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Some ecological aspects and potential threats to an intertidal gastropod, *Umbonium vestiarium*

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Abstract

Kalbadevi Bay in Ratgnairi has been identified as potential site for placer mining along the west coast of India. Since, *U. vestiarium* is a keystone species of the region; study on some ecological aspect was carried. The paper also discusses the possible impact of beach sand mining and other threats to this ecologically important gastropod. Seasonal sampling was carried in 2004-2005 at 13 transects by quadrate method. *U. vestiarium* was restricted to mid and low tide zone of Station 1-3 and 8-10 located at the north and south ends of the beach. Abundance was highest at Station 10 MT (16 to 12488 ind m^{-2}). Based on the size-frequency, it may be considered that *U. vestiarium* like other tropical fauna recruit during monsoon. Eleven different colour patterns of *U. vestiarium* were observed. However, average individual size was larger in the samples collected from the north (stn. 1-3) end of the beach. The fastidious nature and sporadic distribution of *U. vestiarium* make them vulnerable to natural and anthropogenic disturbance.

Key words

Ecology, Mining inpact, *Umbonium vestiarium*, Polymorphism, Kalbadevi bay

Introduction

Molluscs are important component of macrofauna on exposed sandy beaches (Datta *et al.,* 2010). Gastropods belonging to genus *Umbonium* inhabit sandy shores in tropical and subtropical regions of the world. Approximately 21 species in the genus have been identified from the Indian Ocean to the western Pacific Ocean and from the tropics to the subarctic. *Umbonium* spp. show unique ecological and evolutionary characteristics and they are sedentary, deposit and suspension feeders (Noda *et al.,* 1995). *Umbonium vestiarium* (Linneaus) is a dominant component of some clean sandy beaches (Berry and Zamri, 1983) and distributed in the Indo-West Pacific region.

During a preliminary survey of Kalbadevi, it was noticed that *U. vestiarium* dominated the macrobenthic community. *Umbonium vestiarium* plays an important role in the economy of a region because they are collected for making curios (Appukuttan and Ramadoss, 2000) and local consumption. Most of the studies on *U. vestiarium* are related to reproductive aspect (Ong and Krishnan, 1995).

Mining will have negative impact on the intertidal fauna (Defeo *et al*., 2009) and understanding the ecology of *U. vestiarium*, the keystone species, is necessary to assess the potential impact of mining. The present paper describes the spatio-temporal variation of population distribution, colour pattern and size structure of *U. vestiarium*. The impact of mining and other potential threats to this ecologically important gastropod is also discussed.

Materials and Methods

The Kalbadevi beach (17° 02' 68" to 17° 04' 07" N latitude; 73° 16' 93" to 73°17' 32" E longitude) is ~ 5 km long and ~250 m wide. It is an arcuate bay with Are and Kalbadevi estuary draining in the north and south respectively. Sampling was carried out in

May, August and November 2004, and April, June and September 2005. Ten stations (Station 1-10) were fixed at 500 m intervals covering the entire beach (Fig.1). At each station, samples were collected at high-, mid- and low tide (HT, MT and LT) in duplicate by quadrate method (0.06 m^2). All the samples were sieved (500 mm sieve) and *U. vestiarium* was sorted out. The remaining fauna was preserved in 5% buffered formalin.

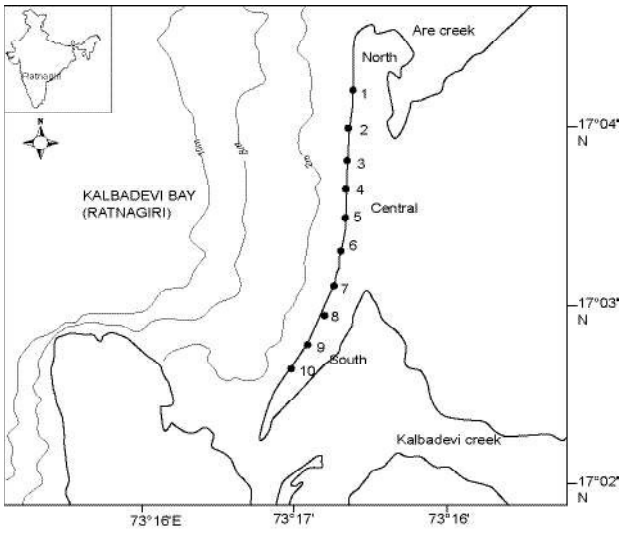

Fig. 1 : Location of sampling stations (1-10) in the intertidal zone of Kolbadevi

