Stock assessment of holothuroid populations in the Red Sea waters of Saudi Arabia

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Abstract

The present work estimates the stocks of sea cucumbers at sites in the Red Sea — for which there is currently a lack of reliable data. The survey was carried out at 18 sites located in three areas (Al-Wajh, Thowal and Farasan Islands) along the Red Sea coast of Saudi Arabia. The major findings revealed that all sites surveyed were subjected to heavy overfishing that led to high depletion of sea cucumber stocks.

Twelve species were recorded during this survey, with the highest diversity recorded at Farasan Islands (eight species), followed by the Thowal area (four species) and the Al-Wajh area (three species). The species included three high value species (*Holothuria fuscogilva*, *H. nobilis* and *H. scabra*), five medium value species (*Actinopyga echinites*, *A. mauritiana*, *Holothuria atra*, *H. fuscopunctata* and *Stichopus variegatus*), three low value species (*Bohadschia vitiensis*, *Pearsonothuria graeffei* and *Holothuria edulis*) and one non-commercial species (*Holothuria leucospilota*). Population structure investigation showed high depletion in populations of *H. nobilis*, while populations of both *H. fuscogilva* and *H. scabra* were completely destroyed. Only *H. atra* showed a healthy population.

Introduction

The Red Sea has a unique environment with a wide range of habitats and outstanding biodiversity, which give it great scientific and ecological importance (Head 1987). Saudi Arabia's Red Sea coast extends for about 2,000 km (nearly all the eastern seaboard of the Red Sea) and many islands exist offshore that have flourishing ecosystems and rich species communities. Holothurians are one of the most important members of the Red Sea ecosystem and influence the structure and functioning of coral reef ecosystems (Bakus 1973), contributing significantly to the food chain and to the modification of the substrate (Lawrence 1975). In addition, sea cucumbers have a high economic value due to their high market demand and high prices (Holland 1994).

The environmental parameters in the marine habitats of Saudi Arabia's Red Sea coast are suitable for the existence of sea cucumbers (Price 1982, 1983). The availability of food, suitable substrata (Roberts 1979; Mercier et al. 1999), a high variety of niches (Clark and Rowe 1971; Guille and Ribes 1981), suitable depths (Preston and Lokani 1990; Lokani et al. 1996) and the small number of natural enemies (Hasan 2003, 2005) favour the existence of sea cucumbers. The trend of overfishing of sea cucumber that started in 1999 resulted in overexploitation of the resource, causing their stocks to deplete (Hasan 2008). This situation not only caused the decrease in species density, but also created the possibility of the disappearance of some species from the marine habitat, especially those with high commercial value.

Due to the overfishing of Saudi Arabia's sea cucumbers and the apparent depletion of natural stocks, the Ministry of Agriculture of Saudi Arabia banned sea cucumber fishing. The Ministry of Agriculture requested a full survey for all sea cucumber fauna and the stock status prior to the reopening of the fishery. In a previous paper (Hasan 2008), I reviewed the status of fisheries and proposed a management plan for Saudi Arabian sea cucumbers. The current study describes a two-month survey that has been made to evaluate the natural stocks of sea cucumbers in Saudi Arabia's Red Sea.

Materials and methods

Study sites

The sea cucumber stocks were surveyed at 18 offshore sites along Saudi Arabia's Red Sea coast from April to May 2006. Three areas along the coast were surveyed: the Al-Wajh area, the Thowal area and the Farasan Islands. The three areas have been extensively detailed in Hasan (2008). At each of these areas a number of sites were considered. In Al-Wajh,

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five sites were explored: North Al-Ewandia (underwater reef), Kotaa Al-Ewandia (shallow reef), Shaab Al-Jaziera (shallow reef), Braim Island and Kaad Al-Jazeira. In Thowal, three sites were surveyed: Bousti (underwater island), Tallah reef and Abou Koussa reef. The Farasan Islands are a group of islands 50 km offshore opposite the Jazan area at the southern borders of Saudi Arabia. Ten sites were surveyed there: Umm El-Hagar (submerged reef), Umm El-Raak (submerged reef), Bagel (submerged reef), Al-Hayla, Al-Shabeen, Umm Al-Madah, Gadeefa (underwater island), Al-Hacece, Al-Sharaa and Abou Atteque.

