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Biofouling by *Saccostrea cucullata* - a major threat to mangroves of Vasishthi Estuary, Maharashtra

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Present work reports heavy biofouling by *Saccostrea cucullata* on mangroves of the Vasishthi Estuary. High heavy metal concentrations in the estuary could be the cause of proliferation of these oyster species. Field observations suggest physiological impairment of mangroves due to oyster biofouling, damaging their capacity to accrue sediments. Thus, biofouling by *S. cucullata* is not only a major threat to the mangrove forests in the Vasishthi Estuary, but also to the tidal flats which are a haven for diverse benthic community, organic carbon sinks and natural adsorbents of pollutants.

[Keywords: *Saccostrea cucullata,* Vasishthi Estuary, biofouling, heavy metal pollution, erosion]

Introduction

Mangrove area in India was estimated to be about 6,819.76 km^2 about five decades ago[1]. By the mid 90's, this expanse had reduced to 4,474 km^2 (i.e. 33% reduction) as deciphered from remotely sensed data[2]. Their destruction has been attributed to several causes, the major one's being- grazing, felling for timber, exploitation of fishery resources, reclamation of land for building, agriculture, aquaculture and saltpans, as well as for dumping of solid, domestic and industrial wastes. However, the damage done by another biotic threat i.e. biofouling, though recognised has neither been given enough importance nor understood, in the Indian context. Table 1 enlists all the published works on biofouling on Indian mangroves[3-12]. The publications are few, preliminary and limited to studies on faunistic composition of borers restricted to few mangrove areas[6]. In contrast, extensive work has been done in other parts of the globe on understanding biofouling on mangroves and their deleterious effects[13]. Observations show that biofouling can infest and destroy healthy and living mangrove populations[10]. Collecting more than 2800 national and sub-national data sets, covering 121 countries where mangroves are known to exist, and comparison with the earliest estimates dating back to 1918, the Food and Agriculture Organization of the United Nations has compiled an updated list of the most recent, reliable estimate for each country[14]. The study concludes that better information on both the extent and the condition of mangroves is needed as an aid to policy and decision making aimed at the conservation, management and sustainable use of the world's remaining mangrove ecosystems.

Table 1 - Previous studies on biofouling on mangroves

	Study area	Author & Year	Aspect of study
1	Sunderbans, West Bengal	Roonawal, 1954[3]	Description of *Bactronophorus thoracites* biofouling on living mangroves
2	---	Pillai, 1961[4]	Monograph on wood-boring Crustacea of India
3	---	Santhakumaran and Sawant, 1991 [5]; Santhakumaran 2003[6]	Enlisted and described different mechanisms of biodeterioration of mangrove vegetation due to marine organisms
4	---	Santhakumaran, 1994[7]	Compilation of an annotated bibliography of marine wood borers
5	Goa coast	Santahkumaran and Sawant, 1994[8]	Damage of mangrove saplings due to marine bio-fouling
6	---	Santhakumaran, 1996[9]	Described marine wood-borers on mangroves from Indian Coasts
7	Goa Coast	Santahkumaran and Sawant, 1998[10]	Enlisted the marine wood-infesting organisms on mangroves of Goa
8	Pichavaram, Tamilnadu	Karuppaiyan and Raja, 2007[11]	Studied the effect of tides on the settlement of oysters and barnacles on Mangroves
9	Vellar Estuary, Tamilnadu	Rani et al., 2010[12]	Attributed barnacle infestation on Mangroves to heightened salinity

The present study aims at reporting extensive biofouling on mangroves within the Vasishthi Estuary of Ratnagiri District, Maharashtra and discusses its causes as well as detrimental effects on the particular ecosystem.

