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Experiments in restoration of benthic biodiversity in Pulicat Lake, south India

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Abstract

Experimental eco- and biodiversity restoration in the rapidly degrading Pulicat Lake (Lagoon), a major wetland in Tamil Nadu, was undertaken, with local fishermen's participation. Since benthic habitats and biodiversity, particularly the edible oysters were surmised to be crucial for biodiversity restoration in Pulicat Lake, batteries of roof tiles were deployed in 16 'protected areas' representing the whole lake, to attract oyster settlement. Within one year of deploying such artificial habitats, 83 species of biodiversity were found to colonise these experimental 'tile-batteries', where the edible oysters served as the 'keystone' species. Species diversity restored at each of the 16 'protected areas', indicated the relative abundance of species, ecological and seasonal succession, monsoon mortality and settlement of rare species and fish aggregations. These model experiments in eco- and biodiversity restoration are replicable in all other lagoons, in India.

Introduction

Biodiversity, which is so rich in tropical countries, is fast disappearing, chiefly by due to habitat destruction and species exploitation. Aquatic ecosystems, in particular, are subjected to water pollution and habitat degradation, due to various developmental interventions. Also, there is no legal provision in India to protect aquatic biodiversity (Sanjeeva Raj, 1995).

Pulicat Lake (13°24' to 13°47'N and 80°02' to 80°16'E) (Fig.1), with an average water spread area of about 461 sq.km, on the Coromandel coast, is the second largest lagoon in India (Sanjeeva Raj, 1993). It extends between the southern Andhra Pradesh and northern Tamil Nadu, running parallel to the Bay of Bengal opening into it, through a narrow mouth, which gets closed up partially every summer due to the formation of a sand bar. There are two monsoonal rivulets, Kalangi and Arni, which open into the lake, and the Buckingham Canal or the east coast canal, that runs parallel to the Coromandel coast, passes through the lake.

As a tropical brackishwater lagoon ecosystem, Pulicat Lake has been so rich in biodiversity and fisheries since ancient times. Nearly one hundred thousand fisherfolk have settled down in 52 fishing hamlets and another equal number of *dalits* also have settled down to eke out their livelihoods through fishing or collection of other resources from this lake. However, since the recent 30 years, this lake has been subjected to a variety of ecological crises, both natural as well as man-made. As a result not only the biodiversity but also fishing has been declining so fast that the livelihoods of the poor dependent on this lake are seriously threatened. This vast wetland attracts nearly 60 thousand birds belonging to 50 species of which 20 of them breed in the nearby Nelapattu Bird Sanctuary, are also critically losing their feeding and breeding grounds.

This is the same fate of all lagoons or wetlands in India as well as in the whole of South-East Asia. The eco-restoration in such degraded lagoon ecosystems is a major and urgent challenge facing aquatic biologists. In shallow water bodies like Pulicat Lake, benthic habitats and benthic biodiversity are crucial for eco and biodiversity restoration.

During 1997 to 1998 the WWF-India has funded a project on eco-and biodiversity restoration in Pulicat Lake, where we initiated certain experiments and have been following them till date. The methodology adopted and the results arrived at would serve as models for biodiversity restoration in all other lagoons in India as well as in South-east Asia.

We are grateful to the WWF-India, particularly to Dr. Parikshit Gautham for his interest in this project, to Dr.K.Rajaratnam, Director, Centre for Research on New International Economic Order, for his constant encouragement, and to the Madras Christian College, for renting out their field laboratory at Pulicat for this project. We wish to express our deep gratitude to the *paadu* fishermen for permitting us these experiments on their lake and to the fisherfolk of the Jamilabad Village for their participation and cooperation in this project. We thank Mr. E. Karunanidhi for serving as a boatman and fieldman.

Ecological crises facing Pulicat Lake

Siltation: The most major ecological threat to the benthic habitat and life in the Pulicat Lake is the escalating and massive siltation during the monsoon floods, which also reduce the depth of the water column. The rate of siltation is estimated to be about one meter deep, per century (Caratini, 1994). All the benthic flora, fauna and detritus get buried under such heavy silt, so that during and immediately after the monsoon, there is little benthic life left in the lake.

