J. Mar. Biol. Ass. India, 48 (2) : 200 - 205, July - December 2006

Immediate effects of experimental otter trawling on the physico-chemical parameters of seawater off Mangalore

P.U. Zacharia[1], Anoop A. Krishnan[2], Raveendra N. Durgekar[2] and P.K. Krishnakumar[3]

[1] *Tuticorin Research Centre of CMFRI, South Beach Road, Tuticorin, Tamil Nadu, India*
Email: zachariapu@yahoo.com
[2] *Mangalore Research Centre of CMFRI, PB No.244, Mangalore, Karnataka, India*
[3] *Veraval Research Centre of CMFRI, Veraval, Gujarat, India. Email: Kkumarpk@sancharnet.in*

Abstract

Experimental otter trawling was carried out for 11 months (May 2001-November 2002) off Mangalore coast to evaluate its immediate effect on physicochemical parameters of seawater. Five stations (1-5) with increasing depths (10m, 20m, 30m, 40 m and 50m) were selected for the study using a systematic BACI (Before/After and Control/Impact) design. Trawling impact on the changes in salinity, temperature, dissolved oxygen, total suspended solids and nutrients (nitrite, nitrate, phosphate and silicate) were assessed. Temperature, salinity and *p*H were similar before and after trawling. The results indicate that TSS at surface and bottom waters increased immediately after trawling which was prominent at the shallow stations with significant difference ($P < 0.05$) at station 2. Changes in nutrient load by trawling were occasionally observed. Trawling had only a minor effect on transparency, dissolved oxygen and nutrients. Multivariate analysis (PCA) also revealed minor impact on the physicochemical parameters due to trawling.

Keywords: Bottom trawling, physico-chemical parameters, nutrients, Mangalore

Introduction

Trawling is one of the most efficient methods of catching fish. It is one of the most important human inflicted physical disturbances in the continental shelves and the physical coastal ecosystems (Dayton *et al.*, 1995; Auster and Langton, 1999). Physical disturbance of the substratum results from direct contact with the fishing gear and the re-suspension of surface sediments and reduction in structural complexity which in turn will affect all aspects of benthic biological diversity including fisheries. Depending on the type of gear and substrate, trawling can be responsible for a variable amount of sediment re-suspension, increasing the sediment load and the turbidity (Main and Sangster, 1981) and loss of surface sediments (Kaiser and Spencer, 1996). There are studies on the impact of trawling on physicochemical parameters (Dayton *et al.*, 1995; Vining *et al.*, 1997; Pilskaln *et al.*, 1998) including the one in the Indian waters off Cochin (Joice *et al.*, 2004).

Mangalore in the west coast of India is one of the major trawl fishing harbours of Karnataka. Trawling, with 623 multi-day units and 752 single-day units operating from Mangalore-Malpe is the most effective and widespread method of fishing along the Karnataka coast (Zacharia *et al.*, 1996). The season commences by September and lasts till end of May. However, the impact of trawling on the physico-chemical parameters of the sea water off Mangalore has not been studied. Hence, an attempt was made to know the impact of bottom trawling on physico-chemical parameters off Mangalore.

Materials and methods

Based on information collected from commercial trawlers, an experimental site was identified at 5-20 nautical miles northwest off Mangalore (latitude 12° 93'–12° 95' N, longitude 74° 71'–74° 75' E) in the Arabian Sea where local commercial trawling activity is concentrated (Fig. 1). BACI (Before/After and Control/Impact) design was employed for the study since a control area or even a less fished area was not available. BA (Before/After) design was used to test the hypothesis that experimental trawling would cause a change in the physico-chemical parameters of sea water in the study area.

Trawling was conducted in the selected site for 11 months during May 2001 to November 2002 (May, November-December 2001, January-May, and September-November 2002). Data could not be collected from June to August, due to the closure of commercial fishing and inclement weather conditions during southwest monsoon. Five stations (1–5) with increasing depths (10m, 20m, 30m, 40m and 50m) were selected for the study using a systematic design. Experimental trawling was conducted for one hour at each depth using a net of 35mm cod-end mesh size. This design was chosen in order to achieve maximum interspersion between the stations. The position of the boat was monitored using a GPS. The experimental trawling was carried out by a Research Vessel (MFV *Dolphin* - 45m OAL) at normal trawling speed (~ 2 knots). Another Research Vessel (RTV *Deepa* - 40m OAL) was used for collecting water samples before trawling (BT) and after trawling (AT) using a Van-Dorn Horizontal water sampler (capacity 2 L). Water samples in replicate from each depth station were collected from the surface and bottom in the morning hours, preserved, and transported to the laboratory in clean polythene bottles for further analysis.