Sediment samples for texture and organic carbon (OC) were collected from all the stations up to a depth of 5cm, using a core (Ø 4.5 cm). Surface sediment was used for analysing the chlorophyll *a* (Chl *a*) and phaeopigment (Phaeo) content.

In the laboratory, all the shells of *U. vestiarium* were cleaned and counted. For the allometry and colour polymorphism study, the samples from Station1-3 were pooled as north samples, while Station 8-10 were pooled as south samples. In Stations 4-7, *U. vestiarium* were absent or observed in very low abundance and hence was not considered for allometry studies. *Umbonium vestiarium* were separated based on colour pattern (Grüneberg, 1980) and counted. The width of *U. vestiarium* was measured to 0.01mm using Vernier calipers. Each animal was weighed to obtain total weight and wet meat weight. For the dry weight, *U. vestiarium* were dried in the oven at 50°C till a constant weight was obtained.

Sediment Chl *a* was analysed by acetone extraction method (Holm-Hansen, 1978) and organic carbon by wet oxidation method (El Wakeel and Riley, 1957). Grain size analysis was carried out by sieving method (Folk, 1968).

Data was initially processed using Excel package. ANOVA was performed to find out the significance of spatial-temporal variation (Statistica 6) and when ANOVA result was significant, Student-Newman-Keuls (SNK) post hoc was performed. Grain size analysis was processed using Gradistat 5 (Blott and Pye, 2001).

Results and Discussion

U. vestiarium contributed to 34 to 56% of the total macrobenthic abundance and biomass and agrees with earlier studies that the species completely dominates the macrofaunal community of intertidal region (Ong and Krishnan, 1995). *U. vestiarium* was restricted to station 1-3 and 8-10 from mid- to low tide region. Abundance showed significant spatial variation ($F=5.22$; $p<0.001$). The SNK test showed that the abundance of *U. vestiarium* was significantly high at station 10 MT (16 to 12488 ind m^{-2}) and lowest at Stn. 7 (0-48; Table 2). One of the reasons *U. vestiarium* shows scattered distribution is due to its preference to medium sand (Tamaki and Kikuchi, 1983). Highest abundance of *U. vestiarium* is found in clean beaches with moderate wave energy. Station 1-3 and 8-10 were composed of fine to median grain size compared to station 4-7 (Table 1). Further, stations 4-7 showed significant seasonal variation in the median grain size ($p<0.001$). Food also play an important role in the distribution of an organism. Stations