Lake-mouth closure : As the monsoon recedes, the outflow of freshwater from the lake is literally nil, and the sand bar formed due to the tidal influence closes the lake-mouth partially in the summer, or fully once in a few years, as happened during 2001-2002. Ingression of plankton, flora and fauna into the lake from the sea is stopped during such periods.

Drying up of the northern regions of the Lake: After the SHAR road-bridge from Sullurpet to Sriharikota was constructed across the lake during the early 1970s, the shallower regions of the lake, north of this road-bridge, literally one-third of the lake, got dried up annihilating the whole biodiversity.

Over-fishing: The demand for prawns

and crabs for exports from Pulicat Lake since 1970s have led to intensification of the fishing efforts, resulting in habitat and species destruction.

Aquafarms: Aquafarms for culture of exportable prawn, in the southern region, not only drain the lake water, but also discharge the untreated effluents back into the lake, polluting it and killing all biodiversity.

Paddy fields: Paddy farming carried out in the dried up regions of the Pulicat Lake, north of the SHAR road-bridge also is a threat to biodiversity including birds due to the pesticides discharged into the waters.

Industrial pollution: The North Chennai Thermal Power Station (NCTPS) at the southern end, discharges its untreated effluents into the Backingham Canal which flow northwards into the Pulicat Lake, causing massive mortality of fish as well as other biodiversity (Sanjeeva Raj, 1999 and 2000).

Material and methods

Principle: The observation that loss of oyster-beds, the "keystone species" for attracting benthic biodiversity has resulted in drastic decline of benthic biodiversity in the southern region of the lake, has provided us the clue for the methodology to be adopted for restoring biodiversity in the experimental sites. Locally available, cheap and non-polluting material was chosen for experiments to attract the settlement of oyster-spat.

"Tile-batteries" country roof tiles which are concavo-convex, eight inches long, four inches wide and with a maximum convexity of three inches, were chosen as the substrata for oyster-spat to settle down. Used tiles from old houses undergoing renovation in Pulicat Town were available at cheap prices. Such roof tiles, in five tiers, two in a tier, were fastened tightly with thin coir rope. The two tiles in each tier were laid oriented at right angles to the two tiles in the adjacent tier. All alternate tiers had their concavity facing downwards and the convexity facing upwards, so that enough crevices were left between two adjacent tiers. Each bundle of ten such tiles, in five tiers, is called a "tile-battery".

"Protected areas": One hundred such "tile-batteries" were laid in an unpolluted experimental plot called a "protected area". Fishermen were requested to protect such areas, from disturbance of any kind. Each area measured roughly 15 x 15 meters, and 16 such areas were chosen all over the lake (Fig.1), representing different habitats. The "tile-batteries" were arranged in different designs within a "protected area".

Caution was exercised to make sure that the "tile-batteries" do not get exposed during the low-tide or obstruct routine navigation and fishing.

Data collection: Each of the 16 "protected areas" was visited once a month, and some "tile-batteries" were pulled out into the boat and examined tier by tier, for settlement of biodiversity. They were then replaced in the "protected area".

