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Biodiversity associated with mussel fishery at Vizhinjam-Arabian sea, South Kerala

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Abstract

The manuscript implies the assessment of species diversity associated with the mussel fishery at Vizhinjam. The objective of the present study is to formulate a data regarding with mussel fishery associated diversity which is usually considered as by catch discard after sorting out the commercially important species like Brown mussel (*Perna perna*) and Green mussel (*Perna viridis*). It can be used for the assessment of diversity loss in relation with the fishery and also helpful to the prediction the impact of the fishery activity in the area. The study was carried out in Vizhinjam, during form 2011 June to 2012 May. Our result includes the total species diversity of mussel fishery discards for a period of one year. The correlation analysis reveals the inter relationships between the plants and animals of the mussel bed and the time series analysis can give a view on species diversity variations in each month. The space between the mussels in the natural mussel bed offers refuges for wide varieties biotic communities, including marine plants, small shore crabs and anemones. Mussel bed ecosystems in Vizhinjam support a variety of marine plants, invertebrates and fishes. Precautions must be taken for reducing the unwanted lose of species diversity while harvesting.

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Introduction

The by catch can be referred to as non-target species or incidental collection of associated fauna represents 40.4% of the total marine catch (Davies *et al.,* 2009). Kelleher (2005) estimated the fishery discards at more than 7 million tonnes, of which 27% contributed by shrimp trawl fisheries. Although the by catches are generally unavoidable, it is possible to quantify the by catch and identify marine by catch species for effective reduction of fishery discards (Kennelly and Broadhurst, 2002).

Biodiversity is serving humans in different ways; it provides food, medicine, recreation, and various types of comforts to humans (Cohen *et al.,* 1997). Mussel beds are an important element of a well-balanced or healthy marine ecosystem, having a major role in coastal sediment dynamics (Meysman *et al.,* 2006), acting as a food source, and providing an enhanced area of biodiversity in sediment dominated environment (Hooper *et al.*, 2005). They also play a role by providing substrtatum for other animals for hididing from predators (Suchanek, 1979) in water decontamination, pollution and in the cycle of important elements like oxygen, nitrogen, hydrogen, carbon, including trace elements, critical for all life systems (Gutierrez *et al.,* 2003). A mussel bed system is surviving through on biotic interrelationships between biotic components referred as symbionts Symbionts and their interactive relationships are the most predominant view in ecology (Childress *et al.,* 1991). Mussel can be used for multi uses including as food for human being and animal feed and fertilizer, which provide business opportunities and employment for the coastal populations (Saritha *et al.,* 2015). In recent years there has been increasing interest in potentially wider impacts of commercial fishing including changes to habitats and effects on non-target species (Parsons 1992; Alverson *et al.,* 1994; Dayton *et al.,* 1995). Structurally mussel bed composed of live shell, dead shells, sediments and debris trapped in between these and the matrix providing different associated biota of the region (Suchanek 1979).

Mussel beds support a variety of seafood such as fishes, mussels, crustaceans, sea cucumbers and seaweeds (Craik *et al.,* 1990; Birkeland 1997a). Worldwide mussel bed communities are ina deteriorating state. Many uses of the coral mussel beds are unsustainable, and in this sense many of the mussel bed associated species are in decline (Weber, 1993). At present, utilization of mussel bed resources in an alarming rate throughout the world and mussel bed ecosystems are being continually disturbed by different natural and man-made stresses that severely deteriorated their biotic relationships (Wilkinson, 2000). Mussel communities play a functional role in the intertidal ecosystems and they are widely distributed and abundant on rocky shores worldwide (Seed and Suchanek 1992, Seed 1996, Connor *et al.,* 2006). Mussels can be thought of as both "allogeneic" and "Autogenic" bioengineers (Jones *et al.,* 1994) and they are providing a structured complex entity that provides habitat and refuge for a wide variety of associated organisms including invertebrates and fishes. And at the same time the hard substrates exposed to intertidal and shallow-sub tidal waters provide varied habitats for colonization by marine algae and invertebrates. On rocky shores, mussel beds allow colonization by in faunal organisms which cannot otherwise live there (Tokeshi and Romero 1995). Mussel beds, therefore, provide different habitats for many organisms (Paineand Suchanek 1983) and any factors which affect the habitat may influence the diversity of associated assemblages and the functioning of the system. Mussels often live in mechanically stressful environments and their survival is dependent on their ability to form a strong attachment to the substratum (Witmanand Suchanek, 1984).

There is an urgent need for generating awareness of the interrelationships and their role in keeping ecological balance of the marine ecosystem globally (Badalamenti, Chemello, D Anna, Henriquez Ramoz, and Riggio, 2002; Carr and Hixon, 1997; Perkol-Finkel and Benayahu, 2004). Increasing demand for food, people force to exploit the natural resources in an unsustainable manner. Mussel bed species include delicious food species like fin fishes, clams, and crustaceans.

So the people tend to over harvest these resources because of the high demand in the both local and foreign market. So the present work seeks to make an attention to a traditionally ongoing fishing activity and related biodiversity of non-target species in Vizhinjam, south Kerala coast.

In Vizhinjam and adjacent areas are endowed with naturally occupying Green mussel (*Perna viridis*) and Brown mussel (*Perna perna*), which have a high demand in the local market itself. Marine mussels are widely distributed along the coast and make a natural habitat by harboring for remarkable collection of plants, invertebrates and fishes. They have potent ecological importance and they have been measured as environmental bio monitors. Communities coupled with mussel patches have high species richness, but are characteristically dominated by a few very abundant species.

