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Spatial and Temporal Distribution of Zooplankton Biomass in the Gulf of Tehuantepec, Mexico[1]

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ABSTRACT: Spatial and temporal zooplankton biomass distribution obtained during three oceanographic cruises in the Gulf of Tehuantepec, Mexico, located between 14°30′–16°12′ N and 92°00′–96°30′ W, in the eastern tropical Pacific Ocean in January, May, and November, 1989, is presented. Samples were obtained by double-oblique hauls with a 333–505 μm bongo net. The study was done with samples from the 333-μm net, extrapolating the values to g/100 m^3 of wet weight. In January, values between 78 and 3,340 g/100 m^3 were found; results in May were between 143 and 6,920 g/100 m^3; and in November, between 27 and 2,290 g/100 m^3. We consider that the distributions obtained in January and in November were induced by upwelling and the contribution of the coastal lagoons. In May, zooplanktonic biomass was determined by the prevailing currents that ascend over the Chiapas continental slope.

TUNA, ANCHOVIES, SARDINES, squid, and shrimp have been the subject of important fisheries developed in the Mexican Pacific Ocean, like those established long ago from the Equator to California. Institutions such as Inter-American Tropical Tuna Commission (IATTC), the California Cooperative Fisheries (CalCOFI), and others in the Tuna Oceanography Research program of the Scripps Institution of Oceanography, have developed oceanographic study programs for this area; we know that important oceanographic events take place in the Gulf of Tehuantepec, such as those pointed out by Roden (1961), Blackburn (1962), Wyrtki (1965), Secretaría de Marina (1978), Weaks (1985), Clarke (1988), Legeckis (1988), Alvarez et al. (1989), Lavin et al. (1992), and Barton et al. (1993). Although these institutions have provided the scientific knowledge necessary to study the conditions under primary fisheries development, not enough research attention has been given to other communities, population dynamics, and ecological aspects. Furthermore, there are only a few papers describing communities of the Gulf of Tehuantepec as the benthic distribution of foraminifers, mollusks, crustaceans, and fishes (Secretaría de Marina 1980, Sosa-Hernández et al. 1980, Carvacho and Haasman 1984, Bianchi 1991) and the phytoplankton community structure (Hernández-Becerril 1993). In addition to these, there are investigations on the analysis of the spatial distribution of higher zooplanktonic taxa by Secretaría de Marina (1978); on the systematics and distribution of the Copepoda (Alameda-de la Mora 1980); on the distribution of the family Euphausiidae (López-Cortés 1990, Färber-Lorda et al. 1994); and on the distribution, morphology, and systematics of jellyfishes in the outer portion of the gulf (Segura-Puertas 1984). Although this community is the base of many fisheries, little information on zooplankton exists for this area.

The purpose of our study was to increase

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our knowledge of the spatial and temporal distribution of the zooplankton biomass (ZB) by three sampling cruises, in January, May, and November in 1989, in the Gulf of Tehuantepec and relate the information to surface temperature and ocean currents.

MATERIALS AND METHODS

Study Area

The Gulf of Tehuantepec is located off southern Mexico in the EASTROPAC region between 14°30′–16°12′ N and 92°00′–96°30′ W (Figure 1). The climatic regimen is regarded as Aw″ or (w)ig: warm climate with two principal periods of rains, separated by a long dry period in the middle of the cold season and another short dry period in the middle of the rainy season (García-de Miranda 1981). The topographical configuration of the gulf was described by Carranza-Edwards et al. (1989), who indicated that the continental shelf is narrower in the western portion, west of Salina Cruz, Oaxaca, and wider in the eastern portion of the gulf.

From October to February, cold winds called "Tehuanos" or "Tehuantepecos" (Alvarez et al. 1989, Carranza-Edwards et al. 1989) greatly influence the gulf (Clarke 1988). They come from the north and pass through the Isthmus of Tehuantepec, causing an acceleration up to 25 m/sec, and affect an area ca. 200 km wide and reaching as far as 500 km offshore (McCreary et al. 1989).

