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Diversity, occurrence and socio-economic aspects of snappers and job fish (Family: Lutjanidae) fisheries from Gulf of Mannar region, south-east coast of India

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Survey were conducted in nine fish landing centres (Pamban South, Mandapam South, Keelakarai, Ervadi, Vembar, Tharuvaikulam, Thirespuram, Tuticorin and Amalinagar) along the Gulf of Mannar region to assess the diversity, catch rate of snappers and job fishes caught in different fishing gears. A total of thirty species of fishes belonging to the family Lutjanidae (snappers and job fishes) were identified which belonged to five genera viz., *Lutjanus*, *Pinjalo*, *Aphareus*, *Etelis* and *Pristipomoides*. Highest species diversity was observed in the gear, coral reef fish trap (24 species), followed by hook and line (21 species). Principal Component Analysis revealed four typical groups based on the fish species caught from five different gears. Fishes caught in hook & line, shrimp trawl net and fish trawl net formed individual group, whereas coral reef fish trap and bottom set gill net together formed another group. Mean CPUE values for the observed fishing practices varied significantly and the value were higher in the Fish trawl net (107±33.5 kg/ fishing trip). Sharing pattern of the fishery resources among the crew members varied between fishing villages and fishing practices.

[**Keywords:** Species composition, Catch per Unit Effort and Average daily revenue]

Introduction

The role of human activity on marine ecosystems is receiving increased attention with the perception that human activities are causing considerable economic loss for local fishing communities[1]. In particular, the increase in fishing pressure in tropical marine ecosystems over the past decade has caused shifts in species composition and habitat structure[2-4], species decline[5-7], depletion of carnivorous species and the dominance of fish from lower trophic levels[3], and reduced fish production[8-9]. The fishermen of Gulf of Mannar use different fishing practices based on the traditional knowledge to harvest the reef associated fishes based on seasonal pattern. The exploited reef fishes in Gulf of Mannar region have a good market value in the domestic market[10], the fishermen use different gear types, which results in variable fishing pressure on the reef area. In most of the South-east Asian countries, the reef fishes are mainly caught by the traditional sectors[11], however, the data on reef fisheries are very poorly documented[12].

The operations of trawl nets are difficult in coral reef areas and demersal traps are therefore the predominant gear used to harvest reef fishes[13]. Artisanal fishing in coral reef ecosystems is an important source of income and food for hundreds of thousands of coastal people in Gulf of Mannar region[14]. The traditional fishing sectors involved in reef fisheries in Gulf of Mannar target fish resources like snappers, groupers, parrot fish, grunts, goat fish and emperor fishes[15]. Among the fishes caught, the snappers have high diversity when compared to other food fishes. Lutjanidae and Serranidae considered as snapper – grouper complexes[16] are the key stone species in the reef ecosystem[17], as well as form the target species for the artisanal fishing sectors.

The fishes of this family have been targeted by the mechanized sectors due to its demand in the international seafood market. The small scale fishery sectors intensively exploit the reef fishery with non selective gears[18-20] and target fishing like hand line /hook line[21]. Most fishing in the tropical oceans is carried out by small-scale artisanal fishermen who largely use human power to generate large catches[22]. Tropical artisanal fishing is therefore a low expenditure and potentially high economic return activity, while the resources are not overexploited[23].

Survey was done on the fish landing centres of Gulf of Mannar to know the diversity of the fishes belonging to the family Lutjanidae (snappers and job fish), fishing methods employed in the exploitation of snappers and job fishes, the species composition of the catch from different gears, the catch per unit effort (CPUE) of the gears and catch revenue generated through the fishing practices in Gulf of Mannar region.

Materials and Methods

The study was conducted in the Gulf of Mannar region (Fig.1) from July 2011 to June 2012. The Gulf of Mannar National Park includes 21 coral islands covering an area of 560 sq.km, which is considered as the no-take-zone of the Gulf of Mannar Biosphere Reserve declared in 1989 under Man in Reserve Programme initiated by UNESCO. Along the Gulf of Mannar Marine National Park, around 89 fishing villages are located, whereas around 60% of the fishing communities depend on reef ecosystem for livelihood and protein source.

Monthly survey were conducted in 9 fish landing centres (Pamban South, Mandapam South, Keelakarai, Ervadi, Vembar, Tharuvaikulam, Thirespuram, Tuticorin and Amalinagar) along the Gulf of Mannar region (Fig. 1) to assess the diversity and catch rate of snappers and job fishes which were caught from different fishing gears for a period of one year (July 2011 to June 2012). The identification of the snappers and job fish was made through FAO Species Catalogue for Snappers[24]. The species composition, catch rate of snappers was recorded from different fishing gears operated in the study area.

The reef fish trap with single and double horse necked funnel (aperture size 4.5 cm) were used by the fishermen, whereas each trap measured about 3 feet in length, 4 feet in width and 2.5 feet in height, having a volume of 30 cu ft. The trap has a hexagonal shape made out of *Acacia* sp. barks. The barks are strapped together using wooden frames on both sides. These *Acacia* traps have a durability of about three to six months. The deployments of the trap were mainly done in the fringing reefs of the Gulf of Mannar Marine National Park region. The soak time (the time over which the trap was allowed to fish) was between 18 to 22 hours and the shrimp head was used as bait for catching the reef fishes. The traps were placed both in landward and seaward side of the coral islands on sandy bottom but not more than 3 m from the reef. The observations were made on 14 traps/month from 2 landing centres (Keelakarai and Mandapam) to know the diversity and catch potential.

Gill nets made of monofilament nylon netting with a mesh size of 80 mm were used in the collection of

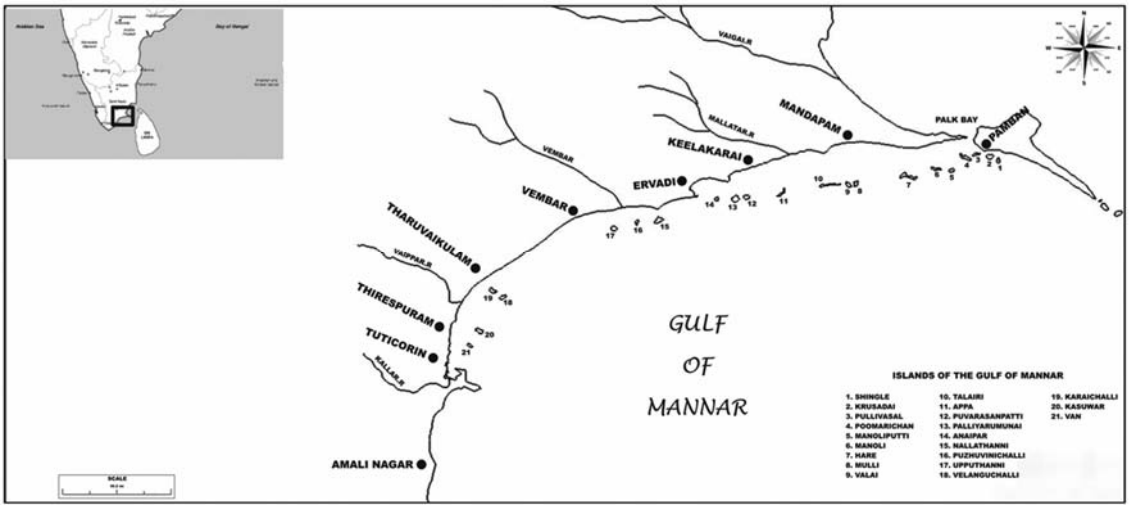


Fig. 1—Map showing the study area.

reef fishes. The nets were operated 3 hours before sunrise and hauled 1 hour after the sun rise. The depth of the net operated varied from 3 to 8 m, whereas the head rope of the net is around 20-27 m in length. During operation, 2 to 4 gill nets are interconnected and this type of fishing is practiced by the traditional sectors. The catch rate was assessed from 24 gill netters/month from 3 different stations *viz*., Tharuvaikulam, Vembar and Ervadi.

