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Spatial variations in the population characteristics of sea cucumber resources in Gulf of Mannar and Palk Bay, south-east coast of India

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ABSTRACT

The lack of data on population abundance, biomass and basic biological parameters of most of the sea cucumber species from Indian waters is a fundamental barrier to impose suitable management measures on these resources. A study was conducted to ascertain the sea cucumber population characteristics in two geographically distinct ecosystems (Gulf of Mannar and Palk Bay) along the south-east coast of India. The stock status of sea cucumber population was assessed both by trawl and dive surveys following standard methods on a random basis. Comparatively, a higher average density of total sea cucumbers was estimated in the Gulf of Mannar (3853±152.3 nos. ha^{-1}) than in Palk Bay (2428.5±504.6 nos. ha^{-1}). The species diversity, average length and weight of individual species were also higher in the Gulf of Mannar. The present study indicated significant variation in status and structure of sea cucumber resources in these two ecosystems. Hence the study warrants the emphasis of ecosystem-based management in formulating conservation measures of these resources in Indian waters.

Keywords: Gulf of Mannar, Management measures, Palk Bay, Sea cucumber, Stock status

Introduction

Sea cucumber fisheries are one of the top non-finfish income streams for coastal people throughout the Indian Ocean, south-east Asia and the Pacific. Sea cucumber fisheries have expanded worldwide in catch and value over the past two to three decades (Conand, 2004; FAO, 2008). Inadequate fishery management along with certain biological traits have caused overexploitation of this resource (Lovatelli *et al*., 2004; Bruckner, 2006; Kinch *et al*., 2008). Of the 377 sea cucumber species examined, the International Union for Conservation of Nature (IUCN) has classified seven species as endangered or at high risk of extinction and nine species as vulnerable or at risk of extinction (www.iucnredlist.org) (Conand *et al*., 2014).

In India, holothurians are mainly distributed in the Gulf of Mannar and Palk Bay, Andaman and Nicobar, Lakshadweep, Gulf of Kutch and along the mainland coast of India in stray numbers. The fishery was artisanal in nature and was introduced by the Chinese more than thousands of years back in Gulf of Mannar and Palk Bay (Hornell, 1917). The industry comprised the fishermen, who are divers, the processors who act as middlemen and the exporters. The fishery was mainly dependent on high valued *Holothuria scabra* and the medium valued *Holothuria spinifera* and occasionally on medium valued *Actinopyga miliaris*, *Actinopyga echinites* and *Stichopus hermanni* based on their availability (Asha *et al*., 2017).

The industry came to a standstill when the Ministry of Environment, Forests and Climate Change (MoEF and CC), Govt. of India imposed a total ban on sea cucumber fishery in June 2001 and listed all holothurians as protected animals under the Schedule I of the Indian Wildlife (Protection) Act, 1972, which severely affected the livelihood of the poor fishers of this region. A reliable long-term estimate is not available on the exploited as well as potential stocks of holothurians in Indian waters. The short-term survey conducted by the Zoological Survey of India (ZSI) along the Gulf of Mannar in 2007 reported the availability of seven species with *Holothuria atra* as the dominant one (Venkitaraman, 2007). The survey conducted by the ZSI in 2011-12 also indicated the occurrence of nine and seven species in the Gulf of Mannar and Palk Bay respectively (Venkataraman *et al*., 2012).

A fundamental barrier to improved knowledge and management of sea cucumbers is the lack of data on population abundance/biomass and basic biological parameters of most of the species. The large dependent coastal population in the Gulf of Mannar and Palk Bay, high value of the species and the ease with which the sea cucumbers can be collected, allows illegal harvest, leading to potential biological and ecological vulnerability of the stocks. Fourteen years of sea cucumber fishing ban has caused considerable changes in the stock status. Scientifically supported information on the population characteristics of sea cucumber resources in the Gulf of Mannar and Palk Bay, two geographically distinct ecosystems, are very much needed for formulating sustainable management measures for these resources and the present study was aimed to fulfil the gap in this aspect.

Materials and methods

The studies were carried out during the period January to June 2015 in the Gulf of Mannar and Palk Bay of south-east coast of India. Gulf of Mannar, the large shallow bay in the Indian Ocean is located between south-eastern India and north-west Sri Lanka and is about 130-275 km wide and 160 km in length. The island system comprising 21 islets, is situated between Rameswaram and Thoothukudi, covering an area of 623 ha, is declared as a Marine National Park by the MoEF, Govt. of India. The Palk Bay, the waterway between south-east India and northern Sri Lanka is about 64-137 km wide and 137 km long. The study stations were selected based on the previous research documents on sea cucumber landings and also after discussion with fishers. The stock status of sea cucumber population was assessed both by trawl and dive surveys following standard methods on a random basis (Pauly, 1980; Long *et al*., 1996).