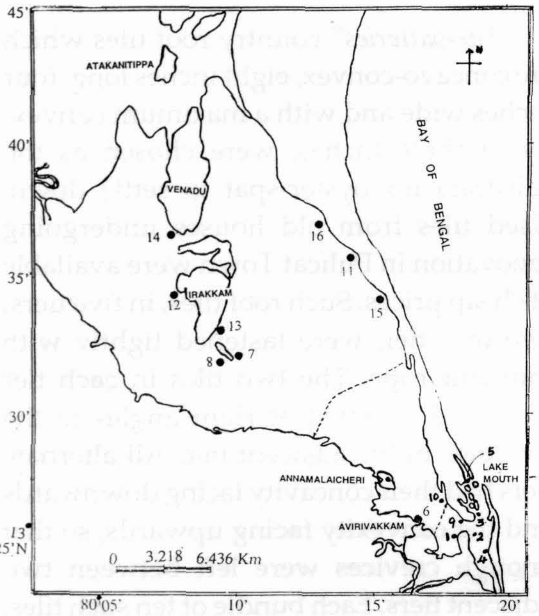

Fig.1. *Pulicat Lake showing the protected areas in the north*

Results

Ecological sub-divisions in the lake

Ecologically, Pulicat Lake can be divided into two major sub-divisions, the southern region and the northern region (north of the Venadu and Irakkam Islands). The southern region, being closer to the mouth is less turbid (35-40cm) and comparatively deeper subjected to tidal influences. The northern region is more turbid (15-20 cm), shallower and is not under tidal influence. Accordingly, the whole biodiversity of the lake, including birds, is influenced by these two ecological zonations, with characteristic southern and northern biodiversity composition.

Species diversity

An amazing diversity of 83 species of brackish water fauna was restored to these artificial habitats, within an year, as listed in Table 1. The relative frequency or abundance of all these species, at each protected area, is also indicated in the same table. Protected areas 1 to 8 are in the southern region of the lake and 9 to 16 are in the northern region, and one can see the distinct biodiversity composition of each region.

Ecological succession

In the southern region, the pioneer settlers on artificial habitats like hard roof tiles are barnacles like *Balanus amphitrite*, *B. reticulatus* and *B. cirratus*, followed by the spat of the edible oyster, *Crassostrea madrasensis* (Preston), which is the most dominant climax species, and also the "keystone species". In between such oyster spat, the tubicolous polychaete, *Hydroides norvegica* settles, followed by *Modiolus matcalfii* and just one or two green mussels, *Perna viridis.*, free-living isopods and amphipods move amidst these sessile forms, particularly on the bottom tiers where silt is more common. Since barnacles are continuous breeders, with two peaks, one in January-February and the other in July-August (Thangavelu and Sanjeeva Raj, 1988) and also since the edible oyster has also two breeding seasons, one in February to April and the other in June-July (Thangavelu, 1983), their settlement is highest during such breeding months.

A few *Modiolus* and *Perna* have been found to settle down occasionally, in between barnacles and oysters, in the southern region. On the contray, in the northern regions, the primary settlers are species of *Modiolus,* followed by a few barnacles

(*Balanus* sp.) but no spat of the edible oyster could be seen in the north. Being more turbid with silt, isopods and amphipods were more common in the north.

Therefore, the edible oyster is characteristic of the less turbid southern area. *Modiolus* is characteristic of the more turbid north side. Once the oysters begin to grow, they act as "keystone species", attracting a wide variety of other biodiversity. The green mussel *Perna viridis* thrives better in deeper waters, more saline and with less silt.

Seasonal succession

Being a euryhaline habitat with salinities fluctuating between zero during the monsoon to 53 ppm during summer, seasonal succession of biodiversity also can be expected in Pulicat Lake. During the less saline monsoon season, freshwater organism like the gastropod, *Clithon ovalensis* is more common but declines with increasing salinity. Even freshwater fishes like *Ophiocephalus punctatus* and *Tilapia mossambica* frequent the experimental sites, during the monsoon, but disappear with increasing salinities.

Monsoon mortality

In a brackishwater ecosystem like the Pulicat Lake, monsoon brings about not only spectacular changes in biodiversity composition, but also heavy loss of biodiversity. The northeast monsoon (November - December) is more dominant on the Pulicat Lake. The sessile or encrusting forms like barnacles and edible oysters die and decline in numbers, due to sudden lowering of salinity, excessive siltation, burial of these encrustations, and above all, because it is a non-breeding season for them.

However, silt settled down would be washed away within the ensuring two or three post-mosoon months, so that biodiversity would once again begin to settle down, because of the presence of hard substrata provided, like tiles and empty shells of oysters, left behind.