The hook number 8 to11 are used for the fishing of snappers and job fishes in water depth more than 75 m in Gulf of Mannar region. Each setting consisted of a sequence of similar hooks ('J'shaped) with 1000 to 1200 hooks for each setting locally called as '*Ayiramkal thoondil'*. The inter-space between two hooks was 1.5 m. All hooks were hand baited with squid wings or *Sardinella* sp., which ensured a homogenous baiting. The soak time varied from 5 to 9 hrs. A total of 12 settings/month were observed from 2 landing centres *viz.,* Thirespuram and Amalinagar.

The bottom trawlers (shrimp and fish) built of wooden planks extending to a length ranging between 9–12 m and a breadth of 3-4 m with a gross tonnage of 9 to 20 were used in Gulf of Mannar region to target the shrimp catch. The fishing of shrimp is carried out within a depth range of 10 to 45 m, whereas during each fishing period, 3 to 4 hauls are made with a towing period ranging from 1 to 1.3 hrs. The mesh size of the shrimp trawl net starts from 45 mm with a cod end mesh size of 20-15 mm. Around 21 shrimp trawlers/month were assessed from 3 landing centres *viz.,* Vembar, Mandapam and Pamban.

Fish trawlers are similar to the shrimp trawlers fishing within a depth regime of 12 to 55 m, with a mesh size of 400 mm to 25 mm at the cod end. Fishermen also deploy wooden rollers at the bottom of the foot rope which encourages the fishermen to trawl in hard bottom to target highly valued food fishes. Around 3 to 6 hauls are made during each fishing trip with a towing period of 1 to 2 hrs. Diversity and catch rate of snappers were assessed from 12 trawlers/month from 2 different stations (Tuticorin and Pamban).

Traditional fishers involved in fishing along the reef areas of the Gulf of Mannar Marine National Park supply fresh fish to their near by villages, since there is a great demand for fishes caught from these fishing gears (trap, bottom set gill net and hook and line). The domestic village market is active for 3-4 hours and the time duration depend upon the fishing practices. The fisher mostly sells their catch to fish traders (same fishing village or nearby villages) from whom they have taken advance money as loans. Sometimes, the traders provide financial help to the fishers, particularly during the off season like period of rough weather and fishing holidays (15th April – 31st May; 45 days). At present, strong pressure from the stakeholders for fishing snappers, groupers, emperors and Napoleon wrasses exists in the Gulf of Mannar region whereas the status /consequences of the stocks are not known.

Mostly the reef fishers target the demersal fishes, whereas in bottom set gill nets, molluscs (*Cymatium* spp., *Cypraea* sp., *Strombus canarium*, *Murex ramosus*, *Lambis* sp., *Babylonia spirata* and *Turbinella pyrum*) forms a good fishery as incidental catches. In the case of trap fishery, marine ornamental fishes (*Abudefduf vaigiensis*, *Acanthurus leucosternon*, *Acanthurus triostegus*, *Apolemichthys xanthurus*, *Chaetodon collare*, *Chaetodon octofasciatus*, *Chaetodon vagabundus*, *Cheilinus trilobatus*, *Coris formosa*, *Dascyllus trimaculatus*, *Heniochus acuminatus*, *Lactoria cornuta*, *Labroides dimidiatus*, *Neopomacentrus nemurus*, *Pomacanthus annularis*, *Pomacanthus imperator*, *Pomacanthus semicirculatus*, *Pomacentrus caeruleus*, *Pterois volitans*, *Thalassoma lunare*, *Zanclus cornutus* and *Zebrasoma veliferum*) provide a considerable income to the fishermen based on the domestic market demand.

All statistical analyses were performed with STATISTICA version 6.0. Measured variables were tested to normality and homogeneity by Spearmen Rank Correlation and the significance in all statistical test was judged at P= 0.005 level[25]. Catch per Unit Effort (CPUE) was calculated by using the Schaefer model[26].

All the recorded species data were log transformed [as log(x=1)] to meet the assumption of normality and homoscedasticity. The transformed data were subjected to Principal Component Analysis (PCA) and Cluster Analysis (CA) to determine variable groups with respect to different species. Since no fish species were recorded in hook and line, shrimp trawl and fish trawl nets during the month of May, the variables H5, S5 and F5 were not considered for data analysis. Cluster Analysis based on Paired group algorithm following Euclidean similarity measure was used to group gears having similarity in species recording. The cluster groups defined by Cluster Analysis were marked on the PCA ordination plot. All these multivariate analysis were run with the program PAST ver. 3.9[27].

Results

Thirty species of fishes belonging to the family Lutjanidae (snappers and job fishes) *viz*., *Lutjanus argentimaculatus*, *L. bengalensis*, *L. bohar*, *L .decussatus*, *L. ehrenbergii*, *L. erythropterus*, *L. fulviflamma*, *L. fulvus*, *L. gibbus*, *L. guilcheri*, *L. johnii*, *L. lemniscatus*, *L. lunulatus*, *L. lutjanus*, *L .malabaricus*, *L. madras*, *L. quinquelineatus*, *L. rivulatus*, *L. russelli*, *L. sanguienus*, *L. sebae*, *L. stellatus, L. vitta, Pinjalo lewisi, P. pinjalo*, *Aphareus furca*, *A. rutilans*, *Etelis radiosus*, *Pristipomoides filamentosus* and *P. multidens* were identified during the study period from five different fishing gears operated in Gulf of Mannar waters (Plate 1).

Four major groups were defined based on the species composition through the Cluster Analysis (Fig. 2). Coral reef fish trap and bottom set gill net together formed a group and separate cluster each for hook and line, shrimp trawl net and fish trawl net based on the species caught from these fishing gears. The formation of groups based on species composition suggest that gears like hook and line, shrimp trawl net and fish trawl net are operated in different fishing ground while the trap and bottom set gill nets are operated in the same fishing ground.

The association of the fish species to different gear types is illustrated in the PCA graph (Fig. 3). It is evident that the use of 5 different gears forms four typical groups as found in cluster analysis. This can be inter-related with the fishing operation of different gears to that of specific ecological niches and at different depth levels. The hook and line fishing is done at greater depths (more than 75 m), while shrimp and trawl nets are operated at more or less at similar depths (~15 to 45 m). The coral reef fish trap and bottom set gill nets are operated at much shallower depths ranging from 1 to 7 m near the reef area thereby the possibility of similar fish species getting caught in these two gears are more.

Since the Eigen values of the first two components of the PCA are higher than 1 and their explained cumulative variance is 65.79%, the first two components were taken for plotting the ordination graphs. The first component explained 41.14% of the total variance and was positively correlated with all species except *P. lewisi, L. lutjanus, L. decussatus, L. gibbus, L. fulvus, L. lemniscatus* and *L. sanguienus* (23.3% species). Of these, the former three species are restricted only to coral reef fish trap while the latter four are observed both in coral reef fish trap and bottom set gill nets. The second component explained 24.65% of total variance and exhibited positive correlation with 56.6% of the species caught.

