Economic Valuation of Bivalves in the Aghanashini Estuary, West Coast, Karnataka

Boominathan, M.

Subash Chandran, M.D.

Ramachandra, T.V.

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Web: http://ces.iisc.ernet.in/hpg/envis
http://ces.iisc.ernet.in/energy/
http://ces.iisc.ernet.in/biodiversity
Email: cestvr@ces.iisc.ernet.in,
energy@ces.iisc.ernet.in

ENVironmental Information System [ENVIS]
Centre for Ecological Sciences,
Indian Institute of Science,
Bangalore – 560012, INDIA

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Summary

Estuaries provide valuable resources like fishes, bivalves, crabs, shrimps, etc. Thus, it plays a pivotal role in rural livelihood and constitute as an important socio-economic entity. Mangrove vegetation, ranking high in productivity, is often associated with tropical and sub-tropical estuaries. Biological productivity in estuaries depend on fresh water ecosystem and hence its terrestrial ecosystems. Estuaries being inter-tidal zones form a vital interface between marine and terrestrial environments. These semi-enclosed bodies of coastal water have a free connection with the open sea and within which seawater is measurably diluted with fresh water of terrestrial origin, forms a highly productive, dynamic and unique ecosystem providing food, transport, recreation, etc.

A study was undertaken focusing on bivalves of the Aghanashini river estuary of South Indian west coast, in an effort to document the edible bivalve diversity and the often neglected socio-economic life based on it. Estimates have been made of people involved in bivalve collection and trade, quantity and species collected and the overall role of bivalves in sustaining a rural economy. Bivalves harvested are *Paphia malabarica*, *Katelysia opima* and *Meretrix meretrix*, *M. casta* and *Crassostrea* sp. The estuary provides diverse kinds of habitats (in terms of water depth, salinity, soil nature and rockiness) for different bivalve species. Harvests are higher during post-monsoon (November-May) compared to monsoon (June-October). The bivalve-based economy has an estimated turnover of Rs. 57.8 million per year. It generates direct employment for about 2,347 people, and nutritional security of millions more along the Karnataka coast and also in neighbouring states. This study was undertaken at a time when an ultra-thermal plant was to be set up in this estuarine base inconsiderate of its ecology and economics.

Keywords: Biodiversity, Bivalves, Estuary, Economic valuation, Hotspots, Molluscs, Western Ghats

INTRODUCTION

India has a coastline of 7,516 km (http://india.gov.in/sectors/defence2.php), adjoining the continental regions and the offshore islands and a very wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marsh, rocky coast, sand stretches and coral reefs, which are unique biotic and abiotic properties and process (Venkataraman and Wafer, 2005). This study attempts to quantify the ecosystem goods and services provided by bivalve mollusks in the Aghanashini estuary of west coast of Karnataka State, India. Estuaries play a pivotal role in rural livelihood by providing valuable resources like fishes, molluscs, crabs, prawns, shrimps, etc. and thus constitute an important socio-economic entity. They are highly productive, dynamic and unique ecosystem providing food, transport, recreation, etc. Mangroves, one of the unique ecosystems, high ranking in productivity, are often associated with tropical and sub-tropical estuaries. These are semi-enclosed coastal body of water, which has a free connection with the open sea, and within which seawater is measurably diluted with fresh water derived from land drainage (Pritchard, 1967). The Karnataka coastal region, which extends between the Western Ghats edge of the Karnataka Plateau in the east and the Arabian Sea in the West, covers of Uttara Kannada, Udupi, and Mangalore districts, which encompass number of estuaries along the 267 km (http://www.karnataka.com/profile/physiography.html) coastal line. The Uttara Kannada district located in central Western Ghats comprises four estuaries namely Kali (Sadashivagad), Bedthi (Gangavali), Aghanashini (Tadri) and Sharavathi (Gersoppa/Banaganga).

The Western Ghats in India is one among the 34 biodiversity hotspots of the world (http://www.biodiversityhotspots.org/) is a chain of mountains, stretching north-south along the western peninsular India for about 1,600 km, harbours rich flora and fauna. Various forest types such as tropical evergreen, semi-evergreen, moist and dry deciduous and high altitude sholas mingle with natural and manmade grasslands, savannas and scrub, in addition to, agriculture, plantation crops, tree monocultures, river valley projects, mining areas and many other land-uses. Over 4,000 species of flowering plants (38% endemics), 330 butterflies (11% endemics), 156 reptiles (62% endemics), 508 birds (4% endemics), 120 mammals (12% endemics) 289 fishes (41% endemics) and 135 amphibians (75% endemics) (Daniels, 2003; Babu and Nayar, 2004; Dahanukar *et al.*, 2004; Gururaja, 2004) are among the known biodiversity of the Western Ghats. This rich biodiversity coupled with higher endemism could be attributed to the humid tropical climate, topographical and geological characteristics, and geographical isolation (Arabian Sea to the west and the semiarid Deccan Plateau to the east). The four major rivers (Kali, Bedthi, Aghanashini and Sharavathi) of Uttara Kannada district of Karnataka together account for 92 fish species (Bhat, 2003).

Recently, the government proposed to set up a coal (fossil fuel) based 4,000 MW Ultra Mega Power Plant in the estuarine complex of Aghanashini River. Burning of fossil fuels in the Power Plant will leave the flying ashes, increase the temperature of water body by leaving hot water, would likely be pollute the environment and is detrimental to the sustenance of ecologically sensitive Western Ghats. This study, under taken at the time when such a major threat was looming large over this productive but fragile estuarine complex, highlights the need for restrain while locating major developmental projects which could be detrimental to precious ecosystems and scores of livelihoods dependent on them.

MOLLUSCS

The name Mollusc (=Mollusk) was derived from Latin *mollus* meaning soft. They belong to the Phylum Mollusca. The first Mollusc appeared as far back as the Cambrian period, approximately 500 million years ago. They are the second largest phylum among the invertebrates comprising more than 100,000 species. In India, till today, 5070 species of Mollusca have been recorded of which, 3370 species are from marine environment (Venkataraman and Wafer, 2005), while rest from the freshwater and terrestrial environment. They have been exploited worldwide for food, ornamentation and pearls throughout human history. Geologic evidence from South Africa indicates that systematic human exploitation of marine resources started about 70,000 to 60,000 years ago (Volman, 1978).

In Molluscs, Lamellibranchia (Pelecypoda or Bivalvia), Gastropoda and Cephalopoda are the only classes fished. The utilization of gastropods for food is very limited, and a few important species occasionally collected for this purpose. In India, Molluscs fishery comprise mainly by bivalves such as clams, mussels and oysters. Except for the chank and pearl-oyster beds, the most productive of which are concentrated on the south eastern coast, the shell-fish resources of other commercial species of molluscs are generally more plentiful on the west coast (CSIR, 1962b).

LAMELLIBRANCHIA (PELECYPODA OR BIVALVIA)

Bivalves are the second largest Class in the Phylum Mollusca. It has two shells or valves join together with the help of teeth like structure called hinge and fibrous tissue - ligament (Figure 1). The shells are made up of calcium carbonate.

Figure 1: *Paphia malabarica*

Most of the forms are completely sedentary remaining attached to hard substrata (Figure 2) by thread-like byssus of the foot or by one of their shell valves. A few forms burrow into submerged timbers, and commensal and parasitic types are also known. Some marine forms extended to a depth of 4.94 km. Life histories of bivalves pass through larval stages, which undergo remarkable changes before attain adult characteristics. Most commonly utilized bivalves for food include clams (Veneridae), sea-mussels (Mytilidae) and edible oysters (Ostreidae) (CSIR, 1962a).

Figure 2: *Perna viridis* attached to stone by thread-like byssus.