The swept area method was adopted for the stock survey by trawling. Shrimp trawl nets, modified with added sinkers or bobbins in the foot ropes locally called as *'Attai madi'* were used for the survey. The area from 08°46.555 N to 078°18.846 E in Gulf of Mannar and from 09°15.861 N to 79°20.470 E in Palk Bay were covered for the trawl surveys (Fig.1a). The trawl operations were carried out at a depth range of 4-19 m in the Gulf of Mannar and 4.5-16 m in Palk Bay, and the details of markings were saved in hand held GPS (GARMIN 72). The trawl tow was made for a duration of 30 min to 1h based on the bottom substrates. The distance travelled was calculated using the formula D = V * t, where 'V' is the velocity of the boat and 't' is the time taken to reach the spot. The swept area 'a' was estimated as a = D * hr *X_2, where 'D' is the distance covered, 'hr' is the length of the head-rope, 'X_2' is that fraction of the head-rope length hr, which is equal to the width of the path swept by the trawl. The value of X_2=0.5 as suggested by Pauly (1980) was used in the present study. After the overhaul of trawl content, the weight of individual catch component was sorted out and estimated group-wise. The estimate of the average biomass per unit area was calculated using the formula b=CPUE/ (a*X_1) kg km^{-2}, where CPUE is the catch per unit effort divided by 'a' the swept area covered multiplied by X_1, where the value of 'X_1' = 0.75 as suggested by Vivekanandan (Personal Communication), which is reasonable for sedentary stocks.

The dive survey employed a rapid marine assessment technique that has been used for sea cucumber (Long *et al*., 1996). The sampling sites were selected at a depth range of 3-20 m in the Gulf of Mannar and 3-8 m in Palk Bay. Nine sites in Gulf of Mannar and 14 in Palk Bay were fixed for dive surveys. At each station, country boats with a team of two divers were operated for transect survey, and sampling sites were located using a portable global positioning system (GPS) device. The area from 08°45.188N to 078°20.252E in the Gulf of Mannar and from 09°37.750N to 78°59.359E in the Palk Bay were covered (Fig.1b). A 50 m tape was laid over the bottom substrate, and one diver swam along the transect to record the habitat structure and resources on 1m either sides of the transect line and another diver was engaged in sea cucumber collection for biometric measurements. A total of 1400 m^2 in Palk Bay and 900 m^2 in the Gulf of Mannar were covered in the study. In both trawl and dive surveys, locations were marked with Google Earth Ver. 5.1.3533.1731. The collected sea cucumbers were identified upto species level based on standard literature (James, 1995; Purcell *et al.,* 2012).

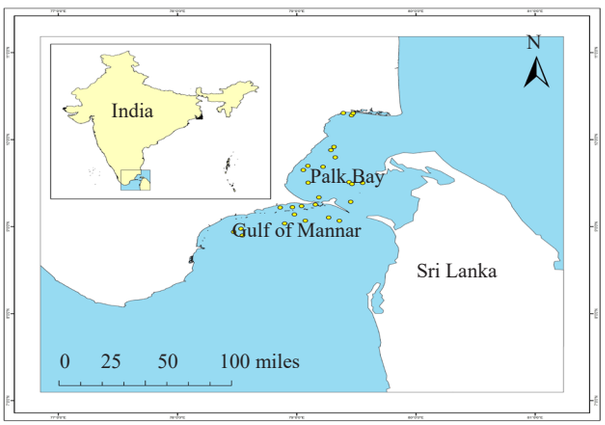
All the sea cucumbers were numbered species-wise and were individually measured for total length and weight after relaxing for a while to drain on an absorbent cotton towel. The body length was measured to the nearest 1cm using a soft measuring tape and weighed to the nearest 1g using an electronic balance. After measurement, all the specimens were released to the natural environment. The numerical density and biomass of sea cucumbers was calculated at all stations. The length and weight frequency distribution were assessed to find out the variation. The weight-length relationships (WLR) were used for estimating the weight corresponding to a given length, and WLR was determined according to the general equation $W= aL^b$., where 'W'= weight in g, 'L'= body length in cm, a= the ordinate and b= the slope of the curve. The parameter 'a' is a scaling coefficient for the weight at length of the sea cucumber species. The parameter 'b' is a shape parameter for the body form of the sea cucumber species. In general, the exponent 'b' would have a value of roughly

three because the volume of a 3-dimensional object is approximately proportional to the cube of length for a regularly shaped solid and the deviation from 3.0 indicates the direction and rate of change of form or condition. If b<3.0, it indicates a decrease in state or elongation in shape with an increase in length, whereas b>3.0 indicates an increase in condition or increase in height or width with an increase in length (Cone, 1989). The mean values (±SE) were estimated for all measurements, and the results were statistically interpreted. The correlation and one-way analysis of variance (ANOVA, a = 0.05) were tested in SPSS 16 statistical package, to identify the difference if any among locations.

