Evaluation of sea cucumber abundance in Abu Hashish area on the Sudanese Red Sea coast in the years 2000 and 2021: Are *Holothuria atra* resilient to climate change?

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Abstract

Shallow benthic communities, such as coral reef ecosystems, are among the most vulnerable to ocean warming and acidification. Sea cucumbers are essential member of these benthic communities. The presence of high density sea cucumber populations, as characteristic of unfished reefs may be particularly important for the integrity of reefs due to the potential of sea cucumbers to buffer changes in local carbonate chemistry caused by ocean acidification through the digestion of benthic sands and particles. The aim of the study is to provide information on abundance of sea cucumbers from a selected area of the Sudanese coast, and to assess the tolerance of *Holothuria atra* present in the area during two time periods (2000) and (2021) using line transects method. Two species of sea cucumber were found from two different families The most dominant species found along transects was *H. atra* which found on substrate of seagrass zone (0.5315 ind./m2) and back reef corals (0.0356 ind./m2). Significant correlations was found between abundance and most of the physical factors. Almost same abundance was noticed regarding *H. atra* population (p>0.05), in contrast to Actinopyga echinites population which disappeared during 2021 study. The difference in abundance among the investigated zones, indicate the tolerance of *H. atra* within two decades of time which underscore the importance of *H. atra* as an adaptive and resilient organism nominating it among organisms that are adaptive and resilient to climate change and qualifies it for further studies in this aspect. Sea cucumber communities are in dire need of managing their current fisheries and areas to continue their ecological benefits.

1. Introduction

Sea cucumbers (Echinodermata: Holothuroidea) are significant members of benthic invertebrate communities, occurring in all of the major oceans and seas of the world (Birkeland, 1988). There is a wide variety of forms made up of about 80 species belonging to 22 genera in the Red Sea, where it is usually found on seagrass beds, sandy and muddy substrata with rubble or coral reefs (Vine, 1986).

Recent studies indicate that several aspidochirotid sea cucumber species can increase local seawater alkalinity and dissolved inorganic carbon through their digestive processes and release of ammonia, thereby facilitating calcification by associated organisms such as corals and calcareous algae (Uthicke and Klumpp, 1997; Schneider *et al.,* 2011, 2013).

The population of sea cucumber are particularly vulnerable to anthropogenic threat of habitat degradation and overfishing due to effectiveness and increase intensity of harvesting (Uthicke and Benzie, 2000; Zhang, 2021). It is both the warm temperatures and shallow habitats that permit easy harvesting by coastal fishers and make these fisheries vulnerable to degradation from impacts associated with global climate change (Kinch *et al.*, 2008).

Recreational restaurants at Abu Hashish beach line accompanied by boating picnics which had been established since 2010 may posed significant negative pressure on sites where sea cucumbers naturally inhabit. The ecology and distribution of sea cucumbers in this area had been studied by Ibrahim (2001) before the start of this activity. Therefore, the aim of the study is to compare between the environmental characters; distribution and abundance of sea cucumbers from Abu Hashish at the Sudanese Red Sea coast, and to assess the tolerances of some holothurian species with a focus on *Holothuria atra* present in the area during two time periods (2000 and 2021).

2. Material and methods

2.1 Study site

Mersa Abu Hashish is situated about 2 Kilometers north of the northern point of Port Sudan harbour entrance (fig. 1). It is considered as a Marsa of small boats

2.2 Site description

The study site was divided into three zones as follows:

Zone 1:About 150 meters in width, characterized by small sandy domes.

Zone 2:This zone which is 80 meters wide comprises a strip of seagrasses and seaweeds.

Zone 3: Extends 320 meters from zone 2 and is bordered by the reef face. The first part of it being a coastal lagoon of about 150 meters followed by a rocky area. The substratum is sandy, underlain by a hard rocky bed. This zone is dominated by colonies of corals

2.3 Methods

2.3.1 Environmental Characteristics

Every month during the years 2000 and 2021 Transects of about 550 m in length and 5 m in width at the shore of Abu Hashish were made crossing the zones from land to seaward direction. Air temperature and some water physical-chemical parameters (water temperature, salinity, depth, pH, dissolved Oxygen, Phosphate, Silicate, Nitrite, and Nitrate) were determined. Sediment samples were collected from Zones and Transects for the analysis of substrate texture (particle size PS) and C-organic content.

