Indian Journal of Geo Marine Sciences
Vol. 40(3), June 2011, pp. 411-423

Fishery biology, demography of three spotted seahorse, *Hippocampus trimaculatus* inhabiting Gulf of Mannar region, Southeast coast of India.

A. Murugan[1*], S. Dhanya[2], A.B. Sarcar[1], V. Naganathan[1],
S. Rajagopal[3] & T. Balasubramanian[3]

[1*]Gulf of Mannar Biosphere Reserve Trust (GOMBRT), 102/26 Jawan Bhavan, Kenikarai, Ramanathapuram-623 504, Tamilnadu, India

2Centre for Marine Living resources and Ecology, P.B.No. 5415, Kakkanad, Kochi, Kerala–682 037, India

3Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamilnadu– 608 502, India

[*][E.mail:arumugam.murugan@gmail.com]

Received 21 August 2009; revised 10 March 2010

Seahorse populations show social, spatial patterns in the wild and coupled with its biology that renders them more vulnerable to intense fishing. Seahorses are mainly exploited through gears like shrimp trawl net, country trawl net and shore seine operation and their catch is considered as fortuitous. During the demanding period target fishing like skin diving is also done. The ecosystem of the study area is well diverged with seagrass, seaweed and coral reef, which form the suitable habitat for these unique creatures. Present study provides the base line information regarding the species abundance, catch per unit effort, occurrence of brooding males, sex ratio for the four commonly found seahorses in the Gulf of Mannar. Length – weight relationship and growth studies were restricted to the dominant species *H. trimaculatus*. Information provided through the research will be helpful in the conservation of this unique creature since they are considered as endangered and placed in Schedule I of the Indian Wild Life Protection Act, 1972 from July, 2001.

[**Keywords:** Syngnathidae, seahorse, habitat preference, fishing gears, sex ratio, population parameters, brooding males]

Introduction

Seahorses are placed under the single genus *Hippocampus* that includes about 40 described species throughout the world[1-4]. The word *Hippocampus* was derived from the Greek word 'Hippos' meaning horse and 'campus' meaning sea monster[5]. Ancient poets used the word *Hippocampus* as a mythical creature on which God's of the sea rode. It is also believed that seahorses evolved 40 million years ago[6]. Seahorse is a popular fish for marine aquaria because of their unique appearance and their unusual mating system. Public aquaria and hobby aquarist are keen to close the life cycle in captivity but they were plagued by persistent problems, making seahorse captive breeding intractable[7-8]. Thailand was the only country to export live seahorses to Hong Kong in 1998 out of 256,000 HK$ of marine ornamental fish trade live seahorse included about 152,000 HK$[9], whereas the culture of seahorse for commercial and aquarium trade is practiced in 28 countries world wide[10]. In earlier days seahorses were mostly caught as by-catch during shrimp trawling, shore seine operation and country trawl net but in recent years (1995-2001) they are being caught by target fishing like skin diving because of the increasing demand geographically[11-12]and it is considered as the alternative species to depleting sea cucumber resources. Dried seahorses fetch about 300-400 US$ per kilogram in Hong Kong and China[1], whereas Rs.3-6 were paid to fisherman for a single seahorse in Gulf of Mannar and Palk bay region. In India (Palk bay region) the rate of the dried seahorse ranges from Rs. 2,000 to 4,700 per kilogram (dry weight) depending on their size[13], with huge profit for the stakeholder rather than the dependant community. In Coromandel coast the seahorse (*H. kelloggi*) fetches Rs.35-75/seahorse, this high price rate being due to its larger size and other seahorses (*H. spinosissimus* and *H. kuda*) fetch around 10-15/seahorse[14]. Every year over 20 million seahorses are bought and sold by more than 45 countries worldwide and majority of them are used

[*]Corresponding Author

in Traditional Chinese Medicine and less frequently in curiosity and marine aquarium trade[15].

The seahorse exhibits monogamous pair bonding behavior and they were site faithful[16], and the incidental capture of seahorse and other marine organism is now recognized as a serious problem in fisheries management and conservation[17-18]. As a conservative measure commercial aquaculture activity has been carried out globally[10] to reduce the pressure on the wild seahorses. Bottom trawl fisheries have been considered as the largest source for by-catch, accounting 35% of the world's total by-catch[19] as well as disturbing the ecosystem[20-21]. The conservation impacts on non-commercial fishes and invertebrate species remain unstudied[22] with fare amount of studies on Indian context[23]. Species, which comprise of a small portion in the by-catch, may also experience heavy loss in their population size and structure due to the long term effect[24]. Seahorses are affected mainly due to non-selective fishing gear operated for multiple species fishing in the shallow regions by traditional sectors and during exploitation of shrimp especially *Penaeus semisulcatus* and *Metapeneus* spp., on seagrass beds by shrimp trawl net, which leads these fishes to be vulnerable to overexploitation and disturbs the social pattern even though they are not targeted. The present study was undertaken to study the status of seahorse by-catch in Gulf of Mannar region in 3 different gears which are found to collect them from their habitat. Seahorse derived from by-catch appears to be contributing greatly to the large and growing international trade in these fishes round the world[25]. In our country captive breeding and culture of seahorses has been done for *H.trimaculatus*[26] and *H.kuda*[27] at present *H.kuda* is being cultured in National Institute of Oceanography, Goa) with an objective to conserve this unique creature.

Materials and Methods

Three stations were fixed viz. Rameswaram (Station I, N 09°16'861"; E 79°18'908"), Pamban (Station II, N 09°16'996"; E 79°12'661") and Mandapam (Station III, N 09°16'611"; E 79°09'086") along the Gulf of Mannar region (Fig. 1) to find out the exploitation rate because the habitat along this region constitutes a good feeding and breeding ground for seahorses. Regular sampling was carried out in the fixed stations from August 2002 to July, 2003. In these stations seahorses were caught as by-catch during shrimp trawling, shore seine operation (Kara

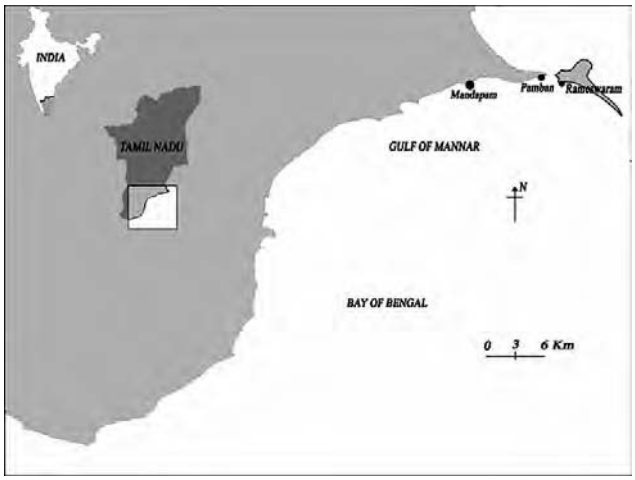

Fig.1—Map showing the study area

vallai and Ola vallai) and country trawl net (Thallu vallai) operation. These gears are operated in different ecological niches of Gulf of Mannar region, even fishing activities happen in the core region of the biosphere reserve. In the case of shrimp trawl net they were operated from 5 to 44 km offshore between 2.8 and 40.7 m deep water (25.84 ± 6.69 m) and spent around 8.2 ± 0.48 h actively trawling per night in Mandapam (South) and Pamban (South) with 4 to 6 tows per fishing trip and the fishing activity was carried out 6 days/week . In the case of Rameswaram the fishermen trawled from a depth range of 5 to 35 m depth (21.42 ± 8. 27 m) and spent around 16.8 ± 1.25 h actively trawling day and night with 16 to 20 sweeps per fishing trip, within the EEZ stretch of 5 to 35 km. The data collection was taken in trawlers which trawled in Gulf of Mannar water, where fishing happened thrice a week with fishing days commencing on viz. Monday, Wednesday and Saturday. The country trawl net was operated in shallow regions with depth range from 4 to 7 m (5.5 ± 1.58 m) and spents around 6 ± 1.28 hours trawling with the help of wind and had 5 to 7 tows per fishing trip, with each tow period of 1 h. Shore seine net was also operated in shallow regions covering a water spread area of~1.7 km^2, with depth range from 1-5 m (3.2±0.7 m) and the net was pulled towards the shore, with 1 or 2 operations per day depending on catch composition and biomass. The duration time for the net depended on how many persons were involved in dragging the net towards the shore, usually 25 to 30 peoples including women.

