Edible Bivalves of Central West Coast, Uttara Kannada District, Karnataka, India

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Soft body of *Meretrix* sp. inside the shell

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SUMMARY

Bivalves (Clams and oysters) contribute to the livelihoods of many people in India. Shell and sand mining in the molluscan beds, over-exploitation of bivalves, and sustained freshwater flows from the hydel projects are expected to have adverse consequences on estuarine bivalve resources. The present study was conducted in the four major estuaries of Uttara Kannada District (Kali, Gangavali, Aghanashini, and Sharavathi), to see the diversity of edible bivalves and their distribution. The study was conducted in 2011-2012 period in these estuaries. The status of edible bivalves of the estuaries was collected through primary observations and interviews with local fisher folks. Past studies were also referred to gather such information. *Anadara granosa, Meretrix casta, M. meretrix, Paphia malabarica, Polymesoda erosa, Villorita cyprinoides* and oysters were present in the Uttara Kannada estuaries. In Sharavathi estuary only *Polymesoda erosa* and oysters were found. The distribution zones of edible bivalves, and thereby their abundance, in the Kali estuary were less than the Aghanashini and Gangavali estuaries. The reasons for such disparity between the neighboring estuaries could be attributed to major human intervention in the form of construction of hydel projects upstream that caused low salinity conditions in the downstream causing depletion of most estuarine bivalves, as is glaringly evident in the Sharavathi estuary.

Keywords: Bivalves, estuary, Uttara Kannada, Impact of dams

Introduction

The Molluscs are soft bodied invertebrates with or without an external protective shell. They inhabit usually water bodies, marine, estuarine, as well as fresh water; many are also terrestrial, often associated with moist shaded lands. If the body of the Molluscan taxa is enclosed by a pair of shells hinged in the middle it can be classified under the Class Bivalvia. Bivalves, which include clams and oysters contribute to the livelihoods of many people in India. The first Mollusc appeared at the end of the Pre-Cambrian period, approximately 550 million years ago (Sturm et al., 2006). It is the second largest phylum in the invertebrates comprising more than 100,000 species worldwide of which, 5070 species are present in India (Venkataraman and Wafar, 2005). Molluscs have been exploited worldwide for food, ornamentation, pearls, lime, and medicine (Nayar and Rao, 1985). Geologic evidence from South Africa indicates that systematic human exploitation of marine resources had started about 70,000 to 60,000 years ago (Volman, 1978).

Of the 5070 species of molluscs recorded from India, very few of them, especially of the bivalves, are exploited for food and other economic purposes. In the estuarine villages of the Karnataka three clam genera, *Meretrix*, *Paphia* and *Villorita,* and some oysters are used as food and sustain the livelihoods scores of people (Rao and Rao, 1985; Rao et al., 1989; Boominathan et al., 2008). Even these few edible bivalves are threatened of late due to shell and sand mining, over-exploitation, and salinity changes brought about in the estuaries due to constant releases of fresh water from hydel projects upstream in the rivers. A study conducted in Kali estuary by Boominathan et al. (2012) revealed that the edible estuarine bivalves lost about 15 kms of their occupational territory, pushed more westwards towards the Arabian Sea, due to water releases from upstream dams. Such a study was necessitated, to begin with, in all the estuaries of Uttara Kannada, which are getting subjected to ever increasing human pressures. The present study covered the situation of the edible bivalves, their diversity and its distribution, in Kali, Gangavali, Aghanashini, and Sharavathi estuarine areas.

UTTARA KANNADA ESTUARIES

The Uttara Kannada District has four major estuaries viz. Kali, Gangavali, Aghanashini, and Sharavathi (Figure 1.1). The Kali estuary is located in the northern most part of the district, the Bedthi or Gangavali about 32 km south from Kali river-mouth, the Aghanashini or Tadri estuary, about 10 km south of Gangavali, and the Sharavathi estuary is about 24 km south of the Aghanashini estuarine mouth.

***Kali Estuary*:** The Kalinadi originates near the village Diggi in the Joida taluk of Uttara Kannada, and has many tributaries. It is also known as Karihole and as Dagi in its upper reaches. Its total length is 184 km and meets the sea, three km north of Karwar. It has four major dams with hydel power stations viz. Supa, Nagjhari power house, Kodashalli, and Kadra (Figure 1.2).

