and stained with Rose Bengal vital stain. In the laboratory, the fauna were sorted to phylum level and preserved in 4% buffered formalin for further identification. The fauna were identified to the lowest possible taxonomic level and classified following standard nomenclature of Fauvel (1953) and Day (1967). The number of each individual species that occurred in a sample and the number of individuals of particular species present in the sample were noted and the data of replicates were averaged for further statistical analysis.

Univariate community measures (number of species, number of individuals) were calculated using the PRIMER statistical software package developed by the Plymouth Marine Laboratory (Clarke and Warwick, 1994). Two measures of species diversity were calculated: Simpson's reciprocal, D, was chosen as a Type II index which is more sensitive to changes in more abundant species and the exponential of the Shannon – Weiner function (exp H') was used as Type I index, most sensitive to changes in rare species (Peet, 1974). Differences between the values of these statistics were also tested using nested ANOVA of SAS statistical package, Version 9.2.

Comparisons of individuals or gross community parameters such as species richness or diversity may fail to appreciate directional changes in relative species abundance. However, these changes may be detectable using multivariate discrimination techniques such as those described in Clarke and Warwick (1994). The similarity matrix was constructed using the Bray – Curtis similarity index after 4th root transformation of data. The macrobenthic community structure among the sampling was tested using analysis of similarity (ANOSIM). The interpretation of ANOSIM result is based upon the calculation of global R statistic value. The relative contributions of each species to the average similarities of these groupings were calculated using SIMPER analyses.

Results

The benthic faunal community at the culture and reference sites consisted of different species of annelids, crustaceans and molluscs (Table 1). The number of individuals was more or less similar at both the farm site, 1278 no. m^{-2} and at reference site (1470 no. m^{-2}). Crustaceans were the dominant group in the farm site, forming 60 % (762 no. m^{-2}) of the benthic community followed by annelids (37 %) and molluscs (1%). At the reference site, annelids contributed to 53% while crustaceans formed 42% and the molluscs 3% of total benthic community. Unidentified fauna formed 2% of the sample at the sites. At the farm site, 22 species of annelids belonging to 16 genera were recorded while at the other site there were 23 species of 19 genera. *Ceratonereis mirabilis*, *Diopatra neapolitana capensis*, *Lumbrineris magalhaensis*, *Nephtys macroura* and *Prinospio cirrobranchiata* occured only at the farm site while *Diopatra monroi*, *Glycera unicornis*, *Glycinde kameruniana*, *Lumbrineris heteropoda*,

Table 1. *Average abundance (no. m^{-2}) of benthic macrofauna at farm and reference sites*

Species	Farm	Reference
Ancistrosyllis parva	6	12
A. robusta	19	6
Capitella capitata	81	118
Ceratonereis keiskama	19	44
C. mirabilis	25	0
Cossura coasta	31	31
Diopatra monroi	0	62
D. neapolitana capensis	25	0
Drilonereis longa	19	37
Glycera unicornis	0	12
Glycinde kameruniana	0	44
Lumbrineris heteropoda	0	6
L. magalhaensis	12	0
Lysilla loveni	19	19
Maldanella harai	31	19
Mediomastus capensis	0	19
Megalomma quadrioculatum	0	6
Nephtys macroura	12	0
N. polybranchia	68	68
Nerindes gilchristi	6	19
Notomastus aberans	6	105
N. fauveli	6	37
N. latericeus	6	25
Petaloproctus terricola	12	31
Prinospio cirrifera	12	37
P. cirrobranchiata	25	0
P. pinnata	12	12
Spiophanes bombyx	19	12
Annelida Total	**472**	**782**
Alpheus sp.	6	0
Ampithoe sp.	31	0
Apseudus chilkensis	167	161
Penaeus sp.	19	6
Gammarus sp.	452	452
Tanaidacea sp.	86	0
Crustacea Total	**762**	**619**
Paphia malabarica	12	43
Mollusca Total	**12**	**43**
Unidentified	31	25
Grand Total	**1278**	**1470**

Mediomastus capensis and *Megalomma quadrioculatum* were recorded only from reference sites. Seventeen species were common to both areas

Crustaceans belonging to 6 genera *viz.*, *Alpheus* sp., *Ampithoe* sp., *Tanaidacea* sp., *Apseudus chilkensis*, *Penaeus* sp. and *Gammarus* sp. were found at the farm site, but the former three genera were absent at the latter site. At both the areas *Gammarus* was numerically abundant. Molluscs were represented by the bivalve *Paphia malabarica*, but the density was high at the reference site.

