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Effects of the 1983 El Niño on Coastal Nekton Off Oregon and Washington

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Introduction

The 1982-83 El Nino event in the northeastern Pacific has been associated with significant changes in sea temperatures, vertical thermal structure, coastal currents and upwelling (this volume). Such physical changes may affect the species composition, abundance or availability of fishes and other nektonic animals in a variety of ways: e.g.,

1) passive advection of water and animals and active migration of nekton, resulting in changes in species composition;
2) changes in the vertical distribution of species in response to warm surface waters that result in low availability near the surface, movement offshore into deeper water, or modified migration patterns;
3) decreased productivity or availability of prey, and concomittant adverse effects on growth, reproduction or survival; and
4) changes in inshore-offshore environmental gradients and frontal structure that concentrate fishes in narrow bands where predation or competition may be intensified.

Such responses of nekton have been described off Peru during the 1982-83 El Nino event (Barber and Chavez, 1983). Similar effects either occurred or were anticipated along the west coast of North America. This paper evaluates possible effects of the recent El Nino on distributions and abundances of fishes and other nekton along the coast of Oregon and Washington. Our observations are based on collections of unusual animals, systematic purse seining and commercial landings.

Methods

Our observations came from several sources. In early 1983, we initiated "Fish Watch '83" to alert fishermen and residents along the coast to the possible occurrence of unusual animals in the coastal ocean and to encourage the collection, preservation and return of animals to university or state personnel. Publicity stimulated by this program, by the subsequent discoveries of rare animals, and by the El Nino event in general resulted in more reports than in previous years. The degree that this public awareness increased the number of reports, and hence biased our results, is unknown. However the news media publicity on El Nino subsided months after waning of the major physical effects, making 1984 a better "control" year than 1981 or 1982.

Our purse seining for juvenile salmonids during the summer months of 1979-1984 provided samples of nektonic animals in surface waters off Oregon and Washington. The purse seines were large (475-495 m long) and fished to a depth of 30 to 55 m. All seines had 32-mm (stretch) mesh. A summary of the number and location of the 843 round haul sets along inshore-offshore transects, from the 37-m contour to 46 km offshore, is given in Table 1. Only June cruises were completed off Oregon in 1979 and 1980. In subsequent years, three or four cruises were made in different months (see Pearcy, 1984). Cruises extended from Cape Flattery off northern Washington south to Yachats or Coos Bay, Oregon in 1982, 1983 and 1984. All nekton were identified and samples were preserved for species verification and laboratory analyses.

Data on the commercial landings were provided to the Oregon Department of Fish and Wildlife and the Pacific Fishery Management Council.

Table 1. Summary of sampling by cruise from 1979 to 1984. Number of sets includes only quantitative, round hauls taken within 56 km of the coast.

Year	Dates of Cruise	Latitudinal (°N) Range Sampled	Number of Sets
1979	June 18-29	46°20'-43°18'	49
1980	June 20-28	46°20'-44°30'	33
1981	May 16-25	46°35'-44°30'	63
	June 9-19	46°35'-43°11'	67
	July 9-19	46°35'-44°25'	71
	August 8-19	46°35'-43°11'	66
1982	May 19-June 2	48°20'-44°00'	62
	June 7-22	47°20'-44°20'	56
	Sept. 4-14	47°20'-44°20'	40
1983	May 16-27	48°20'-44°20'	57
	June 9-27	48°20'-43°00'	58
	Sept. 15-24	48°20'-43°28'	52
1984	June 6-20	48°20'-43°28'	66
	July 19-30	48°00'-44°00'	40
	Sept. 1-15	48°20'-44°00'	63

Results

Range extensions and rare species

Northern range extensions were reported by Fish Watch '83 for four species of fishes (Table 2). None of these species was previously known to occur north of California (Eschmeyer et al., 1983). The finescale triggerfish and California lizardfish were reported even farther to the north, to Willapa Bay and Puget Sound respectively, after they were collected in Oregon (Schroener and Fluharty, this volume). Not included in Table 2 are northern records of the mollusk the sea hare (Aplysia californica) taken off the Yaquina Bay jetty on October 14 and 19, 1983.

