Rev. Biol. Trop. 46. Supl. 6: 81-90, 1998
www.ucr.ac.cr

Macroinfauna of a tropical fjord-like embayment: Golfo Dulce, Costa Rica

Roy León-Morales[1] and José A. Vargas[2]
[1]Escuela de Biología, Universidad de Costa Rica, 2060 San José, Costa Rica.
[2]Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica, 2060 San José, Costa Rica. E-mail: javargas@cariari.ucr.ac.cr

(Rec. 13-V-1998. Rev. 16-VI-1998. Acep. 16-VII-1998)

Abstract: A total of 136 sediment subsamples was analyzed (500 µm mesh screen) for benthic invertebrates from 26 box corer samples collected by the RV Victor Hensen (Dec. 7, 8, 9, 1993), at nine stations ranging in depth from 43 to 200 m in the Golfo Dulce embayment, Pacific coast of Costa Rica. A total of 1690 individuals and 69 species was found; polychaetes dominated the fauna in terms of number of individuals (1506) and species (47). Eight species of polychaetes accounted for 73% of the total number of individuals: *Prionospio* (*Minuspio*) sp. A (19.53%) *Aricidea* (*Acesta*) *catherinae* (13.31%), *Levinsenia gracilis* (11.00%), *Aphelochaeta longisetosa* (10.18%), *Paraprionospio pinnata* (6.63%) *Cossura brunnea* (5.27%), *Mediomastus californiensis* (3.61%), and *Scoletoma platylobata* (3.43%). No organisms were collected at the two deepest stations (200 m) located inside Golfo Dulce; however, a diverse fauna was found at similar depths at the embayment mouth and in waters shallower than 100 m inside Golfo Dulce. The station located at the sill (75 m) was the most diverse (37 species). The species composition of the fauna found during this study has little resemblance to that reported for Golfo Dulce in 1976. Diversity (H') and Evenness (J'), however, were similar in both surveys. The results of cluster analyses performed on the 1976 and 1993 data sets yielded two main groups of stations. One group was made of the stations located at the mouth and shelf, while another group included those located inside Golfo Dulce. The fauna of the sill sediments may represent a transition zone between the environments characteristic of the entrance to Golfo Dulce and those inside the embayment. The fluctuating bottom conditions of hypoxia-anoxia characteristic of most of Golfo Dulce, in addition to the likely impact of strong El Niño in the marine ecosystems, might be the causes for drastic shifts in species composition and abundance. Golfo Dulce is still a relatively unpolluted embayment, but an Integrated Area Management Plan is urgently needed. This paper, in addition to those already published resulting from the RV Victor Hensen Expedition, are a step towards this goal.

Key words: Anoxic basin, benthos, box corer, infauna, polychaetes, Golfo Dulce, Costa Rica.

Golfo Dulce, an embayment on the Pacific coast (8° 40' N, 83° 20' W) of Costa Rica, Central America, is a fjord-like structure with a deep inner basin (200 m) separated from the open waters of the Pacific by a shallow (75 m) sill (Fig. 1).This morphology, similar to a temperate fjord, restricts the influx of oxygen-rich water into the basin resulting in temporally anoxic conditions, first described by Richards *et al.* (1971).The shallower benthic environments of Golfo Dulce were sites for the development of coral reef growth in the recent past, but are now deteriorating. Siltation seems to be the main cause of coral reef demise in Golfo Dulce (Cortés 1990, 1992).

More recently, basic information on the Golfo Dulce ecosystem has become a necessity for the establishment of policies regarding the management of its coastal zone and surrounding areas, many of which are still

