Sahyadri Conservation Series 27

Valuation of Estuarine Ecosystem, Uttara Kannada District, Karnataka

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Western Ghats Task Force, Government of Karnataka
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ENVIS Technical Report: 45

JULY 2013

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ABSTRACT

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 those resources. The present study aimed at economic analysis of possible goods and services from the five estuaries - Kali, Gangavali, Aghanashini, Sharavathi and Venkatapura of Uttara Kannada, Karnataka. The provisioning services provided by these estuaries ranges from 55707 (Venkatapura) to 2,19,545 Rs (Gangavali) for smaller estuaries, 2,40,395 Rs/hectare/year (Kali), to 286964 Rs (Sharavathi) for estuaries of rivers with dams and 11,35,847 Rs/hectare/year (Aghanashini) for an estuary without any human interventions.

The total economic value (provisioning, regulating, supporting and information services) of Kali estuary is 25,71,398 Rs/hectare/year, Gangavali is 26,76,261 Rs/hectare/Year, Aghanashini is 50,05,035 Rs/hectare/year, Sharavathi is 24,53,510 Rs/hectare/year and Venkatapura as 13,33,092 Rs/hectare/year. This highlights the contributions by estuarine ecosystems in sustaining the economy of the district while providing jobs to thousands of ecosystem people in the district without any support from the government. Quantification of all benefits associated with coastal ecosystem goods and services, would help in arriving at an appropriate policy and managerial decisions. In absence of such valuations, decisions are skewed in favor of environmentally degrading practices by neglecting the diffuse social interests that benefit from the use and non-use benefits of fragile ecosystems.

Keywords: estuarine ecosystem, provisioning services, total economic valuation

Valuation of Estuarine Ecosystem, Uttara Kannada District, Karnataka

1. INTRODUCTION

Ecosystems consist of biotic and abiotic resources with complex interactions. It is a complex fabric of plant, animal, and other microscopic life and its interactions with the non-living environment (Kumar and Kumar, 2008). The ecosystem provides various vital benefits such as food; soil production, erosion and control; climate regulation; water purification; bioenergy, etc. These benefits and services are referred to as 'Ecosystem services' and are very crucial for the survival of humans and other organisms on the earth. The structural components of the ecosystem include physical features (such as water, sediment and soil profile, the gradient of conditions in water body), biotic compositions (like species, number of individuals and their biomass), etc. Interactions between these elements, i.e., the flow of nutrients, energy, etc. between different ecosystems constitute the functional aspects of an ecosystem. The ecosystem can be broadly categorized as aquatic and terrestrial ecosystem, on the basis of their major source and sink of nutrient, i.e., water or land. Aquatic ecosystem with rich nutrient contents is substantially different from terrestrial ecosystem. Both these ecosystems are dependent upon each other, as there is an overlap of the functional boundary between the two, irrespective of the physical boundaries. The Terrestrial ecosystem mainly comprises of forests whereas the Aquatic ecosystem can be broadly classified into marine and freshwater ecosystems.

The Aquatic ecosystems consist of groups of interacting organisms dependent on one another in the aquatic or water environment for nutrients and shelter. Aquatic ecosystems are broadly classified into marine (oceans, Sea, estuaries, mangroves, etc.) and freshwater ecosystems (rivers, ponds, streams, puddles, etc.). Life forms in an aquatic ecosystem usually contain a wide variety of ecosystems usually contain a wide variety of organisms including bacteria, protozoan, fungi; bottom dwelling organisms such as insects, larvae, snails; large plants such as grasses and reeds; and also fish, amphibians, reptiles, birds and mammals. The assemblages of these organisms vary across ecosystems because of diverse habitat and environmental conditions in each ecosystem that tend to affect species distribution.

Planet Earth is a coastal planet and it comprises 361.13million km^2 of water (71% of total planet surface) and 148.94 million km^2 of land area (29% of total planet surface) (Martinez *et al.,* 2007). They both interact intensively and extensively along the world's total 1,634,701 km of coastline (Burke *et al.,* 2001). The extensive distribution of the coasts results in an ample variety of geomorphological features, weather regimes and biomes (Martinez *et al.,* 2007). The coasts include soft-shores, rocky shores and cliffs, hilly or flat coastal plains, narrow or wide coastal shelves and a wide variety of wetlands (estuaries, salt marshes, deltas) (Schwartz, 2005).

An estuary is a partially enclosed body of water where the rivers meet sea and the salinity is intermediary to that of marine and fresh water. This makes the estuarine ecosystems unique in their ecological and biological functions (Anoop and Sooryaprakash, 2008). Forming a dynamic zone of convergence between land and sea, the coastal regions of the earth serve as unique geological, ecological and biological domains of vital importance to a vast array of terrestrial and aquatic life (Wilson *et al.,* 2005). Estuaries are one of the major specialized ecosystems where organic matter is built up in large quantities and offers ideal biotic conditions to sustain considerable aquatic population (Rao and Suresh, 2001). Estuaries and surrounding areas are transitory places where the landscapes change from land to sea and water quality from fresh to salty. Although influenced by the tides estuaries are protected from the ocean waves, winds and storms by reefs , barrier islands and land, mud or sand that define an estuaries seaward boundary (Madhyastha *et al.,* 2002). More than 200 rivers are seen flowing towards the west coast of India and evolve as estuaries before joining the Arabian Sea (Ansari, 1977).

Fresh water influx and density difference between the two merging water entities, a constant replenishment of nutrients and versatility in their structure make it a nursery ground for many marine organisms (Rao and Suresh, 2001). Diverse habitats that are found in and around estuaries can be grouped as shallow open waters, fresh water and salt marshes, sandy beaches, mud and sand flats, rocky shores, mangrove forests, river deltas, tidal ponds and sea grass beds. The estuarine ecosystem is essential for the survival of many species which include birds, mammals, fish and wildlife depend on this ecosystem for live, feed and reproduce. Many marine organisms, including commercially valuable fish species depend on estuaries at some stage during their development (Madhyastha *et al.,* 2002). Estuaries are the year round home for many species (oysters), while other species move in and out of estuaries on a seasonal basis for reproduction and growth (salmon and shrimp) (Wilson and Farber, 2010).

Estuaries provide an array of natural resource entitlements to rural communities and supply a variety of living and non-living resources, which offer opportunities for employment, income, amenities and pleasure to the local people (Thomson, 2003). Estuaries and inlets serve as places of relative shelter that also provided staging areas for harvesting food and fibre (Wilson *et al.,* 2005). Fishing is one of the major economic activities of the rural coastal communities (Thomson, 2003; Anoop and Sooryaprakash, 2008). Apart from these direct tangible flows of economic benefits, estuaries also provide a variety of indirect services to local communities and to the rest of the world which enhance the economic significance of these systems manifold. The capacity of estuaries to regulate various gases, climate, water currents and flow, soil erosion and sedimentation, retention and soil formation, nutrient cycling, waste treatment, pollination and thereby control the various biological processes is well recognized. Moreover, estuaries supply various kinds of recreation services and act as the primary pool of genetic resources. In fact, these diverse ecosystem functions along with the direct flow of benefits through the supply of various goods and services make these systems valuable to humanity. These services are enjoyed by human users almost free of cost or at a price much below the cost of acquiring alternate but similar services (Thomson, 2003; Anzari, 1977).

The estuaries are also the repositories of mangroves biodiversity which serve as a wall for the coastline apart from providing numerous other benefits. Mangroves are salt tolerant forest ecosystems found mainly in tropical and sub-tropical intertidal regions (Hirway and Goswamy, 2004; Ghasemi *et al.,* 2010) where they may receive organic materials from estuarine or oceanic ecosystems (Badola *et al.,* 2003; Ghasemi *et al.,* 2010). The presence of mangroves enriches various forms of living organisms and ensures smooth delivery of various ecosystem services to humanity at large. These rich ecosystems provide a wide range of ecological and economic products and services, and also support a variety of other coastal and marine ecosystems, which again provide several economic and ecological benefits (Hirway and Goswamy, 2004). The mangroves supply forestry products (firewood, charcoal, timber, honey *etc*.) and fishery products (fish, prawn, crab, mollusk *etc*.). Due to high calorific values, mangrove twigs are used for making charcoal and firewood. Mangrove extracts are used in indigenous medicine; for example, *Bruguiera* species (leaves) are used for reducing blood pressures and *Excoecaria agallocha* for the treatment of leprosy and epilepsy (Kathiresan, 2005). Mangrove swamps act as traps for the sediments, and sink for the nutrients. The root systems of the plants keep the substrate firm, and thus contribute to a lasting stability of the coast (Kathiresan, 2005).

1.1 ECOSYSTEM GOODS AND SERVICES

Ecosystem provides various vital benefits for our survival such as food; soil production, erosion and control; climate regulation; water purification; bioenergy, etc. these benefits and services are referred to as 'Ecosystem services' and are very crucial for the survival of humans and other organisms on the earth. The ecosystems, if in a good condition perform functions which are of bio-geophysical in nature. These functions result in the flow of various services and benefits for humans and their society (Kumar and Kumar, 2008). Ecosystem Functions can be defined as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (De groot *et al.,* 2002). Millennium Ecosystem Assessment defines ecosystem services as the benefits people obtain from ecosystems. It includes provisioning services such as food and water, regulating services such as flood and disease control, cultural services such as spiritual, recreational and cultural benefits, and supporting services such as nutrient cycling that maintains the conditions for life on earth (MA, 2003). Hassan *et al.,* (2005) and Fischlin *et al.,* (2007) distributed the ecosystem goods and services into four different categories as:

i. Provisioning services – it includes products i.e., food (including roots, seeds, nuts, fruits, spices, fodder), fiber (including wood, textiles) and medicinal and cosmetic products (Table 1).

ii. Regulating services – which are of immense importance to the human society such as (a) carbon sequestration, (b) climate and water regulation, (c) protection from natural hazards such as floods, avalanches or rock-fall, (d) water and air purification and (e) disease and pest regulation (Table 2).

iii. Supporting services – such as primary and secondary production and biodiversity; a resource that is increasingly recognized to sustain many of the goods and services that humans enjoy from the ecosystem (Table 3).

iv. Cultural services – which satisfy human spiritual and asthetic appreciation of ecosystems and their components (Table 4).

Wilson and Farber (2010) described the different components of the ecosystem goods and services provided by the estuary which can be summarized in Table 1-4.

Table 1: Provisioning services provided by the estuaries

Provisioning Services	**Provision of natural resources and raw materials**	
Water supply	Filtering, retention, and storage of water	Provision of potable water and water purification Medium for transportation and ports Provision for irrigation and industrial use
Food	Edible plants and animals Arable land	Hunting, fishing, crops, grazing, and aquaculture
Raw materials	Building and manufacturing	Lumber, skins, plant fibers, oils, dyes, etc.
	Fuel and energy	Fuel wood and organic matter
	Fodder and fertilizer	Leaf litter, salt hay, excrements, etc.
Genetic resources	Genetic resources	Variety of gene pools in fish species
Medicinal and plant resources	Biological and chemical substances for use in agriculture and human treatment	Medicines and pest control chemicals obtained from estuarine dependent species
Ornamental resources	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs	Shells used as jewelry Dried grasses

Table 2: Regulating services provided by the estuaries

Regulating services	Maintenance of essential ecological processes and life support systems	
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	Biotic sequestration of CO2 Vegetative absorption of VOCs
Climate regulation	Regulation of local and global energy balance and hydrological cycle, and other biologically mediated climate processes	Direct influence of land cover on temperature, precipitation, wind, humidity, etc.
Disturbance regulation	Dampening of environmental fluctuations/disturbance	Storm protection (e.g., by barrier islands) Flood protection (e.g., by wetlands and forests)
Soil retention	Erosion control and sediment retention	Prevention of soil loss by wind, wave action, runoff, or other removal processes from wetlands and barrier islands
Waste Assimilation	Removal or breakdown of nutrients and compounds	Pollution detoxification and sequestration Water purification

Table 3: Supporting services provided by the estuaries

Supporting services	Ecosystem structures and functions that are essential to the delivery of ecosystem services	
Nutrient cycling	Storage, processing, and acquisition of nutrients	Net Primary Productivity
Soil formation	Capture of sediments and accumulation of organic matter	Formation of wetlands substrate and soils
Biological regulation and Biodiversity	Species interactions, including pollination	Control of pests and diseases Reduction of herbivory Pollination of wetlands plants
Habitat	The physical place where organisms reside	Refugium for resident and migratory species Spawning and nursery grounds for

		shrimp and other fish
Hydrological cycle	Movement and storage of H_2O through the biosphere	Aquifer recharge Maintain salinity gradients

Table 4: Cultural services provided by the estuaries

Cultural Services	**Enhance emotional, psychological and cognitive well being**	
Recreation	Opportunities for rest and enjoyment	Ecotourism, bird watching, outdoor sports, beach going, fishing, etc.
Aesthetic	Enjoyment of landscape and its elements	Coastal beaches and wetlands, added value to coastal housing Clean water
Science and education	Development of knowledge	A "natural field laboratory" for understanding coastal biological and physical processes
Spiritual and historic	Spiritual or historic information	Use of estuaries as motif in books, film, painting, folklore, national symbols, architecture, advertising, etc.
		Natural features with religious or historic

Estuarine and coastal ecosystems are some of the most heavily used and vulnerable natural systems globally (Barbier *et al.,* 2011). Throughout history, humans have preferred coastal locations as desirable places to live, work, and play. Estuaries—bodies of water where oceans and rivers meet—served as places of relative shelter that also provided staging areas for harvesting food and fiber. The population and development pressures that estuarine areas are now experiencing raise significant challenges for planners and decision makers (Wilson and Farber, 2010). The deterioration due to human activities is severe and increasing; 50% of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of sea grasses are either lost or degraded worldwide (MEA, 2005). The loss of biodiversity, ecosystem functions, and coastal vegetation in estuarine and coastal ecosystems may have contributed to biological invasions, declining water quality, and decreased coastal protection from flooding and storm events (Barbier *et al.,* 2011).