Four other species are listed in Table 2 as "rare occurrences" off Oregon. Although they have been reported in waters off or to the north of Oregon in previous years, these fishes are usually uncommon north of California (Eschmeyer et al., 1983).

Some of these occurrences (i.e., larval and juvenile California tonguefish, small California lizardfish and sea hare) were probably advected to the north by the intensified California Countercurrent (McLain, 1984; Huyer and Smith, in press) as pelagic eggs or larvae. With the exception of the yellowtail, none of these species listed in Table 2 is noted for long, swift migrations, and most are associated with the sea floor.

During 1983-84 about half of the animals reported to us were known from the ocean off Oregon, though sometimes uncommon near the coast (e.g., the brown cat shark Apristurus brunneus, smalleye squaretail Tetragonurus cuvieri, white croaker Genyonemus lineatus). With the exception of a pilotfish (Naucrates ductor) caught off Oregon during the summer of 1984 (C. E. Bond, pers. comm.), there were no reports of rare fishes later than January 1984 despite the continuing wide publicity that El Nino received in this year.

Purse seine catches

The rank order of abundances (ROA) of the 10 most common species in the purse seine catches for June 1979-1984 (Table 3) shows some interesting trends. Pacific mackerel (Scomber japonicus), followed by jack mackerel (Trachurus symmetricus), were the two most abundant species in 1983 and 1984. With the exception of 1982, when jack mackerel ranked 8th, neither species ranked in the top ten species caught during June of other years. Jack mackerel occurred in low numbers during August 1981, June and September 1982, and May and September 1983. Only two Pacific mackerel were captured, both in June 1982, on the nine cruises before 1983. Pacific mackerel were also common in May of 1983 when they ranked second in overall abundance, and a few were caught in September 1983.

Other species showed marked changes in ROA, 1979-84. The rank of spiny dogfish (Squalus acanthias) increased from ninth and tenth in 1979 and 1980 to third in 1983 and 1984. Loligo opalescens, the market squid, on the other hand, ranked first in abundance in purse

Table 2. Rare fishes reported in 1983-84 by Oregon State University's Fish Watch '83.

SPECIES	SL-mm (or No.)	Date	Location	Lat. N., Long W	Depth of Capture (m)	Gear
A. Northern Range Extensions						
Echinorhinus cookei Prickly shark	1365	Jan 22, '83	off Moolack Bch.	46°11'; 124°40'	439	otter t.
Synodus lucioceps California lizardfish	62	Apr 6, '83	off Moolack Bch.	44°42'; 124°04'	11	beam t.
	75	Jun 23, '83	off Newport	44°37'; 124°05'	9	beam t.
	167	Jan 14, '84	off Astoria	46°09'; 124°11'	73	shrimp t.
Pristigenys serrula Popeye catalufa	181,198	Apr 6, '83	off Newport	44°38'; 124°07'	40	otter t.
	203	Jan 15, '84	No. of Brookings	42°03'; 124°15'	52	otter t.
Balistes polyepis Finescale triggerfish	273	Sept 4, '83	off Yachats	44°19'; 124°07'	15	crabpot
	277	Dec 23, '83	No. of Coos Bay	43°31'; 124°17'	55	crabpot
B. Rare Occurrences						
Genyonemus lineatus White croaker	(1)	Apr 6, '83	off Moolack Bch.	44°42'; 124°04'	11	beam t.
	14	May 3, '83	off Moolack Bch.	44°41'; 124°02'	8	beam t.
Medialuna californiensis Halfmoon	210-247 (12)	Sept 17, '83	off Grays Hbr.	46°56'; 124°33'	0-40	Purse s.
Seriola lalandi Yellowtail	(1)	Aug '83	off Port Orford	42°44'	0	troll
Symphurus atricauda California tonguefish	21	Mar 11, '83	Yaquina Bay	44°37'; 124°03'	F1	beach s.
	27	Mar 22, '83	Yaquina Bay	44°37'; 124°03'	3	beam t.
	24,25	Apr 6, '83	Yaquina Bay	44°37'; 124°03'	3	beam t.
	57,64,85	Dec 13, '83	Yaquina Bay	44°37'; 124°02'	6	beam t.

