IDENTIFICATION AND EVALUATION OF ECOSYSTEM SERVICES PROVIDED BY CLAM (*VILLORITA CYPRINOIDES*) FISHERIES IN WETLAND

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ABSTRACT: Black clam (*Villorita cyprinoides*), constitute a major molluscan based subsistence level fishery in Vembanadlake providing a variety of ecosystem services to the dependent populations of the ecosystem. The non-realization of the values of the services provided by clams coupled with the anthropogenic activities like dredging aggravated the non-sustainable harvest of the resource. The paper attempts to evaluate the provisioning and cultural services provided by clams in-order to highlight the importance of the management of this ecosystem service provider and various tradeoffs between anthropogenic activities and clam resource utilizations.

Keywords: *Black clam management, ecosystem service provider, ecosystem service evaluation,*

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As per the Ramsar Convention definition, most of the natural water bodies (such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefs) and manmade wetlands (such as ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms and canals) constitute the wetland ecosystem in India (Bassi etal, 2010). Globally, the areal extent of wetland ecosystems ranges from 917 million hectares (m ha) to more than 1275 m ha (Bassi et al, 2014). As per the estimates, India has about 7.57 lakh wetlands with a total wetland area of 15.3 m ha, accounting for nearly 4.7 per cent of the total geographical area of the country (SAC, 2011). Vembanadlake in Kerala is one among the 26 wetlands designated as Ramsar sites(Ramsar, 2013). Vembanadlake, a backwater, formed by the backward flow of seawater due to an obstruction in the natural current, is a unique ecosystem found in Kerala. Vembanad Lake, the largest backwater in Kerala, and second largest brackish water lake in India covering an area of 2033 sq. km is renowned as a major contributor to inland fisheries. The designation of this wetland system as a Ramsar site in 2002 calls for the immediate conservation of the ecosystem from the major threats like urbanization, population growth, pollution, tourism, dredging etc as well as sustainable utilization of its resources.

Vembanad Lake, an ecotone between brackish water and freshwater environment, is an abode of aquatic biodiversity. The soft organically rich sedimentary substratum of the inshore region is an ideal habitat for shrimps. Vembanad serves as a habitat for a variety of fin fishesand shell fishes, and a nursery for several species of aquatic life (Kurupet al, 1990). The major species supporting the fisheries include the molluscan bivalve, *Villoritacyprinoides (*Black clam*)*and *Etroplussuratensis* (Pearl spot). The lake contributesto nearly 99 per cent of total *Villorita* harvest (56700t). The collection and sales of the harvested clams is organized via co-operative societies formed of clam collectors residing in the clam-fishery based villages distributed across Alapuzha and Kottayam districts of Kerala. Nearly 75% of the total harvest is contributed by Muhamma and Vechoor clam shell cooperative societies located in Alapuzha district of kerala.

The anthropogenic activities affected the phytoplankton production upon which *Villorita*sp (suspension feeders) are wholly dependent. The value of the services provided by clam fisheries are not realized and quantified to the fullest extent yet, which acts as limiting factors highlighting the aspects of conservation and sustainable harvest of the species. And hence, we are in an attempt to destroy the resource knowingly or unknowingly by our activities. Any service, when expressed in monetary or quantifiable terms will emphasize its evaluationmore rationally taking into account the socioeconomic costs and benefit aspects. Identifying the lacunae, Millennium ecosystem assessment (2005) emphasized that the various services provided by the ecosystem benefitting human population needs to be identified and evaluated for judicious utilization of the resources.

MEA (2005) which propounded the concept of the evaluation of ecosystem services asserts the need for the identification of ecosystem service providers (ESP) as the preliminary step in the evaluation process. This study identifies clams as ESPs and focusses on the

identification and economic evaluation of various services provided by the clam fishery to the human settlement. The objectives are to develop a conceptual framework encompassing the different ecosystem services provided by the clam resources, estimating the values of selected ecosystem services using appropriate proxies, analyze the tradeoffs between anthropogenic activities like dredging *vis-a-vis* clam resources utilizations.