Globally, commercial exploitation of bivalves for food is dominated by epifaunal taxa such as ostreids, mytilids and pectinids. Annual harvests of bivalves for human consumption represent about 5% by weight of the total world harvest of aquatic resources (Roberts, 1999). In India eight species of oysters, two species of mussels, 17 species of clams, six species of oysters, four species of giant clams, one species of window-pane oyster are exploited extensively from marine regions. However, the Molluscan fishery is not well organized along the Indian coast. They are exploited in large quantities by traditional methods and sold live and dried conditions in the market for human consumption (Venkataraman and Wafer, 2005; Chatterji, 2002). Rushikulya estuary, Orissa has 317 species of molluscs (Ghosh, 1992). 34 of 70 creeks of Maharashtra support clam fishery (Mane, 1973) and clam fishery in Maharashtra is mainly dependent on *M. meretrix, Katelysia opima* and *Paphia laterisules* (Ranade, 1964). Molluscs especially clams, are abundant in South Kanara district, Karnataka and are harvested by traditional methods during non monsoon period (James *et al.*, 1975; Chatterji *et al.* 2002). The CMFRI (Central Marine Fisheries Research Institute) estimate shows of increasing trend with 4,583 t of bivalves (in 2006), compared to 905 t (in 1997). Total molluscs collection in Karnataka shows similar trend with 16,225 t (in 2006) and 239 t in 1985 (http://www.cmfri.com/html/cmfriDATA01.html). Table 1 lists some edible species of bivalves in India (CSIR, 1962a; CSIR, 1962b). The bivalves are rich in nutrients, particularly proteins, fats and minerals (CSIR 1962a). The Indian edible bivalves have protein (5-14%), fats (0.5-3%), calcium (0.04-1.84%), phosphorus (0.1-0.2%) and iron (1-29 mg/100 g of the fresh weight). Chemical composition of a few important edible Indian Bivalves (CSIR, 1962a; Nagabhushanam and Thompson, 1997) are given in Table 2.

The role of small-scale fisheries and how they fit into the rural economy remains poorly understood. Unlike large-scale industrial fisheries, they receive little attention from policy-makers. Globally, this kind of informal small-scale fisheries and fisheries-related activities (processing, trading, etc.) make an important contribution to the nutrition, food security, sustainable livelihoods and poverty alleviation of many, especially developing countries (Staples *et al*., 2004).

This study focuses on intertidal shellfishery, especially bivalve gathering – a informal small-scale fishery in the Aghanashini River estuary situated towards the center of south Indian west coast, in the State of Karnataka. Bivalve gathering has been a tradition among the inhabitants for centuries, and it is still being practiced. Harvesting is done manually during low tides. The collectors may wade through shallow waters or use small boats to collect in deeper water. The targeted bivalve speceis are Clams *P. malabarica, K. opima, Meretrix* sp., and *V. cyprinoides,* Mussel *P. viridis,* and Oysters *Crassostrea* sp. The harvesters sell the bivalves to traders who come to the collection area or sell to the local consumers by house to house sale or in the local markets.

Typically, harvesting is carried out in the 19 coastal villages by Harikanthra and Ambiga fishing communities as well as by Halakkivokkals, Namdharis, and Gramvokkals (basically farming communities). Both men and women are involved in the harvest and about 2370 people were dependent on bivalve fisheries, for employment. This study will provide an insight to policy and decision makers in understanding the role of small-scale fishery and its sustainable livelihood value and enable them to conserve such neglected, nevertheless ecologically and economically important, habitats for posterity.

Table 1: Some edible species of bivalves in India

Sl. No.	Common Name	Scientific Name
1	Bay clam	*Meretrix meretrix* (Linn.)
2	Backwater clam	*M. casta* (Deshayes)
3		*Katelysia* (Eumarcia) *opima* (Gmelin)
4	Black clam	*Velorita cyprinoids* (Gray.)
5	Cockle clam	*Gafrarium* (Gafrarium) *tumidum* (Roding)
6		*G.* (Circe) *divaricatum* Gmelin
7	False cockle	*Cardita bicolor* Lam.
8	False clam	*Paphia malabarica* (Dilwyn)
9		*P. marmorata* (Reeve)
10		*P. marmorata* (Reeve)
11		*Mesodesma glabratum* (Lam.)
12		*Mactra corbiculoides* (Deshayes)
13	Asiatic cockle	*Cardium asiaticum* (Bruguiere)
14	Wedge-shells/clams	*Donax cuneatus* Linn
15		*D. scortum* Linn.
16	Green mussel	*Perna viridis*
17	Bearded weaving mussel	*Modiolus barbatus* (Linn.)
18	Estuarine oyster	*Crassostrea madrasensis*
19	Rock oyster	*C. cucullata* (Born)
20	Disc oyster	*C. discoidea* (Gould)
21	Giant oyster	*C. gryphoides* (Newton & Smith)
22	Ribbed ark-shell	*Acra granosa* Linn.
23	True scallop	*Chlamys senatoria* Gmelin (Pectinidae)
24		*Sanguinolaria* (Soletellina) *diphos* (Gmelin)
25		*S.* (Soletellina) *atrata* (Deshayes)
26	Razor-shells	*Solen truncatus* (Sowerby)
27		*S. brevis* (Hanley)

Clams are considered to be nutritious and delicious and are fished in considerable quantities in some coastal places. Clams and other bivalves of their kind are usually handpicked in shallow waters at low tides.

Indian waters have two species of large size mussels; they are the brown mussel, *Perna indica* and the green mussel, *Perna viridis* Linn, belonging to Mytilidae family usually grow over submerged rocks where they attached themselves by means of their slimy thread like structures called byssus. The brown mussel, *Perna* sp., is restricted in its distribution from south of Quilon to Cape Comorin on the west coast and up to Tirunelveli dist. on the east coast. The green mussel, *Perna viridis* Linn. is abundant at Cochin, Malabar and north of Kerala and distributed on both the coasts. In Bombay, Ratnagiri and Karwar it is reported to be rare. The green mussel occurs not only in the coastal waters, but also in the brackwaters. The bearded weaving mussel, *Modiolus barbatus* (Linn.), occurring in great abundance in the Palk Bay and pearl bank region of the Gulf of Mannar, is also used as food (CSIR, 1962a; Nagabhushanam and Thompson, 1997). Oysters are inhabited where brackish water is renewed by tidal flow and the substratum is suitable for their attachment. The backwater oyster, *Crassostera madrasensis* (Peterson), is commonly found to be confined to the southern regions on the west coast but widely distributed in all estuaries and backwaters of the east coast, the rock oyster, *C. cucullata* (Born), from the intertidal rocky coast, of Bombay and Karwar, the disc oyster *C. discoidea* (Gould), from the littoral zone of the coastal areas and *C. gryphoides* (Newton & Smith) found in the muddy creeks, of Kutch, Dwarka, Bombay, Ratnagiri, Jaytapur, Karwar, etc. on the west coast, all belonging to the family Ostreidae of the class Bivalvia (CSIR, 1962a).

Table 2: Chemical composition of a few important edible Indian Bivalves

Species	Edible Portion %	Moisture %	Protein %	Fat %	Carbo-hydrates %	Ash %	Ca %	P %	Iron mg./ 100 g.
Backwater clam (*Meretrix casta*)	7.62-17.72	73.18-84.02	5.96-12.29	0.5-1.89	-	0.67-2.31	0.06-0.37	0.11-0.20	1.42-16.56
Backwater oyster (*Crassostrea madrasensis*)	5.03-17.36	76.67-85.04	5.72-13.31	1.36-3.07	-	0.52-2.06	0.04-0.40	0.10-0.21	2.53-29.63
Green mussel (*Perna viridis*)	42.8	81.46	9.92	1.97	-	3.04	1.84	0.16	-
Freshwater mussel (*Lamellidens marginalis*)	-	79.45	14.50	1.61	2.13	2.31	0.59	0.41	-

ECONOMIC IMPORTANCE OF BIVALVES

Bivalves have been exploited worldwide for food, ornamentation and pearls throughout human history. Economic importances of bivalves are:

i.) **Fish bait:** Molluscs like cuttlefish, squids, octopods and fingered chank shells are used as efficient bait in fishing. Mussels, clams, and gastropods are also often used as fish bait (CSIR, 1962a).

ii.) **Medicinal uses:** A number of species of Molluscan soft bodies and their shells are used in the treatment of various diseases and preparation of medicines and medicinal oils. Some of the medicinally useful species and their treatment in different diseases are listed in the following table 3 (CSIR, 1962a).