Seahorses caught from these gears were recorded and the species identification was done using the standard protocol[1]. Length (SL, from tip of snout to

tail end), sex, number of seahorses caught in different gears, numbers of brooding males, non brooding males were recorded. The number of young ones inside the brood pouch of males was recorded from dead seahorses. All the seahorses which were caught in shrimp trawlers had 0% survival; those caught by country trawl net has 45%, whereas all live seahorses could be noticed in shore seine operations (100% survival) at landings in the shore. Due to the lack of awareness and because of clandestine trade the fishermen were not willing to put the animal back to the marine ecosystem after encountering them in their fishing gear.

Length–weight relationship[28] and analysis of population parameters was restricted to the dominant species *H. trimaculatus*. The computer package FiSAT[29]developed by the International Living Aquatic Resources Management (ICLARM) and the Food and Agricultural Organization (FAO) was employed to find out the growth rate of *H. trimaculatus* in the wild. This method attempts to combine the principle of Peterson method and that of modal progression analysis method with a minimum of subjective inputs.

Data analyses

All statistical analyses were performed with PC based Minitab Version 8.3[30]. Measured variables were tested to normality and homogeneity by Cochran's test[31]. The Chi-square test was used to analyze the variation in sex-ratio of adult seahorses from a normal sex ratio of 1:1[32]. Regression analyses were used to assess the height and weight for male and female seahorses. Regression lines were compared by one-way ANOVA and the significance in all statistical tests was judged at a P=0.005 level. Catch per unit effort (CPUE) was calculated by using the Schaefer model[33].

Results

Totally 17,266 seahorses were caught from different gears for a period of one year in the fixed stations along Gulf of Mannar Biosphere reserve during 36 fishing day (Table 1). The seahorse caught from the fixed stations comprised of 4 species viz. *H. trimaculatus*, *H. kuda*, *H. spinosissimus* and *H. fuscus*. Shrimp trawl net, shore seine operation and country trawl nets which were operated in these regions. Among the total catch *H. trimaculatus* was found to be the dominant species (53.93%), followed by *H. kuda* (21.19%), *H. spinosissimus* (13.73%) and *H. fuscus* (11.15%). Among the stations the occurrence of seahorse was more in station III (Mandapam, 50.50%), followed by station I (Rameswaram, 33.32%) and station II (Pamban, 16.18%). The percentage occurrence of individual seahorse species based on the total catch for the fixed station is shown in Table 2.

Seahorses caught through incidental occurrence suggest October and April as the peak occurrence period for Gulf of Mannar region (Fig. 2). The monthly occurrence suggests that for seahorses like *H. trimaculatus* and *H. fuscus* the peak occurrence period was during October and low catch rate during February. In the case of *H. kuda* and *H. spinosissimus* the peak catch period was during April with low catch during July and February respectively.

In station I (Rameswaram) *H. trimaculatus* constituted about 53.25% of the total catch, *H. kuda* (21.42%), *H. spinosissimus* (12.92%) and *H. fuscus* (12.41%). Seahorses were mainly caught through shrimp trawling (74.97%), shore seine operation (16.85%) and country trawl net operation (8.18%). Seahorses caught in this region were mainly from seagrasses when compared to other habitat. In station II

Table 1—Total number of seahorse recorded during the study period

Station I	5754
Station II	2794
Station III	8718
Total	17,266

Table 2—Total seahorse recorded from the landing sites

Species	Rameswaram (No./%)	Pamban (No./%)	Mandapam (No./%)
H.trimaculatus	3064 (17.75)	1347 (7.80)	4902 (28.39)
H.kuda	1232 (7.14)	619 (3.59)	1806 (10.46)
H.spinosissimus	744 (4.31)	498 (2.88)	1129 (6.54)
H.fuscus	714 (4.41)	330 (1.90)	881 (5.10)

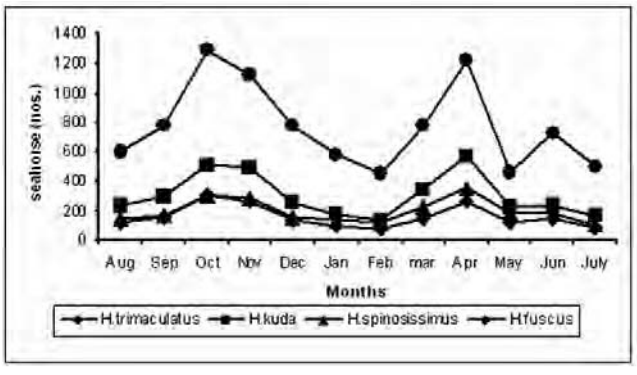

Fig. 2—Monthly occurrence of seahorses in landing sites of Gulf of Mannar region

(Pamban) the occurrence of *H. trimaculatus* was 48.20%, *H. kuda* (22.17%), *H. spinosissimus* (17.84%) and *H. fuscus* (11.79%). The gears used for collecting seahorse were shrimp trawling (49.50%), shore seine operation (17.85%) and country trawl net (32.65%). The habitat used by the seahorse in this region mainly constitute of dead coral reef, seagrass and seaweed. In station III (Mandapam) *H. trimaculatus* accounted about 56.23% of the total catch, *H. kuda* (20.71%), *H. spinosissimus* (12.95%) and *H. fuscus* (10.11%). In this region seahorse were mainly caught during shrimp trawling (95.84%) whereas shore seine operation constituted (4.16%). The holdfast used by the seahorse in this region mainly comprised of seagrass and seaweed (*Sargassum* spp.). The number of seahorses recorded from different gears during the study period is shown in Fig. 3.

Along with seahorse 104 species of fishes, 178 of invertebrates and 8 groups of marine fauna (not identified) were discarded as trash from shrimp trawl net (Tables 3 & 4). Since no effort has been made to study the species composition of the non-target organisms a preliminary attempt was made to know the identity of species affected by bottom trawling. At present all the non-target and undersized fauna are brought to the landing centers for it utilization in poultry feed and it is believed that it partially compensate the expenses for the purchase of ice blocks or fuel.