There are numerous alternative uses of ecosystem functions and services. To choose from among these competing options, it is important to know not only what ecosystem goods and services will be affected but also what they are actually worth to different members of society. The issue of valuation is indivisible from the choices and decisions we have to make about ecological systems (Costanza and Folk, 1997; Costanza *et al.,* 1997). Without efforts to assess and quantify all the benefits associated with coastal ecosystem goods and services, policy and managerial decisions will ultimately be skewed in favor of environmentally degrading practices by neglecting the diffuse social interests that benefit from the non-use characteristics of such systems (Wilson *et al.,* 2005). Economic valuation helps to compare the real costs and benefits of ecosystem use and degradation, and allows more balanced decision-making concerning the protection and renovation versus degradation of wetlands. This facilitates optimal decision-making which maximizes societal welfare (Turpie *et al.,* 2010).

De Groot *et al.,* (2002) have given an integrated framework (Figure 1) for assessing the ecosystem goods and services. According to this framework, the ecosystem which involves complex structures and processes can be divided into a limited number of ecosystem functions which, in turn provide the goods and services that are valued by humans. The ecosystem functions can be broadly classified into four different functions namely – Regulation, Production, Habitat and Information. The value of the ecosystem functions, goods and services can be roughly divided into three types – ecological, socio-cultural and economic values.

- **Ecological value** - The capacity of ecosystems to provide goods and services depends on the related ecosystem processes and components providing them and the limits of sustainable use are determined by ecological criteria such as integrity, resilience, and resistance (De Groot *et al.,* 2002). The 'Ecological Value' or importance of a given ecosystem is, therefore, determined both by the integrity of the Regulation and Habitat Functions of the ecosystem and by ecosystem parameters such as complexity, diversity, and rarity (De Groot *et al.,* 2000).
- **Socio-Cultural value** - In addition to ecological criteria, social values and perceptions play an important role in determining the importance of natural ecosystems, and their functions, to human society (De Groot *et al.,* 2002). Social reasons play an important role in identifying important environmental functions, physical and mental health, education, cultural diversity and identity (heritage value), freedom and spiritual values.
- **Economic value** - Economic value can be defined as the most that a person is willing to give up in other goods and services in order to obtain a good, service, or state of the world. In a market economy, money is a universally accepted measure of economic value, because the amount that someone is willing to pay for something tells how

much of all other goods and services they are willing to give up to get that item. Thus their willingness to pay reflects the economic value (Turpie *et al.,* 2010; Ramachandra and Rajanikanth, 2003).

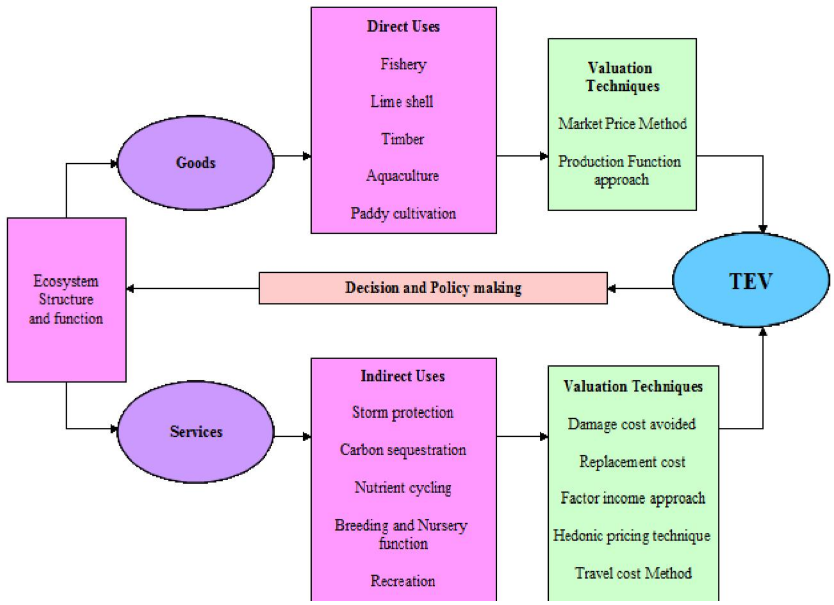

Figure 1: Assessment of ecosystem goods and services

1.2 TOTAL ECONOMIC VALUE (TEV) FRAMEWORK

The total economic value (TEV) is the sum of all the benefits that are attributable to the specific resource or ecosystem being valued (UNEP, 2007). The total economic value is composed of (i) use value (UV) and (ii) non-use value (NUV). Use value to humans consists of direct, indirect and option value. Direct-use values can be consumptive or non-consumptive and are commonly derived from goods and services by the inhabitants of the ecosystem whereas Indirect-use values are those that are more functional, the benefits of which often extend away from the ecosystem itself and are not consumed (Watson, 2007). Figure 2 outlines an economic valuation approach to valuing estuarine ecosystems (UNEP, 2004).

- **Direct Use Values** - The direct use values of a resource or a system are the tangible or physical aspects of such resources, which can either undergo physical processing or provide direct (personal) utility or satisfaction and which have direct market prices for quantification (UNEP, 2007). According to Bann (1997), these are the "values derived from the direct use or interaction with a (for example) mangrove's resources and services". These direct use values are further categorized as extractive or consumptive, and non extractive or non-consumptive (Ebarvia, 1999).
- **Indirect Use Values -** Indirect use values consist of the various functions that a natural system may provide, such as shoreline protection functions, carbon

sequestration, and nutrient or contaminant retention (UNEP, 2007). These values have no direct market prices but equivalent values can be derived through the use of different valuation methods. The indirect use value of an environmental function is related to the change in the value of production or consumption of the activity or property that it is protecting or supporting (Ebarvia, 1999).

- **Option Values -** Option Use or option value is a special category of value, which arises because of an individual's uncertainty about his or her future demand for a specific resource, or the availability of this resource in the future (UNEP, 2007). It is still considered as a "use" value since it still relates to future direct or indirect use of the resource (Barbier *et al.,* 1997).
- **Quasi-option Value** - This non-use value is related to option value such that there is still willingness to pay by the individual for the preservation of the resource, but instead of worrying about its future use, the preservation is for the value that it can presently provide (UNEP, 2007).
- **Bequest Value** - This is an important subset of non-use value that results from an individuals' willingness to pay for the preservation or conservation of a resource so that future generations will still be able to reap its benefits (UNEP, 2007). This may be particularly high among those who are currently enjoying the rights to use the resource because they may want their heirs and future generations to be able to derive the same benefits from the system.
- **Existence Value** - Existence value can be related to aesthetic, cultural, and moral aspects that a resource may have in that it is the value that an individual places on the resource because of the satisfaction that he or she derives from merely knowing that the resource, ecosystem or species exists, regardless of whether it will be used or not (UNEP, 2007). This is a form of non-use value which is difficult to measure since it involves subjective valuations by individuals unrelated to their own or others' use.

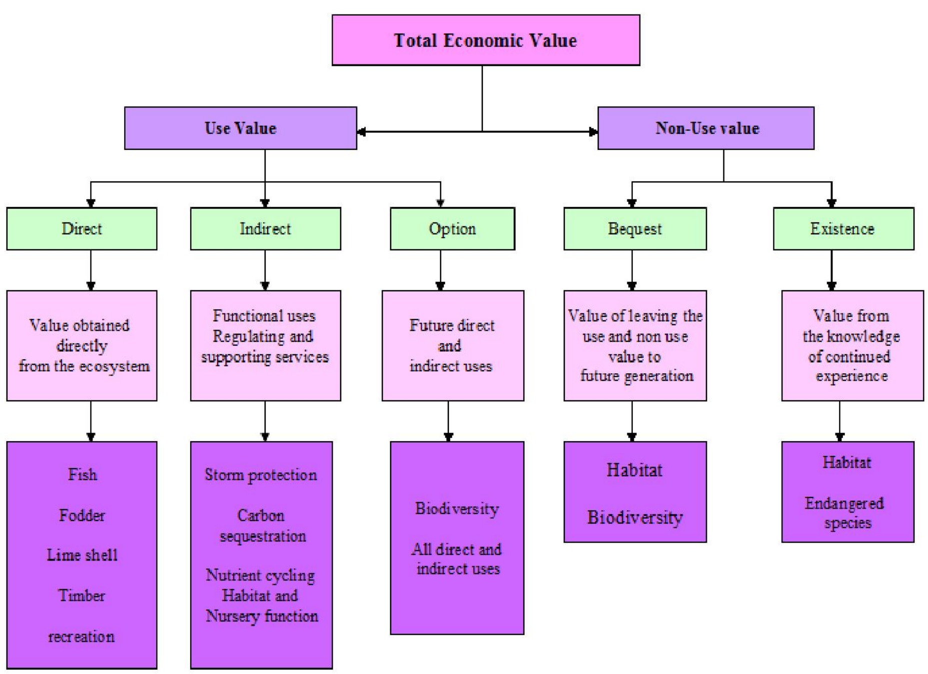

Figure 2: Framework for economic valuation of estuarine ecosystems

1.3 TECHNIQUES FOR QUANTIFICATION OF ECOSYSTEM GOODS AND SERVICES

The economic valuation methods for ecosystem goods and services broadly fall into four basic types – (1) Direct Market valuation, (2) Indirect market valuation, (3) Contingent valuation and (4) Group valuation.

- **Direct Market valuation:** this valuation technique involves the use of market price which can be used to value the products from the coastal habitats, i.e. resources that are marketed and can be used directly and indirectly (UNEP, 2007). Direct values can be attributed to both extractive and non-extractive uses of the ecosystem. The benefits and costs of fishery products, fuel wood, genetic materials and raw materials derived from coastal habitats can be estimated as can non-extractive uses such as recreation and tourism (UNEP, 2007). The values of both extractive and non-extractive uses are based on market price (accounting price), which can be quantified and monetized from the direct use of the coastal ecosystem (Bann, 1997).
- **Indirect Market valuation:** When there are no explicit markets for services, indirect means of assessing the values can be used to establish the Willingness To Pay (WTP) or Willingness To Accept compensation (WTA) for the availability or loss of these services (De Groot *et al.,* 2002). This includes various techniques like Avoided Cost (AC) method, Replacement Cost (RC) method, Factor Income (FI) method, Hedonic Pricing (HP) method and Travel Cost (TC) method.
- **Contingent Valuation:** Contingent Valuation Method (CVM) is a method that enables economic values to be estimated for non–marketed goods, such as environmental assets, amenities, and services by relying on surveys to ascertain respondents' preferences regarding an increase or decrease in the level of environmental quality (UNEP, 2007). The preferences are valued through surveys to ascertain how much respondents would be willing to pay for the preservation or improvement of a certain resource or environment or to accept payment for doing away with said resources or environment (Tietenberg, 1996).
- **Group valuation:** this is another important approach for ecosystem valuation that has gained attention recently and involves group deliberation (Wilson and Howarth, 2002; Jacobs, 1997). Derived from social and political theory, this valuation approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from open public debate (De Groot *et al.,* 2002).

Benefit transfer method – Benefits transfer refers to the practice of using values estimated for an alternative policy context or site as a basis for estimating a value for the policy context or site in question. Benefits transfer studies are often the only recourse where data is poor or funds are not sufficient for a full-scale valuation study (Barbier *et al.,* 1997). It is an easy and seductive approach, as it is cheap and fast (Stefano, 2004). This method involves various steps like identifying resources or services to be valued, identifying relevant existing studies, evaluating applicability and conducting the benefit transfer. This method can be used for damage assessment, where there is a need of existing estimate of value of the natural resource or services provided by the resource.

2. OBJECTIVES

The overall objective of the present study is to estimating the total economic value of estuarine ecosystem of Uttara Kannada in order to enhance natural resource productivity.

This includes:

- Estimating value of provisioning services from Five estuaries namely, Kali, Ganagavali, Aghanashini, Sharavathi and Venkatapura in Uttara Kannada
- Estimating the value of indirect products and services of the estuarine ecosystem such as regulating, supporting and information services.

