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A study on the effect of the sea cucumber *Actinopyga mauritiana* (Echinodermata: Holothuroidea) on the sediment characteristics at El-Gemsha Bay, Red Sea coast, Egypt

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ABSTRACT
Deposit-feeding holothurians play an important role in regenerating nutrients of coastal sediments. The present study examined the effect of feeding by the sea cucumber *Actinopyga mauritiana* on sediment characteristics. Feeding effects were investigated in a designed cage system at the area of El Gemsha Bay, Red Sea. Three treatments of high density (60 individuals/cage of $9m^2$), low density (10 individuals/cage of $9m^2$) and zero (control). *A. mauritiana* were used to investigate their effect on sediment's redox potential, organic carbon, chlorophyll a, bacteria and nutrients contents. The sediment parameters were measured bi-weekly over a period of 16 weeks.
In the three treatments, data analysis showed no significant effect on sediment redox potential. Significant high concentrations of organic carbon, bacteria and chlorophyll A were recorded in sediment of the control cages (not populated with *A. mauritiana*) in comparison to sediments in the populated cages. In contrast, the concentrations of nitrogenous materials (ammonia, nitrite and nitrate) and phosphorus were higher in cages populated with *A. mautitiana* than the control cages. The study emphasizes the vital role of holothuroids in generating and/or regenerating nutrient in the marine environment.

1. INTRODUCTION

Sea cucumbers are represented in seas at all water depths. They inhabit a wide variety of substrates and habitats (Graham and Ballaglene, 2004). Patterns of feeding behavior are predominantly nocturnal in Phylum Echinodermata (Reese, 1966). On the other hand, nocturnal feeding activity characterizes most holothurians (Bakus, 1968; Konnecker and Keegan, 1973). However, some species feed uniformly day and night (Bakus, 1973). Sediment ingested by deposit feeding holothuroids is of low nutrient value (Santos *et al*., 1994).

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The low richness of organic matter forces the deposit feeders to ingest large amounts of sediment to obtain their needed energy (Santos *et al*., 1994). This means that the level of the physical and chemical recycling activity to the sediment surface are substantial and important (Sibuet and Lawrence, 1981; Sibuet *et al*., 1982; Roberts *et al*., 2000). Kitano (2003) reported that feeding and movements of sea cucumbers on the sea bottom recovered the bottom conditions and increased the number of diversity of species by inhibition of anaerobic conditions. It was also reported that extirpation of sea cucumbers caused hardening sea floor, eliminating habitat for other benthic and infaunal organisms (Bruckner *et al*., 2003).

During the last decade, sea cucumber fishing has appeared as major additional threats to Egyptian reefs of the Red Sea. After the depletion of sea cucumber fisheries in other parts of the world (kinch, 2002), a small-scale sea cucumber fisheries began in the Egyptian Red Sea coast during the late 1990s. By 2000, the sea cucumber fisheries in Egypt had increased greatly as a result of high demand for beche-de-mer and the high prices paid for it. Between 2002 and 2004, extensive fishing of sea cucumber caused a serious depletion in the natural stocks where 5 commercial species disappeared completely from many reefs. Lawrence *et al*. (2004) found that sea cucumber fishery from the Egyptian coast of the Red Sea had followed a similar pattern found elsewhere; a boom in the fishery followed by a collapse of most stocks. Although there is no quantitative investigation, the impact of removal of sea cucumber from marine sensitive habitats especially the most ecologically and economically valuable coral reefs ecosystem could lead to disastrous consequences. This work is designed to investigate the impact of sea cucumber removal, represented by *Actinopyga moritiana*, on physico-chemical characteristics and bacterial content of the sea floor sediment.

2. MATERIAL AND METHODS

2.1 The experimental site & design

The experiment was conducted at El Gemsha Bay (27° 66' 56" N and 33° 51' 45" E) which locates 45 km north of Hurghada (Fig. 1). The Bay is characterized as a 40 km^2 area and 0.3 - 1m sandy bottom, back reef extending to 250-750 m to the slope. Sea grass and brown algae are the main benthic coverage with scattered, low diversity of coral patches.

