Infaunal macrobenthos off Cap Blanc, Spanish Sahara

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ABSTRACT

Cap Blanc, Spanish Sahara is characterized by a nearshore benthic faunal province physically controlled by rates of sedimentation, conservatively estimated at 4 cm/yr, with a gradual transition across the continental shelf to a second province in a zone with high phytoplankton production of 2 gm C $m^{-2}d^{-1}$ induced by upwelling at the continental shelf's outer margin. Average wet weight biomass of the benthic infauna in both provinces was 34.7 gm m^{-2}. There were no marked or consistent variations in macrofaunal biomass or organic matter in the sediments with increased depth or distance from land. The absence of such a gradient is probably due to the persistence of the upwelling at the outer margin of the continental shelf. Standing stocks of polychaetes and bivalves are used to make rough estimates of production based on production/biomass ratios of congeners in the literature. Based on these estimates, production in the offshore upwelling province is somewhat greater than that in the nearshore province.

1. Introduction

For the past six years the Sahelian zone of West Africa has experienced a severe drought. The boundaries of the Sahara Desert are extending at a reported rate of 30 miles/yr (Wade, 1974) and prevailing northerly winds carry large quantities of sand out to sea. From 5 to 14 × 10^6 m^3/yr of sand were estimated to move south across an 80 km line extending from Cap Blanc east into Spanish Sahara, meaning that the region of ocean called Banc d' Arquin in Mauritania receives this material, some of which is presumed to escape to the deep-sea via the submarine canyons bordering this semienclosed bay system (Sarnthein and Walger, 1974; Senin, 1974). High sedimentation rate, associated with the drought conditions, is not the only meso-scale phenomenon influencing the bottom in this region. In addition a seasonal upwelling phenomenon occurs off the coast of Cap Blanc, and presumably a large fraction of the organic matter produced in the upwelling region is buried in the bottom or nourishes the benthos. There have been, however, no quantitative investigations of the benthos off Cap Blanc. Therefore we undertook as part of the JOINT I expedition (IDOE, Coastal Upwelling Ecosystems Analyses) an investigation of the bottom invertebrate communities and sediments off Cap Blanc.

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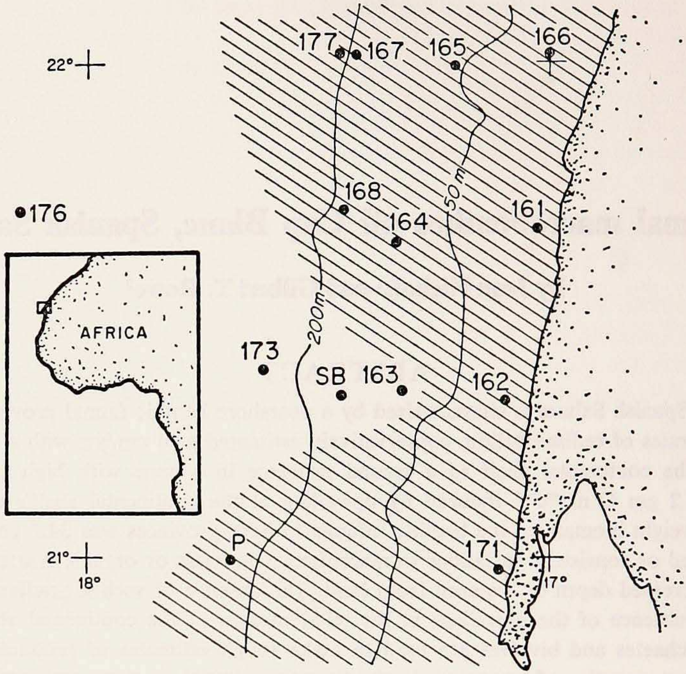

Figure 1. Locations of quantitative benthic samples. Shaded area is greater than 20 g/m² wet weight.

2. Methods

Samples were collected during R.V. *Atlantis II* Cruise 82, Leg 4 (of the JOINT I Expedition) and from R.V. *Almoravide*, during April and May, 1974, at locations depicted in Figure 1. A 0.1 m² van Veen grab was used to take 2 to 3 samples at each station. The samples were sieved through 0.42 mm mesh screen and preserved in 10% buffered formalin. They were later sorted to major groups in the laboratory using a dissecting microscope. Wet weights of the preserved animals were obtained by blotting all individuals of each species on a paper towel for three minutes and then weighing them on a Mettler microbalance. After weighing, the animals were separated to species and stored in 70% ethanol. Nematodes were dehydrated in glycerin and fixed in glycerin mounts for identification. Biomass of nematodes was not estimated.