3. LITERATURE REVIEW

More than 60% of the world's population is concentrated in coastal areas or located in areas influenced by coastal climate dynamics (Lacambra *et al.,* 2008). UNEP-WCMC (2006) and McFadden *et al.,* (2007) have presented the case for coastal ecosystems in coastal protection; drawing on conceptual and theoretical papers on vulnerability and examples of ecosystems uses, services and status in both temperate and tropical settings. 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). 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. Comprised of wetlands, lagoons, mangroves, and seagrass beds, India's estuaries, linked to the country's vast network of rivers, are sources of nutrients and are rich in biodiversity (Swaminathan, 2008).

The capacity of estuaries to regulate various gases, climate, water currents and flow, soil erosion and sedimentation, retention and soil formation, nutrient cycling, waste treatment, pollination and thereby control the various biological processes is well recognized. The economic importance of these ecosystems to the local communities and to the world at large has been recognized in the Rio Conference and in the various forums of the Convention of Biological Diversity way back in 1992 (Thomson, 2003). In spite of being rich and diverse in various aspects, these ecosystems are under considerable stress. Demographic pressures (more than 300 million people live in India's coastal areas) and pollution problems have had significant impacts on these ecosystems, including the extension of settlements and industrial activities (Swaminathan, 2008). The natural disasters have also played a key role in the dynamics of the Indian coastal zone. Though the valuation of coastal resources and the ecosystem services appropriately is essential to accurately calculating tradeoffs in investment decisions in the coastal zone, the challenge before policy makers in India is enormous when it comes to capturing and valuing the ecosystem services provided by India's coastal areas and estuaries (Swaminathan, 2008).

The most comprehensive study for economic valuation of ecosystem goods and services was done by Costanza *et al.,* (1997) by estimating the current economic values for 17 different ecosystem services for 16 different biomes based on earlier published studies and some original calculations. They classified the world ecosystems into two major classes namely Marine ecosystems (including estuaries, sea grass/algae beds, coral reefs, and shelf systems) and terrestrial ecosystems (including two types of forest (tropical and temperate/boreal), grasslands/rangelands, wetlands, lakes/rivers, desert, tundra, ice/rock, cropland, and urban). Their study estimated that the annual value of the ecosystem services of the terrestrial and aquatic biomes of the world in the range of US$16–54 trillion with an estimated average of US$33 trillion. This value was found to be 1.8 times higher than the current gross national product (GNP) value for the world. About 63% of the estimated values of ecosystem services were found to be contributed by the marine ecosystems while about 38% of the estimated values were found to be contributed by the terrestrial ecosystems, mainly from the forests and wetlands.

Thomson (2003) conducted a detailed socio-economic survey for valuation of various direct, indirect and non-use values of Kali estuary in Karnataka and Cochin estuary in Kerala. Various activities in the estuaries like fishing, wetland agriculture, prawn filtration, aquaculture, sand mining, navigation and ferry services, etc. were valued by market valuation methods whereas indirect use values of estuaries were estimated using travel cost methodology and the non-use economic values of estuaries were estimated using contingent valuation methods. The results revealed that 469 households were found to be engaged in gazani paddy cultivation in Kali estuary and generated an average annual income of Rs. 12,216,491 while in the case of Cochin estuary the income generated from Pokkary paddy cultivation was Rs. 5, 83, 97,238. The gross value generated by fishing activities in Cochin estuary was Rs. 6357.4 lakhs while the value generated in Kali estuary was Rs. 271.8 lakhs. Sand mining was found to be a popular activity in Kali estuary and it generated an average economic value of Rs. 276.37 lakhs. The clam fishery and lime shell collection is a live activity in Cochin and Kali estuary and generated a value of Rs. 176 lakhs and Rs. 39.87 lakhs respectively. The aquaculture was also a major economic activity in both the estuaries generating a total value of Rs. 17339.281 lakhs in Cochin estuary and Rs. 420.65 lakhs in Kali estuary. The aggregate value of Cochin estuary from the traditional, modern, recreational and non-use values was found to be Rs. 44380 lakhs while the aggregate value of Kali estuary from the traditional and modern activities was found to be Rs. 1163.56 lakhs.

The mangrove vegetation also plays a vital role in the coastal resources, thereby contributing an important part towards our socio-economic development. Mangroves are sources of highly valued commercial products and fishery resources and also as sites for developing a burgeoning eco-tourism (Kathiresan and Bingham, 2001). The mangrove forests sustain more than 70 direct human activities ranging from fuel wood collection to fisheries

(Dixon, 1989; Lucy, 2006). It has been estimated that small scale fisheries in mangrove waters in the world produce nearly one million tons of fisheries, molluscs, crabs and shrimps annually, that is equivalent to about 1.1 percent of the world fishery catch (Kapetsky, 1985). The mangroves attract honey bees and facilitate apiculture activities in some areas. Krishnamurthy (1990) has shown that Sundarbans provide employment to 2000 people engaged in extracting 111 tons of honey annually and this accounts for about 90% of honey production among the mangroves of India. In Bangladesh, an estimated 185 tons of honey and 44.4 tons of wax are harvested each year in the western part of the mangrove forest (Siddiqi, l997). The mangroves also provide seeds for aquaculture industries. Chaudhuri and Choudhury (1994) have shown that 40,000 fishers get an annual yield of about 540 million seeds of *Penaeus monodon* for aquaculture, in the Sundarban mangroves of West Bengal. Each hectare of a managed mangrove ecosystem can produce as much as $ 11,300 a year at par with an intensive shrimp farming (Primavera, 1991). The biodiversity protected and supported by mangroves include a wide range of creatures, ranging from small insects like bacteria, and fungi, a variety of fish, prawns, shrimps, etc., to a variety of birds along with a variety of flora – sea weeds, small plants and creepers (Hirway and Goswami, 2004). It has been estimated that mangroves support a large variety of microorganisms, plants, invertebrates, fish and prawns, amphibians and reptiles, birds, mammals, etc. (Singh, 1999).

Badola and Hussain (2003) conducted a study to enumerate ecological functions and the key productive uses of the Bhitarkanika mangrove ecosystem and estimate the values of ecological services provided by the ecosystem. For identifying the use values and ecological functions performed by Bhitarkanika mangrove ecosystem, discussions were held with the Park management and staff, field biologists, scientists, commercial fishermen and local people along with performing door-to-door socioeconomic survey. By applying the market price method, the monetary values of major nutrients like nitrogen, phosphorous and potassium in one ha of mangrove soil was found to be Rs 29070 per kg, Rs 433.74 per kg and Rs 11092.66 per kg respectively, while in one hectare of non-mangrove soil it was Rs 20576.70 per kg, 309.83 per kg and Rs 8667.24 per kg respectively. The estimated value of catch per hour for inshore fishery in the region was found to be Rs. 89.91 for 3.77 kg of fish. The catch/hr for White prawn, Tiger prawn and Mud crab was found to be 65.3, 5.9 and 14.8 respectively with the earnings (Rs/hr) from these species being 6.53 to 32.65, 2.36 to 3.54 and 2.96 to 5.92 respectively. In the village having mangrove cover the damage cost avoided was estimated to be 116.28 US$/household while the land accretion function was estimated to be 983795.7 US$ over a period of 111 years.

Hirway and Goswami (2004) carried out a study on the changing status of mangroves and the monetary value associated with it in the coastal region of Gujarat state. The use values, non-use values and replacement values of the mangroves of Gujarat coast were calculated using appropriate methods. The results revealed that in spite of having the longest coastline in the country, the mangrove cover on the coastal stretch of Gujarat state had declined severely in the last fifty years due to increasing anthropogenic factors. The results also showed that loss of mangroves experienced by the state during 1998-2001 could be met by spending Rs. 23.30 crores on its regeneration whereas the cost for the full restoration of mangroves in the state was estimated to be about Rs. 118 crores. The direct use value of mangroves for the present area under mangroves in the state was estimated to be Rs. 160.30 crores per year during the year 2003 while the indirect use value of the current status of mangroves was estimated to be Rs. 285.80 crores per year. It was also observed that the state could earn Rs. 773.13 crores per year as the total use value of mangroves by restoring the mangroves in the state. The overall value of benefits (use and non-us values) generated by mangroves in Gujarat was about Rs 2246.93 crores per year.

Boominathan *et al.,* 2008 have estimated the economic value of Aghanashini estuary based on bivalve production. The bivalve collection and marketing provides job opportunity for 2347 people in the estuarine villages. The total revenue generated from bivalve economy was 57.8 million per year. The income generated from estuarine fisheries of Aghanashini estuary were estimated by Mahima *et al.,* (2010).The fishing in open estuary generates 497990 man days of work and the per capita income was 56695 Rs annually. Prakash *et al.,* (2010) evaluates the tangible goods like fish, salt, shrimp culture, bivalve food, mangrove fodder, lime and sand mining from Aghanashini estuary. The integrated value of goods estimated for the estuary from 4801 ha was Rs.142.98 Crore/year. The tangible goods value Rs /ha/year was 2,97,813.

Annop and Sooryaprakash (2008) estimate the indirect benefits such as shrimp larvae protection and carbon sequestration of Ashtamudi estuary in Kerala. The value of shrimp larvae protection was estimated using replacement cost method. The cost of rearing larvae in hatcheries was used as the value of shrimp larvae protection that is about 475.8 Rs/ha. For estimating the carbon sequestration potential they have taken the price of carbon as $20 /t C. The total value of carbon sequestration in Ashtamudi estuary was 9110.20 Rs/ha. The option value of this estuary is assed using a double bounded dichotomous contingent valuation method, separately for fishermen, tourists and coir producers. The total option value is obtained as 38.84 lakhs with a net present value of 871 lakhs. The study undertaken in the same estuary in 2007 estimated the total direct use value as Rs. 77.30 million per annum among which fishery alone contributed Rs. 67 million, recreation benefit provided was 1.5 million Rs and the coconut husk retting service and inland navigation services accounted Rs.5.1 million and Rs.3.7 million per annum. The NPV of total direct benefit of Ashtamudi estuary amounted to 1927.50 million Rs Anoop and Sooryaprakash (2007).

Viswanathan *et al.,* (2010) evaluated the benefits provided by mangroves to the local community in Gujarat. There was a change of 20.58% improvement in the quantity of fish catch after restoring the mangrove forest and also they reported that there was a significant change in the salinity ingression to the farmlands closer to the coastal areas. The replanted mangrove reduced the purchased fodder consumption by 24 %. Karthi Stone *et al.,* (2008) evaluated the community participation in mangrove restoration project in Aghanashini mangrove forest, West coast of India through contingent valuation method. The mean WTP for restoring the mangrove ecosystem was obtained as 626 Rs/year, 342 Rs/year, 395 Rs/year for rice farmers, fishermen and fisher women respectively.

Gunawardena and Rowan (2004), estimated the total economic value of the mangrove ecosystem in Rekawa lagoon, Srilanka. They focused on the subsistence level evaluation of fishery and forestry benefits using actual data. The value generated per hectare per year was 18570 Rs/ha/year (lagoon fishery), 34,500 Rs/ha/year (coastal fishery) and 1500 Rs/ha/year respectively. The services such as buffer against storm and erosion control of mangroves was calculated using replacement cost approach and reached the value of 21000 Rs/ha/year. According to the same study the existence bequest and option value to local community was 181.2 Rs/ha/year .The valuation approach taken was open ended approach of contingent valuation that estimating the WTP (Willingness to Pay) in terms of voluntary contribution for a hypothetical mangrove protection fund.

The valuation study in Krabi river estuary in Southern Thailand aimed at maintaining the ecological linkages. Due to limited availability of data, benefit transfer method is applied for assessing the indirect and non-use benefits. The estimated annual use value of the site was $9.7 million for recreation and tourism. The economic value of mangrove forests was $758/ha. The net present value of mangrove forests was $73.1 million based on 7% discount rate and 15-year time line (Janekarnkij, 2010).

Sathirathai and Barbier (2001) estimated the Net Present Value of 400 ha mangrove area of Tha Po village by calculating the direct benefit through wood and non-timber forest products and indirect benefits like off-shore fishery linkages and coastline protection. Based on the estimated net income from village use of mangrove products the total annual value of the 400 ha of mangrove forest was $88 per ha. The support off-shore fishery by serving as a nursery ground for fishes was estimated using the “production function approach” that is the net welfare change occurring by change in the mangrove area. For all mangrove dependent fisheries the change in the mangrove area ranges from $21 -$69 per ha. The annualized value of coastline protection was estimated using replacement coast method and the value was $3697 /ha. The net present value for 20 year period with 15 % discount rate was obtained as US $ 632.27 /ha and including indirect use values it was US$ 27,264.13-21,610.22 /ha.

Economic analysis of twelve year mangrove plantation had carried out in the Gazy bay in Kenya. Major goods and services identified for valuation is wood products, onsite fishery, ecotourism, shoreline protection, carbon sequestration and science and education. The net value of extractable wood products from the plantation was estimated at US$ 379.17/ha/yr. For non-extractable products, the net value ranged from US$ 44.42/ha/yr in Carbon sequestration to US$ 770.23/ha/yr for research and education. The total economic value of 12 yrs old *Rhizophora* plantation is therefore US$2902.87/ha/yr (Kairo *et al.,* 2006).