Table 3: Medicinal uses of few Molluscs

Scientific Name	Common Name	Treatment
Turbinella pyrum	Sacred chank	Dyspepsia, piles, general debility, and some skin and lung diseases
	Calxed shell	Demulcent and cardiac stimulant
	Chank	Spleen enlargement in Bengal
Cypraea moneta Linn		Spleen enlargement
Pila globosa	Apple snail	Sore eyes in south India
Achatina fulica Ferusasc		Shell is used in the preparation of medicated oils
Placuna placenta Linn	Windowpane oyster	Eye diseases
Pinctada margaritifera (Linn.)	Black-lipped pearl-oysters	Used medicinally in the form of ash
Crassostrea madrasensis	Estuarine oyster	Demulcent
C. gryphoides	Giant oyster	Demulcent
	Freshwater mussels	Seed pearls are credited with invigorating properties
	Sea-mussels	Manufacture of vitamin products

iii.) **Ornaments and Jewellery:** The pearl oysters and other molluscan shells fished for decorative and ornamental purposes are of considerable commercial importance in Madagascar, Western Australia, Philippines, Japan and Ceylon. In India, pearl fisheries and chank fisheries have been exploited from ancient times. Among bivalves the shell of the windowpane oyster, *Placuna placenta*, is used for glazing windows and verandah roofs. The common freshwater mussel, *Lamellidens marginalis*, produces pearls of fair quality in large numbers; they are collected and sold in South India. Pearls of poor lustre are also reported from the green mussel, *Perna viridis*, from Sonapur backwaters (CSIR, 1962a; Nagabhushanam and Thompson, 1997).

iv.) **Pearl fisheries:** Pearls of high value are obtained from pearl-oysters of the genus *Pinctada* Roding (class Bivalvia, family Pteriidae), of which several species, viz. *P. vulgaris* (Schumacher), *P. chemnitzi* (Philippi), *P. margaritifera* (Linn.), *P. anomioides* (Reeve), and *P. atropurpurea* (Dunker), occur in Indian waters. Of these *P. vulgaris* is by far the commonest and the most important and is widely distributed in the Gulf of Kutch, Gulf of Mannar and the Palk Bay (CSIR, 1962b).

v.) **Shells:** The calcium rich bivalve shells are mainly used for lime making and poultry feeds. The lime is used for white-washing and for chewing with betel pan. Lime is used neutralizing acidic agricultural soils (CSIR, 1962a).

vi.) **Lime manufacture:** The production of lime from molluscan shells (Figure 3.1 and figure 3.2) is important industry in the coastal areas of India. Shells of various species of gastropod and more especially bivalves are gathered in large quantities from the estuaries and backwaters. Lime produced by burning molluscan shells is of superior quality for use in masonry construction and white washing. It is used also as a fertilizer, prawn feed and poultry feed. The shells are directly used for the production of high grade cement (CSIR, 1962a).The commonly used bivalve species for lime manufacture in the Aghanashini estuarine region are the *Paphia malabarica, Meretrix meretrix, M. casta, Katelysia opima* and *Vellorita cyprinoids.* The death shells of these bivalves are mixed with charcoal or outer coat of coconut then the mixture burn in to powder. Burning process may continue for one to two hours depends upon the amount of material kept for the lime making process.

vii.) **Miscellaneous:** The shells, of the *Placuna* Bruguiere, *Spirula* Lam., and of cockles (Chiefly Cardiidae), are used in the manufacture of tooth pastes. The shells are collected in Tuticorin and sent to Calcutta and Madras for this purpose (CSIR, 1962a).

Figure 3.1: Bivalve shells burnt along with coconut shell to make lime powder.

Figure 3.2: Lime powder packing

Harmful molluscs

Marine borers belonging to the families *Pholadidae* and *Teredinidae* of Bivalvia cause substantial damage to underwater wooden construction, wooden sailing craft and floating timber, particularly in the tropics. The sea fishing industry which depends mainly on wooden catamarans and boats is reported to suffer an annual loss of about a crore of rupees as a result of borer damage.

Martesia striata Linn is a common burrowing pholad mollusc can bore into floating wood up to a depth of 17 m. in the sea. Several species of teredinids of shipworms belonging to the genera *Teredo* Linn. and *Bankia* Gray are particularly destructive. A few important among them are: *Teredo manni* (Wright), *T. diedrichseni* Roch, *Bankia carinata* Leach and *B. companuellata* Moll. Some species of the genus *Teredo* burrow in the wood when it is tiny and continue to live in the burrow. Some species would attain a length of 1 m or more, with a diameter of *c.* 6.3 mm (CSIR, 1962a).

MORPHOLOGY OF BIVALVES

Figure 4 illustrates the typical morphology of bivalves. Some of the general features are:

- **SHELL:** The bivalve shell acts as a skeleton to protect against predators, and in burrowing species it helps to keep mud and sand out of the mantle cavity. Its main component is calcium carbonate and is formed by the deposition of crystals of this salt in an organic matrix of the protein, conchiolin. Calcium for shell growth is obtained from the diet, or taken up from seawater. The colour, shape and markings on the shell vary considerably between the different groups of bivalves (Gosling, 2003).
- **Shell Formation:** The shell is secreted by the mantle. The calcium ions excreted from the blood mix with the fluid present in the mantle cavity, forming calcium carbonate. The calcium carbonate is absorbed by "conchiolin", a secretion of the mantle. The conchiolin crystallises into various forms, of which calcite and argonite forms are utilised in shell formation (Apte, 1998).
- **MANTLE:** In bivalves the mantle consists of two lobes of tissue which completely enclose the animal within the shell. Between the mantle and the internal organs is a capacious mantle cavity. Cilia on the inner surface of the mantle play an important role in directing particles onto the gills and in deflecting heavier material along rejection tracts towards the inhalant opening (Gosling, 2003).
- **GILLS:** The lamellibranch gills, or ctenidia, are two large, curtain-like structures that are suspended from the ctenidial axis that is fused along the dorsal margin of the mantle. Generally, the gills follow the curvature of the shell margin with the maximum possible surface exposed to the inhalant

water flow. Cilia on the gill filaments have specific arrangements and functions. They are responsible for drawing water into the mantle cavity and passing it through the gill filaments, and then upwards to the exhalant chamber and onwards to the exhalant opening. In bivalves the gills have a respiratory as well as a feeding role. Their large surface area and rich haemolymph supply make them well suited for gas exchange (Gosling, 2003).

- **STOMACH:** The mouth is ciliated and leads into a narrow ciliated oesophagus. Ciliary movement helps to propel material towards the stomach. Indeed, this method of moving material is found throughout the length of the alimentary canal, primarily because it lacks a muscular wall. The stomach is large and ovalshaped and lies completely embedded in the digestive gland, which opens into it by several ducts (Gosling, 2003).The digestive gland, which is brown or black and consists of blind-ending tubules that connect to the stomach by several ciliated ducts, is the major site of intracellular digestion. Within these ducts there is a continuous two-way flow: materials enter the gland for intracellular digestion and absorption and wastes leave en route to the stomach and intestine. Rejected particles from the stomach as well as waste material from the digestive gland pass into the long coiled intestine. The waste is formed into faecal pellets that are voided through the anus and are swept away through the exhalant opening (Gosling, 2003).
- **FOOT:** The primitive mollusc had a broad ciliated flat foot, well supplied with mucous gland cells, and the animal is believed to have moved over the lubricated substrate in a gliding motion, using a combination of ciliary action and muscular contractions. In the evolution of bivalves the body became laterally compressed. Consequently, the foot lost its flat creeping sole and became blade-like and directed in an anterior direction as an adaptation for burrowing. Bivalves use the foot for locomotion and burrow in to substrate (Gosling, 2003).
- **GONADS:** The reproductive system in bivalves is exceedingly simple. The gonads are paired and each gonad is little more than a system of branching tubules, and gametes are budded off the epithelial lining of these tubules. The tubules unite to form ducts that lead into larger ducts and eventually terminate in a short gonoduct (ibid). In primitive bivalves, e.g. the nut shell, *Nucula*, the gonoducts open into the kidneys, and eggs and sperm exit through the kidney opening (nephridiopore) into the mantle cavity. In most bivalves the gonoducts open through independent pores into the mantle cavity, close to the nephridiopore. With the exception of oysters (*Ostrea* sp.), fertilisation is external and the gametes are shed through the exhalant opening (Gosling, 2003).
- **HEART:** The heart lies in the mid-dorsal region of the body, close to the hinge line of the shell. It lies in a space called the pericardium, which

surrounds the heart dorsally and a portion of the intestine ventrally. The heart consists of a single, muscular ventricle and two thin-walled auricles. The circulatory system is an open system with the haemolymph in the sinuses bathing the tissues directly. From the sinuses the haemolymph is carried to the kidneys for purification (Gosling, 2003).