A species list is not provided because of limited space, and as no invertebrate systematic specialists confirmed our identifications, we would present such a list only with trepidation. We are confident that our separations to species for the most part are valid. Our species list is available on request from the first author.

Shannon-Wiener Information Function was used to determine species diversity (Shannon and Wiener, 1963). Evenness of distribution (*E/S*) was also determined as e^H/S. Percent similarity was determined by the index of Whittaker and Fairbanks (1958):

$$S = 100 - 0.5 \sum_{1}^{N} |P_{ij} - P_{ik}| \text{ where } n = \text{total}$$

number of species, P_{ij} and P_{ik} are proportions of the ith species in the jth and kth samples. The 25 numerically most abundant species in all the samples were used in the percent similarity analysis.

Organic carbon and nitrogen content of the sediments were determined with a Perkin Elmer #240 Elemental Analyzer, after phosphoric acid removal of carbonate.

Sedimentation rates have been estimated using arrays of sediment traps suspended at various heights off bottom. The traps were cylinders 9.5 cm in diameter and 14 cm deep. They were attached in pairs to a line anchored to the bottom and held vertical and taut by a subsurface float. The traps were covered with water-tight plastic lids and set in place by SCUBA divers. Once on bottom the lids of the traps were carefully removed by the divers. At the end of the deployment the SCUBA divers carefully replaced the lids and brought the arrays to the surface. The whole content of each trap was filtered through a 0.4 μ mesh glass fiber filter preweighed. The filters were dried and reweighed to provide an estimate of total particulate flux.

3. Results

Nearshore biomass was dominated by the bivalve *Tellina* sp. At the northern station the polychaete Onuphidae sp. c and the decapod *Pagurus pollicarus* also made major contributions to the total biomass. Northern midshelf station biomass was dominated by a holothurian of the order Dendrochirota, while southern samples were variously dominated by the polychaetes *Tharyx* sp., *Cirratulid* sp. c, *Cirratulis* sp.

The polychaetes, *Aphrodite* sp., *Chaetopterus* sp., *Hylionecia* sp., a Terebellidae, and the pelecypod *Macoma* sp. provided the largest percentage (20%-35% each) of the biomass. *Macoma* sp. also dominated the biomass in samples from station 173 (37% and 26% respectively).

Midshelf samples (St. 163 & 165) were numerically dominated by the polychaete species *Spio* sp. A. In all except one sample this species comprised 34%-54% of the population while the next most abundant species at any station contributed 8%-16%. The one exception was sample 165-1 where *Spio* sp. A was the most abundant species but contributed only 12% of the total number of individuals. In the nearshore samples (162 & 166) no single species contributed more than 18% of the total numerical abundance. *Spio* sp. A was always one of the three most abundant species in the samples. At the shelfbreak there were only two instances

Table 1. Benthic abundance and biomass (wet weight in grams/m²) of infauna greater than 0.42 mm.

Station	Depth (m)	No./m²	Biomass (gm/m²)	Biomass Ind.⁻¹ (mg)
161 A	30	7830	4.1	10.7
B	30	3410	46.8	
162 A	39	3400	15.7	
B	39	6890	27.1	4.4
C	39	5600	27.1	
163 A	62	22000	16.3	
B	62	10830	18.0	.61
C	62	35200	8.1	
164	90	15620	37.63	2.41
165 A	57	22380	94.4	2.8
B	57	23520	33.7	
166 A	35	7560	33.5	3.0
B	35	6280	7.6	
167 A	180	5530	24.3	5.3
B	180	6840	41.8	
168 A	180	4500	24.6	5.3
B	180	4220	21.7	
171 A	36	5700	17.5	4.0
B	36	7025	33.1	
173 A	482	2060	12.04	5.01
B	482	2930	17.10	
176	1830	1635	10.9	6.6
177	556	6770	31.6	4.6
P A	480	6290	25.6	4.8
B	480	7210	39.9	
SB A	100	1770	36.73	11.1
B	100	1750	2.35	

of a single species comprising more than 15% of the sample. In both samples from station 168 *Paraonis lyra*, a polychaete, comprised 20%-22% of the individuals. Further offshore, at station 173, the polychaetes *Paraonis lyra* and *Tharyx* sp. were numerically dominant, comprising not more than 14% of the assemblage.