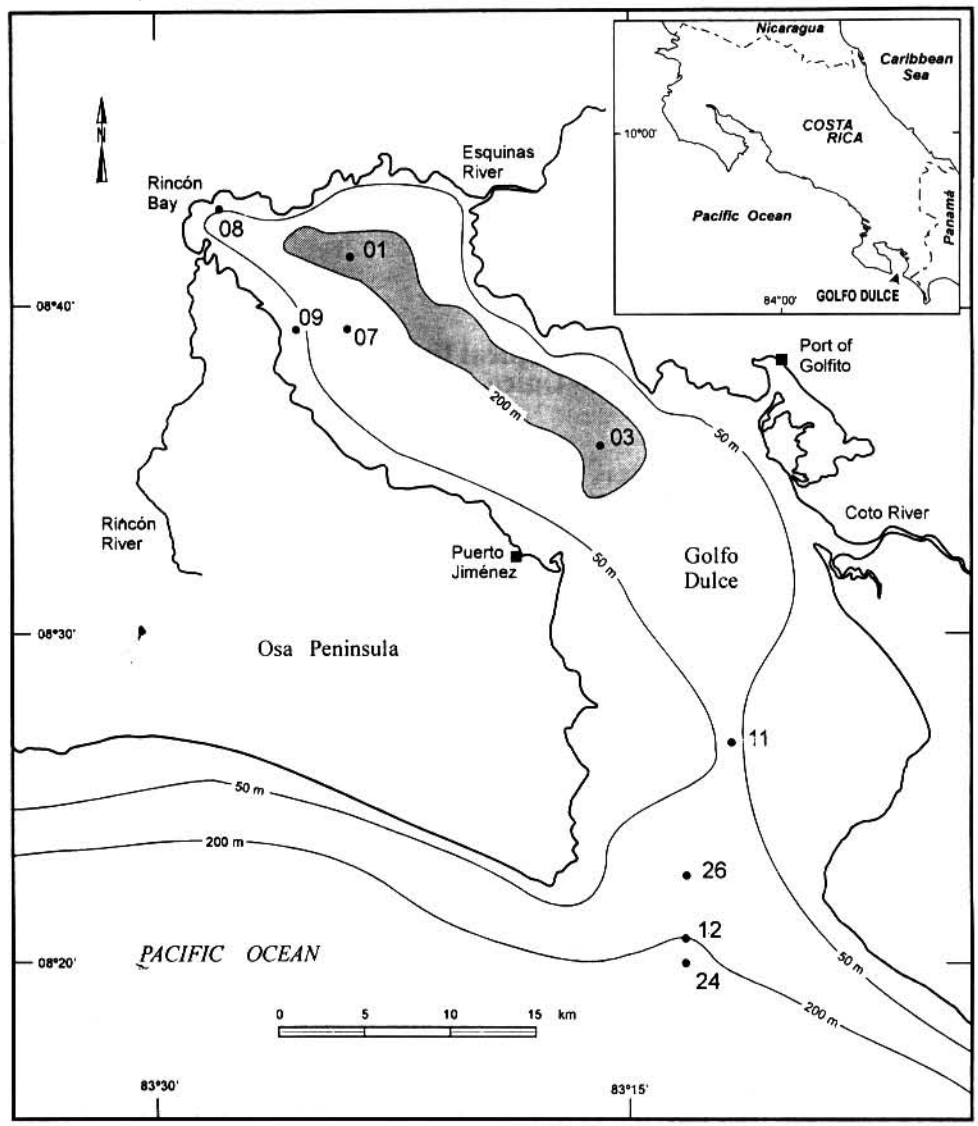

Fig. 1. Golfo Dulce, Pacific coast of Costa Rica, Central America. Location of the box corer stations taken during the R.V. Victor Hensen Expedition (Dec. 7, 8, 9, 1993). Dark gray indicates the deep inner basin. The sill is located at station 11.

covered with rain forests and mangroves. Thus, a detailed oceanographic expedition to Golfo Dulce aboard the RV Victor Hensen was organized during 1993-1994, and covering studies on the geology (Hebbeln *et al.* 1996), microbiology (Thamdrup *et al.* 1996, Kuever *et al.* 1996), plankton (Morales-Ramírez 1996, Wangelin & Wolff 1996, Molina-Ureña 1996, Hossfeld 1996), and water temperature, salinity, oxygen, and nutrient profiles (Córdoba & Vargas 1996). The study of the benthic epifauna included surveys (otter trawl) of the molluscs (Cruz 1996), crustaceans (Jesse 1996, Castro & Vargas 1996, Vargas *et al.* 1996) and fish (Bussing & López 1996, Wolff 1996). A pilot trophic model of Golfo Dulce was constructed by Wolff *et al.* (1996) which points out that this embayment acts differently from most tropical ecosystems as it is dominated by biomass and energy flow

within the pelagic domain; thus, resembling more an open ocean system than a coastal one.