In all the three stations four species of seahorse were caught incidentally as by-catch in the above mentioned fishing gears. The number of seahorses per shrimp trawling ranged from 2 to 16/fishing day (approximately 8 hrs trawling the net); whereas in shore seine and country trawl net it varied from 2 to 23 fishing day (approximately 1.3 hrs seining the net) and 1 to 9 fishing day (approximately 6 hrs dragging the net) respectively. The CPUE for seahorse in all the stations for different gears is shown in Table 5. The CPUE for bottom trawl was higher in station III when compared to the other two stations, whereas the

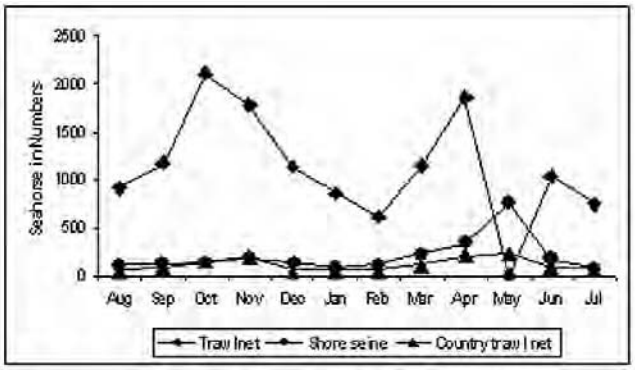

Fig. 3—Monthly gear wise occurrence of seahorses from Gulf of Mannar region

Table 3—Fish species recorded in the trash along with seahorses in Gulf of Mannar

Abalistes stellatus	*Chaetodon selene*	*Halieutaea indica*	*Pomadasys maculatus*
Abudefduf vaigiensis	*Chaetodon vagabundus*	*Lactoria cornuta*	*Priacanthus hamrur*
Acanthurus leucosternon	*Cheilnus trilobatus*	*Lagocephalous lunaris*	*Pseudanthias* spp.
Acanthurus mata	*Chiloscyllium griseum*	*Leiognathus dussumieri*	*Pseudorhombus elevatus*
Anacanthus barbatus	*Cirrhitichthys bleekeri*	*Leiognathus fasciatus*	*Pseudorhombus* sp.
Anthias spp.	*Ctenotrypauchen* sp.	*Leiognathus ruconius*	*Pseudotricanthus striglifer*
Apogon fasciatus	*Cyanoglossus punticeps*	*Lethrinus nebulosa*	*Pterocaesio chrysozona*
Apogon fraenatus	*Cyaanoglossus lingua*	*Lutjanus bengalensis*	*Pterois volitans*
Apogon moluccensis	*Cyanoglossus macrolepidotus*	*Lutjanus decussatus*	*Rhina ancylostoma*
Apogon nigripinnis	*Cyanoglossus semifasciatus*	*Lutjanus quinquelineatus*	*Rhinobatus annandalei*
Apolemichthys sp.	*Dactyloptena orientalis*	*Mypristis botche*	*Rhinobatus granulatus*
Arius jella	*Dascyllus trimaculatus*	*Mypristis kuntee*	*Sargocentron rubrum*
Arius maculatus	*Diodon holocanthus*	*Narcine timlei*	*Saurida undosquamis*
Arothron hispidus	*Diodon hystrix*	*Narcine lingula*	*Scolopsis bimaculatus*
Arothron immaculatus	*Dipterygonotus balteatus*	*Neotrygon kuhlii*	*Scolopsis vosmeri*
Arothron stellatus	*Epinepheleus diacanthus*	*Odonus niger*	*Sufflamen fraenatus*
Atherinomorus sp.	*Epinepheleus malabaricus*	*Parachaeturichthys* sp.	*Synchiropus lineolatus*
Bathycongrus spp.	*Euryglossa orientalis*	*Paramonocanthus spp.*	*Syngnathoides biaculeateus*
Bothus myriaster	*Eurypegasus draconis*	*Parapercis maculata*	*Trachyramphus seratus*
Bothus pantherinus	*Fistularia petimba*	*Parupeneus cyclostomus*	*Takifugu oblongus*
Canthigaster solandri	*Gymnothorax monostigma*	*Pegasus volitans*	*Tetrasoma gibbosus*
Centriscus scutatus	*Gymnothorax flavimarginatus*	*Pemperis* spp.	*Uranoscopus* spp.
Chaetodon auriga	*Gymnothorax meleagris*	*Pennahia anea*	*Xyrichtys bimaculatus*
Chaetodon collare	*Geres abbreviatus*	*Petroscrites mitratus*	*Xyrichtys cyanifrons*
Chaetodon lunula	*Geres filamentosus*	*Plotosus lineatus*	*Zebrasoma veliferum*
Chaetodon octofasciatus	*Halichoeres chlorurus*	*Pomacanthus imperator*	*Zebrias quagga*

Table 4—Invertebrates recorded in the trash along with seahorses in Gulf of Mannar

CRABS
Arcania erinaceus
Arcania novemspinosa
Calappa gallus
Calappa lophos
Calappa philargius
Carcinoplax longipes
Charybdis feriata
Chrybdis lucifera
Charybdis natator
Charybdis rostratum
Demania splendida
Doclea canalifera
Doclea ovis
Dorippe frascone
Dromia dehaani
Galene bispinosa
Halimede ochtodes
Myra fugax
Platylambrus prensor
Portunus gladiator
Portunus pelagicus
Portunus gracilimanus
Portunus sanguinolentus
Thalamita prymna
Thalamita crenata

GASTROPODS& BIVALVES
Amusium pleuronectes
Architectonica prespectiva
Babylonia spirata
Bulla ampulla
Bursa spinosa
Casius cornuta
Cardita bicolor
Cardium sp.
Conus amadis
Conus betulinus
Conus fugulinus
Conus monile
Conus augur
Conus bayani
Conus lentiginosus
Conus leopardus
Conus malacanus
Conus hyaena
Conus loroisii
Conus textile
Conus terebra
Conus inscriptus
Conus striatus
Conus achatinus
Conus virgo
Conus tessulatus
Conus zeylanicus
Conus caracteristicus
Cuculea cuculata
Cyprea tigris
Cyprea arabicana
Cypraea guttata
Cymatium perryi
Distorsio reticulata
Donax scortum
Donax cunneateus
Ficus gracilis
Ficus ficus
Ficus subintermedius
Fusinus longicaudatus
Gaffarium spp.
Harpa conoidalis
Hemifusus conchlidium
Hemifusus pugilinus
Hydatina velum
Lambis chiragra
Lophiotoma indica
Melo melo
Murex carbonnieri
Murex tribolosus
Meretrix meretrix
Meretrix casta
Natica didyma
Natica tigris
Nassarius dorsatus
Oliva gibbosa
Oliva oliva
Oliva spp.
Paphia malabaricus
Paphia textile
Phalium glaucum
Pinctada fucata
Pinna sp.
Pyrene sp.
Pecten spp.
Modious metcalfei
Solen kempi
Strombus canarium
Strombus marginatus
Sunneta scripta
Tonna dolium
Tona cummingi.
Tellina spp.
Telescopim telescopium
Tureitella acutangula
Trisodos tortuosa
Turriculana javana
Umbonium vestarium
Xanchus pyrum

CEPHALOPODS
Sepia inermis
Sepia pharaonis
Sepia aculeate
Sepia brevimana
Sepia prashadi
Octopus aegina
Octopus dulfusi
Octopus fusiformis
Loligo uyii
Loligo duvauceli

SHRIMPS
Penaeus monodon
Fenneropenaeus indicus
Penaeus semisulcatus
Melicertes latisulcatus
Melicertes canaliculatus
Penaeus merguiensis
Metapenaeus monoceros
Metapenaeus dobsonii
Metapenaeus affinis
Metapenaeus ensis
Metapenaeopsis stridulans
Metapenaeopsis sp.
Parapenaeopsis uncata
Parapenaeopsis stylifera
Parapenaeopsis coromandelica
Parapenaeopsis sculptilis
Parapenaeopsis sp.
Heterocarpus woodmasoni
Solenocera crassicornis

MANTIS SHRIMPS
Harpiosquilla annandalei
Harpiosquilla harpax
Harpiosquilla raphidea
Llysiosquilla tredecemdentata
Oratosquilla woodmasoni
Oratosquilla gonypetes
Oratosquilla holosctista
Oratosquilla nepa
Oratosquilla quinquedentata

SAND LOBSTERS
Thenus orientalis
Scyllarus martensii
Scyllarus sp.

PISTOL SHRIMPS
Alpheus malabaricus
Alpheus sp.

JELLY FISHES
Lobonema smithii
Chrysaora spp.
Acromitus flagellatus
Rhopilema hispidum

EHINODERMS
Holothuria atra
Holothuria scabra
Holothuria spinifera
Holothuria fuscogilva
Actinopyga echinites
Acaudina malpodioides
Pseudocolochrius violaceus
Stichopus varigatus
Salmacis bicolor
Salmacis virgulata
Stomopneustes variolaris
Tropiometra spp.
Lavenia spp.
Clypeaster spp.
Anthenea pentagonula
Astropecten indicus
Echinodiscus aurifus
Pentaceraster regulus
Poraster superbs
Protoreaster linckii
Stellaster equestris
Linckia levigata
Linckia spp.
Lucidia maculata
Ophiactis spp.

