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Hydrobiological aspects of Palk Bay and Palk Strait area

PART (I) : Preliminary investigations on the abundance, distribution and diversity of benthic invertebrates and sediment texture in the marine environment of the Palk Strait, off Jaffna, Sri Lanka.

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Abstract

This study was carried out with the aim of assessing the potential impact on the macrobenthos community in the marine waters of the Palk Strait, off Jaffna of the Sethusamudram ship canal project (SSCP), a mega-development project proposed by India. The specific objectives were to determine the abundance, distribution and diversity of benthic invertebrates in the area and to identify the relationships between their distribution and sediment characteristics. The study was carried out during the North East Monsoon in 2005, within the continental shelf of Sri Lanka at a depth of 5 - 40 m. A total of 18 randomly obtained benthic samples were analyzed in the course of the study. Macrobenthos were separated by wet sieving and identified up to the lowest possible taxonomic level. The diversity and evenness of macrobenthos were determined using Shannon-Wiener and Pielou's indices, respectively. The similarities among the macrobenthic communities at different sites were determined using Bray-Curtis similarity coefficient and ordinations of Non-parametric Multidimensional Scaling (MDS). The BIO-ENV function of the Primer 5 software package was used to relate the multivariate community structure to environmental variables and to determine which variables were most responsible for the inter-site variability of the benthic community. Thirty species of invertebrates consisting of 21 species of polychaetes, 2 species of gastropods, 5 species of crustaceans and 2 species of bivalves were recorded during the study. The major environmental factors that influenced the separation of the clusters in Bray-Curtis similarity coefficient and ordinations of Non-metric Multidimensional Scaling (MDS) appeared to be the depth of the water and proportion of gravel in the sediments.

Introduction

The Sethusamudram Shipping Canal Project (SSCP) proposes linking the Palk Bay and the Gulf of Mannar between India and Sri Lanka by creating a shipping canal through the shallow sea, and through the island chain of Rama's Bridge. This would provide a continuous navigable sea route around the Indian Peninsula. The project involves digging a 44.9 nautical miles (83 km) long deepwater channel (Anon. 2004). The Palk Strait is an inlet of the Bay of Bengal which is 64 – 137 km wide and 137 km long. It receives fresh water from several rivers including Vaigai from India and contains many islands which are part of Sri Lanka. The total length of SSCP would be around 260 km; about 120 km from Tuticorin Port to Adam's Bridge in the Gulf of Mannar, and a further 140 km north of Rameswaram from Adam's Bridge to Bay of Bengal channel in the Palk Bay. In general, the canal will have a depth of 12 m enabling 10,000 to 12,000 GRT (Gross Registered Tons) vessels to pass through. The Government of India is proposing to dredge a width of 300 m through a 44 nautical miles (81 km) long stretch. It is estimated that 32.5 million m^3 of sand in the Adam's bridge area and around 52 million m^3 of sand in the Palk Strait would be dredged (Tamilinfoservice, 2006).

Dredging could make a considerable impact on benthic fauna and habitats, including removal of benthic communities completely from the area where it takes place, erosion of the areas immediately close to dredging, deposition of silt which escape from dredging on the benthic organisms and increase in the mortality of animals due to injuries following direct contact with the gear (Lindeboom and de Groot, 1998; Jenkins et al., 2001) as well as increasing their chances of predation (Kaiser and Spencer, 1994; Veale et al., 2000). Long-lived, slow-growing epifaunal species often have a fragile body structure and are especially sensitive to dredging, whereas taxa protected by exoskeletons or thick shells are more resilient (Gislason, 1994; Hall-Spencer and Moore, 2000; Kaiser et al., 2000; Hall- Spencer et al., 2002). Dredging can also increase the sediment load, relocate boulders, and destroy topographic features (Caddy, 1973; Eleftheriou and Robertson, 1992; Gislason, 1994).

Benthic macrofauna play an important role in aquatic ecosystems. In the aquatic food webs, they act as primary or secondary consumers representing diversified feeding habits as grazers, omnivores, carnivores and bacteriovores. Benthic invertebrates are very important as a food resource for a large number of predators such as benthic fish and some aquatic insects, and as primary material exchangers across the sediment water interface (Darby 1962; Popchenko 1971; Bouguenec & Gaini 1989).