The study of the Golfo Dulce benthic infauna was initiated by Nichols-Driscoll (1976) based on a set of samples collected with a Van Veen grab. She found that below 100 m the sediments were azoic while the infauna of shallower waters was dominated by the polychaete *Paraonis lyra*.The total number of species collected with the grab was close to 75. A comparison of the polychaete fauna collected by Nichols-Driscoll (1976) with that collected during the RV Victor Hensen expedition (1993-1994) was conducted by Dean (1996a). He found that both surveys yielded a similar number of families (23 and 25, respectively), and a similar number of species (46 and 47, respectively), but there were only seventeen families and eight species common to both lists. No species was identified as *P. lyra*. Dean (1996a) pointed out that the different sampling gear used in both surveys (grab and box corer), dissimilar station sites and taxonomic problems may be important in explaining at least in part the lack of agreement between both (1976 and 1996) lists of polychaete species.

As a follow up of Dean´s (1996a) study, the objective of this report is to further describe the composition and species distribution of the macrobenthic infauna collected during the RV Victor Hensen survey and to compare the results with data from Nichols-Driscoll (1975-1976).

MATERIALS AND METHODS

Samples were collected (December 7, 8, 9, 1993) with a 50 cm x 50 cm x 50 cm box corer operated by the RV Victor Hensen. Samples were taken at nine stations, five of which were located within the Golfo Dulce itself, one at the sill depth, and three at the entrance to the Golfo, at depths ranging from 43 m to 200 m (Fig. 1, Table 1). Water temperature, salinity, and dissolved oxygen were measured with a CTD at selected stations. Stations GD 1, GD 3, GD 7, GD 8, GD 9, GD 11, GD 12 were located at or close to stations sampled by Nichols-Driscoll (1976), Table 3. Three box corers were taken per station, except at GD-12 where only two were taken, and a minimun of 10 subsamples were taken from each one (Table 1). Subsamples were collected from the box corer sample with a plastic cylinder of 17.7 cm^2 of area and to a depth of 15 cm into the sediment. The extruded subsamples were then stored in heat-sealable polyester bags and preserved with 10% buffered formalin in sea water stained with Rose Bengal.

In the laboratory the contents of the bags were sieved through a 500 micrometer mesh screen and the organisms collected were stored in vials filled with 70% ethanol. A collection of the morphospecies was made and later identified to species, whenever possible. Voucher specimens are deposited at the Museo de Zoología, Universidad de Costa Rica.

TABLE 1

Station code, location (Lat. N/Long. W), station name, depth (m), sediment description, silt and clay (%), number of box corers (A), number of subsamples (B), number of individuals (n), area (m^2) sampled, (C) number of species (s), Diversity index (H'), Evenness index (J'). RV Victor Hensen expedition, Golfo Dulce, Pacific coast of Costa Rica. Dec. 7, 8, 9, 1993 - (500 µm mesh screen)

Station code	Location	Station name	Depth	Sediment description	Silt and clay (%)	A	B	C	n	s	H´	J´
GD-01	8°42' / 83°24'	Basin	200	Black-very soft	92.2	3	15	0.026	0	0	0	0
GD-03	8°35' / 83°16'	Basin	200	Black-very soft	95.7	3	15	0.026	1?	1	0	0
GD-07	8°39' / 83°24'	Upper gulf	100	Green - soft	67	3	15	0.026	356	8	1	0.2
GD-08	8°43' / 83°29'	Rincón Bay	50	Brown - soft	90.2	3	15	0.026	249	25	2	0.5
GD-09	8°39' / 83°26'	Upper gulf	43	Grey - soft	89.3	3	15	0.026	97	21	3	0.6
GD-11	8°27' / 83°13'	Sill	75	Green-very hard	18.4	3	15	0.026	253	37	3	0.7
GD-12	8°21' / 83°14'	Golfo´s shelf	200	Green - hard	70.2	2	10	0.018	167	25	2	0.4
GD-24	8°20' / 83°14'	Golfo´s shelf	200	Green - soft	86	3	18	0.032	241	29	2	0.5
GD-26	8°23' / 83°14'	Golfo´s mouth	100	Grey- soft	53.9	3	21	0.037	326	34	3	0.7
TOTALS						26	139	0.246	1690	69		