Similarly, when the gears are compared with the ordination plot in PCA, the first component separates

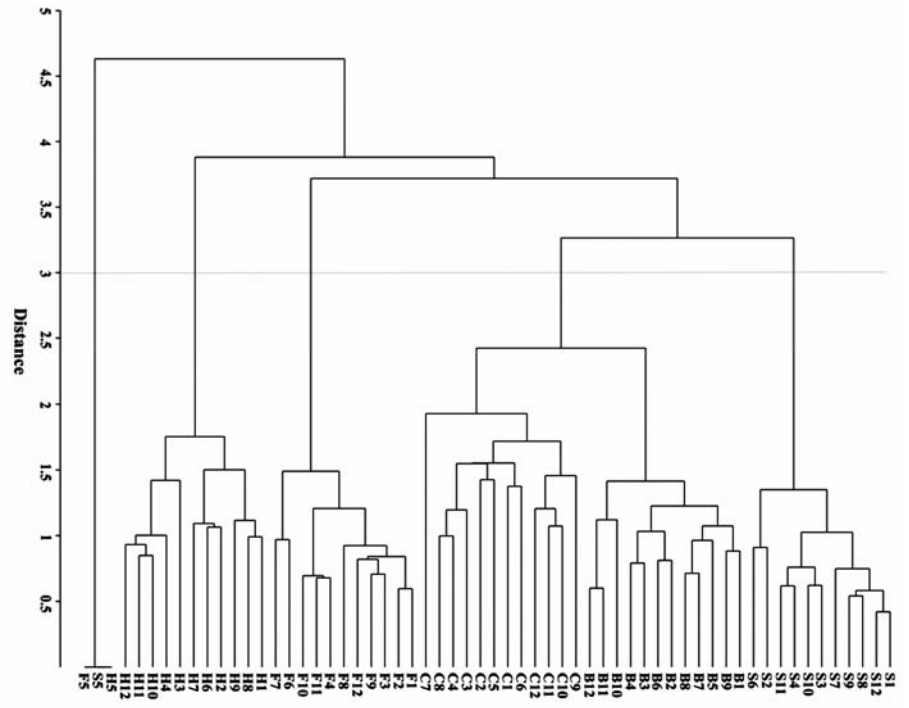
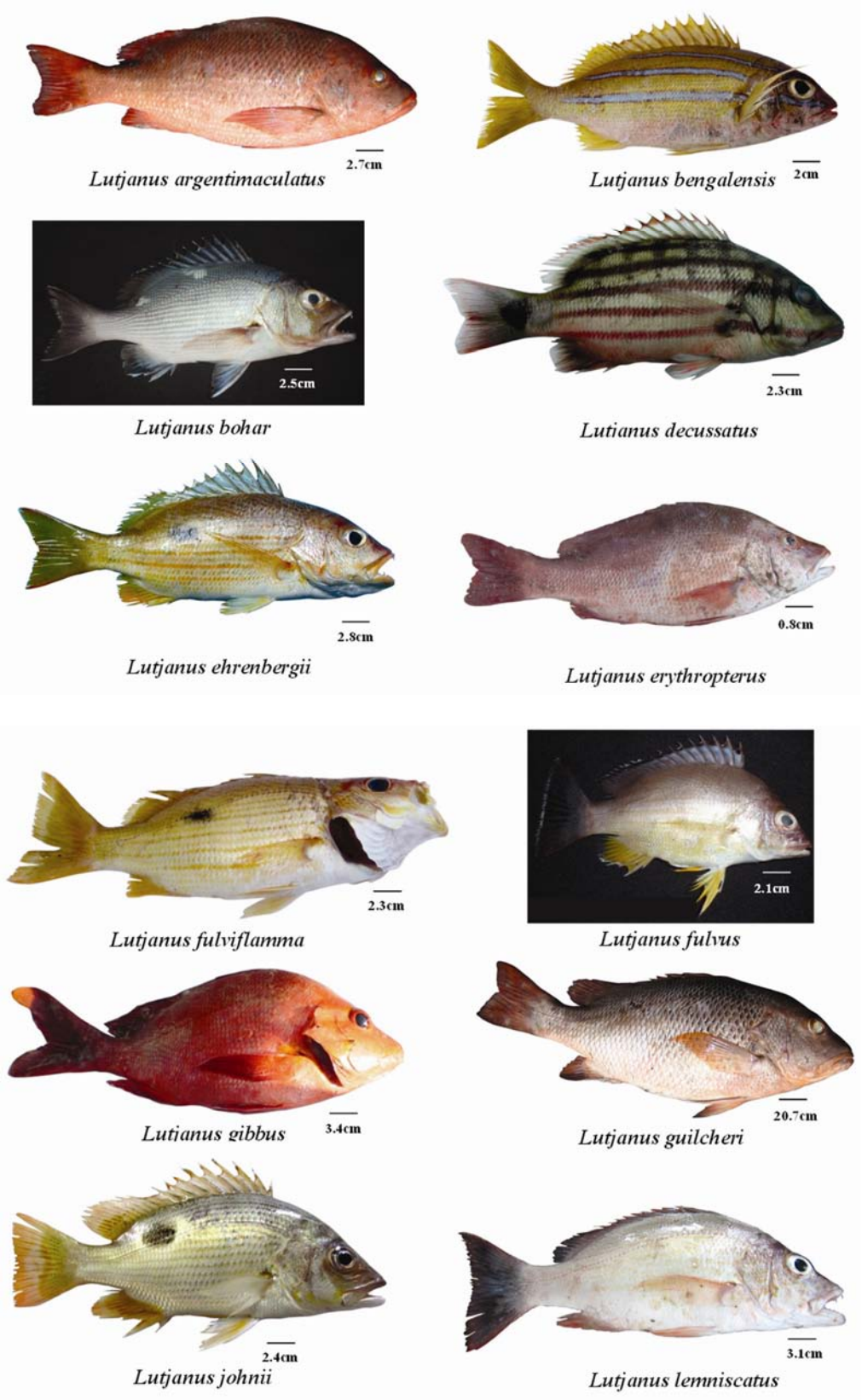


Fig. 2—Cluster analysis of different fishing gears and fish species


2.7cm
Lutjanus argentimaculatus
2cm
Lutjanus bengalensis
2.5cm
Lutjanus bohar
2.3cm
Lutianus decussatus
2.8cm
Lutjanus ehrenbergii
0.8cm
Lutjanus erythropterus
2.3cm
Lutjanus fulviflamma
2.1cm
Lutjanus fulvus
3.4cm
Lutianus gibbus
20.7cm
Lutjanus guilcheri
2.4cm
Lutjanus johnii
3.1cm
Lutjanus lemniscatus