Sampling and Techniques

The zooplankton samples were obtained on three cruises of the R/V *El Puma* in 1989: 8–15 January (Tehuanos-I), 2–12 May (Mimar-V), and 11–20 November (Fiquimbi-I) (Figure 1). Double-oblique hauls followed the techniques of Smith and Richardson (1979). A 333–505 μm Bongo net was used in circular trajectories during the hauls at a towing speed around 1m/sec; both nets were equipped with a flowmeter. For each sampling, the maximum towing depth was estimated from the angle and length of the wire. The depth of the hauls varied according to the bathymetry, reaching at least 200 m when it was possible, to minimize the day-night migration effect: 11–200 m during Tehuanos-

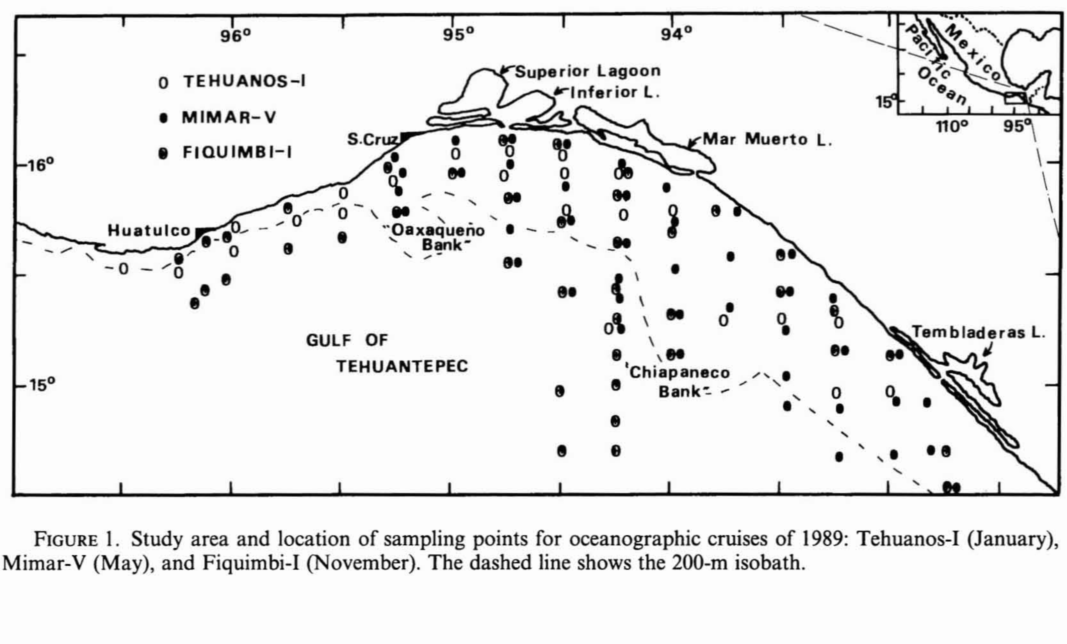

FIGURE 1. Study area and location of sampling points for oceanographic cruises of 1989: Tehuanos-I (January), Mimar-V (May), and Fiquimbi-I (November). The dashed line shows the 200-m isobath.

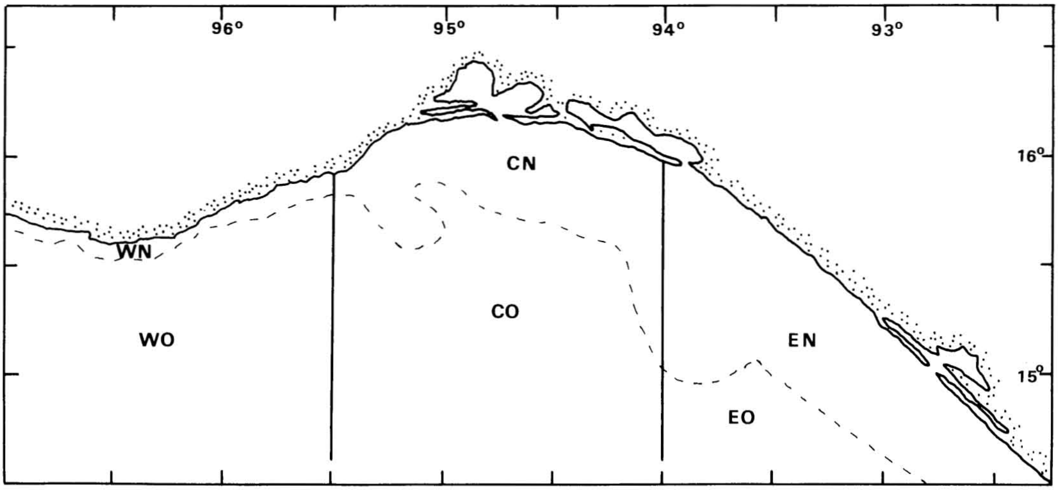

FIGURE 2. Zone division of the Gulf of Tehuantepec: EN, Eastern Neritic; EO, Eastern Oceanic; CN, Central Neritic; CO, Central Oceanic; WN, Western Neritic; WO, Western Oceanic. The dashed line shows the 200-m isobath.