2.3.2 Species composition, abundance, and density

The number of each Sea cucumber was observed along the line transect and recorded, some specimens were collected from and outside the transects and identification based on (Vine, 1986, Conand, 1990).

Abundance stands for the total number of a sea cucumber species counted along transects every month. Density at each zone was calculated as ind./m2

Figure1. Location Map of Abu Hashish area.

3. RESULTS

3.1 Environmental and sites characteristics:

Water characteristics and some soil properties from the study site for two time periods are shown in Table 1. The degree of variance in these variables was not significant at the 95% confidence level between the two time periods 2000 and 2021 (Table 1).

Table .1. Sea cucumber species composition found at Abu Hashish area during 2000 and 2021 study

Parameter	Zone 1	Zone 2	Zone 3
Depth (cm)	20-90	20-85	20->150
Nature of substratum:			
Fine sand	+	+	
Medium sand			+
Coarse sand			

Table 2. Physico-chemical characteristics of Sea water at Abu Hashish during 2000- 2021

Variable	Mean value	
	Year 2000	Year 2021
Air temperature (°C)	30.94	31.29
Water Temperature (°C)	29.38	29.96
Salinity (‰)	40.15	40.50
Dissolved Oxygen (mg/ L)	5.12	5.06
Median grain size ( )	0.13	0.12
TOC	0.310	0.303
Phosphate (µ mole/ L)	0.25	0.30
Silicate (µ mole/ L)	7.24	6.95
Nitrite (µ mole/ L)	0.104	0.099
Nitrate (µ mole/ L)	0.49	0.48
pH	8.10	8.12

3.2 Species composition and abundance:

3.2.1 Species composition.

Table .3. Sea cucumber species composition found at Abu Hashish area during 2000 and 2021 study

Class	Order	Family	Genus	Species
Holothuroidea	Aspidochirotida	Holothuriidae	Actinopyga	*A.echinites*
			Holothuria	*H. atra*

3.2.2 Species abundance and density

The species observed during the study appeared to show a consistent pattern of abundance throughout the year 2000, with numbers increasing during the summer and declining during the winter. In 2021; almost the same pattern was observed with respect to *H. atra* abundance and no significant difference was observed (t=0.23; p > 0.05) while; there was a statistically significant absence of *A. echinites* between the two study periods. (t =2.908; p<0.05) (Fig. 2,3 and Table 3). The comparison of density between different zones was illustrated in table (4)