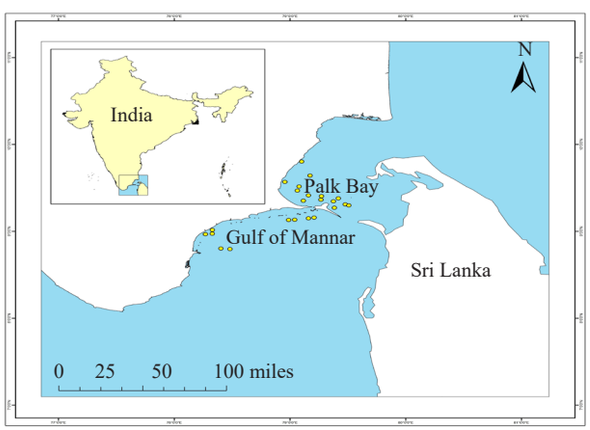
Results and discussion

Trawl catch component

A total swept area of 545,200 m^2 (13 trawl hauls) in Gulf of Mannar and 213,100 m^2 (12 trawl hauls) in Palk Bay were covered during the survey. Seagrass was the major catch component in both the ecosystems and constituted 76.4 and 50.2% of the total catch respectively. Echinoderms other than sea cucumbers were the second dominant group, which was comparatively higher in Palk Bay. Bony fishes were the fourth major component at both sites and were relatively higher in Palk Bay than in the Gulf of Mannar. Sea cucumbers constituted the fifth major group and comprised 3.4 and 3.04% respectively at Gulf of Mannar and Palk Bay.



(a)



(b)

Fig.1. (a) Trawl and (b) Dive survey locations of sea cucumbers in Gulf of Mannar and Palk Bay

In the trawl survey, the sea cucumber biomass was 3.28 kg ha^{-1} and 2.59 kg ha^{-1} in the Gulf of Mannar and Palk Bay respectively which was lower than the earlier reports of 5.7 kg ha^{-1} and 3.8 kg ha^{-1} at the same locations by Venkataraman *et al*. (2012). The present survey was conducted for a short duration which could not account for the seasonal variation in sea cucumber abundance. Lampe (2013) has highlighted the influence of environmental parameters like salinity, temperature, turbidity and nutrient composition on holothurian distribution and occurrence. The high percentage of seagrass removed as bycatch from both the ecosystems in the present study indicated the need for their protection as habitat for sea cucumbers. The higher abundance of sea cucumbers in seagrass beds and coral reefs has been discussed by several authors highlighting the importance of these habitats in the early life history stages of sea cucumbers for settlement (Conand, 2008; Friedman *et al*., 2011). In the present study, a high positive correlation was noticed between the sea cucumber and seagrass biomass at both the sites ($p<0.001$).

Species-wise variation in sea cucumber resources in the Gulf of Mannar and Palk Bay

In the present study, the biomass estimated in survey sites varied in accordance to the abundance of massive species like *Bohadschia marmorata* and *H. scabra*, rather than dominance of lean species like *H. atra*, *Holothuria leucospilota* and *Stichopus horrens*. Due to this species-wise variation in body forms and average body weight of sea cucumbers, the density of sea cucumbers as a whole was considered to assess the ecosystem variation in population status. The relative abundance of different sea cucumber species collected from both trawl as well as dive survey sites in Gulf of Mannar and Palk Bay is given in Fig. 2 and the mean value as well as range in density of major sea cucumber species are given in Table 1.

Broadly, the sea cucumbers are categorised into high, medium and low-valued based on their international market value. Nine sea cucumber species with discrete commercial value were collected from the Gulf of Mannar and low-valued species were dominant. The medium valued *S. horrens* was the major species with the highest

mean density of 1599.8±619.2 nos. ha^{-1}. It comprised 44.5% of the total catch followed by 27.4% of low-valued *H. leucospilota* with a mean density of 987.4±362.5 nos. ha^{-1}. The low-valued *H. atra* was in the third position with a mean density of 767.7±177.01 nos. ha^{-1} and constituted 15.9% to the total catch. *B. marmorata* was the 4th significant species, and the high-valued *H. scabra* and medium-valued *H. spinifera* were available in small quantities (1.5% each) *Colochirus quandrangularis*, *Holothuria edulis* and an unidentified *Bohadschia* sp. were also found on a few occasions (Fig. 2a; Table 1).

In Palk Bay, the population was dominated by a single species, the high -valued *H. scabra* (84.7%) with a mean density of 2352.6±546.7 nos. ha^{-1}. Other sea cucumber species like the low-valued *H. atra* (8.98%), medium valued *H. spinifera* (3.5%) and low-valued *B. marmorata* (1.95%) were recorded in small quantities. Species like *S. horrens* and *H. leucospilota* (0.39% each) were also recorded in a few numbers (Fig 2b; Table 1).

In Palk Bay, the present study revealed the dominance of high-valued *H. scabra* in reasonably good numbers at all the stations. The mean density was much higher than the previous estimates made from the same locations (Venkataraman *et al.,* 2012). Higher density was noticed for other low-valued species also. The fluctuation in population density of sea cucumbers in Palk Bay in shallow areas indicated the need for continuous monitoring for the development of time series data on population characteristics from the region. In the past 30-50 years,

Table 1. Species density (Mean ±SE and range) of major sea cucumber species in Gulf of Mannar and Palk Bay

Species	Gulf of Mannar	Palk Bay
H. scabra	178.94±110.2 (0 - 1818.2)	2352.6±546.7 (0 -7868.9)
H. spinifera	69.14±33.02 (0 - 545.5)	75.5±57.7 (0 -1315.8)
H. atra	767.7±177.01 (0 - 2096.4)	190.3±101.9 (0 -1827.7)
H. leucospilota	987.4±362.5 (0 - 7875)	-
S. horrens	1599.8±619.2 (0 - 9536.8)	-
B. marmorata	192.9±89.1 (0 - 1750)	-

there is a decrease of 50% population of *H. scabra* and hence IUCN has recently listed this species as "Endangered" (A2bd ver 3.1 IUCN). It is advisable to set a short list of allowable species, excluding threatened species and those critical for ecosystem function and to implement capacity and effort limitation (Conand *et al*., 2014).