I; 10–215 m during Mimar-V, and 6–200 m in the Fiquimbi-I cruise. The duration of each haul was variable (between 5 and 25 min), according to the observation of density of organisms at the previous station. Samples were fixed and preserved with a 4% sea water–formaldehyde solution and buffered with sodium borate according to the recommendations of Griffiths et al. (1976). The samples from the 333-μm net were used for the gravimetric determination of wet ZB; for this purpose, jelly organisms larger than 5 cm were removed from each sample. Afterward, zooplankton wet weight was determined, according to Beers (1981). ZB was expressed and extrapolated to g/100 m^3 units.

A convenient six-zone division of the Gulf of Tehuantepec was made for an easier interpretation of results: Eastern Neritic (EN), Eastern Oceanic (EO), Central Neritic (CN), Central Oceanic (CO), Western Neritic (WN), and Western Oceanic (WO) (Figure 2). To facilitate reporting of results, contour maps were prepared using the ZB values. Isotherm distributions for all three cruises were used to facilitate explanation of the ZB distribution patterns. When it was necessary to have additional support of certain biomass results, some vertical isotherm distributions were analyzed.

RESULTS

In January, ZB values between Huatulco (WN) and Mar Muerto Lagoon (CN) were from 3,485 to 78 g/100 m^3 (Figure 3, Table 1), diminishing toward the open sea, perpendicular to the coast. Gradients were strongest in western zones and weaker in central and eastern zones.

In May, the range of ZB values was much greater, from 16,924 to 143 g/100 m^3 (Figure 4, Table 2), exhibiting a gradient from the EO zone, near the edge of the Chiapaneco Bank, toward the northeast (EN), near Tembladeras Lagoon. In front of Mar Muerto Lagoon (CN), near the edge of the continental shelf, there was an area of high ZB concentration, whose highest value was 2,000 g/100 m^3, and this peak diminished greatly in the surrounding area.

In November, ZB values, from 2,293 to 27 g/100 m^3 (Figure 5, Table 3) were lower than those in January and May. Several areas of high ZB concentration were observed in

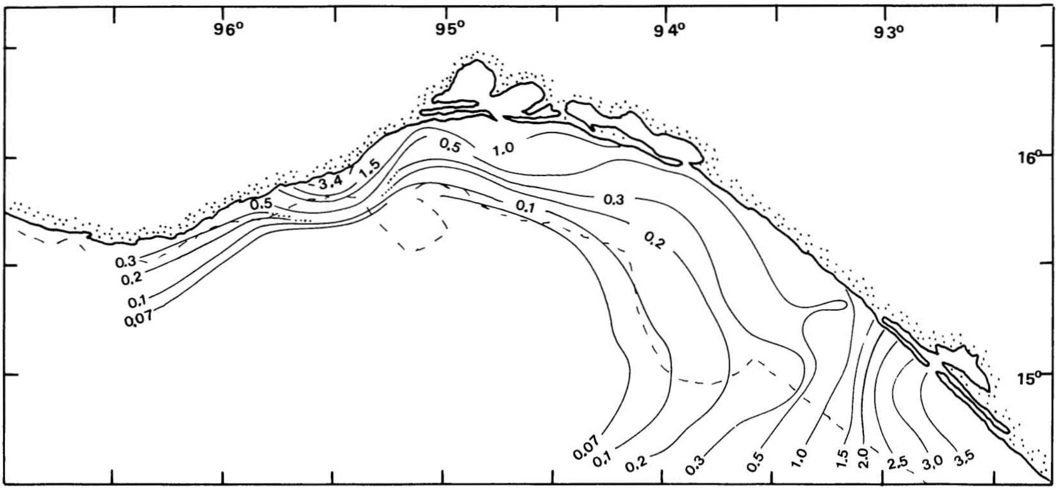

FIGURE 3. Spatial distribution of ZB as wet weight in January of 1989; the values are g × 10^3/100 m^3.

