NORTHERN ANCHOVY AND PACIFIC SARDINE SPAWNING OFF SOUTHERN CALIFORNIA DURING 1978-80: PRELIMINARY OBSERVATIONS ON THE IMPORTANCE OF THE NEARSHORE COASTAL REGION

GARY D. BREWER
Institute for Marine and Coastal Studies
University of Southern California
University Park
Los Angeles, California 90007

PAUL E. SMITH
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, California 92038

ABSTRACT

Estimates of egg and larval abundance of northern anchovy *(Engraulis mordax)* and larval abundance of Pacific sardine *(Sardinops sagax caeruleus)* from monthly Ichthyoplankton Coastal and Harbor Studies (ICHS) cruises during 1978-80 within the nearshore Southern California Bight (to the 43-m isobath) were contrasted with comparable estimates from CalCOFI region 7. The ICHS region encompassed 3.8 percent of the area in region 7.

Raw survey data, uncorrected for potential sampler biases, indicated that about 3 percent of northern anchovy larvae occurred within the nearshore zone relative to the entire region 7. This number may be equivalent to about 2 percent of the larvae spawned by the central subpopulation.

The abundance of Pacific sardine larvae in the coastal region increased from 1978-79 to 1979-80. Sardine larvae occurred most frequently during the summer and fall and were captured most often in Santa Monica Bay. CalCOFI data on Pacific sardine were too infrequent for comparison with ICHS data.

The ichthyoplankton data sets are discussed in relation to the nursery function of nearshore versus offshore waters and the need for additional criteria for assessing recruitment potential from the two regions.

RESUMEN

Se comparó la abundancia estimada de huevecillos y larvas de la anchoveta *Engraulis mordax* y la abundancia de larvas de la sardina del Pacífico *(Sardinops sagax caeruleus),* determinadas en los cruceros mensuales de Estudios del Ictioplancton en Puertos y la Costa (ICHS) durante 1978-80 en la zona costera del sur de California (hasta la isóbata de los 43 m.), con estimaciones comparables de la región 7 de CalCOFI. La región del ICHS abarcaba un 3.8 por ciento del área en la región 7.

Los datos sin procesar y sin corrección de los sesgos potenciales del muestreador mostraban que alrededor del 3 por ciento de las larvas de anchoveta ocurrieron en la zona cercana a la costa por toda la región 7. Este número podría ser equivalente a alrededor del 2 por ciento de las larvas producidas por la subpoblación central.

La abundancia de la sardina del Pacífico en la región costera aumentó de 1978-79 a 1979-80. Las larvas de sardina se observaron con mayor frecuencia durante el verano y otoño y se capturaron más a menudo en la Bahía de Santa Mónica. Los datos de CalCOFI referentes a la sardina del Pacífico eran muy poco frecuentes como para compararlos con los datos del ICHS.

Los datos del ictioplancton son discutidos en relación a la función de criaderos en las aguas cercanas a la costa contra aquéllos fuera de la costa, así como la necesidad de criterios adicionales para evaluar el potencial de reclutamiento de las dos regiones.

[Manuscript received February 8, 1982.]

INTRODUCTION

The variable abundance and distribution of the early life stages of clupeiform fishes off the Pacific coast of North America have been investigated for more than three decades by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) (Ahlstrom 1966; Smith 1972). The time series on ichthyoplankton, developed by CalCOFI, was supplemented from 1978-80 by a regionally intensive project within the Southern California Bight; the project was entitled Ichthyoplankton Coastal and Harbor Studies (ICHS).

The ICHS data includes temporal and spatial features of ichthyoplankton abundance that are not available from CalCOFI cruises. Important differences exist in the species structure of ichthyoplankton between ICHS and adjacent CalCOFI regions (Brewer et al. 1980; Loeb et al.[1]). Other investigators have shown gradients in potential food for larval fishes—phytoplankton (Eppley et al. 1978; Kleppel 1980) and microzooplankton (Beers and Stewart 1967; Arthur 1977)—that increase toward shore. The ICHS data make it possible to assess longshore variability of ichthyoplankton within the bight and, with CalCOFI data, to evaluate nearshore versus offshore regions as spawning grounds for adult fishes and as habitats for the survival of larvae.

[1]Loeb, V., H. Moser, and P. Smith. Seasonal and geographic patterns of ichthyoplankton distributions in the CalCOFI area, 1975. Admin. Rep., unpub.

This report gives estimates of egg and larval abundance of northern anchovy *(Engraulis mordax)* and larval abundance of Pacific sardine *(Sardinops sagax caeruleus)* from monthly cruises within the nearshore ICHS region. These estimates are compared with similar estimates from an adjacent CalCOFI region. The data sets are discussed in relation to the nursery function of nearshore versus offshore waters and the need for additional criteria for assessing recruitment potential from the two regions.

ICHS sampled the nearshore Southern California Bight along the 8-m, 15-m, 22-m, and 36-m isobaths, inshore of most CalCOFI stations. The circulation and chemistry of these shallow waters are not well studied (Jones 1971; Tsuchiya 1980; Winant and Bratkovich 1981). Compared to offshore waters, coastal features are complicated by boundary effects, shoreline topography, local wind conditions, runoff from sporadic rainfall, and anthropogenic influences. Industrial, municipal, and thermal wastewaters from at least 24 discrete outfalls are discharged within the Southern California Bight (Southern California Coastal Water Research Project 1973).

MATERIALS AND METHODS

Sampling techniques and laboratory procedures used by the CalCOFI program have been discussed in detail by Kramer et al. (1972) and Smith and Richardson (1977). Briefly, 70-cm bongo[2] plankton samplers (0.505-mm mesh) were lowered to 210 m, depth permitting, and retrieved at 20-m•min^{-1} while a constant towing wire angle was maintained. Plankton samples were preserved and returned to the laboratory, where they were sorted and the fish eggs and larvae identified and enumerated. Data on tow depth, volume of water filtered, and numbers of eggs and larvae in each sample were then used to estimate ichthyoplankton abundance under unit areas of sea surface.

An important goal of the ICHS program was data compatibility with CalCOFI. Hence, a primary objective in the nearshore sampling (as in CalCOFI surveys) was an oblique tow trajectory with 70-cm bongos, whereby equal volumes of water were filtered per unit depth. Certain details of the ICHS methodology differed from CalCOFI techniques. ICHS sampled almost exclusively at night, whereas CalCOFI sampled during all hours. The ICHS bongo was fitted with a messenger release, opening-closing device as described by McGowan and Brown (1966). A steel bar, 0.7 m long and weighing about 40 kg, was tied 0.3 m below the bongo frame as a depressor weight. The nets were made of 0.333-mm mesh Nitex with a 1.5-m cylindrical section and a 1.5-m conical section leading to 0.333-mm mesh cod-end sock.

[2]Cruise 7901 used the CalCOFI 1-m bridled net.

The ICHS bongo was slowly lowered to the bottom (canvas doors covered the mouths of the nets) with the ship under way. The angle and length of the towing wire were monitored in order to bump the depressor weight on the bottom. The canvas doors were then opened by messenger and the sampler retrieved immediately at a constant rate of 20-m•min^{-1} while maintaining a towing-wire angle of about 45°. A General Oceanics instrumented trawl block provided continuous readings of towing-wire angle, meters of cable out, and retrieval rate. Ship speed was monitored by a General Oceanics speedometer with a deck readout. General Oceanics flowmeters, located in the mouth of the bongo frame, were used to compute the distance traveled by the nets; from this data, the volume of water filtered was determined. With a combined ship speed and net retrieval rate of about 1.0-1.1-m•sec^{-1}, about 3-4 m^3 of water were filtered per meter of depth.

A depth transducer was mounted on the bongo frame beginning with cruise 12 to insure contact with the bottom by providing continuous depth readings of the sampler via a deck readout.

Fish eggs and larvae were carefully sorted from 25-100 percent of each sample with the aid of stereomicroscopes. Aliquots were made by using either the port or starboard bongo sample, and/or by splitting with a Folsom plankton splitter (McEwen et al. 1954). Ten percent of each sorted fraction was checked to ensure that sorting efficiency remained at least 90 percent. Fragmented larvae were counted, but were not considered in the determination of sorting efficiency prior to July 1979. Also, some samples collected prior to July 1979 were not sort-checked. Data for these cruises may underestimate abundance relative to subsequent cruises, but probably by no more than 5 percent, based on the numbers of fragments found and the sorting efficiency during the later cruises.