These communities exhibit significant temporal and small-scale spatial variations in abundance and diversity which should be recognized when considering global patterns of marine biodiversity. Many of the species associated with tropical mussel beds are also represented by taxonomically and functionally equivalent species in mussel communities from temperate waters. The phenomenon of 'parallel communities' on rocky shores is thus apparently replicated on a finer spatial scale within mussel patches. The present study is an evaluation of the mussel fishery associated biodiversity. And the results include correlation analysis of mussel (target species) and the associated animals. On other hand, the same result analyzed through time series analysis for the assessment of species availability or species variations in each months of the study period. So we assumed that the present way of mussel harvesting activities may not leads to heavy rate of biodiversity loss, in by the time go may status will change. But the area demands detailed and continues monitoring and study due to its importance on ecological and social point of view.

Materials and methods

Study Site

Fig. 1. The map showing the study site.

Vizhinjam (N08^{o}2230" E 076^{o}5918.0"), the major fish landing center in the Thiruvananthapuram district (fig. I) Kerala. It is situated at 16 km south of Thiruvananthapuram town. Only traditional and motorized boats are operated from Vizhinjam and hence fishing activities are carried out round the year. The Vizhinjam Bay is protected by the breakwater system, made of rocks and concrete structures (Polypods), which protect against high waves, are arranged along the sides of this wall of stone blocks facing the sea. Vizhinjam is an ideal site for small-scale collection of marine ornamental fishes. Vizhinjam Bay provides suitable environmental conditions for a variety of marine ornamental fishes. The collection of ornamental fishes is also made easier because of the breakwater even during the monsoon season. From the previous literatures the breeding period of the mussels is during November to February, and the State government has imposed a ban on shell collection during this period. In reality, the actual breeding period is not fixed, but depends on the tide character and other weather variables, may sometimes prolong for another month or so. The community is not aware of this, and observes a frequent collection practices in the area without any obstructions during the time.

The study was done at Vizhinjam, which is one of the prominent centre for the mussel fishery on the Kerala coast and also is an important fish landing centre in Trivandrum district. In Vizhinjam coast, the mussel collection is carried out round the year. Nearly fifty five to sixty eight collection units are engaged in the mussel fishery and it includes thirteen motorized canoes and fifty five catamarans. Usually three people work in each catamaran and four to five men are engaged in motorized canoes. Around 250 people are actively participating in the mussel fishery activities in this area. The harvested fresh mussels are supplied in the domestic market, which is a very popular delicate seafood in Kerala. The collection of the brown mussels is carried out year round. The collection is done by scraping the mussel mat using chisels. Diving is done using locally fabricated mask, and the fishermen engaged in the activity are skilled. As soon as they catch reaches the landing area, bulks of the catch are auctioned. Local buyers who actively engage in mussel trade are mostly women. Thus the mussel fishery plays a major role in the women empowerment by providing a livelihood.

The present study tries to analyze the diversity of plants and animals which is landed along with the mussel catch and these will lately sorted out as discard after selection of target species *(Perna perna)*. The present data can be used for the coming studies like this fishery related biodiversity loss and its impacts on the ecosystem. Vizhinjam is an area having a high species richness in the Kerala's coastal belt. And at the same time the area has muscular human intervention due to fishing activities for their lively hood. Indiscriminate exploitation of the resources leads to a heavy reduction of the species concerned along with associated marine communities which may lead to serious environmental impacts and the magnitude of biodiversity loss has been quantified. The impacts of biodiversity loss and their after effects on the Eco balance of this coastal system have become a matter of great concern to ecologists to maintain diversity and sustainability.

Data collection

Collections of samples were made twice in a month from the daily landings of the entire catch before sorting, for a period of one year during 2011 June to 2012 May. The animals were sorted and photographs were taken in fresh condition and preserved in 10% formalin for further studies. Mussel bed associated diversity was assessed by taxonomic identification of the animals from the landings.

Fishery economics

Bivalve exploitation plays an important role in the national economy of many countries (Vakily, 1992). On peak season, the cost of mussel in the market sixty paisa per piece and it may hike to two rupees during the off seasons. The market value of the mussel may vary according to the seasonal availability and demand. During the peak months (September–May) catch may be above 250 kg per fishing unit. The mussel collection, fishery is a part time job for the local fisherman in the area; majority of the fishers will divert to fin fish fishing during the off season of mussel fishery. Nearly 250 to 300 people engage in the fishery directly and indirectly. Auctioned catch is transported to the market mainly by the fisher women of the local area. There is no organized society in the mussel collecting community that facilitates the collection of the catch for the export market, and so, a few agents who act as middlemen reap the profits.

Fig. 2. Landing center.

Fig. 3. Mussel catch.

Fig. 4. Catamaram

Fig. 5. Motorised canoes.

Fig. 6. Snorkel glass.

Fig. 7. Chisel and hook

Catamarans and motorized canoes are used for the mussel fishery at Vizhinjam coast (fig. 4 and 5). Which is mainly plak built and fiber coated canoes. In the catamarans probably one to three fishers and in the case of motorized canoes is four to five. The spatula is used to scrap the mussel meat from the rocky surfaces and collected mussels are gathered in a bag tied at the waist of the collector (fig. 6 and 7). The device using for the scraping of mussels from rocky substratum comprises of an iron spatula, fixed on wooden handle and a hook like device is used to maintain the position of fisher in the water. A locally made snorkel make them clear vision underwater. The collected catch were kept in a basket tied around the waist of the fisher or some fishers used hand scoop net for collecting the scrped mussel which found more handy than the first one. After each dive the collected mussels will be transferred to the big net bag in the catamaran or canoes. The entire activity may extended up to 3 to 4 hours and the total catch carried to the shore where it is auctioned.

Result

127 species of flora and fauna were reported in the present study. When considering the total biotic community, invertebrate fauna took an influential position by bagging 82%, followed by fishes (12%) and marine flora 6% (fig. III). So the present result relaying strong dependence on mussel beds, were providing space for habitat or settlement, foraging.