Purse seine catches of gelatinous zooplankton were noted in 1982 and 1983. Table 5 shows that the scyphomedusa Aurelia aurita, the salp Thetys vagina and the heteropod Caranaria japonica occurred more frequently in 1983 than 1982. Medusae such as Chrysaora fuscesens and Aequorea victoria, on the other hand, occurred more often in 1982 than 1983. Literally tons of these medusae were caught in purse seine sets before 1983 when dense concentrations occurred close to shore (Shenker, 1984).

Table 5. Comparison of purse seine catches of gelatinous macrozooplankton from 1982 and 1983. All data expressed as percent frequency of occurrence (J. Shenker, unpublished data).

Species	1982 (161 sets)	1983 (168 sets)
SCYPHOMEDUSAE		
Aurelia aurita	6.2	22.6
Chrysaora fuscesens	53.4	30.3
Cyanea capillata/ Phacellophora camtschatica*	50.9	36.9
HYDROMEDUSAE		
Aequorea victoria	59.6	26.1
Other (mostly Eutonina indicans and Vellela vellela)	14.9	1.2
CTENOPHORA		
Beroe spp. and Pleurobrachia spp.	6.8	1.8
SALPIDAE		
Salpa fusiformis	7.4	---
Thetys vagina	---	30.9
HETEROPODA		
Caranaria japonica	---	8.9

*No distinction was made between these two species in the field.

Commercial landings

Data from commercial landings in Oregon also indicate distinct changes in the relative abundance or availability of some species (Table 4). No Pacific bonito (Sarda chiliensis) were reported in the landings of 1981 and 1982, but 663 kg (1,462 pounds) were landed in 1983. Mackerel, including both Pacific and jack mackerel, were much more numerous in 1983 than 1981 or 1982 landings. Mackerel were also common in 1984 landings. Albacore (Thunnus alalunga) were not landed in large numbers in Oregon in 1983 despite the warm water temperatures close to shore. High catches of albacore are known to occur along the offshore boundaries of thermal and color fronts or "edges" produced by coastal upwelling (Laurs et al., 1984). Because of the absence of cold upwelled water, such fronts were thought to be poorly developed in 1983. A few skipjack tuna (Euthynnus pelamis) were caught off Oregon in 1983. The larger landings in 1982 were presumably caught in warm waters far south of Oregon (L. Hreha, pers. comm.).

One species of rockfish, Sebastes rufus, appeared to increase in bottom trawl catches in 1983 compared to other years. This species comprised 2.3% of the weight of rockfish caught in bottom trawls from Cape Perpetua to Cape Blanco from April-December 1983 but was not reported in the catches in either 1981 and 1982. During April-July 1984 it comprised 0.1% of the catch compared to 3.0% for the same period in 1983, suggesting that it was most common in the 1983 El Nino year.

Salmon

Juvenile salmon. Juvenile salmon were less common in nearshore waters off Oregon and Washington during the summer of 1983 then previous summers. The frequency of occurrence of juvenile salmonids in purse seine catches was lower in June and September 1983 than any of the previous ten cruises, and the average catch per set of juvenile coho salmon, the most abundant species in our catches, was lower during June 1983 than during June 1981 or 1982 from Willapa Bay to Alsea Bay, but it was slightly higher than the average catch per set in June 1984 (Table 4; Pearcy, 1984). The average catch per set in September 1983 was the lowest found for any prior cruise, 1979-1982 (Table 5 in Pearcy, 1984).

Chung (1985) found higher purse seine catches of juvenile coho salmon farther inshore and to the north in June 1983, when upwelling was weak and sea surface temperatures were elevated, than in June 1982, when upwelling and offshore Ekman transport were more pronounced. Major differences in sea surface temperatures and surface chlorophyll concentrations are illustrated for June 1982 and 1983 in Figure 1. North-south distributions of juvenile coho in September 1982 resembled those of June 1983. In September 1983, catches were very low along the coasts of Oregon and Washington, except for the northern-most stations off Cape Flattery, Washington where large catches were made. Juvenile coho salmon occupied waters that were several degrees warmer in May and June of 1983 than 1982. The relationship between catch per set and temperature was similar, however, in September 1982 and 1983 (Chung, 1985).