Gangavali Estuary: The river Bedthi or Gangavali originates at two places; one is near Someswara temple, south of Dharwad and another is near Hubli, both join near Kalghatgi. The total length of the river is 161 km, and it has no dam or hydel power station. It joins the Arabian Sea at Gangavali near Ankola. The estuarine part starts near the village Gundbale (about 15 km interior) and the area of the estuary is 640 ha (Gazetteer 1984; Rao et al. 1989).

Aghanashini Estuary: The Aghanashini or Tadri (total length 121 km) river rises at Manjguni near Sirsi. It has two sources, the Bakurhole rising in a pond at Manjguni about 25 km west of Sirsi and the Donihalla whose source is close to Sirsi. These streams meet near Mutthalli about 16 km south of Sirsi. At Uppinapattana the river meets the tide and it winds south-west and then north-west together about 13 km to Mirjan. From Mirjan it runs parallel to the coast for about 13 km and meets the Arabian Sea at Aghanashini or Tadri. This river has no dam or hydel power station in it (Gazetteer, 1984).

Sharavathi Estuary: Sharavathi originates at Ambutirtha in Tirthahalli taluk of Shimoga district and flows for 128 km to join the Arabian Sea near Honavar. Traditionally the estuarine portion extended from the river mouth to the village of Gersoppa, about 27 km interior, towards the base of the Western Ghats. The total area of the estuarine portion was stated to be 1600 ha (Gazetteer, 1984; Rao et al., 1989). This river has two major dams with hydel power stations, first one built at Linganamakki in Shimoga district and the second dam at Gersoppa (www.karnatakapower.com). These dams have caused substantial changes in the estuarine characteristics, primarily by reducing its salinity (Figure 1.3).