SEA ANEMONES
Heteractis magnifica
Stichodactyl haddonni

Nudibranchus
Polychaetes
Ghost shrimp
Soft coral
Ascidians
Gorgonids
Sponges
Corals

Table 5—Mean CPUE of seahorse from Gulf of Mannar region

Stations	Shrimp trawl(n)	CPUE/ Shrimp trawl	Shore seine(n)	CPUE/ Shore seine	Country trawl net(n)	CPUE/ Country trawl net
I	900	4.79 ± 1.12	90	10.77± 3.47	216	2.18 ± 0.89
II	432	3.20 ± 1.43	54	9.22 ± 2.80	360	2.53 ± 1.07
III	1332	6.27 ± 1.82	44	8.25 ± 2.04	-	-

CPUE for shore seine and country trawl net was higher in station I and III respectively.

The maximum size recorded during the study period was 156 mm for *H. trimaculatus*, 202 mm for *H. kuda*, 162 mm for *H. spinosissimus* and 198 mm for *H. fuscus*. Mean standard length and mean weight of the seahorse caught in these regions are shown in Table 6. Males were significantly longer than females ($P<0.05$) and had a greater weight when compared to that of females ($P<0.05$).

The sex ratio for all the species was female biased in the existing populations of Gulf of Mannar region. In *H. trimaculatus* the male: female ratio was 1:1.59 with a chi-square value of 17.5 (Table 7). For *H. kuda* the ratio was 1:1.35, whereas in *H. spinosissimus* the ratio was 1:1.5 and in *H. fuscus* the ratio was 1:1.6. Gear wise sex ratio shows that shrimp trawl net collected populations were dominated by female for all the observed species (Table 8). In shore seine net *H. fuscus* had higher occurrence of males when compared to females, whereas for other species females dominated in the catch. Country trawl net catch suggested higher occurrence of males in the catch for *H. trimaculatus* and *H. kuda*, whereas females dominated in *H. spinosissimus* and *H. fuscus*. The present occurrence of males, females and juveniles collected from the three stations were 33.71%, 53.13% and 13.6% respectively.

When a brooding male die the young ones which are present inside the seahorse brood pouch don't survive, but not in the case of species having parental care or that merely guard a brood. The percentage occurrences of brooding and non brooding males for all the four species were 52.01% and 47.99% respectively, suggesting that in all the three stations the number of brooding males was found higher when compared to non brooding males (Table 9).

Table 6—Sample size (n), mean and standard deviation for standard length (mm) and weight (g) of males, females and juvenile seahorse collected from Gulf of Mannar.

Species	Mean(SL) male	Mean(SL) female	Mean(SL) juvenile	Mean Weight(g) males	Mean weight(g) females	Mean weight(g) juveniles
H. trimaculatus	122 ± 36.4 n = 3176	115 ± 30.7 n = 5052	66 ± 15.1 n = 1085	5.6 ± 1.92	4.9 ± 1.34	2.7 ± 0.93
H. kuda	152 ± 48.2 n = 1384	143 ± 41.3 n = 1869	75 ± 13.8 n = 404	7.3 ± 2.01	6.8 ± 1.81	3.2 ± 0.85
H. spiniosissimus	135 ± 44.6 n = 825	127 ± 38.2 n = 1240	68 ± 14.4 n = 306	6.8 ± 1.84	5.2 ± 1.73	3.0 ± 0.71
H. fuscus	148 ± 40.9 n = 655	139 ± 41.7 n = 1045	72 ± 11.5 n = 225	7.0 ± 1.79	6.5 ± 1.77	2.8 ± 0.69

Table 7—Species – wise sex ratio of seahorses caught from Gulf of Mannar region.

Species	Male	Female	Male (%)	Female (%)	M:F	X^2	P-value
H.trimaculatus	3176	5052	38.6	61.4	1:1.59	17.5	NS (p=0.094)
H.kuda	1384	1869	42.55	57.45	1:1.35	2.56	NS (p=0.995)
H.spinosissimus	825	1240	39.95	60.05	1:1.5	4.33	NS (p=0.959)
H.fuscus	655	1045	38.52	61.48	1:1.6	6.48	NS (p=0.839)

Table 8—Gear-wise sex ratio for seahorses caught from Gulf of Mannar region.

Species	Male	Female	Male (%)	Female (%)	M:F	X^2	P-value
				Bottom trawl net			
H.trimaculatus	2638	4375	37.62	62.38	1:1.66	25.31	S (p=0.005)
H.kuda	1061	1462	42.05	57.95	1:1.38	14.02	NS (p=0.995)
H.spinosissimus	601	928	39.31	60.69	1:1.54	15.15	NS (p=0.959)
H.fuscus	447	815	35.42	64.58	1:1.82	15.73	NS (p=0.839)
				Shore seine operation			
H.trimaculatus	252	400	38.65	61.35	1:1.59	6.69	NS (p=0.823)
H.kuda	184	280	39.66	60.34	1:1.52	4.86	NS (p=0.938)
H.spinosissimus	150	207	42.02	57.98	1:1.38	7.79	NS (p=0.732)
H.fuscus	153	142	51.86	48.14	1:0.93	11.01	NS (p=0.443)
				Country trawl net			
H.trimaculatus	286	277	50.80	49.20	1:0.97	13.62	NS (p=0.255)
H.kuda	139	127	52.26	47.74	1:0.91	13.86	NS (p=0.241)
H.spinosissimus	74	105	41.34	58.37	1:1.42	6.25	NS (p=0.856)
H.fuscus	55	88	38.46	61.54	1:1.6	6.53	NS (p=0.836)

Length-Weight relationship of wild population of the seahorse *H. trimaculatus*

The length–weight relationship for males (n=1071) and females (n=1420) was analyzed using ordinary least square regression with 95% confidence. The results are shown if Figs 4 and 5. The obtained regression equation was:

logW : -2.5869+ 2.9362 log L (Male), r^2 = 0.9197
logW : -2.5089+ 2.8312 log L (Female), r^2 = 0.9042

The length – weight relationships were found significant (P<0.005) in both the sexes. Negative allometric growth for male and female was observed for the existing population of *H. trimaculatus* in Gulf of Mannar region. However, there were no significant differences in slope or intercept between male and female (P>0.005).

Age and Growth of *H. trimaculatus* using indirect method of calculation

The length frequency data obtained over a period of one year for males and females were plotted as a histogram (Figs 6 and 7). Length-frequency data of the catches were converted to age – frequency using von Bertalanffy growth parameters[34]. Standard length frequency histogram suggests that the by catch was composed of three year classes. The length frequency growth curves were fitted by the ELEFAN I in the FiSAT package II. The non – seasonalized restructured length-frequency histograms with growth curve for male and female *H. trimaculatus* are shown in Figs 8 and 9. The 'Lα' values obtained for males and females were 162.26 and 161.86 mm. The value of 'K' for males and females were 0.49 and 0.73. The t_0 values calculated for the respective 'Lα' and 'K' for male and female obtained by ELEFAN I are-0.07 and -0.03. The indirect estimation suggests that the life span of *H. trimaculatus* is around 3 years for this species inhabiting in Gulf of Mannar region.