Emerton and Kekulandala (2003) applied market price method for economic benefits associated with fishing, agriculture and plant based handicraft production activities in Muthurajawela marsh land in Sri Lanka. The total benefit from agricultural production was Rs.30.29 million per year. Fire wood collection and fishing activities contributes 7.96 million rupees/year and 6.26 million rupees /year respectively. The leisure and recreation value in Muthurajawela was estimated by assessing the visitor travel cost. The Muthurajawela wetland provides 5.28 million rupees annually. Cost estimates of constructing a proper drainage system in Mundu Ela wetland lies just south of Muthurajawela was taken as a proxy for flood attenuation function valuation. Thus the value given for flood attenuation property was 480 million rupees annually. Wetlands provides fresh water supply to local population. To estimate this function Emerton and Kekulandala adopted the avertive expenditure avoided method that assess the cost of constructing deeper wells in dry season and it estimated as Rs.3.78 million/year. The cost avoided for constructing improved latrines for household who currently discharges the sewage into the wetland were taken as value for domestic sewage treatment function. It works out at more than 4.32 million a year. The total cost of constructing a industrial waste water treatment plant (Rs.162 million) were taken for assigning the value for industrial waste water treatment function of Muthurajawela wetland .The wetlands provide a number of services that support the fishery such as the sediment trapping, wastewater purification and fresh water supplies and fish breeding and habitat. So with the absence of these functions there is decline of 10% in downstream fisheries. In the case of Muthurajawela it was Rs 20 million/year loss in case of downstream production. They have extrapolates the carbon fixation value of Puttalam lagoon for Muthurajawela and calculated the damage cost avoided by carbon sequestration using the conservative value of US $ 10/tC. It was 776,250 Rs /year.

Ronnback (1999) illuminating the hidden support of mangrove to capture fisheries. Fish species richness has been reported to be high as almost 200 species in mangrove dominated estuarine environments in Australia and India. The most widely accepted explanation related to this is food abundance, shelter from predation and the hydro dynamic ability of mangroves to retain immigrating larvae and juveniles. Spanninks and Beukering (1997) reviewed the scope and limitations of different valuation methods for assessing management alternatives for mangrove ecosystems. Many of the goods and services provided by the mangrove ecosystems were not traded on market and thus do not have an observable value and also some of these goods and services occur onsite and are therefore not readily acknowledged as being related to mangrove ecosystem.

Gammage (1998) found out the net present value of the mangrove forest in El Salvador for three different management strategies that is sustainable management strategy, partial mangrove conversion for shrimp culture and current management options and arrived at the NPV of 1598671, 1596671 and 12232816 for 56 years at7.08 discount rate. The value of the function ‘supporting off-site fisheries’ represent an indirect use value which derives from the value of off-site fisheries mangroves support. The very important mangrove forest services provide it as a site for scientific research and education. That represents the use value since it represents the actual use of resources that is the value of the application of the acquired knowledge and the value of increased understanding of mangrove ecosystem in itself. The second aspect is the non-use phase of scientific research (Gammage, 1998).

Benefit transfer method was used for assessing the ecotourism value of Pagbilao mangrove forest and it was US$ 9.30/ha/year. The value of research function has two components that is the value of providing a site for scientific research and the value of providing the result of the research. In Pagbilao mangrove forest the value of research component was estimated using contingent valuation method (Gammage, 1998).Ghasemi *et al.,* in 2010 had carried out an economic valuation study of Gaz and Hara delta located in South Iran. The mangrove resource utilization data were collected by direct interviews and secondary data collection and given the total economic value as 10000-20000 US$/ha/year.

Wilson *et al.,* 2005 developed a conceptual frame work for the assessment of ecosystem goods and services within the coastal zone that consider the ecological structures and processes ,land use decisions and the human welfare. The concept of ecosystem goods and services is useful for coastal zone science and management for three fundamental reasons i.e. it helps synthesis essential ecological and economic concepts allowing researcher and managers to link human and ecological systems in a viable and policy relevant manner. Secondly it draws upon the latest available economic methods for economic valuation and finally the scientists and policy makers can use the concept to evaluate social and political tradeoff between coastal land use development and conservation alternatives (Wilson *et al.,*, 2005)

Beaumont *et al.,* 2008 evaluate the goods and services from United Kingdom's marine biodiversity. According to this study marine biodiversity have significant influence on goods and services from marine zones. Phytoplankton diversity determines the carbon sequestration rate and a decrease have potential impact on climate change. The biogenic structures prevent and alleviate the flooding and storm events in coastal zones. Organisms in the marine environment contribute number of waste treatment processes (bioremediation of waste). Also the marine diversity has significant cognitive value in terms of education, training and university involvement in marine sciences. Many leisure and recreational activities are depending on marine diversity like bird watching, leisure fishing whale watching etc. The genetic materials from biodiversity have significant importance in future for food provision. Goods and services approach is a viable and comprehensive methodology to value biodiversity.

A survey conducted by Nair *et al.,* in 1984 revealed that the Kali river estuary had a vast clam bed which extends from the river mouth to a distance of 18 Km upstream to Mallapur. The clam resources comprise of species *Meretrix meretrix, Paphia malabarica* and *Villorita cyprinoides*. Locally the large clams *M. meretrix* and *P, malabarica* are called *Kube* and *Tisra* respectively. *V. cyprinoides* is also known as *Kube*. Two species of oysters *Crassostrea madrasensis* and *Saccostrea cucullata* have veen recorded from the river. The oysters are known locally as *Kalo*. Rough estimates of annual clam landings were 2000t. Major clam fishing centers are Kodibag, Nandangadda, Sunkeri, Kinnar Kadwad, Sadasivagad, and Kanesgiri. The clam fishery of the river is a very important one and a large number of fisher folk are engaged in the fishery. In Kali River, on an average about 500 individuals including men, women and children fish for clams in the river every day. The study by Rao *et al.,* in 1989 given that the production of clam in Kali estuary as 545t the *Meretrix meretrix* contributed 20 t and V*lorita cyprinoide* contributes 525 t. Karwar is the major clam centre in kali estuary, annual production of clams from Kali nadi river alone would be around 1000 m tons. There was 20 lime Kiln around Karwar (Alagarswami and Narasimham,1973).

Clams and oysters were present in Venkatapura estuary. *P. malabarica* was the main clam, found near the bar mouth forming about 96% of the clam population and *M. casta* and *M. meretrix* forming the rest. *Anadara granosa* was found in stray numbers. The rate of production of clams over the beds was 4 t/ha (Rao *et al.,* 1982).The estimated shell reserve of the estuary is 464400 tonnes and the annual production was estimated to 100 tonnes (Rao *et al.,* 1989).

The survey result of Central Marine fisheries Research Institute during the periods of 1979 to 1980 in Sharavathi estuary shown that Oyster resources are absent in the estuary due to the continuous fresh water discharge from the Sharavathi hydroelectric project and the consequent low salinities. There is considerable difference in the salinity between the high tide (17.57 *%)* and low tide (5.89 %), even during summer.*M. casta* and *M. meretrix* were found near river mouth and near the Mavinakurve. The *C. madrasensis* found only near the river mouth only. The clams were collected regularly by about 100 persons and *meretrix* was the predominant species (Rao *et al.,* 1989). But there was a good lime shell deposit showing the existence of good clam resources in the earlier times. Estimated lime shell reserve in the estuary was 116090 tonnes (Rao *et al.,* 1982,1989).

The clam bed is located in the Aghanashini estuary at Tadri and this bed comprises of *Meretrix meretrix* and *Mretrix casta.* The adjacent bed is about 5 kms from the barmouth and extends from opp. Betkuli to near Mirjan and covers an area of 225 ha. *Meretrix casta* and *Villorita cyprinoides* occur in this bed. A third bed is located in the centre of the estuary in Mirjan-Hegde area and it contains only *V. cyprinoides. Meretrix casta* and *Villorita cyprinoides* occur in this bed. The total annual production is 755 t and *M.casta* constitutes more than 60%. The production of *V. cyprinoides* is only 5 t. The estimated annual effort in man days is 23000 and fishing is by handpicking. Shell deposits are exploited about 7600 tons annually from the Tadri area and utilized for industrial purposes (Rao *et al.,* 1989). Mining of mollusc shells is a flourishing business in Tadadi village, where shells worth about Rs.40-50 million are gathered and transported to far away cities for making poultry feed and for many other industrial uses (Mahima *et al.,* 2010). In Gangavali estuary *Paphia malabarica* was dominant and the fishing is peak during March-June (Rao *et al.,* 1989).

Oysters were present in Kali nadi estuary but they were absent in the intertidal regions of the coast of Karwar. The species present in the estuary are *Saccostrea cucullata* and *Crassostrea* *madrasensis*. The total estimated quantity of oyster per bed was 1355 Kg (Ramachandran, 1987). Mining of sub-fossil deposits oyster by lessees carried out in many estuaries like Kali River, Athankarai and Bahuda river yield nearly 15,000 t of oyster shells annually (Nair and Mahadevan, 1987).

Of all the maritime States, clam production of Karnataka State was intensively studied. In the Kalinadi Estuary, earlier, Alagarswami and Narasimham (1973) estimated the annual production at 1 000 t, Nayar *et al.,* (1984) at 2 000 t, Neelakantan *et al.,* (1985) at 69 to 662 t and Rao *et al.,* (1989) at 545 t. For the Mulky Estuary, Rao (1984) estimated the annual clam landings to vary between 271 to 951 t, Rao and Rao (1985) at 500 t and Rao *et al.,* (1989) at 2,392 t (Table I) indicating considerable fluctuations in the catches.

In the region between Basaldurga and Kumta mussel settlement was observed in 2280 m^2 area with 2.1 tonnes of mussel. The adjacent zone had extensive areas, 21,526 m^2 with mussel seed settlement. About 26 tonnes of mussel seed spread along 7 sites was present in this region. The major mussel bed extending to 8000 m^2 was located along the coast of Belekeri that is characterized by extensive rocky coves and submerged rock formation had 10 tonnes of mussels. In another zone the extent of mussel bed was 13,319 m2 contributing to 26.5% of the States' mussel bed. The mussel biomass was estimated at 19 tonnes in the region between Harwada and Kumta (Appukkuttan *et al.,* 2001).

In Karnataka state, mussels are found in Hanavar-Mallukarve, Shedeguli,Gudiangadi, Holangadde, Gangavali, Belambare, Chendia, Binage, Kamath's Beach, Nichanhippal- Majali and around Kurmgad Islands in Karwar Bay. The total quantity of mussel from Karwar was 1.2 tons (Jones and Alagarswami, 1973).

Pai *et al.,* (1982) studied the economics of traditional prawn filtration farm in Haldipur. The species comprised of *Penaeus indicus*, *P.monodon*, *Metapenaeus monoceros* and *M.dobsoni*. The total annual production (February, March, April and May) of the farm was 375 Kg. The net profit from the prawn filtration was 7770 Rs. The returns from Keppekurve (Kumta) and Asnoti farm (Karwar) were 69006 Rs and 229925 Rs respectively.

Closer to the river mouth, in the village of Aghanashini are a couple of large mudflats, spread over about 180 ha, which have an incredible productivity of edible bivalve mollusks, the annual production of which was estimated at Rs. 57 million (Mahima *et al.,* 2010; Boominathan *et al.,* 2008).

A total of 78 fish types have been recorded in Aghanashini estuary. Estuaries are known as nurseries for several marine fishes which visit them for laying eggs and deriving shelter and food for their juveniles. Predominantly marine fishes like *Stolephorus indicus*, *Scomberomorus sps, Rastrelliger kanaguta* move into the estuary during summer*, and Pomfretess*, *Scoliodon sp during* winter (Mahima *et al.,* 2010).

Occurrence 48 fish species belonging to 25 families were observed in the Kali estuary. The fish species common to all the landing centres are *Mugil cephalus*, *Liza parcia, L.macrolepis*, *Etroplus suratensis*, *Scatophagus argus*, *Ambassis commersonii*, *Therapon jarbua*, *Gerres lucidus*, *G.filamentosus*, *Gobius ornatus*, *Sillagosihama*, and *Drepane punctata* (Kusuma *et al.,* 1985).

Among the shell fish resources of Kali estuary, clams form the most prominent group supporting the organized fishery throughout the year. The landings of mollusks from Karwar waters for the year 1972-1979 were given by the Neelakantan *et al.,* (1985).It was 86 t in 1972,116 t in 1973, 121 t in 1974, 138 t in 1975,130 t in 1976,421.5 t in 1977, 363 t in 1978 and 726 t in 1979. The edible mussels in Indian coast are *Perna viridis* and *P. indicus.*

4. STUDY AREA

The Uttara Kannada district lies in the mid-western part of Karnataka state between $74^0$9' to $75^0$10' E and $13^0$55' to $15^0$31' N extending over an area of 10,291 sq.km. It extends from north south to a maximum of 180 km, and from west to east a maximum width of 110 km. It is surrounded by Belgaum district and Goa territory in the north, Dharwad in the east, Shimoga and parts of Daskshina Kannada in the south and the Arabian Sea to the west. Uttara Kannada district is one of the northernmost districts in Karnataka State. The topography of the region can be divided into three distinct zones. The coastal zone, comprising of a narrow strip of the coastline, is relatively flat and starts sloping gently upwards towards the east. The ridge zone abruptly rises from the coastal strip, is much more rugged and is a part of the main range of the Western Ghats. Compared to other parts of the Western Ghats, the altitude of the ridge is much lesser and rises to about 600 msl. The third zone is the flatter, geographically more homogenous zone that joins the Deccan plateau. The district comprises of 11 Taluks namely, Supa, Haliyal, Mundgod, Yellapur, Karwar, Ankola, Sirsi, Siddapur, Honnavar, Kumta and Bhatkal. Supa is the largest taluk in Uttara Kannada in terms of area. The district has 11 taluks spread over the three regions described above- the coast lands comprise of Karwar, Ankola, Kumta, Honnavar and Bhatkal taluks, the forested interior areas which are part of the Western Ghats range comprises of Supa, Sirsi and Siddapur taluks and the eastern areas which are plateau regions comprises if Haliyal, Yellapur and Mundgod taluks.