The benthic community structure analyses using PRIMER indicated high diversity and richness at both the sites (Table 2). The Shannon (H') was marginally higher (2.64) at the reference site than at the farm site (2.53). Simpson (1-λ) dominance indices were almost similar. The Pielou's (J') evenness index was 0.79 at the reference site while at the farm site it was marginally lower (0.75). The Margalef (d) species richness index was higher at the farm site, 4.05 while at the reference site it was 3.70. The differences in Univariate diversity indices were not significant (P>0.05).

Mutivariate analysis indicated the variation in the community structure. The low similarity percentage at both sites indicated the seasonal variations within the sites. The results of SIMPER analysis have indicated high similarity between the farm and the reference site. *Gammarus* sp, *Apseudus chilkensis, Capitella capitata, Nephtys polybranchia* and *Notomastus aberans* were the main taxa which contributed to the differences in the community structure (Table 3).

Table 2. *Diversity measures of benthic faunal assemblages at the farm and reference sites*

Diversity measure	Farm	Reference
Total species (S)	30	28
Total individuals (N)	1278	1470
Margalef (d) species richness index	4.05	3.70
Pielou's (J') evenness index	0.75	0.79
Shannon (H') diversity index	2.53	2.64
Simpson (1-λ) dominance index	0.84	0.87
Average Similarity percentage	14.28	16.28
Global R Statistic value	-0.07	

Table 3. *SIMPER analysis results showing the taxa that contributed with more than 90% of the dissimilarity between farm and reference sites of F1*

Species	Average dissimilarity ± SD	Contri-bution %	Cumul-ative %
Gammarus sp.	18.91 ± 0.99	22.84	22.84
Apseudus chilkensis	8.36 ± 1.04	10.10	32.95
Capitella capitata	5.71 ± 1.05	6.89	39.84
Nephtys polybranchia	5.34 ± 0.70	6.46	46.30
Notomastus aberans	4.28 ± 0.69	5.18	51.47
Diopatra monroi	3.48 ± 0.61	4.21	55.68
Cossura coasta	2.80 ± 0.67	3.38	59.07
Maldanella harai	2.53 ± 0.45	3.06	62.12
Petaloproctus terricola	2.08 ± 0.36	2.52	64.64
Glycinde kameruniana	2.02 ± 0.44	2.44	67.08
Prinospio cirrifera	1.98 ± 0.70	2.40	69.47
Ceratonereis keiskama	1.97 ± 0.73	2.38	71.85
Tanaidacea sp.	1.84 ± 0.46	2.22	74.07
Paphia malabarica	1.81 ± 0.44	2.19	76.26
Unidentified	1.76 ± 0.72	2.12	78.38
Drilonereis longa	1.63 ± 0.60	1.98	80.36
Notomastus fauveli	1.50 ± 0.56	1.81	82.17
Prinospio pinnata	1.39 ± 0.38	1.68	83.85
Prinospio cirrobranchiata	1.37 ± 0.45	1.66	85.51
Notomastus latericeus	1.31 ± 0.54	1.58	87.09
Ancistrosyllis robusta	1.25 ± 0.58	1.51	88.60
Penaeus sp.	1.22 ± 0.46	1.48	90.07

Discussion

The benthic faunal community structure at the farm and reference sites were similar and there was no negative impact due to short-term farming of oysters when the biomass of the farm ranged between 27 to 288 kg (Ramalinga, 2006) over a period of eight months with an average density of 30,000 oysters per 25 m^2. The average number of oysters per shell (cultch) was 12. High seasonal variation in the community structure at both sites were noticed, but the overall faunal assemblage was similar without any marked change. Contrary to this, Kasper *et al.* (1985) found that the benthic community structure was strongly affected by the presence of mussel farms. They have attributed the reason to the build of reef –like aggregate including live mussel and shell materials which provide sites of attachment for large epibiota including tunicates and sponges. Decreased diversity of infaunal assemblages was also observed. In the oyster farms at Ashtamudi Lake such shell assemblages were not observed.

In the present study, average abundance of annelids and crustaceans was found to differ but the variations were not significant. However, in prolonged oyster farming, the average annelids abundance has been found to decrease with the period of farming. On the other hand the crustacean abundance decreased with advancing period of farming suggesting that these two groups were sensitive to organic enrichment and increased sedimentation rates. Such changes in benthic communities under shellfish farms have been documented in several studies (Tenore *et al*., 1982; Cho *et al.* 1982; Findlay *et al*., 1995; Grant *et al.*, 1995; Stenton-Dozey *et al.*, 1999). Benthic community shifts associated with an increase in organic and silt composition beneath the oyster trestles have been reported by Simestad and Fresh (1995) and Nugues *et al.* (1996). In the present farm site also increased organic carbon content, silt and clay composition was observed but in short-term farming these changes were not significant (Ramalinga, 2006). Hence, it can be concluded that concurrent with the sediment texture and seasonal changes, variations occur in the benthic community structure at oyster farm sites but these changes are not significant in short term low-density operations.