Viable marine habitats are needed to sustain healthy fish populations, and the disturbance, degradation or destruction of such habitats is a globally important issue. Scientific research has indicated that fishing, dredging and other anthropogenic activities may alter physical and biological characteristics of the benthos. Improved access to scientific research on the effects of fishing gear and dredging on fish habitat will facilitate a greater understanding of the issue, promote informed discussion amongst scientists, policymakers and interested stakeholders, and encourage more rapid progress toward management solutions (Dieter et al., 2003). This entire SSCP area is biologically rich and rated among the highly productive seas of the World; macrobenthos have been found to be represented by 78 varieties in this SSCP area (Tamilinfoservice 2006)

Therefore, the present study was carried out to determine the spatial variation of macrobenthos in the Palk Strait and the likely impact of the SSCP on them.

Materials and Methods

Macrobenthos sampling & analysis

Sampling was carried out from 27th October to 07th November 2005. Triplicate benthic samples were collected form 18 locations in the Palk Strait, off Jaffna (Fig. 1) using a Peterson grab and immediately fixed using 10% formalin. The positions of all sampling sites were taken by a GARMIN hand held GPS and depth measurements were taken using Bathy 1500 echo sounder with an accuracy of ±20 cm. The benthic samples were subjected to wet sieving through 500 µm mesh sieve to separate the benthic fauna from the substrate (Sutherland 1997). The organisms retained in the sieve were collected, preserved in 70% alcohol and identified up to the lowest possible taxonomic level using Needham & Needham (1962), Fauchald (1977), Kirthisinghe (1978), Fernando (1990) and Robertson *et al.* (1997). The number of organisms of each species was also recorded.

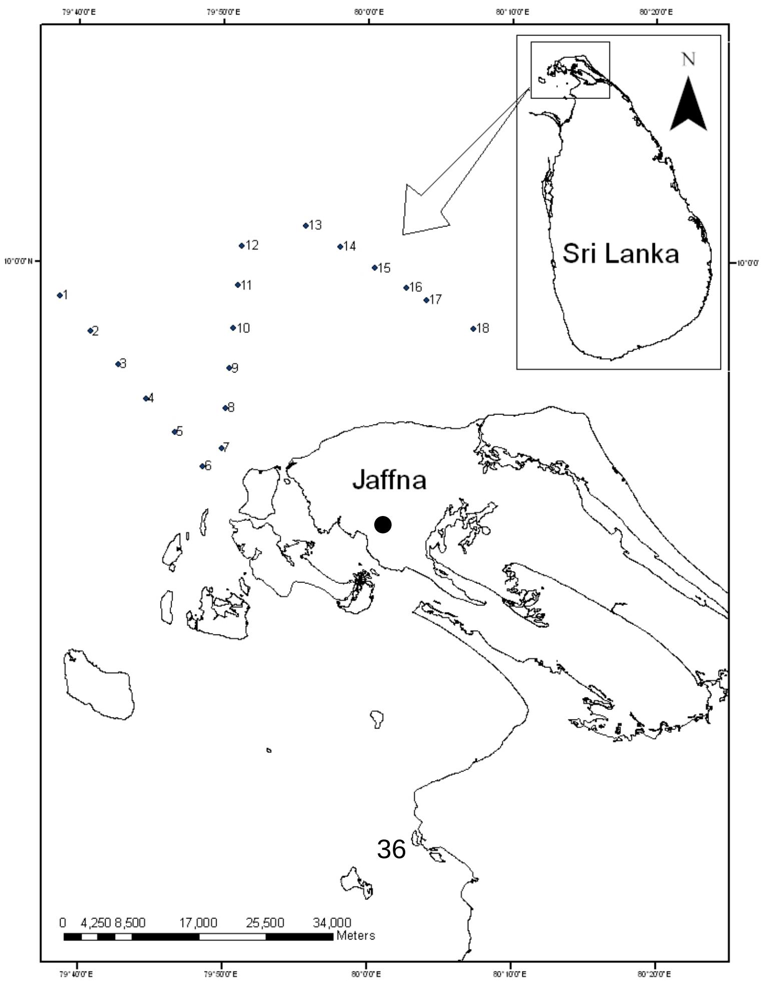
Sediment sampling & analysis

The hand held Van Veen type grab sampler was used to collect sediments. A total sample of 1 kg of sediment was collected at each location during the survey. Samples were weighed to the nearest 0.01 g, digested using H_2O_2