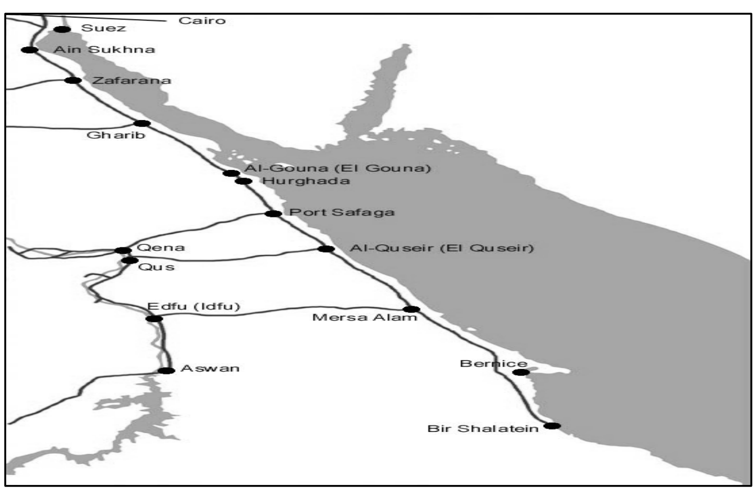

Fig.1: The Red Sea map of the studied area.

The slope is characterized by a sandy bottom with heavily distributed patches of sea grasses (*Halophila stipulacae* and *Halodula uninervis*) to the bottom which is sandy with maximum depth of 8m depth.

An experimental unit divided into nine treatment cages was constructed in a quadrate shape (9 X 9m) using metal (1 inch) water pipes welded together, and with a total area of 81 m^2 (Fig. 2).

Each treatment cage was therefore 9 m^2 (3 X 3m). This unit was placed at 5m depth. Three treatment of high (60 individuals / cage), low (10 individuals /cage) and no (control) sea cucumber were used to investigate the effect of holothurians *A. mauritiana* on sediment characteristics.

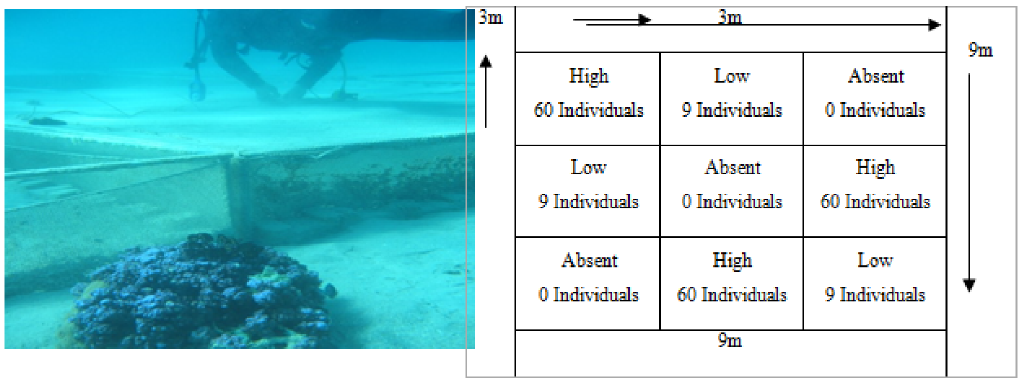

Fig. 2: Experimental design and layout of sea cucumber cages.

Three cages were used per each treatment. The cages were totally covered with a 0.5 cm mesh size fishing nets to keep the animals inside and to prevent entrance of other animals. The edges of each cage were secured by attaching the net to the bottom with small-cemented blocks. Only a small hatch, in the top of the net, was kept for sample collection. The bottom of the cages was positioned in an area free of seagrasses or sand dollars that might have affected the data. The experimental unit was placed away from the dominated southeast current to avoid sediment accumulation. *A. mauritiana* specimens of 15-20 cm lengths were collected from the area of El Gemsha Bay using SCUBA diving and populated in the experimental cages.

2.2 Sediment sampling and analysis

Sediment samples were collected on bi-weekly intervals using a cylindrical corer of 4.5 cm diameter and 50 cm length. The samples were collected in 1 kg plastic bags. Three cores with 10 cm heights of sand were collected randomly from each cage and placed into labeled plastic bags. Different physico-chemical parameters were analysed for each samples. The redox potential was read on Lutron 206 portable PH meter, mV and temperature meter in the sediments. Total Organic Carbons (mg C g^{-1}) was analyzed according to Gaudette *et al.* (1974). Chlorophyll a was determined spectrophotometery utilizing 90% acetone extraction followed the most common used method (APHA. 1985). Ammonium (NH^+_4 - N µg l^{-1}) was measured coloromitrically by using the Phenate method as reported by Booth and Lobring (1973). Nitrate (NO_3^- - N µg l^{-1}) was determined using the Cadmium reduction method as described by Nydhal (1976). Nitrite ((NO_2^- - N µg l^{-1}). was determined by applying Barnes and Folkards & Barnes (1951). Phosphorus was determined following the method of Bray and Kurtiz (1945).