Correlation analysis were done for revealing the interrelationship between associated biota and the target species.. And also time series analysis studies were done for each biotic components to show their presence or dominance in each months.

In India the green mussel *Perna viridis* and brown mussel *Perna indica* are found in plenty in the intertidal zone of the coastal areas attached to rock, pilings and other hard substrates Appukuttan and Nair (1980). *P. indica*has very limited distribution. Evaluation and assessment of mussel bed associated fauna and flora gives an approximation of biodiversity status of the coast, because the habitat harboring a huge number of animals and plants. And the present study is a door steps to detailed analysis on species diversity associated with mussel fishery of Vizhinjam.

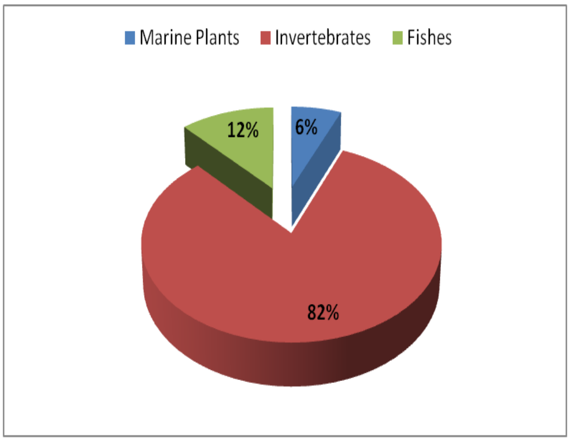

Fig. III. Group wise diversity of mussel bed associated flora and fauna.

When considering the total biotic community, invertebrate fauna took an influential position by bagging 82% of the biota followed by fishes (12%) and marine flora 6% (fig. III). In the group wise diversity, molluscans were constituted a major part with forty species, arthropods secured the second position with twenty two species followed by echinoderms (20), chordates (16), sponges, cnidarians and platyhelminthes (7), annelids (3).

Diversity of marine plants restricted to eight species, comes under six genera and three phyla (**Table.** I). Species composition of each group was Chlorophyta green algae (3), Phaeophyta brown algae (3) and Rhodophyta-red algae (2). This result showing that the mussel harvesting is mainly carrying where in the places with maximum mussel growth. As part of ecological succession mussels the climax community will be dominating the intertidal ecosystem.

Table I. Check list of marine species associated with mussel mat.

Scientific Name	Common Name	Abundance
Phylum : Chlorophyta		
Ulva fasciata	Lettuce Algae	A
Ulva lactuca	Sea lettuce	C
Bryopsis plumose	Plume Algae	C
Phylum : Phaeophyta		
Sargassum wightii	Sargassum Weed	C
Sargassum myriocystum	Sargassum Weed	C
Padina tetrastromatica	Brown seaweed	C
Phylum : Rhodophyta		
Gracilaria corticata	Red Seaweed	C
Centroceras clavulatum	Red Seaweed	C
Phylum : Porifera — Sponges **Class : Demospongiae**		
Callyspongia diffusa	Callyspongiid sponge	A
Cliona celata	Boring Sponge	A
Cliona sp.	Boring Sponge	A
Microciona sp.	Boring Sponge	A
Spirastrella hartmani	Peach Encrusting Sponge	U
Spheclospongia inconstans		U
Haliclona sp.	Haliclona sponge	A
Phylum: Cnidaria- Corals, Hydroids, Anemone **Class: Hydrozoa**		
Pocillopora verrucosa	Pink Cauliflower Coral	C
Dentronephthy sp.	Soft Coral	U
Pocillopora woodjonesi	Mushroom coral	U
Poicillopora damicornis	Cauliflower Coral	U
Class : Anthozoa		
Bunodosoma goanense	Burgundy anemone	A
Un Identified sp. 1		A
Un Identified sp. 2		A
Phylum: Platyhelminthes		
Class : Turbellaria		
Pericelis sp	Planeria	C
Phylum : Annelida — Segmented Worms		
Class : Polychaeta		
Marphysa sp		A
Un Identified sp 1		A
Un Identified sp 2		A
Un Identified sp 3		A

Scientific Name	Common Name	Abundance
Phylum : Arthropoda — Jointed Leg Animals		
Class : Crustacea		
Balanus sp	Barnacles	A
Alpheus sp	Snapping Shrimp	A
Synalpheusstimpsoni	Crinoid snapping shrimp	U
Alpheus . cf. pacificus	Pistol Shrimp	C
Alpheus gracilipes	Daisy Snapping Shrimp	C
Alpheus coetivensis	Snapping Shrimp	C
Alpheus	Nymph snapping shrimp	C
Eaphrosyne Euphrosyne		
Dardanus setifer		C
Aniculus erythraeus		U
Thalamita prymna		C
Pugettia producta	Sargassam crab	A
Petrolithis coccineus		A
Petrolisth esboscii		C
Etisus sp		A
Petrolisthis lamarckii		C
Pisidia dehaani		C
Pisidia gordonii		C
Atergatis reticularis		C
Liomera cinctimana	American Samoa	A
Matuta planipus	Flower moon crab	C
Atergatis reticularis		C
Seulocia pubescens	Pebble Crab	C
Phylum: Mollusca- Snails, Bivalves, Octopus, Squid		
Class : Gastropoda		
Mauritia arabica	Arabian cowry	C
Erosaria ocellata		C
Monetaria moneta		U
Conus ebraeus	Black-and-white cone	U
Conus inscriptus		U
Mitra sp		C
Ergalatax heptagonalis		C
Drupella ochrostoma		C
Fasciolaria		A
Cymatium perryi	Hairy triton	C
Thais rugosa		C
Thais mancinella		C
Pollia undosus		C
Trocus radiates		C