We have assumed that damaged specimens identified conservatively as engraulids and clupeids were, in fact, *Engraulis mordax* and *Sardinops sagax caeruleus*, respectively. Also, damaged specimens identified only as clupeiformes have been proportioned into the two specific categories for each sample, based on the ratio of individuals identified positively.

While the central subpopulation of northern anchovy encompasses at least eight CalCOFI regions and an area of about 571,000 km^2 (Vrooman et al. 1980), in this report data from region 7 only were compared with the ICHS data. The ICHS region is contiguous with region 7 (Figure 1), and region 7 is the center of

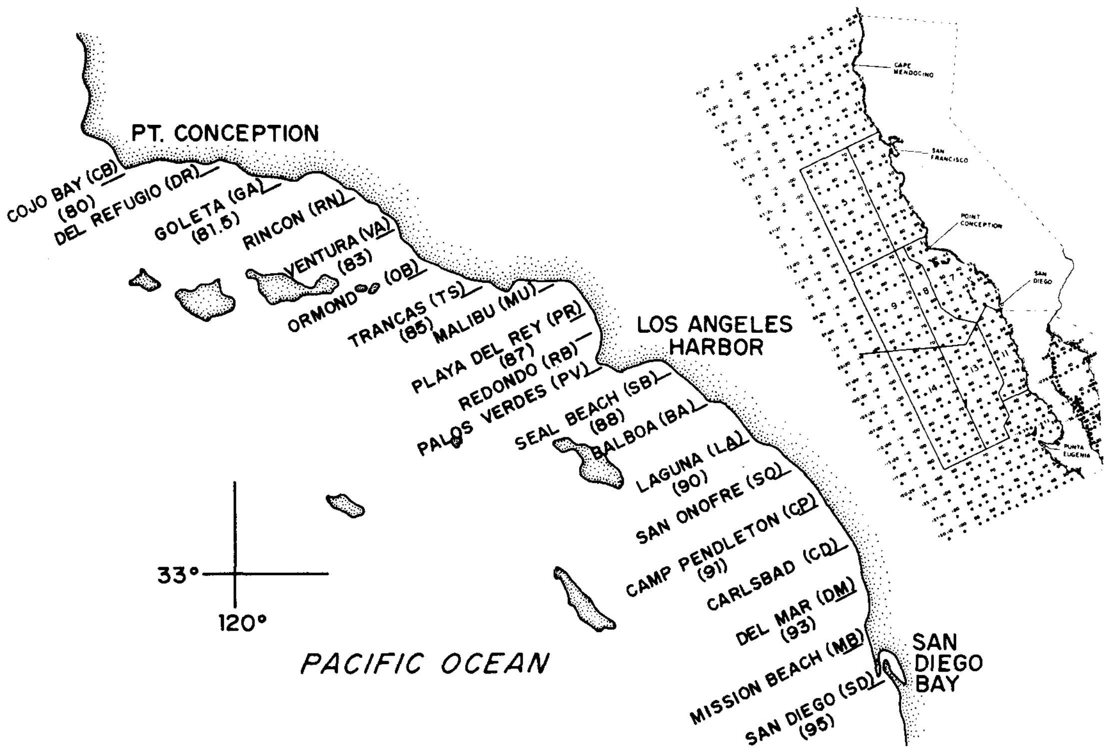

Figure 1. Locations of ICHS transects in relation to adjacent CalCOFI regions (inset). The ICHS region includes the area from shore to the 43-m isobath—approximately 3.8 percent of the area within region 7.

the northern anchovy central subpopulation biomass (Smith and Eppley 1981).

Station locations for ICHS and CalCOFI region 7 are listed in Tables 1 and 2, respectively. Stations occupied by ICHS varied between June 1978-July 1979 (Phase I) and August 1979-July 1980 (Phase II). Phase I sampling encompassed 10 transects and 4 stations per transect over isobaths of 8, 15, 22, and 36 m (Table 1). Data from eight ICHS cruises were available from this period. Phase II cruises occupied 46 stations each month along 20 transects. Only the 8-m and 22-m isobaths were sampled along 17 of the transects. Transects off Ormond, Redondo, and San Onofre beaches were sampled at 8-m, 15-m, 22-m, and 36-m isobaths. The volume of water filtered per unit depth was increased by a factor of four during Phase II, relative to Phase I. This was accomplished by decreasing the net retrieval rate from 20-m•min^{-1} to 10-m•min^{-1} and replicating each sample. The speed of the net (i.e., retrieval rate + ship speed) was maintained at about 1.0-1.1 m•sec^{-1} during both Phase I and II.

For purposes of this report, the ICHS stations represent a nearshore region that extends from just below the United States-Mexico border (32°24.5'N) to just above Pt. Conception (34°40.0'N). and extends offshore to the 43-m isobath (Figure 1). This area encompasses about 2652 km^2 that lie within the area (69,055 km^2) of CalCOFI region 7. The area of the ICHS region was determined by multiplying the longshore distance covered by the transects as determined from National Ocean Survey charts 19720 and 18740. The distance to the 43-m isobath was estimated by extrapolating the average seaward distance of the ICHS stations along the 8-m, 15-m, 22-m, and 36-m isobaths.

Station data from both CalCOFI and ICHS regions were scaled for each taxon to numbers of individuals under unit areas of sea surface (Smith and Richardson 1977). Regional census estimates (Smith 1972) for each survey cruise were computed from the mean number of eggs or larvae per m^2 of sea surface for all stations sampled, times the area within the respective region.

TABLE 1
ICHS Station Coordinates

Transect	Station (depth-m)	N. Latitude	W. Longitude	Distance from shore (km)
80				
(Cojo Bay)	* 08	34°26.8′	120°26.7′	0.35
	15	34°26.7′	120°26.5′	0.79
	* 22	34°26.5′	120°26.5′	1.17
	36	34°26.2′	120°26.5′	1.20
DR				
(Del Refugio)	* 08	34°27.5′	120°03.0′	0.20
	* 22	34°27.3′	120°04.4′	0.31
81.5				
(Goleta)	* 08	34°24.6′	119°47.4′	0.74
	15	34°24.1′	119°46.4′	1.00
	* 22	34°23.9′	119°46.5′	1.33
	36	34°23.5′	119°46.5′	2.04
RN				
(Rincon)	* 08	34°22.0′	119°27.5′	0.25
	* 22	34°21.4′	119°28.7′	1.40
83				
(Ventura)	* 08	34°15.7′	119°16.6′	0.35
	15	34°14.9′	119°17.3′	1.79
	* 22	34°13.4′	119°21.5′	7.50
	36	34°11.9′	119°24.1′	11.95
OB				
(Ormond Beach)	* 08	34°07.3′	119°10.4′	0.28
	* 15	34°07.1′	119°10.9′	0.79
	* 22	34°06.6′	119°11.8′	1.70
	* 36	34°06.1′	119°12.8′	2.55
85				
(Trancas)	* 08	34°03.1′	118°58.2′	0.37
	15	34°02.8′	118°58.0′	0.94
	* 22	34°02.6′	118°58.0′	1.26
	36	34°02.2′	118°58.0′	1.67
MU				
(Malibu)	* 08	34°02.2′	118°36.2′	0.11
	* 22	34°01.6′	118°37.4′	0.56
87				
(Playa del Rey)	* 08	33°57.0′	118°27.2′	0.41
	15	33°57.0′	118°27.9′	1.48
	* 22	33°57.0′	118°28.6′	2.41
	36	33°57.0′	118°30.1′	4.43
RB				
(Redondo Beach)	* 08	33°50.3′	118°23.7′	0.20
	* 15	33°50.1′	118°23.8′	0.50
	* 22	33°50.0′	118°24.2′	0.82
	* 36	33°49.6′	118°24.9′	1.57
PV				
(Palos Verdes)	* 15	33°40.7′	118°24.7′	0.19
	* 22	33°44.4′	118°25.0′	0.39
88				
(Seal Beach)	* 08	33°42.4	118°04.4′	0.93
	15	33°41.1	118°04.6′	3.52
	* 22	33°39.4′	118°05.0′	5.30
	36	33°37.2′	118°05.4′	8.37
BA				
(Balboa)	* 08	33°36.2′	117°54.5′	0.21
	* 22	33°35.9′	117°54.9′	0.62
90				
(Laguna Beach)	* 15	33°30.3′	117°45.3′	0.52
	22	33°30.3′	117°45.5′	0.74
	* 36	33°30.2′	117°45.8′	1.24
SO				
(San Onofre)	* 08	33°21.7′	117°33.8′	0.50
	* 15	33°21.2′	117°34.6′	1.45
	* 22	33°20.7′	117°35.3′	2.01
	* 36	33°20.6′	117°35.8′	2.54
91				
(Camp Pendleton)	* 08	33°15.1′	117°26.4′	0.70
	15	33°14.6′	117°27.2′	2.31
	* 22	33°14.3′	117°27.5′	3.26
	36	33°13.7′	117°28.2′	4.39
CD				
(Carlsbad)	* 08	33°07.4′	117°20.2′	0.27
	* 22	33°07.1′	117°20.7′	0.72
93				
(Del Mar)	* 08	32°57.6′	117°16.3′	0.52
	15	32°57.6′	117°16.7′	1.04
	* 22	32°57.5′	117°17.1′	1.63
	36	32°57.5′	117°17.5′	2.22
MB				
(Mission Beach)	* 08	32°46.7′	117°15.4′	0.25
	* 22	32°46.3′	117°16.5′	1.13
95				
(San Diego)	* 08	32°37.9′	117°08.7′	0.44
	15	32°37.8′	117°09.8′	2.00
	* 22	32°36.9′	117°11.3′	4.89
	36	32°35.8′	117°13.6′	9.07