and was subjected to wet sieving through a series of sieves with mesh sizes as follows; 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm. The sediments retained in each sieve were weighed to the nearest 0.01 g and cumulative percentages of different grain sizes were computed. The proportion of carbonate was measured using an acid digestion procedure.

The diversity and evenness of macrobenthos in each site were estimated using the Shannon-Wiener index (H') and Pielou's index (J') respectively (Zar 1984; Krebs 1999) and the similarities of benthic communities among sampling sites were determined using the Bray-Curtis similarity coefficient (Bray & Curtis 1957). In this analysis, the 4th root transformation was used to increase the influence by rare species. Ordinations of Non-metric Multidimensional Scaling (MDS) of sampling sites were determined based on the Bray-Curtis similarity matrix (Clarke & Warwick 2001) using PRIMER-5 software package (Version 5.2.2). The BIO-ENV function in the PRIMER-5 package was used to relate the multivariate community structure to environmental variables and to determine which variables were most responsible for the inter-site variability of the benthic community.

Figure 1: The locations of sampling sites.



Results

Thirty species of invertebrates were recorded in the benthic samples during the present study. Among them were 21 species of polychaetes, 2 species of gastropods, 5 species of crustaceans and 2 species of bivalves (Table 1). The highest number of species was recorded at sampling sites 6 and 7 while no macrobenthos were recorded at the sampling sites 8, 11, 13 and 15. The higher values for species diversity, which were above 1.25 were recorded at sampling sites 6, 7 and 17 (Table 2) which are located closer to the coastline of Jaffna. Most of the sites, which were located further away from coastline showed a lower species diversity (eg. Sampling sites 1, 3, 4, 5, 8, 9, 11, 13, 15 and 16).

The values for the physico-chemical parameters of water and sediments at different sampling sites are given in Table 3. Depth of water ranged from 5 to 12.5 m and the carbonate percentage of sediments ranged from 3.4 to 98.4%. According to the results, gravel content of <10%, sand content of >50% and silt content of <50% were observed. About 50% of the total samples had more than 50% of carbonate. The maximum carbonate content in the study area was around 98%. However, the carbonate percentage was found to decrease towards the offshore, probably along the Pedro channel and may be due to the shallow morphology and the current action along this channel. The grain size analysis indicated that there is a gradual decrease of grain sizes towards the offshore area. This may be due to the density variations of the grains, heavier grains being transported for shorter distances than the lighter ones.

Sampling sites 8, 11, 13 and 15 were excluded from the study of Non-metric MDS and Bray- Curtis similarity, as no macrobenthos were present at those sites.

When the Bray-Curtis similarity index based on the abundance of macrobenthos is considered, sampling sites 3, 5, 7, 9, 14, 16 and 17 were separated from other sampling sites and each other at about the 0% level of similarity (Fig 2) due to presence of unique species. Those sampling sites were clearly separated from other sampling sites in the MDS ordination too, based on the abundance of macrobenthos (Fig 3). Sampling sites 1 and 4 clustered together at the Bray-Curtis similarity, mainly because of the presence of Nephtyid species at both sites.

Table 1: The relative abundance of different species of macrobenthic invertebrates recorded at each sampling site in the marine waters of Palk Strait off Jaffna during the study period.