Scientific Name	Common Name	Abundance
Tutufa rubeta	Red mouthed frog shell	A
Purpura bufo		A
Nerita albicilia	Blotched Nerite	A
Clipidina notate	Black- ribbed Limpets	
Tayuva lilacina	Sea slug	U
Sclerodoris nubilosa	Sea slug	U
Berthellina citrine	Sea slug	U
Sclerodoris tuberculata	Sea slug	U
Lamellaria lateens	Sea slug	U
Dendrodoris fumata	Marine Slug	R
Class : Bivalvia		
Perna perna	Brown mussel	A
Perna viridis	Green mussel	A
Pinna bicolor		C
Sunetta donacina		C
Drupella onchrostoma		A
Spondylus sp		A
Venus recticulata		C
Vepricardiumasiaticum		A
Limariafragilis		U
Placuna placenta		U
Spondylusanacanthus		C
Spondylussquamosus		C
Circe scripta		U
Pinctada sp		U
Pinna antennata		U
Class : Cephalopod		
***Amphioctopus* sp**	North Pacific Giant Octopus	U
Callistoctopus sp 1		U
Callistoctopus sp 2		U
Calistoctopusmacropus sp		U
Callistoctopusluteus		U
Phylum: Echinodermata-Sea Stars, Urchins		
Class : Crinoidea		
Comaster sp		C
Comanthina schigelli		U
Tropiometra carinata	Black and White Sea Lily	U
Stephanometra sp		U
Comatella nigra		C
Tropiometra carinata		U
Lamprometra palmata		U

Scientific Name	Common Name	Abundance
Class : Asteroidea		
Stellaster equestris	Sea Star	C
Asterina Burtoni		U
Class : Ophiuroidea		
Ophiocoma erinaceus		U
Ophiocnemis marmorata		C
Ophiopsammus sp (1)		U
Macrophiothrix aspidota		C
Class : Echinoidea		
Echinometra oblonga	Black Boring Urchin	C
Stomopneustes variolaris		U
Echinometra mathaei		C
Phylum : Echinodermata — Sea Cucumbers Class : Holothuroidea		
Actinocucumis typicus	Holothuroids	A
Staurothyonerosaceae	Not designated	A
Holothuria cinerascens	Ashy sea cucumber	A
Holothuria edulis	Edible cucumber, sea	U
cucumber, pink fish		A
Phylum : Chordata		
Subphylum : Urochordata - Tunicates		
Class : Ascidiacea		
Phallusianigra	Black Solitary Tunicate	C
Subphylum : Chordata		
Class : Pisces		
Family : Opisthognathidae		
Opisthognathus nigromarginatus	Birdledjaw fish	U
Family : Muraenidae		
Muraena retifera	Reticulate moray	C
Echidna nocturna	Palenose moray	U
Family : Mullidae		
Upeneus doriae	Gilded goatfish	U
Parupeneus fraserorum		U
Family : Terrapondidae		
Teraponputa	Small-scaled terapon	U
Family : Gobiidae		
Bathygobius cyclopterus	Spotted frill goby	C
Bathygobius sp.		C
Bathygobius coalitus	White spotted frill goby	C
Lupinoblennius paivai	Paiva's blenny	U
Family : Plotosidae		
Plotosus lineatus	Striped eel catfish	U
Family : Antenaridae		
Antennatus sanguineus	Bloody frogfish	C
Family : Scorpeonidae		
Parascorpaena aurita	Golden scorpion fish	C
Pterois russelli	Plain tail Turkey fish	U
Family : Samaridae		
Samaris cristatus	Cockatoo Right eye Flounder	U

Key to Abundance: R - Rare A- Abundant C - Common U - Uncommon

Algal diversity is comparatively minimized due to the domination of mussels and other invertebrate community. And also algal community were under the grazing activity of invertebrate and fishes. When comes to the species contribution by animal phyla, phylum mollusk shared 34 %, arthropods represents 17 %, subsequently echinoderms with 16 %, followed by the chordates which include one species of tunicate and fishes (Chordata) accounts 13 % and followed by Cnidaria (6%), Porifera (5%), Annelida (3%), Platyhelminthes (1%)respectively, thus the mussel bed offering a good harbouring site for number of animals (**Fig. IV**).

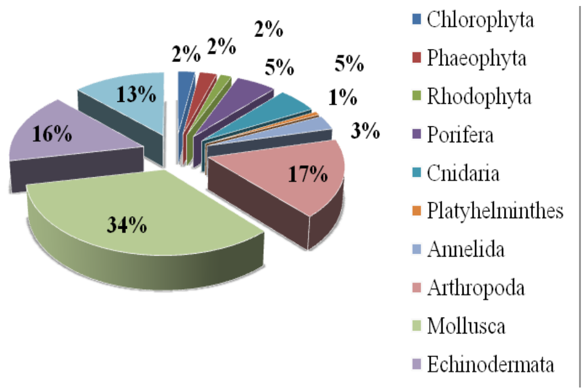

Fig. IV. Species diversity in each Phyla.

Sample collection were done for a period of one year, while considering the diversity of animals identified in the study, dominating group is suspension-feeding organisms like (sea cucumbers, Polychaete, bivalves) followed by grazing gastropods, shrimps and crabs.

Predators include sea stars and brittle stars and scavenger also arrived at high profusions while deposit- and detritus-feeding organisms were of minority. This is in contrast to the fauna coupled with mussel beds on soft bottoms, which comprises many species feeding on material gathered by mussels (fecal matter and pseudo fecal matter) and deposited within the mussel bed.

Many of the organisms dwelling between mussels both on hard bottoms and on soft bottoms have direct development, but organisms with pelagic development also occur in abundance within mussel beds. Species with direct development are disproportionately preferential by the structurally complex habitat with diverse interstitial spaces between the mussels, which provide ample shelter for small organisms. Mussels on hard-bottoms primarily provide substratum for associated fauna while mussels on soft bottoms provide both substratum and food resources.