The total number of commercial sea cucumber species reported in the present study is more or less similar to the previous reports of Venkataraman *et al*. (2012), but lower than the earlier observation of 27 species made by James (1995) and 39 species by Sasthri (1998) from the Gulf of Mannar area. The less number of species recorded in the present study might be due to inadequate sampling without covering the entire habitat. The diversity and

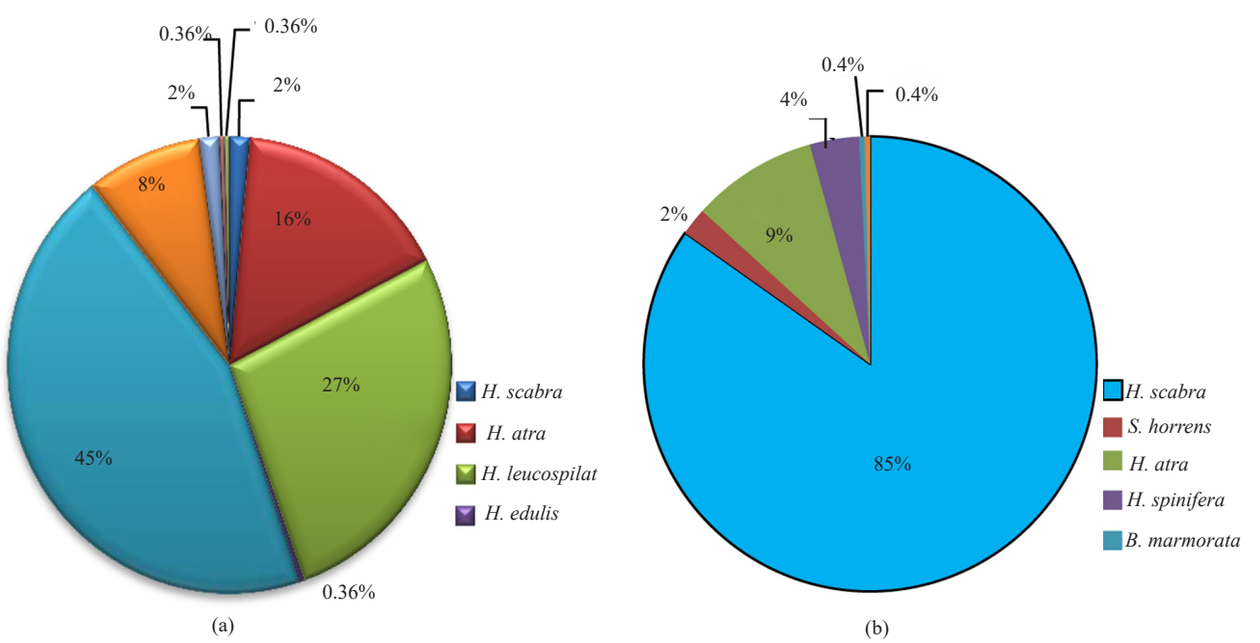


Fig. 2. Relative abundance of sea cucumber species in (a) Gulf of Mannar and (b) Palk Bay

density of sea cucumbers were comparatively higher in Gulf of Mannar than in Palk Bay, which might be due to the high diversity of habitats like coral reefs, seagrass, salt marshes, mangroves, rocky, sandy and muddy shores and more depth in Gulf of Mannar along with other physical, chemical and biological factors of the ecosystem. The density of the species like *H. scabra, H. atra, H. leucospilota*, *B. marmorata* and *S. horrens* was found significantly different between the two ecosystems ($p<0.01$).

Spatial variation in the numerical density of sea cucumbers in the Gulf of Mannar and Palk Bay

The variation in the density of sea cucumbers between sampling sites in the Gulf Mannar trawl survey is depicted in Fig. 3a. Among the 13 trawl survey stations, the maximum density of 13,079 nos. ha^{-1} was at Keezhakarai, followed by 10,895 nos. ha^{-1} at Seeniappadarga. The lowest value of 325.2 nos. ha^{-1} was noticed at Thoothukudi. The density of sea cucumbers recorded from the Gulf of Mannar dive survey sites is presented in Fig. 3b. Comparatively lower density was observed in dive survey. The maximum density of 7875 nos. ha^{-1} was observed off Chulli Island followed by 3750 nos. ha^{-1} at Vembar. The lowest value of 750 nos. ha^{-1} was noticed at Keelakarai.