The lower catches of juvenile coho in 1983 than in 1979-82 could reflect differences in numbers of smolts migrating to sea, or their mortality or availability. Numbers of yearling coho smolts released by hatcheries in the Columbia River and along the Oregon coast have remained fairly constant since 1979. Total smolts released in these regions (yearling plus age 0) were about 15% lower in 1983 than 1982 (Oregon Department of Fish and Wildlife, 1985),

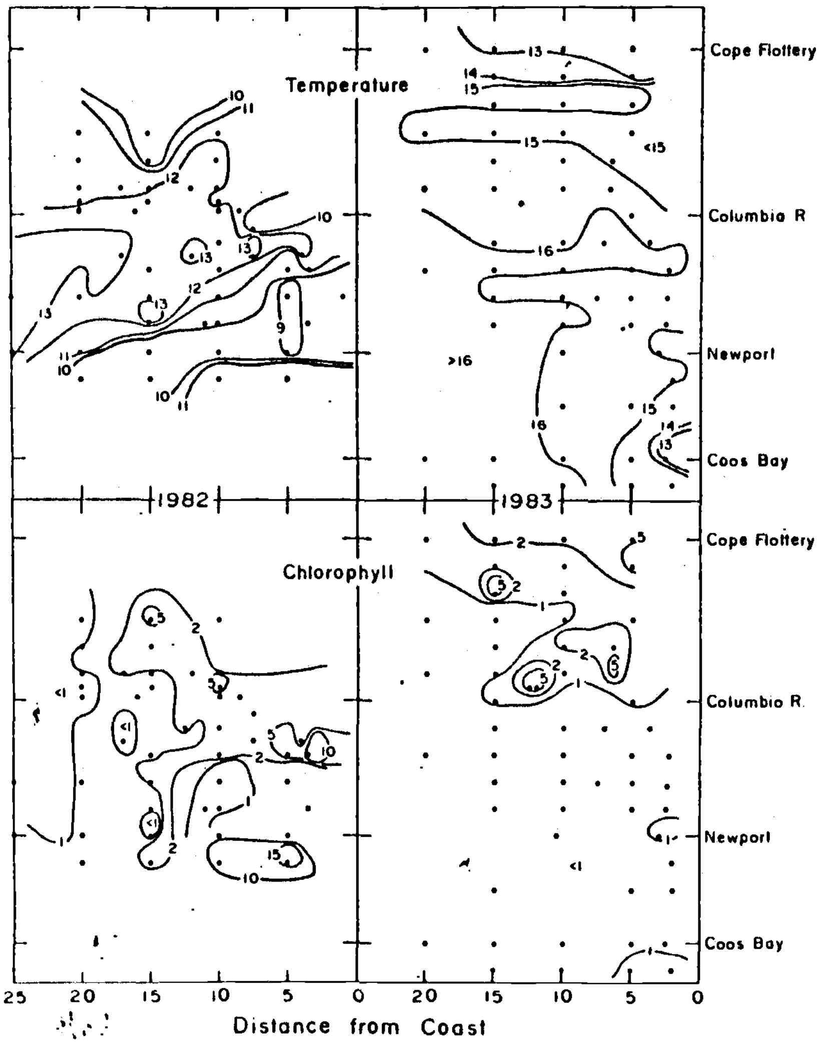

Figure 1. Contours of surface temperature and cholorphyll, June 1982 and 1983. (Note expansion of horizontal scale.)

not nearly enough to explain the four-fold decrease in juvenile coho caught in 1983. The fact that 1983 catches of juvenile coho were highest off southern Washington in June and northern Washington in September may be an indication of northward movement out of our sampling area. Northward migrations of juvenile coho salmon along the Oregon-Washington coast have been reported based on recovery of tagged juvenile coho (Pearcy, 1984). However, the number of sexually precocious male coho salmon (jacks) returning to the Columbia River and coastal index streams during the fall of 1983 was the lowest on record since 1969. These trends indicate that environmental conditions associated with the 1983 El Nino apparently caused poor survival of coho smolts in the ocean.