Table 9—Occurrence of brooding and non–brooding male and mean number of developing young ones in brooding male

Species	Brooding Male	Non brooding Male	Mean No. of embryos
H. trimaculatus	1328	1898	413 ± 137.59
H.kuda	526	858	497 ± 146.35
H.spinosissimus	247	578	451 ± 148.14
H.fuscus	294	361	293 ± 135.75

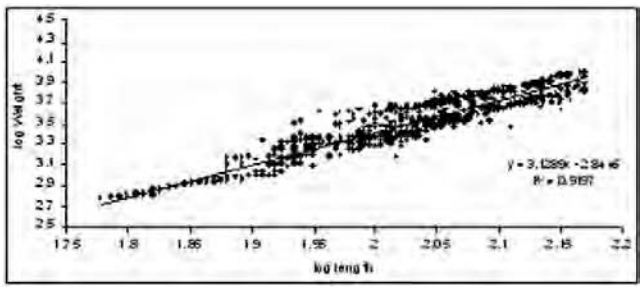

Fig.4—Length-weight relationship of male H. trimaculatus

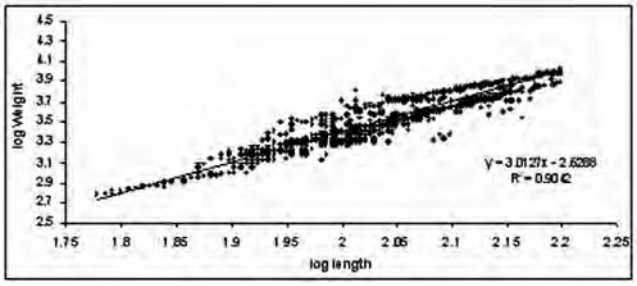

Fig.5—Length-weight relationship of female H. trimaculatus

Discussion

Different species share the same environment, competing for food and space. Most fishing methods are relatively unselective and many species experience high level of mortality as by-catch even if fishing does not target them. Because of the population dynamics of different species in the same habitat it is impossible for even the most careful fisher to catch only selected species at a time with most gears, the by catch associated with many fisheries having been highlighted by conservation organizations and scientists. By-catch may be a serious threat when it affects populations of rare and endangered species. The by-catch is composed of the sum of the discarded catch and the incidental catch. An average of 27 million tonnes of fish catch are discarded each year in comparison with the target catch of 77 million tonnes[19]. Habitat degradation and loss for natural and anthropogenic effects have also been identified as major threats to seahorse population[11-12].

The amount of seahorses caught from the Palk Bay region is about 5,300 kg/year[35]. Along Coromandel coast 22,97,474 seahorses have been caught as by-catch[14], while previous survey along Tamilnadu coast recorded 1,04,018 seahorse during 2000-01[36]. In Gulf of Mannar region 17,266 seahorses were recorded during sampling period of 36 days, whereas in a previous survey 31,386 seahorses were recorded[36], suggesting declining trend of seahorses caught as by-catches of different fishing gears. The study area harbors seagrass, seaweeds and coral reef, which provide shelter, holdfast and food for seahorse existence. The habitat like seagrass and seaweed

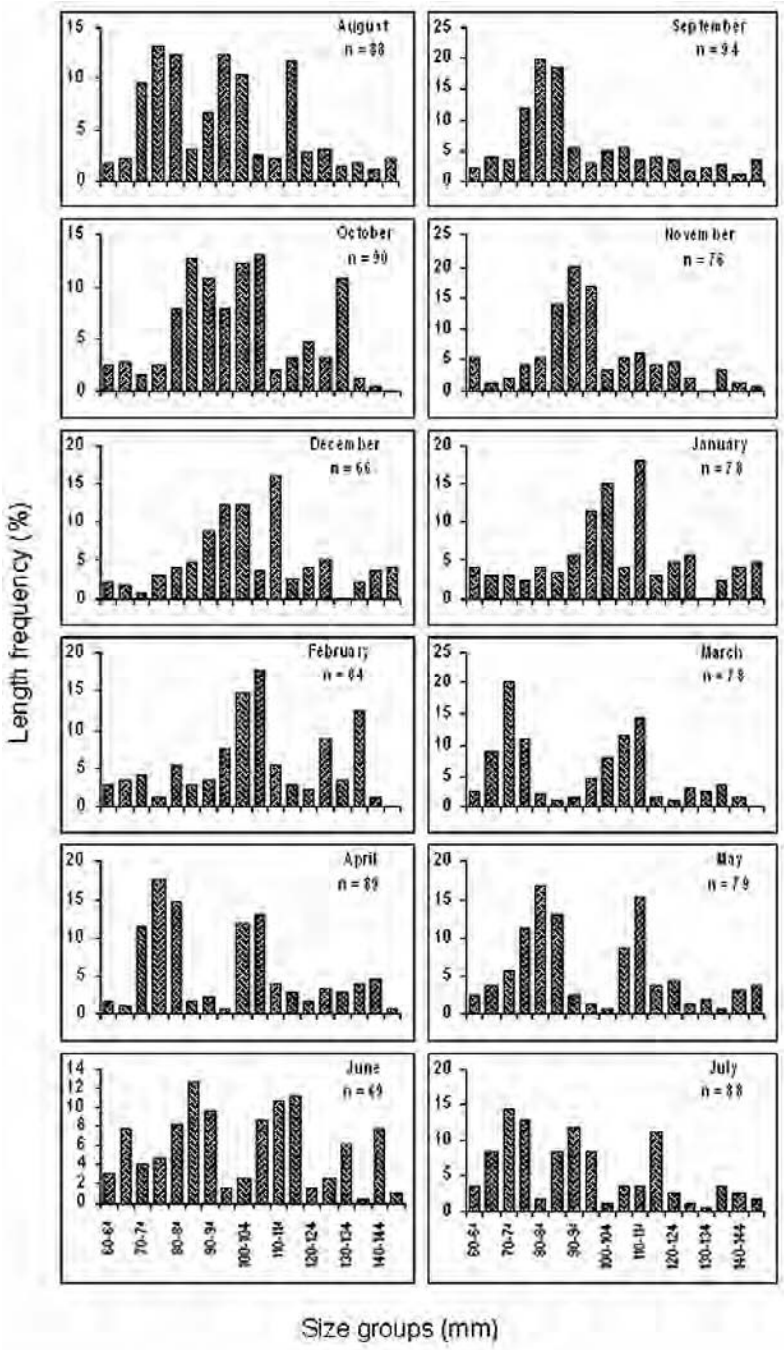

Fig. 6—Length frequency analysis of H. trimaculatus (Male) August 2001-July 2002)

harbors large amount of associated organisms which include polychaetes, isopods, amphipods, settled molluscan spats, small baby crab, small fishes and shrimps, whereas dead coral reef harbors cryptic organism which are considered as seahorse prey organisms[12].

In Coromandel coast the seahorse *H. kelloggi* dominated the catch with 44.3% respect to, *H. spinosissimus* (26.7%), *H .trimaculatus* (16%) and *H. kuda* 13%[14]. In Palk Bay region *H. kuda* dominated with 85.29%, respect to *H. trimaculatus* with 11.7% and *H. fuscus* contributing 2.94%[35]. Present study in Gulf of Mannar revealed that *H. trimaculatus* constituted about 53.93%, *H. kuda* (21.19%), *H. spinosissimus* (13.73%) and *H. fuscus* constituted 11.15% of the total catch. Previous study on these stations in Gulf of Mannar during October 2000 to September 2001 confirms that *H. trimaculatus* was