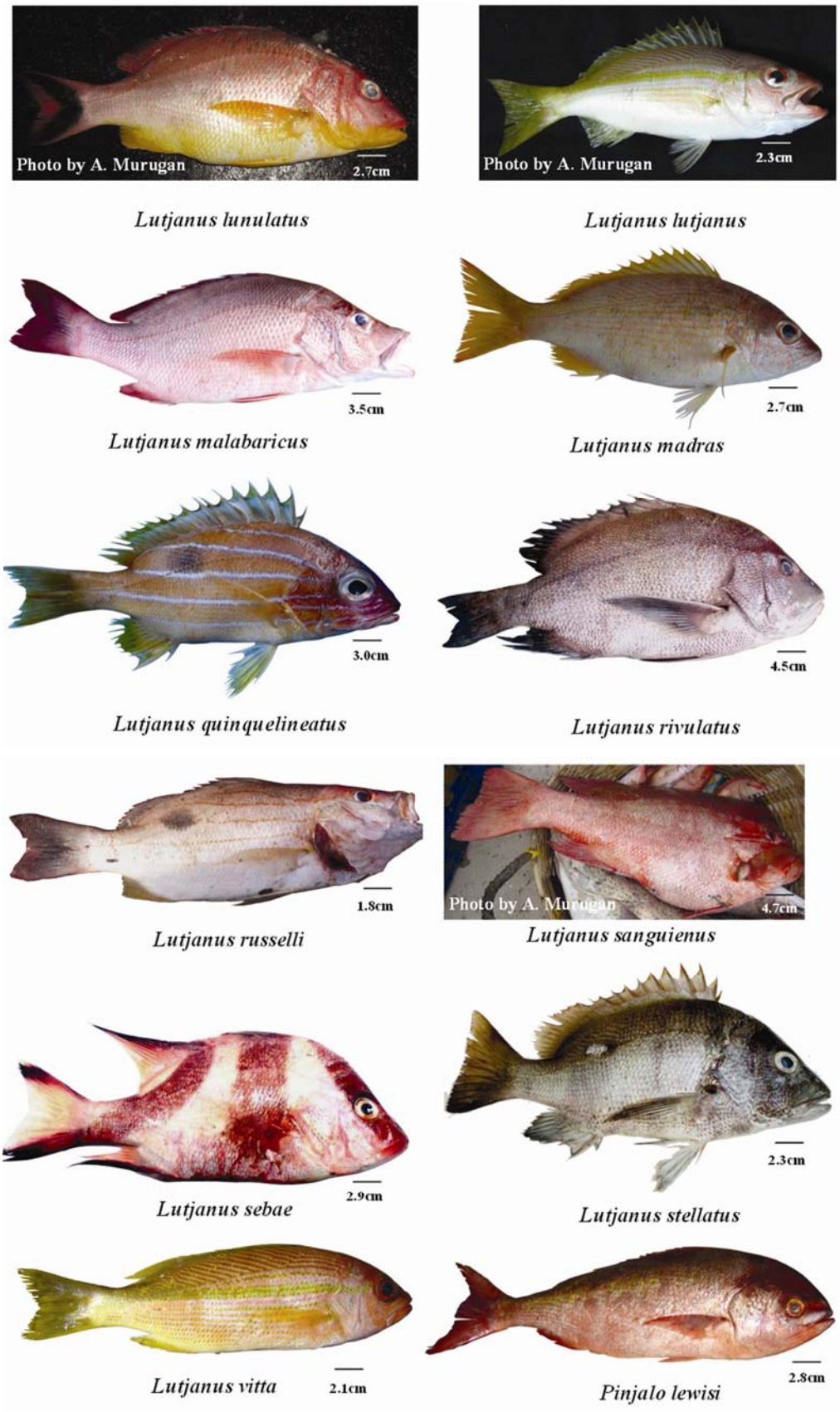


Photo by A. Murugan
2.7cm
Lutjanus lunulatus
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Lutjanus lutjanus
3.5cm
Lutjanus malabaricus
2.7cm
Lutjanus madras
3.0cm
Lutjanus quinquelineatus
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Lutjanus rivulatus
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Lutjanus russelli
Photo by A. Murugan
4.7cm
Lutjanus sanguienus
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Lutjanus stellatus
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Lutjanus vitta
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Pinjalo lewisi

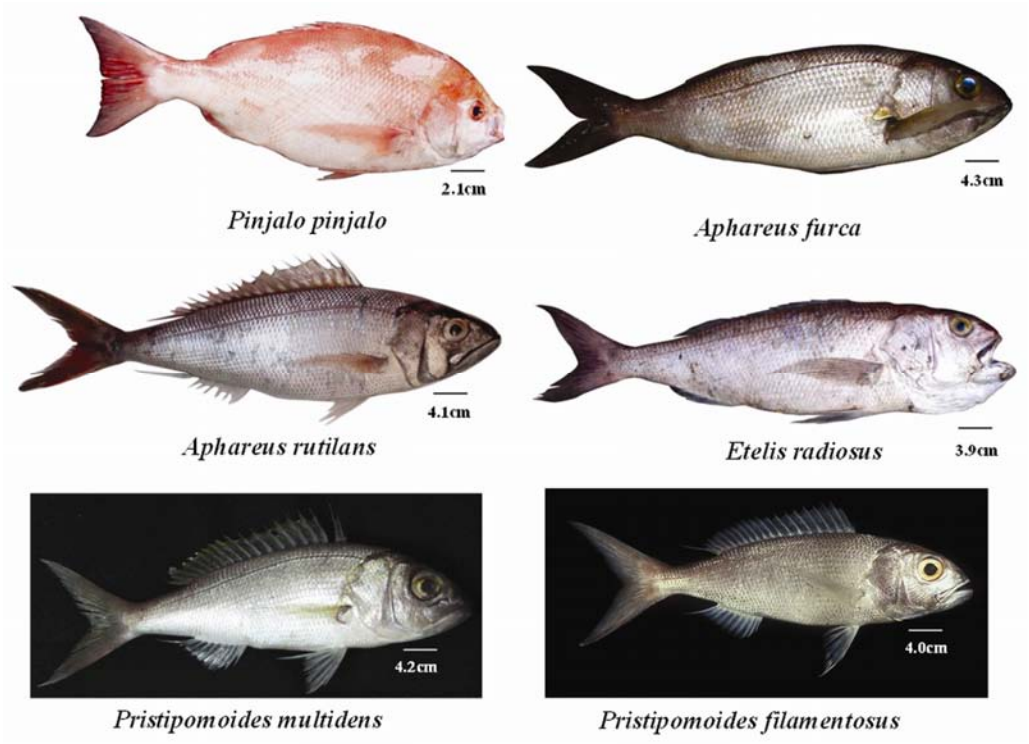

Plate 1

the fish and shrimp trawl nets from coral reef fish trap and bottom set gill nets; whereas, the hook and line gear shares some species restricted to the other gear types. The second component separates hook and line from all other gear types; which means, the species restricted only to this type of gear is differentiated from others. The association of the fish species to different gear types is illustrated in the PCA graph (Fig. 3).

Seven species of snapper *viz*., *L. fulviflamma, L. fulvus, L. malabaricus*, *L. quinquelineatus, L. rivulatus, L. russelli and L. sanguienus* were recorded in all gear types which reveals that these species are not restricted to any certain gear types or ecological niches. Seven species *viz*., *L. argentimaculatus, L. bengalensis, L. johnii, L. lemniscatus, L. lutjanus, L. stellatus* and *L. vitta* were observed in four gears while four species *viz*., *L. decussatus, L. erythropterus, L. gibbus* and *P. multidens* were observed in three gears. Four species *viz*., *L. bohar, L. lunulatus, L. sebae, P. lewisi* were recorded only from two gears whereas eight species *viz*., *L. ehrenbergii, L. guilcheri*, *L. madras*, *P. pinjalo, Pristipomoides filamentosus, A. furca, A. rutilans* and *Etelis radiosus* were observed only in one gear type.

Among the 30 identified species observed during the study period, around 24, 14, 21, 14 and 18 species were observed for coral reef fish trap, bottom set gill net, Hook and line, shrimp trawl net and fish trawl net respectively (Table 1). The coral reef trap fishery provided ample information about the species diversity of snappers in the Gulf of Mannar region, since this fishing practice is done exclusively in the reef ecosystem. The percentage occurrence of major species for different fishing gears is shown in Figs 4 to 8. The most frequently caught snappers appeared to be *L. fulviflamma* and *L. fulvus* in coral reef fish traps and gill net, whereas in shrimp trawl net and Hook and line fishing practices *Lutjanus argentimaculatus* and *L. rivulatus* appeared to be the dominant species in the catches. In fish trawl net, the occurrence of *L. quinquelineatus* and *L. fulvus* occurrence was on the higher side when compared to other snappers and job fishes caught.