MATERIALS AND METHODS

The study is conducted with the cooperation of seven black clam cooperative societies namely Aaryad, Muhamma, Vaikkom, Vechoor,Thycattussery, Kavalam and Kuthiathode .These co-operative societies located in Kottayam and Alappuzha districts are involved in the implementation of multitude of welfare schemes, provision for festival allowance, floating insurance schemes etc. Almost four to five clam fishing villages come under the jurisdiction of each society (Suja and Mohamed, 2011).Ten key informants have been identified from each co-operative society. A socio-economic survey was conducted to identify and evaluate the various services provided by the clam population to the human settlement in the area post a reconnaissance study. The survey schedule included various details encompassing socio-economic status, livelihoods, outlets of clam shell utilization and choice experiments on impact on dredging using key driver indicators etc. The sampling areas have been represented in the Fig 1. The clam production data for the quinquennial period from 2009-2014 were collected from the respective cooperative societies to arrive at clam production estimates and its utilisation.

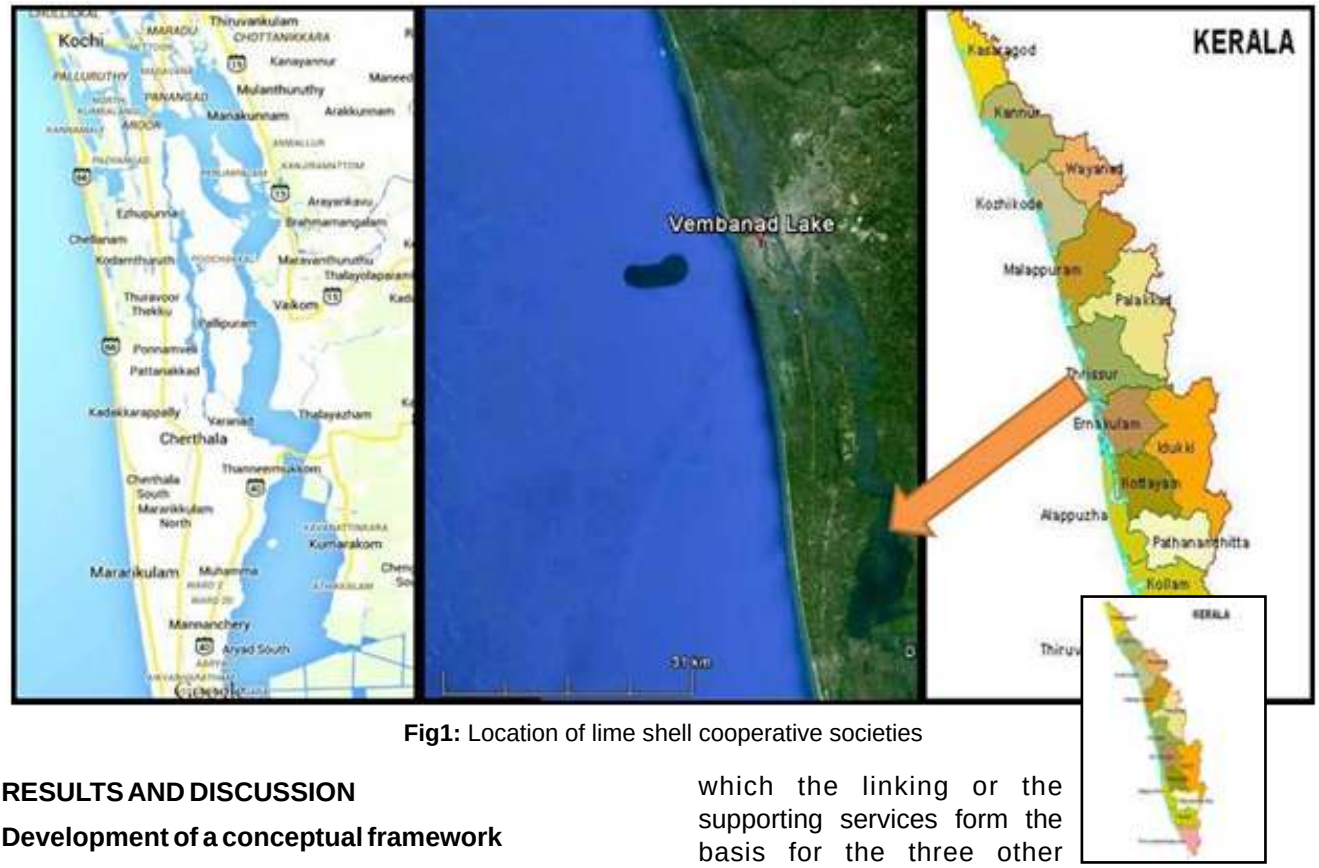

Fig1: Location of lime shell cooperative societies

RESULTS AND DISCUSSION

Development of a conceptual framework

MEA (2005) defines the services provided by the ecosystems which benefitted humans directly and indirectly as ecosystem services. The concept of ecosystem services helps to express the usefulness of biodiversity in a region to the wellbeing of human population who are solely dependent on the ecosystem for various needs. The ecosystem services are categorized into four viz., linking, provisioning, cultural and regulating services (MEA 2005, TEEB 2010b), of which the linking or the supporting services form the basis for the three other services. A conceptual framework of the services provided by clamsis provided in Fig 2.

Conceptual framework of the ecosystem services

The clams are providers of various ecosystem services, which are broadly classified under four categories as provisioning services, regulating services, linking or supporting services and cultural services. The services

that are provided by (clams) benefactors are mainly provisioning services. The various services provided by clams vary with the necessities of the society.