3. RESULTS

The presence of *A. mauritiana* showed no significant effect (P>0.05) on sediment redox potential of the whole core (0-10cm). The overall mean values of oxidation-reduction in the high and low populated cages over the 16 weeks of the experiment period were 186.01 mV and 186.70 mV, respectively compared with 186.83 mV in the non-populated cages (control), although, the redox values fluctuated with time (weeks) in all treatment cages (Table1. and Fig.3).

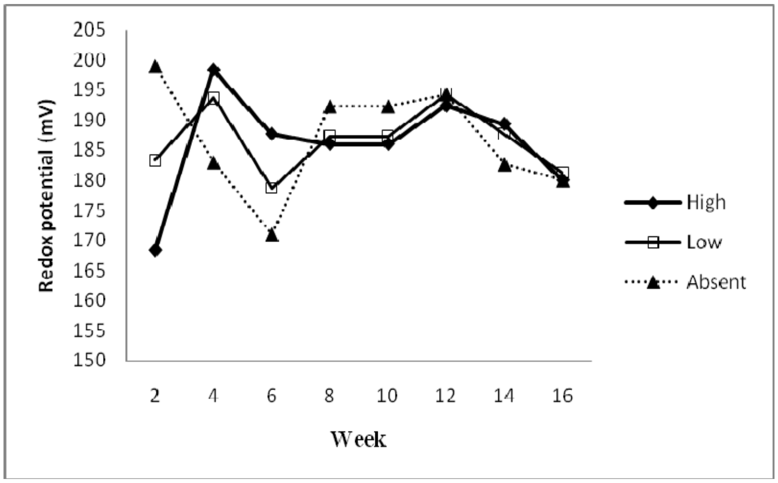

Fig. 3: Mean redox potential (mv) measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

Table 1: Overall mean of the measured parameters in the sediment of the treatment cages populated with *A. mauritiana* (i.e. high =60, low=9 and absent= zero individuals /cage) over experimental period of 16 weeks.

	Redox potential mV	**Organic carbon** mg C g-1	**Bacteria** 10^{-2}Cfu g^{-1}	**Chlorophyll a** µg g^{-1}	**Ammonium** mg g^{-1}	**Nitrite** mg g^{-1}	**Nitrate** mg g^{-1}	**Total phosphorus** mg g^{-1}
High	186.01	3.22	9.20	1.18	5.70	0.84	0.70	1.22
Low	186.70	4.62	13.90	1.49	4.80	0.79	1.00	0.84
Absent	186.83	5.24	20.40	2.07	4.60	1.10	1. 20	0.59

A. mauritiana showed a highly significant effect (p<0.001) on the total organic carbon, bacterial population count and chlorophyll a in the sediment after 16 weeks. The three parameters showed the same trend; their lowest values were recorded for highest populated cages (Table 1). The overall means of total organic carbon in the high and low populated cages estimated 3.22 mg C g^{-1} and 4.62 mg C g^{-1}, respectively compared with 5.24 mg C g^{-1} in the non-populated cages.

The overall mean bacterial population in the high and low populated cages was 9.2 and 13.9 Cfu g^{-1} respectively compared with 20.4 Cfu g^{-1} in the non-populated cages. The overall mean *chlorophyll a* levels in the high and low populated cages was 1.18 µg g^{-1} and 1.49 µg g^{-1} respectively compared with 2.07 µg g^{-1} in the non populated cages. Meanwhile, the levels of these previous parameters fluctuated with time (weeks) in all treatment cages (Fig. 4, 5 &6).