TABLE 1

TEHUANOS-I CRUISE (JAN. 1989), FIELD DATA AND ZOOPLANKTON BIOMASS VALUES

STATIONS N LAT.	STATIONS W LONG.	DAY	LOCAL TIME	BOTTOM DEPTH (m)	MAX. DEPTH SAMPLING (m)	SURFACE TEMP. (°C)	WET WEIGHT (g/100 m^3)
15°34.964′	96°29.990′	08	2055	1,295	160	25.8	357
15°35.832′	96°14.863′	09	0044	1,300	130	21.1	255
15°39.885′	96°00.010′	09	0645	360	162	25.8	247
15°48.850′	95°59.980′	09	0809	114	75	24.5	377
15°48.380′	95°42.410′	09	1635	200	157	24.5	188
15°55.090′	95°29.960′	09	1843	87	60	24.5	3,342
15°50.000′	95°30.200′	09	2202	146	95	24.5	484
15°59.970′	95°15.100′	10	0748	52	35	25.5	168
16°06.980′	95°00.120′	11	2008	39	16	24.9	496
16°06.860′	94°44.970′	11	2206	38	21	24.9	1,144
15°59.330′	94°46.800′	11	2341	75	60	24.9	386
15°50.000′	94°30.130′	12	0723	178	105	25.2	118
15°59.900′	94°30.150′	12	0904	50	30	26.1	713
16°07.090′	94°32.560′	13	0034	28	18	26.5	600
16°00.000′	94°14.920′	13	0438	33	15	26.5	484
15°50.070′	94°00.100′	13	0813	42	30	26.5	261
15°48.990′	94°13.880′	13	1139	52	40	26.5	267
15°19.085′	94°18.030′	14	1422	245	200	27.4	78
15°20.280′	93°46.000′	14	1926	120	75	28.0	223
15°20.019′	93°29.914′	14	2201	53	25	28.7	675
15°19.990′	93°14.940′	15	0231	30	11	28.6	283
15°00.230′	93°00.093′	15	0639	43	21	28.6	3,485
15°00.200′	93°14.830′	15	1035	60	46	28.6	214

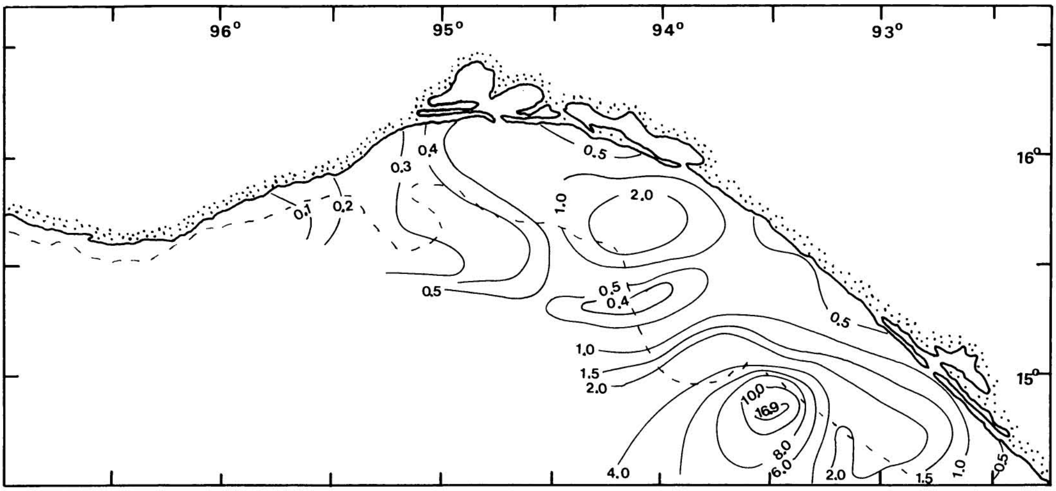

FIGURE 4. Spatial distribution of ZB as wet weight in May of 1989; the values are g × $10^3/100\ m^3$.

the CN zone, which fluctuated between 2,293 and 100 g/100 m^3 in front of Superior Lagoon and on the Chiapaneco Bank border, respectively. The lowest ZB values were found at Huatulco (WN and WO) and near Tembladeras Lagoon (EN).

DISCUSSION

Differences are evident between the spatial and temporal distribution of ZB density among the sampling months: intermediate ZB values were found in January, highest values in May, and lowest values in November.

In regard to the spatial distribution, in January (Figure 3) there were high ZB concentrations in the WN, EN, and EO zones. Lavin et al. (1992) and Färber-Lorda et al. (1994) reviewed hydrodynamic events that occurred a few days after our zooplankton sampling and found low temperatures at or near the surface, evidence of coastal upwelling. Moreover, Färber-Lorda et al. indicate an anticyclonic gyre in front of Huatulco. This is the same gyre that was mentioned by Roden (1961), Blackburn (1962), and Alvarez et al. (1989). We think that this gyre is responsible for the WN ZB distribution in our January results: the anticyclonic gyre pushes superficial isotherms toward the coast (as with 25.5°C in Figure 6), showing a notable coastal closeness, with resulting high ZB values (3,342 g/100 m^3) through biomass increase at trophic levels.