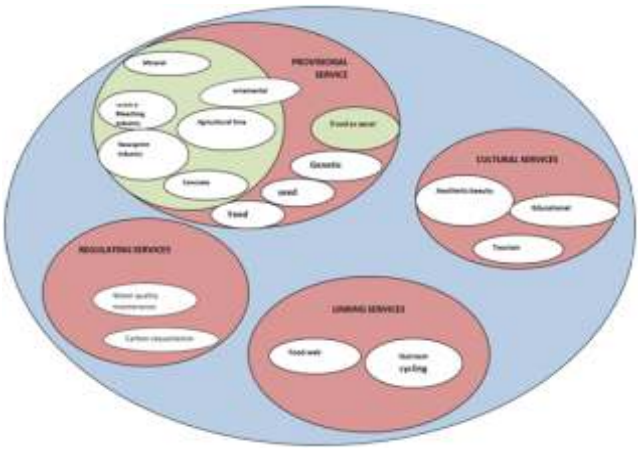

Fig 2: Conceptual framework of ecosystem services of clams

Provisioning services

The provisioning services are those ecosystem services that describe the material or energy outputs from the ecosystem (MEA, 2005). The ecosystem service provider (clams) act as sources for a multitude of natural as well as metamorphosed resources in the form of food, minerals, feed, seed, genetic and ornamental resources, thus performing the provisioning services of the ecosystem benefitting the dependent human population.

Food

Clams are famous for their nutritional benefits as well as their taste. The nutritional characteristics of clams include rich protein, high trace elements, high omega-3 fatty acids, iron and calcium. A unit weight of 100 grams of clams possess calcium content in the range of 32-592 milligrams. Clams are rich source of vitamin B_{12} (cyanacobalamine) which is significant for normal blood metabolism. (Sen, 2005, Gopal etal, 2014). Table 1.0 depicts the nutritional characteristics of clams in quantitative terms and throws light upon the fact that since clams are a good source of many micro elements and macro elements, the very consumption of clams in prescribed doses would be adequate to overcome various health related issues.

Minerals

Fossil deposits from Vembanadlake are the major contributors of raw materials for cement manufacture by Travancore Cements Limited, a government undertaking. When low magnesia content in the fossil deposits used for cement manufacture ensures brilliant whiteness and durability, the light fast pigments ensure color retention. These qualities affirm demand for the particular cement sourced out from fossil beds. Ravindranet al (2006) has also detailed the quality of white cement made out of lime shell as highly durable and of superior quality. The clam shells are also used in titanium producing company as a source of calcium carbonate. Locally lime shell is heated and powdered to produce lime which is used in agriculture. It is also used as a cost effective substitute for gravel in the concrete mix at a rate double that is required of gravel. Though this is an indigenously developed technology, it was primarily used to sell out the un utilized clam shells. It is also used in tanning industry, bleaching of sugar, and carbide industry and as a constituent for newspaper manufacturing industry.