Table- 1: Environmental parameters (range) in the study area

Stn	Tide	Grain size (D_{50} µm)	Chl a (µg g^{-1})	Phaeo (µg g^{-1})	OC (%)
1	HT	103 -180	0.05 - 0.07	0.02- 0.05	0 - 0.63
	MT	167 - 180	0.05 - 0.12	0.011 - 0.1	0 - 0.32
	LT	185 - 191	—	—	0 - 0.34
2	HT	—	—	—	0.1 - 0.52
	MT	—	—	—	0 - 0.3
	LT	—	—	—	0.1 - 0.6
3	HT	63 - 183	0.01 - 0.12	0.01 - 0.12	0.1 - 0.5
	MT	170 - 205	0.02 - 0.2	0.01 - 0.2	0.2 - 0.6
	LT	170 - 207		0.02 - 0.3	0 - 0.51
4	HT	175 - 208	0.02 - 0.03	0.01 - 0.02	0 - 0.12
	MT	190 - 342	0.01 - 0.1	0.01 - 0.13	0 - 0.7
	LT	189 - 190	0.01 - 0.1	0.01 - 0.04	0.3 - 0.8
5	HT	190 - 865	0.02 - 0.02	0.01 - 0.02	0 - 0.6
	MT	198 - 1071	0.02 - 0.1	0.02 - 0.03	0 - 0.5
	LT	198 - 420	0.02 - 0.1	0.02 - 0.03	0 - 0.4
6	HT	185 - 215	0 - 0.15	0 - 0.13	0 - 0.4
	MT	191 - 205	0 - 0.3	0 - 0.24	0 – 1.0
	LT	185 - 218	0 - 0.14	0 - 0.74	0 - 0.4
7	HT	195 - 293	0 - 0.2	0 - 0.14	0 - 0.7
	MT	180 - 825	0 - 0.04	0 - 0.05	0 - 0.4
	LT	180 - 344	0 - 0.2	0 - 0.2	0 - 0.5
8	HT	160 - 845	0.02 - 0.5	0.02 - 0.4	0 - 0.3
	MT	122 - 255	0 - 0.6	0 - 0.53	0.23 - 0.42
	LT	122 - 190	0.02 - 0.7	0.02 - 0.4	0.2 - 0.60
9	HT	70 - 183	0.1 - 0.15	0 - 0.13	0 - 0.30
	MT	124 - 208	0.14 - 0.22	0.12 - 0.2	0 - 0.30
	LT	150 - 249	0.1 - 0.13	0.02 - 0.1	0.02 - 0.4
10	HT	70 - 146	0.04 - 0.73	0 - 0.55	0 - 0.40
	MT	138 - 206	0.03 - 0.53	0.02 - 0.63	0 - 0.8
	LT	185 - 206	0.04 - 0.41	0.03 - 0.36	0.02 - 0.7

1-3 and Stations 8-10 are located towards the north and south end of the beach which is drained by rivers fringed with rich mangrove vegetation that increases nutrient and carbon flow to the region (Dham *et al.,* 2002). High values of sediment Chl *a* and OC was observed in these stations (Table 1).

Specimen in north i.e stations 1-3 (7-14mm) were larger than the south (6-12 mm). The high abundance in the south (stations 8-10) can generate stiff feeding competition resulting in the smaller size of individuals (Boaventura *et al.,* 2003). Smallest individuals in the south were observed during August and September (Table 3) and in the north during April and September. Further, *U. vestiarium* was completely absent in the intertidal region during peak monsoon (June). During monsoon, the increased wave action and beach erosion results in disturbance and dispersion of benthic fauna and redistribution to the subtidal region (Berry and Zamri, 1983). Furthermore, changes in salinity can cause mortality in some organism or trigger reproduction, as in *Umbonium* population (Sivadas *et al.,* 2011). A similar reduction of *U. vestiarium* during monsoon was observed along the Malaysian coast (Berry, 1987).

Climatic conditions are calmer by end of monsoon and along with reduced wave action favours the settlement and establishment of *Umbonium*. The absence during monsoon and appearance of smaller sized individuals during late monsoon (August and September) indicate that the species like other tropical fauna recruit during the monsoon. Berry (1987) reported the reproductive period of *U. vestiarium* from March-June for the Malaysian population and reported that the degree of isolation in *Umbonium* populations has led to genetic differences between populations throughout the species distribution range.

Most molluscs undergo annual spawning cycles (Ward and Davies, 2002). However, species may show variation in spawning periodicity across its geographic range. Several trochid species such as, *Umbonium costatum* from Japan (Noda *et al.,* 1995) and *Astrea undosa* from Mexico (Belmar- Perez *et al.,* 1993) spawn twice a year. Incomplete spawning for a number of gastropods has been reported (Ramesh *et al.,* 2010). The recruitment seen in April in the north may be an occasional case of delayed spawning (Table 3).