Mean CPUE of snapper was considerably higher in the fish trawl net (Table 2). The mean CPUE values for the observed fishing practices varied significantly (P<0.05). In trap fishing, highest CPUE value of 8.2 was observed in the month of October 2011, while the lowest value of

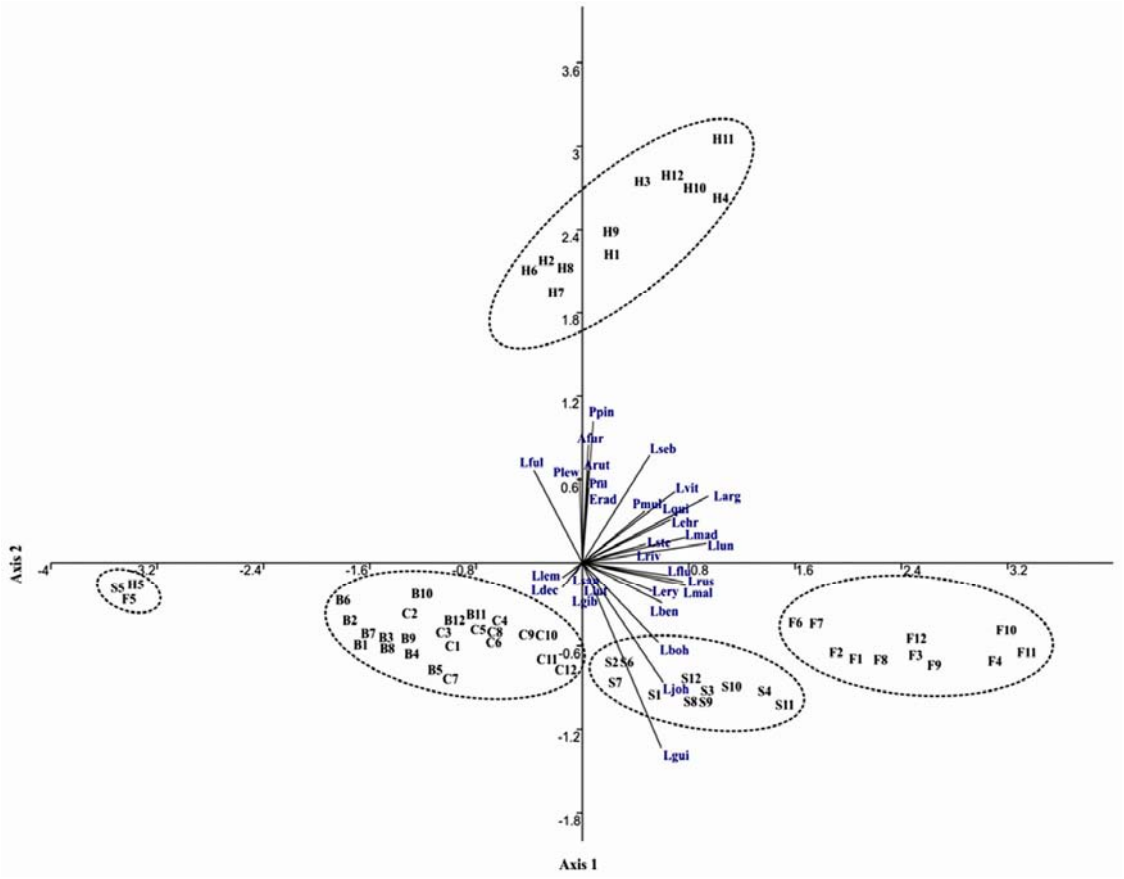

Fig. 3—Principal Component Analysis (PCA) of different fishing gears and fish species. Species name abbreviated as: *Lseb-Lutjanus sebae, Lvit-Lutjanus vita, Larg- Lutjanus argentimaculatus, Lqui- Lutjanus quinquelineatus, Lehr-Lutjanus ehrenbergii*, *Lmad-Lutjanus madras, Llun-Lutjanus lunulatu, Lriv-Lutjanus rivulatus, Lste-Lutjanus stellatus, Lflu-, Lrus- Lutjanus russelli, Lmal-Lutjanus malabaricus*, *Lery-Lutjanus erythropterus*, Lben-*Lutjanus bengalensis* Lboh-*Lutjanus bohar, Ljoh-Lutjanus johnii, Lgui-Lutjanus guilcheri, Lgib-Lutjanus gibbus, Llut-Lutjanus lutjanus, Lsan-Lutjanus sanguienus, Ldec-Lutjanus decussates, Llem-Lutjanus lemniscatus, Lful-Lutjanus fulvus, Lflu-Lutjanus fulviflamma*, *Plew:Pinjalo lewisi, Ppin-Pinjalo pinjalo, Arut-Aphareus rutilans, Afur-Aphareus furca, Erad-Etelis radiosus, Pfil-Pristipomoides filamentosus, Pmul-Pristipomoides multidens.*

3.8 was observed in February 2012. In bottom set gill net, highest CPUE value was observed in October 2011 (46) while the lowest value was observed in January 2012 (17.6). In hook and line fishery, CPUE value was highest in September 2011 (99.5) while the value was lowest in February 2012 (39.7). In shrimp trawl net, highest CPUE value was observed in June 2012 (65.9), while the lowest value was observed in September 2011 (23.6). In fish trawl net, the highest and lowest CPUE values were observed in June 2012 (107) and January 2012 (30.5) respectively. A significant difference (P<0.05) in the mean CPUE values was observed while comparing within the active and passive gears (Table 3).

The average daily revenue generated for each fishing activities was calculated based on the total catch of the gear (Table 4). The average monthly income of fishermen operating the different gears is depicted in Figs 9 to 13. The price of fishes in Gulf of Mannar region is driven by the stakeholders (purchasing agents/processing unit) and the price rate varies since the selling of fishes is done by auction mode. The snappers like *Lutjanus argentimaculatus*, *L. malabaricus*, *L. rivulatus* and *L. stellatus* fetched good income when compared to other species. The sharing pattern of the fishery resources between the crew mainly depend on the type of relationship with the boat owners, whereas the sharing pattern varied spatially along the Gulf of Mannar coast.

Table 1—Gear-wise species occurrence during the study period (2011-12)

Species	Coral reef fish trap	Bottom set gill net	Hook & line	Shrimp trawl net	Fish trawl net
L. argentimaculatus	+	-	+	+	+
L. bengalensis	+	+	+	-	+
L. bohar	+	-	-	-	+
L. decussatus	+	-	-	+	+
L. ehrenbergii	+	-	-	-	-
L. erythropterus	+	-	+	-	+
L. fluviflamma	+	+	+	+	+
L. fulvus	+	+	+	+	+
L. gibbus	+	+	+	-	-
L. guilcheri	+	-	-	-	-
L. johnii	+	+	-	+	+
L. lemniscatus	+	+	-	+	+
L. lunulatus	+	+	-	-	-
L. lutjanus	+	-	+	+	+
L. madras	+	-	-	-	-
L. malabaricus	+	+	+	+	+
L. quinquelineatus	+	+	+	+	+
L. rivulatus	+	+	+	+	+
L. russelli	+	+	+	+	+
L. sanguienus	+	+	+	+	+
L. sebae	+	+	-	-	-
L. stellatus	+	+	+	-	+
L. vitta	+	-	+	+	+
P. lewisi	+	-	+	-	-
P. pinjalo	-	-	+	-	-
Aphareus furca	-	-	+	-	-
A. rutilans	-	-	+	-	-
Etelis radiosus	-	-	+	-	-
Pristipomoides filamentosus	-	-	+	-	-
P. multidens	-	-	+	+	+

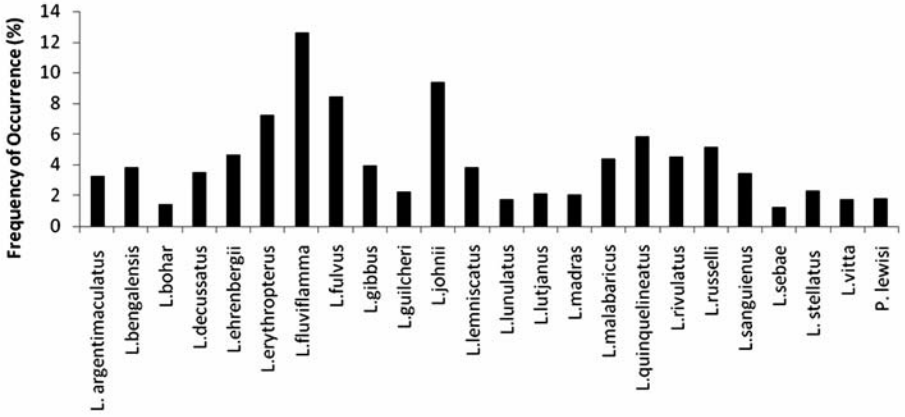

Fig. 4—Percentage composition of coral reef trap catch by frequency of occurrence.