This district also has a number of seasonal small and medium sized rivers, most of which are westward flowing. The rivers namely Kalinadi, Gangavali (Bedthi), Aghanashini, Sharavathi, and Venkatapura arise in the Western Ghats and flow westwards through the district to finally join the Arabian Sea. The length of Uttara Kannada coastline is about 144 kms. The coastal Uttara Kannada consists of five taluks namely Karwar, Ankola, Kumta, Honnavar and Bhatkal from north to south and has a total area of 3300 sq.km. This study describes the ecological goods and services obtained from the five different estuaries in Uttara Kannada namely – Kali, Aghanashini, Gangavali, Sharavathi and Venkatpura estuaries.

Kali estuary - Kali estuary situated at 14.816^0 to 14.917^0 N and 74.125^0 to 74.267^0 E in the Karwar taluk of Uttara Kannada district of central west coast in the Karnataka State (figure 3). Kali river originate near the Diggi village in the Supa taluk with a total length of 184 Km meets the Arabian sea, 3 Km north of Karwar and forming an estuarine expanse of 3240 ha in area. The Kali estuary is surrounded by a variety of ecosystems such as mangrove swamps, mudflats, creeks and backwaters. The estuary is surrounded by 23 villages and one municipality.

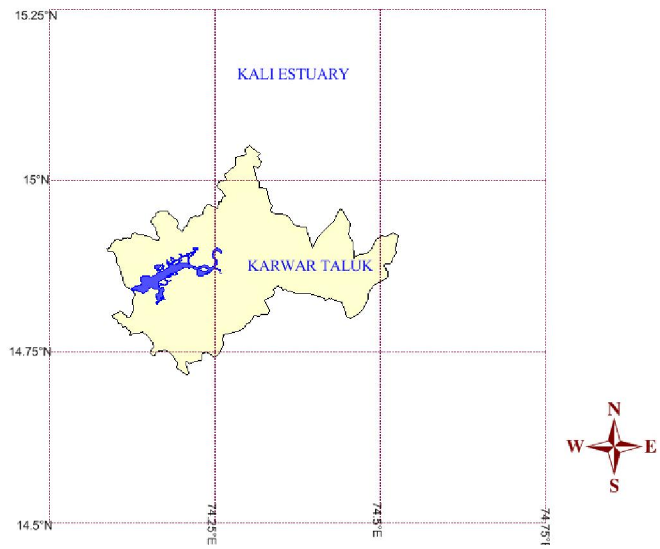

Figure 3: Kali estuary in Karwar taluk, Uttara Kannada district

Gangavali Estuary - Gangavali or Bedthi River is formed by the confluence of two streams at Khalghati in Dharward district and flows 25 Km westwards and reaches the Uttara Kannada district (figure 4). After a fairly straight south western flow it joins Arabian Sea at Manjuguni village of Ankola taluk and forming an estuarine habitat of about 700 ha area (at 14.586^0 to 14.618^0 N and 74.278^0 to 74.385^0 E). The estuarine habitat support 43.20 ha mangrove vegetation and it is surrounded by 15 villages.

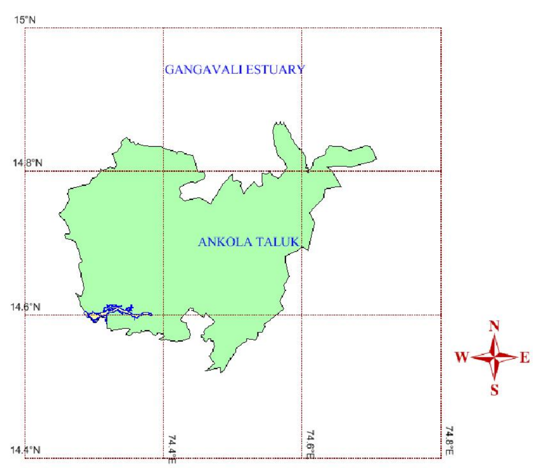

Figure 4: Gangavali estuary in Ankola taluk, Uttara Kannada district

Aghanashini Estuary - Aghanashini River has its source in the forest clad village Manjguni situated at an altitude of about 600 m in the central Western Ghats. Running its course of about 121 km, winding through gorges flanked with evergreen forests and valleys lush with spice gardens and rice fields, the river widens into an estuary covering about 4801 ha before its confluence with the Arabian Sea in the west coast between the villages Aghanashini in the south and Tadadi in the north, lies between 14.391° to 14.585° N and 74.304° to 74.516° E of Kumta taluk in the Uttara Kannada district of central west coast in the Karnataka State of India (Figure 5). All along its estuarine banks and few of the tiny islands are villages whose inhabitants mainly are traditionally dependent on agriculture and fisheries. There are about 21 villages of Kumta taluk situated on the estuarine banks.

Sharavathi estuary - Sharavathi estuary is located between 14.241^{O} to 14.385^{O} N, 74.418^{O} to 74.507 ^{O} E of Honavar taluk of Uttara Kannada district having an area of 1600 ha (Figure 6). The river has its origin at Tirthahalli taluk of Shimoga district and it joins the Arabian Sea at Honavar. The estuary is brackish in dry weather but during the rains it sweet even close to the mouth. About 8 Km from the mouth, the river widens to lagoon, about 3 Km broad containing a few islands. Towards the estuaries, swamps induce saline sand cultivation. In spite of the silted-up harbour and treacherous sand bar at the mouth, there is a good deal of sailing traffic.

Venkatapura estuary - The Venkatapura river (total length 20 Km) rising in the Sahyadri , near the village of Kranti north east of Bhatkal Taluk falls into the Arabian Sea near Venkatapur and forming a small estuarine expanse located between 14.008^{O} to 14.085^{O} N and 74.502^{O} to 74.569 ^{O} E (Figure 7).

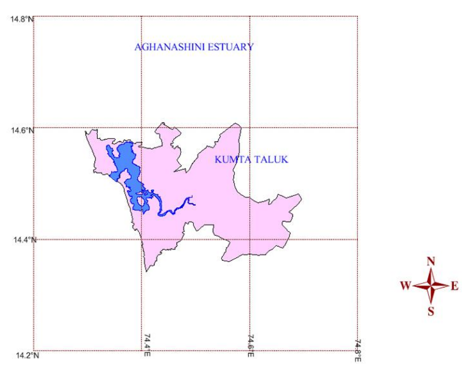

Figure 5: Aghanashini estuary in Kumta taluk, Uttara Kannada district

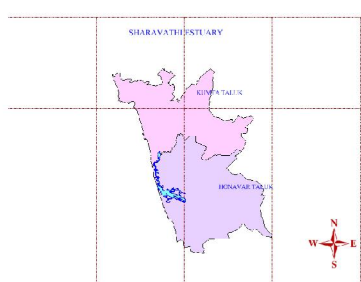

Figure 6: Sharavathi estuary in Honnavar taluk, Uttara Kannada district

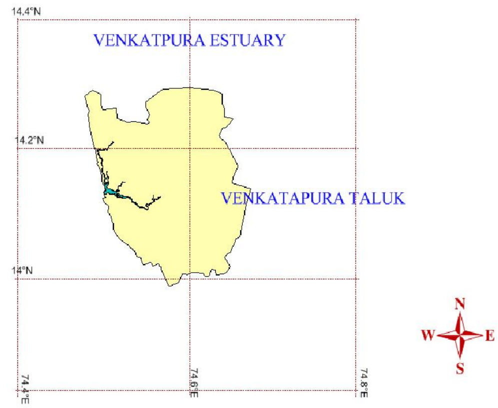

Figure 7: Venkatpura estuary in Venkatpura taluk, Uttara Kannada district

5. MATERIALS AND METHODS

The secondary data was obtained from various sources for assessing the resource availability and consumption scenarios in the five estuaries. Discussions with local persons were carried out regarding the fish resources, sand mining and salt production in the estuaries. The secondary data regarding the ecological functions of the estuaries was collected from Central Marine Fisheries Research Institute (CMFRI) centres of Cochin and Karwar; Department of Marine Biology, Karnatak University, Karwar; Cochin University of Science and Technology. The socio-economic data related to the coastal taluks including the villages around the estuaries were obtained from 2001 Census Report, Govt. of India; District Administrative Reports, Govt. of Karnataka. The data regarding the production of Gazani paddy and Coconut in the estuarine region was obtained from Karnataka State Horticulture Department.

Both the direct and indirect values obtained from the estuaries were calculated. The Market Valuation Technique was employed for valuing the goods and services having direct market prices such as fishing, Gazani paddy cultivation, timber and fodder obtained from the mangrove vegetation, aquaculture, sand and lime shell mining, navigation, ferry services and port activities. The market price values were assigned to these goods based on the interaction with the locals residing in that region. The gross revenues obtained from these resources were obtained in the following manner:

Net benefit from the fisheries = Total fish production in the estuary (tons) x Price per ton

$$\text{Net income from mining/agriculture products} = \Sigma\ (P\ Q)$$

Where, P = price of the product; Q = quantity of the product

Besides providing the direct use value goods, the estuaries also provide various other important benefits such as climate regulation, shoreline stabilization, natural hazard mitigation, habitat and refugia for various organisms, nutrient circulation, recreation and aesthetic benefits, etc. Generally a CVM (Contingent Valuation Method) is adapted to survey indirect values obtained from an ecosystem which is based on the people's Willingness to Pay (WTP) for it. For the current valuation study, the values for the indirect ecosystem services were adapted from Costanza *et al.,* (1997), De Groot *et al.,* (2002) and other internationally accepted references. The values were given in US dollars which were converted into Indian Rupees (INR) given in Table.5.

Table 5: Economic values assigned to different indirect ecosystem services

FUNCTION	COUNTRY/ REGION	TECHNIQUE USED	UNIT (RS/HA)	REFERENCE
Regulating services				
Coastal erosion control	Gujarat	Damage cost avoided	137606	Hirway *et al.,*,2004
Flood control	Srilanka	Replacement cost	158249.67	Emerton and Kekulandala (2003
Storm protection	Srilanka	Replacement cost	45000	Kathiresan,2005
Nutrient retention	Orissa	Replacement cost	11034.5	Badola *et al.,*,2003
Disturbance regulation	Global estuaries	Benefit trabsfer	25515	Costanza *et al.,*,1997
Waste treatment	Global mangroves	Benefit transfer	301320	Kathiresan,2005
Nutrient cycling	Global estuary	Benefit transfer	949500	Costanza etal,1997
Carbon sequestration	Ashtamudi estuary, Kerala	Damage cost avoided	9110.2	Anoop *et al.,*, 2008
Gas regulation	Global estuary	Benefit transfer	9600	Costanza etal,1997
Climate regulation	Global estuary	Benefit transfer	4800	Costanza etal,1997
Oxygen provision	Global estuary	Benefit transfer	5280	Costanza etal,1997
water regulation	Global estuary	Benefit transfer	209088	Costanza etal,1997
water supply	Global estuary	Benefit transfer	145920	Costanza etal,1997
Ground water recharging	Global estuary	Benefit transfer	192000	Costanza etal,1997
Natural hazard mitigation	Global estuary	Benefit transfer	9600	Costanza etal,1997
Supporting functions				
Habitat/refugia	Global estuary	Benefit transfer	5895	Costanza *et al.,*,1997
Breeding ground and Nursery	Thailand	Benefit transfer	5271.3	Janekarnkij,2010

Biodiversity	Global estuary	Benefit transfer	216000	Costanza *et al.*,,1997
Information Functions				
Recreation	Global estuary	Benefit transfer	17145	Costanza *et al.*,,1997
Cultural and artistic information	Global estuary	Benefit transfer	1305	Costanza *et al.*,,1997
Aesthetic information	Global estuary	Benefit transfer	100	Costanza *et al.*,,1997
Science and Education	Kenya	Research funds	34660.35	Kairo *et al.*,,2006

The direct, indirect and recreational benefits obtained from the estuaries were summed up together to obtain the Total Economic Values (TEV) of the ecosystem. This value is divided by the total geographical area of the estuary to arrive at the per hectare value of the estuary as a natural resource. These economic values can be considered as underestimates as the natural ecosystems are much more worth in terms of the benefits they provide. The valuation of natural resources is useful for policy formulations and decision making.