The faunal data, converted to grams per square meter and density of individuals per square meter, have been tabulated (Table 1) and biomass was contoured (Fig. 1).

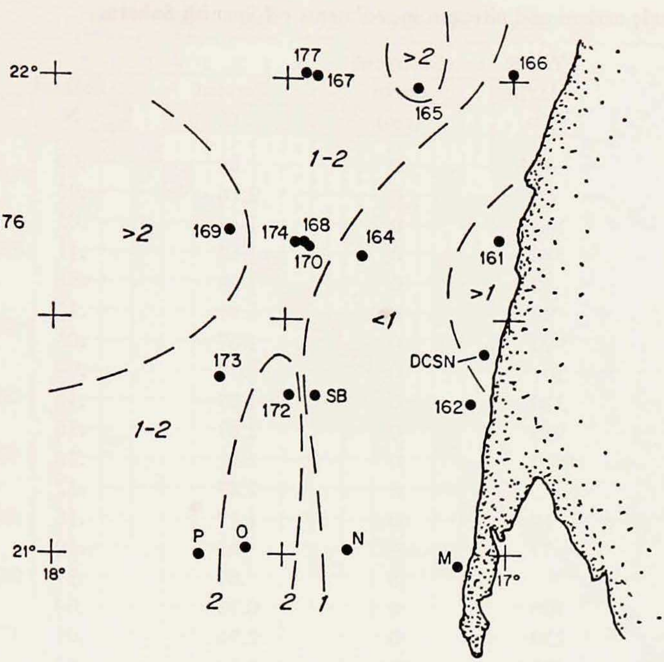

Figure 2. Locations of sediment samples for organic carbon and nitrogen off Spanish Sahara. Contours of percent organic carbon of dry sediment.

The average nearshore value was 36.3 gm m^{-2} while the average of the shelfbreak and midshelf stations was 33.2 gm m^{-2}. However, the usual distinct pattern of decreasing biomass with increasing distance from shore was not observed.

As for the organic carbon (Table 2), the lowest values ($<1\%$) were on the shelf and high values ($>2\%$) were found off the shelf, deep on the continental slope. Although the station with the lowest biomass was also the locale with the lowest sediment organic carbon, there was no general trend relating sediment organic carbon and biomass. We were surprised that this same station of low biomass had the highest average abundance for any station, because biomass and abundance are usually strongly correlated (Sanders, Hessler, and Hampson, 1965; Rowe and Menzel, 1971; Rowe, Polloni and Hornor, 1974).

Diversity based on numbers was lowest at the two midshelf stations and station 161 nearshore (Table 3). One exception, midshelf sample 165-1, had a greater diversity because of a decrease in numerical abundance of polychaete species *Spio* sp. A. Since numerical abundance was greater at the midshelf stations, yet species list length was similar for all stations, lower diversity midshelf must result from uneven distribution of individuals between the species present. Station 161 and midshelf E/S values were, with one exception, less than 0.25 (Table 3) while all

Table 2. Organic carbon and nitrogen in sediments off Spanish Sahara.

Station	Water depth (m)	Sediment depth (cm)	Percent C	Percent N	C/N
166	35	0	.61	.09	6.8
165	60	0	2.16	.03	72
167	180	0	1.49	.05	29.8
177	546	0	1.12	.11	10.2
161	22	0	1.03	.96	14.7
164	90	0	.91	.12	7.6
168	180	0	1.67	.03	55.7
170	101	0	.27	.04	6.8
174	320	0	1.25	.16	7.8
169	880	0	2.83	.36	7.9
176	1830	0	2.61	.38	6.9
		6	2.47	.32	7.7
DCSN	12	0	1.17	.16	7.3
162	33	0	.92	.10	9.2
		6	.88	.11	8.0
SBS	100	0	0.38	.04	9.5
172	230	0	2.33	.08	29.1
173	482	0	1.36	.17	8.0
M	36	0	0.90	.08	11.3
		6	1.02	.11	9.3
N	63	0	.7	.09	7.8
O	110	0	2.81	.05	56.2
P	480	0	1.27	.14	9.1

Table 3. Diversity and evenness values based on abundance for samples off Spanish Sahara.

