003)
Sept. 1999	50	34.9 (13.5)	0.018 (0.003)
Sept. 2000	75	37.5 (13.7)	0.017 (0.003)

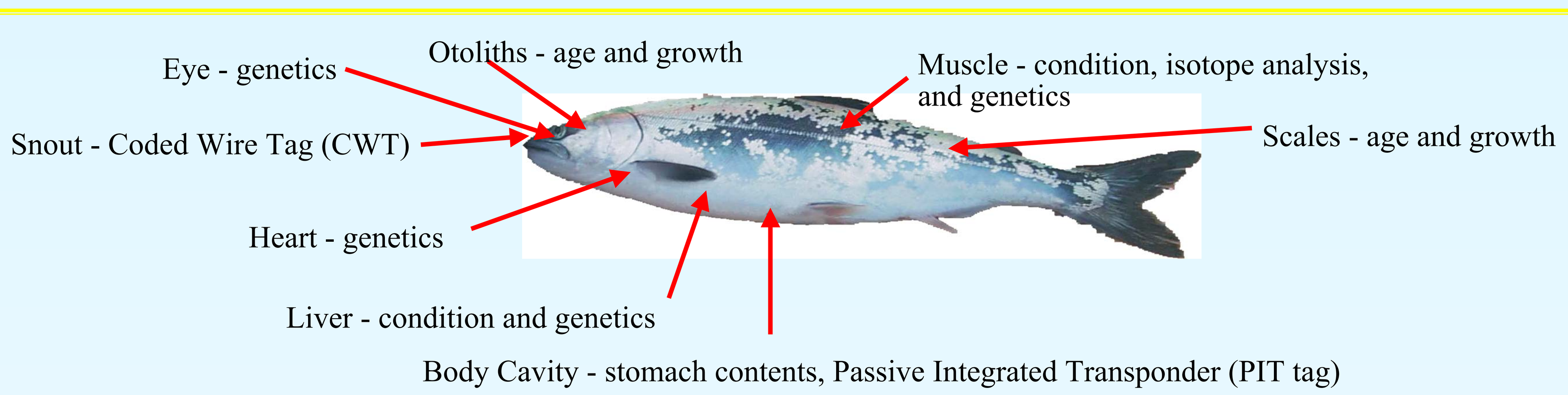
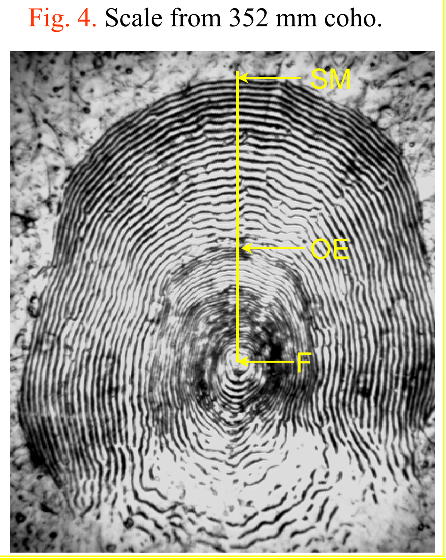


Fig. 3. Tissues taken for laboratory examination from juvenile salmon.

Fig. 4. Scale from 352 mm coho.