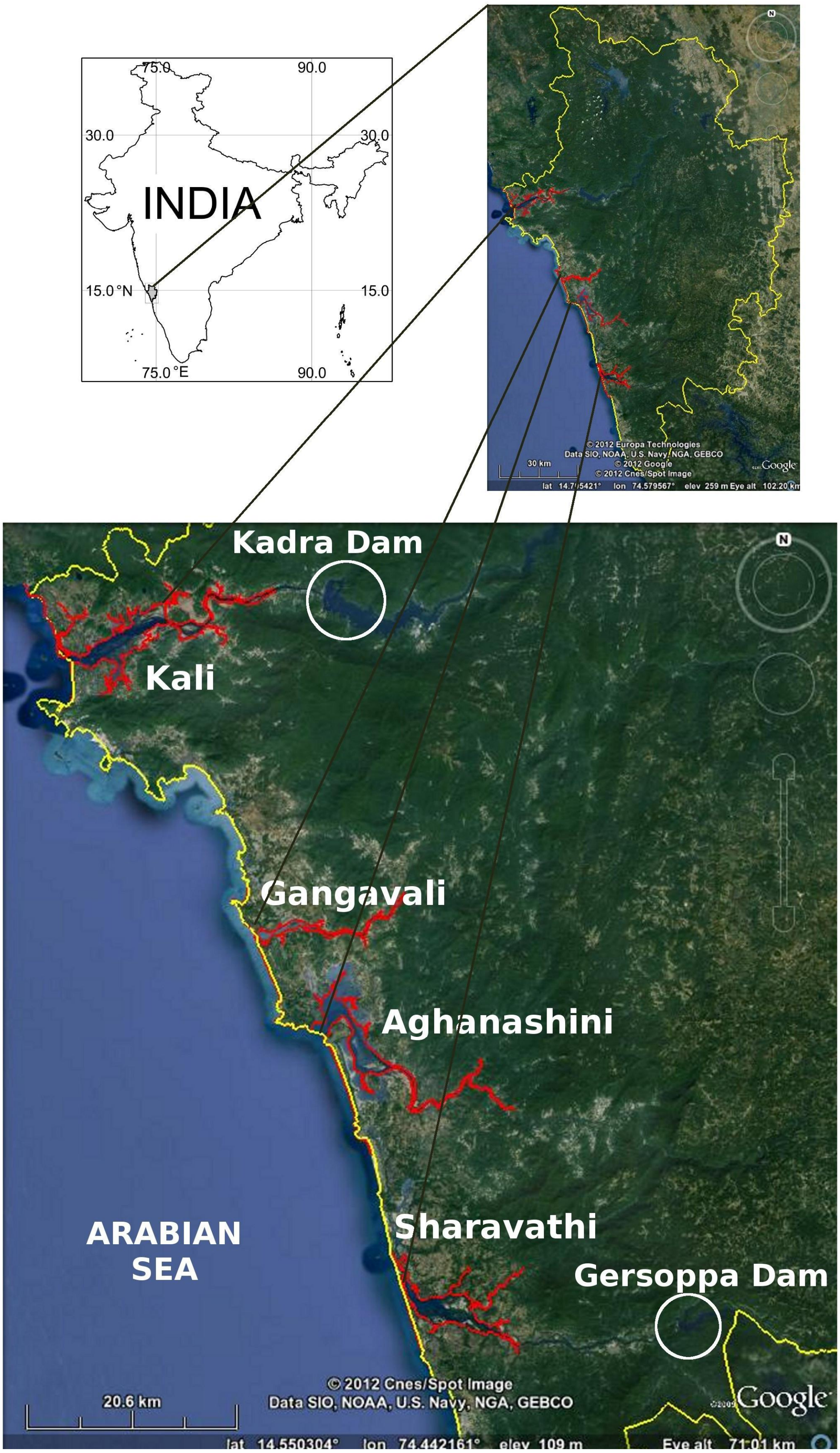

Figure 1.1: Estuaries of Uttara Kannada District viz. Kali, Gangavali, Aghanashini, and Sharavathi.

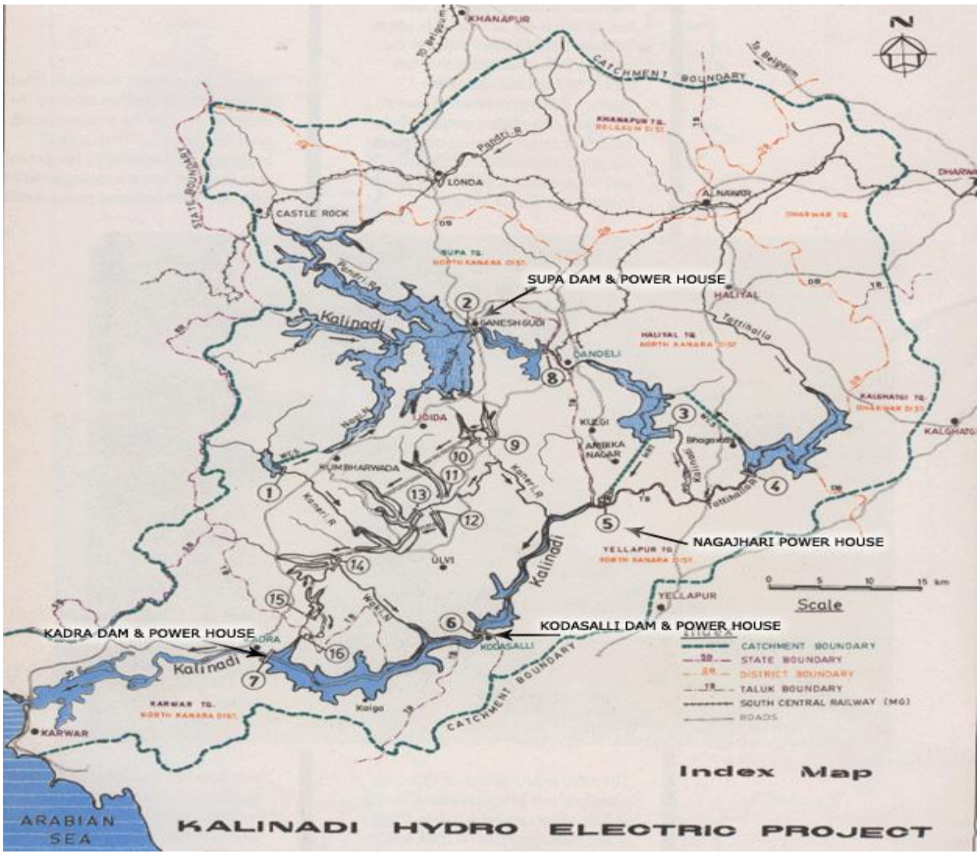

Figure 1.2: Kali River with Dams.
Source: www.karnatakapower.com [accessed on 10 February 2012]

Figure 1.3: Sharavathi River with dams
Source: www.karnatakapower.com [accessed on 10 February 2012]

EDIBLE BIVALVES OF UTTARA KANNADA ESTUARIES

There are six edible clams, viz. *Anadara granosa, Meretrix casta, Meretrix meretrix, Paphia malabarica, Polymesoda erosa, Villorita cyprinoides* and some oysters present in all the estuaries of Uttara Kannada district (table 1), except in Sharavathi estuary where only one clam *Polymesoda erosa* occurs today and the oysters can be seen on rocks close to the river mouth with higher salinity. Among these edible bivalves the genus *Meretrix*, *Paphia*, and *Villorita,* and oysters contributes to the livelihoods of many peoples (Rao and Rao, 1985; Rao et al., 1989; Boominathan et al., 2008).

