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BIOTIC ENVIRONMENT AND SAND MINING - A CASE STUDY FROM ITHIKKARA RIVER, SOUTH WEST COAST OF INDIA

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ABSTRACT

Ithikkara river was blessed with unique assemblages of aquatic flora and fauna. The biological environments of the Ithikkara river is under severe stress due to indiscriminate sand mining from the active channels and the floodplain areas and other anthropogenic activities. The paper stresses the need for re-evaluation / re-examination of the biological wealth of our aquatic systems in regard to the rampant sand mining activities of Kerala rivers. This is utmost important for the conservation and better management of our aquatic ecosystems which carries the pristine water resources for the present and future generations.

INTRODUCTION

Rivers of Kerala are known for their scenic beauty, purity and rich biological wealth. The culture, prosperity and well being of the people are linked to the health of rivers and adjoining backwaters - nearshore systems. But, unfortunately, indiscriminate scooping of construction grade sand and gravel from the active channels and floodplain regions, over the past few decades, has imposed marked impairments to these natural assets. Although many studies exist on the physico-chemical impact of sand mining (CWRDM 1999; CESS 2001 and many others), studies on biological impacts are very limited (Sunil Kumar, 2002). Hence, an attempt has been made in this paper to address the biological impact of sand mining in one of the perennial rivers of southern Kerala, the Ithikkara river, draining mainly through the midlands and the lowlands of Kollam (major) and Thiruvananthapuram (part) districts.

Ithikkara river (Fig.1), originating from Madathurikunnu at an elevation of about 240 m above msl, has a length of about 56 km and a catchment area of about 642 km2. The river merges with the Paravur lake near Paravur. Previous studies on the physico-chemical and biological environment of the Ithikkara river revealed that the river is under severe stress due to indiscriminate scooping for construction grade sand from the active channels and the floodplain/over bank areas (Sheeba, 1999; CESS 2001). The river channel and the adjoining wetlands are deepened at many places, especially in the lowlands, to dangerous levels consequent to illicit scooping of sand. Formation of pits, pit capturing and changes in the natural course of the river at some locations are noticed from the area. In addition to the physical effects, sand mining adversely affects the biological environment of the system as well. The impacts are not limited to mining site alone but extend even to other parts of the riverine ecosystem. The deepening of river course, changes in stream flow, etc., not only destabilize the fluvial system, but also increases turbidity of the overlying water column. Increased turbidity prevents photosynthetic

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activity and decreases planktonic and benthic growth (Nautiyal, 1985). Changes in the active channels and floodplains are invariably linked to changes in other physico-chemical processes such as erosion, sedimentation, dynamics and heat transfer process that are important to the very existence of the aquatic communities. Previous studies revealed that the Ithikkara river is deteriorating year after year due to indiscriminate sand mining through about 50 kadavus / sand mining locations, working in the river basin. As per the estimates of CESS, a total of 350 truck loads (equivalent to 1400 m3) per day of the sand are being quarried from the Ithikkara river and adjoining parts of Paravur kayal.

MATERIALS AND METHODS

An inventory of fishery resources and other biotic communities has been made based on a detailed field survey and interview among fishermen. The study of physico-chemical and biological environments of Ithikkara river by Sheeba (1999) and CESS (2002) were also used for this paper. The primary and secondary data collected were analysed for evaluating the impact of sand mining on biotic communities. Ecology and feeding biology of the fresh water fishes were collected from standard references (Nikolsky 1963; Srinivastava 1988).

RESULTS AND DISCUSSION

The Ithikkara river is blessed with a unique assemblage of aquatic plants and animals. In an earlier study, Sheeba (1999) reported about 56 species of fish, 50 species of benthic fauna, 29 species of macro invertebrates (9 species of prawns, 6 species of mollusca, 2 species of crab), 39 species of zooplankton and 128 species of phytoplanktons (Table 1). The distribution of flora and fauna shows remarkable changes towards river confluence zones. But it is unfortunate to note that there are notable discontinuities in the distribution pattern of the biological communities along the profile of the river due to anthropogenic activities like sand mining, pollution, unscientific fishing practices, etc,. Many of the species are either under threat or even disappeared from this riverine ecosystem.