Sea cucumber population assessment methods

Estimation of sea cucumber populations at the surveyed sites was carried out using underwater visual transects. Direct visual assessment is the method conventionally used and is effective for the direct enumeration of specimens of epifauna (Lokani et al. 1996). At each site, transects were made covering the different depths, zones and habitats. The length of each transect was about 150 m. Between five and nine replicates were made at each zone and/or depth. Along each transect 10 quadrats of 10 m x 10 m (100 m^2) were made. The shallow areas were surveyed by snorkelling and the deep areas were surveyed by scuba diving.

Population estimates and distribution

The population density of different sea cucumber species inside each quadrat was counted and expressed as number of individuals per 100 m^2. At each quadrat the different biotopes of the reef and type of substrate were described in terms of percentage of sand, rubble, pavement, seagrass, algae, rocks, and dead and live corals.

The total population was estimated for each species for all the surveyed sites. The following formula was used to estimate the species population:

$$T = X * N$$

where:

T = total population
X = mean number per transect
N = number of transects that fit into the total area (N = total area/transect area).

The total area of each site was calculated based on distances measured by using a boat with a fixed speed and the formula:

$$D = S * T$$

where D is the distance, S is the boat speed and T is the time.

Estimation of standing stocks

Biomass was calculated by collecting the different sea cucumber species from representative quadrates and weighing them, after which they were returned them to the same site. Weight was measured after gently drying the animals with a cloth and leaving them out of the water for five minutes. The standing stocks were calculated by the formula:

$$SS = M.wt. * TA / QA$$

Where SS is the standing stocks, M.wt. is mean weight at the representative quadrats, TA is the total area and QA is the quadrat area.

Results

Sea cucumber faunal composition

A total of 12 species were recorded in the three surveyed areas. The species composition included three high value species: *Holothuria fuscogilva*, *H. nobilis* and *H. scabra*; five medium value species: *Actinopyga echinites*, *A. mauritiana*, *Holothuria atra*, *H. fuscopunctata* and *Stichopus variegatus*; three low value species: *Bohadschia vitiensis*, *Pearsonothuria graeffei* and *Holothuria edulis*; and one non-commercial species (*Holothuria leucospilota*) (Table 1). Of the 18 sites surveyed, 5 sites had no records of sea cucumber (North El-Ewandia, Al-Hayla, Al-Shabeen, Umm-El-Madah and Al-Sharaa). *Holothuria atra* was the most common species (recorded at nine sites), followed by *Holothuria nobilis* (recorded at three sites), while the rest of the species recorded were recorded at only one or two sites.

The surveyed sites differ in the diversity and density of species recorded. It was evident that all sites have low diversity of sea cucumber species. The study revealed that of the surveyed sites, 27.78 per cent did not have any sea cucumber species, 27.78 per cent recorded only one species, 38.89 per cent recorded two species and only 5.56 per cent recorded six species.

Species density and habitat distribution

In the Al-Wajh area, sea cucumbers were recorded at four of the five surveyed sites at low densities and diversities. Only one high value species was recorded in the area (*Holothuria nobilis*; recorded at Shaab Al-Jaziera), and was found at low densities that ranged between 0.1 and 0.2 individuals 100 m^{-2} (Table 2A). The medium value species *Holothuria atra* was recorded at three of the five surveyed sites (Shaab Al-Jaziera, Braim Island and Kaad El-Zawrak Island). The highest densities were recorded in sandy habitats (ranging between 4.3 individuals 100 m^{-2} at Shaab Al-Jaziera and 8.4

Table 1. Sea cucumber species composition at the surveyed sites (present/absent)

	Al-Wajh area				Thowal area			Farasan Islands					
Species	Kotaa Al-Ewandia	Shaab Al-Jaziera	Baim Island	Kaad El-Za-wrak Island	Bousti	Tallah	Abou Koussa	Umm El-Hagar	Umm El-Raak	Bagel	Gadeefa	Al-Hacece	Abou Atteque
Actinopyga echinites									+		+		
A. mauritiana							+						
Bohadschia vitiensis											+	+	
P. graeffei	+												
Holothuria atra		+	+	+		+	+	+	+	+	+		
H. edulis											+		
H. scabra										+	+		
H. fuscogilva					+								
H. nobilis		+			+	+							
H. fuscopunctata												+	
H. leucospilota													+
Stichopus variegatus											+		

individuals 100 m^{-2} at Braim Island), while the lowest densities of *H. atra* were recorded in dead coral habitats. The species were not recorded in areas with live coral habitats.