Feed manufacture

The clam shells and juvenile clams sized less than the minimum legal size are the major inputs used in poultry industry. In poultry, egg breakage, a major constraints faced by the farmers, is due to the deficiency of calcium in the bird diet during egg formation and layingresulting in thin shelled eggs. Inorder to maintain equilibrium between health management aspects of poultry and loss in calcium for the birds and to obtain hard shelled eggs, these growth overfished clams along with the clam shells are incorporated in the poultry feed as they are a good source of calcium. enrich

Table1: Quantification of various nutritional characteristics of clams

Macroelements	Quantity in 100g wet muscle(mg)	Suggested daily intake (mg)
Sodium	81-726	1200-1500
Potassium	130-452	477
Calcium	32-592	1000-1300
Phosphorus	88-415	
Microelements		
Iron	24.53	11.5-49.5
Zinc	122.1	15.5
Copper	4.73	2.2
Manganese	2.8	5.5

(Source: Sen, 2005)

Ornamental resources

Clams are used for decorative purposes and as curios mainly. The chains and bangles encrusted with clams are used as jewelry. The clams embedded mirrors, curtains and other show pieces, available in markets could possibly generate huge revenue for the traders involved in the industry (Fig 1.0)

Fig 3. Ornamental value of clamshells (Kid's crafts and clam candles)

Seed resources

The clam resources are the sources of feral clams, analogous to feral fishes which represent valuable genetic resources for capture fisheries and for aquaculture and related research. The culture of clams still relies on the collection of seed from natural populations or wild specimens (Pullin, 2006). Natural spawning and setting of clams occurs annually in brackish water environment of the lake with suitable substrates and low predation throughout the year.

Genetic resources

These natural variants, with its abundance of genes and gene interactions, are a store of useful genes for future researches. The natural breeds of Villorita sp. apart from being a part of our common cultural heritage represent a vital basis for future molluscan culture. Genetic diversity ensured by wild specimen is a fundamental resource for the continuous development of new and improved variants of the species(Davis,1985).

Regulating services

MEA(2000) describes regulating services as those benefits obtained from the regulation of ecosystem services of the physical, chemical and biological processes between the organisms and their environments.

Water quality maintenance

The water quality maintenance services of shellfish is a direct result of their suspension-feeding activity. The clams , a primary consumer in the trophic guild, reduces concentrations of microscopic algae (phytoplankton) and suspended inorganic particles in surrounding waters (Brumbaugh et al, 2006) by way of filter feeding mechanism. Water quality control service provided by these service providers is accomplished both by direct removal of suspended material and by controlling the rate that nutrients are exchanged between the sediments and overlying waters.

Carbon sequestration

Clams help in carbon sequestration where in carbon is absorbed from water to secrete its calcium carbonate (CaCO3) based shellduring their various growth stages from larvae to adult. Reports from Lake Burullus, Egypt which evaluated the carbon sequestration rate from lake as 4.04 Gg C $year^{-1}$ (Ebrahimand Kamal, 2013) supported the fact that wetland lakes are a major sink of carbon. Many reports mention that the carbon sequestration rate ranged from 4.39- 17.39 tC/ha/yr in bivalves suggesting that the clams play a major role in mitigating climate changes.

Cultural / spiritual services

These services are nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Ancestral services

The fishing activity in Vembanadlake is an ancestrally followed occupation. The methods of capture of clams are also followed from the ancestors. The various methods of clam collection are

a) Handpicking by women and children from shallow areas where depth is less than 0.5 m during low tides(Laxmilatha and Appukuttan,2002).

b) Fishing is practiced by women by feeling and detecting the clam beds by their feet

c) Fishing is also done from a canoe where kolli is used to catch the fish. The aesthetic beauty of the clam collection is not yet evaluated in the assessment of ecosystem services.

Tourism

Tourism operates at the intersection of a huge industry and the ecosystem. These nature based tourism ensures appropriate level of environmental quality and consumer services and can educate people about the importance of biological diversity mainly through eco-tourism and wilderness travel. Collection of live clams in the presence of tourist offers added revenue to the clam collectors which inturn attributes to tourism.