Table 1: Edible Bivales of Uttara Kannada estuaries. P = Present, A = Absent.

Species	Kali	Aghanashini	Sharavathi	Gangavali
Anadara granosa	P	P	A	P
Meretrix casta	P	P	A	P
Meretrix meretrix	P	P	A	P
Paphia malabarica	P	P	A	P
Polymesoda erosa	P	P	P	P
Villorita cyprinoides	P	P	A	P
Oysters	P	P	P	P

Anadara granosa is present in all the estuaries except, Sharavathi. In Kali, Gangavali, and Aghanashini the distribution of *A. granosa* is restricted to one kilometer range from river-mouth (Table 2.1). It prefers soft intertidal muds bordering mangrove swamp forest (Pathansali, 1966) and salinity range of 13.69 – 34.40 ppt (Narasimham, 1988) hence, *A. granosa* present only close to the river-mouth where the salinity is usually high. This species was previously reported from Kali (Boominathan et al., 2012), Aghanashini (Boominathan et al., 2008, 2012), and Venkatapur (Rao and Rao, 1985) estuaries of Uttara Kannada District.

Table 2: Current distribution of bivalves in the Kali, Gangavali, Aghanashini, and Sharavathi estuaries. P = Present.

Table 2.1: Current distribution of *Anadara granosa.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)	P																						
Gangavali	P																						
Aghanashini	P																						
Sharavathi (dammed)																							

Meretrix casta is distributed in Aghanashini and Gangavali (without any dams) estuaries from the river-mouth to six km interior. Compared to this, *M. casta* is distributed in Kali (with dam) only for three km range from the river-mouth (table 2.2), its occupational area reduced on account of the influx of fresh water releases from the hydel projects upstream. *M. casta* is a euryhaline species (adapted to a wide range of salinity) (Rao et al., 1989) and it has a greater degree of physiological adaptation in the salinity range of 25.00 to 56.00 ppt (Durve, 1963). Since, the salinity of Kali estuary is very low *M. casta* is distributed only upto three kilometer distance from river-mouth. Whereas in Sharavathi estuary *M. casta* is absent, probably because of extremly low salinity due to dam water releases. *M. casta* was reported by various authors from Kali, Gangavali, Aghanashini, Sharavathi, and Venkatapur estuaries (Alagarswami and Narasimham, 1973; Harkantra, 1975a, 1975b; Rao and Rao, 1985; Rao et al., 1989; Bhat, 2003; Boominathan et al., 2008, 2012).

Table 2.2: Current distribution of *Meretrix casta.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)	P	P	P																				
Gangavali	P	P	P	P	P	P																	
Aghanashini	P	P	P	P	P	P																	
Sharavathi (dammed)																							

Whereas the distribution of *Meretrix meretrix* in the undammed Aghanashini and Gangavali estuaries range from river-mouth to three kms inside, in Kali (with dams) *M. meretrix* has only a one km range from river-mouth (table 2.3). *M. meretrix* prefers high salinity (Rao et al., 1989) hence, its presence closer to the river mouth can be justified. In the Sharavathi estuary *M. meretrix* was present earlier (Alagarswami and Narasimham, 1973; Rao and Rao, 1985), but seems have vanished today, obviously because of decline in salinity caused by release of fresh water from hydel projects. *M. meretrix* is present to this day in all the other estuaries (Alagarswami and Narasimham, 1973; Rao and Rao, 1985; Rao et al., 1989; Bhat, 2003; Boominathan et al., 2008, 2012).