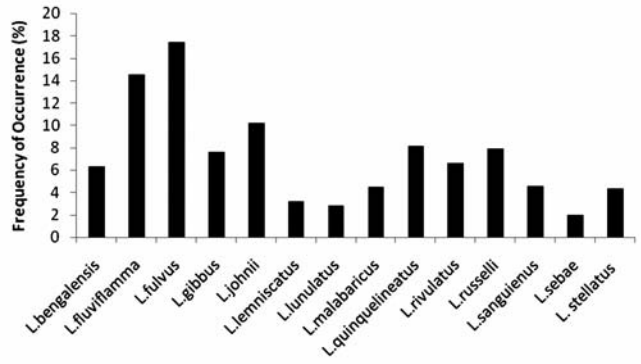

Fig. 5—Percentage composition of bottom set gill net catch by frequency of occurrence.

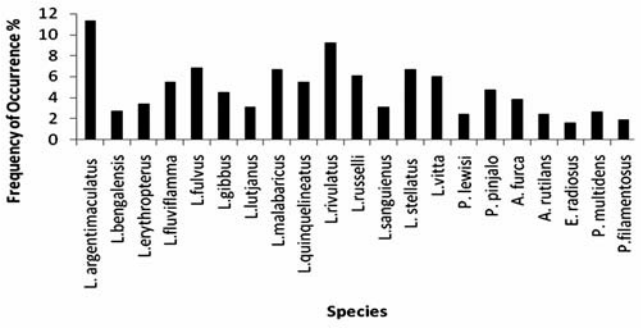

Fig. 6—Percentage composition of hook and line catch by frequency of occurrence.

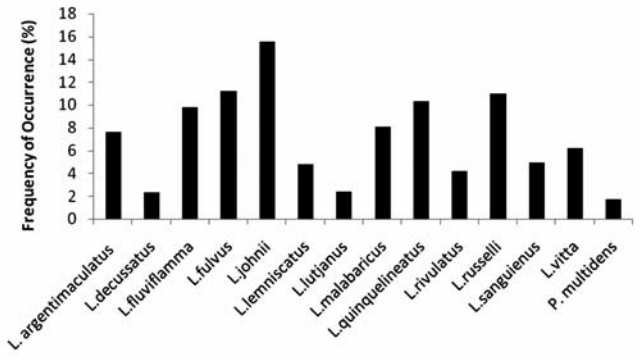

Fig. 7—Percentage composition of shrimp trawl net catch by frequency of occurrence.

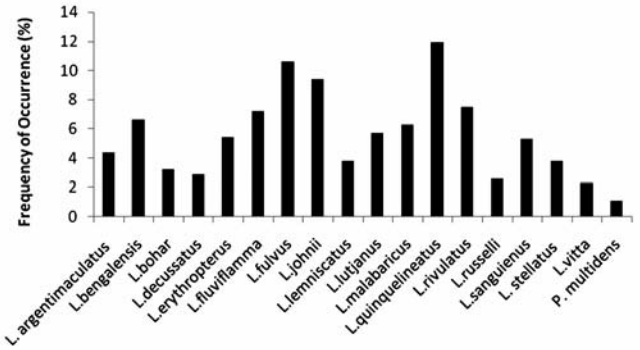

Fig. 8—Percentage composition of fish trawl net catch by frequency of occurrence.

Table 2—Mean CPUE recorded during the study period (2011-12)

Months	Coral reef fish trap (n=14)	Bottom set gill net (n=22)	Hook & line (n=12)	Shrimp trawl net (n=21)	Fish trawl net (n=9)
July	6.1±0.5	18.4±1.5	53.1±4.8	30.4±19.2	75.2±40.3
August	5.5±0.4	30.7±2	76.8±10.1	28.8±23.5	65.1±29.8
September	5.9±0.9	41.6±4.8	99.5±12.5	23.6±20.8	64.5±41.4
October	8.2±1	46.9±7.1	90.3±14.8	32.9±25.9	84.3±16.1
November	7.7±0.4	38.2±4.9	76.3±9.3	35.7±20.6	73.7±19.6
December	6.7±0.6	23.3±3.5	61.5±8.2	33.8±12.3	44.6±14.9
January	5.6±1.2	17.6±2.7	45.9±4.5	35±16.9	30.5±12.4
February	3.8±0.7	19.7±5.2	39.7±3.3	34.2±21.3	37.4±18.9
March	4.6±0.5	29.9±4.3	54.8±5.9	48.5±10.6	67.6±14.7
April	5.4±1.3	37.4±2.9	68.6±7.2	42.5±9.7	72.2±19.3
May	6.1±0.2	23.3±3.2	0	0	0
June	5.4±0.7	19.2±2.2	48.2±6.6	65.9±16.8	107±35.5

Table 3—Comparison of mean CPUE values within the active and passive gears

Pairs of Variable	Spearman Rank Correlation	P-Level	Significance
Trap and Bottom set gill net	-0.237	0.4568	< 0.05
Trap and Hook and Line	-0.223	0.4844	< 0.05
Bottom set gill net and Hook and Line	0.898	0.0084	< 0.05
Fish Trawl net and Shrimp Trawl net	0.629	0.0283	< 0.05

Table 4—Estimated average fishing income (excluding the operation expenditure) during 2011-12

Gears	Average number of fishing per week	Estimated Average income/ fishing trip (in Rs.)
Coral reef fish trap	5.5	2086.2±546.5 (n=168)
Bottom set gill net	4	1616±686.2 (n=264)
Hook &line	3	18579.4±2730.9 (n= 132)
Shrimp trawl net	2.5	15075±4312.2 (n=231)
Fish trawl net	2	17763.3±4021.1 (n=99)

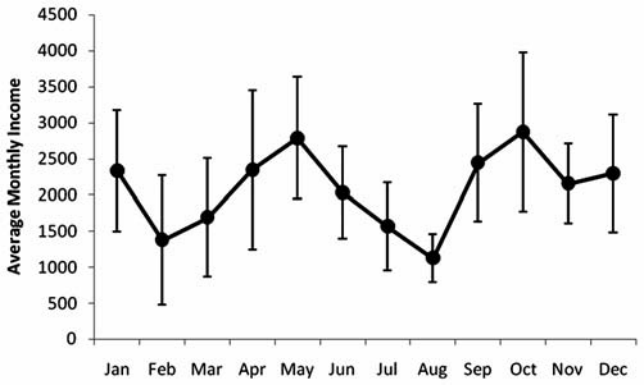

Fig. 9—Average monthly income for coral reef trap operation.