Collection, preservation, and analysis of samples were done following standard methods (Strickland and Parsons, 1972; Grassholf *et al.*, 1983; APHA, 1992). Water temperature was recorded *in situ* with a precision thermometer of 0.5° C accuracy. Salinity was determined following Knudsen's method and *p*H was measured using Jenway model–350 *p*H meter. Water transparency (extinction coefficient) was determined using the conventional Secchi disc of 30 cm diameter. Water samples (500 ml) were filtered using Whatman GF/F glass fibre filters for analysis of total suspended solids (APHA, 1992). Dissolved oxygen was estimated following Winkler's method (Parson *et al.*, 1984). Water sub-samples were collected from the filtrate for nutrient analysis (PO_4, NO_3, NO_2, and SiO_3), frozen immediately, and stored at -20° C until analysis in the shore laboratory by colorimetric method following Parson *et al.* (1984). Analysis of Variance (ANOVA) was done to statistically test the variance of parameters before and after trawling. Principal Component Analysis (PCA) was applied in order to reveal the dominant patterns in the data sets, and to reduce the number of variables to a few principal components that are independent and correlated with the original variables using SPSS (ver.13.0).

Results

Temperature, salinity and pH: Temperature, salinity and *p*H showed little temporal and spatial variations before and after trawling. Seawater temperature varied from 22 - 32.9° C (BT) to 21.5-32.7° C (AT). Salinity ranged from 32.4-35.3 ‰ (BT) to 32.8 - 35.50 ‰ (AT), and *p*H from 7.57-8.44 (BT) to 7.57-8.54 (AT). The impact of trawling on these parameters was not significant ($P > 0.05$).

Extinction coefficient: Extinction coefficient ranged from 0.86 at station 1 to 17.80 at station 3 with a mean of 4.98 (Table 1). It decreased in all stations immediately after trawling with a mean of 5.29 (BT) to 4.67 (AT) (Fig. 2 A). However, the decrease was not statistically significant ($P > 0.05$).

Total suspended solids (TSS): Total suspended solids ranged from below detection limit (ND) at stations 2 and 3 to 114 mg/l at station 4 (Table 1). At surface it showed a mean of 23.90 mg/l (BT) to 24.45 mg/l (AT) while at bottom it showed a mean of 23.59 mg/l (BT) to 27.01 mg/l (AT) (Fig. 2 B). However, these changes were not statistically significant ($P > 0.05$). Generally TSS was found to increase after trawling at all stations with a significant ($P < 0.05$) change observed at station 2.

Dissolved oxygen (DO): Dissolved oxygen ranged from 0.98 mg/l at station 1 to 8.82 mg/l station 1 (Table 1). At surface the mean value was 6.38 mg/l (BT) to 6.34 mg/l (AT) while at bottom it was 5.34 mg/l (BT) to 5.59 mg/l (AT) (Fig. 2 C) which were not statistically significant ($P > 0.05$).

Inorganic phosphate (PO_4): Phosphate ranged from ND at stations 1 to 2.02 mM at station 1 (Table 1). At surface the PO_4 showed a mean of 0.12 mM (BT) to 0.15 mM (AT) while at bottom it showed a mean of 0.16 mM (BT) to 0.17 mM (AT) (Fig. 3 A) but these changes were not statistically significant ($P > 0.05$).

Nitrates (NO_3): Nitrate ranged from 0.01 at all stations to 2.04 mM at station 1 (Table 1). At surface the

Table 1. *Range of physico-chemical parameters recorded during the study*

Station	Ext. coeff:	T.S.S (Mg/l)	D.O (Mg/l)	PO_4 (mM)	NO_2 (mM)	NO_3 (mM)	SiO_3 (mM)
Stn.1	0.86 – 4.05	2.00 – 46.00	0.98 – 8.82	ND – 2.02	ND – 3.60	0.03 – 1.71	0.27 – 9.60
Stn.2	1.76 – 7.32	ND – 92.00	1.00 – 8.42	ND – 0.44	ND – 0.76	0.01 – 0.98	0.37 – 9.59
Stn.3	2.36 – 17.80	ND – 48.00	1.25 – 8.32	ND – 0.33	ND – 1.64	0.04 – 2.00	0.39 – 10.96
Stn.4	3.55 – 12.90	1.00 – 114.00	5.18 – 7.77	ND – 0.25	ND – 0.41	0.05 – 2.03	0.05 – 10.02
Stn.5	4.47 – 13.52	3.00 – 101.00	3.81 – 7.40	0.01 – 0.46	ND – 0.70	0.01 – 2.04	0.66 – 6.17

NO_3 showed a mean of 0.34 mM (BT) to 0.40 mM (AT) while at bottom it showed a mean of 0.31 mM (BT) to 0.32 mM (AT) (Fig. 3 B) but these changes were not statistically significant (P > 0.05).