Excessive scooping of sand from the river basin destabilizes the delicate balance set in naturally within the river environment. Of the 60 fishermen interviewed in the basin, more than 75% of them opined that the fishery wealth of the Ithikkara river was found to be declining over the past few years consequent to sand mining. The major impacts of sand mining which affects the biological environments are rise in turbidity of the overlying waters, loss of feeding and breeding grounds, removal of detritus (the common food form of aquatic organisms of the lower levels), aggravated salt water intrusion, particularly in the river mouth areas, etc.

Suspended solids and turbidity

Sand mining enhances levels of suspended solids, in the overlying water column, which in turn leads to higher turbidity levels. The finely divided suspended matter which does not settle quickly makes the water more opaque/cloudy and negatively affect light penetration. This definitely reduces the photosynthetic activity, productivity and growth of planktonic and benthonic animals (Nautiyal, 1985).This imposes scarcity on the nature's food items and exerts pressure on feeding of juveniles and the adults of higher order animals like fishes. Excessive concentration of suspended solids in water imposes respiratory disorders in fishes due to chocking up of the gills (Waters,1995). In extreme cases, gill lamellae become blocked up and fail to function, properly. Protective mucous of fish also gets affected, making it conducive for infection by bacteria, fungi and other disease prone vectors.

Feeding, Hiding and Spawning

Generally, primary producers are rare in river waters and the primary energy input will be in the form of organic detritus (Dobson and Frid, 1998). Sand mining depletes this crucial form of primary energy input, as a substantial part of detritus would be removed along with quarried sand. Non-availability of detritus adversely affects the population of detritus feeders. Detritus is the food item to many fishes and other macro invertebrates.

Ecology and feeding biology of the fresh water fishes of the Ithikkara river furnished in Table 2, enlighten new information on the impact of sand mining on biological community. Scooping of sand along with organic detritus and subsequent exposure of hard rocks/hard substratum may adversely affect the feeding and hiding places of these animals. One of the examples is the case of Wallago attu, a sluggish edible fish, once flourished in the Ithikkara river. But according to the Inland fishermen of the region, no catch of this edible fish has been reported over the

past 5-6 years. *Wallago attu* is a soft bodied fish, gather food mainly from river bottom and hides in safe places on the banks (like crevices, holes etc). The destabilization of the riverbanks consequent to sand mining destroys the hiding places and helps fishermen to hunt easily this fish. As per IUCN (1990), decline of prey species, hunting for food, siltation, pollution, trade, etc; are the major causative factors for the threat of *Wallago attu*. From this, it is very clear that sand mining, which affects decline of prey species, rise in siltation and river bed changes, has a major role in the disappearence of *Wallago attu* in the Ithikkara river. Another important observation is in the case of *Puntius* spp. This species scoops a mouthful of sand from the river bed and sort out the desired food particles. Feeding biology of *Puntius* spp., Danio acquipinnatus, *Parluciosama daniconius, Channa striatus, Anabas testudineus, Glossogobius giuris, Macropodus cupanus* and *Clarias batrachus* revealed that sand mining negatively affects their feeding grounds and reduces continued supply of food items. Major food items of these fishes are plankton, organic detritus, benthic organisms (molluscans, crustaceans, nymph or larval forms of terrestrial insects – Odonata, Diptera, Trichoptera, Ephemeroptera, Chironomid, etc.). *Macrobrachium rosenbergii* is the giant fresh water prawn once distributed well in Ithikkara river. Prawns are demersal in habit and it feed on detritus, animal and vegetable matter, aquatic worms, aquatic insects and inset larvae. Analysis of the feeding habit of prawn revealed that sand mining is a major cause in the decline/disappearance of this fresh water prawn as well.