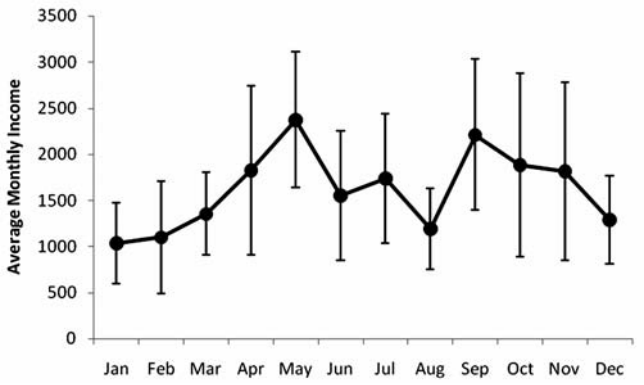

Fig. 10—Average monthly income for bottom set gill net operation.

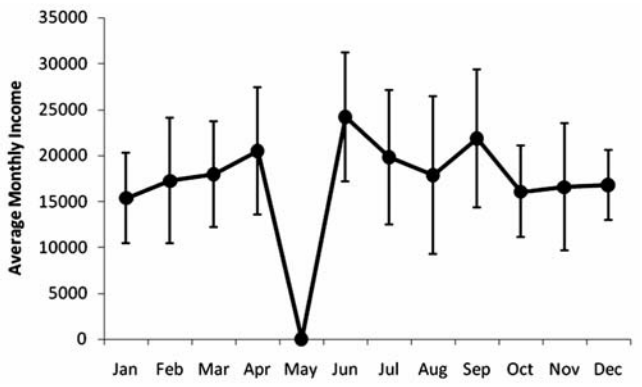

Fig. 11—Average monthly income for hook and line operation.

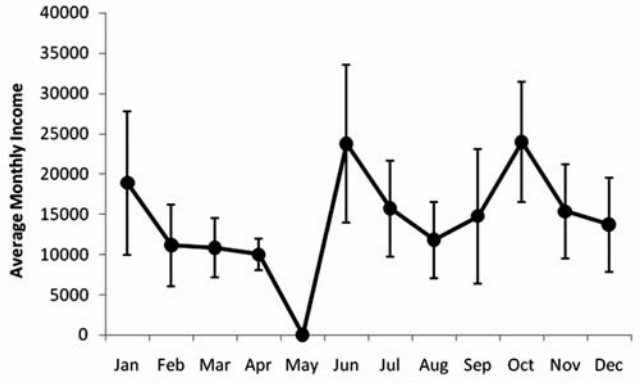

Fig. 12—Average monthly income for shrimp trawl net operation.

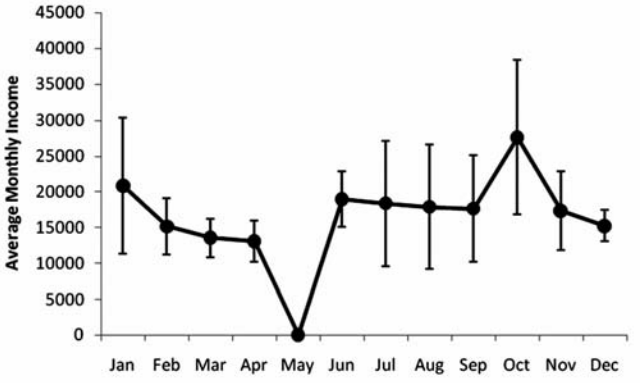

Fig. 13—Average monthly income for fish trawl net operation.

Discussion

The demand for live seafood in Asia has spawned a lucrative trade in live coral reef fishes[28]; whereas in Indian scenario, the chilled fish export industry depend mostly on the reef fisheries and as of now no Live Reef Fish Trade (LRFT) exist in Gulf of Mannar even though candidate species for those trade are available in considerable quantities like snappers (*Lutjanus* spp.), hinds (*Cephalopholis* spp.), groupers (*Epinephelus* spp.) and Napoleon wrasses

(*Cheilinus undulatus*). Coral reef biologists and geologists agree that fishing is one of the biggest human-induced factors affecting the ecology and diversity of coral reefs[29-30] and it is true in the case for Gulf of Mannar also[31]. Fishing has a number of direct and indirect effects on reef communities such as reduction in species diversity, alteration in the size structure of target species, and cascading effects on other reef fish species composition, biomass and density[32-35] and reducing the live coral cover[36].

Demersal reef fishes were mainly caught by the artisanal fishermen from the reef ecosystem; especially snappers and groupers are the most intensively fished taxa on the reefs round the world[37]. Around 43 species of snappers has been recorded from Indian waters, of which 22 species has been recorded from Cochin waters, 17 from Mandapam, 11 from Vizhinjam, 10 from Veraval and 6 from Visakhapatnam[38]. Around 42 species of fishes belonging to the family Lutjanidae has been recorded from the Srilankan waters which include Gulf of Mannar falling within the Srilankan territory also[39]. In the present study, 30 species of fishes belonging to the family Lutjanidae has been recorded from Gulf of Mannar, whereas the previous report has recorded 17 species[38]. The major reason for the high diversity of snappers might be due to the interrelationship between coral reef, seagrass, rocky substratum and mangrove ecosystem which is a unique trait of the Gulf of Mannar region[38], which helps in the recruitment of this diverse family. Even though the present study recorded 30 species belonging to the family Lutjanidae, intensive periodical surveys including underwater surveys in the reef ecosystem may help to unravel and upgrade the diversity of fishes of this family, as the present study was based only on the fish landed in the landing sites.

The snappers caught from different gears indicate that species diversity/composition was more in fishing activities near the reef areas especially in traps (24 species). The study also suggests that the fishes coming under the category of job fishes were mainly caught by hook and line fishing and they are caught mainly in deeper waters (more than 75 m). The overall high taxonomic diversity of catches per gear type illustrates the multispecies fishery in the study area. However, most small-scale reef fishers especially trap and gill netters are forced to select fishing locations around the Gulf of Mannar Marine National Park, owing to the proximity from their villages and also due to their small nature of operations. In the absence of time series observations on fish composition at all permanent landing centres around the Gulf of Mannar region, it is very hard to describe a fishery through spatial comparison, since Gulf of Mannar Marine National Park include 21 uninhabited islands and the diversity of fish varies between reef since oceanographic and geographic features varies [40].

Catch rates for the most important reef fishery like gill net and hook & line; have already been shown to be significantly different between areas, characterized by shelf zone, latitude and water depth and between seasons[41-42]. In the present study, the catch rates for all observed gears varied significantly on a monthly basis (P<0.005). Among the observed gears operated in the Gulf of Mannar, hook and line was most effective in the exploitation of snappers (39.7 to 99.5 kg/effort) when compared to coral reef fish trap (3.8 to 8.2 kg/trap) and bottom set gill net (17.6 to 46.9 kg/effort). In the Gulf of Mannar waters, exploitation of snapper has been carried out from 15 to 45 m depth and the catch rate of snappers from fish trawl net/roller net (30.5 to 107 kg/effort) was higher when compared to shrimp trawl net (23.6 to 65.9 kg/effort). The CPUE estimates obtained in this study are substantially higher in a multiple species catching gears especially for snappers and the results obtained could not be compared with snappers caught from other reefs of the country where artisanal reef fisheries/mechanized fishing are in practices. Also, the fishing pressure in the Gulf of Mannar waters is quite high when compared to the other coral reef ecosystems of the country like Andaman and Lakshadweep waters.