In the Thowal area four sea cucumber species were recorded at the three sites. Two high value species — *Holothuria fuscogilva* (only at Bousti), and *Holothuria nobilis* (at Bousti and Tallah) — were recorded in rocky and dead coral habitats at low densities (Table 2B). The medium value species *H. atra* was recorded at high densities at Tallah in both sandy (12.3 individuals 100 m^{-2}) and rocky areas (2.4 individuals 100 m^{-2}). Low densities were present at Abou Koussa (0.2 individuals 100 m^{-2}), in both sandy and rocky habitats. *Actinopyga mauritiana*, another medium value species, was recorded at very low densities (0.01 individuals 100 m^{-2}) on corals at only one site (Abou Koussa).

In the Farasan Islands, the high value species *Holothuria scabra* was recorded only on sandy substrates but at low densities at Bagel (0.1 individuals 100 m^{-2}) and Gadeefa (0.3 individuals 100 m^{-2}). The medium value species were also present at low densities. Of them, *H. atra* was found at the highest densities. *H. edulis*, another medium value species, was found only in dead coral (0.1 individuals 100 m^{-2}) and coral habitats (0.2 individuals 100 m^{-2}) at Gadeefa. Two other medium value species were found in the Farsan Islands: *Actinopyga echinites*, recorded only at Umm El-Raak (0.1 individuals 100 m^{-2} in both rocky and dead coral habitats), and *Stichopus variegatus*, recorded only in sandy habitat at Gadeefa. The non-commercial species *Holothuria leucospilota* was recorded at high densities at the Abou Atteque site in sandy habitats (7.8 individuals 100 m^{-2}) and rocky habitats (3.9 individuals 100 m^{-2}) (Table 2C).

Stock assessment

The population size recorded for *Holothuria scabra* was 35 individuals at Gadeefa and only 8 at Bagel. *Holothuria fuscogilva* is another high value species that is important in the catch composition of Saudi Arabia's sea cucumber fishery. There were only 10 individuals at Bousti. *Holothuria nobilis* was recorded at three sites: 14 individuals at Shaab Al-Jaziera, 7 individuals at Bousti and 18 individuals at Tallah reef. The only species that showed higher number was the medium value *Holothuria atra*, of which a population of 1567 was recorded at Tallah reef with signs of population recovery after three years of closure. It was also found at Shaab Al-Jaziera (87 individuals), Braim Island (189 individuals), Kaad El-Zaurak Island (112 individuals), Bagel (65 individuals) and Gadeefa (92 individuals).

The total biomass (in wet weight) was little more than half a tonne (Table 3). The majority of the biomass consisted of *Holothuria atra*, of which a total of 450.5 kg was recorded. The high value species were recorded at negligible levels at all surveyed sites. A

Table 2A. Species density of sea cucumber (individuals 100 m[-2]) at different habitats at the surveyed sites in the Al-Wajh area (data expressed as means).

Species	Bousti			Tallah			Abou Koussa		
	Rocks	Dead corals	Live corals	Sand	Rocks	Dead corals	Sand	Seagrass	Live corals
Holothuria atra	0	0	0	12.3	2.4	1.2	0.2	0.2	0
Holothuria nobilis	0.1	0.1	0	0	0.2	0.1	0	0	0
Holothuria fuscogilva	0	0.2	0.01	0	0	0	0	0	0
Actinopyga mauritiana	0	0	0	0	0	0	0	0	0.01

Table 2B. Species density of sea cucumber (individuals 100 m[-2]) in different habitats at the surveyed sites in the Thowal area.