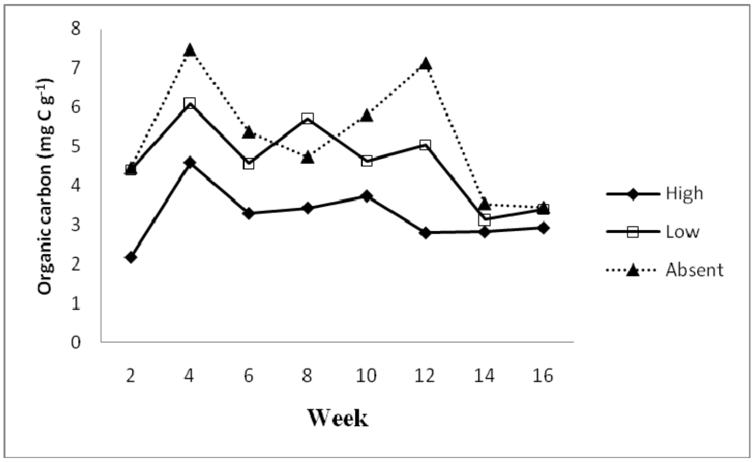

Fig.4: Mean values of total organic carbon measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

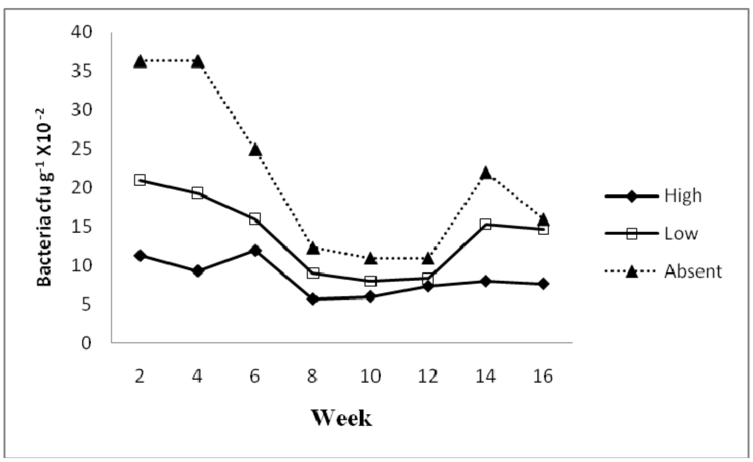

Fig.5: Mean values of bacterial content counted bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

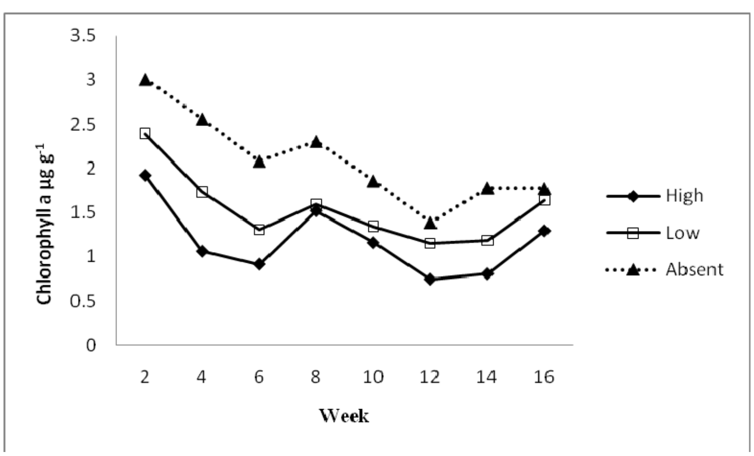

Fig.6. Average of chlorophyll content measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

Statistical analysis of variance showed no significant impact of *A. mauritiana* on ammonium and Nitrite ($p>0.05$), and significant impact on nitrate and phosphorus concentration in sediment ($P<0.05$) after16 weeks experimental period. The sediment in the high-populated cages recorded the highest values of ammonium. The overall means of ammonium in the high and low populated cages was 5.70 mg g^{-1} and 4.80 mg g^{-1} respectively compared with 4.60 mg g^{-1} in the non-populated cages (Table 1). The overall mean of nitrite levels in the sediment of the high and low populated cages were slightly varied between 0.84 mg g^{-1} and 0.79 mg g^{-1} respectively, compared with 1.1 mg g^{-1} in the non-populated cages. On contrary, the high-populated cages had the lowest values of nitrate concentration in the sediment. The overall mean nitrate levels in the high and low populated cages were 0.7 mg g^{-1} and 1.00 mg g^{-1} respectively compared with 1.2 mg g^{-1} in the non-populated cages. On the other hand, bi-weekly changes in the three previous parameters were not pronounced and without out obvious trends (Figs. 7, 8 &9).