Cluster analyzes were performed on the station / species data matrices from this study and from Nichols-Driscoll (1976) survey. The latter data was reduced to include only those stations listed in Table 3. The Euclidean distance coefficient was used, and abundance data were log (X + 1) transformed (Clarke and Warwick 1994). Shannon-Weiner diversity index H', and Evenness (Equitability) index J', were also computed according to Clarke and Warwick (1994).

RESULTS

A total of 26 box corers were taken at nine stations and 139 subsamples analyzed for infauna (Table 1). A brief sediment description is included in Table 1; however, the following observations are relevant: stations GD-01 and GD-03 were characterized by soupy sediments resembling black yogurt, with a thin brown layer of plant debris at the top. This layer was particularly evident at GD-03. No H_2S odor was detected at these stations. Stations GD-07 had sandy sediments with shell debris and GD-08 had soft reddish-brown sediments, similar in color to exposed soils in deforested patches found in this area of Rincón Bay. Sediments at GD-09, the shallowest station, (Table 1) were gray at the top with many holes, and having a sharp transition to deeper, black, anoxic sediments a few cm below the surface. The station located at the sill (GD-11) had very hard sandy sediments mixed with the highest content of shell debris (including coral fragments) of stations sampled. The sediments at station GD-11 also had a few tubes sticking out of the surface, and no trace of organic debris at the top. Similar, but softer sediments were found at GD-12. Stations GD-24 and GD-26 (shelf-mouth) had an intact thin brown flocculent top layer and many holes.

At station GD-01 (basin) surface water temperature was 30 °C, with a strong thermocline around 40 m depth. Bottom (200 m) temperature at station GD-01 was 16 °C, and no dissolved oxygen was detected. At station GD-11 (sill) surface and bottom water temperature were 30 °C and 16 °C, respectively. Salinity at the surface was 28.0 and 34.7 at the bottom. At station GD-11 oxygen was detected near the bottom (70 m) at concentrations of 10% saturation.

A total of 1690 individuals and 69 species were found in the 139 subsamples analyzed (Table 1). No organisms were found at station GD-01 and only one dubious record from GD-03. Both stations are located in the Golfo Dulce basin in waters deeper than 100 m. Organisms were present, however, in high numbers in deeper waters at the mouth of Golfo Dulce. The samples collected at the sill depth yielded the highest (37) number of species and station GD-07 yielded the highest (356) number of individuals. Diversity (H') ranged from 0 (GD-1, GD-03) to 3.0 (GD-11) while Evenness (J') ranged from 0 (GD-1, GD-03) to 0.7 (GD-11, GD-26) Table 1.

Polychaete worms dominated the infauna in terms of the number of individuals (1506) and number of species (47). The abundances of the 35 more numerically important species are listed in Table 2. An unidentified species of the spionid polychaete, *Prionospio* sp. A, was the most common organism represented by 330 individuals (19.5%). Eight species of polychaete worms accounted for 73% of the total number of individuals (Table 2). Station GD-07 was dominated by *Prionospio* sp. A (268 individuals) and *Paraprionospio pinnata* (73). Station GD-08 had *Levinsenia gracilis* (71) and *Aphelochaeta longisetosa* (51) as the more common organisms. Station GD-11 was characterized by *A. longisetosa* (36) and oligochaetes (32) while stations 12, 24, and 26 were characterized by *Aricidea catherinae* (51, 102, and 50 individuals, respectively) and *L. gracilis* (26, 27, 26, respectively).

Results of the cluster analysis are included in Figure 2. Those stations located at the entrance to Golfo Dulce (GD-12, 24, 26) were placed in group A while the stations located in the interior of Golfo Dulce (GD 01, 03, 07, 08, 09) were placed in group B. Within group A stations 12 and 24 were the most similar while station 11 (sill) was the most dissimilar to the other stations in this group. For group B stations 01 and 03 (basin) were the most similar to each other. Station 07 (100 m) was the most dissimilar to the other stations taken inside Golfo Dulce.