Deep Station		Shelfbreak		Midshelf		Nearshore	
		167	3.637	165	3.671	166	3.020
			0.040		0.678		0.569
			3.267		2.423		3.403
			0.074		0.188		0.537
		168	3.320			161	1.216
			0.050				.025
			2.864				2.197
			0.050				0.196
173	3.186	SB	3.685	163	2.183	162	3.213
	0.733		0.664		0.189		0.621
	3.656		3.575		2.047		3.229
	0.553		0.605		0.215		0.549
					2.519		3.062
					0.234		0.737

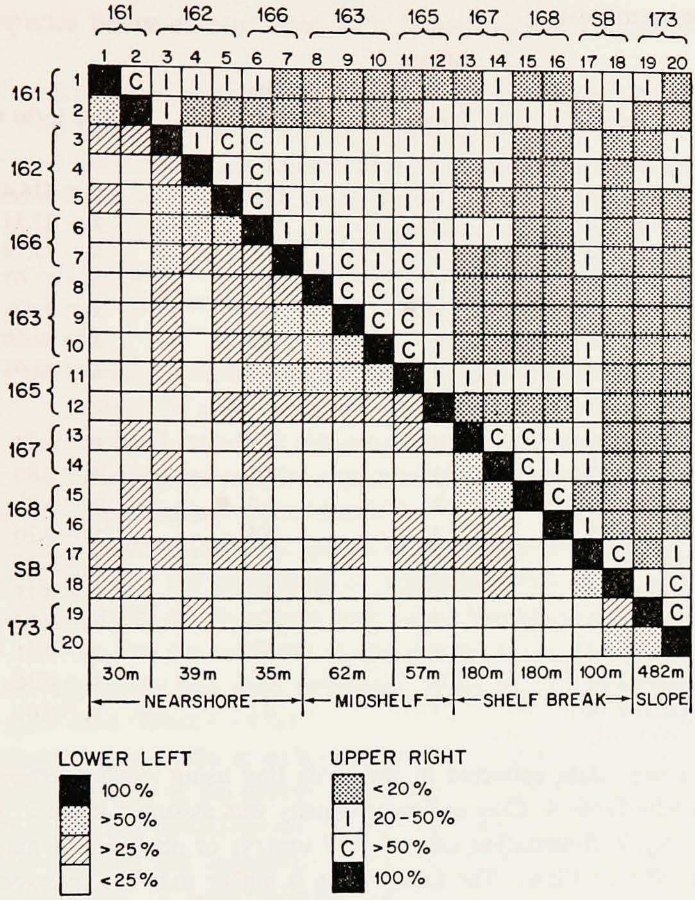

Figure 3. Benthic fauna percent similarity between stations off Spanish Sahara.

other *E/S* values were greater than 0.4. Results of the percent similarity index indicate that there are two more or less distinct faunal provinces (Figure 3). The nearshore-midshelf province "within province" similarity is greater than the "within province" similarity of the shelfbreak-offshore region. However, almost all stations had a high "within station" similarity.

The average rate of sedimentation, at Station 171, calculated for all traps higher than one meter above the bottom was 25.43 g/hr m^2 (Table 4). Assuming a quartz sand density of 2.5 g/cc gives a sedimentation rate of 10.2×10^{-4} cm/hr or 8.9 cm/yr. Since the prevailing winds blow most strongly during the day and all measurements were made during daylight, the measured rate may be higher than the actual rate. If the actual rate is arbitrarily assumed to be one half the measured rate, the result (4.4 cm/yr) is still a high rate of sedimentation.

Table 4. Sediment trap data.

Date	Meters off Bottom	Time (hrs)	Rate (g/hr m²)
Joint I			
April 74	1	12	$\bar{x}_2 = 216.43$
April 74	2	12	$\bar{x}_2 = 22.11$
May 74	2	4	$\bar{x}_2 = 15.19$
May 74	3	4	$\bar{x}_2 = 13.07$
May 74	4	4	$\bar{x}_2 = 8.00$
May 74	2	4.5	$\bar{x}_2 = 62.20$
May 74	3	4.5	$\bar{x}_2 = 32.01$
Buzzards Bay			
July 73	2	4.5	$\bar{x}_2 = 3.92$
July 73	3	4.5	$\bar{x}_2 = 2.86$
August 73	2	3.5	$\bar{x}_2 = 1.82$
August 73	3	3.5	$\bar{x}_2 = 0.70$
January 74	1	6	$\bar{x}_2 = 1.85$
January 74	2	6	$\bar{x}_2 = 0.75$
January 74	3	6	$\bar{x}_2 = 0.90$
July 74	3	5	$\bar{x}_4 = 0.41$
September 74	3	4	$\bar{x}_4 = 0.36$
November 74	3	4	$\bar{x}_4 = 0.01$