Nitrites (NO_2): Nitrite ranged from ND at all stations to 3.60 mM at station 1 (Table 1). At surface the NO_2 showed a mean of 0.20 mM (BT) to 0.21 mM (AT) while at bottom a mean of 0.24 mM (BT) to 0.20 mM (AT) (Fig. 3C), but these changes were not statistically significant (P > 0.05)

Silicate (SiO_3): Silicate ranged from 0.05 at station 4 to 10.96 mM at station 3 (Table 1). At surface the SiO_3 showed a mean of 2.80 mM (BT) to 2.52 mM (AT) while at bottom it was 3.13 mM (BT) to 2.89 mM (AT)

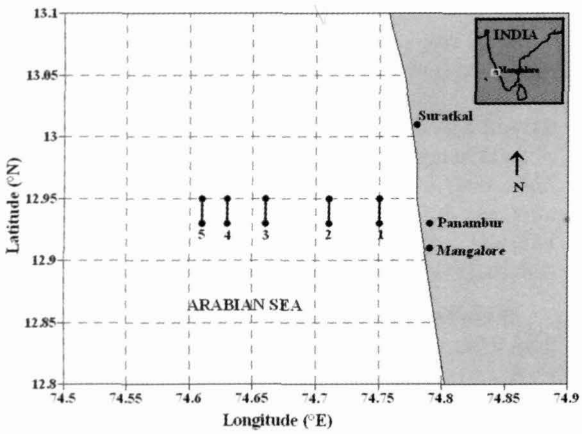

Fig. 1. Map showing the sampling area, the trawling and sampling track at 5 stations.

(Fig. 3D) but these changes were not statistically significant (P > 0.05).

PCA yielded six components with Eigen values greater than 1, which explained 71% of the variance in the data (Table 2). Stations and TSS content was forming the first component with high loading (PC1) followed by nitrate and nitrite (PC2), depth and DO (PC3), silicate (PC4), month, temperature and salinity (PC5) and trawling, *p*H and phosphate (PC6).

Discussion

The present study indicates that trawling make marginal impact on the physicochemical parameters of seawater. Extinction coefficient, which is a measure of light penetration, ranged from 0.86 to 17.80, and is relatively higher compared to earlier studies (Reddy *et al.*, 1979). Changes in transparency due to trawling will lead to poor