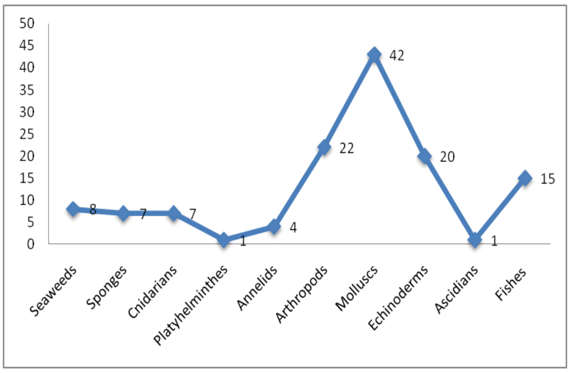

Fig. V. Group wise species representation.

Mussel beds are generally very productive habitats that support high levels of biodiversity (Tsuchiya 2002).In the present study a total of 127 species were collected and identified most of which included marine algae (8 species), sponges (7 species), cnidarians (7species), platyhelminthes (1 species), annelids (3 species), arthropods (22 species), mollusks (42 species), echinoderms (20 species), chordates (tunicates-1 species) and fishes-15 species) (**Fig.** V).

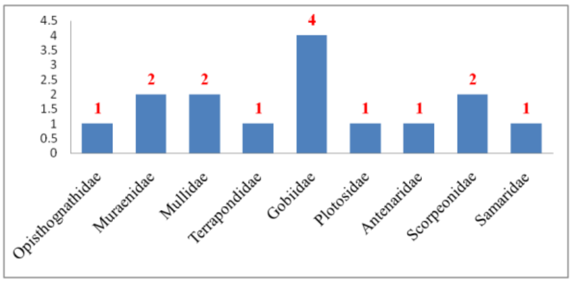

Fig. VI. Family wise fish species composition.

There were 15 fishes reported belongs to the nine families, with maximum species from *Gobiidae* (4), followed by *Muraenidae, Mullidae, and Scorpaenidae* (2). Least number of species were recorded from *Opisthognathidae, Terrapontidae, Plotosidae and Samaridae* (1) (Fig. VI).

Correlation analysis

All mussel bed communities are in linked each other by a biotic assemblage. Here in mussel beds, the invertebrates acts as cleaning agent by consuming the mussel excreta in the same side mussels providing space for shelter and foraging. Correlation analysis were done for revealing the inter relationships among the species diversity and occurrence of each months of the study period collected in the present study and findout the how they are depended each other.

Presence or absence of a biotic component may be an indication of presence or absence of some other species which is hardly objecting the species which is absent. For example in a rocky mussel bed the initial stages of the ecological succession the algal mat were dominating gradually the mussel community will replace the dominancy. Thus we can assess the status of an ecosystem by these studies.

In the present investigation we try to analise the inter relationships between the each biotic components. The correlation analysis of algal species and the target species (*Perna* sp.) shows the negative correlations, so we can say the harvesiting has being carring in the areas with hundred percent mussel growths. In that sense we can claim mussel harvesting carrying in a sustainable way.

Correlation analysis between the target species (*Perna*) and species from phylum porifera and Cnidarian were negatively correlated. Correlation studies between the species of phylum platyhelminthes and the target species shows that only one species *Percelis* sp. Shows positive correlation (730**) to the target species. All species of annelids were showing negative correlation to the target species.

Only few species of mollusca showing positive correlation to the target species, for example the gastropod species *Thais mansinella* (583*) and a species of seaslug *Tayuvalilacina* (720**). None of the species in phylum Arthropoda is not positively correlated with the target specie. When comes to the phylum Echinodermata a couple of species like *Comatella nigra* (658*) and *Ophiocomam armorata* (755*) were positively correlated to the target species.

Out of 16 chordates reported in the present investigation only a single species were positively correlated to the target species.

So the correlation studies between the target species and associated biota were shows that comparatively a few members depended to the target species *Perna*, so the study result proving that the mussel fishery of Vizhinjam coast do not harm to the biodiversity of the area and the fishery carrying out in a sustainable way.

Time series analysis

A time series model for the observed data {xt} is a specification of the joint distributions (or possibly only the means and covariances) of a sequence of random variables {Xt} of which {xt} is postulated to be a realization. Here it is used to asses the species composition and comparison of monthly species varions of the study period.

Marine algae

Time series analysis of algal species shows high degree of variations in the availability in each months. All algal species shows high degree of abundance during the early months from January to may, and in June, July with comparatively low abundance. And again species availability reaches to the peack during the months from August to December.

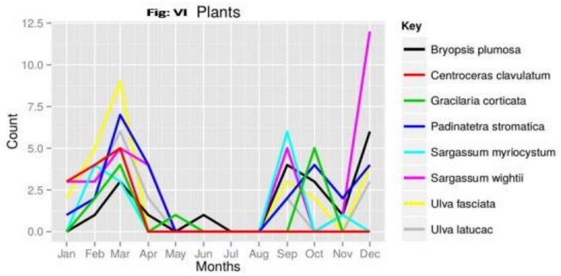

Fig. VII. R world gg plot 2 the monthly species variations of plants.

Cnidarians

Species in phyluum Cnidarians shows considerable variations in their presence on each months of the study period. For example a species of soft coral *Dentronephthy* sp. Present only in the month of January. At the same time species belongs to the sponges *Cliona celata, Callyspongia diffusa,* and a hard coral species *Pocillopora verrucosa* shows their presence at regular intervells.