Table 2.3: Current distribution of *Meretrix meretrix.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)	P																						
Gangavali	P	P	P																				
Aghanashini	P	P	P																				
Sharavathi (dammed)																							

Paphia malabarica occurs closer to the river mouths (Rao et al., 1989) with salinities of 20 to 30 ppt (Mohan and Velayudhan, 1998). It occurs to this day in the high salinity regions of Kali, Gangavali, and Aghanashini estuaries (table 2.4). However, in Sharavathi estuary *P. malabarica* was not reported earlier nor it occurs currently. The species occurs in all the other estuaries viz. Kali Gangavali, Aghanashini, and Venkatapur (Alagarswami and Narasimham, 1973; Harkantra, 1975a; Rao and Rao, 1985; Rao et al., 1989; Bhat, 2003; Boominathan et al., 2008, 2012).

Table 2.4: Current distribution of *Paphia malabarica.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)	P																						
Gangavali	P	P	P																				
Aghanashini	P	P	P																				
Sharavathi (dammed)																							

Polymesoda erosa prefers salinity of 7 to 22 ppt (Modassir, 2000). It is present in all the four estuaries (table 2.5). Even though, it is present in Kali, Gangavali, Aghanashini, and Sharavathi estuaries, the population is high in Sharavathi estuary than the other estuaries and also it is the only species of edible clam present to this day. *P. erosa* was earlier reported by Ingole et al., (2002) from Sharavathi estuary where it is still present. Boominathan et al., (2012), for the first time, reported its occurrence in Kali and Aghanashini estuaries.

Table 2.5: Current distribution of *Polymesoda erosa.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)	P	P	P	P	P	P																	
Gangavali	P	P	P	P	P																		
Aghanashini		P	P	P	P	P																	
Sharavathi (dammed)		P	P	P	P																		

Villorita cyprinoides associated with medium salinity conditions is known to withstand freshwater conditions (Nair et al., 1984; Rao et al., 1989; Boominathan et al., 2012). It was reported from Kali (Rao et al., 1989; Boominathan et al., 2012), Aghanashini (Rao et al., 1989; Bhat, 2003; Boominathan et al., 2008, 2012), and Venkatapur (Alagarswami and Narasimham, 1973) estuaries. Extremely low salinity of Sharavathi estuary might have caused its present elimination from here where according to elderly fisher-folks the species was present earlier. In Kali estuary, which has more salt water ingress, despite the dams, it is found in 6-12 km range. It occurs in 5-16 km zone in Gangavali, and 9-23 km zone in Aghanashini respectively (table 2.6).

Table 2.6: Current distribution of *Villorita cyprinoides.*

~ Distance from river-mouth (km)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Kali (dammed)						P	P	P	P	P	P	P											
Gangavali					P	P	P	P	P	P	P	P	P	P	P	P							
Aghanashini									P	P	P	P	P	P	P	P	P	P	P	P			
Sharavathi (dammed)																							

Oysters are present in all the estuaries (table 2.7), usually it occurs in moderate to high salinity regions in the estuary. They were also previously reported from Kali (Rao, 1974; Boominathan et al., 2012), Gangavali (Rao, 1974), Aghanashini (Rao, 1974; Boominathan et al., 2008, 2012), Sharavathi (Rao, 1974; Rao and Rao, 1985), and Venkatapur (Rao and Rao, 1985) estuaries.

Table 2.7: Current distribution of oysters.

~ Distance from river-mouth (km)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Kali (dammed)	P	P	P																				
Gangavali	P	P	P	P	P	P																	
Aghanashini	P	P	P	P	P	P																	
Sharavathi (dammed)		P	P	P	P																		

CONCLUSION

Estuaries although are ranked among the highest productive ecosystems of the earth, and are of immense economic importance to the humans, they have not merited enough attention yet to safeguard their integrity from various kinds of anthropogenic interventions. The fact notwithstanding that estuarine productivity is sustained naturally without any inputs from humans, unlike in agricultural ecosystems or fish farming systems, the ecological conditions of the estuaries, particularly of the Indian west coast are under alterations by humans. Many of the Maharashtra estuaries are already heavily polluted due to industrial effluents and urban sewage (Quadros and Athalye, 2002; Quadros et al., 2002; Rathod et al., 2002). Sedimentation from mining waste is of high order in the north Goan estuaries, in addition to pollution from densely populated towns and villages. Estuaries of Dakshina Kannada and Cochin backwaters are also under high anthropogenic pressures challenging their biodiversity and productivity. We have seen here that in the Uttara Kannada district, which has some of the best preserved forest wealth and water bodies with minimal pollution levels, how alteration of an even single factor like salinity due to continuous water release from hydel projects, can upset their ecology as evident from the decline in abundance and changes in distributional ranges within these estuaries of the edible bivalves. Not only that where especially dams are constructed upstream for power generation, as in Kali and Sharavathi, even fisheries and mangroves are affected. The impact is of the highest order in Sharavathi where only a single species of moderate salinity tolerant clam *Polymesoda erosa* and some oysters are all that are left of the edible bivalves unlike in other estuaries where six species of clams and some oysters are still present. In Sharavathi most of the high and medium salinity tolerant mangroves have given way to low salinity preferring tree *Sonneratia caseolaris*. Fresh water fishes from the upstream areas and low salinity tolerant fishes have occupied the zones where earlier marine fishes used to visit. The very case of the near local extinctions of most of the edible bivalve species from Sharavathi estuary and decrease in distribution range of edible bivalves in Kali estuary, as a consequence of dilution of salinity, is a classical instance highlighting the need for exercising greater caution before executing large-scale development projects like dams for power generation, upsetting ecology of tropical estuaries, rated among the highest productive ecosystems of the world.