Because of an intense vertical mixture of subtropical subsurface water and tropical surface water originated by the "Nortes" winds as indicated by Färber-Lorda et al. (1994), values of ZB decreased offshore in the CN and CO zones. However, values in the EN zone, where there was a value of 3,485 g/100 m^3, coincide with the highest temperature values (28.5°C), showing that necessary nutrients to sustain this ZB through the trophic chain come from Tembladeras Lagoon.

For the May values, Vázquez-Gutiérrez and Alexander-Valdés (1993), who carried out physicochemical analyses of the results of the Mimar-V and Fiquimbi-I cruises, pointed out that the fluvial contribution has physicochemical repercussions along the coastal zone. We found that high ZB concentration areas (Figure 4) have a proportional relationship with the surface temperature distribution (Figure 7); the highest ZB values were in the EO zone, which also had the highest

TABLE 2

MIMAR-V CRUISE (MAY 1989), FIELD DATA AND ZOOPLANKTON BIOMASS VALUES

STATIONS				BOTTOM	MAX. DEPTH		
N LAT.	W LONG.	DAY	LOCAL TIME	DEPTH (m)	SAMPLING (m)	SURFACE TEMP. (°C)	WET WEIGHT (g/100 m³)
16°03.283′	95°16.853′	02	1405	38	23	—	232
16°00.577′	95°14.533′	02	1641	45	35	—	242
15°55.680′	95°15.381′	02	1923	85	73	—	265
15°50.694′	95°14.930′	02	0002	204	170	24.5	338
16°00.823′	95°00.010′	03	2355	60	40	26.5	415
16°08.990′	94°59.810′	04	0124	22	10	27.0	565
16°08.900′	94°45.750′	05	0234	25	15	27.0	372
16°02.890′	94°44.930′	05	0401	52	40	29.0	1,653
15°53.940′	94°44.890′	05	0613	200	190	28.0	283
15°45.061′	94°45.135′	05	1005	242	215	28.0	366
15°36.419′	94°44.854′	05	1456	171	160	—	394
15°26.591′	94°27.626′	05	1806	205	140	26.0	272
15°26.717′	94°15.370′	05	2029	241	140	28.0	217
15°47.937′	94°30.091′	05	2220	195	140	28.5	184
15°56.994′	94°30.071′	05	2350	52	30	28.0	1,460
16°07.430′	94°29.980′	06	0143	25	22	28.5	321
16°03.000′	94°14.990′	06	0339	27	22	23.0	318
15°54.530′	94°15.140′	06	0507	43	35	27.0	781
15°41.620′	94°15.060′	06	0705	155	145	28.0	4,469
15°29.649′	94°14.992′	06	0842	240	185	—	143
15°19.023′	94°15.040′	06	1258	248	185	—	354
15°11.634′	94°00.238′	06	1552	190	142	—	234
15°22.319′	94°00.016′	06	1835	203	140	29.5	469
15°34.343′	93°59.971′	06	2024	70	57	28.5	360
15°47.176′	94°00.020′	06	2343	42	22	29.0	4,870
15°56.386′	94°02.542′	07	0228	28	15	27.0	946
15°50.250′	93°43.060′	07	0600	27	19	28.0	519
15°37.553′	93°44.973′	07	0853	49	35	29.0	612
15°24.091′	93°45.002′	07	1140	80	64	—	519
15°05.590′	93°29.940′	08	1635	120	115	29.0	539
15°17.840′	93°29.984′	08	1806	54	29	29.0	1,037
15°28.408′	93°30.049′	08	2043	39	21	29.0	793
15°38.384′	93°29.951′	08	2309	22	15	—	516
14°57.213′	93°29.560′	09	0746	205	195	28.0	16,924
15°26.110′	93°16.930′	10	0200	27	20	28.0	533
15°12.140′	93°15.080′	10	0456	35	25	27.0	696
14°56.387′	93°15.174′	10	0820	75	64	28.5	3,235
14°42.985′	93°15.081′	10	1007	192	142	—	1,050
14°30.022′	93°00.003′	10	1207	222	177	—	833
14°43.876′	93°00.006′	10	1359	64	55	—	3,369
15°11.050′	93°00.390′	10	1919	25	20	—	514
14°57.460′	92°51.230′	10	2231	27	15	—	1,356
14°45.338′	92°49.908′	11	0239	40	30	—	2,434
14°33.040′	92°44.947′	11	0410	69	60	—	671
14°30.220′	92°18.180′	12	0235	18	10	—	3,262