It is well understood that many species of fishes prefer to hatch eggs on sandy or gravelly substrata. Removal of sandy / gravelly substrata together with the eggs. badly affects the very survival of many of the fish species of the basin.

In short many of the fish fauna and other aquatic organisms of the Ithikkara river is under threat due to loss of habitat, feeding and breeding grounds, decline of food sources etc. In Ithikkara river, out of the 56 fish species, 16 species can be enlisted under threatened fresh water fishes, as per IUCN (1990) and are depicted in Table 3. Out of the16, the major causative factor for threatening 10 species is the loss of habitat. In Ithikkara river, habitat loss occurs mainly through indiscriminate sand mining.

Seawater ingression

According to the fishermen community of Ithikkara river, the population of mussels, clams, crabs, prawns, etc., is declining, year after year, consequent to various reasons linked to human activities. Shibu (1991) reported the abundance of *Villorita cyprinoides* in the confluence zones of Ithikkara river with Paravur kayal. But present observation of population size and distribution of *Villorita cyprinoids* revealed that these bivalves are declining due to removal of sand bed for construction works and aggravated salt water ingression. *Meristrix casta*, prefer fairly high saline conditions and it adapted to live in the marine end of an estuary, dominates in place of *Villorita cyprinoids*. This change may be attributed to the salt water ingression consequent to lowering of river beds due to sand mining. Studies of Shaji (2002) revealed that the salinity level and marine influence of the Paravur kayal and the river confluence zones of the Ithikkara river are increasing year by year due to various types of man - made activities. It is obvious that indiscriminate sand mining and subsequent lowering of river/estuarine beds one of the reasons for the above change in the biological environment.

Sand mining and terrestrial fauna

The common benthic forms in Ithikkara river are insecta, crustacea and mollusca. Sand mining destroys these benthic forms severely and prevent its recolonization (Sunilkumar, 2002). Feeding biology of fishes revealed that majority of fishes feed aquatic insects, larvae and nymph of terrestrial insects inhabiting the aquatic environment. Terrestrial insects like May fly (Ephemerella), Dragan fly, Damsel fly (Odonata), Caddis fly (Rhyancophila), Chironomous (Diptera), Stone fly (Plecoptera) and their nymphs and larval forms are all aquatic. May fly, Stone fly and Caddis fly prefers substrates composed of cobbles, pebbles, coarser clastics and sand. Chironomids prefer to finer substrates (Waters, 1995). The insects and larvae, inturn, form the major food for fish, frog, birds and man and hence maintain the normal food web pattern. Both Odonata as well as Hemipterans have great role to play in the biological control of harmful insects as they voraciously feed on the obnoxious insects like mosquito larvae, May fly naiads, gnats, midges and other harmful insects (Sharma *et al*. 1996). Thus larval forms of terrestrial insects have a major role in the aquatic ecosystem. Aquatic insects and larval forms of terrestrial insects act as major food of fishes and other macro fauna and have major role in the biological control of harmful organisms. These terrestrial insects, whose larval