Educational

Clam resources form the essence for a variety of knowledge systems especially education and provide resources for generation, transmission, adaptation and use. Apart from being a focal area in the publication of many international and national scientific papers, clams also invite the attention of various organizations in the governmental and non-governmental levels towards conservation and sustainable management aspects. The intuitiveness to correlate the various biotic and abiotic factors to the clam based resource management on the basis of earlier works would bring in added publications with an intention to evaluate the value of the services offered by the resource to the human settlement.

Political services

The clam resources form the core for many political services, particularly in the formation of committees for studying the black clam fishery in Vembanad Lake. The traditional as well as novel knowledge on resources has promoted various environmental based studies including the impact of dredging on clam beds, sand mining, deforestation of riparian vegetation, pollution, illegal clam fishing etc in succession to numerous community level agitations and meetings organized by the affected clam fishers. These initiatives have brought awareness into the conservation as well as sustainable management of the resource to save it for the future.

Linking services

The services those are necessary for the production of all other ecosystem services or goods may be defined as linking or supporting services. The clam patches in the Vembanad lake which act as a gene pool protector, help in the maintenance of their stratum in the trophic food chain. Nutrient cycling is another supporting service offered by clam resources.

Food web

Though clams are traditionally assigned to the same trophic guild (primary consumers filtering algae from water column), recent studies show that they feed at multiple trophic levels like bacteria, phytoplankton and zooplankton. Newell (2004) suggests that bivalves sometimes exert a top-down grazer control on the phytoplankton community and reduce the plankton production.

Nutrient cycling

In bivalve dominated ecosystem, nutrient cycling is elevant. Nitrogen and phosphorus excreted by bivalves and regenerated from their fossil deposits are recycled back to the water column and further support plankton production ensuring bottom up nutrient regeneration process (Newell, 2004) forming a cyclic process in continuation with the top down grazer control mechanism.

Despite all these benefits, many decision-makers and even many of the 'primary stakeholders' consider wetlands as 'wastelands' and the related resources `unimportant'. Every one claims a stake in them, as they are in the open access regime, but rarely are willing to pay for this extractive use (Verma, 2001).

Evaluation of the ecosystem services using various proxies

An emphasis on economic significance of the ecosystem in monetary terms would generate the demand for the implementation of the conservation and sustainability measures of the ecosystem (MEA, 2005). The ecosystem services, in particular the provisioning and cultural services, provided by the resource have been attempted to evaluate using various proxies in this paper.

The provisioning services of clams are evaluated employing diverse array of proxies. Prior to evaluation, the provisioning services are segregated into two subcategories, those with a pre-identified value *vis* food, mineral, feed and seed resources (Table 2.1) and those services with an unidentified value *vis* ornamental, genetic resources and food resources (Table 2.2). The provisioning services with identified values are mainly goods which are sold on a market. Such goods*viz* clam meat and clam shells disposed of, for various uses are evaluated using market price method. The weighted averages of income from various channels of utilization of clam shells have been used as the market price for diversely utilized clam shell resources (Table 2.1). Market price method is a revealed preference technique of estimating the value of an ecosystem service using market data and consumer characteristics, activities and purchases (Isaacs, Keithly, and Lavergne 2004). The other common revealed preference methods are hedonic pricing method, travel cost method and cost-based methods.

The unidentified category of provisioning services (Table 2.0) is evaluated with the help of alternative evaluation methods. The nutrient quality of clams like vitamins, trace elements etc that cannot be directly measured based on market prices, is assigned a value equivalent to the cost the people would possibly incur in the absence of the same in the resource. This value is obtained by considering the cost in procuring

multivitamin medicament doses that would provide the concurrent quantity of nutrients in the food.

There are mainly two schools of thought that are followed in the evaluation of genetic resources. The first school considers these resources as commodities for food security and imputes replacement cost method in the evaluation of genetic resources. The latter considers the genetic diversity as a supporting service (Poulson, 2001). Since the paper identifies the clams as a provisioning genetic resource, the first school of thought is being followed in the evaluation of the genetic resource. It has also been identified that the value of clams as genetic resources may be arrived at by taking into account the cost for either the ex-situ conservation of the resource using selective breeding programmes or the in-situ culture of the resource. This paper evaluates the genetic resources (Table 2.0) using the latter method on the basis of an early in-situ culture of the species reported by Narasimham (1993).