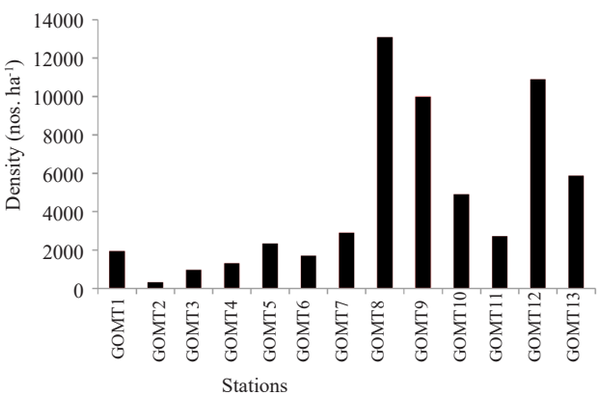
In Palk Bay, among the 12 trawl stations, the highest density of 8032.8 nos. ha^{-1} was noticed at Devipattinam followed by 7291.7 nos. ha^{-1} at Rameswaram. The lowest density of 1388.9 nos. ha^{-1} was seen at Seerankotai (Fig. 4a). The variation in density of sea cucumbers between dive survey sites in Palk Bay is shown in Fig. 4b. Among the 14 stations surveyed, the maximum density of 6875 nos. ha^{-1} was noticed at Uchipulli followed by 1875 nos. ha^{-1} at Munivarpattinam. The lowest density of 125 nos. ha^{-1} was seen at Pudhupattinam, Panaikulam and Periyavanthalli.

The numerical density of various sea cucumber species obtained in the present study in Gulf of Mannar is comparable to the previous estimate from the same location or to those reported from elsewhere. The lower density of high-valued *H. scabra* in Gulf of Mannar might be due to the historical fishing pressure and the inability of the stock to repopulate to its original level. Similar observation has been reported from several parts of Indo Pacific region (Lovatelli *et al*., 2004; Uthicke and Conand, 2005).

Comparatively a higher average density of sea cucumbers was estimated in Gulf of Mannar (3853±152.3 nos. ha^{-1}) than in Palk Bay (2428.5±504.6 nos. ha^{-1}), and these values are much higher than the depleted population reported in the Milne Bay (27 nos. ha^{-1}) (Skewes *et al*., 1999; 2002) and are also higher than 350±648 and 90±130 nos. ha^{-1} reported in the north-west and east coasts of Sri Lanka (Dissanayake and Stefansson, 2010); Moreton Bay (1035 nos. ha^{-1}) and Solomon Islands (1115 nos. ha^{-1}) (Skewes *et al*., 2004; Buckius *et al*., 2010), but lower than that reported from Heron Island (8460 nos. ha^{-1}) (Klinger and Johnson 1998).

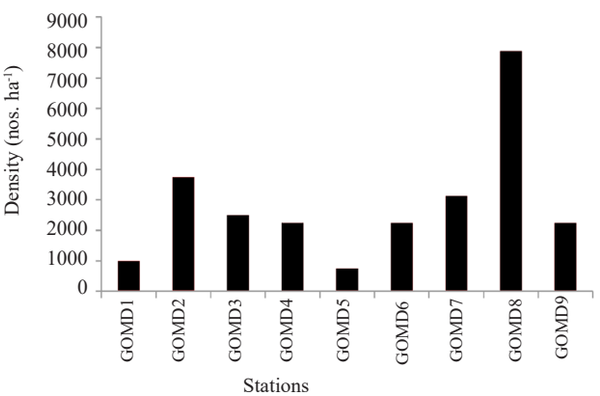
Length-weight frequency distribution of sea cucumbers in the Gulf of Mannar and Palk Bay

The length frequency distribution of sea cucumber species in the Gulf of Mannar and Palk Bay are summarised in Fig. 5a (i-vi) and 5b (i-iv) and the range and mean



GOMT1 - Off Tuticorin1; GOMT2 - Off Tuticorin 2; GOMT3 - Off Tuticorin 3; GOMT4 - Pudumadam; GOMT5 - Periayapattinam-1; GOMT6 - Periayapattinam-2; GOMT7 - Pakkirappa; GOMT8 - Keezhakarai; GOMT9 - Bharathinagar; GOMT10 - Ervadi; GOMT11- Pamban; GOMT12 - Seeniappadarga; GOMT13 - Vedhalai

(a)



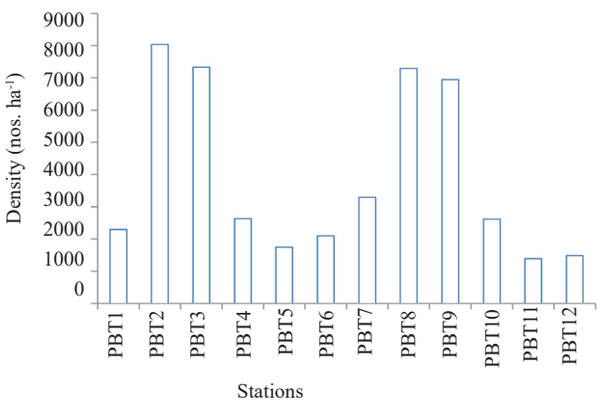
GOMD1 - Mandapam; GOMD2 - Vembar; GOMD3 - Keelakarai-1; GOMD4 - Keelakarai-2; GOMD5 - Keelakarai-3, GOMD6 - Off Tuticorin1; GOMD7 - Off Tuticorin2; GOMD8 - Off Chulli Island; GOMD9 - Off Koswari Island