Stations along numerically designated (CalCOFI) transects 80-95 were sampled from June 1978-July 1979 (Phase I). Stations marked by an "*" were sampled from August 1979-July 1980 (Phase II). Note that no samples were collected at the 8-m isobath along transects PV and 90.

TABLE 2
CalCOFI Region 7 Station Coordinates

Transect	Station	(Depth-m)	N. Latitude	W. Longitude	Distance from shore (km)*
80	51.0	110	34°27.0′	120°31.4′	4.6
	52.0	242	34°25.0′	120°35.6′	11.9
	55.0	763	34°19.0′	120°48.1′	30.9
	60.0	2151	34°09.0′	121°09.0′	66.5
82	46.0	539	34°16.2′	119°56.3′	16.1
	47.0	541	34°14.2′	120°00.5′	22.8
83	40.6	33	34°13.5′	119°24.7′	10.2
(83.3)	42.0	167	34°10.7′	119°30.5′	19.1
	51.0	213	33°52.7′	120°08.0′	63.5
	52.0	410	33°50.7′	120°12.1′	69.3
	55.0	981	33°44.7′	120°24.6′	77.8
87	32.5	24	33°54.4′	118°27.3′	2.8
(86.7)	32.7	33	33°54.0′	118°28.2′	4.3
	33.0	49	33°53.4′	118°29.4′	6.7
	34.0	70	33°51.4′	118°33.6′	14.1
	35.0	575	33°49.4′	118°37.7′	19.8
	36.0	801	33°47.4′	118°41.9′	24.8
	40.0	840	33°39.4′	118°58.5′	41.7
	45.0	1630	33°29.4′	119°19.1′	70.6
	50.0	77	33°19.4′	119°39.8′	99.6
	51.0	104	33°17.4′	119°43.9′	107.0
	55.0	1205	33°09.4′	120°00.4′	131.9
90	27.6	43	33°29.9′	117°44.4′	1.3
	28.0	302	33°29.1′	117°46.1′	2.8
	29.0	609	33°27.1′	117°50.2′	10.0
	30.0	616	33°25.1′	117°54.3′	17.2
	31.0	395	33°23.1′	117°58.5′	23.7
	33.0	751	33°19.1′	118°06.7′	36.5
	37.0	1173	33°11.1′	118°23.2′	58.9
	41.5	1372	33°02.1′	118°41.7′	84.1
	45.0	1720	32°55.1′	118°56.1′	103.7
	53.0	1138	32°39.1′	119°28.9′	157.4
93	26.7	45	32°57.4′	117°18.3′	3.5
	26.9	75	32°57.0′	117°19.1′	5.0
	28.0	553	32°54.8′	117°23.7′	10.9
	29.0	592	32°52.8′	117°27.8′	17.4
	30.0	779	32°50.8′	117°31.9′	23.3
	35.0	605	32°40.8′	117°52.4′	57.6
	40.0	1686	32°30.8′	118°12.8′	92.0
	45.0	1347	32°20.8′	118°33.3′	127.0
	50.0	1413	32°10.8′	118°53.6′	163.5
97	29.0	41	32°17.4′	117°04.8′	3.0
	30.0	59	32°15.4′	117°08.8′	10.6
	32.0	1289	32°11.4′	117°17.0′	25.0
	35.0	1183	32°05.4′	117°29.2′	47.6
	40.0	1489	31°55.4′	117°49.5′	84.6

*Nearest point on mainland.

RESULTS

Northern Anchovy Larvae

Northern anchovy spawn all year within the bight, but their estimated regional abundance may vary by a factor of 10 between adjacent months and a factor of 100 between adjacent seasons (Table 3). About 80 percent of northern anchovy spawning takes place in winter and spring (Stauffer and Parker 1980). CalCOFI sampling was concentrated during the months when anchovy spawning is greatest; ICHS sampled throughout the year. Seasonal spawning, possible biases resulting from different egg and larvae retention between the ICHS (0.333-mm mesh) net and the CalCOFI (0.505-mm mesh) net, and day-night differences in net avoidance require cautious comparison of ICHS and CalCOFI data.

The nearshore Southern California Bight contained an average of 38 *E. mordax* larvae per m^2 of sea surface during 1978-80 based on 861 plankton tows (Table 3). Similarly, during the same period, CalCOFI nets towed within region 7 captured an average of 102 larvae per m^2 from 466 plankton samples (Table 4). In order to eliminate temporal bias in comparing ICHS and CalCOFI regional abundance, nine surveys conducted during concurrent periods were contrasted (Tables 3 and 4). The relationship (Figure 2) between monthly census estimates of larval abundance in region 7 versus the ICHS region suggests that numbers of larvae covaried between the two regions. The overall means of the nine paired cruises were 5673 x 10^9 ($82.4 \cdot m^{-2}$) and 162 x 10^9 ($61.1 \cdot m^{-2}$) larvae in the two regions, respectively. The ICHS region, encompassing 3.8 percent of the area in region 7, contained about 3 percent of the northern anchovy larvae.

The abundance of larvae per m^2 varied directly with station depth within the ICHS region (Figure 3). This relationship indicates that the census data underestimated total numbers of larvae to the 43-m isobath during Phase II when stations over the 15-m and 36-m isobaths were not well represented (Table 1). Without data from the 15-m and 36-m isobaths, monthly census estimates were low by a factor of about 1.5 based on the regression equation in Figure 3. Figure 3 also shows that the average density of larvae (number per unit volume) rises to a near asymptote at the 36-m

TABLE 3
Summary of Egg and Larval Abundance of Northern Anchovy and Larval Abundance of Pacific Sardine from ICHS Cruises during 1978-80