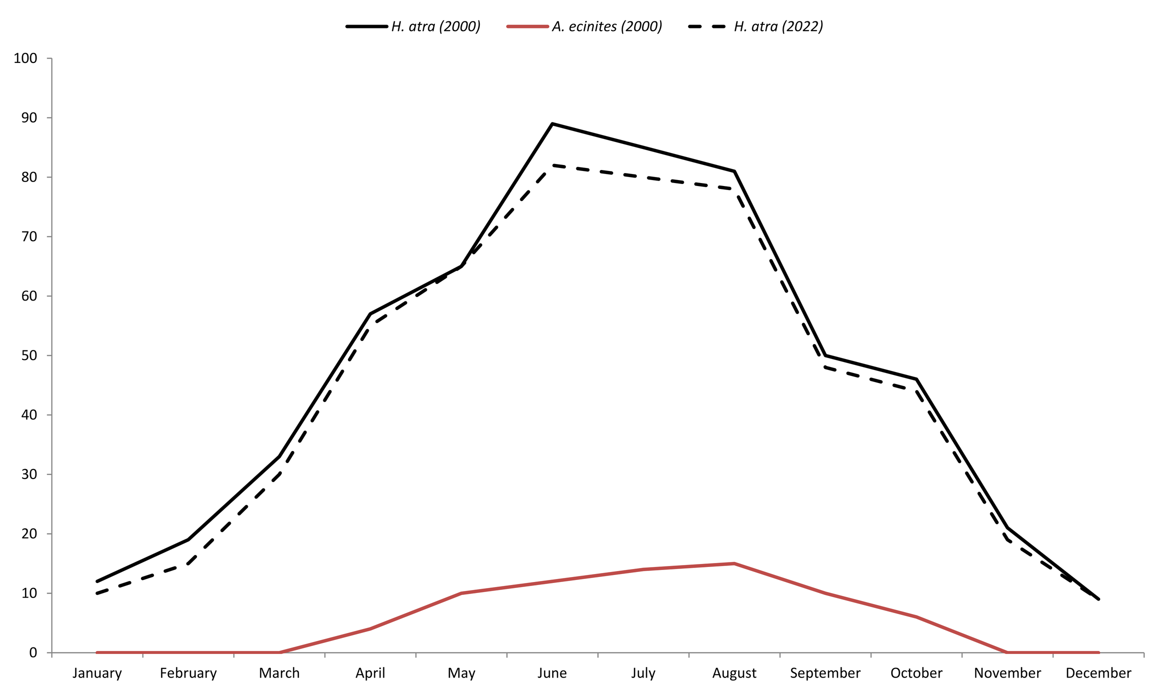

Fig. 2. Sea cucumber abundance during months of the years (2000) and (2021) at Abu Hashish

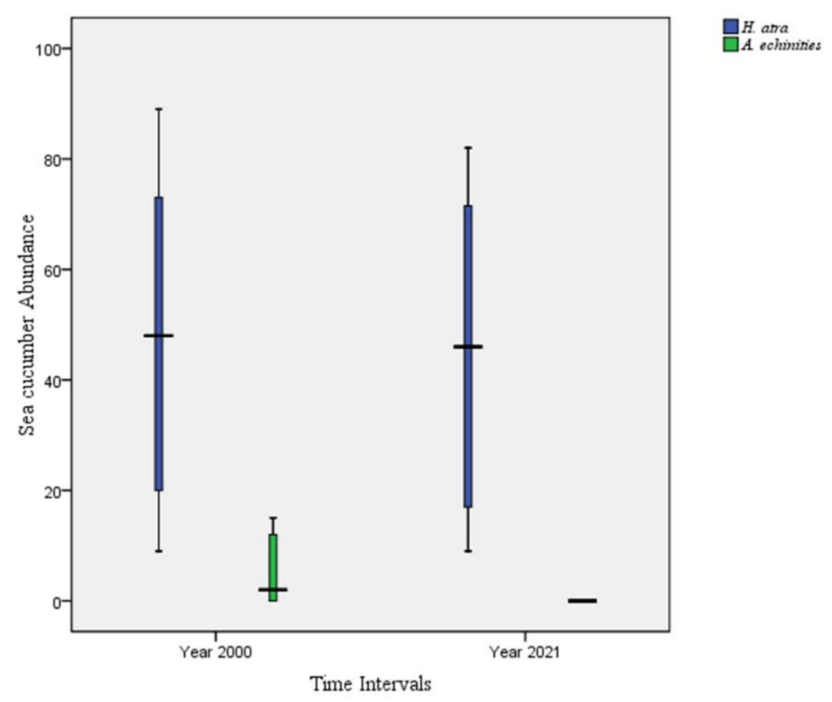

Fig.3. Sea cucumber abundance in the years (2000) and (2021) at Abu Hashish

Table. 3. Difference in Holothurian abundance between the year 2000 and year 2021 at Abu Hashish

Species	Abundance Mean ± SD		p. Value
	Year 2000	Year 2022	
H. atra	47.25 ± 28.72	44.58 ± 27.819	> 0.05
A. echinites	5.25±6.25	0.00	< 0.05

Table. 4 . Density of sea cucumber species between different zones during the periods 2000-2021

Zones	N/ m² (2000)		N/ m² (2021)		*p*-Value	
	H. Atra	A. echinites	H. Atra	A. echinites	H. Atra	A. echinites
Z1	0.0481	0	0	0	<0.05	<0.05
Z2	0.5315	0	0.4275	0	>0.05	<0.05
Z3	0.0356	0.0049	0.0038	0	<0.05	<0.05
Total	0.6152	0.0049	0.4313	0		

Table.5. Values of Correlation coefficient r of holothurians abundance with the environmental factors in Abu Hashish during year 2000 (1) and year 2021(2).