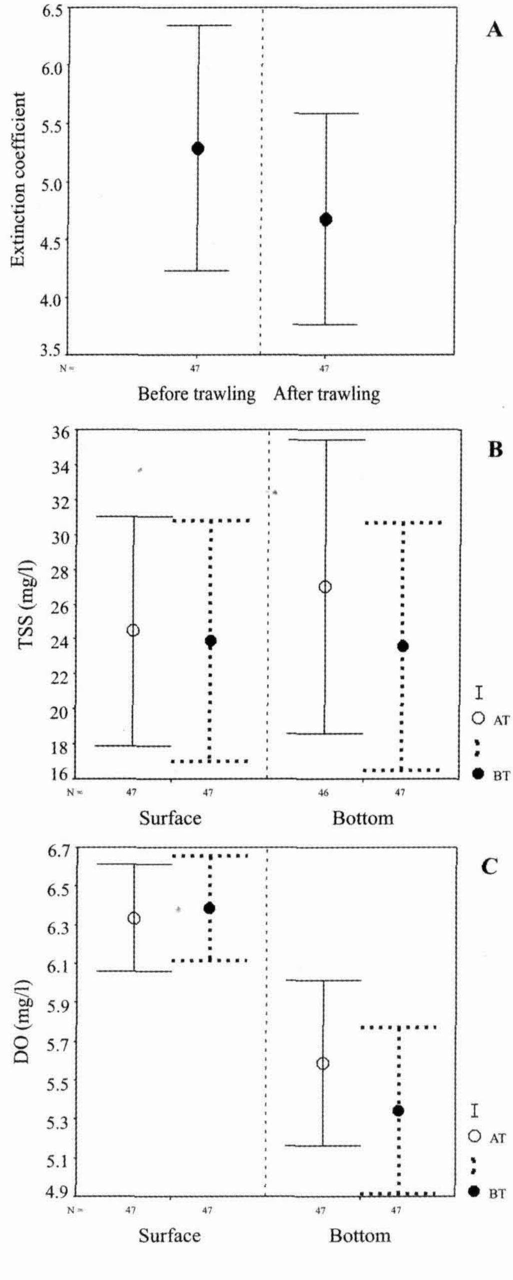

Fig. 2. Extinction coefficient, total suspended solids and dissolved oxygen at surface and bottom before and after trawling represented by Error plot based on mean and standard error. (The middle point represents the mean and the extend from the points represent the standard error).

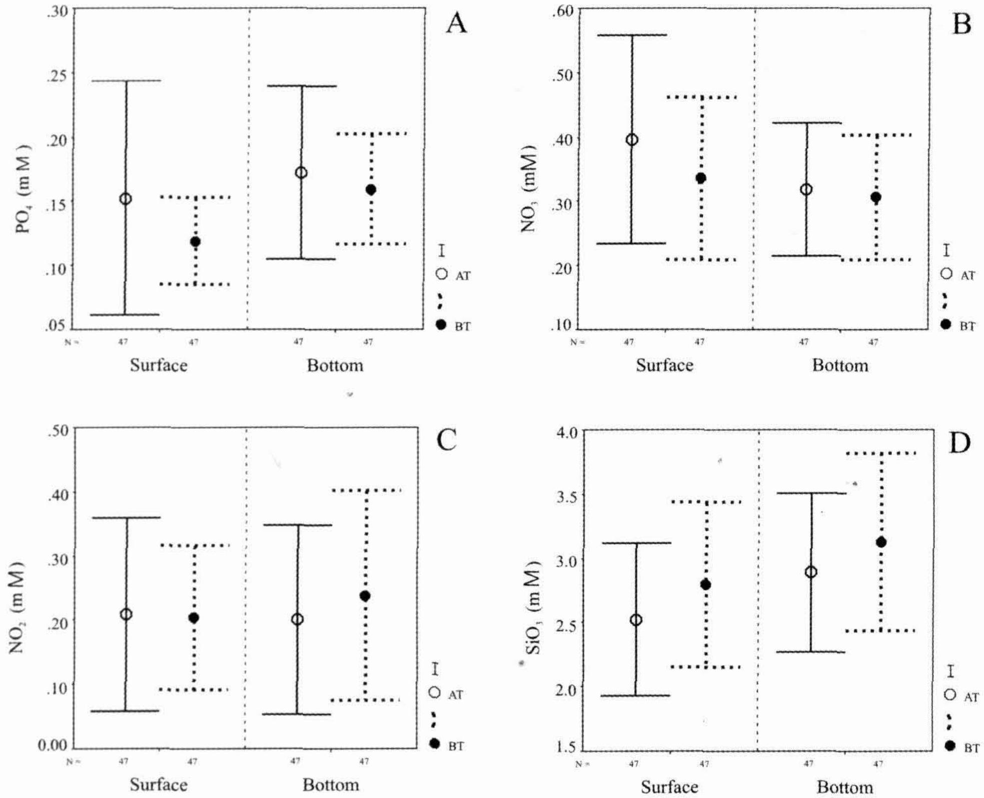

Fig. 3. Nutrient concentration at surface and bottom before and after trawling represented by Error plot based on mean and standard deviation. (The middle point represents the mean and the extend from the points represent the standard error).

primary productivity, impaired growth of bottom vegetation and other benthic fauna (Morgan *et al.*, 1983; Newcombe and MacDonald, 1991). In the present study, extinction coefficient decreased after trawling, but increased with increasing depths (Table 1). Higher extinction coefficient indicates lower light penetration in seawater due to high turbidity.