The third unidentified provisioning service, ornamental resources is evaluated on the basis of the willingness to pay for the embellished clam resources. The ornamental cost of clam resources has been assessed in comparison with the cost of certain bivalve based attractive collectibles available in the market. These include clam wreath, clam roses, kid's candles, greeting cards, clam crafts and clam decorated juice tumbler. The value of clams as ornamental resources are worked out based on the perception of traders on the possible proportionate frequency with which these products may be bought by the consumers which in turn is dependent on the cost of the curios.

Regulatingservices can be valued by using stated preferences, revealed preferences, marginal damage costs or marginal reduction costs. The cultural services and the attributes people attach to nature from a recreational, emotional or spiritual point of view was evaluated using travel cost method and willingness to pay method (Table 2.3).These valueshave been expressed in monetary terms using stated and revealed preferences (Inkeet al,2009., Groot etal, 2010). Tourism activities benefitted by the clam resources are assessed by the monetary benefit the clam collectors get hold of, when they are being paid off by the tourists in demonstrating the harvesting of live clam resources (Table 2.3). The respondents claimed that on an average they receive Rs.500 from each tourist boat per day that stop beside them to watch the clam collection process unique to the region. An average of six boats per day during the fifteen days of their working period in a month is used for the evaluation of tourism created monetary benefits to the fishers. Aesthetic services existing in the lacustrine ecosystem and the availability of good water quality, patchy distributionetcprovided by the clam resourceshave been taken into account in monetary terms using travel cost method which the person would forgo in order to get access to the particular service of the ecosystem (Table 2.3).

Clam resources have attracted considerable interest for researchers over the past many years. Over the years around35-40 research works have been initiated, published and policy guidelines had been developed involving the different stakeholders till date. A cost of one lakh per research has been imputed to arrive at the valuation of educational services based on the time spent , logistic costs and remunerationsfor the contractual staff and key informants engaged (Table 2.3).Evaluation of cultural services have also been done by choice experiment in which two scenarios namely dredged and non-dredged are compared and analyzed based upon the perceptions of the affected persons (Table 3.0).

Table 2.1: Evaluation of provisioning services of clams on the basis of market value

Sl. No		Provisioning services that are identified	Qtyutilised perton of clams (kg)	Rate per ton(Rs)
1.		Food		
	A.	Clam meat	97.50	9750
2.		Minerals		
	B.	Clam shell	**900**	**2602.25**
		Lime for agriculture	303.66	391.72
		Lime for Vellore newsprint	459.25	464.82
		concrete mixing	36.62	405.13
		Lime for mineral companies	12.02	450.15
		Lime for agents (bleaching sugar, tanning etc)	30.51	570.19
3.		Feed		
	A.	Feed for poultry(whole clam small size)	57.95	300.10

Table Contd. .....

Sl. No		Provisioning services that are identified	Qtyutilised perton of clams (kg)	Rate per ton(Rs)
4.		Seed		
	A.	Seed for clam culture	2.5	20.15
		Total(1+2+3)	1000kg	12352.25

Table 2.2: Evaluation of provisioning services not yet identified

Sl.No		Provisioning services that are to be considered	Qtyutilised	Amount
1.		Food		
	A.	Clam meat		
		Calcium (gm)	32g	770
		Trace elements and vitamins, fatty acids (IU)		265.95
		Genetic (conservational aquaculture cost in Rs)	1 ton	8058
		Ornaments (lakhs)	1 ton	4.67

Table 2.3: Evaluation of cultural services

Sl.No	Cultural services	Amount(lakhs)
1.	Tourism (500Rs/boat*6 boats*15days/month*10months)	4.50
2.	Educational and political services	33.00
3.	Aesthetic service (cost for tour in lake/day=Rs.10000) for 15 days of operation of boat/month*10 months in an year	15.00
	Total	52.50

Analysis of the tradeoff between anthropogenic activities like dredging *vis-a-vis* clam resources utilizations

MEA (2005) single out an alternative method for evaluating ecosystem services on the basis of the impact of a driver. One of the many competing drivers affecting the clam resources along with sand mining, pollution, tourism etc is dredging. The activity is performed by a public undertaking, to manufacture cement. The dredging is carried out round the year to collect the sub-fossil clam deposits rich in calcium content. These sub-fossil deposits also called white clams are categorized qualitatively under high quality criteria on account of quality of cement produced from it. The dredger works on an average for eight consecutive hours a day and sometimes throughout the day as long as the adequate quantity of raw materials is harvested to effectively utilize its processing capacity (160 tonnes).