Table 1. Biological diversity of Ithikkara river

Type of organism	Name of species

1. **Phytoplankton Cyanophyceae :** *Microcystis* sp., *Aphanocapsa* sp., *Merismopedia* sp., *Gomphosphaeria* sp., *Myxosarcina* sp., *Spirulina* sp., *Oscillatoria* spp., *Phormidium* sp., *Lyngbya* sp., *Microcoleus* sp., Anabaena sp., *Scytonema* sp., **Chlorophyceae:** *Eudorina elegans, Sphaerocystis* sp., *Asterococcus* sp., *Cylindrocapsa* sp., *Stigeoclonium* sp., *Oedogonium* sp., *Bulbochaete* sp., *Rhizoclonium* sp., *Golenkinia* sp., *Micractinium* sp., *Pediastrum tetras, Pediastrum* sp., *Coelastrum* sp., *Dictyosphaerium* sp., *D. pulchellum, D. chrenbergianum, Treuabaria* sp., *Dimorphococcus* sp., *Ankistrodesmus* sp., *Selenastrum* sp., *Kirchneriella* sp., *Tetraedron gracile, Scenedesmus quadricauda, S. obliquus, S. dimorphus, S. bernardii, S. abundans, Crucigenia* sp., *Tetrastrum* sp., *T. heteracanthum, Tetrallantos* sp., *Mougeotia* sp., *Zygnema* sp., *Spirogyra* sp., *Cylindrocystis* brebissoni, *Cylindrocystis* sp., *Netrium digitus var rhomaboideum, Gonatozygon* sp., *Closterium* moniliferum, *C. lineatum, C. gracile, C.kuetzingii, Penium spirostriolatum, Pleurotaenium kayei, P. baculoides, P. ovatum, Triploceros gracile var undulatum, Euastrum* sp., *E. verrucosum, Micrasterias pinnatifida, M. foliacea, M. thomsiana, M. mahabalipurensis, Actinoctaenium* sp., *Cosmanium decoratum, C. quadratum, C. subspeciosum, Cosmarium* sp., *Xanthidium bengalicum, X. freemanii, X. hastiferum,* Xanthidium sp., *Staurodesmus curvatus, Staurastrum* sp., *S. sexangulare, S. setigerum, Arthrodesmus* sp., *Spondylosium* sp., *Sphaerozosma* sp., *Desmidium* sp., *Gymnozyga* sp., *Hyalotheca* sp., **Euglenophyceae:** *Euglena* spp., *Euglena acus, Phacus* sp.,**Chrysophyceae:** *Mallomonas* sp., *Dinobryon* sp., *Hyalobryon* sp., **Dinophyceae:** *Ceratium fusus, C. tripos, Peridinium depressum, Goniaulax polyedra,* **Bacillariophyceae:** *Melosira* sp., *Cyclotella* sp., *Chaetoceros* sp., *Tabellaria* sp., *Diatoma* sp., *Fragillaria* sp., *F. brevistriata, F. capunica, Synedra* sp., *Synedra ulna, Synedra affinis, Eunotia alpina, E. lunaris, Achnanthes* sp., *Cocconeis placentula, Navicula* sp., *N. gracilis, N. longicephala, Pinnularia viridis, Diploneis* sp., *Gyrosigma* sp., *Pleurosigma* sp., *Gomphonema lanceolatum, Cymbella affimis, Amphora ovalis, Nitzschia amphibia, N. reversa, Surirella robusta, Surirella tenera, Campylodiscus* spp.,*Rhodophyceae Compsopogon* sp., *Audouinella quilonensis, A. godwardense, Batrachospermum* sp.

2. **Zooplankton Protozoa :** *Difflugia* spp., *Astramoeba* sp., *Arcella* sp., *Centropyxis* sp., *Euglypha* sp., *Polystomella* (Elphidium) sp. **Rotifera :** *Lecane* sp., *Bachionus falcatus, B. calciflorus, Brachionus* sp., *B. angularis, Keratella cochlearis, K. tropica, K. vulga, Monostyla* sp. *M. quadridentata, Philodina* sp., *Trichocerca* sp., *T. longise*ta, *Notholca* sp. **Crustacea:** *Daphnia* sp., *Moina daphnia, Streblocerus* sp., *Daphanosoma* sp., *Cypris* sp., *Stenocypris* sp., *Nauplius* sp., *Zoea larva, Cyclops, Mysis larva, Cyclopoid copepod, Harpacticoides, Calanoid copepod, Veliger larva of Eulimella intidissima*. **Meroplankton:** *Nymph of may fly, Nymph of stone fly, Larvae of diptera, Nymph of mites, Damsal fly larva.*