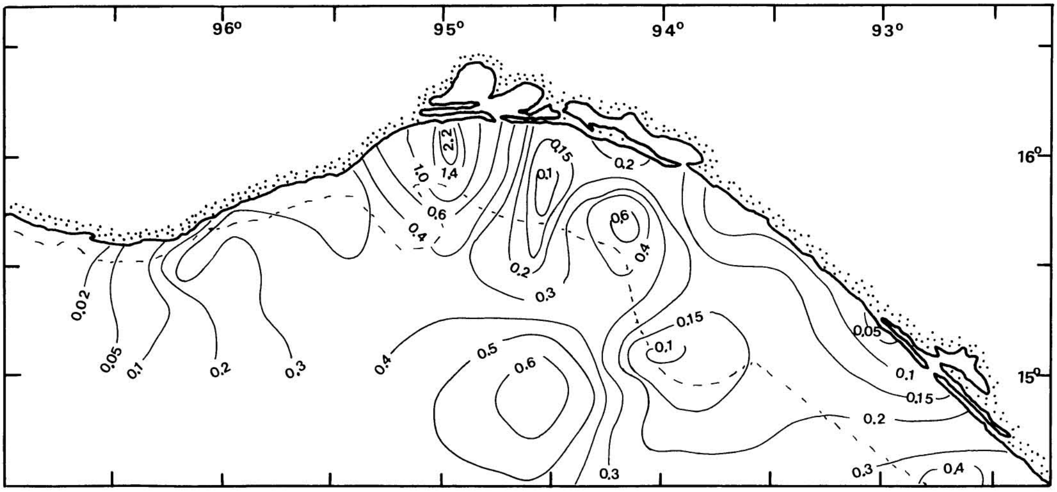

FIGURE 5. Spatial distribution of ZB as wet weight in November of 1989; the values are g × 10^3/100 m^3.

values of surface temperature. Other areas of ZB concentration, although lower than those in the EO zone, were observed in the CN and CO zones, which showed a gradual decrease in temperature.

To understand ZB distribution during the month of May, another aspect that should be considered is the water incursion toward the eastern portion of the continental shelf of the gulf (Wyrtki 1965); at that time, the current travels from Central America toward the northwest. When it arrives in the Gulf of Tehuantepec, it ascends over the continental shelf, causing nutrient enrichment that increases the phytoplanktonic abundance, which subsequently supports the zooplanktonic community that we recorded. We observed in the EO and EN zones the rise of the 18°C isotherm to 35-m depth; in the CN and WN zones, this isotherm registered at 60-m depth (Table 4). The combined effects of deep water ascending toward the neritic zone and fluvial contributions to the coastal zone in May cause high ZB in the EO, EN, and CN zones of the gulf.

In November, the upwelling phenomenon is present, detected by Vázquez-Gutiérrez and Alexander-Valdés (1993) as a minimal value of dissolved oxygen near the surface. We found that higher ZB values (Figure 5) correlated with areas of high surface temperature (Figure 8) and that these areas are associated with the drainage contribution of the lagoons in the CN zone. Blackburn et al. (1970) indicated that spatial differences in the density of organisms have strong relationships with physical changes in the ocean, because these changes greatly affect biological production; furthermore, those authors indicated that in the EASTROPAC region, areas of high density of organisms are associated with upwelling zones and broken thermoclines, generated by turbulence from wind action.

In January, the density and distribution of ZB, as in November, are the results of the combined effects of coastal upwelling and the drainage contributions of the lagoons. In May ZB density and distribution are affected mainly by advection because of the entrance of water to the Gulf of Tehuantepec and its ascent to the Chiapas continental slope.