Lower vs upper tiers of tiles

Lower tiers of tiles being in slush and more silt-laden, harbour more isopods, amphipods and free-living polychaetes. On the uppermost tier, more algae are noticed. Barnacles and oysters as well as the tubicolous polychaete *Hydroides norvegica* are present on all tiers, uniformly.

Lower vs upper surface of tiles

Generally, sessile or encrusting fauna is photo-negative, settles down on the shady regions of substrata. Accordingly, in these experiments also, the topmost tier of tiles has more encrustations on the lower side than on the upper side of the tiles which are directly exposed to the sun. On the other hand, the lower tiers, show encrustation on the upper side since they are under the shelter of the topmost tier. However, amphipods, which prefer silt, are found on both the upper and lower surfaces of the lowest tier which lies in slush.

Oyster settlement and growth

Natural settlement of the edible oyster-spat is highest during their breeding sea-

Table 1. *Biodiversity restored and relative dominance at protected areas.*

Species	Protected areas															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polychaetes																
Nereis chilkensis	P	M	M	R	R	-	M	R	M	R	P	R	R	-	R	-
Tylonereis fauveli	R	R	M	R	-	-	-	-	-	-	-	-	-	-	-	-
Harmathoe ampullifera	R	M	R	R	R	-	-	-	-	-	-	-	-	-	-	-
H. imbricata	-	M	R	R	R	-	-	R	-	-	-	-	-	-	-	-
Heteromastus similis	M	M	M	R	-	-	-	R	M	-	-	-	-	-	-	-
Potamilla leptochaeta	M	M	R	R	-	-	-	-	-	-	-	-	-	-	-	-
Hydroides norvegica	P	M	M	R	M	-	-	-	M	M	M	-	-	-	-	-
Pectinaria abranchiata	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Amphicteis gunneri	-	*R*	-	*R*	-	-	-	-	-	-	-	-	-	-	-	-
Marphysa gravelyi	M	M	P	M	R	-	-	-	M	M	-	R	-	-	-	M
Crustaceans																
B. amphitrite	P	P	P	M	P	R	R	M	M	M	M	R	M	R	R	R
B. reticulatus	P	P	P	M	R	-	R	-	R	M	-	-	-	-	-	R
B. cirratus	P	P	P	M	R	-	-	-	-	-	-	-	-	-	-	-
Corophium sp.	M	P	P	M	R	-	P	P	P	P	P	P	P	P	P	P
Penaeus indicus	M	P	P	M	R	M	M	M	P	P	R	M	M	M	M	M
P.monodon	M	P	P	M	R	M	-	M	M	P	M	M	R	M	R	M
P.semisulcatus	M	P	M	P	-	M	-	-	M	M	M	-	-	-	-	-
Metapenaeus dobsoni	R	R	M	R	-	-	-	-	M	-	-	-	-	-	-	-
M.monoceros	R	R	M	R	-	-	-	-	-	-	-	-	-	-	-	-
Acetes indicus	-	R	M	R	R	-	-	-	-	-	-	-	-	-	-	-
Macrobrachium equidens	-	R	M	R	-	-	-	-	-	-	-	-	-	-	-	-
Alpheus malabaricus	M	P	M	M	R	-	-	-	M	M	M	-	R	-	-	P
Clibanarius longitarsus	R	R	R	R	M	-	-	-	-	-	-	-	-	-	-	-
Diogenes avarus	-	-	R	R	P	-	-	-	-	-	-	-	-	-	-	-
Scylla serrata	-	R	M	R	M	-	-	-	M	-	-	-	M	-	-	-
S.tranquebarica	-	R	M	R	M	-	-	-	R	-	-	-	M	-	-	-
Thalamita crenata	R	R	M	R	M	-	-	-	M	P	M	-	M	-	-	M
Portunus pelagicus	-	-	M	R	M	-	-	-	-	-	-	-	-	-	-	-
P.sanguinolentus	-	-	M	M	M	-	-	-	-	-	-	-	-	-	-	-
Pinnotherus sp.	R	M	M	M	-	-	-	-	M	-	-	-	-	-	-	-
Molluscs																
Thias sp.	M	P	P	R	M	-	-	-	-	-	-	-	-	-	-	-
Chthon ovalensis	M	P	M	M	P	-	-	-	R	R	-	-	-	-	-	-
Cerithedia cingulata	R	R	P	M	P	-	-	-	R	-	-	-	-	-	-	-