- **EXCRETORY ORGANS:** There are two types of excretory organs in bivalves, the pericardial glands and the paired kidneys (in *Mytilus* U-shaped). The brown-coloured pericardial glands, sometimes referred to as Keber's organs, develop from the epithelial lining of the pericardium and come to lie over the auricular walls of the heart. Waste accumulates in certain cells of the pericardial glands and this is periodically discharged into the pericardial cavity and from there it is eliminated via the kidneys (Gosling, 2003).
- **NERVES:** The nervous system of bivalves is fundamentally simple. It is bilaterally symmetrical and consists of three pairs of ganglia and several pairs of nerves. The cerebral ganglia innervate the palps, anterior adductor muscle, and part of the mantle, as well as the statotocysts and osphradia. The pedal ganglia control the foot. The visceral ganglia control a large area: gills, heart, pericardium, kidney, digestive tract, gonad, posterior adductor muscle, part or the entire mantle, siphons and pallial sense organs (Gosling, 2003).

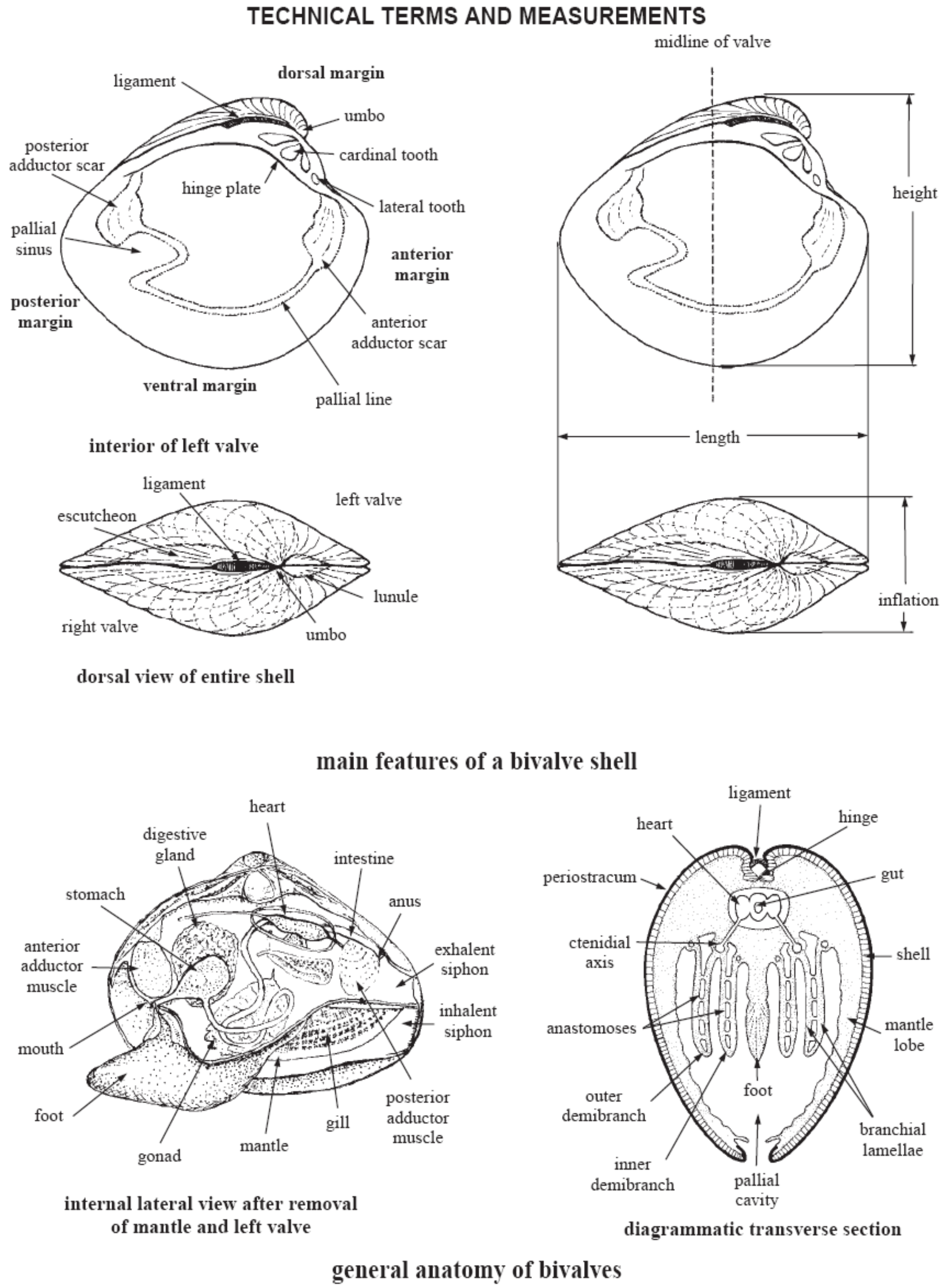

Figure 4: General features of a bivalve (ftp://ftp.fao.org/).

ECONOMIC VALUATION

Economic valuation is a tool to aid and improve wise use and management of natural resources by providing a means for measuring and comparing the various benefits of resources. The resources are quantified based on the goods and services made possible by ecosystem's functions. The economic worth of goods or services, generally measured in terms of what individuals are willing to pay for. The value of the benefit is determined by its price, i.e., the amount of money for which it will be exchanged. The value of a benefit is the price of that product in the open market and the worth of that benefit to a potential buyer. This is measured in economic terms as willingness to pay. In other words, the economic value of the ecosystem services/commodity is measured by people's *willingness to pay* (WTP) for those benefits (http://wgbis.ces.iisc.ernet.in/energy/water/paper/ecodoc2004.htm). Economic valuation is an effective method to understand the significance of ecosystem goods or services provide by nature. The strength of the economic valuation methods is that their concept of value incorporates the relationship between humankind and ecosystem products (Winkler, 2006).

OBJECTIVE

The study will provide a substantive basis to the planners to have a re-look at the estuary. These ecosystems have been under constant threat due to lack of knowledge of the benefits derived from these ecosystems and a more importantly lack of holistic approaches in the implementation of developmental projects. Locating major projects in an ecologically sensitive regions rather demonstrates lack of understanding of ecosystem functioning and also services and goods on the part of regional decision makers.

Objectives of this endeavour were: i) to document the diversity of bivalves and ii) to describe the benefits derived from them by harvesters and others who are associated with processing and trade. This involved:

- Inventorisation and mapping of the edible bivalve species of Aghanashini estuary
- Estimation of the number of people associated with bivalve collection and trade
- Methods and techniques of bivalve harvesting and
- Quanitification of benefits derived from bivalves: economic valuation of bivalves

MATERIALS AND METHODS

Study Area

The Aghanashini or Tadri River (total length 121 km) originates in the Sirsi taluk of Uttara Kannada district in the central Western Ghats of Karnataka State. Winding its way through deep gorges and valleys the river meets the tides of the Arabian Sea and forms a large estuarine expanse (13 km long and 2 to 6 km wide) in the coastal taluk of Kumta. The estuary has its outlet into the sea in between the villages of Aghanashini in the south and Tadri in the north. The study area lies between the lat 14.391° to 14.585° N and long. 74.304° to 74.516° E. Situated in the estuarine complex of the river are about 25 villages of which people from 19 villages traditionally are associated with bivalve harvesting (Figure 5).