Materials and Methods

The Vasishthi River is 50 km long and flows through a rugged hilly and largely bare terrain of the Ratnagiri District (Fig. 1). It flows in the southeast – northwest direction, has a funnel shaped mouth, and joins the Arabian Sea at Dabhol. It is dominated by semi-diurnal tides[15-16]. Dabhol is a small but strategic port at the mouth of the Vasishthi Estuary. It is an important ship-building and dry-docking centre located on the northern bank of the estuary, 2 km inland. 1080 acres of Lote –Parshuram MIDC at Khed is established on the banks of the River Jagbudi. It is a chemical zone, comprising of 200 big and small industries, manufacturing dyes, intermediates, bulk drugs, agro chemicals and specialty chemicals[17]. This estuary, once known to house nearly 107 species of fish now allegedly supports only six to seven species[18-19]. About 55 villages along the entire stretch of the estuary are dependent on sea-catch to meet their daily needs of fish, their staple food. As early as in 1980, Untawale identified and proposed the need of onservation of mangroves along the Vasishthi Estuary[20].

GPS locations of biofouling, point - non-point sources of sewage disposal, and other relevant observations were recorded in the estuary. Mudflats infested by biofouling were revisited using a small boat and traverses in the mangrove forestation were made by foot. Trials were made to count number of biofoulers per unit area. But due to dense, three dimensional infestation and layered adherence of oysters, it was impossible be correctly estimate the number in field. Thus, mangrove root and stem samples infested with biofoulers were collected for their further identification. Borers were isolated from infested lengths of root and stem specimens in the laboratory. Effects of biofouling were photographically documented in the field as well as in the laboratory. Benthic water and sediment samples were collected along the length of the estuary at every 2 km interval, in order to estimate the quality of the environment. Ecological parameters such as salinity, temperature, pH and DO were measured onboard whilst toxic metal concentrations in the sediment were measured on the ICP-MS at the National Institute of Oceanography, Goa.

Results

The lower reaches of the estuary is rocky and mudflats are poorly developed. Thus, mangrove vegetation is sparse in this stretch.