For comparison, data collected in Buzzards Bay using similar sediment traps is also presented in Table 4. Clay sediment density was assumed to be 2 g/cc, resulting in an average sedimentation rate of 4.55 mm/yr or an order of magnitude less than the rate off Cap Blanc. The latter value is higher than the average rate based on the age of Buzzards Bay and the total depth of its sediment (1.5 mm/yr, Hough, 1940), but agrees well with the thickness of layering in its upper few centimeters, prior to compaction.

4. Discussion

The two benthic faunal provinces suggested by the %-similarity indices probably exist in response to the environmental conditions. The nearshore province is physically controlled by sand blowing off the desert (Milliman, 1977). Sedimentation rates measured in the nearshore environment (approximately 8 cm/yr) are less than those shown experimentally in Buzzards Bay to prohibit escape from burial (Nichols *et al.*, in prep.). However, the constant expenditure of energy to escape burial could explain the observed small size of individuals nearshore. It has been suggested elsewhere that small size is an advantage when organisms are buried in fine sediments (Thayer, 1975). *Spio* sp. A dominant offshore was not eliminated from the nearshore community by burial, but the competitive advantages were shifted to species better able to cope with burial, sediment instability and high turbidity.

Lower diversity values at midshelf stations were caused by the dominance of *Spio* sp. A. Two other spionid species were also found in great numbers at these stations. Spionid polychaetes are known to feed by extending their palps into the water column and randomly waving them. Organic material collected by the palps is scraped off and ingested (Ms. Charlene Long, pers. comm.). This type of feeding would not be advantageous where a high concentration of terrigenous material is suspended in the bottom water and could account for the lower abundance in spionids nearshore.

Further evidence that feeding type influences community structure, in the nearshore-midshelf province, is seen in the nematode fauna. Nearshore the number of large nematodes (retained on a 0.42 mm-mesh screen) was very low. Samples 162-1 contained no such nematodes and the remaining four samples never had more than 12. Midshelf samples contained from 42 to 272.

Wieser (1952) has described four groups of nematodes based upon buccal structure. Types 1a and 1b are composed of organisms with small unarmed buccal cavities; types 2a and 2b are organisms with armed buccal cavities and some species are capable of extending the teeth out of the mouth. Types 1a and 1b dominate in soft mud and organically rich sand sediments, while types 2a and 2b dominate in organically poor sand (Wieser, 1952).

All nematodes found in the nearshore samples were members of Wieser's type 1 group while the majority of the species represented in midshelf samples were type 2 organisms. Type 1 nematodes probably feed by sucking organic material off the larger mineral particles and aggregates in the sediment. Their small buccal cavities prohibit the ingestion of large mineral particles which could cause mechanical damage, while admitting fine organic material contained in interstitial spaces. Type 2 nematodes are carnivores, actively seeking prey in the interstitial spaces. Their directed search apparently results in more efficient food-gathering in the organic-poor and larger interstitial space environment of the midshelf region.

Biomass of the macrobenthos off northwestern Africa was high, as should be expected from the high productivity there. Estimates of biomass were several times what would be expected off the northeast United States (Rowe, Polloni and Hornor, 1974), where primary production is about half that off Cap Blanc (1.3 gm m^{-2} day^{-1}, see Ryther, 1963, versus 2 gm C m^{-2} day^{-1}, see Barber and Huntsman, 1977). Normally, benthic biomass is directly proportional to the primary productivity in the surface waters above it and inversely proportional to depth, in an exponential fashion (Rowe, 1971a); however, this relationship did not occur off Cap Blanc.