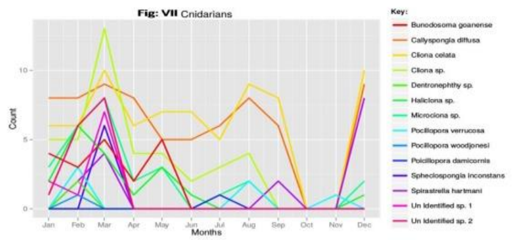

Fig. VIII. R world gg plot 2 the monthly species variations of Cnidarians.

Marine worms

Marphysa sp. Shows high number of occurrence during the months of May to July but the rest of the species were absent.

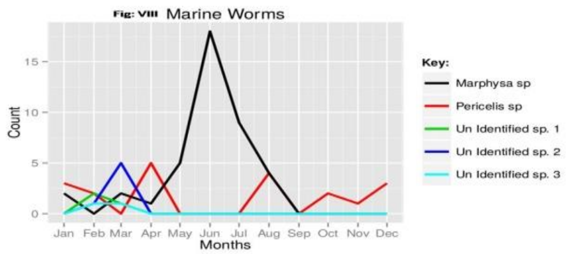

Fig. IX. R world gg plot 2 the monthly species variations of marine worms.

Shripms and Balanus sp

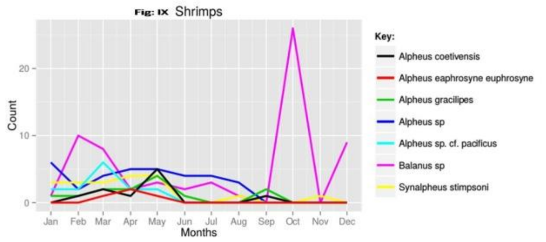

Fig. X. R world gg plot 2 the monthly species variations of shrimps.

All species of this group, the shrimps were marked their presence throuout the study period except *Alpheus sp.cf. pacificus* which is present only during the January to June and *Balanus* sp is dominating among the all and maximum were shown during September to November and again goes high on December.

Crabs

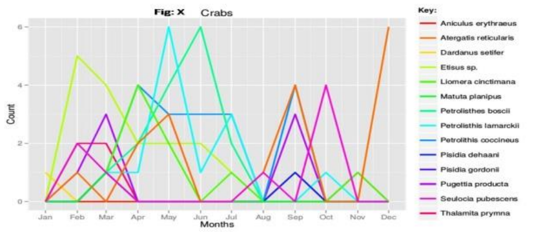

Fig. XI. R world gg plot 2 the monthly species variations of crabs.

Most of crab species were observed in a regular mode in all months of the study period. But few species like *Seulociapubescens* is completely absent during the months of April to July. And the species *Pisidia dehaani* and *Pisidia gordani* present only in the months of April to May and August to October respectively.

Gastropds

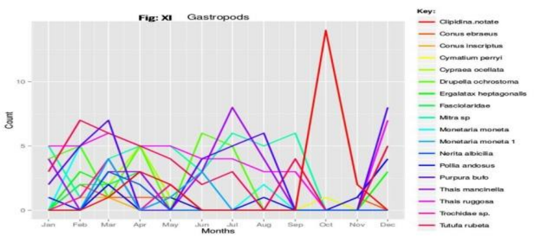

Fig. XII. R world gg plot 2 the monthly species variations of Gastropods.

All species of gastropods were shown their presenc almost in a same frequency except the species like *Turtufaru beta*, *Trochidae* sp., *Thais rugossa, T. mancinella, Monetaria* and *Pollia undosa* were shows high frequency variations in each months of the study period.

Nudibranchs

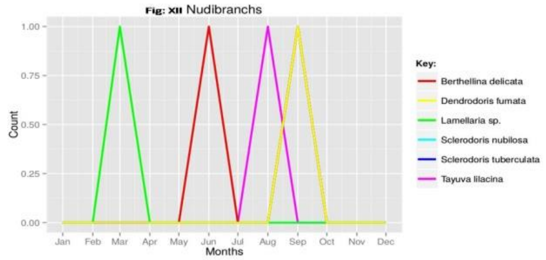

Fig. XIII. R world gg plot 2 the monthly species variations of *Nudibranchs*.

The species of sea slugs made their presence in different months and never overlape in any months of the study time. Sea slugs were scattered in different months and their avilabilty is not merged in any months of the study period.

Cephalopods

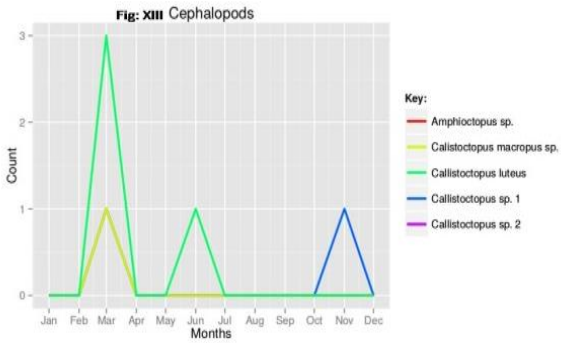

Fig. XIV. R world gg plot 2 the monthly species variations of Cephalopods.

Cephalopod species were shows scatered presence in different months and totally absent in few months like April, May and July to October. *Callistoctopus luteus* reach the maximum in the group in the month of march. Rest of the four species were equally distributed in each months *Amphioctopus* sp., *Callistoctopus macropus, Callistoctopus sp.* 1 and 2 March, June, November respectively.

Echinodermata

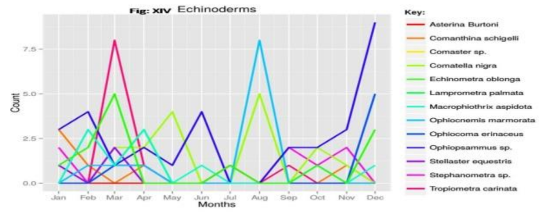

Fig. XV. R world gg plot 2 the monthly species variations of echinoderms.