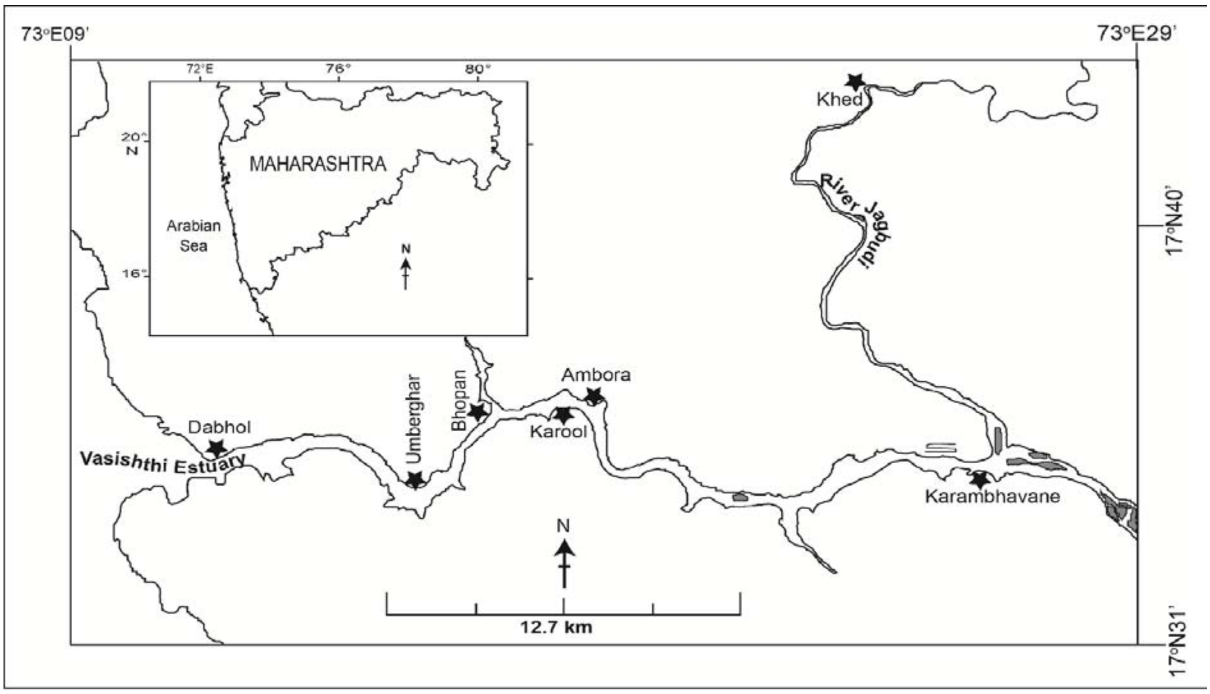

Fig. 1 – Map of the study area

Fig. 2 - a-c: *S. cucullata* infestation on network of pneumatophores and associated erosion of mudflat; d. Close-up view of the biofouling on mudflats; e. Biofouling on prop roots in the form of aggregates; f. Biofouling in the form of nodules on a collected rhizophore specimen; g. Close up view of a profusely biofouled mangrove root specimen; h. Easily exposed xylem and arenchyma tissues, during separation of oysters from biofouled root in lab; i. under-cutting of mangrove mudflats due to erosion

Oyster biofouling is evident, right from the mouth of the estuary inland and intensifies in the middle reaches where dense mangroves occur on wide tidal flats. In the 10 km stretch between Umberghar and Ambora (11 to 20 km inland), prolific biofouling by oyster species was observed

Table 2 - Comparison of heavy metal concentrations in the sediments of Vasishthi Estuary with permissible limits defined by other agencies

Metal	Concentrations (ppm)		Permissible limits of metal concentration in sediments defined by different State agencies			
	Min.	Max.	US EPA[21]	Florida Department of Environmental Protection [22]	Ontario Ministry of Environmental Protection[23]	ANZECC[24]
Cr	244	301.6	<25	33 to 240	26	<80
Mn	1638	2488	NA	NA	NA	NA
Co	52.87	77.08	NA	NA	50	NA
Ni	115	126.4	NA	NA	16	<21
Cu	245	358.4	<25	28 to 170	16	<65
Zn	129.1	224.5	<90	68 to 300	120	<200
Cd	0.05	0.18	NA	0.0075	NA	<1.5
Pb	6.48	14.68	<40	21 to 160	31	<50

*NA – Not available

on the pneumatophores as well as prop roots of the mangroves (2a-e). On the prop roots of mangroves, the oysters occur as densely cemented nodules (Fig. 2f). They form thick and hard encrustations on the branches, leaves and stems (Fig. 2g) of mangroves as well as on the tidal flats and available hard substrates. Wading through the tidal flats was extremely injurious. On an average, 70 to 80 specimens of live *Saccostrea cucullata* could be isolated from a foot-long mangrove root, with a diameter of 1.5 cm. Of these 10-15% of shells were juvenile. The shells were calcified to each other and difficult to separate from one other. However, the oysters easily got separated from the roots; they mostly broke away along with the bark of the root, exposing the xylem bundles or the spongy, gas filled arenchyma (Fig. 2h). It is also interesting to record that the biofouling community comprised of a single species, *S. cucullata* throughout the 10 km stretch. Occasional specimens of gastropod *Neretina* sp. and bivalve *Solena* sp. were recovered during the process of separating the biofouled plant material.

A significant associated observation was made in field. Extensive undercutting and erosion of mangrove bearing tidal mud-banks (Fig. 2a-c & 2i) has caused mangroves to capsize. Some patches of the mangrove forest have dried up because of such uprooting / erosion of supporting mudflats. The scale of undercutting of mud-banks and biofouling is much larger along the southern bank.

Measurements made on benthic water samples within this 10 km stretch of biofouling, revealed a pH of 6.5 whilst the DO varied between 3.6 to 4.45 mg/l which are normal for estuarine conditions. Concentrations of Cr, Cu, Co, Cd, Ni, Pb, Mn and Zn determined are listed and compared with various guidelines[21-24] in Table 2.