Total Economic Value = Direct use value +Indirect use Value

6. RESULT AND DISCUSSION

The present study focused on accounting the economic value of five estuaries namely, Kali, Gangavali, Aghanashini, Sharavathi and Venkatpura located in the Uttara Kannada district of Karnataka State. These are providing variety of living and non-living resources to local communities which offer employment, income, amenities and pleasure to local people. Apart from the direct benefits these ecosystem provides many indirect benefits to surrounding communities. But the policy and management circle has not considered the significance of this precious ecosystem. This study is an attempt to highlight the economic importance of the estuarine ecosystem in Uttara Kannada.

6.1 Demarcation of Study Area and Characterization of ecosystem goods and services from the estuarine ecosystem

We selected the five estuaries of Uttara Kannada for the study purpose. Kali estuary spreads across 3240 ha and 100 ha of mangrove patches. The Kali estuarine villages have a population of 41897. Gangavali has 700 ha total area and 43.2 ha of mangrove forest. The total population in this region is 15569 as per 2001 census. Aghanashini is the biggest estuary in Uttara Kannada having 4801 ha of total expanse and it includes the 101.6 ha of mangrove area. Aghanashini supports 64709 peoples. Total area of Sharavathi estuary is 1600 ha with a total population of 47352 and it possess less area of mangrove (5 ha).The smallest and southern most estuary Venkatpura is only 250 ha and there is 8.64 ha of mangrove cover. The population in the Venkatpura estuarine villages is 57685.

Major goods and services from the estuaries were compiled through literature survey and discussion with local persons. These goods and services are then classified as per Millennium Ecosystem Assessment (2003) categorization as Provisioning Services, Regulating Services, Supporting Services and Information Services.

6.2 PROVISIONING SERVICES FROM UTTARA KANNADA ESTUARIES

Provisioning services are estuarine fishery including the fish, finfish, shellfish and aquaculture, mining products, mangrove resources, salt production, agriculture including the saline paddy and coconut and water transport activities like ferry services, navigation and the port activities. In order to calculate the total value, the market price approach was used.

- ***ESTUARINE FISHERY:*** The fishery sector contributes the major livelihood options of the estuarine dependent communities in the coastal villages. It includes the common estuarine fishes, clam, oyster, mussels, bivalves, prawns and aquaculture. The market price of fish and quantity obtained from each category of fish resources are given in the table 6.1.

The net income generated from utilization of estuarine fish resources from Kali estuary is 23.05 Crores per year. It is the 5.19% of total Uttara Kannada estuarine fishery resources. The total value includes the contribution of fishes, bivalves, clam, oyster, crab, prawns and aquaculture; from which aquaculture contributes the major portion of income about 17.82 crores and it is the 77.32% of the total revenue obtained. Following the aquaculture estuarine capture fisheries and crab collection contribute 7 % and 5.64% with an income of 16.23 million and 13 million Rs annually. The contribution from prawn fishery is only 2.38 % (5.47 million) and the remaining part filled by the shell fish captures. Out of the shell fish revenue, clam fishery gives the highest value of 8.17 million Rs. (3.55 % of total fishery value).

From the Gangavali estuary the total income for the entire year is 4.2 crores. Here also the aquaculture sector contributes the major percentage (63.07%) of total revenue with annual earning of 2.67 crores. Crab and prawn fishery sector contributes 4.60% and 1.94 % respectively. There is a significant income from bivalve production in Gangavali estuary. The bivalve contributes 20.18% of total production Followed by estuarine fishes and clam production. Mussels are absent in the Gangavali estuary. The estuary contributes only 0.95 % fishery value of Uttara Kannada district.
Aghanashini estuary provides the 92.93% of the income from estuarine fisheries in Uttara Kannada. The annual revenue is 4.12 billion Rs. The 94.64 percentage (3.9 billion) comes

from aquaculture activities in the estuarine belt. Aghanashini estuary fishes contribute 12.07 crores with 2.93%. Aghanashini estuarine villages have been benefited by the bivalve collection with a total annual income of 5.7 crores. The total revenue from shell fish collection in this estuary is 7.35 crores comprising of bivalves, clams, oyster, mussels and other molluscans.

Compared to the above mentioned estuaries Sharavathi contributes only 0.73 % (3.24 crores) of total fish production from the estuaries in Uttara Kannada. The table reveals that only estuarine fishes and crab collection contributes the major part of the economy of Sharavathi estuary. Bivalves, mussels and oysters are absent here due to the continuous freshwater discharge from hydro electric station. The aquaculture production is also very less in this region, about 0.52 % (1.6 lakh) only contributes by this sector. The total revenue from crab, prawns and fishes are 6.5 million, 1.53 million and 2.29 crores respectively. Sharavathi estuary support small percentage of clams, i.e. 1.5 million Rs annually.

Venkatpura is the smallest and southern most estuary of Uttara Kannada. It supports 0.20% of the total fishery value of estuarine fishery sector of the district. The total income from fishery sector of the estuary is 8.71 crores annually. Out of these 61% is coming from aquaculture activities. The net income from fishes in estuary is 7.3 lakhs and it is the 8.3% of the total fishery value of the estuary. Venkatpura supports bivalve harvesting in a significant level that gives net income of 1.71 crores and it is the 19.62% of total fishery of Venkatpura. Mussels are absent in the estuary but the presence of clam, oyster and other mollusks make the estuary rich.

Table 6.1: Estuarine fisheries value

Estuary	Item	Total fish catch ton	Price per unit Rs /ton	Income generated Rs /year
Kali	Fishes	1624	150000	16235712
	Bivalves	285	200000	5701871
	Clam	55	15000	8175000
	Oyster	0.459	200000	91750
	Mussels	20	120000	2400000
	Other molluscs	9.963	120000	1195500
	Crab	40	325000	13000000
	Prawns	27	250000	5475000
	Aquaculture	396	450000	178,200,000
Total				**230,474,833**

Gangavali	Fishes	244	150000	2435357
	Bivalves	428	200000	8552807
	Clam	11	15000	1698750
	Oyster	0.069	200000	13763
	Mussels	0	120000	0
	Other molluscs	14.94	120000	179325
	Crab	6	325000	1950000
	Prawns	4	250000	821250
	Aquaculture	59	450000	26730000
Total				**42,381,251**
Aghanashini	Fishes	12076	150000	120762000
	Bivalves	2851	200000	57018710
	Clam	76	15000	11325000
	Oyster	0.642	200000	128450
	Mussels	28	120000	3360000
	Other molluscs	14	120000	1673700
	Crab	56	325000	18200000
	Prawns	38	250000	7665000
	Aquaculture	8680	450000	3906000000
Total				**4,126,132,860**
Sharavathi	Fishes	2273	150000	22729997
	Bivalves	0	200000	0
	Clam	10	15000	1500000
	Oyster	0	200000	0
	Mussels	0	120000	0
	Other molluscs	0	120000	0
	Crab	20	325000	6500000
	Prawns	8	250000	1533000
	Aquaculture	0.375	450000	168750
Total				**32,431,747**
Venkatapura	Fishes	73	150000	730607
	Bivalves	86	200000	1710561

	Clam	2	15000	339750
	Oyster	0.014	200000	2753
	Mussels	0	120000	0
	Other molluscs	0.299	120000	35865
	Crab	1.2	325000	390000
	Prawns	0.826	250000	164250
	Aquaculture	118.8	450000	5346000
Total				**8,719,785**

- ***AGRICULTURE PRODUCTS:*** The estuarine belt of Uttara Kannada support saline tolerant paddy (Gazani) and coconut cultivation. Total quantity of production and market price of coconut and paddy is given in the table 6.2. The Kali estuarine belt gives an annual income of 3.9 crores from paddy and coconut plantations .It is the 23.53% of the total production from Uttara Kannada estuarine villages. The returns from gazani paddy are highest in the Aghanashini estuarine region with a value of 4.39 crores. The total agricultural production from the estuary is 4.95 crores; it contributes the 29.64% of district total. The table shows that the highest percentage of agriculture production to the total estuarine ecosystem of the district is from Sharavathi (37.43%) and the net return is 6.2 crores. Gangavali and Venkatpura contribute 7.8% (1.3 crores) and 1.5% (2.6 million) respectively to the Uttara Kannada estuarine belt.

Table 6.2: Goods from Estuarine Agriculture

Estuary	Item	Total production ton	Price Rs/ton	Income generated Rs/year
Kali	Gazani paddy	2036	18000	36648000
	Coconut	30	90000	2717025
Total				**39365025**
Gangavali	Gazani paddy	713	18000	12826800
	Coconut	3	90000	258409
Total				**13085209**
Aghanashini	Gazani paddy	2443	18000	43977600
	Coconut	62	90000	5614776
Total				**49592376**
Sharavathi	Gazani paddy	0	18000	0
	Coconut	696	90000	62621327

Total				62621327
Venkatapura	Gazani paddy	143	18000	2565360
	Coconut	0.574	90000	51682
Total				**2617042**

- ***MINING PRODUCTS*****:** Mining and dredging activities are happening in the estuary of Uttara Kannada in significant level. Amount dredged and the price of unit quantity is given in the table 6.3.and these are the livelihood options for many poor people in this region. This shows it occurs in higher degree in Aghanashini. The net returns from the region are 120.88 crores annually; out of these 99.26% comes from lime shell collection only. Kali estuary contributes 22.87% (48.36 crores) of net income generated from total estuarine area of the district. Here also the lime shell mining provides the higher contribution of about 36.7 crores. Sand mining is highest in Kali estuary with an income of 11.28 crores/year. Gangavali estuary provides revenue of 6.2 crores and here silt dredging is absent. Sharavathi and Venkatpura region also free from silt mining. The annual return from those two estuaries are 35.7 crores and 1.5 million Rs respectively. In Sharavathi 97.29% of the income is from lime shell mining, though the region having huge lime shell deposit. Only sand mining is occurs in the Venkatpura estuary.

Table 6.3: Estimation of Revenue from Mining activities

Estuary	Item	Quantity extracted	Rate Rs/unit	Income generated Rs/year
Kali	Sand (Cu.m)	282120	400	112848000
	Lime shell (ton)	24500	15000	367500000
	Silt(Cu.m)	16425	200	3285000
Total				**483633000**
Gangavali	Sand (Cu.m)	19038	400	7615385
	Lime shell (ton)	3675	15000	55125000
	Silt(Cu.m)	0	200	0
Total				**62740385**
Aghanashini	Sand (Cu.m)	17308	400	6923077
	Lime shell (ton)	80000	15000	1200000000
	Silt(Cu.m)	9855	200	1971000
Total				**1208894077**
Sharavathi	Sand (Cu.m)	24231	400	9692308

	Lime shell (ton)	23218	15000	348270000
	Silt(Cu.m)	0	200	0
Total				**357962308**
Venkatapur	Sand (Cu.m)	3808	400	1523077
	Lime shell (ton)	0	15000	0
	Silt(Cu.m)	0	200	0
Total				**1523077**

- ***MANGROVE PRODUCTS*:** Mangrove forest is being used by the local inhabitants as fodder for live stocks and timber for fire wood needs and construction activities. Table 6.4 lists the mangrove resources with market price and quantity. The revenue obtained from mangrove product extraction is highest in the Kali ecosystem and the net return 5.7 million annually. The Aghanashini contributes 31% of total mangrove product harvest of Uttara Kannada; the income is 5.4 million Rs/ year. In Gangavali region the utilization of mangrove product harvest is only limited to timber. The value generated is 5442 Rs/year. From the Sharavathi and Venkatapure the value generated from mangrove product is 5.2 million and 1 million respectively.

Table 6.4: Estimation of Net income from Mangrove product harvesting

Estuary	Item	Quantity produced Ton	Price Rs/ton	Net income Rs/Yr
Kali	Fodder	7920	600	4752000
	Timber	148	150	22255
	Charcoal	45	150	6677
	Thatch	223	2000	445104
	Fish poison	5	1000	5000
	Medicine	26	18000	475200
Total				**5706235**
Gangavali	Fodder	0	600	0
	Timber	36	150	5422
	Charcoal	0	150	0
	Thatch	0	2000	0
	Fish poison	0	1000	0
	Medicine	0	18000	0
Total				**5422**

Aghanashini	Fodder	7200	600	4320000
	Timber	215	150	32199
	Charcoal	64	150	9660
	Thatch	322	2000	643973
	Fish poison	6	1000	6000
	Medicine	24	18000	432000
Total				**5443831**
Sharavathi	Fodder	8640	600	5184000
	Timber	23	150	3422
	Charcoal	0	150	0
	Thatch	34	2000	68445
	Fish poison	0	1000	0
	Medicine	0	18000	0
Total				**5255868**
Venkatapura	Fodder	1728	600	1036800
	Timber	1	150	124
	Charcoal		150	
	Thatch		2000	
	Fish poison		1000	
	Medicine		18000	
Total				**1036924**

- ***SALT FROM ESTUARIES***: Table 6.5 shows that salt production in the Kali, Ganagavali and Aghanashini estuaries of Uttara Kannada. Net returns from the estuaries are 2 million, 3.5 million, 5 million respectively. According to Mahima *et al.*,, (2010),salt making is a traditional enterprise associated with some of the villages close to Gokarna, Aghanashini where salt pans annually produce Rs.30-40 million worth of salt.