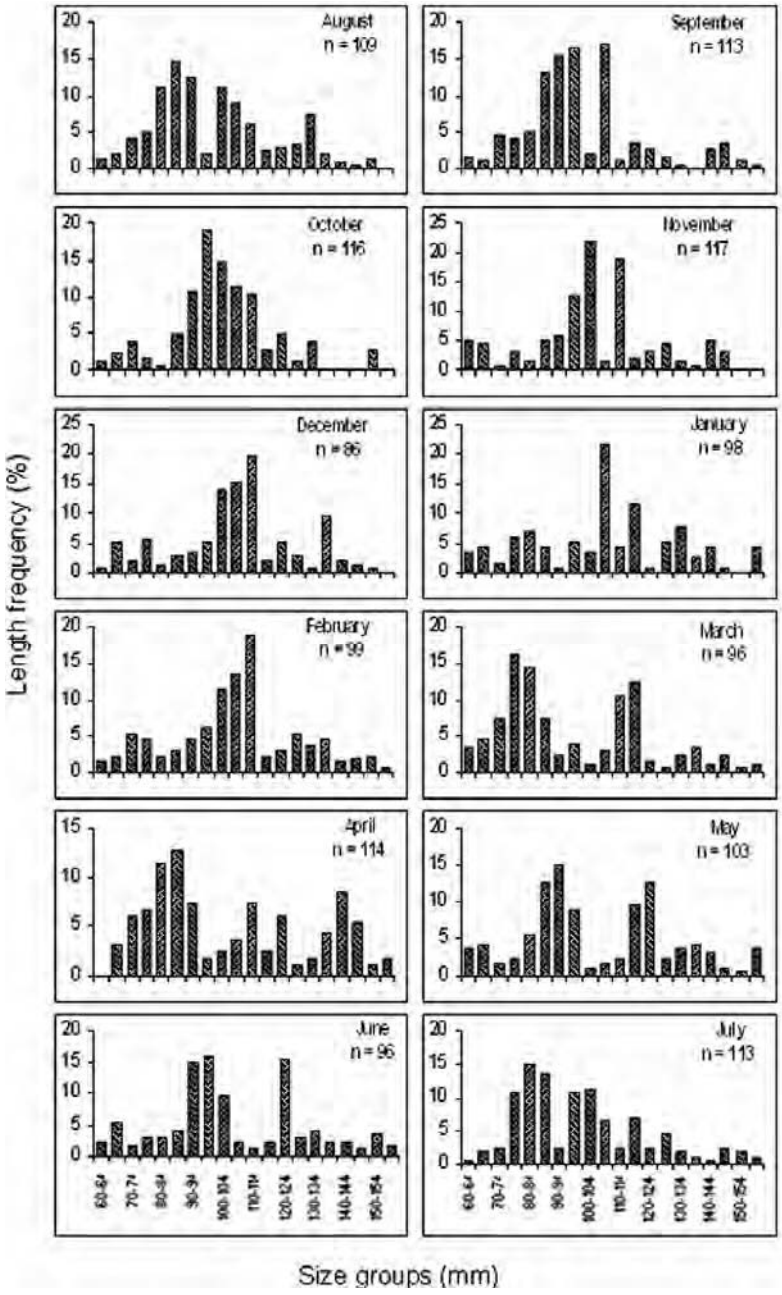

Fig. 7—Length frequency analysis of H. trimaculatus (Female) August 2001-July 2002)

dominant in this region with 53%, followed with *H. kuda* (23%), *H. spinosissimus* (14%) and *H. fuscus* (11%)[36].

There have been no studies on *H. trimaculatus* estimating its density in the wild. Seahorses in the wild are generally found to have low densities (0.006-0.51 ind/m^2) and patchy distribution[37]. High densities of seahorses were observed in 1960s in Indonesia with densities of 20 ind/ m^2 in coral reef and 10 ind m^2 in *Sargassum* spp. beds[38]. In some seagrass habitat 10-15 ind/ m^2 were observed[25], *H. comes* an exploited species found in coral reef in the tropics had localized densities of 0.019/m^2 in a marine protected area[38]. *H. whitei* occurred with a density of 0.088 – 0.215/m^2 in wild ecosystem[39]. *H. erectus* from Gulf of Mexico suggested a very patchy distribution with most of the trawls showing no seahorse and the number of seahorse per trawl ranged from 0 to 16 during peak catching period[24]. In 2001 densities of 0 -5 ind/m^2 were observed during August to September, whereas during April to May densities of 0 to 8 ind/m^2 were observed in the fishing ground where target fishing

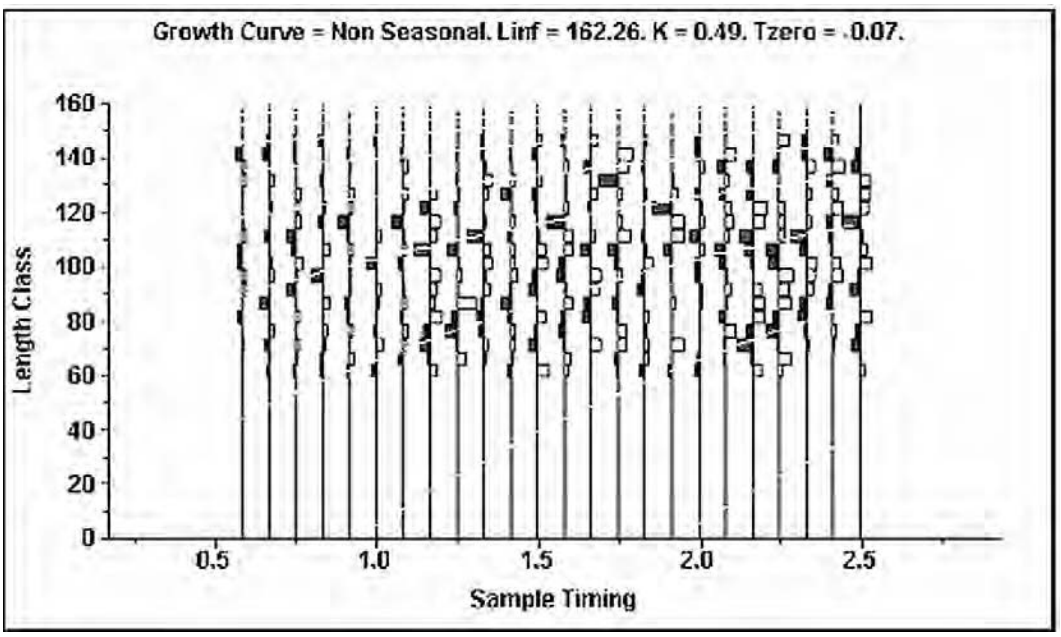

Fig.8—Restructured length frequency with growth curve for H. trimaculatus (Male)

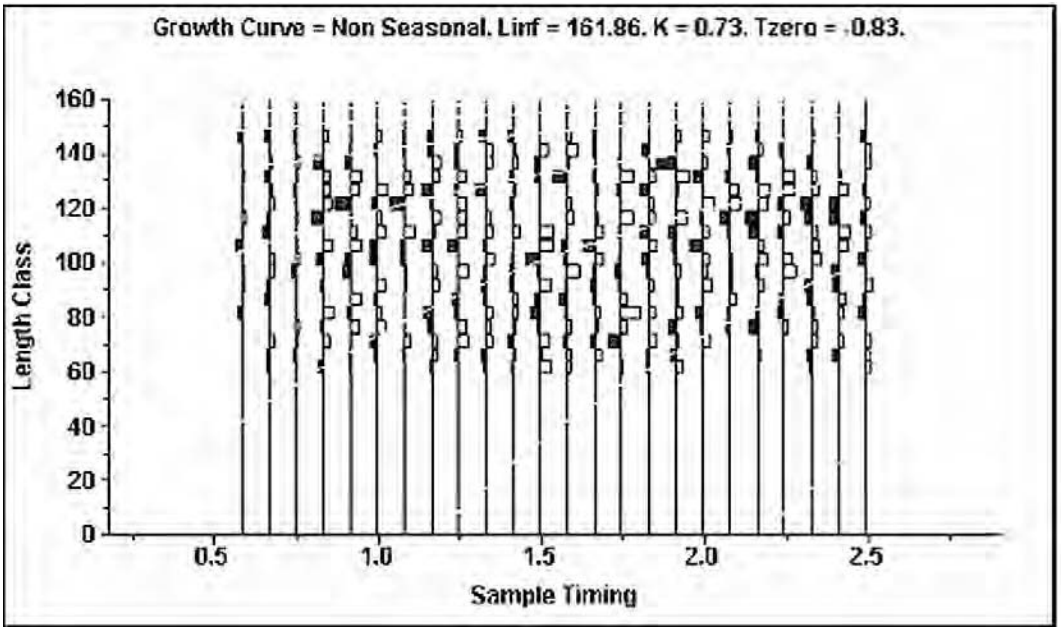

Fig.9—Restructured length frequency with growth curve for H. trimaculatus (Female)

were employed using skin divers before the implementation of the wild life protection act, 1972 on seahorse exploitation. The variation in population density in the wild ecosystem should attain research priority to know the population status. Our study suggests a patchy distribution in the Gulf of Mannar with the catch per gear varying from 0 to 16, 2 to 23 and 1 to 9 for shrimp trawl net, shore seine operation and country trawl net operations respectively.