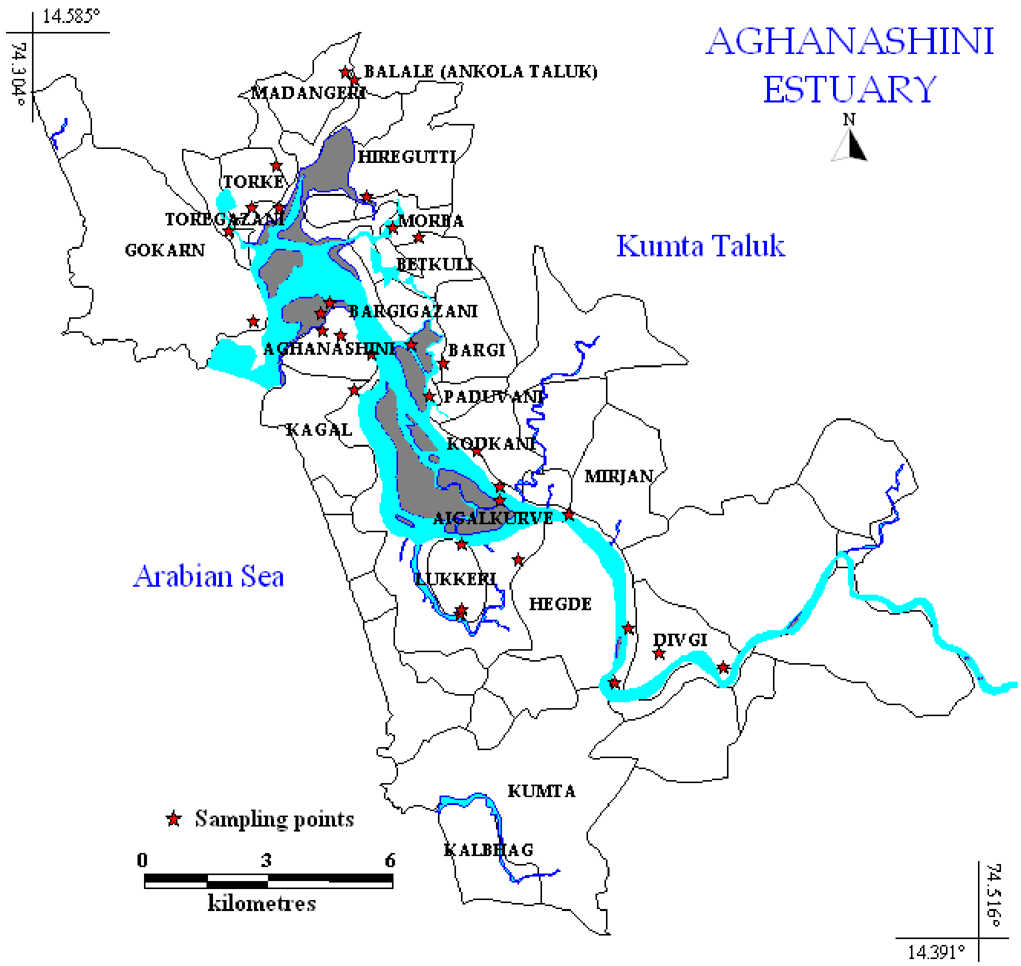

Figure 5: Sampling points in Aghanashini Estuary

Methods

The survey (both household and field) was undertaken during June 2006 to March 2007. Diversity and distribution of edible bivalve species, was documented by field observations. Bivalve harvesting villages were identified by interviewing people living closer to Aghanashini estuary. In the bivalve collecting villages, household surveys were undertaken using questionnaires. Within the identified villages we located the hamlets of communities which have bivalve collection as major activity. The local gram panchayath also guided us regarding bivalve collecting families. About 10% of these households of the bivalve collecting families were surveyed primarily to estimate:

i.) Number of individuals involved in bivalve harvesting
ii.) Number of bivalve harvesting months and
iii.) Number of bivalve harvesting days per month.

In addition to these, 5% of the bivalve collecting community households in each village was subjected to another level of survey to elicit the following information:

i.) Quantity of bivalve collection per person per day
ii.) Valuation of bivalves collected and
iii.) Expenditure incurred in collection (including local transport and processing).

We also estimated the additional income generated from the sale of bivalve shells as well as from dried bivalve meat, which constitute smaller components of the economy. There is also a shell mining industry in operation which mines for deposits of empty shells from another part of the estuary where live bivalves are not normally available. This industry also procures from bivalve collectors, a small quantity of empty shells incidentally gathered or disposed off after removing the meat. Employment generated from this activity is also estimated.

RESULTS

Figure 6 gives the spatial distribution of clams, mussel and oysters in the Aghanashini estuary. Clam *P. malabarica* inhabits deeper water whereas species like *K. opima, M. meretrix* and *M. casta* are associated with the mud flats of the estuary. The estuarine as well as fresh water bivalve species *V. cyprinoides* inhabits farthest part of estuary with lower salinity in the moderately deep water region. One specimen of blood clam *Arca granosa* was encountered near Aghanashini village. Mussel **(***P. viridis)* occupies deep water rocky surface of the river mouth region, while two species of oysters **(***Crassostrea* sp.) occupied littoral zone of the estuary region which is often referred as oyster bed (Figure 7).

Figure 6: Spatial distribution of Calm, Mussel and Oysters in the Aghanashini Estuary.

Figure 7: Oyster bed.

Distribution of bivalves

The bivalve harvesters of Aghanashini estuary normally collect eight species of edible bivalves. However, yet another edible species, *Arca granosa* known as blood clam, is rare and not of significance to the collectors. The edible bivalves are popularly categorised as clams, mussels and oysters. Table 4 provides species-wise habitat and distribution and use of these bivalves in Aghanashini estuary and also elsewhere in India. Spatial distribution of these bivalves is given in Figure 6. Harvested bivalve species, except *V. cyprinoides* are found within a distance of 4 km from the river mouth. In this part of the estuary the summer (in April) salinity at high tide, as estimated by Bhat (2003) is almost closer to the sea water at 32-34 ppt. Of the bivalves here the green mussel *P. viridis* (Figure 8.1), grows on steep rocky substratum towards the river mouth in the sub-tidal zone in close proximity to the sea. Two oyster species of *Crassostrea* (Figure 8.2) occupy inter-tidal zone on mud-flats mixed with sand and shell fragments. *P. malabarica* (Figure 8.3) inhabits deeper water with sandy substratum normally not exposed during low tides. *K. opima* (Figure 8.4), *M. meretrix* (Figure 8.5) and *M. casta* (Figure 8.6) are associated with mud-flats of this zone. *A. granosa* (Figure 8.7) also occurs here. *K. opima* has its distribution zone extending up to Paduvani (7 km away) where summer (in April) salinity is 31-32 ppt. The clam *V. cyprinoides* (Figure 8.8) inhabits the farthest part of the estuary that is 10 km away from the river mouth (salinity 26-34 ppt; Bhat 2003)) and beyond into the freshwater zone more than 18 km away.

Table 4: Species-wise habitat and distribution of edible bivalves in Aghanashini estuary and elsewhere in India

Scientific name	Common name	Habitat in Aghanashini estuary	Distribution and habitat in India	Uses
Paphia malabarica	False clam	At water depth >1 m at low tide	East and west coasts sandy bottom, mid-littoral	Food for humans, lime production and poultry feed
Katelysia opima		Mud-flats or sandy bottom	Marine and estuarine shallow waters, mud-flats or sandy bottom	-do-
Meretrix meretrix	Bay clam	Mud-flats or sandy bottom	West coast mud-flats or sandy bottom, mid-littoral	-do-
Meretrix casta	Backwater clam	Mud-flats or sandy bottom	Estuaries and backwaters of east and west coasts, mud-flats or sandy bottom, mid-littoral	-do-
Villorita cyprinoides	Black clam	At water depth <1 m at low tide	West coast backwaters and estuaries	-do-
Arca granosa	Blood clam	Sandy bottom inter-tidal	Back-waters and estuaries along the Indian coast, sandy bottom, inter-tidal	
Crassostrea sp.	Oyster	Inter-tidal mud-flats mixed with sand and shell fragments	East and west coast estuaries, and backwaters	Food for humans, lime production fertilizer and poultry feed
Perna viridis	Green mussel	Sub-tidal: steep, rocky areas near river mouth	East and west coast marine intertidal, sub tidal and estuarine, rocky shores	Food for humans

Source: Apte 1998; Chatterji *et al*. 2002; CSIR 1962a; CSIR 1962b.