Species	Kotaa Al-Ewandia	Shaab Al-Jaziera			Braim Island			Kaad El-Zawrak Island	
	Live corals	Sand	Rocks	Dead corals	Sand	Seagrass	Dead corals	Sand	Rocks
Holothuria atra	0	4.3	1.1	0.9	8.4	4.2	0.3	5.6	1.2
Holothuria nobilis	0	0.01	0.2	0	0	0	0	0	0
Pearsonothuria graeffei	0.01	0	0	0	0	0	0	0	0

Table 2C. Average regional variation in species density of sea cucumber (individuals100 m[-2]) in different habitats at some representative sites in the Farasan Islands area.

Species	Umm El-Hagar		Umm El-Raak		Bagel		Gadeefa			Al-Hacece		Abou Atteque	
	Sand	Rocks	Sand	Dead corals	Sand	Rocks	Sand	Dead corals	Live corals	Sand	Live corals	Sand	Rocks
Actinopyga echinites	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0
Bohadschia vitiensis	0	0	0	0	0	0	0.2	0	0	0.2	0.1	0	0
Holothuria atra	0.4	0.2	0.2	0.1	0.5	0.2	4.6	2	0	0	0	0	0
H. edulis	0	0	0	0	0	0	0	0.1	0.2	0	0	0	0
H. fuscopunctata	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0
H. scabra	0	0	0	0	0.1	0	0.3	0	0	0	0	0	0
H. leucospilota	0	0	0	0	0	0	0	0	0	0	0	7.8	3.9
Stichopus variegatus	0	0	0	0	0	0	0.3	0	0	0	0	0	0

total biomass of 32.5 kg was recorded for *Holothuria scabra*, with 26.85 kg recorded at Gadeefa and 5.65 kg at Bagel. The situation was not better for *Holothuria nobilis,* of which a total biomass of 24.95 kg was recorded. *Holothuria fuscogilva* was recorded only at Bousti, with a biomass of 6.5 kg (Table 4).

The status of sea cucumber stocks is given in Table 4. Tallah recorded the highest biomass (347.45 kg wet weight), but most of the sea cucumbers are of poor value. Sea cucumbers at Bousti are high value species, but the biomass is very low.

Discussion

The major finding of this study is that there has been heavy overfishing in all the surveyed sites. It is evident that illegal fishing is continuing, especially in the southern and northern sections of the coastline. In spite of satisfactory environmental conditions that would enable sea cucumber species to grow, the species diversity is low and the density of the high value species is even lower. It is probable that the natural parameters are not enough for maintaining the Saudi stocks of sea cucumbers.

Table 3. Standing stocks (biomass expressed in kg) of different sea cucumber species at the surveyed sites.

Site	*Actinopyga echinites*	*A. mauritiana*	*Bohadschia vitiensis*	*Pearsonothuria graeffei*	*Holothuria atra*	*H. edulis*	*H. leucospilota*	*H. fuscogilva*	*H. nobilis*	*H. fuscopunctata*	*H. scabra*	*Stichopus variegatus*
Kotaa Al-Ewandia	-	-	-	0.5	-	-	-	-	-	-	-	-
Shaab Al-Jaziera	-	-	-	-	18.50	-	-	-	9.25	-	-	-
Braim Island	-	-	-	-	36.75	-	-	-	-	-	-	-
Kaad El-Zaurak Island	-	-	-	-	21.10	-	-	-	-	-	-	-
Bousti	-	-	-	-	-	-	-	6.5	2.75	-	-	-
Tallah reef	-	-	-	-	334.50	-	-	-	12.95	-	-	-
Abou Koussa reef Umm El-Hagar	-	0.65	-	-	0.85	-	-	-	-	-	-	-
Umm El-Raak	-	-	-	-	2.10	-	-	-	-	-	-	-
Bagel	2.3	-	-	-	1.45	-	-	-	-	-	-	-
Gadeefa	-	-	-	-	13.65	-	-	-	-	-	5.65	-
Al-Hacece	2.7	-	4.1	-	21.60	1.25	-	-	-	-	26.85	21.35
Abou Atteque	-	-	4.8	-	-	-	-	-	-	1.35	-	-
	-	-	-	-	-	-	189.75	-	-	-	-	-

Table 4. Total abundance, total wet weight and proportion of total high commercial value species (*Holothuria scabra*, *H. fuscogilva* and *H. nobilis*) by site.