Nassarius stolata	R	-	R	M	-	-	P	M	P	P	M	M	M	M	R	P
Catelysia opima	R	R	R	M	-	-	M	M	M	-	M	-	-	R	-	M
Perna viridis	R	R	R	R	M	-	M	-	P	M	-	-	-	-	-	-
Crassostrea madrasensis	P	P	P	P	P	-	-	-	P	M	M	-	-	-	-	-
Modiolus metcalfii	R	R	R	M	R	M	P	M	M	P	P	P	P	P	P	P
Pinctada margaritifera	R	R	-	R	R	-	-	-	R	-	-	-	-	-	-	-
Anadara granosa	R	-	-	R	M	-	-	-	-	-	-	-	-	-	-	-
Tellina cuspis	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Tellina sp.	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Webbed Octopus	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Chordata - Fishes																
Teleostomi																
*Platycephalus insidiater+**	M	M	M	M	R	-	-	-	-	-	-	-	-	-	-	-
Arius dussumieri	R	M	M	M	R	-	M	M	M	M	M	R	M	M	M	M
Mystus gulio	R	R	R	-	-	-	-	-	R	M	M	M	M	-	M	-
*Plotosus canius+**	R	R	M	-	-	M	M	M	M	P	P	P	P	P	P	P
Hemiramphus far	R	-	-	R	R	-	M	M	M	M	M	-	-	-	-	P
Tylosurus leiurus	R	-	-	-	-	-	M	-	-	R	-	-	-	-	-	M
Liza parsia	M	R	M	M	R	-	M	M	-	M	-	-	-	-	-	-
L.macrolepis	M	R	M	M	-	-	M	M	M	R	-	-	-	-	-	-
Sphyraena jello	-	-	R	M	R	-	-	-	-	-	-	-	-	-	-	-
*Ophiocephalus punctatus**	-	R	M	R	-	-	-	-	-	-	-	-	-	-	-	
*Promicrops lanceolatus**	P	M	M	R	R	-	-	-	-	-	M	-	-	-	-	-
*Gerrus filamentosus**	P	M	M	M	R	-	-	-	M	R	-	-	-	-	-	-
Ambassis gymnocephalus	P	M	M	M	R	R	-	-	M	-	-	-	-	-	-	M
Secutor ruconius	P	M	M	R	-	-	-	-	-	-	-	-	-	-	-	-
Gnathanodon speciosus	M	M	M	M	R	-	-	-	M	-	-	-	-	-	-	-
Upeneus sulphureus	R	R	M	R	-	-	-	-	-	-	-	-	-	-	-	-
Pomadasys kaakan	M	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-
*Lutjanus fulviflamma**	R	M	M	M	R	R	M	-	M	M	M	R	M	M	R	M
*L. argentimaculatus**	R	M	P	M	R	-	M	R	R	-	M	R	R	-	R	-
Thrissocles mystax	R	R	-	R	R	-	-	-	-	-	-	-	-	-	-	-
T. jarbua	M	M	P	M	-	-	-	-	R	-	-	-	-	-	-	-
Therapon puta	M	M	P	M	-	-	-	R	R	-	-	-	-	-	-	-
Caranx ferdau	-	R	M	M	-	-	-	-	-	-	-	-	-	-	-	-
Leiognathus dussumieri	-	M	M	M	R	-	-	-	M	-	-	-	-	-	-	-
*Epinephelus malabaricus+**	P	P	P	M	R	-	-	-	M	M	M	-	-	-	-	-
*Bostrichthys sinensis+**	R	R	M	R	-	-	-	-	M	-	-	-	-	-	-	-
*Stigmatogobius minima**	R	R	M	R	-	-	-	-	M	M	-	-	-	-	-	-
*Etroplus suratensis+**	P	P	M	M	R	M	-	-	M	M	-	-	-	R	-	M