Figure 8.1: *Perna viridis*

Figure 8.2: *Crassostrea* sp.

Figure 8.3: *Paphia malabarica*

Figure 8.4: *Katelysia opima*

Figure 8.5: *Meretrix meretrix*

Figure 8.6: *M. casta*

Figure 8.7: *Arca granosa*

Figure 8.8: *Vellorita cyprinoides*

Table 5: Taxonomic hierarchy of *Paphia malabarica* (Chenmitz), *Katelysia opima* (Gmelin), *Meretrix meretrix* (Linne), *M. casta*, *Villorita cyprinoides* (Gray.), *Perna viridis* (Linne), *Arca granosa* (Lamarek), *Crassostrea* sp.

Kingdom:	Animalia			
Phylum:	Mollusca			
Class:	Bivalvia			
Order:	Veneroida			
Family:	Veneridae			
Genus:	*Paphia*	*Katelsia*	*Meretrix*	*Meretrix*
Species:	*malabarica* (Chenmitz)	*opima*(Gmelin)	*meretrix* (Linne)	*casta* (Deshayes)
Order:	Veneroida	Mytiloida	Arcoida	Ostreoida
Family:	Corbiculidae	Mytilidae	Arcidae	Ostreidae
Genus:	*Villorita*	*Perna*	*Acra*	*Crassostrea*
Species:	*cyprinoids* (Gray.)	*viridis* (Linne)	*granosa* (Lamarek)	

Bivalve harvesting and trade

Both men and women are engaged in harvesting of bivalves (Figure 9.1 and figure 9.2), except *P. viridis* which only men harvest. Women normally avoid dangerously deep waters and rocky substratum towards the interface of the sea, which is the preferred habitat of *P. viridis*. Harvesting is done by hand, feet or with the aid of a small hand-held digging stick. The collectors work for three to four hours per day during the low tides. Bivalves are collected in cone shaped nets, baskets, plastic boxes, cement bags, etc. Small non-mechanised crafts are normally used for collection from deeper waters and for transport of bivalves from the collection site to the villages. The boats may be steered by men or women. Harvesting methods, for various bivalves are briefly discussed below.

- *Clams*: *P. malabarica* is most common in Aghanashini estuary followed by *K. opima, M. meretrix, M. casta* and *V. cyprinoides*. Searching for *P. malabarica* is done in shallow water by using hands or feet. *K. opima, M. meretrix, M. casta*, associated with mud-flats are picked by hand or dug out using sticks, mostly by women. *V. cyprinoides* is collected from shallow water, through direct searching using hands or feet mostly by women.
- *Mussels*: *P. viridis*, the only edible mussel of Aghanashini is usually found attached to the steep sub-tidal rocky parts of the river mouth. The species adheres to the substratum by thread like structures called byssus and is manually picked by men.
- *Oysters*: *Crassostrea* sp. form beds on the mud-flats and also attach to the inter-tidal rocks. Usually women extract the meat by opening the oyster shell using a knife.

Figure: 9.1: Bivalve collecting men

Figure: 9.2: Bivalve collecting women

Processing

Dead bivalves and empty shells are removed from the collection (Figure 10) before marketing. These empty shells are used for making lime and poultry feed. Small quantities of bivalves, especially *P. malabarica*, are boiled for couple of hours along with shells and then meat is removed and sundried for preservation and subsequent usage.

Figure 10: Women removing empty and dead shells from the collection.

An estimated 2,347 individuals from 1,202 households are associated with bivalve harvesting; of these 1,738 are men and 609 are women, who belong to 19 estuarine villages, 1,202 families (Table 6 and Figure 5). The majority who harvest bivalves for trade belong to local fishing communities such as Harikanthras and Ambigas. Halakkivokkals, Namdharis, and Gramvokkals, who are traditionally agriculturists, also gather bivalves mostly for domestic consumption and sometimes for trade. Bulk of the harvesters are from Aghanashini village (35.15%) followed by Divgi (18.75%), Gokarn (9.67%), Torke (7.84%) and Mirjan (7.63%). Aghanashini closer to the river mouth has a substantial production of bivalves and also accounts for the largest number of harvesters (825).

Total number of bivalve collecting days in a year is 140 for male and 147 for females. Hence, bivalve harvest in the estuary alone generates 332,843 days of human employment per year. Bulk of the employment for men is through the collection of *P. malabarica*, which is found in deeper parts of the estuary (water depth >1m at lowtide). However, collecting *P. viridis* from steep and rocky parts of the river mouth being a riskier task only a small number of men (2.11% of men collectors) venture to do it. *V. cyprinoides* is collected from shallow waters by both men and women. Collection of the *K. opima*, *M. meretrix*, *M. casta* and *Crassostrea* sp. from the mudflats is mostly woman's domain.

Table 6: Village-wise estimated number of bivalve collecting (BC) households (HH) and number of individuals involved in bivalve harvesting

Village	No. of HH**	BC HH	% of BC HH	BC men	BC women	Total BC persons
Hiregutti	596	1	0.17	1		1
Bargigazani	14	5	35.71	5		5
Aigalkurve	120	5	4.17	2	6	8
Bargi	359	7	1.95	7	4	11
Paduvani	331	13	3.93	3	11	14
Balale	213*	10	4.69	14		14
Betkuli	316	22	6.96	25		25
Lukkeri	280	32	11.43		34	34
Kodkani	407	29	7.13	25	10	35
Hegde	1311	31	2.36	29	19	48
Kagal	711	33	4.64	44	9	53
Madangeri	279	20	7.17	56		56
Morba	180	34	18.89	81	10	91
Toregazani	38	38	100	69	28	97
Mirjan	630	89	14.13	85	94	179
Torke	261	72	27.59	158	26	184
Gokarn	2,532	98	3.87	205	22	227
Divgi	524	323	61.64	237	203	440
Aghanashini	579	340	58.72	692	133	825
Total	9,681	1,202	12.42	1,738	609	2,347

**http://zpkarwar.kar.nic.in/CensusKumtaVWP.htm

*http://zpkarwar.kar.nic.in/CensusAnkolaVWP.htm

Village and season-wise estimated quantity of bivalves harvested per day is listed in Table 7. The quantity of bivalves harvested per day is 11.17% more during November to May. Aghanashini and Divgi village people alone contribute 67% of the bivalve harvested per day.

Table 7: Village and season-wise average quantity (Kg. wet weight with shells) of bivalves harvested per day

Village	Jun-Oct	% of total harvest	Nov-May	% of total harvest
Hiregutti	105.00	0.09	105.00	0.07
Aigalkurve	300.00	0.25	300.00	0.20
Bargigazani	337.50	0.28	337.50	0.22
Bargi	412.50	0.34	412.50	0.27
Balale	420.00	0.35	420.00	0.28
Lukkeri	431.25	0.36	637.50	0.42
Paduvani	489.00	0.41	588.00	0.39
Betkuli	708.75	0.59	843.75	0.56
Hegde	851.25	0.71	2,062.50	1.37
Kodkani	1,275.00	1.06	2,175.00	1.45
Madangeri	1,680.00	1.40	1,680.00	1.12
Morba	2,497.50	2.08	3,060.00	2.04
Toregazani	2,551.50	2.13	6,014.25	4.01
Kagal	4,890.00	4.08	4,230.00	2.82
Torke	5,782.50	4.82	7,188.00	4.79
Mirjan	5,940.00	4.96	7,320.00	4.88
Gokarn	9,945.63	8.30	11,922.00	7.95
Divgi	23,565.00	19.66	30,465.00	20.31
Aghanashini	57,683.20	48.12	70,270.96	46.84
Total	119,865.58		150,031.96	

Village, season and gender-wise average quantity of bivalves harvested is given in Table 8.1 and 8.2. The post monsoon period of November to May is more congenial for bivalve harvesting. Women collect bivalves from shallow regions and mudflats compared to men who harvests from deeper regions. Bivalves are abundant in deeper parts of estuary compared to shallow regions and mudflats. The average quantity harvested is 65±24.78 kg/individual/day for men and 22±13.46 kg/day/individual for women.