Comatella nigra, Echinometra oblonga, Lamprometra palmate present in all months of the study period. *Tropiometra carinata, Ophiocoma erinaceus, Macrophiothrix aspidota* were shown the marked variations in their availability in all months. *Tropiometra carinata* and *Ophiocnemis marmorata* showed maximum during the months of March and August respectively.

Echinodermata (Holothurians)

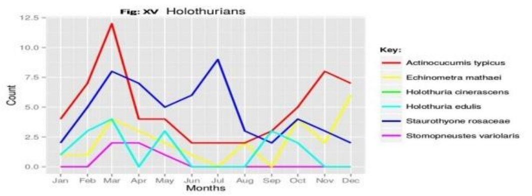

Fig. XVI. R world gg plot 2 the monthly species variations of Holothurians.

The species *Actinocucumis typicus, Echinometra mathaei, Staurothyonerosa ceae, Holothuria cinerascens* showing continuous distribution pattern throughout the study period. In other hand species like *Holothuria edulis*, *Stomopneustes variolaris* exibit in an intrupted distribution present only in the months of January to May and *Holothuria edulis* absent during April and June to December.

Bivalvia

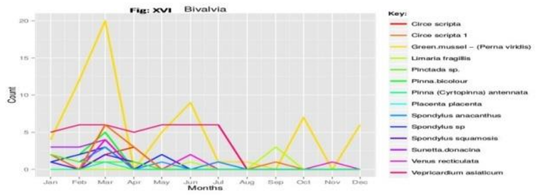

Fig. XVII. R world gg plot 2 the monthly species variations of Bivalvia.

All bivalve species were dominated during the early months of the study period and gradually decreased in their number and diversity and ended with two species in the last months.

Vertebrates

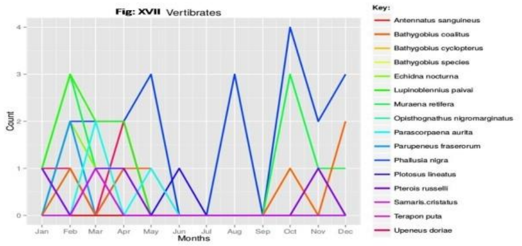

Fig. XVIII. R world gg plot 2 the monthly species variations of Vertebrates.

All species of vertibrates shows their presence in an intrupted frequency. The vertebrate diversity includes single species of Ascidian (*Phallusia nigra*) and fifteen species of fishes belongs to nine families, The time series analysis of vertibrates group showing the tunicate species *Phallusianigra* showing the maximum number during the October, followed by *Muraena retifera,* but the species like *Opisthognathus nigromarginatus, Parascorpa enaaurita, Samaris cristatus* present only in the months of May, March.

Discussion

The study result showing a total of 127 species including flora and fauna were reported. In this species composition, floral diversity encomposes the total species of 8 species of seaweeds comes under the 3 classes. Lorena *et al.,* 2014, studied the Intertidal mussels as ecosystem engineers: their associated invertebrate biodiversity under contrasting wave exposures at 350 km of coastline in Nova Scotia, Canada. And the sresultencomposes the identified 50 invertebrate taxa from 10 phyla. A total 15 species of marine fishes representing 9 families and 13 genera were collected in the present assessment and that result shows that mussel beds are a major hiding and foraging site for the fishes from different families. These mussel bed ecosystems providing favourable conditions for breeding and rearing ground for fishes.

Majority of the fish species collected in the study were recognised as ornamental valued varieties. The unpublished data available with Central Marine Fisheries Research Institute and the Department of Aquatic Biology and Fisheries also indicate that about 100 species of marine ornamental fishes reported from Vizhinjam bay. An investigation carried out by Bijukumar and deepthi (2006) discussed about trawl bycatch associated biodiversity of Kerala. But here describing the diversity associated with a traditional fishery.

Stephenson and Stephenson, 1972; Van Erkom Schurink and Griffiths, 1990; Field and Griffiths, 1991; Branch and Branch, 1993; Harris *et al.*, 1998 was studied on mussel beds around the coast of southern Africa and given a detailed information's on the spatial variation, with huge changes in structural complexity, dominant mussel species and associated fauna and flora as one moves around the coast. The present manuscripts also enlightened the species complexcity of mussel bed by studying the species association of mussel fishery at Vizhinjam coast and explore the inter realtion ships between the target species and associated biota. Saier, (2002) studied the various features like compare species composition, abundance and diversity of non-attached epifauna (>1 mm) in low intertidal and adjacent shallow subtidal zones of three mussel beds (*Mytilus edulis* L.) near the island of Sylt in the North Sea. So the our study result also claiming some similarities on above described study result by species diversity of mussel bed associated flora (8 species of seaweeds) and fauna (127 species), which includes both epifauna (Gastropods (24 species) and Arthropods (22 species), in fauna (Polycheates, 4 species) and non-attached epifauna or visitors (Fishes 15 species and Cephalopods, 4 species). Marine biodiversity management is a burning global issue and has been pessimistically affected by human intervention like unsustainable way of resource harvesting, coastal development programs, and utilization for tourism, dumping of organic wastes etc., exerts extreme pressure on coastal biodiversity (Gray, 1997).

Community structure and species abundances of marine organisms may change for long periods of time by continues unsustainable way of utilization. In this exploration of the species community associated with mussel bed in the Vizhinjam area are heavily affected with severe biodiversity loss in relation with mussel fishery of the area. Mussel bed provides secondary space and microhabitats for a wide diversity of associated benthic species (Suchanek, 1985; Sebens, 1991; Lintasand Seed, 1994; Kostylev, 1996). Arribas *et al.,* (2014) investigated the role of intertidal mussel community in favoring the occurrence of many small invertebrates by increasing habitat complexity and improving local environmental conditions. Intertidal mussels as ecosystem engineers: their associated invertebrate biodiversity under contrasting wave exposures in total, we identified 50 invertebrate taxa (from 10 phyla) and their study shows that arthropods, annelids, and molluscs were the phyla with the highest number of species, representing together almost 70% of the total number.