Table 6. Growth rate estimates for marked jacks returning to the Anadromous facility at Coos Bay based on mean weights and days at liberty.

Year	No. Jacks	Weight at release (g)	Weight at recapture (g)	days at liberty	Growth (g/day)
1980	126	33.1	600	152	3.7
1981	1335	36.6	730	132	5.3
1982	173	31.5	530	120	4.2
1983	157	44.1	350	106	2.9

How were growth rates and body condition of juvenile salmon affected by the El Nino? We examined growth rates of juvenile coho by three methods: a) average changes in lengths of age I coho between June and August or September (age-0 was not used since they have a more prolonged period of release), b) differences between lengths at time of capture and lengths at ocean entrance (back-calculated from scales) of marked fish collected 60 days or more after release, and c) increase in length between release and recovery of 2-year old coho jacks returning to the private hatchery, Anadromous Inc. at Coos Bay. The first two methods did not reveal a drastic difference in growth between 1983 and 1981-82. The average growth rates for 1981, 1982 and 1983 were 1.2, 1.4 and 1.2 mm/day, respectively, from the average changes in lengths of age I coho, and 0.9, 1.4 and 1.2 mm/d from marked fish. The average size and growth rate of jacks returning to the Anadromous facility, however, were appreciably lower in 1983 than in 1980-1982 (Table 6). Thus 1983 appeared to be a year of below average growth for these coho jacks.

Length-weight relationships calculated for juvenile coho salmon were not significantly different in either slope (P>0.1) or the intercept (P>0.5) between 1982 and 1983. The condition of survivors caught off the coast did not reflect adverse effects of El Nino. Therefore, although survival of coho smolts off Oregon apparently was poor, the body condition and perhaps growth rates of smolts surviving to be caught in our purse seines were not abnormally low.

Fullness of stomachs of juvenile coho salmon also indicated little difference between 1983 and 1982 (Fig. 2, K-S test, P>0.05). The composition of food of juvenile coho salmon was different between these years however (Table 7). Larval northern anchovy were the most common prey of coho smolts in 1983 but were not even a major prey category in 1982. This agrees with the observation that larvae of northern anchovy were much more numerous in inshore plankton samples in 1983 than earlier years (Brodeur et al., in press). The