Discussion

There are reports of oyster infestation on mangroves from Hong Kong[25], Vietnam[26] and Africa[27]. There is a solitary report of *S. cucullata* and *S. madrasensis* on the stilt roots of Pichavarm mangroves along East Coast of India[11], but their associated environmental effects have not been recorded. Present study appears to be the first report on *S. cucullata* as the prime and sole biofouler on mangroves, from the west coast of India. *S. cucullata*, commonly called the Hooded Oyster is found in the Indian Ocean and tropical west Pacific Ocean[28]. In India, it is one of the several commercially exploited oyster species[29]. It favours rocky habitats in the intertidal zone and is found at depths down to about 15 m (49 ft), often growing among seaweed[30]. It is part of the fouling community and is found on harbour walls, pilings and other underwater structures[31]. The hooded oyster is common on the east coast of Africa, where it cements itself to rocks or to the branches and roots of mangroves[27]. Oysters and barnacles are known to foul mangrove roots and trunks[13, 32-33] and can negatively affect root growth[34]. Zhou et al.[35] pointed out that serious fouling by oysters on mangrove tree trunks and branches can cause adverse impacts on the tree itself, by blocking the lenticles, which affect the physiological functioning of the plant, breakage of branches due to overloading of biofoulers and even death if severe fouling conditions persist. Heavy oyster cover can damage or break prop roots[36]. Barnacle infestation and bio-fouling can negatively impact mangrove seedling survival[37-

39). They contribute to eco-physiological stress e.g. reduction in photosynthesis and gaseous exchange impedance in saplings and mature plants[40-42]. The adhesive cement produced by barnacles upon stem settlement may also diffuse into sapwood and be deleterious to tree or shrub growth[8]. The borers concentrate their attack near the mud level and due to intensity of riddling, the tree eventually gets uprooted even during a mild gale[6]. Given the background of these previous studies, the erosion/undercutting of biofouling associated mudflats and patches of dried and capsized mangroves, observed in the Vasishthi estuary is suggestive of their hampered soil-holding capacity.

Discussing possible reasons of proliferation of *S. cucullata* 10 to 20 km inland, away from its favoured inter-tidal, rocky habitat, it is interesting to correlate its occurrence and proliferation with the heavy metal concentrations in the estuary. From table 2 it is evident that the concentrations of toxic metals in the Estuary, namely Cr, Co, Ni, Cu and Zn are much higher than their permissible concentration in sediments. Residents of the villages along the estuary claim that the oysters (locally called '*kalva*') were introduced into the ecosystem only over the past few years, ever-since effluent discharge from Lote MIDC has increased. Local population consider these oysters 'poisonous' and do not eat them. Previous ecological studies in the Vasishthi Estuary also report high concentration of heavy metals, namely Cr, Mn, Co, Ni, Cu and Zn in the upper reaches and suspect anthropogenic sources for the same[43]. Bivalves are sedentary and fairly resistant to chemical contamination. As a result, they can be found living in areas where more sensitive species cannot survive[44]. The Hooded Oyster is a filter feeder, wherein contaminants may enter them via intake of food and water[45]. In polluted waters, it accumulates heavy metals in its tissues. Thus, it is used as a bio-indicator for monitoring pollution[28]. Recently several case studies along the Iranian coasts have revealed alarming concentrations of Ni, V, Cu and Pb in the tissues and shells of *S. cucullata* [46-48], that exceeded the concentration in adjoining sediments and water.

Conclusions

Intense biofouling by oyster species *S. cucullata* poses a serious threat to the existence of mangroves of the Vasishthi estuary. They serve as a biomonitor and testify the effects of heavy metal toxicity in the estuarine ecosystem. The biofouling on mangrove root system appears to have damaged their sediment holding capacity, in turn leading to pronounced erosion of tidal mud-banks within the estuary.

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