In previous works inter tidal biotic community of the area were recorded from the area. Ravinesh and Bijukumar (2013) reported shoreline armoring support biodiversity in the bay. And the study wase recoded the diversity of 147 species including the seaweeds (32), sponges (11), coelenterates (6), byozoans (2), mollusks (31), annelids (7), sipunculids (2), isopods (6), amphipods (12), hermitcrab (1), brachyuran crabs (16), alpheid shrimps (4), barnacle (1), echinoderms (9) and ascidians (7). The present study clearly shows that the mussel beds are carrying high species diversity in Vizhinjam coast with species representation of 127 species belonging to 8 species of seaweeds, 7 species of sponges, 7 species of cnidarians, I species of Platyhelminthes, 4 species of Annelides, 24 species of Gastropods, 14 species of bivalves, 4 species of Cephalopods, 22 species of Arthropods, 20 species of Echinoderms, 1 species of ascidian and 15 species of fishes. So the present study result proven that mussel bed sustaining a wide range of biodiversity up to vertebrates (fishes).

Based on the report, the interaction between the epibiont and host is a crucial factor for the survival of each biotic components of the ecosystem. Some works intimate that size of mussels affect the structure of associated macro-faunal assemblages, but here it's not studied because lack of time. Crowe *et al.,* (2004) found that variation in the structure of assemblages associated with mussel beds was related to the volume of sediment trapped between them. In the Vizhinjam coast the sedimentation rate is comparatively high, sand grains were seen on every landing, this is because of high tidal influences. Animals associated with mussel bed are dominated by sessile invertebrates. This is probably because most of the species that live amongst mussel beds are highly mobile (Dittman, 1990) and colonize in suitable habitat as it becomes available to them. Patterns of distribution may also be linked to feeding preferences and the availability of resources, however, this is difficult to interpret as the feeding preference of many marine organisms such as isopods and amphipods are poorly understood and may be quite plastic (Ingólfsson and Agnarsson 2003). This study shows that the invertebrates including shrimps, crabs, echinoderms, visiting mussel bed for feeding. The majority of organisms associated with these hard bottom mussel beds feed on resources obtained from the water column or growing on the surface of shells of mussels rather than on materials deposited by the mussels. Previous studies on mussels and other assemblages have shown that diversity and community structure are linked to topographic complexity (Beck 1998, 2000; Davenport *et al.*, 1999; Crowe *et al.,* 2004). Coral mussel beds of the province are the most vulnerable with more than 80% at risk primarily pressures from coastal development and fishing related activities (Bryant *et al.,* 1998). Here we try to assess the species wise diversity association of the mussel fishery, and the output of the study to reveals that the mussel beds in Vizhinjam bay apart from supporting livelihood of fisher's, harbours wide range of plants and animals including of fishes. The number of fishes were collected along with the mussel landing apart from hundreds of fishes may have to associated with mussel beds of the area which is unable to collect. The collected species age range almost juvenile stage which is normally refuging in iter mussel spaces.

Correlation anslysis were helpful to understood the interrelationships between the target species and the associated species, and it also reveals that the mussel harvesting intensity and the rate removel of associated species. So the result prove that presently on going harvesting activity not causing the strong biotic erosion. In the other side the time series analysis were give a proper view on species diversity variations in each months landings.

Conclusion

The present studies were conducted at vizhijam area where there is most number of mussel fishery carrying. For a period of one year during 2011 June to 2012 May. The impact of fishing on ecology is of growing concern in the environmental management and among scientists; however, to assess the impact of such form biodiversity especially from the benthic community and habitat structure is unpredictable. Here the fish diversity relatively low when compared to the sedentary animals like gastropod, arthropods and echinoderms. In concern to shield the environment, the deterrent approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. The result of the present study indicates that mussel beds of the Vizhinjam coast supports ample range of species diversity from marine plants to fishes. A precautionary approach is recommended towards the resource harvesting and utilization in sustainable manner from the area. This mussel bed associated biotic fauna and flora supporting a wide range of economically important fishery resources including table fishes and species very popular in marine ornamental trade industry. At the same time the traditional fisher folk in the districts were meeting their source of revenue from the system.

In this case study, conservation of species is related with the fishing activity that is limited by the economic context of the fishery. At the same time the people occupied in the fishing is oblivious about the significance and the relevance of these biodiversity and consequence of its loss.

Hence it is essential to create an awareness of its sustainable use and conservation importance accordingly there is an urgent need of institutional level wakefulness line up. At the same way providing the training for sustainable methods for mussel bed resource harvesting and make sure the accessibility of such kinds of instruments and accessories. Indian fishery sector demands a through monitoring and management procedure, especially in the area of traditional fishing sectors.

Recommendations

The fishery needs considerable attention from the government and organizations to develop a on sustainable approach of resource exploitation to minimize the biodiversity loss and related impacts on highly productive and diverse ecosystems. The present study recommended a detailed monitoring study for a period of time. The area demands detailed and continues monitoring and study due to its importance on ecological and social point of view. Precautions must be taken for reducing the unwanted lose of species diversity while harvesting.

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Appendices

Appendix 1 Fig. I Study Site

Appendix 2 Fig. II Showing the gears using for the fishery.

Appendix 3 Fig. III Group wise diversity of mussel bed associated flora and fauna

Appendix 4 Fig. IV Species diversity of each phylum.

Appendix 5 Fig. V Group wise species contribution of mussel bed associated fauna.

Appendix 6 Fig. VI Family wise fish species contribution.

Appendix 7 Fig. VII to XVIIIR world gg plot 2 the monthly species variations of different groups.

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