ACKNOWLEDGMENTS

We wish to thank the Universidad Autónoma Metropolitana-Iztapalapa (UAM-I);

TABLE 3

FIQUIMBI-I CRUISE (NOV. 1989), FIELD DATA AND ZOOPLANKTON BIOMASS VALUES

STATIONS N LAT.	STATIONS W LONG.	DAY	LOCAL TIME	BOTTOM DEPTH (m)	MAX. DEPTH SAMPLING (m)	SURFACE TEMP. (°C)	WET WEIGHT (g/100 m³)
15°25.800′	96°10.040′	11	1300	4,000	200	29.5	134
15°37.146′	96°15.089′	11	1758	700	200	27.7	144
15°42.585′	96°07.762′	11	2013	159	90	27.8	27
15°29.274′	96°07.979′	11	0008	900	82	26.6	900
15°32.509′	96°01.978′	12	0204	360	77	25.5	160
15°43.614′	96°01.981′	12	0559	197	103	22.8	325
15°51.500′	95°45.000′	12	0832	73	45	—	166
15°39.932′	95°44.919′	12	1238	650	100	18.3	416
15°43.443′	95°30.127′	12	1502	250	100	14.5	274
16°01.967′	95°17.353′	13	0151	44.5	20	27.7	527
15°50.555′	95°15.192′	13	0832	260	75	25.8	271
16°01.026′	95°00.015′	13	1207	50	30	26.8	2,293
16°10.020′	94°46.009′	13	2015	20.7	13	28.3	341
15°54.126′	94°45.144′	13	2343	163	80	28.6	65
15°36.462′	94°45.105′	14	0304	175	95	28.68	128
14°45.154′	94°30.074′	18	2244	4,000	115	19.8	571
15°01.599′	94°30.722′	18	2003	1,700	172	21.0	809
15°28.051′	94°30.022′	16	1601	227	129	23.8	175
15°47.778′	94°29.966′	14	0717	195	140	29.12	130
16°08.660′	94°30.931′	14	1119	23.4	6	29.18	131
16°01.160′	94°12.723′	14	1512	28	10	30.34	302
15°54.573′	94°14.927′	14	1628	42	20	29.76	128
15°41.484′	94°15.058′	14	1931	150	69	29.9	995
15°29.600′	94°15.145′	14	2120	240	123	—	309
15°20.485′	94°14.964′	14	2255	240	75	28.97	385
15°11.275′	94°14.902′	15	0040	240	115	28.9	158
15°02.943′	94°14.964′	15	0229	260	115	28.9	60
14°53.223′	94°14.996′	15	0425	270	125	24.25	442
14°44.813′	94°14.795′	15	0630	1,250	172	24.26	200
15°45.154′	94°00.000′	19	0257	240	103	18.7	109
15°11.259′	93°59.933′	19	0520	193	130	19.3	99
15°50.641′	93°47.817′	19	2009	25	10	—	65
15°28.481′	93°29.975′	20	0059	38	18	24.3	210
15°38.402′	93°30.286′	19	2246	24	10	24.8	98
15°22.805′	93°15.430′	20	0520	26	10.6	21.3	70
15°12.025′	93°15.030′	20	0355	41	15	20.9	145
15°10.952′	92°59.964′	20	0809	24	8.6	19.5	44
14°45.049′	92°45.037′	20	1452	41	19.28	26.5	216
14°33.060′	92°45.144′	20	1654	56	32	25.2	455
14°21.052′	92°44.911′	20	1849	201	106	21.7	147

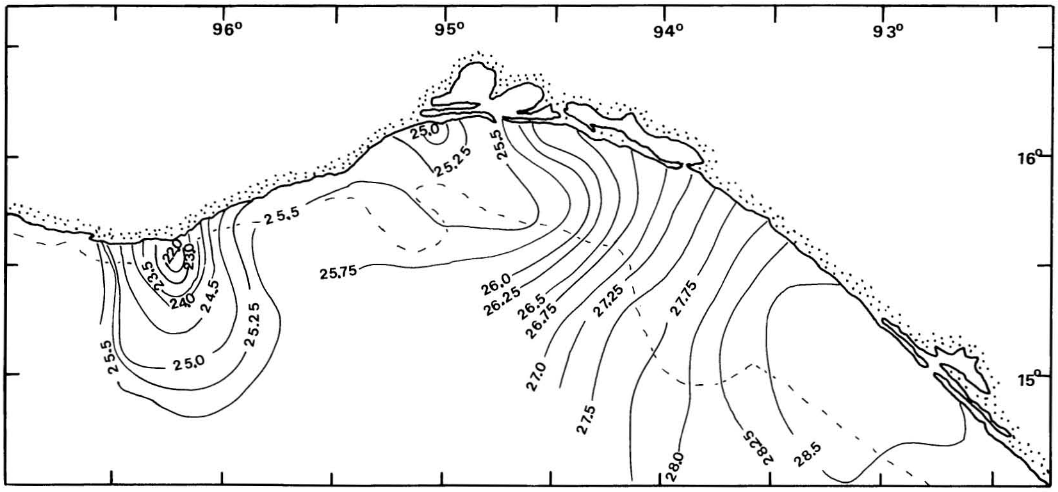

FIGURE 6. Spatial distribution of surface temperature (°C) in January of 1989.