The dredging activity involves entrainment as well as discharge of the unwanted materials. While entrainment process absorbs live clams into the dredge with force affecting its very survival and growth and causes the formation of deep trenches which are unsuitable for spat settlement, the discharge apart from smothering the species, loosens the substrate and makes it unsuitable for clam settlement. Thus entrainment and discharge activities affect the suspension feeders negatively. An attempt is made in this paper to analyze the tradeoffs between the highlighted clam resources and the dredging activities carrying through in the dredged area (Fig 4.0).

For the study, the wetland is divided into two regions as dredged and non-dredged area for the purpose of comparativeeconomic evaluation of the biological resource harvested by the clam fishers as well as the non-biological resource dredged out using dredger. The dredged area, in the northern part of the lake, is located near Vaikkom region, where as the non-dredged area, is located in the southern part of the lake encompassing Muhamma,,Aryaad and Kuthiathode regions (Fig 4.0). Following MEA (2005), the key attributes to assess the value of the various services offered by clams are identified by interviewing nearly seventy clam fishers (Table 3.1). This is similar to the choice experiment used for evaluation of cultural services to study the impact of dredging.

Fig 4.0: Map showing the dredged and non-dredged area

Table 3.1: Key indicators for evaluating and assessing the value of ecosystem services impacted by dredging as perceived by fishermen (N = 70)

Ecosystem services	Key indicators (attributes)	How the services are affected by dredging	Perception of fishers (Numbers)
Provisioning services	Average weight of clams	-ve	100(70)
	Number of clams per predetermined area	-ve	100(70)
	Shell weight of clams	-ve	100(70)
	Survival rate of clams	-ve	100(70)
Cultural services	No. of fishermen involved in clam collection	-ve	85.8(60)
	No. of fishermen following clam collection from ancestors	-ve	100(70)
	No. of tourists that watch clam collection	-ve	100(70)
	No. of visits in the site related to tourism	-ve	100(70)
	No. of scientific papers published on clams	-/+ve	57.2(40)
	No. of committee to study clams	-/+ve	100(70)
	No. of surveys on clams	-/+ve	100(70)
	No. of black clam co-operative societies	-ve	71(50)
Regulating services	Trophic level of clams	Change to detritus	
	Concentration of carbon in water	+ve	

*Figure in parentheses shows the total number of respondents

Table 3.1 indicates that the provisioning services provided by clams would be negatively affected along with the majority of the cultural services due to dredging. The educational and the political services would be positively benefitted or adversely affected in the advent of dredging as the driver may or may not trigger the inquisitiveness of researchers to pursue a work on the related impacts of dredging as well as the public to organize a meeting in connection with the impacts of dredging on clam fisheries as represented in Table 3.1

CONCLUSION

Clams, primary consumers in the ecosystem, apart from provisioning the usual identifiable resources, regulate, support the ecosystem and link other services. It is appropriate to emphasise that when the public undertaking (cement manufacturing company) is wholly dependent on the white clams in the lake for their raw materials, their development and sustenance of livelihood of the workers of the company, the clam fishers on the other hand are exclusively dependent on the live black clams for their sustenance level of livelihood. It would be challenging for the policy makers to evaluate the two means of livelihood of the societies and suggest the governing authority in support of the strategical 'societal gains for community losses'. In this context, the paper would be of immense help as it throws light on the value of the services provided by the resources and has judiciously attempted to externalize the internalities in the ecosystem services evaluation process by considering the various social costs and benefits associated with the resource. Extensive works in future involving various other stake holders may provide a better evaluation of the services provided by these ESPs.

Highlights

- Various unidentified sub-ecosystem services provided by clams are identified
- Assessment of key indicators impacting dredging by respondents has shown that the driver has both positive and negative impacts on the ecosystem services.

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