Site	Total abundance	Weight (kg)	% high value species (no.)	% high value species (wt.)
Kotaa Al-Ewandia	3	0.500	0.00	0.00
Shaab Al-Jaziera	101	27.750	16.09	33.33
Braim Island	189	36.750	0.00	0.00
Kaad El-Zaurak Island	112	21.100	0.00	0.00
Bousti	17	9.250	100.00	100.00
Tallah reef	1585	347.450	1.15	3.73
Abou Koussa reef	8	1.500	0.00	0.00
Umm El-Hagar	19	2.100	0.00	0.00
Umm El-Raak	13	3.750	0.00	0.00
Bagel	73	19.300	12.31	29.27
Gadeefa	186	77.850	18.82	34.49
Al-Hacece	22	6.150	0.00	0.00
Abou Atteque	451	189.750	0.00	0.00

The population density of sea cucumber species differed widely by habitat (Hasan and Hasan 2004), species behaviour (Hammond 1982; Young and Chia 1982) and level of exploitation (Conand 1990, 1998, 2004). The population densities of the high value species *Holothuria scabra*, *H. nobilis* and *H. fuscogilva* were very low in the surveyed sites. The same species showed much higher densities in Papua New Guinea in 1981 (0.29 to 0.37 individuals m^{-2}) (Shelly 1981). In 1979, Lawrence recorded very high abundance of *A. mauritiana* in Guam (12 individuals m^{-2}). The density of *H. scabra* recorded in Saudi Arabia's Red Sea is similar to the reduced densities measured in other places: e.g. in Indonesia *H. scabra* density ranged from 0.0025 to 0.39 individuals m^{-2} (Darsono et al. 1998) and in Papua New Guinea it was 0.01 to 0.02 individuals m^{-2} (Lokani et al. 1996).

The biomass of all the commercial species of sea cucumbers at all the surveyed sites was low and was probably not sufficient to maintain a population or sustain a reliable fishery. Moreover, the quantity of high value species (*Holothuria fuscogilva*, *H. nobilis* and *H. scabra*) was very low, indicating heavy depletion. The quantity of medium and low value species on all reefs at the studied sites was also low. The currently targeted species, *H. atra*, was severely depleted at all sites except for Tallah reef and Braim Island, which showed population recovery and relatively high densities. The biomass of *H. atra* at Tallah reef was low due to the high percentage of small animals.

Harvesting of sea cucumbers in Saudi Arabia started in 1999 and was banned in 2004. The recovery of overfished sea cucumber stocks is a long process, taking several years (Purcell et al. 2002). Reduction of population density by overfishing may render remaining individuals incapable of successful reproduction. It is now apparent that depleted stocks of high value sea cucumber species at the surveyed sites may take decades to recover. The absence of effective control, surveillance and enforcement of regulations has resulted in widespread illegal fishing of sea cucumber leading to depletion of the resource. There is little awareness of the benefits that may be gained from an effective sea cucumber fishery managed by stakeholders in this sector and this is a critical cause of the overexploitation and depletion of sea cucumber. More effective training opportunities for managers of fisheries, scientists, shore protection personnel, environmental protection officers, cooperative staff and fishers are required.

The authorities must make appropriate rules and regulations to maintain sea cucumber resources. These rules and regulations should spell out the proper procedures for harvesting. Also, the recording of reliable and accurate data on the sea cucumber fauna of Saudi Arabia's Red Sea is required. These requirements should be implemented within a management plan.

Acknowledgements

I want to express my thanks to my dear colleagues at Jeddah Fishery Research Center in Jeddah, Saudi Arabia for their help during the field work of this manuscript.

References

Bakus G.J. 1973. The biology and ecology of tropical holothurians. p. 325–367. In: Jones O.A. and Endean R. (eds). Biology and ecology of coral reefs, Vol. 2. New York: Academic press.

Clark A.M. and Rowe F.W.E. 1971. Monograph of shallow water Indo-West Pacific Echinoderms. London: Trustees British Museum of Natural History. 277 p.

Conand C. 1990. The fishery resources of Pacific Island Countries Part2: Holothurians. FAO Fisheries Technical Paper 272(2). Rome: Food and Agriculture Organization of the United Nations. 141 p.

Conand C. 1998. Overexploitation in the present sea cucumber fisheries and perspectives in mariculture. p. 449–454. In: Mooi R. and Telford M. (eds.). Echinoderms. San Francisco: Balkema.