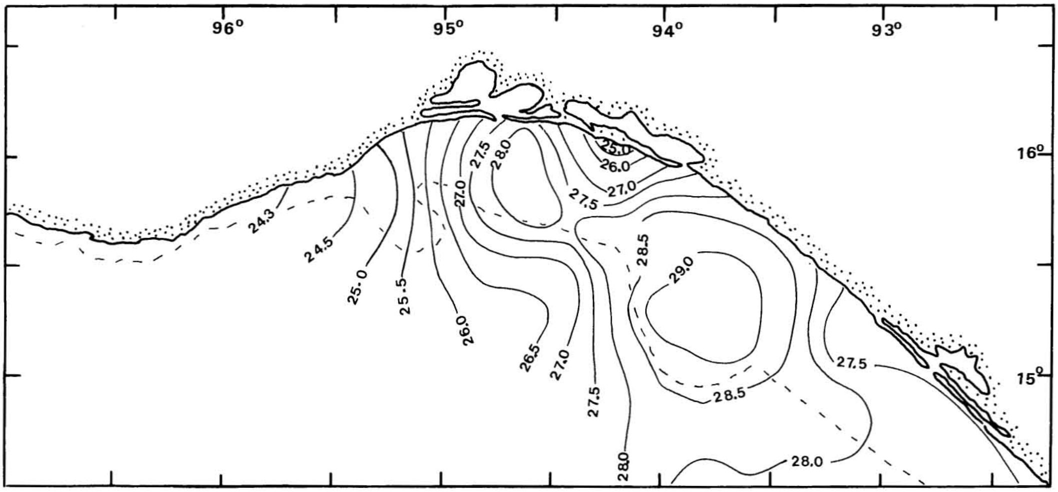

FIGURE 7. Spatial distribution of surface temperature (°C) in May of 1989.

TABLE 4

Isotherm Depths from Mimar-V and Fiquimbi-I Cruises

			ISOTHERM DEPTH[a] (m)		
CRUISE	DATE	ISOTHERM (°C)	EN	EO	WN
Mimar-V	May 1989	26	5	19	5
		24	9	24	5
		22	16	27	12
		20	22	40	44
		18	35	61	57
Fiquimbi-I	Nov. 1989	26	5	5	5
		24	5	5	5
		22	5	5	5
		20	5	5	5
		18	4	21	5
		16	8	28	5
		14	12	43	5
		13	50	—	16
		12	120	—	33
		10	—	—	85

[a] EN, Eastern Neritic zone; EO, Eastern Oceanic zone; WN, Western Neritic zone.

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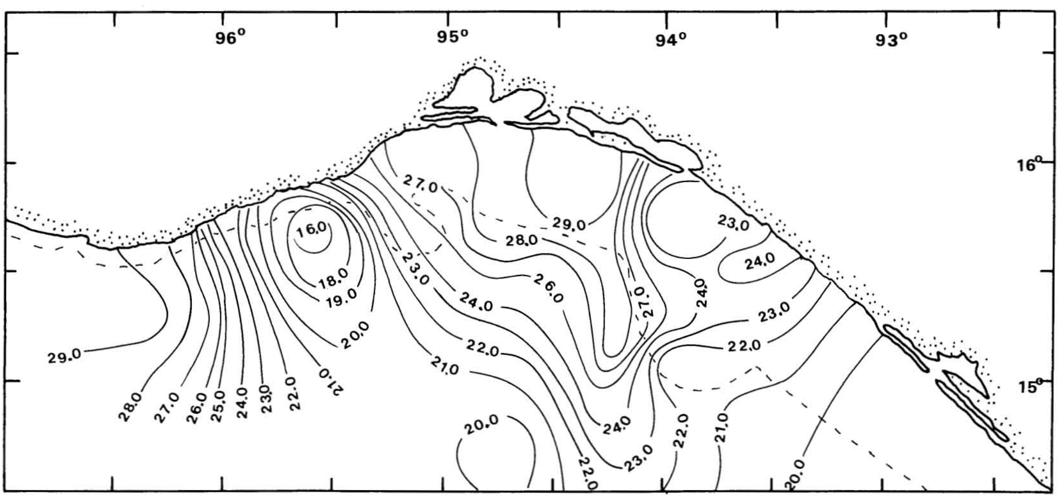

FIGURE 8. Spatial distribution of surface temperature (°C) in November of 1989.

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