The catch composition for hook and line, trap and gillnet was dominated by predatory fish especially the indicator species like snappers, groupers and parrot fish, indicating the healthiness of the ecosystem. Furthermore, the presence of outside fishers especially from Kanyakumari district suggests that fish stocks here are relatively abundant compared to other areas like the wadge bank region (Kanyakumari to Vizhinjam coast), which is considered an area rich in fish biomass and diversity[43]. The target fishing for predatory fishes especially snappers, groupers, parrot fish, seer fish, carangids and emperor fish need to be monitored closely to know the changing pattern in the reef associated fishery.

Artisanal fisheries constitute an important socio-economic component of coastal communities of Gulf of Mannar region. Studies on fishing effort

dynamics have been mainly focused on long-term decisions of fishers[44-45]. However, it is in the short-term that fishermen make their spatial decisions for selecting the fishing ground and target species[46-48] defining what is called 'fishing tactics'[49-50]. The fishing tactics of artisanal and mechanized fishing is closely related to the socio-economic status of the fishers, which also provide useful insights about fishermen's behaviour and spatio-temporal resource dynamics[51]. The present study on socio-economic provides baseline information about the catch revenues generated through different fishing practices operated in the Gulf of Mannar region. The fishes that have high demand become targeted resources among the artisanal fishermen during a particular season/month. This traditional knowledge on the seasonal fishing needs to be documented to improve the socio-economic status of the artisanal fishers. Even though the present study has focused on the socio-economic status of the artisanal fishing and mechanized fishing sectors, the sharing pattern of the resources between the boat crew and the owner need to be documented which will be useful for the managers for drafting policy decisions for socio-economic upliftment of the fishing communities in the region.

Overexploitation is one of the principal threats to coral reef diversity, structure, function and resilience[52-53]. Although it is generally held that coral reef fisheries are unsustainable due to stakeholder pressure[54-55], little is known of the overall scale of exploitation or which reefs are over fished[56]. This is true in the case of Gulf of Mannar also, since the data on the fishery of the different islands are not properly documented. Reef fishing practices has profound effects on the ecology and recruitment of the reefs in Gulf of Mannar Marine National Park[38]. Catch rate for reef fishery varies between gears since these fishing practices are carried out in different areas and depth regimes[43], whereas the fishermen target mostly on the demersal reef fishes like snappers, groupers, rabbit fish and emperor fishes[57]. In Gulf of Mannar, the artisanal fishery considers snappers as one of the target resource while the snappers are incidental catches in the mechanized sector (shrimp and trawl nets). The hook and line fishing practice in Gulf of Mannar is an emerging practice which is gaining momentum at present due to declining fish catch in bottom trawls as well as due to encouragement by the Government.

The reefs cover an area of 62.61 km^2 (include live coral cover and dead coral with macro algae) within the 2 to 6 m depth contour in Gulf of Mannar[58]. Fishing on the coral reef area is the major source of livelihood by the traditional sector sheltering near the Gulf of Mannar Marine National Park (reef fish, marine ornamental fish, gastropod, blue crab, lobsters and seaweed collection). The reef fishery in GOMNP is a multi-specific, however due to the abundance and economical value some species are targeted (Groupers, Snappers, Seer fish and Emperors). Among the nets used for fishing in the reef region, gill net fishers showed the highest number of contacts with live coral reefs[15]; similar observations have been reported from the reefs of South-east Asia[59]. A number of studies have also demonstrated that destructive fishing practices in many areas of the world that have led to reef degradation[60-62]. There is an immediate need to document the damages caused by various gears in the Gulf of Mannar coral reef area which would help the managers to devise appropriate mainstreaming measures for the sustainable utilization and conservation of coral reef resources.

Fisheries have collapsed in countries independent of resource wealth, education level, and quantity and quality of fisheries data[63]. The reasons for fishery failures are numerous. In many cases, greed, ignorance and stupidity overwhelmed scientific advice and common sense[64], while in others, inadequacy of scientific models, environmental variability, ignorance about natural systems, poor data, inadequate compliance with fishery regulations and short-term economic considerations led to fishery collapses[65-66]. In Gulf of Mannar, overexploitation of fishery resources is mainly due to the increased number of fishing gears and fishing in the same fishing grounds which induces conflict between the different sectors of the fishing communities[67].

The creation of marine reserves in representative and critical habitats can provide formal spatial protection for fishery stocks[68]. Social and economic considerations are important for successful establishment and acceptance of marine reserves[69-72]. In many cases, acceptance of marine reserves may be facilitated with education and direct local experience [73-74] a similar effort has been made in the study area by forming the Gulf of Mannar Biosphere Reserve Trust which works on the socio-economic aspects of fisher folk and biodiversity conservation. Even though Gulf of Mannar Marine National Park was established in 1986 and first of its kind in South Asia, the no–take–zones of the parks are not yet demarcated for its protection. The fishing communities are not ready to go out of the

no-take-zone for fishing since they target marine resources like the seaweeds, sea cumbers, molluscs, blue crab, reef fish and lobster through traditional fishing methods. Of course the strong south-west monsoon winds may restrict excessive exploitation by reducing fishing effort from June to September for the traditional and mechanized sectors; this seasonal weather pattern indirectly acts to conserve fish stocks in Gulf of Mannar region. In addition, the closed fishing season of 45 days (15th April to 29th May) for the bottom trawlers also reduces considerable fishing pressure on the Gulf of Mannar ecosystem[75].

The fishes belonging to the family Lutjanidae has been targeted both by the mechanized and artisanal sectors from the Gulf of Mannar region. Given our data, we suggest that the pressure on the reef fisheries will be high in coming decades which will have a direct effect on the health of the ecosystem as well as on the socio economic status of the dependent community. Since fisheries data on the reef fisheries are not properly documented the status of its fishery need to be mainstreamed which will be very much useful for the artisanal sectors to harvest the resources in a sustainable manner. Due to improper management plans fisheries like lobster and blue crab have declined to a very large extent in this ecosystem[76]. The CPUE of the artisanal fishing activities is presented in this study; if the CPUE of the artisanal fishing reduces the fishermen will not falter to reduce the mesh size of the fishing nets, which will have a direct impact on the recruitment of reef fishes as well as the associated ecosystem. Since the fishermen use monofilament nylon net for fishing the snappers and other reef fishes the extent of damages caused to branching coral may be a huge threat to coral reefs of Gulf of Mannar Marine National Park. The no-take–zone of the Gulf of Mannar Biosphere Reserve need to be demarcated to reduce the fishing pressure since the artisanal fishing is practiced in those areas. By demarcating the no-take-zone the population status of the reef fisheries can improve and withhold the fishing pressure. In the mean time the 12 nautical mile fishing ban for bottom trawlers form the shore need to be implemented as per the new Coastal Regulation Act[77], which will ensure the livelihood of the artisanal fishing community to a large extent, as well as help in the restoration process of the degraded habitat.

Although most conservationists and managers prefer proactive management of reef fishes, the main hindrance for management strategies appear to be the lacuna on the data on reef fisheries[38]. The problems with describing the abundance and dynamics of fish population in the reef are well documented[78-80]. In the present study, the diversity and occurrence of snappers from different fishing gears are studied to provide the managers to know some facts of this taxa, which will be helpful while preparing the management plan for this Gulf of Mannar Biosphere Reserve.

Conclusion

At this point, it is not possible to determine conclusively the current status of reef associated and demersal fisheries in the Gulf of Mannar region. More research need to be focused on the documentation of reef fisheries which will provide information about the diversity of reef associated fishes, exploitation rate and impact of artisanal fishing activities in the reef region. Steps need to be undertaken by fishery managers to initiate precautionary policies which will conserve reef resources in the long-term scenario with the participation of the fishing community. In the lacuna of information on the diversity, exploitation rate and socio economic information associated with reef fisheries this study serves as an important starting point for understanding the reef fish diversity in the Gulf of Mannar waters and its associated socio economic issues.

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