Environment factors	Years	H. atra		A. echinites	
		r	p-value	r	p-value
Air Temperature (°C)	1	0.774	< 0.05	0.713	< 0.05
	2	0.836	< 0.05	0.828	< 0.05
Water Temperature (°C)	1	0.786	< 0.05	0.726	< 0.05
	2	0.841	< 0.05	0.822	< 0.05
Water Salinity (‰)	1	0.804	< 0.05	0.797	< 0.05
	2	0.814	< 0.05	0.891	< 0.05
Median grain size (ϕ)	1	0.800	< 0.05	0.788	< 0.05
	2	0.796	< 0.05	0.801	< 0.05
TOC	1	0.843	< 0.05	0.833	< 0.05
	2	0.810	< 0.05	0.861	< 0.05
Dissolved Oxygen (mg/ L)	1	-0.308	> 0.05	-0.307	> 0.05
	2	0.256	> 0.05	0.314	> 0.05
W. Phosphate(µ mole/ L)	1	-0.673	< 0.05	-0.619	< 0.05
	2	-0.542	< 0.05	-0.522	< 0.05
W. Silicate(µ mole/ L)	1	-0.113	> 0.05	-0.117	> 0.05
	2	-0.122	> 0.05	-0.117	> 0.05
W. Nitrite(µ mole/ L)	1	0.081	> 0.05	0.054	> 0.05
	2	0.079	> 0.05	0.051	> 0.05
W. Nitrate(µ mole/ L)	1	0.266	> 0.05	0.325	> 0.05
	2	0.255	> 0.05	0.345	> 0.05

Discussion

The number of species found in the 2021 study is lower than those recorded in the 2000 study conducted in the same area.

the current results seems to be consistent with the global holothurian distribution (Hyman, 1955; and Conand, 1990, 2013) who attributed the predominance of the order Aspidochirotidae to the tropics and to some extent to the littoral and sublittorall waters of those seas, noting the outstanding presence associated with *H. atra*.

The overall distribution showed the predominance of *H. atra* over other species during 2000 and 2021 study which may attribute to a higher tolerance of this species enabling it to occupy a wider niche. Moreover, *H. atra* is more efficient at reproducing by asexual reproduction especially when exposed to environmental stress, with which it can compensate its population to a certain extent (Dolmatov, 2014; Mladenov, 1996; Uthicke, 2001 and Thorne *et al.*,2013)

As mentioned earlier Sigala restaurants had been established since 2010, it may be source of excess nutrients which may lead to coastal hypoxia and anoxia, which increase with warming; represent major stresses for benthic marine species, especially for the least active fauna such as holothuroid in contrast to migrants who had high avoidance behaviour. Moreover, echinoderms possess moderate tolerance to environmental anoxia (Gray *et al.*, 2002; Levin *et al.*, 2009; Riedel *et al.*, 2014; Cosme and Hauschild, 2016).

Sea cucumbers seems to play a role in combating climate change in benthic marine communities, that a variety of responses to warming water by each species must be well studied and confirmed either contribute to the resilience of benthic communities and help maintain their ecological role, or their disappearance will lead to ecological disturbances in the reef system in general. Finally, species that thrive will be able to continue to balance the ocean's calcium carbonate budget despite ocean warming (eg, *H. atra*), while the disappearance of some species will affect the entire ecosystem. Therefore, sea cucumber communities at Sudanese coast are in dire need of managing their current fisheries and areas to continue their ecological benefits.

From the above discussions the preference for *H. atra* as adaptive organisms that mitigate climate change seems appropriate for many reasons:

First: They tend to occupy a wider niche.

Second: They are able to persist in roughly the same abundance for decades.

Thirdly: They thrive even under conditions of low environmental stability.

Finally: they possess high intrinsic biological ability to reproduce asexually compensating their population.

The reasons given may justify the designation of *H. atra* among organisms that are able to adapt and resistant to climate change and qualify it for further studies in this aspect.

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