Table 6.5: Salt production in the estuarine catchment

Estuary	Quantity produced (ton)	Rate Rs/ton	Value generated Rs/year
Kali	4000	5000	20000000
Gangavali	7000	5000	35000000

Aghanashini	10000	5000	50000000
Sharavathi	0	5000	0
Venkatapura	0	5000	0

- **TRANSPORT:** Table 6.6 gives the revenue generated from ferry services, navigation and port activities in the estuarine waters. The net income from water transport activities is highest in Aghanashini (52%) followed by Sharavathi (29%).There is no port activities observed in the estuarine coast of Kali and Venkatpura. The value from ferry services in Venkatpura is 30000 Rs/year. Rs.9.38 lakh is obtained from Sharavathi and 1.4 lakh, 4.6 lakh and 1.6 million from Kali, Gangavali and Aghanashini respectively.

Table 6.6: Revenue from Water transport and Port activities

Estuary	Activity	Value generated Rs/year
Kali	Ferry services	100000
	Navigation	40000
	Port activities	**0**
Total		140000
Gangavali	Ferry services	100000
	Navigation	40000
	Port activities	329300
Total		**469300**
Aghanashini	Ferry services	200000
	Navigation	80000
	Port activities	1418000
Total		**1,698,000**
Sharavathi	Ferry services	200000
	Navigation	80000
	Port activities	658600
Total		**938,600**
Venkatapura	Ferry services	30000
	Navigation	0

	Port activities	0
Total		**30000**

6.3 TOTAL PROVISIONING SERVICES

Provisioning services quantification through the compilation of all direct benefits for each estuary is given in table 7. The provisioning services value of entire estuarine waters of Uttara Kannada is 6.85 billion Rs /year. Aghanashini make up the 79.5% (5.45 billion annually), followed by Kali 11.36 % (77.88 crores/year), Sharavathi 6.7% (45.91 Crores/year), Gangavali 2.24% (15.36 crores) and Venkatpura 0.2% (1.39 crores) respectively. The total value per hectare of estuary are 240395 Rs (Kali), 219,545 Rs (Gangavali), 1135,847 Rs. (Aghanashini), 286,964 Rs (Sharavathi) and 55,707 (Venkatapura) respectively.

6.4 INDIRECT USES

The indirect uses of estuarine ecosystem consist of the Regulating services, Supporting services and Information services. Table 5 lists 23 indirect benefits provided by estuarine ecosystem. All these services are valued by taking the unit value of these benefits (Rs/ha/year) from other studies and adjusted according to the spatial and environmental conditions of our study region.

6.5 REGULATING SERVICES FROM ESTUARIES OF UTTARA KANNADA

The regulating services of estuary ecosystem are coastal erosion control, Flood control, storm protection, carbon sequestration, disturbance regulation, gas regulation, climate regulation, water supply, waste treatment, nutrient retention and cycling, natural hazard mitigation, ground water recharging and oxygen provision. Table 8 gives the details of regulating services in the Uttara Kannada estuaries. The regulating services are calculated from the area of the estuary and unit value (Rs/ha/year) taken from literatures. The regulating services value from total estuarine area in Uttara Kannada is 19.39 billion Rs/ Year. 45% of it is contributed by Aghanashini estuary and 30% by Kali estuary with a benefit of 8.8 billion and 5.9 billion respectively. This is mainly due to the higher mangrove cover and total area of these two estuaries. A value of 1.4 billion, 2.9 billion and 25.7 million Rs/ year is given by Gangavali, Sharavathi and Venkatpura respectively. The per hectare regulating service value of Kali estuary is Rs.1,839,037 and Aghanashini is Rs.2,055,250, Gangavali is Rs. 1,835,288 and for Sharavathi it is 1,828,300 Rs and Venkatapura has 1,028,162 Rs.

6.6 SUPPORTING SERVICES FROM ESTUARIES OF UTTARA KANNADA

The supporting services selected for economic valuation are Habitat/refugium function, Nursery and breeding ground, biodiversity. The estuarine ecosystem support and provide habitat for diverse flora and fauna. And it served as a pool of biodiversity. The estuary and associated mangrove ecosystem and salt pans provide the platform and conditions for breeding and spawning of many marine and fresh water fishes. This quantification is based on Costanza *et al.,* (1997) and Janekarnkij (2010) for estimating the Habitat, biodiversity and Nursery and breeding ground function of the estuary (table4).

Table 9 reveals that the supporting service value of entire Uttara Kannada estuarine region is 11.26 billion Rs/ year. Aghanashini region makes the 82.935% of the total value and the value is 9.34 billion/year. The value per hectare from Aghanashini is 1,946,030 Rs. Kali provides 1.19 billion Rs/ year and it contributes 10.6% of the district total. The total value from per hectare of Kali estuary is Rs.369, 435 .The total value per year is arrived at Rs.23.4 million from Gangavali (348,256 Rs/ha/year), 42.8 million Rs. from Sharavathi (Rs.267, 706/ha/year) and 5.2 million Rs. (211,976 Rs/ha/year) from Venkatpura .

6.7 INFORMATION SERVICESFROM ESTUARIES OF UTTARA KANNADA

The information services from selected estuaries are recreation, cultural and artistic information and Science and Education. Estuaries of Uttara Kannada provide location for recreation and platform for scientific researches and education. For estimating the information services unit value (Rs/ha/year) is taken from literatures and are given in table 10.

The total value (Rs/year) from information service in Kali estuary is Rs. 397,000,602 and the per hectare value of this services per annum in Kali is Rs.1,12,253. It is the 41% of information services from total of the entire estuary. Many research and educational activities are being conducted by local universities and CMFRI regional centers. Aghanashini contributes the highest percentage of information services (43%). These salt pans in this region are the visiting place of migratory birds during seasons (Daniel, 1989). It adds to the aesthetic and recreational potential of Aghanashini. The total value of Aghanashini is 421,867,231Rs/Year with a per hectare value of 87,871,Rs.The per hectare value of Gangavali is 53,210 Rs and Sharavathi has 70,541 Rs/ha. Total value of information services from Venkatpura is 37247 Rs/ha/year.

6.8 TOTAL ECONOMIC VALUE

Total economic value is the sum of all the four services given in Table11 for all five estuaries of Uttara Kannada.

In the case of Kali, the total economic value for the entire year is 8.33 billion Rs. And it gives the productivity of the Kali estuary as 2,571,398 Rs/ha/year. 72% of the total economic value is contributed by regulating services and only 9% is the contribution of provisioning services.15% share is given by supporting services and rest are information services. Kali shares the 21% of the total value from estuarine area of Uttara Kannada.

The total economic value of Gangavali is 1.87 billion Rs/year with a productivity of 2,67,6261 Rs/ha/Year. Provisioning services contributes 8% of the total value. Here also regulating service is the major contributor. Information services are only 2% and 13% is from supporting services. Gangavali have only 4% share in the total economic value of the total estuarine productivity.

Aghanashini estuary is the highly productive and comparatively intact ecosystem; therefore the total economic value is 62% of total district value. The value in Rs/year is 24.03 billion and the productivity per hectare is 5,005,035 Rs/year. Provisioning service makes up the 23% of the total value. Information service share only 2% and regulating and supporting services are 37%,39% respectively.

Sharavathi estuary provides a total value of 3.9 billion Rs annually and the value obtained from per hectare of estuary is 2,453,510 Rs. The total value is shared with 12% by provisioning services and 75% by regulating services and 11% by supporting services and 3% by information services. The total economic value from Venkatapura estuary is 33.32 million Rs/year and it has a production potential of 1,333,092 Rs/ha/year.

The total economic value generated from per hectare of the estuary is highest in Aghanashini estuary 5,005,035 Rs/ha/year followed by Gangavali with value of 2,676,261 Rs/ha/year. Though Kali is second biggest estuary but the value is less than Gangavali due to estuarine health degradation via effluents from Paper and Sugar industries and Kaiga thermal power plant apart series of dams. It makes the estuary lesser productive. Sharavathi has higher spatial extent than Gangavali but the river is dammed and the discharging of the freshwater from hydroelectric station makes the estuary less saline and there is depletion of saline dependent fishery resources (Rao *et al.,* 1989). The higher productivity is observed in the estuaries with no dams and comparatively pristine conditions.

7. CONCLUSION

Ecological systems play a fundamental role in supporting life on earth. Most of the natural ecosystems are rapidly disappearing as a result of the pressure of population growth and economic development.In order to formulate sustainable natural resource use policy and measures, valuation of the uses of these ecosystems becomes essential, for it can help resource managers deal with the effects of market failures, by measuring their cost to society, which otherwise are generally hidden from traditional economic accounting.

The present study was an account of the resource potential of five estuaries - Kali, Gangavali, Aghanashini, Sharavathi and Venkatapura of Uttara Kannada district, Karnataka state, India.

In the case of Kali, the total economic value is 8.33 billion Rs/year. And it gives the annual value per hectare of the Kali estuary as 2,571,398 Rs/ha/year.

The total economic value from Gangavali is 1.87 Rs/year with an annual value of 2,676,261 Rs/ha/Year.

Aghanashini estuary is the highly productive and comparatively intact ecosystem; therefore the total economic value is 62% of total district value. The total economic value for Aghanashini is 24.02 billion Rs/ year and the annual value per hectare is 5,005,035 Rs/year.

Sharavathi provides a total value of 3.92 Rs annually and the value obtained from per hectare of estuary is Rs 2453510. Venkatapura estuary has a value of 33.3 million Rs/year and the annual value per hectare is 1,333,092 Rs/ha/ year.

Results of this study has clearly shown that estuaries of Uttara Kannada sustained the total economy of the district in a significant manner and hence it should be the focal point for the economic development of the district since majority of people living around the estuary earns livelihood from this estuaries.

Nowadays signs of decline in the environmental quality of these ecosystems have been noticed necessitating the concerted effort with native people's participation to conserve the estuary in a sustainable manner.

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ANNEXURE I: TABLES AND FIGURES

Table 7: Provisioning services from Estuaries, Uttara Kannada

Goods	Kali	Gangavali	Aghanashini	Sharavathi	Venkatpura
Area	3240 ha	700 ha	4801 ha	1600 ha	250 ha
Fishery	230,474,833	42,381,251	4,126,132,860	32,431,747	8,719,786
Agriculture	39,365,025	13,085,209	49,592,376	62,621,327	2,617,042
Mining activities	483,633,000	62,740,385	1,208,894,077	357,962,308	1,523,077
Mangrove product harvest	5,265,583	5,422	4,806,298	5,188,107	1,036,924
Water transport	140,000	469,300	1,698,000	938,600	30,000
Salt production	20,000,000	35,000,000	50,000,000	0	0
Total Value (Rs/Year)	778878441	153681566	5453199811	459142088	13926829
Production (Rs/ha/year)	240,395	219,545	1,135,847	286,964	55,707

Figure 8: Provisioning services from Uttara Kannada Estuaries

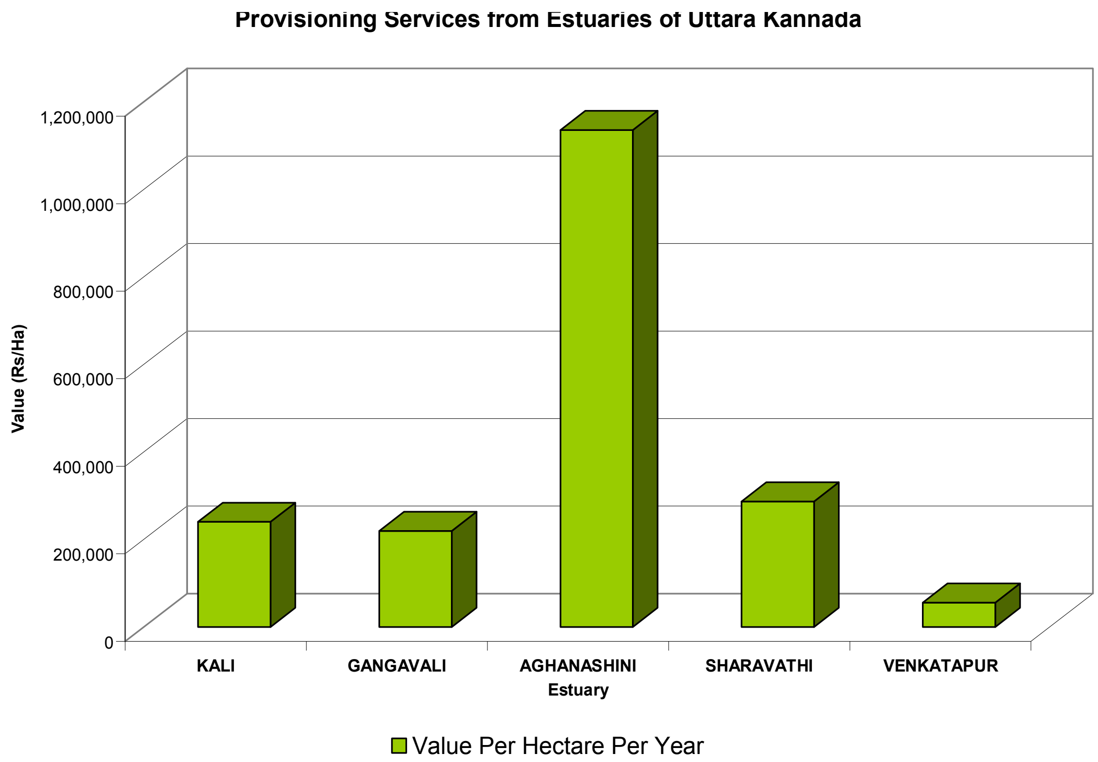

Table 8: Services and goods of estuaries

Services	Kali	Gangavali	Aghanashini	Sharavathi	Venkatpur
Area	3240 ha	700 ha	4801 ha	1600 ha	250 ha
Coastal erosion control	13,760,593	5,944,576	13,980,762	688,030	137,606
Flood control	15,824,967	6,836,386	16,078,167	791,248	158,250
Storm protection	4,500,000	1,944,000	4,572,000	225,000	45,000
Nutrient retention	1,103,448	476,690	1,121,103	55,172	11,034
Disturbance regulation	2,551,500	1,102,248	2,592,324	102,060	20,412
Waste treatment	976,276,800	210,924,000	1,446,637,320	482,112,000	42,184,800
Nutrient cycling	3,076,380,000	664,650,000	4,558,549,500	1,519,200,000	132,930,000
Carbon sequestration	911,020	393,561	925,596	45,551	9,110