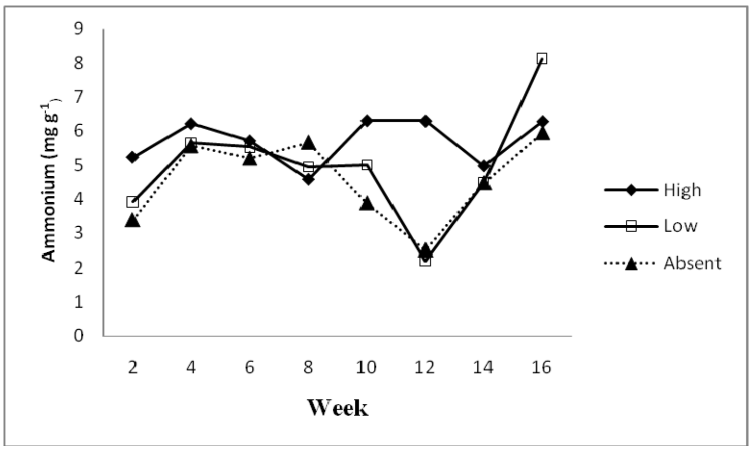

Fig.7: Mean values of ammonia content measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

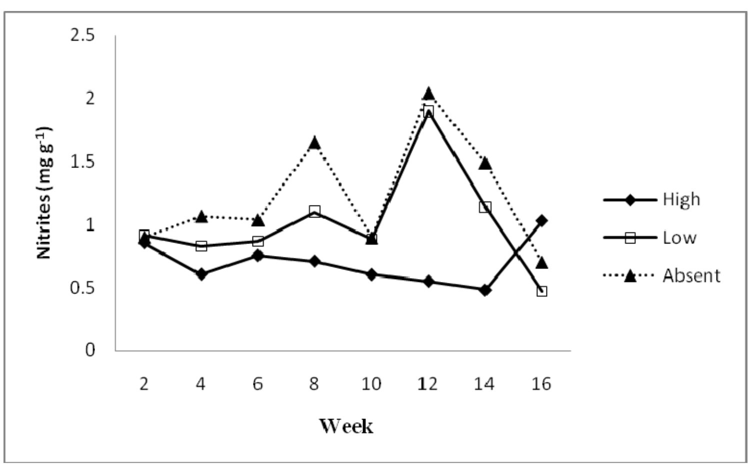

Fig.8. Average of nitrite content measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

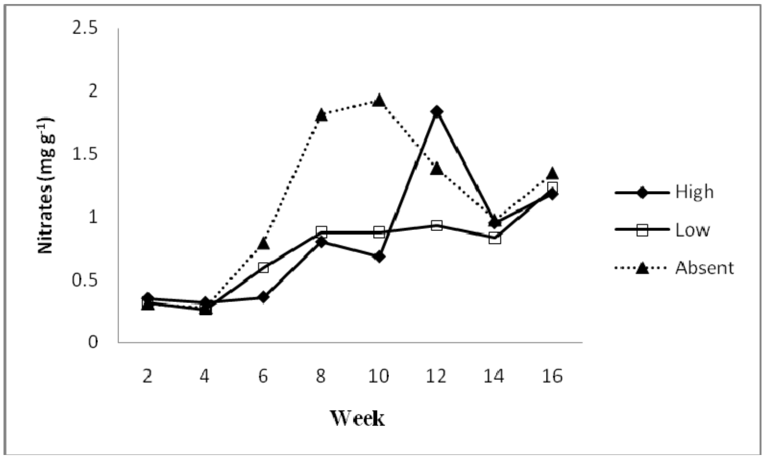

Fig. 9: Average of nitrate content measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

The presence of sea cucumbers *A. mauritiana* had a significant effect ($p<0.001$) on the total phosphorus values in the sediment over the 16 weeks period of the experiment. The high-populated cages had the highest values of total phosphorus concentration (Table 1). The overall means of total phosphorus in the high and low populated cages was 1.22 mg g^{-1} and 0.84 mg g^{-1} respectively compared with 0.57 mg g^{-1} in the non-populated cages. Although the levels of total phosphorus fluctuated with time (weeks) in all treatment cages, there was no obvious trend (Fig.10).