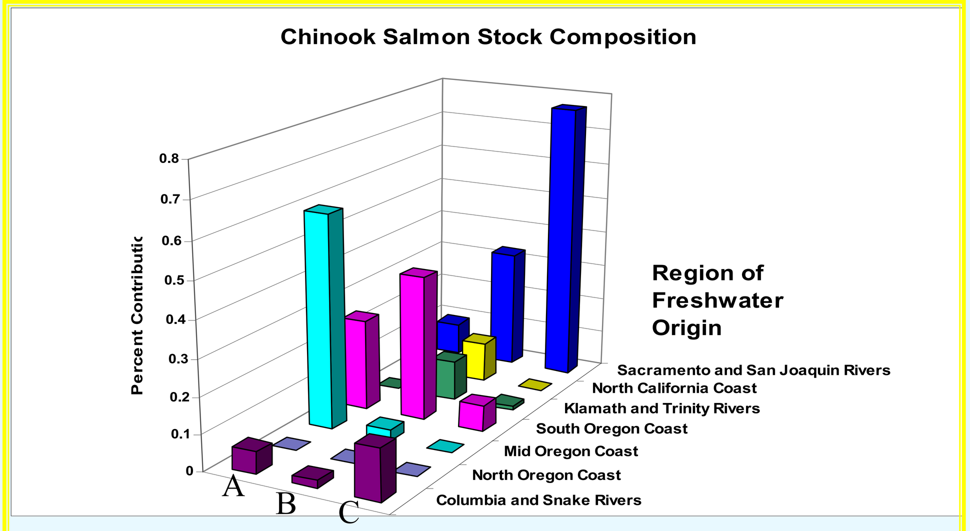


Fig. 7. Stock composition of juvenile chinook salmon by cruise and area. A) June cruise B) August North of Cape Blanco C) August South of Cape Blanco.

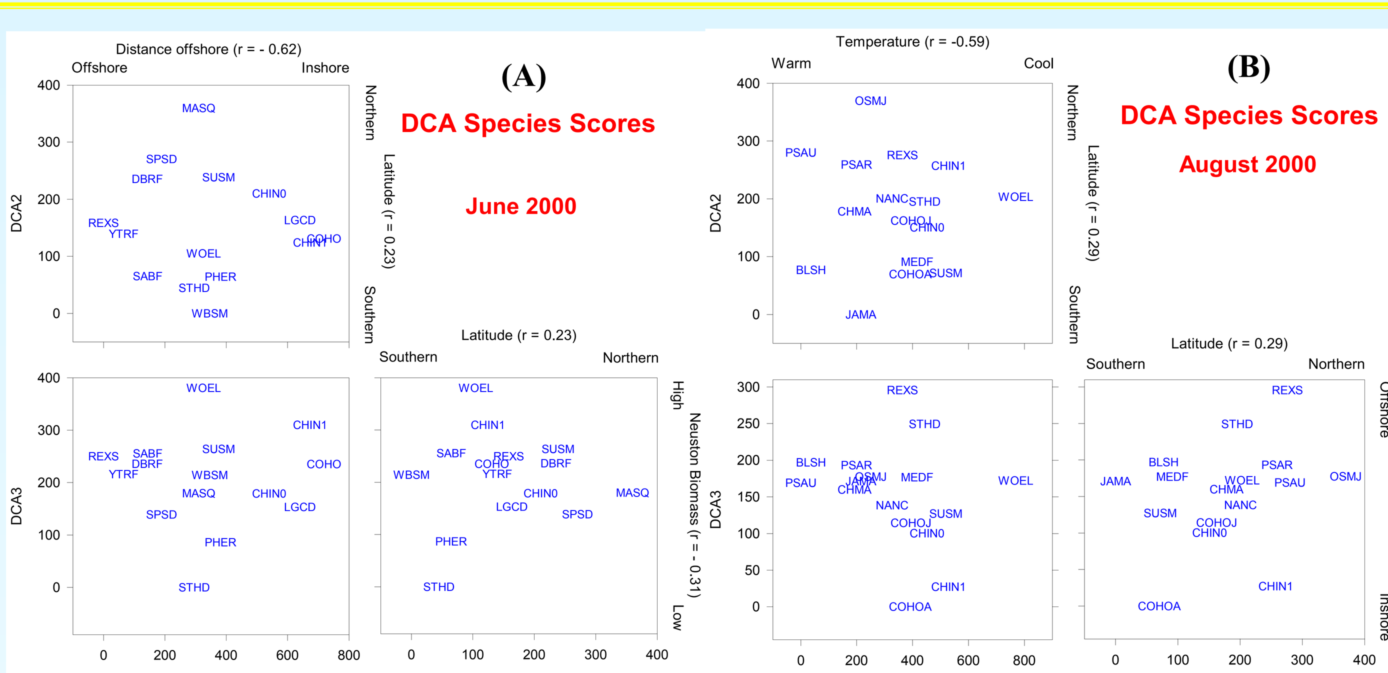


Fig. 9. Relationship of species scores to first three Detrended Correspondence Analysis axes for (A) June and (B) August cruises. Also shown are correlations of each axis to environmental or station variables.