Table- 2: Abundance (ind m^{-2}) of *U. vestiarium* in the intertidal zone of Kalbadevi beach

Station	Tide	Abundance (Range)	Station	Tide	Abundance (Range)
1	HT	0	6	HT	0
	MT	0-9376		MT	0
	LT	0-16		LT	0
2	HT	0	7	HT	0
	MT	177-2008		MT	0
	LT	0		LT	0-48
3	HT	0	8	HT	0-80
	MT	0-80		MT	0
	LT	0		LT	0-2352
4	HT	0	9	HT	0
	MT	0		MT	0-6452
	LT	0		LT	0-2033
5	HT	0	10	HT	0-16
	MT	0		MT	160-12488
	LT	0		LT	0-2532

HT: High tide, MT: Mid tide, LT: Low tide

Average total body weight ranged from 0.21 to 0.54 g in the north during November and September. Meat weight was lower in April (0.049 g) and higher in November (0.115 g). In south, average total weight varied from 0.29 to 0.37 g and the average meat weight ranged from 0.06 to 0.074 g during August and November, respectively.

Umbonium population showed eleven colour patterns (Table 4). Among the eleven colour pattern, eight were common, while three occurred in small numbers. Furthermore, white (7), pink (4) and olive greens (1) were common and others were a combination of these colours. Overall, type 1, 6 and 7 were found to be the most frequent (42%). Type 5, 8 and 9 accounted for 12% of the total population. The two sampling sites individually revealed same colour pattern frequencies except for type 3 which was dominant in south (10%).

Shell colour polymorphism is a characteristic feature of many marine and terrestrial gastropod species including *U. vestiarium* (Miura *et al.,* 2007). In Parangipettai three basic colours were observed in *U. vestiarium* with a total of 24 different morphs. On contrary only four colours were recorded in Kalbadevi (Table 4). The dark were low in number since in intertidal regions they are at a disadvantage as they get quickly heated and more prone to desiccation (Miura *et al.,* 2007). Predation can also markedly affect colour polymorphism in gastropods (Ekendahl, 1998; Rodrigues and Absalão, 2005). Large populations of seagulls (*Larus ridibundus* and *L. brunnicephalus*) were observed but it is not known whether they feed on *U. vestiarium*. The other predators were *Astropecten* sp and *Natica* sp. Gut content analysis revealed the presence of 3-4 adult *U. vestiarium* per *Astropecten* sp. However, abundance of starfish was rather low (1-2 ind. 50 m^2) and may not pose any predation pressure. *Natica* sp. was also observed in low abundance only in August. In most cases, variation in shell colour is related to environmental gradients (Miura *et al*., 2007; Sokolova and Berger, 2000). Many gastropods have demonstrated a direct genetic control of colouration. Hence, the colour polymorphism observed in *U. vestiarium* appears to be genetic since no much variation was observed across the zone and transect (Ekendahl and Johannesson, 1997).

Physical disturbances including mining may be more damaging to the benthic community. Most studies on the impact of physical disturbances on marine benthos revealed >50% to complete defaunation. Other effects include enrichment of the surrounding areas due to re-suspension and consequent settlements of fine

Table- 3: Variation of size-class (Percent composition) in *U. vestiarium*

		2004			2005		
	Size class (mm)	May (%)	August (%)	November (%)	April (%)	June (%)	September (%)
	6-7	0	0	0	0	0	0
	7-8	0	0	0	13	0	7
	8-9	0	0	0	51	0	55
North	9-10	2	1	0	26	0	31
(Station	10-11	33	10	5	8	0	6
1-3)	11-12	51	56	53	2	0	1
	12-13	13	31	34	0	0	0
	13-14	1	2	8	0	0	0
	6-7	0	5	0	0	0	0
	7-8	0	8	0	0	0	2
	8-9	10	20	2	2	0	32
South	9-10	44	25	15	9	0	28
(Station	10-11	41	32	61	51	0	11
8-10)	11-12	5	9	18	37	0	25
	12-13	0	0	4	1	0	1
	13-14	0	0	0	0	0	0

materials. Mining will bring about changes if it results in the hydrographic condition and resultant change in sediment (Newell *et al.,* 1998).