Taxa / Sampling site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Class : Polychaeta																		
Order : Errantia																		
Nereis sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Nephtyidae sp 1	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Nephtyidae sp 2	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-
Aphroditidae sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Eunicidae sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Eunicidae sp 2	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Nephtyidae sp	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-
Pilargidiidae sp	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goniadidae sp	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Un. Errantia sp 1	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Un. Errantia sp 2	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Un. Errantia sp 3	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Un. Errantia sp 4	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Un. Errantia sp 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Un. Errantia sp 6	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Order: Sedentaria																		
Spionidae sp 1	-	+	-	-	-	-	-	-	-	++	-	++	-	-	-	-	-	++
Spionidae sp 2	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Orbiniidae sp	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capitellidae sp	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Maldanidae sp	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un. Sedentaria sp 1	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Class: Crustacea																		
Order: Decapoda																		
Decapoda sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Decapoda sp 2	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda sp 3	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Order: Amphipoda																		
Gammerid sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-
Gammerid sp 2	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Class: Gastropoda																		
Hydrobiidae sp	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Assimineidae sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Class:Bivalvia																		
Veneridae sp	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Un. Bivalvia sp 1	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-

+ Less than 1000 individuals m^{-2} ++ above 1000 individuals m^{-2} - Absent
Un.- Unidentified Species

Table 2: Shannon – Wiener index (H') and Pielou's index (J') of macrobenthic invertebrates recorded at different sampling sites.

Sampling Site	Diversity [Shannon-Wiener index(H')]	Evenness [Pielou's index (J')]
1	0.00	0.00
2	0.69	1.00
3	0.00	0.00
4	0.00	0.00
5	0.00	0.00
6	1.56	0.97
7	1.61	1.00
8	0.00	0.00
9	0.00	0.00
10	1.24	0.90
11	0.00	0.00
12	1.06	0.96
13	0.00	0.00
14	0.50	0.72
15	0.00	0.00
16	0.00	0.00
17	1.39	1.00
18	0.64	0.92

Table 3: Physico-chemical parameters of water and sediments at different sampling sites.

Sampling site	Gravel %	Sand %	Silt %	Carbonate %	Depth (m)
1	0.38	37.28	62.34	57.10	12.12
2	1.81	62.66	35.52	51.70	11.60
3	1.37	79.53	19.09	28.90	11.32
4	1.46	98.28	0.25	58.00	8.40
5	3.08	96.47	0.45	40.60	7.14
6	2.33	92.41	5.26	39.80	10.11
7	5.65	66.69	27.66	53.40	10.80
8	0.01	95.81	4.18	25.30	7.50
9	0.00	75.36	24.64	34.80	11.30
10	0.10	76.93	22.96	50.60	10.50
11	0.41	60.61	38.97	50.73	10.47
12	0.18	98.79	1.02	6.20	7.05
13	0.20	99.62	0.18	3.90	5.40
14	0.11	76.55	23.32	18.10	6.56
15	1.41	76.77	21.81	91.40	9.04
16	0.98	91.06	7.95	22.80	10.65
17	8.14	90.09	1.77	98.40	12.42
18	0.06	99.86	0.08	3.40	6.01

Spearman rank correlation coefficients for permutations of environmental variables of the BIO-ENV function, which are statistically significant, are given in Table 4. These results indicate that the diversity and abundance of macrobenthos is influenced mostly by the proportion of gravel in the sediments. Depth of water was also found to significantly affect the abundance and diversity of macrobenthos in the Palk Strait.

Figure 2: Dendrogram of the Bray- Curtis similarity index for the sampling sites of Palk Strait based on the abundance of macrobenthic invertebrates.