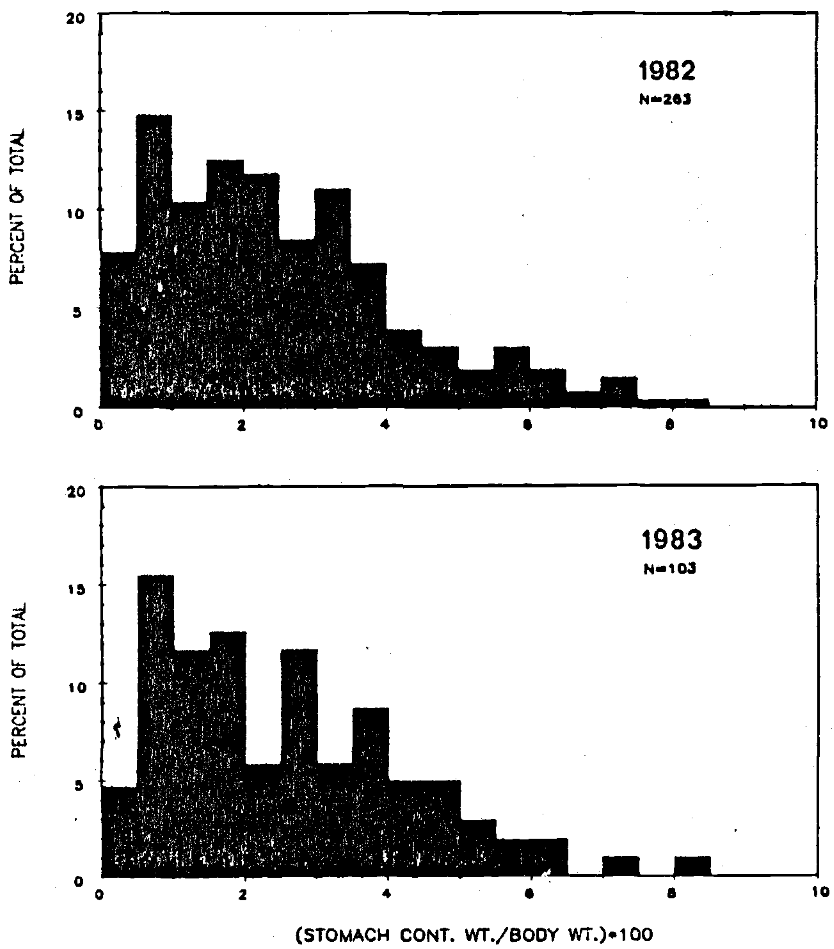

Figure 2. The weight of stomach contents expressed as a percentage of body weight of juvenile coho salmon collected during June 1982 and June 1983.

euphausiid Nyctiphanes simplex, a southern species previously found off central California only during warm years such as 1957-59 and 1977-78 (Brinton, 1981), was the most common euphausiid prey of juvenile coho in 1983. Dungeness crab (Cancer magister) larvae and megalopae were a major prey in 1982 but not in 1983.

Adult Salmon. The 1982-83 El Nino was associated with a disastrous fishing season for salmon off Oregon, California and Washington. The anomolous ocean conditions are believed to be responsible for increased ocean mortality of many salmon stocks and a marked decrease in the average size of adult salmon in 1983 (Pacific Fishery Management Council, 1984).

Table 7. Rank order of abundance of major prey of juvenile salmon in 1982 and 1983.

1982	1983
FISHES (LARVAE AND JUVENILES MOSTLY)	
Ammodytes hexapterus (sand lance)	Engraulis mordax (northern anchovy)
Hemilepidotus spinosus (red Irish lord)	Sebastes spp. (rockfishes)
Psettichthys melanostictus (sand sole)	P. melanostictus
Osmeridae	A. hexapterus
Microgadus proximus (tomcod)	I. isolepis
Clupea harengus (Pacific herring)	Parophrys jordani (English sole)
Sebastes spp. (rockfishes)	Ronquilus jordani (northern ronquil)
Hexagrammidae (greenlings and ling cod)	H. spinosus
Isopsetta isolepis (butter sole)	Lyopsetta exilis (slender sole)
EUPHAUSIIDS	
Thysanoessa spinifera	Nyctiphanes simplex
Euphausia pacifica	E. pacifica
AMPHIPODS	
Hyperoche medusarum	Hyperoche medusarum
Vibilia spp.	Hyperia medusarum
Parathemisto pacifica	Phronima sedentaria
Primno macropa	Vabilia spp.
Atylus tridens (gammarid)	
DECAPOD LARVAE	
Cancer magister (Dungeness crab)	Cancer oregonensis (rock crab)
Pandalus jordani (pink shrimp)	Porcellanidae (porcellanid crabs)
Pinnotheridae (pea crabs)	Pinnotheridae
	Pugettia spp. (kelp crabs)
	Crangon spp. (sand shrimp)

The average weights of coho salmon landed in 1983 in the Oregon commercial troll and Columbia River gillnet fisheries were the lowest on record since statistics are available in 1952 (Fig. 3). The average weight of chinook caught in Oregon by the commercial troll fishery was also the lowest since 1952. Adult coho salmon caught by Columbia River gillnets averaged only 3.0 kg, more than 1.0 kg below the 1957-82 average. For California and Oregon the average size of the troll-caught coho was 28-46% below the 1971-75 average and the average chinook was 5 to 33% below the 1971-75 average (Pacific Fishery Management Council, 1984).