E.maculatus	R	M	R	R	-	-	-	-	R	-	-	-	-	R	-	M
*Siganus javus+**	M	P	M	M	R	R	M	-	M	M	M	M	M	M	M	M
Tilapia mossambica	M	R	R	R	R	-	-	-	-	-	-	-	-	-	-	-
*Scatophagus argus**	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-
*Bathygobius fuscus**	-	R	R	R	R	-	-	-	R	R	-	-	-	-	-	-
Oxyurichthys tentacularis	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-\	-
Sillago sihama	-	R	R	M	-	-	-	-	-	-	-	-	-	-	-	-
*Lates calcarifer+**	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-
Zebrasoma xanthurus	-	-	R	R	M	-	-	-	-	-	-	-	-	-	-	-
Arothron leopardus	-	R	R	R	M	-	-	-	-	-	-	-	-	-	-	-
Triacanthus brevirostris	R	R	-	-	P	-	R	M	-	-	-	-	R	R	M	M

• Protected areas as shown in Fig. 1.
R = Rare, M=Moderate, P=Plenty and -=Absent.
# Classification, after Munro 1982
+ Food fishes preferred by fishermen
* fishes more frequent at the 'tile batteries'.

sons and also in the vicinity of wild oyster-beds. Their growth also is higher in less turbid and more saline brackishwaters. At a free surface, exposed to tidal influence, their growth is faster.

Location in the lake

Biodiversity is more populous at the lake-mouth, where fresh tides bring in a lot of settling larvae. In polluted and turbid waters, biodiversity declines.

Rare species

Two species of tubicolous polychaetes, *Amphicteis gunneri* and *Pectinaria abranchiata,* which were not recorded earlier by Sunder Raj and Sanjeeva Raj (1987), are now seen at one of the protected areas (Munai-jelly). This may be because of suitable shelter available amidst the tiles in a suitable environment, that such rare forms are attracted. However, it indicates that habitat restoration can bring about restoration of rare species also.

Fish aggregation

These "tile-batteries" and even the edible oyster encrustations on them act as Fish Aggregation Devices (FADs). In our experiments, 39 species of fish were attracted to these "tile-batteries" (Table 1.), out of which 15 were more frequent (shown with a cross mark) which fishermen were meeting from the buffer zone of our experimental protected areas.

Plotosus canius, whose sting is very poisonous, was more common amidst the tile-batteries in the north, where silt was more common, but in the south, silt-free region, *Platycephalus insidiator* and *Epinephelus malabaricus* were more common.

Thus, biodiversity restoration through artificial habitats, provides fish diversity also, helping fishermen.

Bird diversity

Significant attraction of wading birds to these experimental sites was not noticed, perhaps because they need soft ooze, for feeding rather than hard tiles.

Discussion

Identifying "Keystone Species" in an aquatic ecosystem is crucial for promoting biodiversity. However, if such keystone specices are exploited for food or for commerce, their exploitation should be regulated in order to conserve an optimum population, to maintain biodiversity.

Local fishermen's participation and co-operation is vital for the success of such experiments in their fishing grounds. For that, fishermen need to be conscientised first about the importance of biodiversity and its conservation, to support a better fishery.

These experiments are replicable in any brackishwater ecosystem in India or in the South East Asia.

Recommendations

Brackishwater ecosystems and habitats in India should be protected chiefly from siltation, eutrophication, pollution and from sudden and extreme salinity changes.

Opening of any brackishwater body into the ocean should be permanently maintained, so that exchange of water, flora and fauna is facilitated.

Benthic vegetation and detritus formation should be promoted, and a variety of benthic substrata or habitats (like sandy, clayey, weedy and rocky) should be promoted to attract a rich benthic biodiversity.

Maintaining shallow water areas along the margins, as well as deeper areas at the center of an aquatic body, is equally important to promote biodiversity.

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