RECOMMENDATIONS

1. Regulating the shell and sand mining in the estuarine region will have positive impact on the diversity and distribution of edible bivalves.
2. The lessons from serious human impacts caused to Sharavathi estuary ecosystem, in the form of massive disappearance of edible molluscs, decline of high salinity tolerant mangrove species and dislocations in associated biodiversity etc., the implications of which are yet uncounted, should teach us to be more cautious in future in dealing with developmental projects especially affecting riverine systems. The role of estuary as breeding places and nurseries for several marine fishes of economic value has been totally ignored while executing such large river valley projects.
3. Maintenance of physico-chemical properties of estuaries need to be considered while executing any major river valley projects so that they can continue to be centres of diversity and productivity meeting the food and livelihood needs of thousands of families while also performing the vital ecological functions traditionally associated with estuaries.

SIGNIFICANT OUTCOMES

1. Six species of edible clam bivalves viz. *Anadara granosa, Meretrix casta, M. meretrix, Paphia malabarica, Polymesoda erosa, Villorita cyprinoides*, and oysters are present in the Uttara Kannada estuaries.
2. According to historical data, five species of edible clam bivalves viz. *Meretrix meretrix, M. casta, Anadara granosa, Polymesoda erosa*, *Villorita cyprinoides* and oysters were present in the Sharavathi estuary. Out of them only *P. erosa* and oysters remain in the estuary; the rest are not traceable today.
3. In Kali estuary, the edible bivalves were distributed for about 27 km from river-mouth in 1978 whereas now it is distributed only for about 12 km from river-mouth, and the population of *Paphia malabarica* declined drastically.
4. The major reason for the low bivalve diversity in Sharavathi estuary and reduced distribution zones in Kali estuary could be attributed to the construction of hydel projects causing continuous release of fresh water into the estuary, after power generation, even during the summer months, resulting in very low salinity that is unable to sustain most bivalves.
5. The collection of edible bivalves is a major activity of fisher-folks and even others which contributes to the livelihood of many estuarine villages, but faded away in Sharavathi due to the disappearance of bivalves.
6. The hydel projects have adverse impact on estuarine biodiversity, not only on bivalves but most of high salinity tolerant mangroves of Sharavathi also are not to be found, except in fringes very close to the river mouth.

CLASSIFICATION OF EDIBLE BIVALVES OF UTTARA KANNADA

Kingdom : Animalia
Phylum : Mollusca
Class : Bivalvia
Subclass : Pteriomorphia
Order : Arcoida
Super family : Arcoidea
Family : Arcidae
Genus : *Anadara* (Gray, 1847)

1. Anadara granosa (Linnaeus)

Order : Ostreoida
Suborder : Ostreina
Super family : Ostredidea
Family : Ostreidae
Genus : *Crassostrea* (Sacco, 1897)

2. Crassostrea madrasensis (Preston)

Genus : *Saccostrea* (Dollfus and Dautzenberg, 1920)

3. Saccostrea cucullata (Born, 1778)

Subclass : Heterodonta
Order : Veneroida
Super family : Corbiculoidea
Family : Corbiculidae
Genus : *Polymesoda*

4. Polymesoda erosa (Solander)

Genus : *Villorita*

5. Villorita cyprinoides (Gray)

Super family : Veneroidea
Family : Veneridae
Genus : *Meretrix* (Lamarck, 1799)

6. Meretrix casta (Deshayes)
7. Meretrix meretrix (Linnaeus)
Genus : *Paphia*

8. Paphia malabarica (Chenmitz)

IDENTIFICATION CHARACTERS OF UTTARA KANNADA EDIBLE BIVALVES

Anadara granosa **(Linnaeus)**

Shell orbucularly-ovate, equivalve, side slightly angulated. Sclupture radiately ribbed; ribs upto 20, tuberculate and crenulated Source: (Dey, 2006).