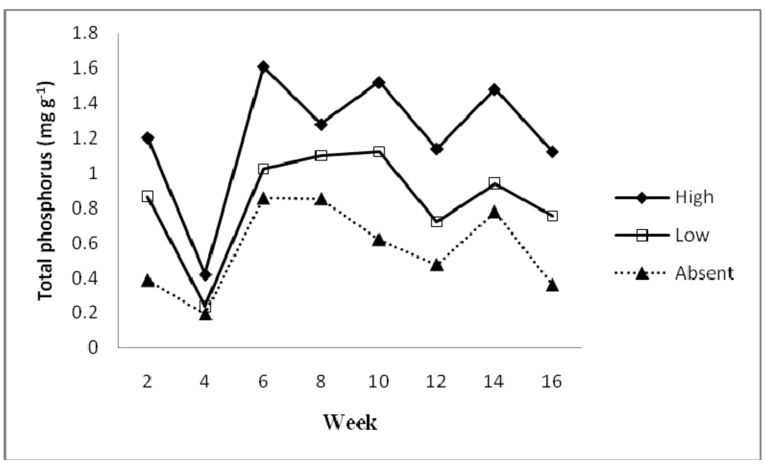

Fig.10: Average of total phosphorus content measured bi-weekly in the sediment of the treatment cages populated with different densities of *A. mauritiana* (i.e. High =60, Low=9 and Absent= zero individuals /cage) over experimental period of 16 weeks.

4. DISCUSSION

Sea cucumbers are one of the animals that appear to reduce the acid volatile sulfide concentration, and increase the oxidation-reduction potential in surface sediment to a depth of 3 cm (Kitano, 2003). However, holothurian on sediment also removes the oxidation consumption of living organisms as well as facilitates larvae of other species to settle (Kitano, 2003). The same author suggested that sea cucumber burrowing activity and reworking of sediment increases the oxygen concentration in the sediment. The present study did not indicate for impact of the holothurians *A. mauritiana* on oxidation-reduction potential of sediment in the treatment cages. This may relate to the used deeper corers of 10cm each, comparing with the pervious finding of Kitano (2003), who limited the impact of sea cucumber on the surface sediment of 3cm depth.

It was reported that sea cucumbers prevent the formation of anaerobic conditions (Uthicke, 2001; Kitano, 2003) by consuming high amount of organic matter inside the sediment (Moriarty, 1982). Low chlorophyll-a and bacterial contents estimated in the sediment of the populated cages is mainly related to the consumption by *A. mauritiana*. Uthicke & Kares (1999) reported that holothurian's feeding activity might reduce microalgal production on coral reef sediment. Moreover, Fujiwara and Sibuet *et al*., (1982) reported a higher phytopigments in the holothurian's gut than the adjacent sediment. In addition, Holothurian gut content analysis showed bacterial populations in the hindgut (Deming & Colwell, 1982; Sibuet *et al*., 1982) as well in the holothurians oesophagus (Ralijaona 1982; Deming & Colwell, 1982). Reports suggest that holothurians depend on the microbial population in their food. For example, the amino acids, which are important to holothurians, are supplied from the feeding on bacteria (Sibuet *et al*., 1982). Chlorophyll-a presence in the gut content indicates that holothurians feed selectively on fresh phytodetrital materials (Wigham, 2002). Some pigments that have been detected in the gut such as phaeophytin and phaeophorbides, indicate the consumption of chlorophyll-a degradation products (Wigham, 2002).

As in most marine invertebrates, the main excretion products of holothurians are ammonium and small amounts of phosphate (Mukai *et al*., 1989). Webb *et al*. (1978) reported that holothurians excrete organic nitrogen and phosphate. This may explain the higher concentrations of ammonium and organic phosphorus in the highly populated cages comparing with the non-populated cages. In agreement, Uthicke (2001) who reported that one sea cucumber may enhance ammonium concentration for a short period of time over an area of nearly 0.2 m^2 h^{-1} in an oligotrophic environment. However, Uthicke and Kares (1999) reported that increase in ammonium concentration caused to 34% enhancement in gross and net production of the microalgal community. However, the fluctuations in the nitrite concentrations companied by decrease of nitrate concentration may refer that there was denitrification. Pfannkuche (1993) reported that denitrification was the dominant process for muddy zones.

In conclusion, sea cucumbers are essential to maintain and improve the quality of sea sediment by recycling nutrients and preventing anaerobic conditions in the sea floor's sediment. This study revealed that removing of sea cucumber due to over fishing and exploiting their populations from the Egyptian coast of the Red Sea is seriously impacting the sea floor sediment quality and possibly the water quality as well. Therefore, long term research on consequent impact on the highly sensitive and economically valuable marine ecosystems, especially coral reefs, as well as enhancing the restoration process in the sea cucumber depleted areas and populations, is urgently needed.

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