For all seahorse species the sex ratio was female biased during the study period. In the case of the seahorse *H. erectus* females outnumbered males up to two times in Chesapeake Bay, Virginia[40]. Female biased sex ratio have also been found in the seahorse *H. zosterae* (33% male) when sampled by push net[41], as well as in *H. abdominalis* from Australian waters[42]. In pipefish *Entelurus aequoreus* and *Nerophis ophidian* the sex ratio was dominated by the females

with a chi-square value of 4.57 and 8.64 respectively[43]. However, equal number of males and females seahorse were also documented in *H. breviceps* [44], *H. reidi* [45] and *H. whitei* [39]. From the earlier reports and through the present study it can be concluded that females dominates in the existing species population along Gulf of Mannar region.

The brooding males caught as incidental by fishing gears was on the higher side when compared to non brooding males, showing a good sign of breeding population in the ecosystem, as well as suggesting the continuous breeding behaviour of seahorses. This continuous breeding behaviour is the important biological parameters which allows seahorse to withstand the fishing pressure despite its low fecundity. The home range of brooding males needs much information especially with regard to its conservation. During breeding season the incidental catch of brooding males reduces the recruitment size, whereas the catch of reproductively active male and female disturbs the monogamous behavior in their population and reduces the operational sex ratio in natural conditions. Agencies, NGOs and research institutions which have the mandate of conservation must give some research priorities to this unique creature to know its population status and act according to the information collected.

The length-weight relationship in fishes can be influenced by different factors like season, habitat, gonad maturity, diet and preservation techniques[46]. The regression line indicated a close relationship between males and females and the exponent values were around the hypothetical value (3). The males were heavier than females due to the presence of brood pouch hence the 'b' value was found to be higher when compared to females. The relationship between length–weight for *H. hippocampus* revealed that weight increases isometrically with length for populations inhabiting Aegean Sea[47]. Population parameters of *H. trimaculatus* indicated it as a fast growing species whereas the asymptotic length is reached within three years. Similar observation has been already noticed in *H. comes* from Central Philippines[48].Though the present study suggests that the life span of *H. trimaculatus* is around 3 years, the life span in seahorses varies depending upon the size of the species. The *in-situ* observation suggests that the smaller seahorse *H. zosterae* has a life span of one year[41], whereas larger ones like *H. erectus* have 3-5 years of life span[49]. The length-frequency analysis indicates that young seahorses (60–110 mm) are caught mainly during July and August. The peak breeding season for seahorse in this region appears to be from March – April and September – October[41]. The growth rate of *H. trimaculatus* was around ~ 100 mm (SL) in three months when they were cultured in *ex-situ* conditions[26].

The gears, which collect seahorse as by-catch, disturb the habitat complexity by removing the emerging epifauna like seagrass and seaweeds. They also damage structure forming forms such as corals, gorgonids and sponges. Repeated intrusion of these gears onto the breeding grounds affects the monogamous pair bonding behaviour and negatively affects the reproduction of the wild stocks hence reducing the recruitment size in the wild. Seahorses collected through the above mentioned gears damages the tail which is essential to grasp the holdfast. In most cases the bone present behind the snout gets detached from the tubular snout indicating the symbol of mortality even though tail movement could be observed. Tail injury in the seahorse *H. fuscus* suggested that bottom gears can create problems during the towing periods especially in the shallow regions by affecting the social structure of this unique creature[50]. Seahorse fishermen can act as key role players in habitat management as well as in conserving wild seahorse by leaving the brooding males back to their ecosystem. Promoting alternative live hoods like culture of clown fish, mussel culture, fattening of edible brachyuran crabs, rock lobster and value addition of non target species from bottom trawl net might reduce the pressure on the fishing of endangered species within critical ecosystem.

The scrutiny of existing literature revealed that scarce information is available on the distribution, exploitation rate and biology of seahorses from Indian waters. The exploitation of these unique creatures from the west coast is rare when compared to the east coast, hence it is a concern of prime importance to study the exploitation rate of seahorses in long term in Tamilnadu coast. It is also important to collect baseline information on seahorses from west coast especially in Kerala and Ratnagiri regions were seahorses are found to occur[51-52], with no information being available till now from Gulf of Kachchh, Andamans and Nicobar and Laccadive waters. Though seahorses have been placed in Schedule I of the Indian Wild Life Protection Act, 1972, research on these fishes are limited and this scenario has to be changed to preserve these unusual fish.

Acknowledgment

Authors are thankful to Ministry of Earth Science, Department of Ocean development (DOD), Government of India for their financial support and to Director , Centre of Advanced Study in Marine Biology and Annamalai university for their immense help throughout this study period.

References

1 Lourie, S.A., Vincent, A. C. J. and Hall, H. J. 1999. *Seahorses: an identification guide to the world species and their conservation*. Project Seahorse, London, 214pp.

2 Lourie,S.A. and Randall, H.J.E. 2003. A new pygmy seahorse, *Hippocampus denise* (Teleostei : Syngnathidae), from the Indo-Pacific. *Zoo.Sci.*, 42: 284-291.

3 Randall, J.E. and Lourie, S.A. 2009. *Hippocampus tyro*, a new seahorse (Gasterosteiformes: Syngnathidae) from the Seychelles. *Smithiana Bulletin*, 10: 19-21.

4 Lourie, S. and Kuiter, R.H. 2008. Three new pigmy seahorse species from Indonesia (Teleostei: Syngnathidae: Hippocampus). *Zoo taxa*, 1963: 54-68.

5 Borror, D. J. 1960. *Dictionary of world roots and combining forms*. Mayfield publishing Company, Palo Alto, California.

6 Fritzsche, R.A. 1980. Revision of the eastern pacific Syngnathidae (Pisces: Syngnathiformes), including both recent and fosil forms, *Proc.Cal.Acad. Sci.*, 42: 181-227.

7 Fenner, B. 1998. Pipes,horses and dragons. A real challenge, *Trop.Fish.Hoby.*, 46: 16-29.

8 Hargrove, M. 1998. Knights of the sea, *Trop.Fish.Hoby.*, 46: 30-40.

9 Chan,T.T.C. and Sadovy,Y. 1999. Profile of the marine aquarium fish trade in Hong Kong. *Aqua.Sci.Conserv.*, 2: 197-213.

10 Project Seahorse,2006. Annual Report, University of British Columbia.

11 Gokulakannan,K. 2002. *Systematics of seahorses and biology of yellow seahorse Hippocampus kuda (Bleeker, 1852) from Palk Bay region, South east coast of India*. Ph.D thesis (unpublished), Annamalai University, India. pp.

12 Murugan, A. 2004. *Biology and culture of the seahorse Hippocampus trimaculatus* (Leach, 1814), Ph.D thesis (unpublished), Annamalai University, India, pp.

13 Marichamy,R., Lipton,A.P., Ganapathy,A. and Ramalingam,J.R. 1993. Large-scale exploitation of seahorse (*Hippocampus kuda*) along the Palk Bay Coast of Tamilnadu. *Mar. Fish. Info. Ser.,* 119: 17-20.