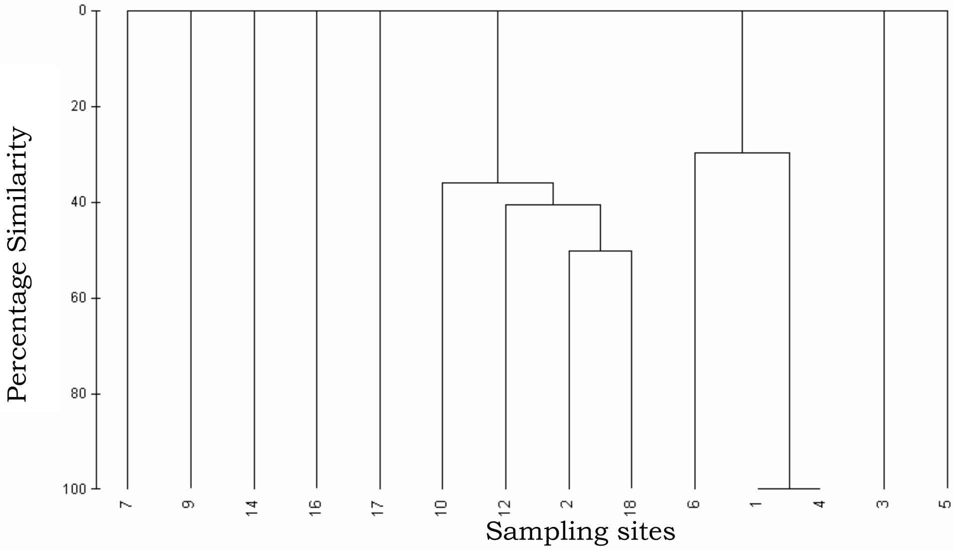


Figure 3: Two-dimensional MDS ordination of sampling sites according to the abundance of macrobenthic invertebrates.

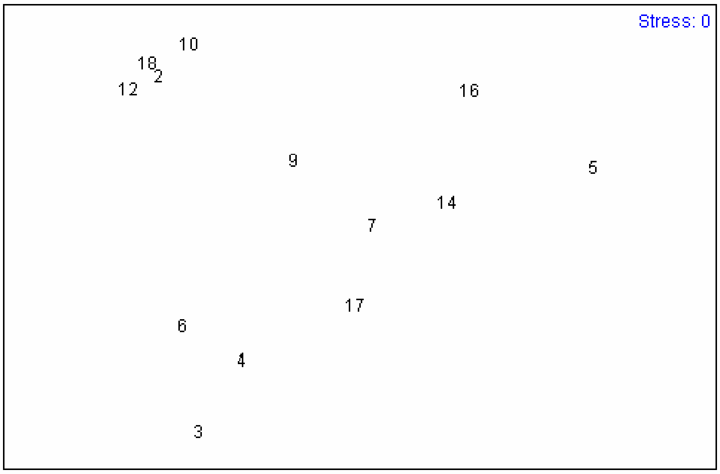


Table 4: Statistically significant values for Spearman Rank Correlation Coefficient ($p<0.05$) for permutations of environmental variables and the abundance of macrobenthos in Palk Strait.

Correlation Coefficient	Environmental Variables
0.134	1
0.095	1,5

Environmental Variables: 1-gravel (%), 2-sand (%), 3-silt (%), 4-carbonate (%), 5- Depth

Discussion and Conclusion

Diversity and abundance of the benthic invertebrates are relatively low in most of the sampling sites in comparison to those recorded in the Environmental Impact Assessment Report (EIAR) of the proposed Sethusamudram Ship Channel Project(Anon.,2004). The EIAR has recorded 78 species of macrobenthos whereas the present study recorded only 30 species. The number of gastropod and bi-valve species recorded in the EIA Report was also higher than that recorded in the present study whereas the number of polychaete species recorded in the EIAR were lower than in the present study. This may be due to variations in sampling sites as well as the different sampling methodology adopted in the two studies. Depth of water can also be another factor that affects the abundance and distribution of the benthic invertebrates (Perkins 1974). The depth of >5m at which the benthic samples in the present study were collected may be another reason for the low species richness and abundance encountered.

Sediment grain size has been identified as another factor that affects the distribution and abundance of macrobenthos (Dahanayaka & Wijeyaratne 2006). This is also confirmed by the present study which indicates that gravel percentage affects the distribution of macrobenthos in the Palk strait off Jaffna, Sri Lanka. The sampling sites closer to the coastline recorded high diversities compared to those offshore as recorded in the EIAR (Anon. 2004).

Dredging can increase the sediment load, relocate boulders, and destroy topographic features (Gislason 1994). However, the magnitude of the impact on benthic communities depends to a large extent on the bottom type. Benthic communities adapted to sandy substrata are, in general, more resilient to disturbance than those living on gravelly, sandshell seabeds (Eleftheriou and Robertson 1992). All the sampling points of the Palk Strait a indicated high percentages of sand and as such the benthic communities in that area will be able to withstand the disturbances that will be caused by dredging of the Sethusamudram ship canal.

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