Coho and chinook salmon also exhibit poorer condition factors in 1983 than non-El Nino years. For example, the dressed weight of a 60 cm coho averaged 1.9 kg in 1983 and 2.4 kg in previous years. Chinook salmon collected near the mouth of the Rogue River in 1983

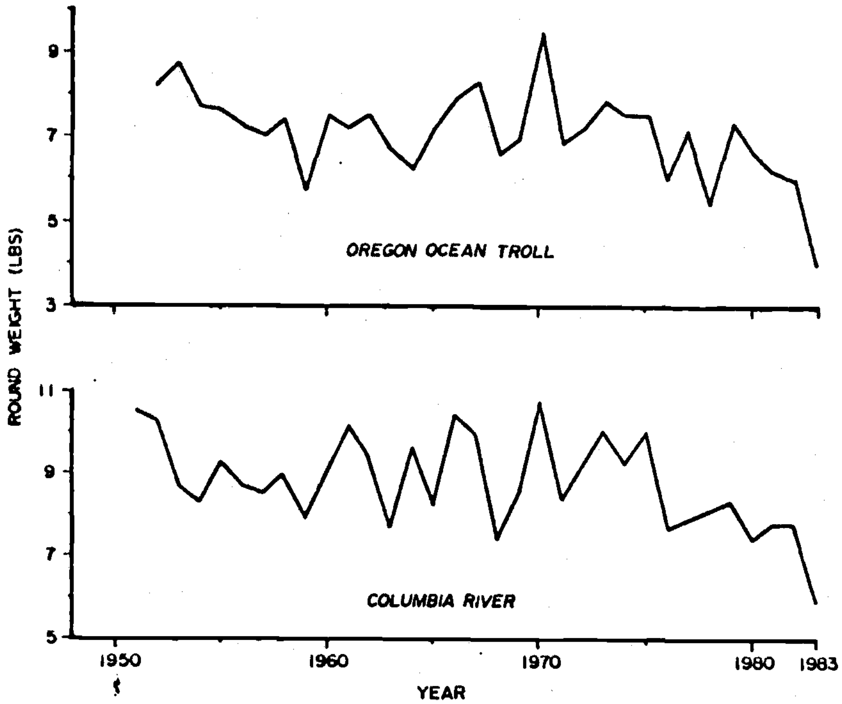

Figure 3. The average round weight of coho salmon landed in Oregon by the commercial troll fishery (July-August) and Columbia River gillnet fishery (Sept-Oct) from 1951-83. Average weight of Columbia River fishery in 1951-56 includes some fish caught in August.

weighed about 0.9 kg less than chinook of equal length sampled in 1974-76 (Johnson, 1984).

Because of large variations in the gonad weights of coho salmon of the same length categories, differences were not apparent between size-specific gonad weights measured in 1983 and earlier years. However, the average number of eggs per female coho salmon returning to public hatcheries in Oregon was 24-27% lower in 1983 than in 1978-82, largely because of the smaller size of returning females. The average egg size of coho was also smaller at some hatcheries than in past years (Johnson, 1984).

A predictive index of the stock size of coho salmon in the ocean south of Willapa Bay, Washington has been developed based on the number of precocious 2-year old males (jacks) returning in the previous year. As seen in Figure 4 this relationship has been a fairly accurate prediction of the abundance of 3-year old coho returning the following year. Mortality rates of year classes are usually similar between the time of jack return, after the first six months in the ocean, and the time of return of 3-year old

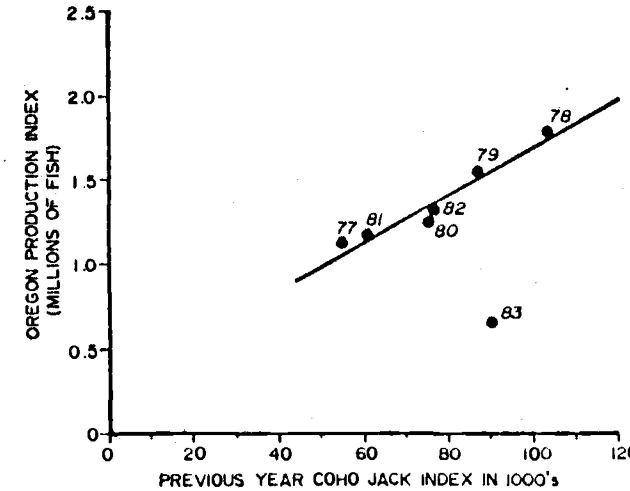

Figure 4. Relationship between the numbers of 2-year-old coho jacks returning to the Columbia River and streams of Oregon and California and the catch and escapement of 3-year-old coho (Oregon Production Index) 1977-83.