Results of the cluster analysis performed on the reduced data matrix of Nichols-Driscoll (1976) are also included in Figure 2 Stations located inside Golfo Dulce at depths greater than 100 m and with zero or few organisms

TABLE 2

Total number of individuals (n) and percentaje (%) for 21 identified species (and other 13 higher taxa) represented by more than 5 individuals. Subtidal sediments (43 to 200 m) collected by box corers, Golfo Dulce, Pacific coast of Costa Rica. RV. Victor Hensen Expedition, Dec 7, 8, 9; 1993. A total of 1690 individuals and 69 species was collected

	Group	n	%
Prionospio (Minuspio) sp. A	P*	330	19.53
Aricidea (Acesta) catherinae Laubier	P	225	13.31
Levinsenia gracilis (Tauber)	P	186	11.00
Aphelochaeta longisetosa Hartmann-Schröeder	P	172	10.18
Paraprionospio pinnata (Ehlers)	P	112	6.63
Cossura brunnea Fauchald	P	89	5.27
Mediomastus californiensis Hartman	P	61	3.61
Scoletoma platylobata (Fauchald)	P	58	3.43
Amphipoda sp. A	C	57	3.37
Prionospio ehlersi Fauvel	P	46	2.72
Oligochaeta spp	O	32	1.89
Amphipoda sp. B	C	22	1.30
Nemertea spp	N	19	1.12
Cumacea sp. A	C	18	1.07
Aglaophamus dicirris Hartman	P	16	0.95
Terebellides californica Williams	P	13	0.77
Aricidea (Allia) sp.	P	13	0.77
Glycera capitata Oersted	P	12	0.71
Decapoda spp	C	11	0.65
Pettiboneia sp.	P	11	0.65
Ceratocephale crosslandi (Monro)	P	11	0.65
Magelona sp. B	P	11	0.65
Eunice vittatopsis Fauchald	P	11	0.65
Diopatra ornata Moore	P	10	0.59
Podarkeopsis brevipalpa (Hartmann-Schröeder)	P	8	0.47
Glycinde pacifica Monro	P	7	0.41
Laonice sp.	P	6	0.36
Diopatra farallonensis Fauchald	P	6	0.36
Amphipoda sp. C	C	5	0.30
Amphicteis scaphobranchiata Moore	P	5	0.30
Pettiboneia duofurca Wolf	P	5	0.30
Chaetozone corona Berkeley and Berkeley	P	5	0.30
Sigambra tentaculata (Treadwell)	P	5	0.30
Gyptis brunnea (Hartman)	P	5	0.30
Gastropoda spp	M	5	0.30
TOTAL		1608	95.17

*P= Polychaeta, C= Crustacea, O= Oligochaeta, N= Nemertea, M= Mollusca

(TH 1, TH 3, TH12, TH 94) clustered together. TH 95, located at 64 m depth inside the embayment, was unlike the deeper stations. TH 11 located at the sill was quite different from all these stations.

DISCUSSION

The results obtained during this study (Tables 1, 2, and Fig. 2) point out three main features of the Golfo Dulce infauna. First, basin sediments below 100 m appear azoic. Second, depths shallower than 100 m with dissolved oxygen concentrations near 10% saturation (or between 0.1 ml/L and 1.0 ml/L, according to Nichols-Discoll 1976) mark the transition from azoic to colonized sediments. Third, the stations located at the sill depth (GD-11 and TH-11) seem to represent a transition zone between the infauna of offshore sediments and that from the inner Golfo Dulce. These three features were also present in Nichols-Driscoll (1976) data as she reported no organisms below 100 m, while a station

located near GD-07 and at 105 m depth yielded only one organism. She also found that the sill samples were the most diverse (40 species, Table 3), as in this study (37 species, Table 1).