3. **Benthic flora** *Oscillatoria* sp., *Lyngbya* sp., *Oedogonium* spp., *Euastrum* spp., *Cosmarium* spp., *Scenedesmus* sp., *Gonatozygon* sp., *Staurastrum* sp., *Hyalotheca* sp., *Closterium* sp., *Pleurotaenium* sp., *Euglena* sp., *Phacus* sp., *Melosira* sp., *Fragillaria* sp., *Cocconeis* sp., *Synedra* sp., *Eunotia* sp., *Navicula* sp., *Pinnularia* sp., *Diploneis* sp., *Diatoma* sp., *Pleurosigma* sp., *Gomphonema* sp., *Cymbella* sp., *Amphora* sp., *Nitzschia* sp., *Surirella* sp., *Campylodiscus* sp., *Gyrosigma* sp.

4. **Benthic fauna Protozoa :** *Dinamoeba* sp., *Actinosphaerium* sp., *Actinophrys* sp., *Paramecium caudatum, Astramoeba radios*a, *Halophyra* sp., *Spirostrum* sp., *Saprophilus agitatus, Stylonychia* sp., *Nassula orinata, Didinium* sp., *Endosphaeria* sp., *Urocentrum* sp., *Dileptus* sp., *Elphidium* sp., *Globigerina* sp. **Aschelminthes :** *Nematode worm*. **Annelida:** *Aelosoma bengalense, Dero digitata, Autophorus tokiensis, Tubifex tubifex, Dero* sp., *Pristina longisets, Hirudinea* sp., *Dendronereis, Prionospiro polybranchiata*. **Arthropoda :** *Crustacea –Macrobrachium* sp., *Caridina* sp., *Penaeus indicus, Photis gemiculata, Photis longicandata, Paracalliope indica,* Cypris sp., *Cando cypris, Onychocampus* sp., *Paramesochra wilsoni, Sphaerosoma telebrans, Cyanthura carinata. Insecta– Chironomus* sp., *Damsel fly nymph, Ephemeralla* sp., *Rhyancophila larva, Larvae of Diptera, Nymph of Mites, Nymph of Stone fly*. **Mollusca :** *Lepidodesmella* (Gastrotrychan) sp., *Melania tuberculata, Villorita cyprinoids, Lamelliden* sp., *Viviparous bengalensis*.

5. **Macroinvertebrate Insecta :** *Notonecta glauca, Rhagovelia* sp., *Cordulegaster* sp., *Ranatra elongata, Laccotrephus maculatus, Orectochilus discifer, Aphelocherius* sp., *Larvae of Psephenus* sp., *Nymph of Odonata* sp., *Chironomus* sp., *Nymph of Ephemerella* sp., *Nymph of Pantala.* **Archinida :** *Argyronecta aquatica*. **Crustacea:** *Macrobrachium canarae, Macrobrachium idella, Macrobrachium dobsoni, Macrobrachium rosenbergii, Penaeus indicus, Penaeus semisulcatus, Penaeus monodon, Metapenaeus dobsoni, Caridina* sp., *Thalamita crenata, Potomonid Crab.* **Gastropod :** *Melania tuberculata, Viviparous bengalensis*. **Bivalves :** *Lamelliden* sp., *Villorita cyprinoids.* **Coelenterata :** *Cassiopea* sp.