Conand C. 2004. Present status of world sea cucumber resources and utilization an international overview. p. 13–23. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.F. and Mercier A. (eds.). Advances in sea cucumber aquaculture and management. Rome: Food and Agriculture Organization of the United Nations.

Darsono P., Aziz A. and Djamali A. 1998. Kepadatan stok teripang pada beberapa lokasi di Indonesia. Prosiding Seminar Nasional Kelaulan 2:264–272.

Guille A. and Ribes S. 1981. Echinoderms associes aux Scleractinaires d'un recif grangeant de l'ile de la Reunion (Ocean Indien). Bulletin du Muséum d'Histoire Naturelle de Paris 3(1):73–92.

Hammond L.S. 1982. Patterns of feeding and activity of deposit feeding holothurian and echinoids from a shallow back reef lagoon, Discovery Bay, Jamaica. Bulletin of Marine Science 32(2):549–571.

Hasan M.H. 2003. Ecology and distribution patterns of the threatened holothuroids as correlated with over-fishing in the Gulf of Aqaba, Northern Red Sea, Egypt. Journal of Egyptian Academic Society of Environmental Development, 4(3):101–118.

Hasan M.H. 2005. Destruction of a *Holothuria scabra* population by overfishing at Abu Rhamada Island in the Red Sea. Marine Environmental Research 60:489–511.

Hasan M.H. 2008. Fisheries status and management plan for Saudi Arabian sea cucumbers. SPC Beche-de-Mer Information Bulletin 28:14–21.

Hasan M.H. and Hasan Y.S. 2004. Natural ecological factors and human impacts influencing the spatial distribution of holothuroid species in the Gulf of Aqaba. Journal of the Egyptian German Society of Zoology 43(D):287–306.

Head S.M. 1987. Introduction to the Red Sea. p. 1–21. In: Edwards A.J. and Head S.M. (eds). Key environments: The Red Sea. Oxford: Pergamon Press.

Holland A. 1994. The status of global beche-de-mer fisheries with special reference to the Solomon Islands and the potentials of holothurian culture [M.Sc. Thesis]. Newcastle, Australia: University of Newcastle. 134 p.

Lawrence J.M. 1975. On the relationships between the marine plants and sea urchins. Oceanography and Marine Biology: An Annual Review 13:213–286.

Lokani P. Matoto S.V. and Ledua E. 1996. Report of a survey of sea cucumber resources at Ha'apai, Tonga. May-June, 1996. Noumea, New Caledonia: South Pacific Commission. 13 p.

Mercier A., Battaglene S.C. and Hamel J.F. 1999. Daily burrowing cycle and feeding activity of juvenile sea cucumber *H. scabra* in response to environmental factors. Journal of Experimental Marine Biology and Ecology 239:125–156.

Preston G.L. and Lokani P. 1990. Report of a survey of the sea cucumber resources of Ha'apai, Tonga. June, 1990,. Noumea: South Pacific Commission. 14 p.

Price A.R.G. 1982. Echinoderms of Saudi Arabia. Comparison between echinoderm faunas of Arabian Gulf, SE-Arabia, Red Sea and Gulfs of Aqaba and Suez. Fauna of Saudi Arabia 4:3–21.

Price A.R.G. 1983. Echinoderms of Saudi Arabia. Echinoderms of the Arabian Gulf Coast of Saudi Arabia. Fauna of Saudi Arabia 5:28–108.

Purcell S., Gardener D. and Bell J. 2002. Developing optimal strategies for restocking sandfish: a collaborative project in New Caledonia. SPC Beche-de-mer Information Bulletin 16:2–4.

Roberts D. 1979. Deposit-feeding mechanisms and resource partitioning in tropical holothurians. Journal of Experimental marine Biology and Ecology 37:43–56.

Shelly C. 1981. Aspects of the distribution, reproduction, growth and fishery potential of holothurians in the Papuan coastal lagoon [M.Sc. Thesis]. Port Moresby: University of Papua New Guinea.

Young C.M. and Chia F.S. 1982. Factors controlling spatial distribution of the sea cucumber *Psolus chitonoides*: Settling and post-settling behavior. Marine Biology 69:195–205.