		Engraulis larvae				*Engraulis* eggs				*Sardinops* larvae			
Cruise	Dates	# Sta./ positive	$\bar{x}$ larvae $\cdot m^{-2}$	Std. dev.	Est. # larvae ICHS region (x 10^9)	# Sta./ positive	$\bar{x}$ eggs $\cdot m^{-2}$	Std. dev.	Est. # eggs ICHS region (x 10^9)	# Sta./ positive	$\bar{x}$ larvae $\cdot m^{-2}$	Std. dev.	Est. # larvae ICHS region (x 10^9)
	1978												
1*	12-24 Jun.	38/36	24.47	38.93	64.89	38/16	9.18	41.78	24.35	38/06	0.10	0.33	0.27
2*	10-21 Jul.	37/33	8.78	13.52	23.27	37/20	21.27	76.31	56.41	37/03	0.06	0.25	0.16
3	14-25 Aug.												
4	18-29 Sep.	39/35	12.76	18.93	33.85	39/18	11.67	44.27	30.95	39/03	0.04	0.13	0.10
5	16-27 Oct.	39/33	16.98	36.73	45.03	39/22	492.25	2878.47	1305.40	39/04	0.04	0.14	0.11
6	06-17 Nov.												
7	04-15 Dec.	39/36	32.18	45.64	85.33	39/27	14.69	54.12	38.96	39/01	0.01	0.09	0.04
	1979												
8*	08-19 Jan.	39/39	27.54	27.10	73.05	39/25	8.04	20.08	21.32	39/04	0.05	0.14	0.12
9	12-28 Feb.												
10*	12-23 Mar.	39/38	75.49	104.98	200.19	30/35	172.96	333.73	458.69	39/07	0.18	0.56	0.47
11*	02-21 Apr.	39/38	55.15	65.95	146.27	39/31	119.75	332.27	317.58	39/01	0.01	0.05	0.02
12	14-25 May												
13	11-22 Jun.												
14	10-18 Jul.												
15	13-24 Aug.	46/45	19.83	35.51	52.58	46/29	37.69	160.60	99.96	46/15	0.18	0.72	0.48
16	10-21 Sep.	46/46	15.05	27.60	39.90	46/24	2.61	6.90	6.93	46/21	0.31	0.66	0.83
17	08-18 Oct.	46/39	4.20	6.45	11.13	46/18	22.21	63.93	58.91	46/23	1.45	3.94	3.85
18	05-16 Nov.	46/25	2.73	9.66	7.25	46/25	15.11	46.76	40.07	46/12	0.18	0.44	0.49
19	03-13 Dec.	46/36	9.36	15.67	24.83	46/33	69.49	121.86	184.28	46/11	0.61	1.70	1.62
	1980												
20	07-19 Jan.	46/42	80.55	149.11	213.62	46/42	69.65	159.18	184.72	46/11	0.28	0.65	0.75
21*	11-28 Feb.	46/46	91.49	121.13	242.63	46/43	191.09	717.70	506.76	46/05	0.04	0.11	0.10
22*	10-22 Mar.	46/45	195.18	196.46	517.63	46/44	294.88	651.95	782.02	46/09	0.13	0.33	0.36
23*	07-17 Apr.	46/46	49.90	54.38	132.34	46/40	124.21	367.51	329.41	46/06	0.12	0.42	0.31
24*	12-25 May	46/43	22.17	38.47	58.79	46/33	33.92	117.21	89.96	46/10	1.93	11.43	5.11
25	16-26 Jun.	46/40	7.07	11.86	18.75	46/24	5.73	16.97	15.21	46/03	0.04	0.16	0.10
26	14-25 Jul.	46/30	1.63	2.24	4.31	46/15	4.26	23.54	11.29	46/00	0.00	0.00	0.00

*Cruises that were concurrent with CalCOFI cruises.

TABLE 4
Summary of Egg and Larval Abundance of Northern Anchovy and Larval Abundance of Pacific Sardine from CalCOFI Cruises during 1978-80

		Engraulis larvae				*Engraulis* eggs				*Sardinops* larvae			
Cruise	Dates	# Sta./ positive	x̄ larvae •m^{-2}	Std. dev.	Est. # larvae region 7 (x 10^9)	# Sta./ positive	x̄ eggs •m^{-2}	Std. dev.	Est. # eggs region 7 (x 10^9)	# Sta./ positive	x̄ larvae •m^{-2}	Std. dev.	Est. # larvae region 7 (x 10^9)
	1978												
7801	05-24 Jan.	42/36	63.96	57.23	4,416.8	42/35	45.09	74.89	3,113.7	42/00	0.0	0.0	0.0
7803	18 Feb.-06 Mar.	42/42	267.81	356.41	18,493.6	42/36	79.99	133.41	5,523.7	42/02	0.071	0.39	4.9
7804	29 Mar.-14 Apr.	42/36	156.46	204.47	10,804.3	42/26	157.24	309.91	10,858.2	42/01	0.007	0.05	0.5
7805*	23 May-02 Jun.	34/29	42.74	134.14	2,951.4	34/13	10.96	36.21	756.8	34/01	0.029	0.17	2.0
7807*	20 Jun.-06 Jul.	41/18	6.75	8.64	466.1	41/08	1.47	5.89	101.5	41/02	0.039	0.17	2.7
7808	31 Jul.-16 Aug.	42/18	6.43	18.77	444.0	42/09	6.46	26.39	446.1	42/02	0.036	0.17	2.5
	1979												
7901*	15-22 Jan.	24/21	29.24	55.96	2,019.2	24/17	37.70	73.99	2,603.4	24/00	0.0	0.0	0.0
7902	19-28 Feb.	24/22	233.39	264.53	16,116.7	24/14	96.61	181.61	6,671.4	24/00	0.0	0.0	0.0
7903*	02-08 Mar.	27/25	117.38	144.40	8,105.7	27/17	44.80	80.31	3,093.7	27/00	0.0	0.0	0.0
7904*	06-17 Apr.	23/23	84.08	95.05	5,806.1	23/17	185.44	349.12	12,805.6	23/00	0.0	0.0	0.0
7905	30 Apr.-16 May	28/26	57.35	63.74	3,960.3	28/15	48.72	93.28	3,364.4	28/00	0.0	0.0	0.0
	1980												
8003a*	24 Feb.-02 Mar.	24/24	105.77	108.63	7,303.9								
8003b*	27 Mar.-06 Apr.	20/19	204.38	201.25	14,113.5								
8004*	11-29 Apr.	29/26	94.16	226.37	6,502.2		Data not available				Data not available		
8005*	24-30 May	24/17	56.75	117.63	3,918.9								

*Cruises that were concurrent with ICHS cruises.

isobath (2.2 larvae•m^{-3}). Extrapolation of a line fitted to the four X's in Figure 3 (Y=2.63-14.07/X) gives an average density estimate of 2.3•m^{-3} at the 43-m isobath (i.e., 99•m^{-2}). The asymptote suggests that the majority of anchovy occurred within the vertical depth range sampled by ICHS. Ahlstrom (1959) found that 85 percent of the anchovy larvae were distributed in the upper 48 m.

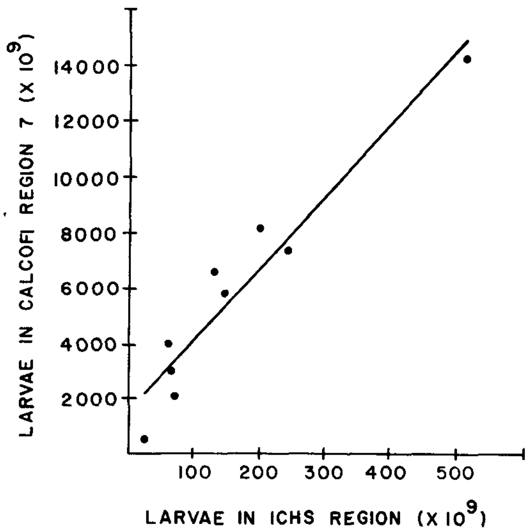

Figure 2. Monthly census estimates of northern anchovy larvae in the ICHS region versus CalCOFI region 7 (Y=1530.0+25.65X; r^2=0.92).

Larval abundance was not well correlated with distance from shore within the ICHS region (Figure 4), and no clear relationship was evident between the highest mean station abundance and distance from shore based on five complementary CalCOFI-ICHS transects (Figure 5). For example, along transect 80,

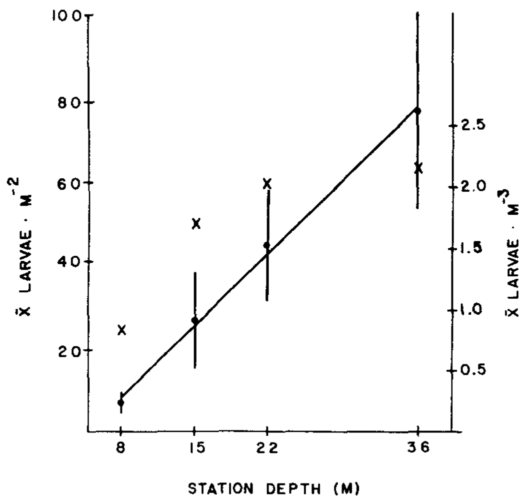

Figure 3. Average abundance per m² and 95 percent confidence intervals of northern anchovy larvae by station depth within the ICHS region (Y=11.76+2.51X). The points represent mean abundance by isobath from all Phase I transects and from those Phase II transects (three) where data from 8-m, 15-m, 22-m, and 36-m isobaths were collected (N=453). The X's represent equivalent data, expressed as mean abundance per m³.