(b)

Fig. 3. Numerical density of holothurians in the (a) trawl and (b) dive surveys of Gulf of Mannar

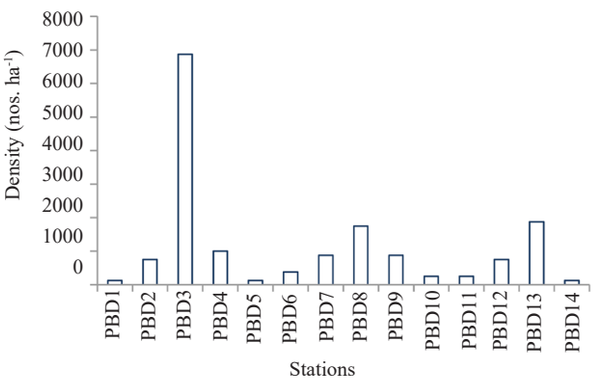
length and weight are given in Table 2 and 3. In the Gulf of Mannar, the dominant species, *S. horrens* has a length range of 2.5-23.5 cm with a mean of 13.95±0.23 cm; and weight range of 20-265 g (mean - 117.9±3.40 g). Most of the specimens were medium-sized with highest frequent size class of 13.5-15.5 cm and 95-105 g for length and weight respectively, whereas, in Palk Bay, the specimens were comparatively smaller, with the highest size frequency of 7-9 cm and 75.1-100 g for length and weight respectively. The size at first maturity of *Stichopus* sp. estimated as 22 cm (Conand, 1993) suggests that majority of *Stichopus* sp. collected during the study period were not mature. Specimens of *H. scabra* were comparatively larger in Gulf of Mannar with higher size class frequency of 14.5-24.5 cm and 300-350 g for length and weight respectively. In Palk Bay, the *H. scabra* specimens were medium-sized with the highest size class of 16.1-18 cm and 201-250 g for length and weight respectively. Majority of the unexploited *H. atra* population in Gulf of Mannar were comparatively smaller than in Palk Bay, whereas specimens of *H. leucospilota*, *H. spinifera* and *B. marmorata* were larger in Gulf of Mannar and only a few specimens of these species were reported from Palk Bay.

Except for *S. horrens* from Gulf of Mannar which is comparatively smaller, the mean length estimated for all other species from both the ecosystems are comparable to the values obtained in the previous estimates (Venkataraman *et al*., 2012). For *H. scabra* specimens, the mean length was much higher than the Warrior reef measurements by Skews *et al.* (2004) and those of Abu Rhamde Island (Hasan, 2005). The population structure of *H. scabra* in Palk Bay during April indicated the dominance of breeders of 13-16 cm length (age: 2 years) as per the growth estimates of Hamel *et al*. (2001). Venkataraman *et al*. (2012) also observed the dominance of breeders during April in Palk Bay. The most frequent size category of *H. atra* observed in the present study was much lower than those reported from Sri Lanka (Dissanayake and Steffansson, 2010). The length distribution pattern was found to be uni-modal for most of the species, but the



PBT1-Thiruppalaikudi; PBT2-Devipattinam; PBT3- Panaikulam; PBT4-Thondi; PBT5-Off Thondi; PBT6-Off Mullimunai; PBT7-Mullimunai; PBT8-Rameswaram; PBT9-Karayoor; PBT10-Ollakudai; PBT11-Seerankotai; PBT12-Mallipattinam; PBT13-Sethubavacharam; PBT14-Mallipattinam

(a)



PBD1-Pudhupattinam; PBD2-Pamban; PBD3-Villondi; PBD4-Mandapam; PBD5- Panaikulam; PBD6-Uchipulli; PBD7-Vedhalai; PBD8-Gothandaramar; PBD9-Kooridweep; PBD10-Rameswaram; PBD11-Seelanpatta; PBD12-Munivarpattinam1; PBD13-Munivarpattinam-2; PBD14-Periyavanthalli

(b)

Fig. 4. Density of holothurians in (a) trawl and (b) dive surveys of Palk Bay

Table 2. Length (Mean ±SE and range) of sea cucumber species in Gulf of Mannar and Palk Bay

Species	Gulf of Mannar	Palk Bay
H. scabra	19.21±1.44 (12.5-24.5)	17.27±0.26 (10.8-45.2)
H. spinifera	22.6±3.06 (9.5-38)	13.46±4.27 (5-18.6)
H. atra	14.09±0.49 (6-32)	13.46±1.11 (5.1-24.8)
H. leucospilota	20.06±0.46 (7.3-42)	-
H. edulis	20±1.00 (19-21)	-
S. horrens	13.95±0.23 (2.5-22)	12.70±1.45 (7-22.5)
B. marmorata	23.12±1.07 (11-41)	-
Bohadschia sp.	24±2.005 (22-26)	-
C. quadrangularis	5.65±0.35 (5.3-6)	-