Table 8.1: Village and season-wise average quantity of bivalves harvested (in kg. wet weight with shells) by men

Village	QHD: Jun-Oct	BCD in Jun - Oct	Total harvest (kg) - Jun-Oct	QHD: Nov-May	BCD in Nov - May	Total harvest (kg) - Nov-May
Hiregutti	105	44	4,620	105	154	16,170
Bargigazani	338	32	10,800	338	64	21,600
Bargi	263	26	6,825	263	96	25,200
Aigalkurve	165	13	2,145	165	182	30,030
Paduvani	225	100	22,500	225	140	31,500
Balale	420	9	3,780	420	108	45,360
Betkuli	709	9	6,379	844	85	71,719
Hegde	638	13	8,288	1,849	120	221,850
Morba	2,475	8	19,800	3,038	78	236,925
Kodkani	1,125	10	11,250	1,875	132	247,500
Madangeri	1,680	96	161,280	1,680	168	282,240
Kagal	4,620	18	83,160	3,960	80	316,800
Toregazani	2,498	48	119,880	5,951	96	571,320
Mirjan	3,960	40	158,400	4,500	138	621,000
Torke	5,760	45	259,200	7,110	102	725,220
Gokarn	9,430	33	311,190	11,378	78	887,445
Divgi	15,960	10	159,600	21,330	90	1,919,700
Aghanashini	56,689	71	4,024,951	67,278	117	7,871,580
Total	107,058		5,374,047	132,307		14,143,159

BCD – Bivalve collecting days; QHD – Quantity harvested per day

Table 8.2: Village and season-wise average quantity of bivalves harvested (in kg. wet weight with shells) by women

Village	QHD: Jun-Oct	BCD in Jun - Oct	Total harvest (kg) - Jun-Oct	QHD: Nov-May	BCD in Nov - May	Total harvest (kg) - Nov-May
Morba	23	34	765	23	119	2,678
Toregazani	54	30	1,620	63	96	6,048
Torke	23	51	1,148	78	102	7,956
Aigalkurve	135	10	1,350	135	133	17,955
Bargi	150	36	5,400	150	126	18,900
Kagal	270	7	1,890	270	98	26,460
Paduvani	264	10	2,640	363	90	32,670
Hegde	214	12	2,565	214	168	35,910
Kodkani	150	10	1,500	300	126	37,800
Gokarn	516	75	38,672	545	105	57,173
Lukkeri	431	10	4,313	638	102	65,025
Aghanashini	994	49	48,694	2,993	114	341,145
Mirjan	1,980	48	95,040	2,820	161	454,020
Divgi	7,605	11	83,655	9,135	120	1,096,200
Total	12,807		289,251	17,725		2,199,939

BCD – Bivalve collecting days; QHD – Quantity harvested per day

Spot purchases of bivalves harvested are made by traders (Figure 11.1) who transport them to nearby towns and even to neighbouring states, especially to Goa. The local marketing is usually carried out by the women of fishing communities, who make household sales in Kumta town and nearby villages. Some female also carry the bivalves to the local fish markets (Figure 11.2). The harvesters also use small part of the collection for domestic use. Bivalve harvested in this estuary is estimated at 22,006 t/yr, which generates a total primary annual net income of about Rs. 57.8 million (Rs. 57,018,710 from bivalve collection and Rs. 816,267 from supplementary products like empty shells and dried meat). Aghanashini village, which accounts for the highest production of bivalves alone earns about Rs. 33 million (58% of total income). More details about village, season and gender-wise income per year is given in Table 9. The average income for the male was Rs. 29,129 from 140 collection days for the study year 2006-07, whereas it was Rs. 10,497 for the female from 147 collection days. Some quantity of bivalves collected is used for the production of dried meat, which earns marginally more profit than sale of fresh bivalves. The estimated annual income from the sale of empty shells is Rs. 483,850 (Table 10) and from dried bivalve meat is Rs. 334,983 (Table 11).

Figure 11.1: Harvester selling the bivalves to the wholesaler.

Figure 11.2: Women selling the bivalves in the Kumta market.

Table 9: Village, season and gender-wise income per year from bivalve collection

Village	Men		Women		Total (Rs.)
	June - Oct	Nov - May	June - Oct	Nov - May	
Aghanashini	14,247,842	17,979,543	158,992	704,600	33,090,977
Divgi	568,830	4,428,772	291,182	2,378,217	7,667,001
Mirjan	563,418	1,422,253	328,839	967,109	3,281,619
Gokarn	969,601	1,836,715	135,472	130,651	3,072,439
Torke	795,644	1,427,533	62,813	285,116	2,571,106
Toregazani	431,482	1,333,506	86,293	201,571	2,052,852
Madangeri	588,305	672,031			1,260,336
Kagal	289,145	719,192	6,867	62,622	1,077,826
Kodkani	41,044	589,468	5,036	79,019	714,567
Hegde	29,770	515,903	9,405	86,184	**641,262**
Morba	60,376	425,015	36,535	77,000	598,926
Paduvani	75,219	65,406	9,579	77,161	227,365
Betkuli	21,459	150,423			171,882
Aigalkurve	7,714	69,957	4,950	43,092	125,713
Balale	13,589	105,607			119,196
Lukkeri			11,397	89,487	100,884
Bargi	14,748	22,534	19,365	43,839	100,486
Bargigazani	38,767	50,173			88,940
Hiregutti	16,848	38,485			55,333
Total	18,773,801	31,852,516	1,166,725	5,225,668	57,018,710

Value which is in bold is the median value

Table 10: Village-wise income (Rs.) per year from shell sale

Village	BHH	SHH	No. of basket (Shells) sales / family	Rs. / basket	Income (Rs.) / family	Total (Rs.) / village
Hiregutti	1	1	25	10	250	250
Aigalkurve	5	3	28	10	280	840
Kodkani	29	20	11	11	121	2,420
Balale	10	10	28	11	303	3,025
Paduvani	13	7	35	13	438	3,063
Hegde	31	19	16	11	176	3,344
Bargigazani	5	5	50	15	750	3,750
Madangeri	20	20	40	10	400	8,000
Mirjan	89	36	23	11	256	9,207
Torke	72	18	75	9	638	11,475
Gokarn	98	33	41	12	488	16,088
Toregazani	38	19	148	11	1,623	30,828
Kagal	33	26	118	12	1,416	36,816
Morba	34	26	143	12	1,710	44,460
Divgi	323	226	35	14	490	110,740
Aghanashini	340	139	118	12	1,416	196,824
Total	1,141	609			10,752	481,129

BHH – Bivalve collecting households; SHH – Shell selling households

Table 11: Village-wise income (Rs.) per year from dried meat sale

Village	BHH	DHH	kg sales / family	Rs. / kg	Expense (Rs.)	Income (Rs.) / family	Total (Rs.) / village
Bargigazani	5	5	2	200		300	1,500
Hiregutti	1	1	18	150		2,625	2,625
Paduvani	13	3	9	250	110	2,140	6,420
Torke	72	13	4	160	20	620	8,060
Aigalkurve	5	3	20	150	135	2,865	8,595
Kagal	33	13	6	175	200	894	11,619
Morba	34	17	8	166	88	1,159	19,709
Balale	10	5	40	100	25	3,975	19,875
Madangeri	20	20	8	175	150	1,163	23,250
Divgi	323	129	2	120	13	183	23,543
Toregazani	38	29	17	150	147	2,353	68,247
Aghanashini	340	170	8	127	175	834	141,696
Total	894	408				19,110	335,138

BHH – Bivalve collecting households; DHH –Dried meat selling households

Shell Mining

Parts of the estuary are leased out for the mining of empty shells, which are used by various industries for the production of poultry-feed, lime, fertilisers, etc. The annual production of shells is around 80, 000 to 100,000 t and the market price ranges from Rs. 750 to 950/t. About 600 persons (only men, especially those operating native boats) are engaged in shell mining (Figure 12.1) in addition to transporters - about 200 persons (Figure 12.2). As shell mining depends largely on the deposits of dead shells, in the long run it is not going to be sustainable. Sustainable harvest has to be limited to procurement of shells of live bivalves and annual deposits of dead shells of unexploited bivalves which needs further investigation. The gross annual value of the shells is about Rs. 76.5 million.