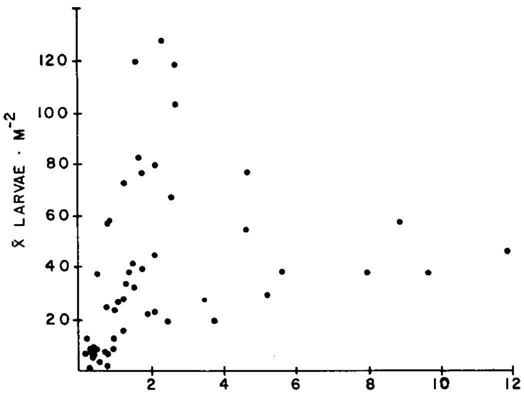

Figure 4. Mean station abundance of northern anchovy larvae by distance from shore. The points represent data from stations as described in Figure 3.

highest mean densities of larvae were found 1.2 km from shore; along transect 90, highest mean densities were found 103.6 km from shore. We have no explanation for the prominent dip in larval abundance that occurred along at least three of the five transects at distances between 10 and 20 km from shore.

We examined the variability of anchovy larvae in the longshore dimension by both average transect abundance and rank transect abundance (Tables 5 and 6). Table 5 summarizes all 1978-80 CalCOFI data along five transects and complementary data from nine CalCOFI-ICHS cruises. The within-transect averages between CalCOFI and ICHS are in surprisingly close agreement, while variability between transects is a factor of over 10 for CalCOFI transects and a factor of about 5 for ICHS transects. Because the standard deviations of the transect means were large, nonparametric techniques were used to test the signifi-

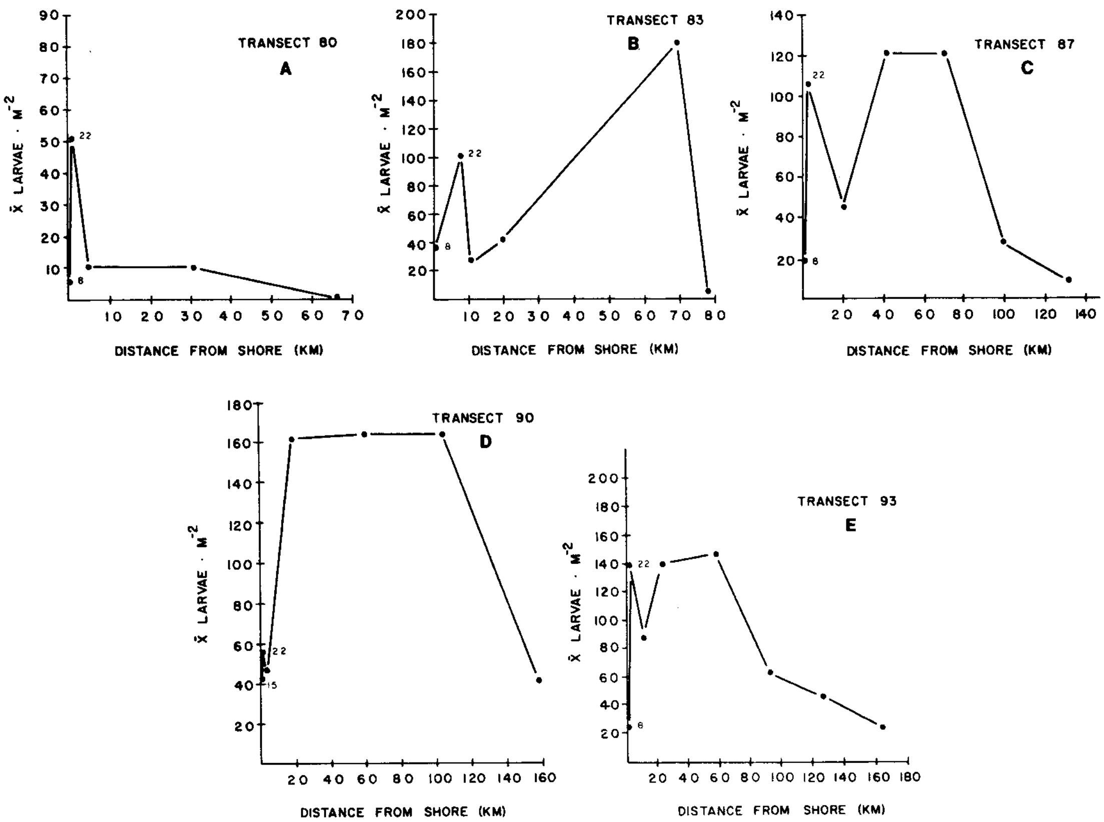

Figure 5. Average abundance of northern anchovy larvae along complementary CalCOFI-ICHS transects 80 *(A)*, 83 *(B)*, 87 *(C)*, 90 *(D)*, and 93 *(E)*. Mean station data were based on 9 concurrent CalCOFI-ICHS cruises (Tables 3 and 4) and only those CalCOFI and ICHS stations that were sampled during 1978, 1979, and 1980. ICHS stations are labeled.

TABLE 5

Abundance of Northern Anchovy Larvae along Complementary CalCOFI-ICHS Transects

	ICHS			CalCOFI					
	Nine concurrent cruises						All cruises 1978-1980		
Transect	# Sta./ positive	x̄ larvae •m⁻²	Std. dev.	# Sta./ positive	x̄ larvae •m⁻²	Std. dev.	# Sta./ positive	x̄ larvae •m⁻²	Std. dev.
80	28/23	20.2	68.5	28/18	8.9	18.7	50/31	15.6	39.2
93	28/28	52.0	99.0	32/29	64.3	208.5	56/52	82.5	184.4
87	26/26	65.8	80.7	53/50	56.7	92.0	103/91	86.8	127.1
90	23/22	60.7	84.1	53/46	118.7	163.9	99/85	182.9	296.0
93	27/27	96.4	116.4	58/53	80.1	108.5	106/92	93.5	131.0

Concurrent cruises are designated in Tables 3 and 4.

cance of the transect differences. All station data from the complementary cruises were used to calculate mean transect abundance for each CalCOFI and ICHS cruise. Transects were ranked, and the ranks were summed across cruises for both CalCOFI and ICHS data. The results of the Kruskal-Wallis one-way analysis of variance by ranks (Siegel 1956) showed that transect ranks were significantly different (Table 7).

While a north (low)-to-south (high) gradient in abundance was suggested by the above rankings, a similar analysis of transect abundance within the ICHS region, which encompasses data from all seasons, showed different results. Table 6 summarizes ICHS transect data on the basis of stations over the 8-m and 22-m isobaths during Phase I and Phase II. We tested the rank sums of larval abundance for 10 transects across 20 months by the Kruskal-Wallis test as above.

TABLE 7

Transect Ranks of Northern Anchovy Egg and Larvae and Pacific Sardine Larval Abundance Based on the Kruskal-Wallis Analysis of Variance by Ranks

	CalCOFI	ICHS			
	Nine concurrent cruises		8- & 22-m isobaths across 20 months		
Transect	*Engraulis* larvae ranking		*Engraulis* larvae ranking	*Engraulis* egg ranking	*Sardinops* larvae ranking
80	5	5	10	10	10
81.5			3	3	8
83	4	4	1	1	3
85			6	6	7
87	3	2	7	2	1
88			2	4	2
90	1	3	8	9	6
91			5	7	9
93	2	1	9	5	5
95			4	8	4
	p<0.01	p<0.02	p<0.30	p<0.001	p<0.01

The probability of equal transect ranks is indicated below each column.

The 10 transects were not significantly different ($p<0.30$ of being equal), and no pattern or gradient was evident.

Northern Anchovy Eggs

Available data on *E. mordax* eggs are summarized in Tables 3 and 4. The highest mean density of eggs within the ICHS region was found in October 1978. However, over 99 percent of the eggs collected during the month were found along one transect (83), where stations over the 22-m and 36-m isobaths (4.5 km apart) yielded 997 and 17,904 eggs•m⁻¹, respectively.