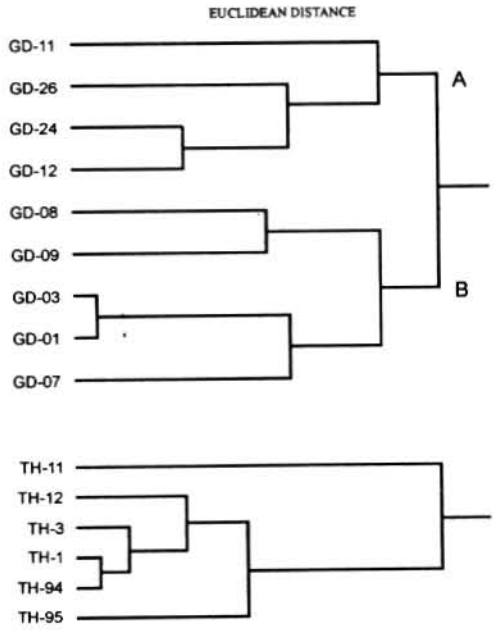

Fig. 2. Dendrograms resulting from cluster analyses (Euclidean distance) performed on the species/abundance data matrices and log (x + 1) transformed abundances, for the nine stations sampled during the R.V. Victor Hensen Expedition (Dec. 7, 8, 9, 1993), and six of the R.V. T.H. Thompson Expedition stations (data from Nichols-Driscoll 1975-1976). Golfo Dulce, Pacific coast of Costa Rica.

A detailed evaluation of the Golfo Dulce bottom topography was conducted by Hebbeln *et al.* (1996). Their ecographs of the sill area indicate a hard bottom without recent sediments while the rest of Golfo Dulce appears covered with young, unconsolidated sediments. Their analyses of sediment cores from the inner basin show that sediments there consist mainly of turbidites characterized by upward fining sequences and high amounts of plant detritus. Our sediment analysis confirm these observations as the silt and clay content of the sill samples was only 18.4%, while those of the basin were higher than 92% (Table 1). An examination of sediment biogeochemistry was conducted by Thamdrup *et al.* (1996) near station GD-01. They found that a 1-2 cm thick brown-black fluff layer covered the very fine-grained sediments and that at the surface 0.5 cm long filaments of the sulfur bacteria *Beggiatoa* were present. They also found that ammonia concentrations in the anoxic bottom water were low implying a turnover time of less than three months and a frequent exchange of bottom waters in Golfo Dulce. In addition, Kuever *et al.* (1996) concentrated their efforts in microbiological observations at station GD-01 and found that sulfate reducing bacteria were important for carbon mineralization in the sediments, but the end product of sulfate reduction (sulfide, as H_2S) was measured at concentrations of zero or very low.

TABLE 3

Station code, depth (m), number of individuals (n), number of species (s), Diversity (H'), Evenness (J'), total number of species (in the two grabs taken per station). Data from Nichols-Driscroll (1975, 1976). RV T.G. Thompson, Van Veen grab (0.1. m² - 420 µm mesh screen). Station code for the nearest station taken during this study. Golfo Dulce, Pacific coast of Costa Rica

Station	Depth	n	s	H'	J'	Species	Nearest station
01a	192	0	0	0	0	0	GD-01
01b	192	0	0	0	0		
03a	190	2	1	0	0	1	GD-03
03b	190	1	1	0	0		
94a	105	0	0	0	0	1	GD-07
94b	105	1	1	0	0		
95a	64	32	8	1.37	0.49	9	GD-09
95b	64	15	7	1.80	0.87		
11a	64	140	29	2.87	0.63	40	GD-11
11b	64	65	18	2.40	0.61		
12a	254	13	7	1.77	0.84	8	GD-12
12b	254	2	2	0.69	1.00		