We were surprised that organic carbon and nitrogen in the sediments offshore in deep water was higher than nearshore. Infaunal biomass at the deepest station was lowest of all stations, but not by an order of magnitude, as would be predicted from other efforts to relate biomass and abundance to depth (Rowe, Polloni and Hornor, 1974). On many continental shelf-slope transects not characterized by upwelling it has been inferred that biomass decreases exponentially due to decreases in supplies of organic detritus for food (Rowe, 1971a). Such a pattern is not typical of northwest Africa or of other upwelling regions (Gross, *et al.* 1972; Carey, 1972). Several complex mechanisms have been proposed to explain such patterns (McCave, 1972). Nonetheless considerable organic matter must be reaching bottom nearshore because microbial metabolism (Christensen and Packard, 1977, and Watson, in press) and nutrient regeneration (Rowe *et al.*, 1977) are higher in the nearshore organic-poor sands than in the deep offshore silts/clay sediments with high organic content. A similar conclusion was drawn by Pamatmat (1973) for the North Pacific.

The ratio of biomass to abundance decreases with depth, at least in deep offshore basins that are depauperate (Rowe and Menzel, 1971; Hessler and Jumars, 1974), which reflects that animals are smaller on the average in deep water. The ratio, however, in our data was high at our deepest offshore station where organic matter also was high. Lowest values were found midshelf in our coarsest sand at Station 163 and 164, where organic matter was at its lowest. This result suggests that the biomass/abundance ratio is related to organic matter. Such a hypothesis is supported by work such as that of Bayne, Gabbott and Wilbur (1975) who demonstrated that larvae developing from gametes of adults fed limited rations had a lower rate of growth than larvae from well-fed adults.

While infaunal macrobenthos biomass did not vary markedly over the area sampled, demersal fishes and large trawl-caught invertebrates evidently reached highest biomass offshore (R. L. Haedrich, personal communication). On the other hand, activity and biomass of the benthic microbiota were both highest nearshore (Christensen and Packard, 1977, and S. Watson, in press). The differences in the quantitative distributions are probably related to the high rates of sedimentation along the coastline and the concentration of high primary productivity on the outer margin of the continental shelf.

Variations in organic supplies occurring between the two faunal provinces might result in major differences in benthic production. One could estimate production rates from published production:biomass ratios; however, the numbers must be considered gross estimates since the life histories of the organisms are not known and may vary from those reported from other regions (Warwick and Price, 1975). Production increments of the numerically dominant organism and the species dominating the biomass at stations 163 (midshelf) and SB (shelfbreak) were summed to provide an estimate of benthic production in their respective faunal provinces.

Spio sp. A, numerically dominant at Station 163, had an average biomass/sample of 251.6 mg. Assuming a *P:B* ratio of 0.8 (reported for *Spiophanes kryoyeri*, Buchanan and Warwick, 1974), we would estimate its production to be 201.3

mg/0.1 m²/yr. *Tharyx* sp. dominated the biomass at Station 163 and was numerically dominant at Station SB. No *P:B* ratios for *Tharyx* or cirratulid polychaetes were available, so we assumed a value of 0.9. From this we would estimate a production of 318.9 mg/0.1 m²/yr for *Tharyx* sp. at Station 163. Production for the midshelf station would total 520.2 mg/0.1 m²/yr. Using the same methods and a *P:B* ratio of 0.9 (Warwick and Price, 1975) for *Macoma* sp., which dominated biomass at SB, results in an estimated production of 590.3 mg/0.1 m²/yr for the upwelling province. These calculations suggest that benthic production in the upwelling province is greater than that in the nearshore province.

P:B ratios of 2-3.5 have been reported (Waters, 1969; Burke and Mann, 1974). If these larger ratios apply to the region off Cap Blanc the total benthic production in the midshelf station might be about 40 g/m²/yr, while as much as 60 g/m²/yr might be produced in the offshore upwelling province. Thus, total production in the upwelling province might be as much as 30% greater than that in the nearshore-midshelf province.

5. Summary

Faunal communities off Cap Blanc reflect the high primary productivity in the water column by maintaining a high biomass as depth of water and distance from shore increase. The types of feeding mechanisms prevalent in a community appeared to depend on terrigenous material excluding suspension feeders nearshore and organic supplies supporting offshore deposit feeders. Estimates of benthic production in the two provinces indicate that the offshore upwelling province may produce as much as or more than the nearshore province. About 5-10% of the 30% total primary productivity appears to be utilized for growth by the macrofauna.

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Received: *21 October, 1976;* revised: *21 March, 1977.*