Table 3. Weight (Mean±SE and range) of sea cucumber species in Gulf of Mannar and Palk Bay

Species	Gulf of Mannar	Palk Bay
H. scabra	360.63±68.07 (115-580)	231.79±9.42 (50-780)
H. spinifera	466.88±138.41 (50-1300)	166±81.64 (8-280)
H. atra	170.65±15.53 (40-1100)	149.78±20.03 (10- 400)
H. leucospilota	259.34±12.52 (20-1000)	-
H. edulis	275±25.07 (250-300)	-
S. horrens	117.96±3.40 (20-260)	104.55±17.06 (10-230)
B. marmorata	714.78±62.15 (100-1800)	-
Bohadschia sp.	1090±290.87 (800-1380)	-
C. quadrangularis	10.25±0.25 (10-10.5)	-

difference in size of specimens observed between Gulf of Mannar and Palk Bay could be attributed to the variation in depth, substrate type and environmental factors of these two ecosystems as opined by Mercier *et al*. (1999).

The weight-length relationships

The weight-length relationships were derived for major sea cucumber species collected during the survey, and the results are given in Table 4. In Gulf of Mannar, the b value ranged from 1.2693 (*S. horrens*) to 2.6449 (*H. scabra*) whereas, in Palk Bay, it was between 0.883 (*S. horrens*) and 2.2269 (*H. scabra*). These values indicate allometric growth, and it appears to be the general case of tropical holothurians (Herrero-Perezrul and Reyes-Bonilla, 2008; Gonzalez-Wanguemert *et al*., 2014). A similar allometric result with b values of 1.83 and 1.92 was also reported from the weight-length relationship of *Isostichopus fuscus* from Espiritu Santo Island, Mexico (Herrero-Perezrul and Reyes-Bonilla, 2008) and of *Stichopus chloronotus* from Samoa, Sweden (Eriksson, 2006). In the case of *S. horrens*, the exponent value and coefficient of determination varied conspicuously between the ecosystems, *i.e.*, 1.2693 for Gulf of Mannar (R^2= 0.591) and 0.883 for Palk Bay (R^2= 0.1681). This phenomenon might be due to the sampling bias, as except *H. scabra*, only a few specimens of other species were analysed from Palk Bay.

The studies by Gonzalez-Wanguemert *et al*. (2014) on sea cucumber populations from the Aegean Sea revealed that b values for *Holothuria polii* ranged from 3.79 to 6.68 suggesting these species grow allometrically, but are more massive specimens. The order in which the

Table 4. Length and weight relationship of sea cucumber species

(a) Gulf of Mannar

Species	Weight-length relationship	R^2 (Coefficient of determination)
S. horrens	$y = 3.917x^{1.269}$	0.591
H. scabra	$y = 0.1308x^{2.6449}$	0.8489
H. atra	$y = 1.8104x^{1.664}$	0.575
H. leucospilota	$y = 2.4436x^{1.5238}$	0.547
H. spinifera	$y = 0.4439x^{2.1734}$	0.8911
H. edulis	$y = 64065x^{-1.822}$	1
B. marmorata	$y = 4.9096x^{1.5532}$	0.583
Bohadschia sp.	$y = 0.0332x^{3.263}$	1
C. quadragularis	$y = 5.1897x^{0.3933}$	1

(b) Palk Bay

Species	Weight-length relationship	R^2 (Coefficient of determination)
S. horrens	$y = 9.5587\ x^{0.883}$	0.1681
H. scabra	$y = 0.3666\ x^{2.2269}$	0.6786
H. atra	$y = 1.5901\ x^{1.6732}$	0.5036
H. spinifera	$y = 0.1033\ x^{2.7021}$	1
H. edulis	$y = 0.1033\ x^{2.7021}$	1
Bohadschia sp.	$y = 0.1033\ x^{2.7021}$	1
C. quadragularis	$y = 0.1033\ x^{2.7021}$	1