6. **Fish Fresh water :** *Puntius melanampyx, Puntius* spp., *Noemacheilus pulchellus, Danio aequipinnatus, Parluciosoma daniconius, Puntius ticto punctatus, Lepidocephalus irrorata, Barilius bakeri, Puntius vittatus, Aplocheilus rubrostigma, Hypselo barbus curmuca, Puntius amphibius, Mystus oculutus, Puntius filamentosus, Garra menoni, Puntius sarana sarana, Xenentodon cancila, Macropodus cupanus, Awaous grammepomus, Puntius sarana subnasutus, Hyporamphus xanthopterus, Anabas testudineus, Glossogobius giuris, Clarias batrachus, Channa striatus*. **Brackish and coastal water :** *Etroplus maculates, Caranx sansun, Gerres fiamentosus, Etroplus suratensis, Liza parsia, Valamugil cunnesius, Oxyurichthys, tentacularis, Lutjamus argentimaculatus, Lutjanus fulviflamma, Synaptura orientalis, Cynoglossus bengalensis, Chelonodon patoca, Tachysurus arius, Tachysurus subrostratus, Ambassis gymnocephalus, Ambassis commersoni, Epinephleus tauvina, Sillago sihama, Caranx ignobilis, Leiognathus splendens, Secutor ruconis, Secutor insidiator, Gazza minuta, Gerres oyena, Pomadasys hasta, Scatophagus argus, Valamugil saheli, Glossogobius biocellatus, Teuthis java, Acanthurus gahm*.

Table 2. Feeding habit of some of the fresh water fishes of Ithikkara river

Sl.No.	Name of fish	Feeding habit	Food items
1.	*Wallago attu*	Carnivorous; predatory	Fry and fingerlings of fishes, Dead animal matter
2.	*Danio aequipinnatus*	Carnivorous; surface feeder	Terrestrial Arthropods, Insects (Nymph of Odonata, Diptera and Ants)
3.	*Puntius amphibius*	Herbivorous; bottom feeder	Detritus, Algae, aquatic plants, Zooplankton
4.	*Puntius filamentosus*	Herbivorous; bottom feeder	Algae, Higher aquatic plant material.
5.	*Puntius vittatus*	Herbivorous; bottom feeder	Detritus, Algae
6.	*Puntius melanampyx*	Carnivorous; bottom feeder	Aquatic larvae, Nymph of Coleoptera, Diptera, Trichoptera Ephemeroptera, Chironomids
7.	*Parluciosoma daniconius*	Omnivorous; bottom feeder	Insects, Plant matter, Dipteran larvae, Coleoptera, Algae, Crustacea
8.	*Clarias batrachus*	Carnivorous; bottom feeder	Detritus, Algae
9.	*Channa striatus*	Carnivorous; Piscivorous	Fishes, Frog, Insects
10.	*Glossogobius giuris*	Carnivorous; predatory	Fry and fingerlings of Barbus sp., Larvae of Insects
11.	*Anabas testudineus*	Omnivorous	Mollusca, Algae, Insects, Dipteran larvae, Macro phytes, Detritus
12.	*Macropodus cupanus*	Omnivorous	Rotifers, Crustaceans, Larvae of Insects, Mosquito larvae, May fly, Damsel fly, Dragon fly, Small fishes

Table 3. Threatened fresh water fishes of Ithikkara river (after IUCN, 1990)

Sl.No.	Name of fish	Threat	IUCN Category
1.	*Anabas testudineus*	Damming, Fishing, Human interference, Over exploitation, Trade (local, domestical, commercial)	VU
	Barilius bakeri	Fishing, Loss of habitat, Pesticides, Poisoning, Siltation, Trade (local) Channa striatus Fishing, Trade (commercial)	VU LRlc
	Clarias batrachus	Trade (commercial, local, domestic)	VU
	Danio aequipinnatus	Human interference, Loss of habitat, Pollution, Trade (local, domestic)	LRnt
	Hyporhamphus xanthopterus	Fishing, Human interference, Loss of habitat, Over exploitation, Pesticides, Poisoning, Trade (local, domestic)	CR
	Hypselobarbus curmuca	Disease, Dynamiting and other destructive method of fishing, Loss of habitat due to exotic animals, Over exploitation, Predation, Predation by exotic animals, Trade (local, domestic)	EN
	Lepidocephalus irrorata	Human interference, Fragmentation, Trade (local)	VU
	Noemacheilus pulchellus	Damming, Fishing, Human interference, Loss of habitat, Over exploitation, Poisoning, Pollution, Trade (local)	DD
	Parluciosoma daniconius	Fishing, Pollution, Trade (local, domestic)	LRnt
	Puntius sarana sarana	Fishing, Human interference, Loss of habitat, Trade (local, domestic)	
	Puntius ticto punctatus	Fishing, Genetic problems, Over exploitation, Trade (local)	CR
	Puntius vittatus	Fishing, Human interference, Loss of Habitat, Over exploitation, Pollution, Trade (commercial)	VU
	Wallago attu	Decline in prey species, Hunting for food, Poisoning, Siltation, Trade (local, domestic, commercial)	LRnt
	Xenentodon cancila	Fishing, Pollution, Trade (domestic)	LRnt
	Glossogobius giuris	Hunting, Trade (local)	LRnt