Córdoba & Vargas (1996) found that oxygen concentrations decreased with depth from values close to 400 µmol/L near the surface but anoxic conditions were not detected below 100 m except near the bottom (200 m). Sampling conducted a few days before by Thamdrup *et al.* (1996), however, detected no oxygen below 100 m at GD-01. Such variability of environmental factors within a few days

was noticed earlier by Richards *et al.* (1971) who proposed the hypothesis of a frequent influx, at sill depth, of oxygen enriched offshore waters into the basin. Thus the high frequency of fluctuations in bottom oxygen concentrations, sometimes reaching anoxic conditions, and the presence of flocculent sediments, perhaps too unstable for macrofauna to settle in, are likely causes for azoic conditions below 100 m inside Golfo Dulce. It is important to mention that an abundant macroinfauna has been reported from the subtidal coastal waters of Pacific Central and South America from 10° N (Costa Rica) to 25° S (Chile) at depths from 50 to 400 m under low oxygen concentrations ranging from 0.2 to less than 2.0 ml/L (Wolf *et al.* 1991). This is also the case for the infauna found at the mouth and shelf of Golfo Dulce (Stations GD-12, 24, 26) at depths equal or greater than 100 m with oxygen concentrations closer to 10% saturation.

Of particular importance in searching for additional arguments to those given by Dean (1996a) to explain the lack of agreement between the polychaete species lists of Nichols-Driscoll (1976) and Dean (1996a) from Golfo Dulce are the observations by Wolf *et al.* (1991) relating drastic increases of macrobenthic density, biomass, diversity, and immigration of benthos and fish species caused by the El Niño Southern Oscillation (ENSO). Under non-ENSO conditions oxygen concentrations near the bottom in the Peruvian and Chilean coast rarely exceed 0.5 ml/L, and in some cases the bottoms are even anoxic. During strong ENSO oxygen periodically increases to more than 3.5 ml/L and these conditions may persist for more than a year after the end of the warming event (Wolf *et al.* 1991). The strong ENSO of 1982-1983 affected the coral communities living in Caño Island (West of Osa Peninsula, Fig. 1), and might have had also an impact on the coral communities in Golfo Dulce itself (Guzmán *et al.* 1987; Cortés 1990, 1992). A warming event took place in 1987-1988 and another in 1992-1993, and at the time of writing of this report (1997-1998) a strong ENSO is in progress. Thus, it may be speculated that the benthos of Golfo Dulce is under the influence of two main sets of environmental factors. The first, characteristic of normal years, is represented by periods of hypoxia-anoxia in the deep basin and relatively higher oxygen concentrations in waters shallower than 100 m. The second set, found during ENSO years, is characterized by warming of the surface waters and deepening of the thermocline and by changes in the frequency and magnitude of the proposed boluses of oxygen-nutrient richer waters entering Golfo Dulce at sill depth, from offshore. These ENSO-impacted water masses may also bring a different plankton assemblage, including larvae of benthic invertebrates settling later in the sediments of Golfo Dulce, thus leading to shifts in species composition and abundance.

In any event, the Golfo Dulce environment appears to be unique in the Pacific coast of the Americas not only because of its "fjord-like" morphology but also because of its behavior as an open ocean system rather than as a coastal-estuarine one. This may explain why its benthic fauna is different from the nearby Gulf of Nicoya estuary, as only twenty species of polychaetes are found in common between the list for Golfo Dulce (Dean 1996a) and that for the Gulf of Nicoya (Dean 1996b). Among these species, *Levinsenia gracilis*, *Diopatra ornata*, *Cerathocephale crosslandi*, *Mediomastus californiensis*, and *Paraprionospio pinnata* are important in Golfo Dulce (Table 3) and in subtidal (Maurer & Vargas 1984) and intertidal (Vargas 1988) sediments of the Gulf of Nicoya. Moreover, as noted by Wolf *et al.* (1991), *P. pinnata* is a spionid worm able to maintain its numerical dominance even during strong ENSO whereas there were numerous shifts among species. *P. pinnata* is a widely distributed deposit feeding species often found to colonize disturbed habitats (Dauer 1985). The question may be asked whether Golfo Dulce is an organically-enriched or polluted ecosystem. The sediments of Golfo Dulce, with the exception of those of the sill, are covered with a top layer of newly settled organic debris. This debris may have its origin in the sediment loads carried into the system by the Rincón, Esquinas, and Coto rivers (Fig. 1) or may be locally generated by settling plankton from the photic layer, or both. At station GD-08, however, the sediments clearly evidence the input of matter coming from deforested soils close to the shore. Other sources of organic pollution such