TABLE 6

Transect Data on Northern Anchovy Egg and Larval Abundance along 8-m and 22-m Isobaths within the ICHS Region

	Engraulis larvae						*Engraulis* eggs					
	Phase I & II			Phase II			Phase I & II			Phase II		
Transect	# Sta./ positive	x̄ larvae •m⁻²	Std. dev.	# Sta./ positive	x̄ larvae •m⁻²	Std. dev.	# Sta./ positive	x̄ eggs •m⁻²	Std. dev.	# Sta./ positive	x̄ eggs •m⁻²	Std. dev.
80	40/30	32.2	111.0	24/19	47.9	141.0	40/12	4.0	21.5	24/06	6.3	27.8
DR	—	—	—	24/17	52.0	141.3	—	—	—	24/13	37.1	167.8
81.5	40/31	29.4	66.6	24/18	36.2	82.6	40/27	15.0	43.3	24/18	21.9	54.8
RN	—	—	—	24/24	82.6	171.9	—	—	—	24/21	277.1	697.7
83	40/40	45.6	86.9	24/24	60.7	108.0	40/36	240.1	522.5	24/22	252.1	622.1
OB	—	—	—	24/23	43.8	97.7	—	—	—	24/24	137.6	199.7
85	40/38	20.5	38.6	24/23	21.6	45.7	40/31	52.0	235.7	24/22	83.7	302.6
MU	—	—	—	24/23	46.0	114.8	—	—	—	24/16	34.7	100.8
87	38/33	39.4	69.0	24/21	41.4	74.3	38/27	156.4	776.4	24/19	247.3	972.8
RB	—	—	—	24/21	31.8	54.8	—	—	—	24/11	30.1	71.5
PV*	—	—	—	24/21	17.2	27.9	—	—	—	24/15	12.9	20.8
88	40/39	27.6	48.5	24/23	30.6	57.8	40/30	56.6	163.9	24/20	89.4	206.5
BA	—	—	—	24/19	19.2	45.1	—	—	—	24/16	8.3	16.3
90*	40/35	24.3	58.1	24/20	29.7	73.1	40/22	5.6	16.3	24/12	3.2	6.7
SO	—	—	—	24/20	26.5	66.7	—	—	—	24/16	22.3	85.3
91	40/35	23.6	50.9	24/22	28.2	61.3	40/23	44.1	134.2	24/14	21.3	46.6
CD	—	—	—	24/18	30.1	70.2	—	—	—	24/12	3.8	8.8
93	39/30	39.6	72.6	24/18	36.3	66.3	39/17	15.3	74.9	24/10	2.9	7.1
MB	—	—	—	24/18	21.3	45.8	—	—	—	24/11	4.3	11.5
95	40/35	17.7	32.7	24/20	16.7	31.9	40/28	30.1	84.8	24/16	17.8	52.3

*Data from 15-m isobath substituted for unavailable 8-m data.

The graph of anchovy egg abundance versus station depth (Figure 6) shows points that both include and exclude the catch of eggs at transect 83, 36-m isobath during October 1978. Also included in the graph are average abundance of eggs per unit volume of water. The mean density of eggs throughout the water column decreased between the 22-m and 36-m isobaths, probably because of their relatively shallow vertical distribution, as noted for the larvae.

Longshore variability of eggs, based on mean transect abundance along the 8-m and 22-m isobaths (Table 6), approached two orders of magnitude. The highest spawning activity occurred in the region off transect 83, as well as transects 87 and 88. The rank differences between transects were highly significant ($p<0.001$) based on the Kruskal-Wallis test as described above (Table 7). The longshore rank of anchovy larvae was related to the longshore rank of anchovy eggs ($p<0.20$) based on the Kendall coefficient of concordance ($w=0.80$) (Siegel 1956). Also, monthly mean egg abundance corresponded reasonably well with mean larval abundance (Figure 7).

Comparisons of egg abundance between ICHS and CalCOFI regions require additional data. Since the 1980 CalCOFI cruises were not sorted for eggs, data from only five concurrent cruises were available. The CalCOFI 0.505-mm mesh net may underestimate egg abundance by a factor of three or more as a result of extrusion, compared to the 0.333-mm mesh net used by ICHS (Smith, P. 1975. Time series of the abundance of anchovy eggs in the California Current region. Admin. Rep. Unpub.).

Pacific Sardine Larvae

Sardine larvae occurred infrequently during most months. Overall, 18 percent of the 861 ICHS samples captured sardine, but estimates of abundance during some months may be reliable only on a presence/absence basis. However, the increase in the number of stations within the ICHS region where sardine larvae occurred between 1978-79 and 1979-80 is noteworthy. Tables 3 and 4 suggest that sardine may have moved from offshore in 1978 to onshore during 1979, but this observation is based on only eight occurrences within the CalCOFI region.

The abundance of sardine larvae as a function of bottom depth within the ICHS region as shown in Figure 8 was based on 453 samples with 73 occurrences, i.e., the same sample data set used to summarize anchovy egg and larval abundance in Figures 3 and 6. These data indicate that the mean density of larvae was highest at the 15-m isobath.

Between June 1978 and July 1979, sardine larvae were found most often along transects 87, 88, 93, and

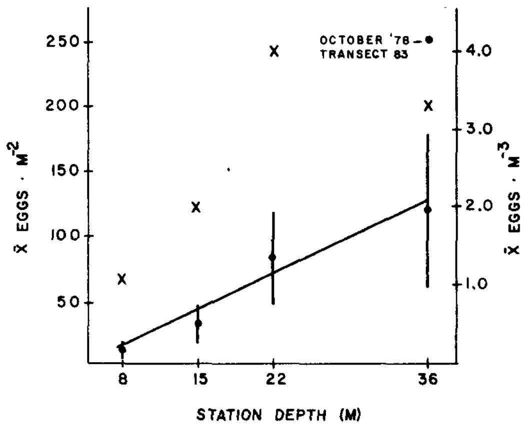

Figure 6. Average abundance per m² and 95 percent confidence intervals of northern anchovy eggs by station depth within the ICHS region ($Y=-22.03+4.12X$). The points and X's represent data from stations as described in Figure 3 with one exception: the datum from October 1978 transect 83, 36-m isobath was not included, as indicated. Inclusion of the one large sample gives a mean of 7.59·m⁻³ for the 36-m isobath.

95; no larvae were found north of transect 85. By September and October 1979, sardine larvae were captured at ICHS stations throughout the bight. Transects from Santa Monica Bay to Seal Beach yielded frequent catches during 1980 (Table 8). A noteworthy peak in estimated abundance in May 1980 resulted primarily from a large number of larvae at the 22-m

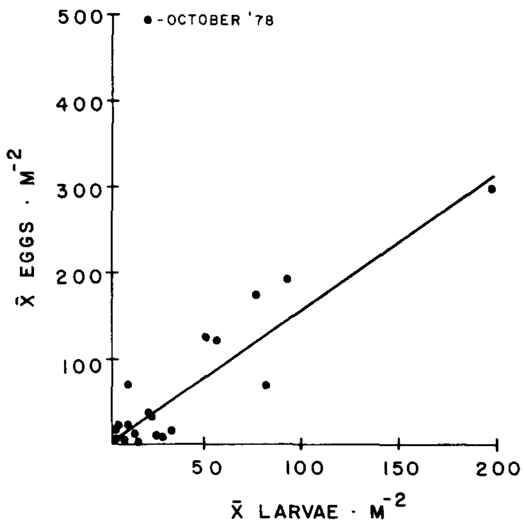

Figure 7. Average abundance of northern anchovy eggs versus larvae for each ICHS cruise ($Y=3.51+1.58X$; $r^2=0.84$). The October 1978 data were omitted.