The impact of mining on the *U. vestiarium* will be from the removal of large amount of sediment. Since *U. vestiarium* is a suspension feeder increased turbidity can interfere with the feeding and result in mortality or reduced growth rate. Furthermore, if mining takes place during the critical recruitment phase, sedimentation will be a major threat to the newly-settled juvenile population. Since the species are not deep burrowers any habitat modification will obstruct recruitment. The gastropods were found buried in the sediment surface, rarely deeper than 1 cm. Along the sand flat in western Kyushu (Japan), the increased sedimentation caused by the bioturbation of the ghost shrimp, *Callianassa japonica* resulted in the extinction of *Umbonium (Suchium) moniliferum* due to the burial of adult and juveniles (Tamaki, 1994). *U. moniliferum* have similar ecological niche as *U. vesitiarium* (Tamaki, 1994). *U. moniliferum* and *C. japonica* densely inhabited the region in 1979. However, by 1983 *C. japonica* completely dominated and *U. moniliferum* became extinct (Tamaki and Ingole, 1993). Decline of *Umbonium* population have also been reported from the intertidal flats of Singapore and Hong Kong due to the degradation of their habitats and the species is listed as 'vulnerable' on the Red List (www.wildsingapore.com).

Table- 4: Percent composition of different colour pattern of *U. vestiarium*

Colour code	Colour/Pattern description	North (%)	South (%)
1	Olive	14	14
2	*Dull pink/ Greyish with pink swirls	9	9
3	*Wheel (white with prominent dark stripes)	5	10
4	*Pink	9	11
5	*Pink spiral	2	2
6	*Bronze	15	12
7	*White	15	13
8	*Olive coarse pattern	5	5
9	*Black	4	5
10	*White wash	12	7
11	Olive with orange spiral	9	11

*Based on Grünberg 1980

Sea surface temperature is predicted to rise by 1-3°C during 21st century, and the sea level rise is expected to be 2 – 6 mm per year (Solomon *et al*., 2007). The direct effect of this would be narrowing down of the intertidal region which is predicted to reduce by 20-70% depending on type of coast and processes operating therein (Galbraith *et al.,* 2002). Kalbadevi beach with flat topography may get submerged with sea level rise and will result in loss of habitat. Nevertheless, the impact of sea-level rise will depend upon the rate of increase. A slow increase in sea-level, will allow the benthic species to expand landward side. However, if the rates of change are high and expansion is restricted by man-made barriers, the intertidal community may be drastically changed, and may even result in local extinction (Przeslawski, 2008).

Further, there has been significant increase in the incidence of prolonged monsoon-breaks, during the core monsoon over the subcontinent in the recent decades (RameshKumar *et al*., 2009). As seen from the present study, *U. vestiarium* recruit during monsoon. As a result, increase in prolonged monsoon-breaks can affect the survival of the juveniles as they are more susceptible to increase in temperature and desiccation. Further, southwest monsoon has weakened and suppressed rainfall over the India is observed since post mid-1970s. Recruitment of most tropical organism coincides with monsoon season so that their larvae could utilize the abundant

planktonic food resulting from the upwelling during southwest monsoon (Sivadas *et al.*, 2008). Therefore changes in the timing or intensity of monsoons may directly affect the reproduction and associated dispersal of benthic community (Przeslawski, 2008). Further, change in rainfall patterns along with a predicted increase in extreme storm events leading to flooding; turbidity and increase in coastal runoff (Solomon *et al.,* 2007) may have detrimental impact on the intertidal community. Since repeated physical disturbances can increase the mortality due physical stress. Further, changes due to ocean circulation pattern will disperse the larvae to unsuitable habitats, resulting in recruitment failure. Although, such changes will have less impact on species with long planktotrophic larval periods (weeks-months), as they can delay settlement (Elkin and Marshall, 2007), however species with short planktonic stage with specific habitat requirement will be affected at greater extent. *U. vesitiarium* has planktonic larvae stage of only 48 hrs (Berry *et al.,* 1987) and hence it may drift out of the range of ideal habitat reducing their survival rate. Ocean acidification may interfere with shell formation in molluscs, as a result their fragile larvae will particularly vulnerable to predation and physical damage (Kurihara and Shirayama, 2004; Shirayama and Thornton, 2005).

U. vestiarium reaches its greatest abundance on undisturbed beaches with moderate wave energy. The fastidious habitat selection of the species probably accounts for its sporadic distribution on a global scale. This makes them highly vulnerable to slight change or disturbance in their habitat, leading to their decrease abundance and mortality.

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