adults; hence adults return in a similar proportion to jacks in the prior year. In 1983, the prediction of the expected stock size was 1,553,600 (excluding private hatchery coho) based on return of jacks in 1982. The actual stock size was only 657,900 fish, 42% of the estimate based on the jack predictor (Pacific Fishery Management Council, 1984). The 1983 El Nino presumably was responsible for the unexpectedly high mortality of adult coho salmon during their final year in the ocean. The 1983 harvest of coho salmon was the lowest since 1961, and stream counts of coho on spawning grounds in Oregon were the lowest since surveys began in 1949 (Johnson, 1984).

The El Nino also affected the returns of many Oregon and California chinook stocks (Pacific Fishery Management Council, 1984). The abundance of chinook stocks from southern Oregon streams and some Columbia River stocks were far below predicted levels (Table 8). The numbers of chinook salmon returning as 2-year old jacks were at record lows in the Columbia River and Rogue River, predicting low returns of 3-year old chinook in 1984. Stocks that migrate to the north, such as coastal stocks north of Elk River and upriver fall chinook in the Columbia, usually had lower adult mortality than stocks having localized or southern distributions and were apparently less impacted by the El Nino conditions off Oregon and Washington (Pacific Fishery Management Council, 1984).

Conclusions

The 1982-83 El Nino was a major oceanographic event that had obvious biological consequences. Off Oregon and Washington it was correlated with a) occurrences of rare and unusual fishes from

Table 8. Comparison of the abundance of adult chinook in 1983 with the 1978-82 average for various Columbia River and Oregon coastal stocks.

Stock	Abundance Index	1978-82 mean	1983	% Change
Rogue Spring	Dam Count	29,841	7,688	-74%
Rogue Fall	Seining CPUE	1.58	0.57	-64%
Umpqua Spring	Dam Count	5,841	4,021	-37%
Elk River	Hatchery and Wild River Escapement	5,652	10,150	+80%
Columbia River Tule Fall	Ocean catch and escapement	849,000	479,000	-44%
Columbia River Upriver Fall	River catch and dam counts	78,100	83,200	+7%
Lower River Spring	River catch, dam counts a hatchery returns	96,100	99,600	+4%

southern waters, b) changes in the relative abundances of animals in purse seine collections, c) changes in the catches of some commercial species, d) poor growth and survival of coho salmon during their final summer in the ocean and e) low numbers and northerly distributions of juvenile coho salmon.

The warm ocean conditions and reduced upwelling of nutrient-rich, cool water apparently had severe effects on the production or availability of food, and hence growth of salmon that resided in coastal waters off Oregon, California and Washington.

Interestingly, tne catches of Pacific and jack mackerel in purse seine sets off Oregon and Washington were higher in 1984 than 1983. Catches of juvenile coho salmon were low in both 1983 and 1984 in this region. Positive temperature and sea-level anomalies persisted from late 1982 into early 1984 off California (Norton et al., this volume) and off Oregon (Huyer and Smith, in press). By April and May 1984, thermal and sea level properties seemed normal in coastal waters (Huyer and Smith, loc. cit.). Sea-surface temperatures during our purse seining cruises off Oregon were several degrees cooler in June 1984 than June 1983.

This trend for the distributions and abundances of large pelagic animals to be affected beyond the subsidence of the physical manifestations of El Nino was also obvious for pelagic red crabs (Pleuroncodes planipes) off California. Pelagic red crabs were found farthest to the north in the California Current in early 1960, following the 1957-58 El Nino, when massive strandings were observed in Monterey Bay (Glynn, 1961; Longhurst, 1967). Pelagic red crabs also moved north during the 1982-83 event, and again were reported farthest north (Fort Bragg) in early 1985 (D. McLain, pers. comm.). Such prolonged biological changes off California, as well as the ones we observed off Oregon and Washington, may be related to long-term changes in sea level and thermal structure in coastal waters along the west coast of North America (McLain, 1984; Norton et al., this volume), as well as to the transient El Nino event itself.

Acknowledgments

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