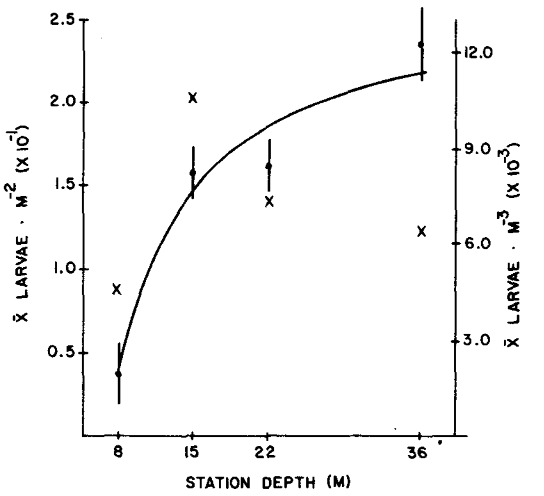

Figure 8. Average abundance per m² and 95 percent confidence intervals of Pacific sardine larvae by station depth within the ICHS region (Y=0.27-1.88/X; r²=0.95). The points and X's represent data from stations as described in Figure 3.

TABLE 8
Transect Data on Pacific Sardine Larvae Abundance along 8-m and 22-m Isobaths within the ICHS Region

	Phase I & II			Phase II		
Transect	# Sta./ positive	x̄ larvae ·m⁻²	Std. dev.	#Sta./ positive	x̄ larvae ·m⁻²	Std. dev.
80	40/01	0.005	0.034	24/01	0.009	0.04
DR	—	—	—	24/01	0.01	0.05
81.5	40/02	0.01	0.05	24/02	0.02	0.07
RN	—	—	—	24/05	0.07	0.16
83	40/06	0.29	0.98	24/06	0.48	1.24
OB	—	—	—	24/04	0.06	0.17
85	40/03	0.14	0.73	24/02	0.22	0.94
MU	—	—	—	24/07	0.35	0.87
87	38/14	0.44	1.10	24/11	0.65	1.34
RB	—	—	—	24/12	0.55	1.22
PV*	—	—	—	24/12	0.72	1.55
88	40/10	0.85	3.93	24/09	1.40	5.04
BA	—	—	—	24/04	0.09	0.29
90*	40/04	0.04	0.15	24/03	0.05	0.16
SO	—	—	—	24/03	0.05	0.14
91	40/01	0.05	0.34	24/01	0.09	0.44
CD	—	—	—	24/05	0.08	0.18
93	39/05	2.17	12.41	24/03	3.43	15.80
MB	—	—	—	24/06	0.26	0.88
95	40/06	0.16	0.44	24/04	0.15	0.41

*Data from 15-m isobaths substituted for unavailable 8-m data.

station off Del Mar. The Kruskal-Wallis test showed that transect differences were significant ($p<0.01$).

The overall temporal abundance of sardine larvae within the ICHS region is of interest, especially as it compares with the abundance of anchovy eggs and larvae (Figure 9). If one considers the monthly time series during 1979-80, when the frequency of sardine occurrence was relatively high (and if one ignores the one large May 1980 sample), sardine larvae were most abundant during late summer and fall; anchovy were least abundant during this same period. Ahlstrom (1967) showed that (during the 1950s) sardine spawning during the second half of the year was confined to a southern population and to waters off central Baja California. One might speculate that the relatively large occurrence of sardine larvae in the late summer and fall indicated that some southern fish had moved north and contributed to the peak abundance of sardine larvae off southern California. If a similar seasonal spawning cycle persists in subsequent years, CalCOFI surveys conducted during the first half of the year to monitor anchovy spawning may miss peak abundance of sardine larvae off southern California.

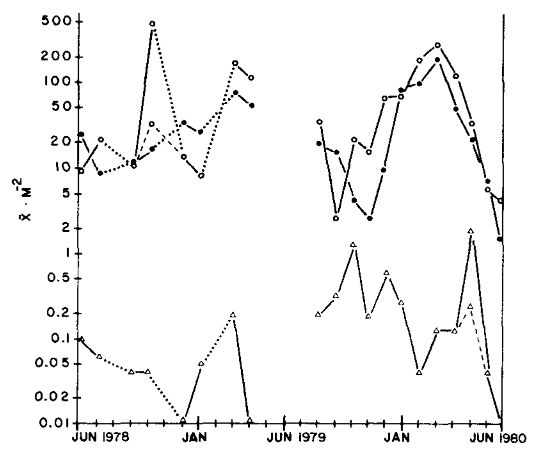

Figure 9. Temporal distribution of northern anchovy eggs (circles), larvae (dots), and Pacific sardine larvae (triangles) within the ICHS region. Dotted lines span months without data. Dashed lines indicate exclusion of unusually large samples from October 1978 transect 83, 36-m isobath (anchovy eggs) and May 1980 transect 93, 22-m isobath (sardine larvae).

DISCUSSION

The spawning habitat of the central subpopulation of northern anchovy extends over 500,000 km² of ocean—roughly between central Baja California and central California—but changing environmental factors apparently restrict the majority of spawning activity to much smaller regions during any one season. Major onshore-offshore and north-south shifts in larval abundance are evident during some years (Hewitt 1981; Smith and Eppley 1981). Broad temporal and spatial variability is a recurring feature of northern anchovy spawning; 20 months of ICHS data spread over 26 months should be interpreted in this context.

Since 1966, the area between Pt. Conception and

San Diego (primarily region 7) has accounted for an average of 64 percent of all larvae from the central subpopulation (Hewitt 1981). Based on the above percentage and the ICHS census estimates, about 2 percent of all anchovy larvae spawned by the central subpopulation were found in the ICHS region. Because densities of anchovy larvae were comparable in concurrent ICHS and CalCOFI cruises, inclusion of ICHS data with existing CalCOFI region 7 data would do little to alter overall abundance estimates used for biomass calculations (Pacific Fishery Management Council 1978). We conclude that the nearshore region off southern California was not a preferred habitat for the adult spawning biomass of northern anchovy during 1978-80. Smith and Duke (1975) reached a similar conclusion on the basis of CalCOFI cruises that sampled nearshore stations during 1964.

Anchovy spawning activity in the ICHS region indicates activity in larger CalCOFI regions. For example, changes in total number of larvae in region 7 were reflected by proportional changes in the ICHS region (Figure 2). Moreover, average density of larvae in ICHS samples during 1979-80 (Phase II) increased 31 percent compared to 1978-79 (Phase I); CalCOFI estimates of larval abundance for the entire central stock increased 36 percent during the same period (Stauffer and Picquelle 1981).

The apparent increase of sardine larvae in nearshore waters is of interest, but data are too infrequent to estimate what proportion of the larvae were spawned in respective ICHS and CalCOFI regions.

A direct relationship is presumed to exist between the abundance of planktonic eggs and larvae of northern anchovy and Pacific sardine and the size of their respective spawning stocks (Smith 1972; Smith and Eppley 1981; Parker 1980). However, numbers of eggs and larvae that survive to recruitment may vary independently of stock size, apparently influenced by environmental factors that are not understood or measured (Lasker and Smith 1977; Lasker 1978; Smith 1978; Bakun and Parrish 1980). The number of larvae that survive to recruitment within the shallow coastal region, i.e., the region's importance as a nursery ground, is not yet clear. Recruitment from any particular region may not be a direct function of the abundance of eggs or young larvae within the area because the environmental factors that favor spawning of adult anchovy (temperatures of 13-18°C and an abundance of available calories, such as large zooplankters) may not coincide with the environmental requirements for larval survival, which include patches of unarmored dinoflagellates or copepod nauplii in a stable ocean, and the absence of predators such as certain large zooplankters and adult anchovy (Hewitt 1982). Currents might transport eggs or young larvae away from spawning grounds to areas favorable or unfavorable for survival (Hunter 1977; Lasker and Smith 1977; Lasker 1978; Hewitt and Methot 1982).

The abundance of eggs and larvae within the ICHS region was consistently greater in certain areas. Transects within the Santa Barbara Channel from Rincon through Ormond Beach were important regions of anchovy spawning, as were transects off Playa Del Rey and Seal Beach. Sardine larvae occurred most frequently at transects throughout Santa Monica Bay and downcoast off Palos Verdes and Seal Beach. Cojo Bay yielded the least anchovy and sardine.

A discussion of environmental features common to the nearshore transects where large numbers of eggs and larvae were found is beyond the scope of this paper; indeed, such a discussion would be premature until we describe how the length-frequencies of the larvae vary between transects; i.e., are large larvae found consistently along certain transects?