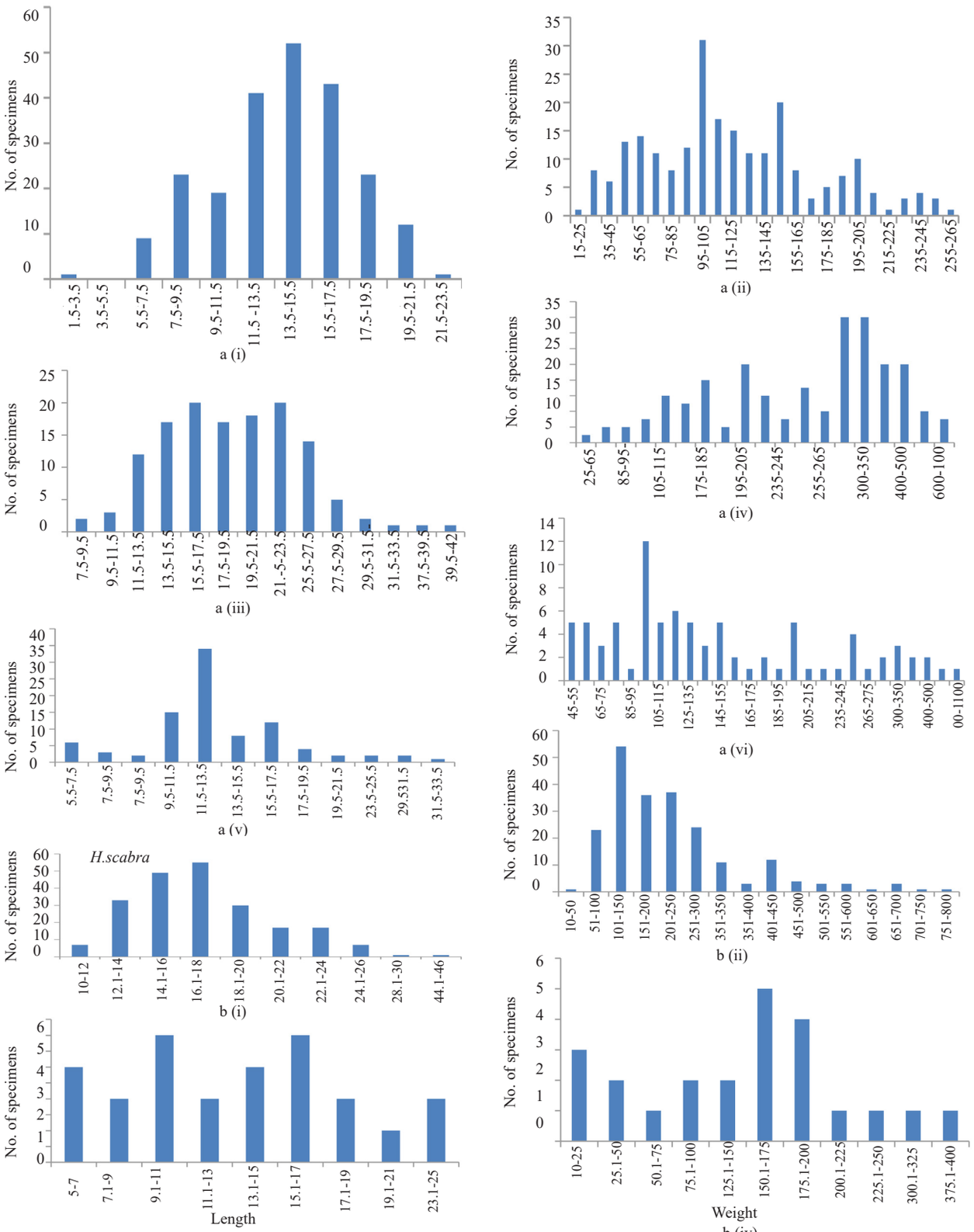


Fig. 5. Length and weight frequency distribution of major sea cucumber species in (a) Gulf of Mannar: a (i) and (ii) - *S. horrens*; a (iii) and a(iv) - *H. leucospilota*; a(v)and a(vi) - *H. atra; (*b) Palk Bay: b(i) and (ii) - *H. scabra*; b(iii) and (iv) - *H. atra*

species are lean in Gulf of Mannar is: *S. horrens* > *H. leucospilota* > *H. atra* > *H. spinifera* > *H. scabra* and for Palk Bay is: *S. horrens* >*H. atra* >*H. scabra*. The allometric coefficient observed in length-weight power relationship of *H. scabra* for Gulf of Mannar (2.6449) and Palk Bay (2.2269) is consistent with the value 2.18 obtained for Oman population (Al-Rashdi *et al*., 2007), 2.28 for New Caledonia (Conand, 1990) and 2.84 obtained for Vietnam (Pitt and Duy, 2004). However, for a given length, the individuals collected from the Gulf of Mannar were stouter than those obtained from Palk Bay. These differences could correspond to actual biological differences concerning the environmental conditions prevailing between the two ecosystems. In the present study, the b values estimated were less than 3.0 which indicate that most of the sea cucumber species have elongated bodies. Moreover, 'a' and 'b', the coefficient of determination values varied between the two ecosystems.

The present study indicated variation in status and structure of sea cucumber resources in the Gulf of Mannar and Palk Bay. The difference is mainly linked to the unique environmental characteristics of both the ecosystems; hence, ecosystem-based management measures should be given more emphasis while formulating conservation measures for these resources in the region. While comparing with previous post-ban surveys, the present study also indicated wide fluctuation in the sea cucumber population status. Hence it is recommended to conduct fishery-independent and dependent surveys of the sea cucumber stock on a regular interval as per the standard survey and methodologies for the development of time series data on population metrics from this region. It is also suggested to implement long-term mark-recapture studies to assess the growth, dispersal, mortality rates and longevity of sea cucumber resources for better clarification on population structure, in order to formulate management measures for the conservation and sustainable utilisation of the resources.

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