Gas regulation	31,104,000	6,720,000	46,089,600	15,360,000	1,344,000
Climate regulation	15,552,000	146,361,600	23,044,800	7,680,000	1,536,000
Oxygen provision	17,107,200	3,696,000	25,349,280	8,448,000	739,200
Water regulation	677,445,120	146,361,600	1,003,831,488	334,540,800	29,272,320
Water supply	472,780,800	102,144,000	700,561,920	233,472,000	20,428,800
Groundwater recharging	622,080,000	134,400,000	921,792,000	307,200,000	26,880,000
Natural hazard mitigation	31,104,000	6,720,000	46,089,600	15,360,000	1,344,000
Total Value Rs/Year	5,958,481,448	1,438,674,660	8,811,215,461	2,925,279,861	257,040,532
Production Rs/ha/year	1,839,037	2,055,250	1,835,288	1,828,300	1,028,162

Figure 9: Regulating services of Uttara Kannada Estuaries

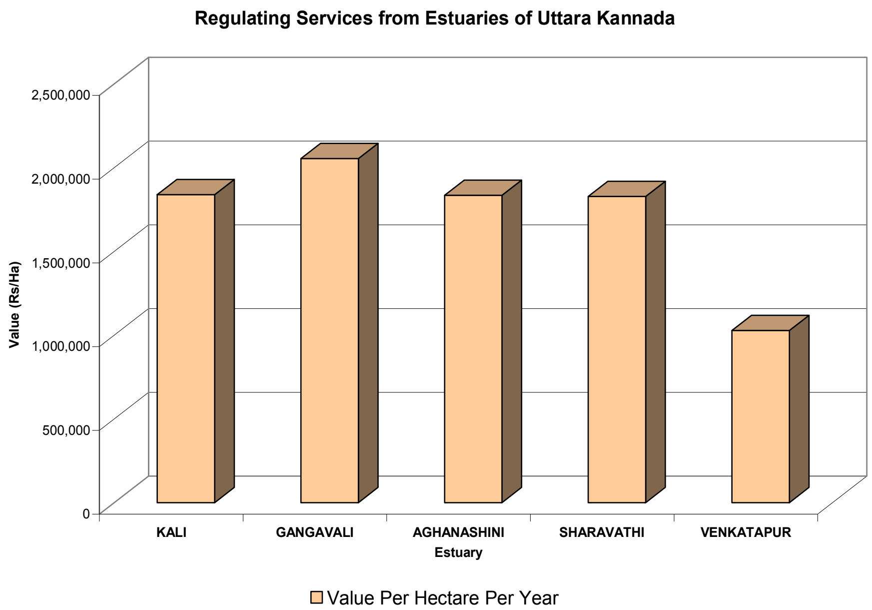

Table 9: Supporting services from Estuaries in Uttara Kannada

Services	Kali	Gangavali	Aghanashini	Sharavathi	Venkatpur
Area	3240 ha	700 ha	4801 ha	1600 ha	250 ha
Primary production	460,949,666	84,762,502	8,252,265,720	64,863,494	21,190,625
Habitat/refugia	19,099,800	4,126,500	28,301,895	9,432,000	825,300
Breeding ground and Nursery	17,079,012	3,689,910	25,307,511	8,434,080	737,982
Biodiversity	699,840,000	151,200,000	1,037,016,000	345,600,000	30,240,000
Total Value (Rs/year)	1,196,968,478	243,778,912	9,342,891,126	428,329,574	52,993,907
Production (Rs/ha/year)	369,435	348,256	1,946,030	267,706	211,976

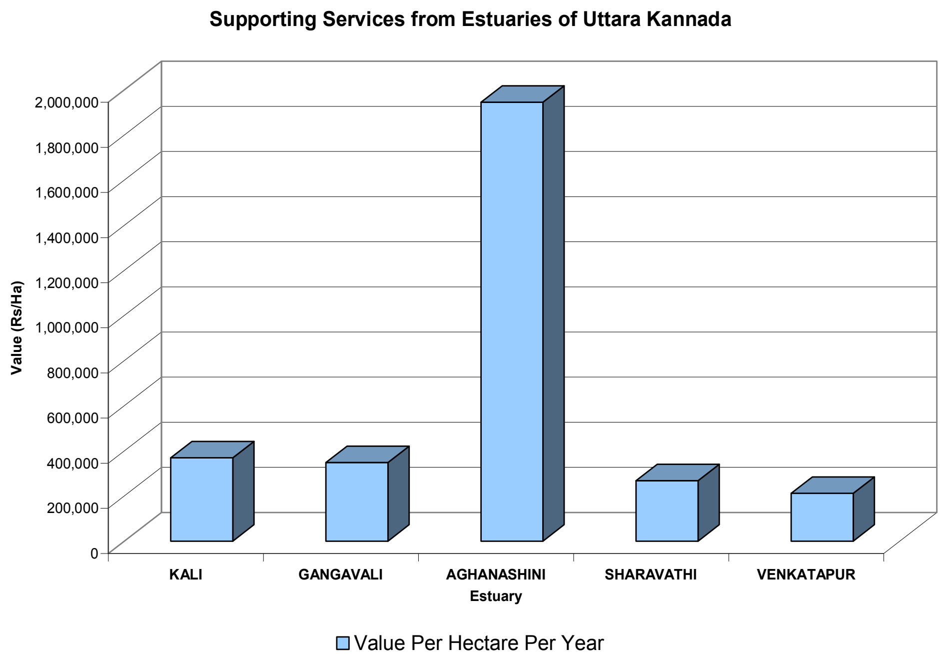

Figure 10: Supporting services of Uttara Kannada estuaries

Table 10: Information services from Estuaries in Uttara Kannada

Services	Kali	Gangavali	Aghanashini	Sharavathi	Venkatpur
Area	3240 ha	700 ha	4801 ha	1600 ha	250 ha
Recreation	55,549,800	12,001,500	82,313,145	27,432,000	3,000,375
Aesthetic information	4,228,200	913,500	6,265,305	2,088,000	228,375
Science and Education	324,000	70,000	480,100	160,000	17,500
Science and Education	336,898,602.00	24,262,245.00	332,808,680.70	83,184,840.00	6,065,561
Total value (Rs/year)	397,000,602	37,247,245	421,867,231	112,864,840	9,311,811
Production (Rs/ha/year)	122,531	53,210	87,871	70,541	37,247

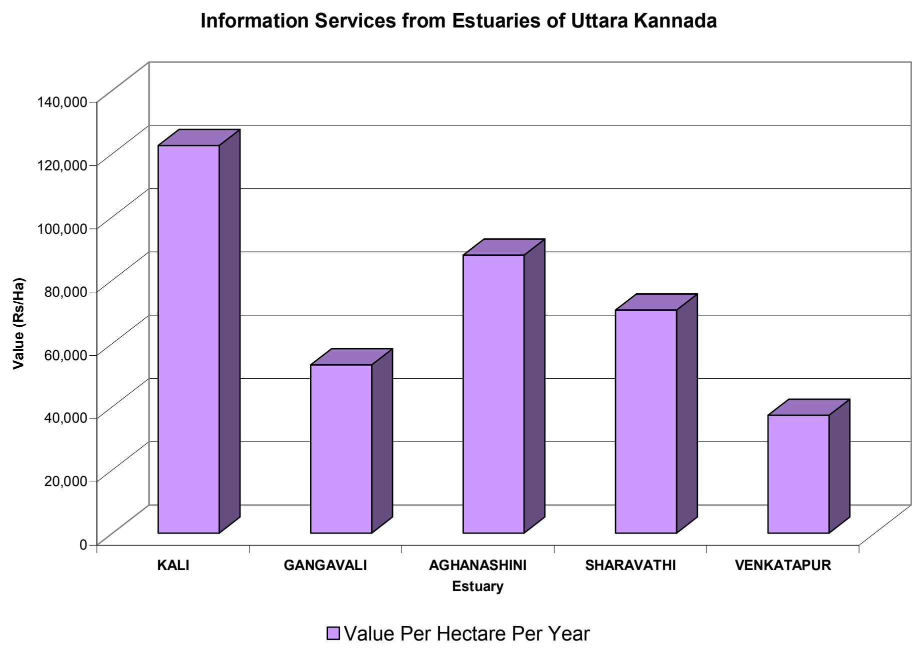

Figure 11: Information Services of Uttara Kannada Estuaries

Table 11: Total Economic Value of Estuarine Ecosystem in Uttara Kannada

		Kali	Gangavali	Aghanashini	Sharavathi	Venkatpura	Total (District)
Total area (ha)		3240	700	4801	1600	250	10,591
Population		41877	15569	64709	47352	57685	227192
Provisioning services	Total Rs/Year	778878441	153681566	5453199811	459142088	13926829	6858828735
	Production Rs/ha/year	240395	219545	1135847	286964	55707	1938457
	%contribution	9	8	23	12	4	17.82
Regulating Services	Total Rs/Year	5958481448	1438674660	8811215461	2925279861	257040532	19390691963
	Production Rs/ha/year	1839037	2055250	1835288	1828300	1028162	8586037
	% contribution	72	77	37	75	77	50.37
Supportng services	Total Rs/Year	1196968478	243778912	9342891126	428329574	52993907	11264961997

	Production Rs/ha/year	369435	348256	1946030	267706	211976	3143402
	% contribution	14	13	39	11	16	29.27
Information Services	Total Rs/Year	397000602	37247245	421867231	112864840	9311811	978291729
	Production Rs/ha/year	122531	53210	87871	70541	37247	371400
	%contribution	5	2	2	3	3	2.54
Total Economic Value	Total Rs/Year	8331328969	1873382383	24029173629	3925616363	333273080	38492774424
	Production Rs/ha/year	2571398	2676261	5005035	2453510	1333092	14039296

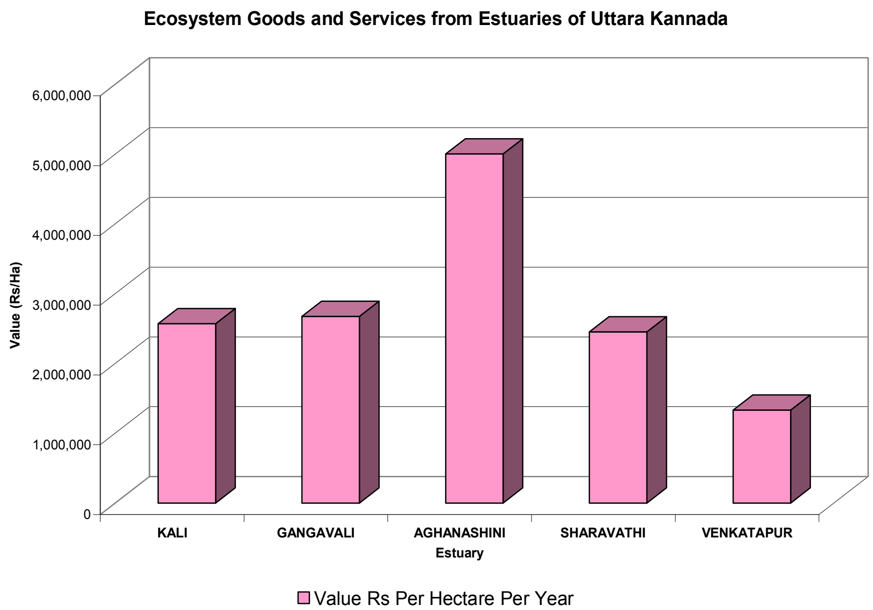

Figure 12: Total Economic Value from estuaries of Uttara Kannada

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