as raw sewage appear of limited impact considering the small size of the Jiménez and Golfito ports and the fact that most of the sewage may remain trapped within the little bay of Golfito (Fig. 1). Other sources of sediment pollution in Golfo Dulce such as pesticides and hydrocarbons have been recently studied by Spongberg and Davis (1998). They found that the deep sediments of the basin have evidence of pesticide metabolites. Samples from the Esquinas river mouth were found to contain persistent pesticides while the Golfito embayment has little pesticide contamination but hydrocarbons are abundant. The concentrations, however, were below those reported for heavily polluted embayments indicating that Golfo Dulce is still a relatively unpolluted ecosystem. These findings clearly point out to the need for and Integrated Area Management Plan (Norse 1993) for this unique ecosystem. The research conducted during the RV Victor Hensen Expedition and follow up surveys are steps towards this goal.

ACKNOWLEDGEMENTS

This research was conducted under the Memorandum of Understanding between the Universidad de Costa Rica (UCR), Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), and the Zentrum für Marine Tropenökologie (ZMT), Bremen, Germany. The authors thank Matthias Wolff Chief Scientist, Rocío Córdoba, and the Captain and Crew of the R.V. Victor Hensen. Processing of the samples was facilitated by grant 808-94-564 from UCR. We thank Harlan Dean for comments on the manuscript and taxonomic advice and Juan B. Chavarría for help with the cluster analyzes. Alberto León prepared the figures and Ruth Mora typed the manuscript.

RESUMEN

Para el estudio de los invertebrados bénticos del Golfo Dulce, costa Pacífica de Costa Rica, se analizó un total de 136 submuestras de sedimento (tamiz de 500 µm de poro) provenientes de 26 muestras tomadas mediante un barreno tipo "box corer" operado desde el Buque Oceanográfico Víctor Hensen (Diciembre 7, 8, 9, 1993) y recolectadas en nueve estaciones, a profundidades entre los 43 y 200 m. Se encontró un total de 1 690 individuos pertenecientes a 69 especies, de las cuales los anélidos poliquetos fueron el grupo dominante en número de individuos (1 506) y de especies (47). Ocho especies de poliquetos representaron el 73% del total de individuos: *Prionospio* (*Minuspio*) sp. A (19.53%), *Aricidea* (*Acesta*) *catherinae* (13.31%), *Levinsenia gracilis* (11.00%), *Aphelochaeta longisetosa* (10.18%), *Paraprionospio pinnata* (6.63%), *Cossura brunnea* (5.27%), *Mediomastus californiensis* (3.61%), and *Scoletoma platylobata* (3.43%). No se encontró organismos en las dos estaciones más profundas (200 m) localizadas dentro del Golfo Dulce. Sin embargo, se encontró una fauna diversa a profundidades similares en la boca del Golfo, y a profundidades menores de 100 m dentro del mismo. La estación localizada en la menor profundidad (75 m) a la entrada del Golfo fue la más diversa (37 especies). La composición de especies encontrada durante este estudio tiene poca similitud con la informada para el Golfo Dulce en 1976. La diversidad (H') y la Equitabilidad (J') fueron, sin embargo, similares en ambos estudios. Los resultados de los análisis de conglomerados efectuados sobre los datos de 1976 y 1993 revelaron dos grupos principales de estaciones. Un grupo está formado por las estaciones localizadas a la entrada del Golfo y en la plataforma, mientras que otro grupo está formado por las estaciones del interior del Golfo Dulce. La fauna de la estación GD-13 parece representar una transición entre los ambientes internos del Golfo Dulce y los de mar afuera. Las fluctuaciones entre hipoxia-anoxia características del fondo del Golfo Dulce, además del posible fuerte impacto del fenómeno de El Niño sobre el ecosistema, se especula que podrían ser las causas que expliquen los drásticos cambios en la composición y abundancia de especies. El Golfo Dulce puede considerarse aun un sistema relativamente no contaminado. Sin embargo, es urgente la preparación de un Plan de Manejo Integral del ecosistema. Este informe, además de los ya publicados resultantes de la expedición del buque Víctor Hensen, son un paso hacia este objetivo.

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