Acknowledgements

The authors are thankful to the International Foundation for Science, Sweden, for the financial support on an Environmental Impact Assessment scheme on suspended bivalve culture (to the second author) and to the Indian Council of Agricultural Research for the Senior Research Fellowship (to the first author). The support extended by the Director, CMFRI and by the staff and scholars who were attached to the Molluscan Fisheries Division is gratefully acknowledged.

References

Castel, J., P. J Labourg, V. Escaravage, I.Auby and M.E. Garcia.1989. Influence of seagrass beds and oyster parks on the abundance and biomass patterns of meiobenthos and macrobenthos in tidal flats. *Est. Coast. Shellfish S.*, 28:71–85

Clarke, K. R. and R.M Warkwick. 1994. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation.* National Environmental Research Council, UK, 144 pp.

Day, J. H. 1967. *A monograph on the Polychaeta of southern Africa. Part 1. Errantia.* British Museum of Natural History, London. 468 pp.

Dinet, A., J.M.Sornin, A. Sabliere, D. Delmas, and M. Feuillet-Girard. 1990. Influence de la biodeposition de bivalves filtreurs sur les peuplements meiobenthiques d'un marais maritime. *Cajiers de Biologie Marine*, 31: 307-322.

Fauvel, P. 1953. *The fauna of India including Pakistan, Ceylon, Burma and Malaya. Annelida, Polychaeta.* The Indian Press Ltd., 507 pp.

Findlay, R. H., L.Watling and L. M. Mayer. 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: a case study. *Estuaries*, 18:145-179.

Grant, J. A., A Hatcher, D.B.Scott, P. Pocklington, C.T.Schafer and G.Winter. 1995. A multidisciplinary approach to evaluating benthic impacts of shellfish aquaculture. *ibid.*, 18: 124-144.

Heral, M., J.M.Deslous-Paoli and J. Prou. 1986. Dynamique des productions et des biomasses des huittres creuses cultivees (*Crassostrea angulata* et *Crassostreagigas*) dans le basin de Marennes-Oleron depuis un siecle. *ICES C.M.* 1986/F: 41, 21 pp.

Kaspar, H. F., P.A. Gillespie, I.C. Boyer and A.L. MacKenzie. 1985. Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sound, *New Zealand. Mar. Biol*., 85: 127-136.

Moore, S.J. 1996. *The impact of an intertidal oyster farm on the benthos.* BSc Thesis presented to the Faculty of Science, University College Cork, Ireland, 34pp.

Nugues, M. M., M. J. Kaiser, B. E. Spencer and D.B. Edwards. 1996. Benthic community changes associated with intertidal oyster cultivation. *Aquaculture Res*., 27:913-924.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanogr. Mar. Biol. Ann. Rev*., 16: 229-311.

Peet, R. K. 1974. The measurement of species diversity. *Annual Review of Ecology and Systematics*, 5: 285 – 307.

Ramalinga. 2006. Environmental Impact Assessment of suspended oyster *Crassostrea madrasensis* (Preston) culture. Ph.D.thesis submitted to Central Institute of Fisheries Education (Deemed University, Versova, Mumbai 147 pp.

Simenstad, C.A. and K.L. Fresh. 1995. Influence of inter tidal aquaculture on benthic communities in Pacific Northwest estuaries: Scales of disturbance. *Estuaries*, 18 (1a): 43-70.

Stenton-Dozey, J. M. E., L.F.Jackson and A.J. Busby.1999. Impact of mussel culture on macrobenthic community structure in Saldanha Bay, South Africa. *Mar. Poll. Bull*., 39: 357-366

Tenore, K. R., L.F.Boyer, R.M.Cal, J. Corral, C.Garcia-Fernandez, N.Gonzalez, E. Gonzalez-Gurriaran, R.B.Hanson, J. Iglesisa, M.Krom, E.Lopez-Jamar, J. MaClain, M.M.Pamatmat, A.Perez, D.C Rhoads, G. Santiago, J.Tietjen, J. Westrich, and H.L.Windom. 1982. Coastal upwelling in the Rias Bajas, NW Spain: contrasting the benthic regimes of the Riasde Arosa and de Muros. *J. Mar. Res*., 40: 701-772

Received: 16 December 2006
Accepted: 7 July 2007