Total suspended solids observed in the present study (Table 1) were found to be higher than the values recorded by Reddy *et al.* (1979). The surface and bottom concentration of TSS were significantly higher following trawling (Fig. 2B). The increase in TSS after bottom trawling may be due to the turbulence created at the bottom either by otter boards, tickler chain or ground rope which leads to re-suspension of sediments and increase in benthic nutrient flux (Krost, 1990). The impact of the otter boards weighing 90 - 100 kg each and tickler chains weighing 50 kg induces turbulence as they are dragged through the bottom leading to the generation of clouds of suspended sediments (Main and Sangster, 1981). The lack of visible surface impacts from trawling activity is related to the fact that the plume is near the bottom and below the thermocline most of the time, which will prevent the turbidity plumes from reaching the surface, and so its impacts are mostly restricted to the bottom. An increase in water turbidity may have an effect on benthic species, in particular, suspension, and filter feeders (Churchill, 1989). Re-suspended particles in the water column are likely to reduce light penetration and may temporarily decrease benthic productivity (Churchill, 1989).

In the present study, a marked difference in DO was observed between surface and bottom with a low values at bottom (Fig. 2). Similar results were reported by earlier work from this coast (Damodaran, 1973). Riemann and Hoffmann (1991) reported depletion of dissolved oxygen in dredged and trawled areas at bottom when they studied

Table 2. *PCA loadings (after varimax rotation) of first six components for the impact of trawling on physico-chemical parameters of seawater from study area*

Variables	PC1	PC2	PC3	PC4	PC5	PC6
Month	0.234	0.486	-0.001	0.494	-0.545	-0.108
Station	0.815	-0.102	-0.054	0.070	0.110	-0.159
Trawling	0.162	-0.004	0.050	0.197	0.176	0.505
Depth	0.127	-0.136	-0.784	-0.094	-0.084	0.001
Temp	0.092	0.062	0.450	0.043	0.745	-0.074
*p*H	0.001	-0.153	0.240	0.443	0.121	-0.598
T.S.S	0.807	0.123	0.103	0.043	-0.189	0.071
Salinity	-0.389	-0.059	-0.476	0.329	0.579	0.024
D.O	0.239	-0.376	0.731	-0.001	0.115	-0.120
PO_4	-0.322	-0.018	-0.048	0.021	-0.142	0.744
NO_3	0.282	0.759	0.043	-0.103	0.119	0.207
NO_2	-0.211	0.795	-0.063	-0.078	-0.103	-0.101
SiO_3	-0.054	0.125	-0.034	-0.884	-0.046	-0.103
Eigenvalues	2.34	2.06	1.40	1.31	1.14	1.00
Cumulative %	18.0	33.8	44.6	54.6	63.4	71.1

the ecological consequences of dredging and bottom trawling in Denmark waters. Nutrients observed in the present study were comparable with earlier reports by Reddy *et al.* (1979); Mridula *et al.* (2002). Riemann and Hoffmann (1991) reported that bottom trawling releases high pulse of nitrogen and other nutrients into the water column by stirring up the sediment and they have recorded high volume of nitrites and inorganic phosphates in the bottom waters. The results of the present study were comparable to this where at the bottom high concentration of phosphate induced by trawling was observed.

The diagnostic feature of a trawl impact would be an abrupt elevation in the concentration of nutrients and TSS after trawling. However, significant increase in nutrients was only occasionally observed during the experiment. Both at surface and bottom elevated concentrations of phosphate and nitrate were observed, while silicate showed slight decrease after trawling. Features such as temperature, salinity and *p*H tend to be relatively similar over wide areas. PCA test aided in the identification of parameters influencing the physico-chemical parameters. The controlling parameters influencing the impact of trawling were found to be the stations followed by TSS (Table 2). Impact on the physicochemical parameters was found to be least (7.7%) compared to month of sampling, depth and stations. Perhaps repeated trawling at frequent intervals in a given path would be deleterious to the sea bed than sporadic trawling.

Acknowledgments

We are grateful to the Director, CMFRI and Scientist-in-Charge, Mangalore for encouragement and for facilities provided and to all our other colleagues for their constant help and encouragement. This work was carried out in the framework of the project, "*Investigations on the effect of bottom trawling on the benthic fauna off Mangalore coast*", which was funded by the Department of Ocean Development, Govt of India and coordinated by Ocean Science and Technology Cell on marine Benthos, Cochin University of Science and Technology. We acknowledge, the practical support of the crew of MFV *Dolphin* and RTV *Deepa*.

References

APHA, 1992. *Standard Methods for the Examination of Water and Waste Water*. (Ed 18), American Public Health Association, Washington D.C, USA, 522pp.