Preliminary length-frequency data from ICHS stations show relatively large numbers of 20-30-mm anchovy larvae; larvae in similar size classes are virtually nonexistent in CalCOFI samples (Hewitt, pers. comm.).

We emphasize that the inherent imprecision of sampling fish eggs and larvae over wide areas leads to biases that must be identified and, if possible, quantified before one can understand the relative nursery function of the ICHS nearshore region. For northern anchovy and sardine larvae, these biases may include escapement and extrusion through the meshes of the net and avoidance of the net mouth. These and other factors, such as temperature, that result in sampler catch bias have been discussed by Zweifel and Smith (1981), who offer larval size-specific adjustment factors for correcting raw survey data. Hewitt and Methot (1982) have recently adopted these techniques for 1978 and 1979 CalCOFI data.

If the number of surviving larvae is proportionally greater, relative to numbers of eggs spawned, in the nearshore region versus offshore areas, or between nearshore transects, the techniques of Zweifel and Smith (1981) should be sensitive to such differences. We plan to test these hypotheses in the near future.

ACKNOWLEDGMENTS

We gratefully acknowledge the technical assistance of the ships' crews and laboratory staffs involved with the arduous tasks of collecting, sorting, and identifying ichthyoplankton from CalCOFI and ICHS surveys. Gerald McGowen supervised the sorting and taxonomic standardization of all ICHS samples. We thank Robert Lavenberg for his efforts as coprincipal investigator of the ICHS project.

Donna Cooksey and T.J. Mueller assisted in compiling and summarizing the ICHS data. Richard Charter and Roger Hewitt helped compile the CalCOFI data. We thank an unnamed reviewer for suggestions that improved the original manuscript. The senior author is indebted to Reuben Lasker and other staff at the NMFS Southwest Fisheries Center for providing office space and a stimulating atmosphere in which to work.

The ICHS project was supported by the Southern California Edison Company and by the NOAA Office of Sea Grant, Department of Commerce, under grant numbers 04-8-M-01-186, NA79AA-D-00133, and NA80AA-D-00100.

LITERATURE CITED

Ahlstrom, E.H. 1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. U.S. Fish Wildl. Serv., Fish. Bull. 60:107–146

———. 1966. Distribution and abundance of sardine and anchovy larvae in the California Current Region off California and Baja California, 1961–64: a summary. U.S. Fish Wildl. Serv., Spec. Rep., Fish. 534, 71 p.

———. 1967. Co-occurrences of sardine and anchovy larvae in the California Current Region off California and Baja California. Calif. Coop. Oceanic Fish. Invest. Rep. 11 (1 July 1963-30 June 1966):117–135.

Arthur, D. 1977. Distribution, size and abundance of micro-copepods in the California Current system and their possible influence on survival of marine teleost larvae. Fish. Bull., U.S. 75:601–611.

Bakun, A., and R. Parrish. 1980. Environmental inputs to fishery population models for eastern boundary current regions. Pp. 67-104 *in* Workshop on the effects of environmental variation on the survival of larval pelagic fishes. FAO Intergovernmental Oceanographic Commission, Workshop Rep. 28, 323 p.

Beers, J., and G. Stewart. 1967. Microzooplankton in the euphotic zone at five locations across the California Current. J. Fish. Res. Board Can. 24:2053–2068.

Brewer, G., R. Lavenberg, and G. McGowen. 1980. Oceanographic features and associated ichthyoplankton distribution in the shallow Southern California Bight. Calif. Coop. Oceanic Fish. Invest., Ann. Conf., 20-23 October 1980, Idyllwild, Calif.

Eppley, R., C. Sapienza, and E. Renger. 1978. Gradients in phytoplankton stocks and nutrients off southern California in 1974–76. Estuar. Coast. Mar. Sci. 7:291–301.

Hewitt, R. 1981. Distributional atlas of fish larvae in the California Current region: northern anchovy, *Engraulis mordax*, Girard, 1966-1979. Calif. Coop. Oceanic Fish. Invest. Atlas.

———. 1982. Spatial pattern and survival of anchovy larvae: implications of adult reproductive strategies. Ph.D. dissertation, University of California, San Diego. 187 p.

Hewitt, R., and R. Methot. 1982. Distribution and mortality of northern anchovy larvae in 1978 and 1979. Calif. Coop. Oceanic Fish. Invest. Rep. 23:(this volume).

Hunter, J. 1977. Behavior and survival of northern anchovy *Engraulis mordax*, larvae. Calif. Coop. Oceanic Fish. Invest. Rep. 19:138–146.

Jones, H. 1971. General circulation and water characteristics in the Southern California Bight. So. Calif. Coastal Water Res. Proj. Los Angeles, Calif., 37 p.

Kleppel, G. 1980. Nutrients and phytoplankton community composition in southern California coastal waters. Calif. Coop. Oceanic Fish. Invest. Rep. 21:191–196.

Kramer, D., M. Kalin, E. Stevens, J. Thrailkill, and J. Zweifel. 1972. Collecting and processing data on fish eggs and larvae in the California Current region. NOAA Tech. Rep., NMFS Circ. 370, 37 p.

Lasker, R. 1978. The relation between oceanographic conditions and larval anchovy food in the California Current: identification of factors contributing to recruitment failure. Rapp. P.-v. Réun. Cons. int. Explor. Mer 173:212–230.

Lasker, R., and P. Smith. 1977. Estimation of the effects of environmental variations on the eggs and larvae of the northern anchovy. Calif. Coop. Oceanic Fish. Invest. Rep. 19:128–137.

McEwen, G., M. Johnson, and T. Folsom. 1954. A statistical analysis of the performance of the Folsom plankton splitter based upon test observations. Arch. Meterol. Geophy. Bioklimatol. (A Meterol. Geophys.) 7:502–527.

McGowan, J., and D. Brown. 1966. A new opening-closing paired zooplankton net. Scripps Institution of Oceanography, SIO Ref. Rep. (66–23).

Pacific Fishery Management Council. 1978. Northern anchovy fishery management plan. Fed. Register 43(141), Book 2:31655–31879.

Parker, K. 1980. A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. Fish. Bull., U.S. 78(2):541–544.

Siegel, S. 1956. Non-parametric statistics for the behavioral sciences. McGraw-Hill, New York, 312 p.

Smith, P. 1972. The increase in spawning biomass of northern anchovy, *Engraulis mordax*. Fish. Bull. U.S. 70(3):849–874.

———. 1978. Biological effects of ocean variability: time and space scales of biological response. Rapp. P.-v. Réun. Cons. int. Explor. Mer 173:117–127.

Smith, P., and S. Duke. 1975. Nearshore distribution of northern anchovy eggs and larvae *(Engraulis mordax)*. Southwest Fishery Center, Admin. Rep. LJ–75–58, 16 p.

Smith, P., and R. Eppley. 1981. Primary production and the anchovy population in the Southern California Bight: comparison of time series. Limnol. Oceanogr. 27(1):1–17.

Smith, P., and S. Richardson. 1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fish. Tech. Pap. 175, 100 p.

Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: implications for water quality management. Three-year report of the Southern Calif. Coastal Water Res. Proj., 531 p.

Stauffer, G., and K. Parker. 1980. Estimate of the spawning biomass of the northern anchovy central population for the 1978–79 fishing season. Calif. Coop. Oceanic Fish. Invest. Rep. 21:12–16.

Stauffer, G., and S. Picquelle. 1981. Estimate of the spawning biomass of the northern anchovy central subpopulation for the 1980–81 fishing season. Calif. Coop. Oceanic Fish. Invest. Rep. 22:8–13.

Tsuchiya, M. 1980. Inshore circulation in the Southern California Bight, 1974–1977. Deep Sea Research 27:99–118.

Vrooman, A., P. Paloma, and J. Zweifel. 1980. Electrophoretic, morphometric, and meristic studies of subpopulations of northern anchovy, *Engraulis mordax*. Calif. Fish and Game 67(1):39–51.

Winant, C., and A. Bratkovich. 1981. Temperature and currents on the southern California shelf: a description of the variability. J. Phys. Oceanog. 11:71–86.

Zweifel, J., and P. Smith. 1981. Estimates of abundance and mortality of larval anchovies (1951–75): application of a new method. Rapp. P.-v. Réun. Cons. int. Explor. Mer 178:248–259.