14 Balasubramanian, R. 2002. *Studies on seahorses with special reference to Hippocampus kelloggi* (Jordan and Synder, 1902) *south east coast of India*, Ph.D thesis (unpublished), Annamalai University, India,pp.

15 Moreau, M.D. 1999. Conservations of the oceans medicinal species: The first international workshop on the management and culture of marine species used in traditional medicine. Out of the shell, Coastal resources research network Newsletter, 7: 1-4.

16 Vincent, A. C. J. and Sadler, L. M. 1995. Faithful pair bonds in wild seahorses, *Hippocampus whitei*, *Anim. Behav.*, 50: 1557–1569.

17 Jennings. S. and Kaiser, M. J. 1998. The effect of fishing on marine ecosystems, *Adv. Mar. Biol.,* 34 : 201-352.

18 FAO (Food and Agriculture Organization of the United Nations),1998. The state of world fisheries and Aquaculture, Rome, 112pp.

19 Alverson, D. L., Freeberg, M.H., Pop, J.G. and Maraski, S.A. 1994. *A global assessment of fisheries by catch and discards*, FAO Fisheries Techinical paper, 339, 233pp.

20 Dayton,P.K., Thrush, M.T., Agardy, M.T. and Hofman, R.J. 1995. Environmental effects of marine fishing, *FreshwaterEcosys.*, 5 :1-28.

21 Auster, P.J.and Langton, R.W. 1999. The effects of fishing on fish habitat, in: *Fish habitats: essentialfish habitat and rehabilitation*, edited by L. R. Benaka, (American Fisheries Society, Bethesda, M.D), 150-187pp.

22 Milton, D. 2001. Assessing the susceptibility to fishing of populations of rare trawl bycatch : sea snakes caught by Australia's northern prawn fishery. *Biol. Conserv.*, 101: 281-290.

23 Thomas, J.V., Sreedevi, C. and Madhusoodana Kurup.2006. Variations on the infaunal polychaetes dueto bottom trawling along the inshore waters of Kerala (south-west coast of India), *Ind.J.Mar.Sci.,* 353: 249-256.

24 Baum, J.K., Meeuwig, J.J. and Vincent, A. C. J. 2003. Bycatch of lined seahorse (*Hippocampus erectus*) in a Gulf of Mexico shrimp trawl fishery. *Fish.Bull.,* 101: 721-731.

25 Vincent, A. C. J. 1996. The international trade in seahorses, TRAFFIC International Cambridge, U K, 163pp.

26 Murugan, A., Dhanya, S., Sreepada, R.A., Rajagopal, S. and Balasubramanian, T. 2009. Breeding and mass- scale rearing of three spotted seahorse, *Hippocampus trimaculatus* Leach under captive conditions. *Aquaculture*, 290: 87-96.

27 Anil, M.K., Kakati, V.S., Ganga, U. and Zacharia, S. 1999. Larval rearing of seahorse *Hippocampus kuda* under laboratory conditions. *Mar.Fish.Info.Ser.*, 162: 23-25.

28 LeCren, E. D. 1951. The length weight relationship and seasonal cycle in the gonad weight and condition in the perch (*Perca fluviatilis*), *J. Anim. Ecol.*, 22: 201-219.

29 Gayanillo, F. C., Sparre, P. and Pauly, D. 1996. The FAO–ICLARM stock assessment tools (FiSAT) user's guide, FAO computerized Information service (Fish), No. 7.

30 Minitab Inc. 1991. Minitab reference manual release 8.2 for PC state College, PA, 234pp.

31 Winer, B.J., Brown, D.R. and Michels, K.M. 1991. Statistical principles in experimental design, 3rd edn, McGraw-Hill, New York, 1057pp.

32 Sokal, R.R. and Rohlf, F.J. 1995. Biometry–The principle and practice of Statics in Biological Research, New York, 887pp.

33 King, M. 1995. Fisheries Biology, Assessment and Management. Fishing News Books, 341pp.

34 von Bertalanffy, L. 1957. Quantitative laws in metabolism and growth. *Quar. Rev. Biol*., 32: 217-231.

35 Lipton, A. P. and Thangaraju, M. 2002. Present status of seahorse fishing along the Palk Bay coast. *Mar.Fish.Info.Ser.*, 174: 5-8.

36 Murugan, A., Dhanya, S., Rajagopal, S. and Balasubramanian, T. 2008. Seahorses and pipefishes of Tamilnadu coast. *Curr. Sci.,* 95: 253-260.

37 Foster, S. and Vincent, A. C. J. 2004. The life history and ecology of seahorses, *Hippocampus* spp. : implication for conservation and management, *J.Fish.Biol.*, 65: 1-61.

38 Pernate, N. C., Pajaro, M. G., Meeuwig, J.J. and Vincent, A. C. J. 2002. Biology of *Hippocampus comes* in the Central Philippines, *J. Fish. Biol.*, 60: 821- 837.

39 Vincent, A. C. J., Evans, K. L. and Mardsen, A.D, 2005. Home range behaviour of the monogamous Australian seahorse, *Hippocampus whitei*, *Env. Biol. Fish.,* 72: 1-12.

40 Teixeira, R. L. and Musick, J.A. 2001. Reproduction and food habits of the lined seahorse, *Hippocampus erectus* (Teleostei:Syngnathidae) of Chesapeake Bay, Virginia. *Rev.Bras.Biol.*, 61: 79-90.

41 Strawn, K. 1958. Life history of the pygmy seahorse, *Hippocampus zosterae* Jordan and Gilbert, at Cedar Key, Florida, *Copeia,* 16 – 22.

42 Martin – Smith, K. M. and Vincent, A. C. J. 2005. Seahorses declines in the Derwent estuary, Tasmania in the absence of fishing pressure, *Biol. Conserv.*, 123: 533-545.

43 Vincent, A. C. J., Berglund, A. and Ahnesjo, I. 1995. Reproductive ecology of five pipefish species in one eelgrass meadow, *Env.Biol.Fish.*, 44: 347-361.

44 Moreau, M. A. and Vincent, A. C. J. 2004. Social structure and space use in a wild population of the Australian short-headed seahorse *Hippocampus breviceps* Peters, 1869, *Mar. Freshwat. Res.*, 55: 231-239.

45 Dauwe, B. 1993. *Ecology of the seahorse Hippocampus reidi on the Bonaire coral reef: habitat, reproduction and community interaction*, M.S thesis, Rijksuniversiteit, Groningen, Netherlands.

46 Wootton,R.J. 1998. *Ecology of Teleost fishes*. Kluwer Academic Publishers, Dordrecht, Netherlands.

47 Gurkan, S. and Taşkavak, E. 2007. Length-weight relationships for syngnathid fishes of the Aegean Sea, Turkey, *Belg.J.Zool.,* 137, 219-222.

48 Pernate, N.C., Vincent, A. C. J. and Pajaro, M. G. 1998. Demographics of *Hippocampus comes* seahorses in Bohol, Central Philippines, In proceedings of the third international conference on the Marine Biology of the South China Sea, Hong Kong, 439- 448pp.

49 Boisseau, J. P. 1967. Les regulations hormonales des I'incubation de I' Hippocampe. Ph.D thesis (unpublished), University of Bordeaux, France.

50 Vincent, A. C. J. 1994. Operational sex ratio in seahorses, *Behaviour*, 128: 153-167.

51 Salin, K.R., Yohannan,T.M. and Mohankumaran, N. C. 2005. Fisheries and trade of seahorses, *Hippocampus* spp., in Southern India. *Fish. Mang. Ecol.,* 12: 269-273.

52 *Sreepada, R.A, Desai, U. M. and Naik, S. 2002. The plight of Indian seahorses: need for conservation and management.* Curr. Sci., *82: 377-378.*