Meretrix casta (Chemnitz)

Meretrix casta does not show colour patterns. Shell ovate to oblong with or without two obscure and often imperfect radial bands. Anterior cardinal tooth in left valve entire. Hinge elongate and strong. Pallial sinus shallow. Length of shell is usually less than 50 mm. Posterior margin of the shell when more angular and pointed are considered as a varietal form as *M. casta* var. *ovum* (Hanley) (Hornell 1917). Source: (Nayar and Mahadevan, 1974; Rao et al., 1989)

Meretrix meretrix (Linnaeus)

Shell large, heavy, thick, ventricose, umbo pointed, elevated and slightly anterior in position; anterior margin rounded, ventral margin convex, posterior margin angulated; valves trigono suborbicular; anterior adductor scar elongately ovate, posterior adductor scar broader posteriorly and pointed anteriorly; pallial sinus very shallow. Posterior lateral teeth in the left valve and corresponding depression in the right valve are finely denticulate or striate. Anterior cardinal tooth of left valve distinctly notched. It is highly variable in colour; length (anterio-posterior axis) 60-75 mm. Source: (Nayar and Mahadevan, 1974; Rao et al., 1989; Apte, 1998; Dey, 2006)

Paphia malabarica **(Chemnitz)**

Shell large, thick, heavy, sculptured with strong close set ridges. Length of the shell about one and one third times as long as high. Pallial sinus 'U' shaped and very deep. Lunule short and broader. Hinge bears three short but strong cardinal teeth. The tooth in front of the cardinals in the left valve and the hollow in the right is rudimentary. Pale yellowish brown colour.
Source: (Rao et al., 1989; Apte, 1998)

Polymesoda erosa **(Solander)**

Shell large, solid, inequilateral, subtrigonal or orbicular with concentric striae on the outer surface, periostracum thin and yellow or thick and brown or dark green or black. Slight, distinct and characteristic flexure extending from the umbo to the mid-posterior margin of the shell. The hinge tooth are strong, larger and antero-lateral tooth located closer to the anterior cardinal tooth.

Source: (Morton, 1984; Rao, 1989; Ingole et al., 1994)

Villorita cyprinoides **(Gray)**

Shell fairly large, trigonal, cordate and very oblique, anterior margin short, regularly curved above, almost straight in the middle, then with a rapid curve and meeting the ventral boarder, the latter curving upwards and meeting the posterior margin, the posterior margin nearly straight, much larger than the anterior, with thick concentric ridges, umbones prominent, near the anterior side, recurved, a large, thick external ligament posteriorly, inflated in the umbonal as well as in the middle regions and greatly compressed ventrally. Shell thick with concentric ridges prominent with anterior portion, umbones striated. Periostracum greenish brown, dark brown or black.

Source: (Rao, 1989; Rao et al., 1989)

Crassostrea madrasensis (Preston)

Shell straight, shape irregular, covered by numerous foliaceous laminae, left valve deep, right one slightly concave, hinge narrow and elongated, adductor scar sub-central, reniform and dark purple in colour, inner surface of valves white, glosssy and smooth, purplish black colouration on the inner margin of the valves . Source: (Rao, 1974)

Saccostrea cucullata (Born, 1778)

Variable in shape, inequivalve, irregularly circular to oval, left valve more thick, deep and large than right valve sometimes cup like, sometimes flat; outer margin with a series of sharp folds, which interlock with each other; sculpture of oppressed lamellae, some becoming spiny, other worn,smooth; muscle scars kidney shaped. Nodular chomata usually present around all margins. Colour whitish or greenish white, marked with deep purple towards the margins, muscle scars darker than surrounding shell area. Source: (Dey, 2006)

Figure 2: *Anadara granosa*

Figure 3: *Meretrix casta*

Figure 4: *Meretrix meretrix*

Figure 5: *Paphia malabarica*

Figure 6: *Polymesoda erosa*

Figure 7: *Villorita cyprinoides*

Figure 8: *Crassostrea madrasensis*

Figure 9: *Saccostrea cucullata*

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