Auster, P.J and R.W. Langton. 1999. The effects of fishing on fish habitat. *In*: Benaka, L. R (Ed.) *Fish Habitats: Essential Fish Habitat and Rehabilitation*. Published by American Fisheries Society, Bethesda, Maryland, 22: 150-187.

Churchill, J.H. 1989. The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight continental shelf. *Cont. Shelf Sci.*, 9: 841-864.

Damodaran, R. 1973. Studies on the benthos in the mud banks of the Kerala coast. *Bulletin Department Marine Science, University Cochin*, 6: 1-126.

Dayton, P.K., S.F. Thrush., T.M. Agardy and R.J. Hofman. 1995. Environmental effects of fishing. *Aquatic Conservation Marine Fresh water Ecosystem*, 5: 205–232.

Grasshoff, K., M. Ehrharott and K. Kremling. 1983. *Methods of sea water analysis*. (2[nd] revised Ed.) Germany, 419pp.

Joice, V. T., P. Premlal, C. Sreedevi and B. M. Kurup. 2004. Immediate effect of bottom trawling in physicochemical parameters in the inshore waters (Cochin – Munambum) of Kerala. *Indian J. Mar. Sci.*, 51: 277-286.

Jorgensen, B.B. 1980. Seasonal oxygen depletion in the bottom waters of a Danish fjord and its effect on the benthic community. *Oikos*, 34: 68-76.

Kaiser,M.J. and B.E. Spencer. 1996. The effects of beam-trawl disturbance on infaunal communities in different habitats. *J. Animal Ecology*, 65: 348-358.

Krost, P. 1990. The impact of otter-trawl fishery on nutrient release from the sediment and macrofauna of Kieler Bucht (Western Baltic). Berichte aus dem Institut für Meereskunde an der Christian-Albrechts-Universität, *In:* Kiel. Nr. Kruskal, J.B and M.Wish (Eds.) *Multidimensional scaling*. Published by Sage publications, Beverly Hills, California. 200: 157pp.

Main, J and G.I. Sangster. 1981. *A study of the sand clouds produced by trawl boards and their possible effect on fish capture*. Scottish Fisheries Research Report 20: 20pp.

Morgan, R.P., V. Raisin, and L. Noe. 1983. Sediment effects on eggs and larvae of striped bass and white perch, *Transactions of the American Fisheries Society*, 112pp.

Mridula, R.M., R.J. Katti, K.M. Rajesh, and T.R.C. Gupta. 2002. Diversity of dinoflagellates in the sea off Mangalore. *Indian J. Fish.*, 49: 45-50.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems, *The American Journal of Fisheries Management*, 11: 72-81.

Parson, T.R., Y. Maita and C.M. Lalli. 1984. *A Manual of Chemical and Biological Methods of Seawater Analysis*. Pergamon Press, New York. 173pp.

Pilskaln, C.H., J.H. Churchill and L.M. Mayer. 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. *Conservation Biology*, 12: 1223-1229.

Rao, K.V.N., K.K. Sukumaran, K.S. Mohamed, P.U. Zacharia and K.U. Bhat. 1993. The trawl fishery of the mid shelf off Mangalore coast. *In:* Varghese T.J., Keshavanath P., Radhakrishnan K. V. and Lokeshwar R. R. (Eds). *The Second Indian Fisheries Forum Proc.* May 27-31, 1990, Mangalore, India, p. 183-188.

Reddy, M.P.M., V. Hariharan and N.P. Kurian. 1979. Some variations in hydrographic condition of Estuarine and Oceanic water adjoining the old Mangalore port. *Indian J. Mar. Sci.*, 8: 73-77.

Riemann, B and E. Hoffmann., 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. *Mar. Ecol. Prog. Ser.*, 69: 171-178.

Strickland, J.D.H and T.R. Parsons. 1972. A manual of sea water analysis (2[nd] Ed.) *Bulletin Fish Research Board Canada,* 167: 310pp.

Vining, I., D. Witherell and J. Heifetz. 1997. *The Effects of Fishing Gear on Benthic Communities*. North Pacific Fisheries Management Council. Ecosystem Considerations for 1998. p. 13-25.

Zacharia, P.U., K.S. Mohamed, C. Purandhara, H.S. Mahadevaswamy, A.C. Gupta, D. Nagaraja and S.B. Uma. 1996. A bio-economic evaluation of the dual-fleet trawl fishery of Mangalore and Malpe. *Mar. Fish. Infor. Serv., T & E Ser.*, 144: 1-12

Received: 8 November 2006
Accepted: 12 February 2007