VU – Vulnerable; LRlc – Lower Risk least concern; LRnt – Lower Risk near threatened; CR – Critically Endangered; EN – Endangered; DD – Data Deficient

phase of life is in rivers and other aquatic systems help pollination and reproduction in plants in adult stage (Miller, 1994). In short, indiscriminate scooping of sand from the riverine environment of Kerala is a major threat to the biological communities of both aquatic and terrestrial environments.

CONCLUSION

Indiscriminate sand mining is one of the potential threats to many of the fresh water biota. Mining of sands to the tune of 350 truck loads per day from about 50 sand mining locations/kadavus can im-

pose marked changes on the biological environment of the Ithikkara river. Increase in turbidity, reduced supply of organic detritus, loss of breeding and spawning grounds, aggravated saltwater ingression, etc., are some of the physico-chemical attributes responsible for the observed changes in the population density and distributional pattern of many aquatic organisms of the Ithikkara river. Stringent efforts are needed to revive the environmental quality of this riverine system which sustain the life and greenery of over 20 local bodies of Kollam and Thiruvananthapuram districts.

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REFERENCES

CESS. 2001. *Sand Mining from Kerala Rivers, Consequences and Strategies*. Centre for Earth Science Studies, Thiruvananthapuram. 14p.

CWRDM. 1999. *Sand Mining in Kerala with Special Reference to Periyar*, Centre for Water Resource Development and Management, Calicut. 61 p.

Dobson, M. and Frid, C. 1998. *Ecology of Aquatic Systems*. Addison Wesley Longman Ltd. Edinburgh Gate, Harlow, England, 222 p.

IUCN. 1990. *IUCN Red List of Threatened Animals*, World Consevation Monitoring Centre. Cambridge, United Kingdom.

Miller, T. Jr. 1994. *Living in the Environment*. Wads Worth Publishing Company, Belmont, California, 701 p.

Nautiyal, P. 1985. Utter Pradesh. *J. Zool*. 5 : 14-19.

Nikolsky, G. V. 1963. *The Ecology of Fishes*. Academic Press Inc. (London) Ltd. 352 p.

Shaji, E. 2002. Pozhikkara irrigation regulator - Environmental impact on land and water, A case study. *Proceeding of the Fourteenth Kerala Science Congress*. 29-31 January 2002, Kochi, pp 3-7

Sharma, B. Dhalla, N. and Renusalaria, 1996. *Advances in Fish and Wild Life Ecology and Biology* Vol -1. Daya Publishing house, New Delhi,332 p.

Sheeba, S. 1999. *Certain aspects of Ecology of Ithikkara River*. PhD Thesis. Mahatma Gandhi Univ., Kerala, 408 p.

Shibu, S. 1991. *Ecology of Paravur lake* PhD thesis University of Kerala, Trviandrum.

Srinivastava, 1998. *A text book of Fishery Science and Indian Fisheries*. Kitab Mahal.15. Allahabad. 306 p.

Sunil Kumar, R. 2002. Impact of sand mining on the Benthic fauna -A case study from Achankovil River in Kerala Study sponsored by CESS, Thiruvananthapuram. 38 p.

Waters, T. F. 1995. Sediment in streams. Sources, biological effects and control. American Fisheries Society Monograph.