Figure 12.1: shell mining people.

Figure 12.2: shell transporting people.

Dried Meat

Clams are used in the drying process. In general, locally collected sticks, woods or purchased wood is used for boil the vessel contain bivalves and freshwater. The boiling process may take about half to one and half hour or more that depends on the quantity involved in the boiling process. Then their shells are removed and flesh sun-dried for two days. The dried bivalves (Figure 13) can be kept for years for human consumption. The cost of one kolaga (approximately 1 to 1.25 kg) of dried bivalves will be Rs. 80 to 200 that depend on the season and demand.

Figure 13: Dried meat

Valuation of estuary based only on bivalve production

The annual harvest of bivalves in Aghanashini estuary is estimated to be 22,006 t (edible portion (Figure 14) about 9% of fresh weight). On an average an individual consumes 50 g of meat for about 200 days a year. Therefore the bivalves of this estuary alone contribute substantially towards protein and mineral rich nutrition of about 198,000 people of the west coast.

Figure 14: Edible portion of bivalves.

About 186 ha of the estuary, estimated to be used for bivalve harvesting (Figure 15). Therefore the average annual income per year for every hectare of bivalve harvesting area can be put at Rs. 306,552. It is an amazing yield/ha compared to any other natural ecosystem or agricultural systems, and that too this yield is without input of any kind into the system by humans. Majority of the 105 harvesters whom we interviewed opined that over the years, despite the harvests, there has been hardly any change in the availability of bivalves. However, a small number of harvesters expressed that there has been a declining trend in recent years. It is learnt that during 2007 – 08 period overharvesting due to rising demand from Goa has created local scarcity and spiraling of bivalve prices.

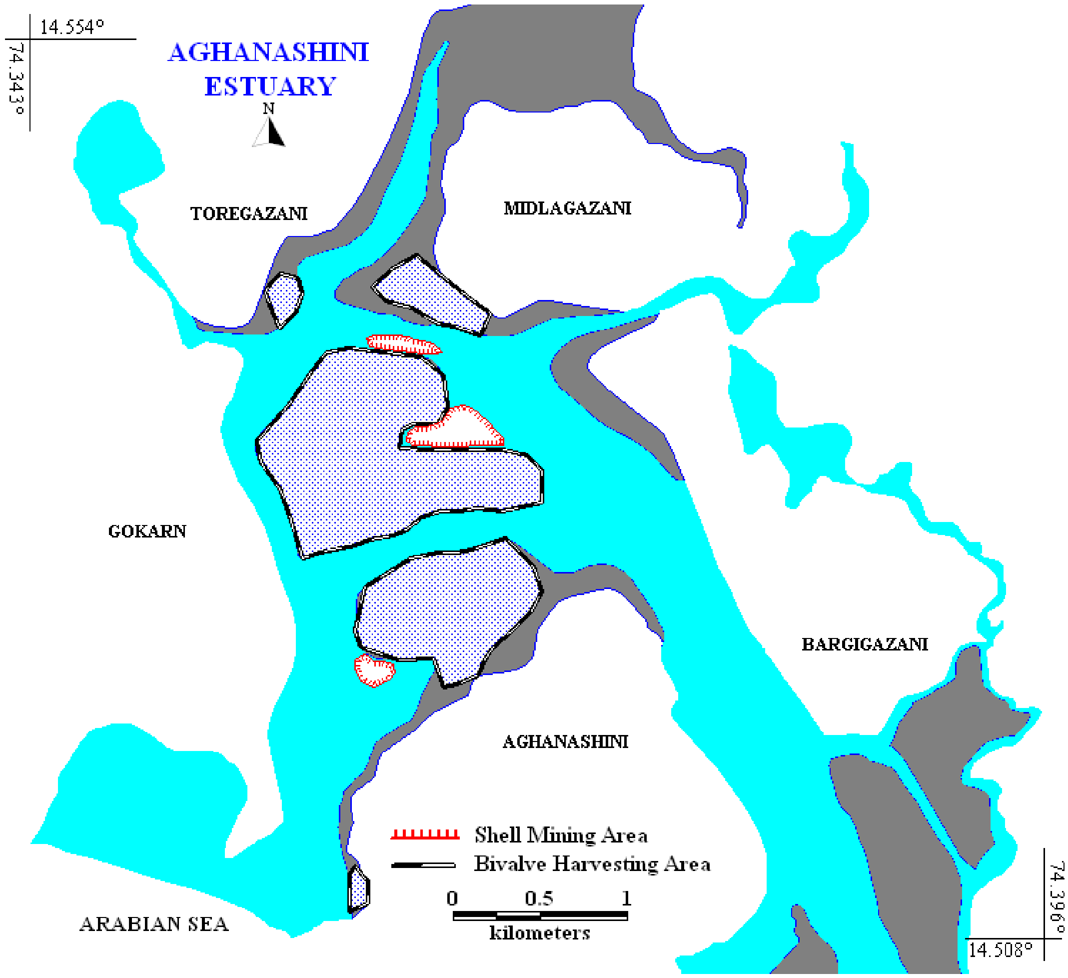

Figure 15: Bivalve harvesting and shell mining areas.

Shell mining is done in an area of 100 ha per year out of a total lease area of 809.37 ha (20 years lease period). The shells mined at prevailing market prices are worth Rs. 765,000/ha/yr. Hence, the total value of the estuary based on live bivalve and shell production is worth Rs. 1,071,552/ha/yr. This demonstrates the high productive potential of the estuary compared to any other economic sectors. This valuation does not include other goods that the estuary provides such as production of shrimps, fish, crabs, salt, mangroves, etc. in addition to services such as fish spawning grounds, nutrient cycling, hydrology, flood control, soil protection, sink for carbon, etc. Estuaries are ranked among the highest productive natural ecosystems of the world. Based on all goods and services that estuaries provide Costanza *et al.* (1997) estimated the value of an estuary as USD 22,832/ha/yr. The west coast of India is dotted with the estuaries of numerous rivers which originate in the Western Ghats, one of the global biodiversity hotspots. Yet there has been an almost callous neglect and misuse of these high ranking productive ecosystems causing inestimable losses.

CONCLUSION

Unplanned developmental activities based on ad-hoc approaches in planning in recent decades have telling effects on the Aghanashini estuary. In the early 1970's about 728.44 ha of productive estuarine ecosystem areas were leased for industrial salt production and subsequently abandoned due to failure of the project. Thereafter in a frenzied drive to promote shrimp production for export substantial portion of the estuary was put to intensive shrimp farming, destroying much of the mangroves as well as the traditional salt tolerant *Kagga* rice fields. There has also been a sharp decline in the rich bird and fish fauna following these perturbations. The most recent threat to the estuary has been from the proposed Ultra Mega Power Plant. However, this project has been shelved due to protests from the ecosystem people whose livelihoods were to be imperiled by such an establishment and also from environmentalists. The study underscores the need for greater sensitivity and vision on the part of planners and decision makers towards conservation and sustainable management of pristine and productive ecosystems, particularly of Western Ghats west coast region. This study is an initial attempt to evaluate some important aspects of estuarine goods, which has a major role in livelihood aspects of ecosystem people. However, valuation of the estuary services and goods of an estuary requires further investigations for a comprehensive understanding of various components.

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ENERGY AND WETLANDS RESEARCH GROUP
CENTRE FOR ECOLOGICAL SCIENCES
INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560 012

Telephone : 91-80-23600985/22932506/22933099
Fax : 91-80-23601428/23600085/23600683[CES-TVR]
Email : cestvr@ces.iisc.ernet.in,
energy@ces.iisc.ernet.in
Web: http://ces.iisc.ernet.in/energy
http://ces.iisc.ernet.in/biodiversity
Open Source GIS: http://ces.iisc.ernet.in/grass