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Is There Any Effect of Hot Springs on the Marine Benthic Ecology at Hamam Pharaon, Gulf of Suez, Red Sea, Egypt

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Abstract: The present study was carried out at Hamam Pharaon hot springs, on the eastern shore of Gulf of Suez. These springs are characterized by outflow of hot gas bubbles and hydrothermal seepage to the surrounding marine environment. The study compares physicochemical parameters of water and sediment of hot springs versus the surrounding marine environment. Also, assesses marine benthic communities and associated fishes of the target area versus reference stations. Temperature, salinity, pH, oxygen concentration were measured at both habitats. Hot (66°C), slightly acidic (pH 6.3), brackish water (9%), with low level of oxygen content (0.2 mg L⁻¹) usually emerges from these hot springs. Then usually seeps through fine sands to adjacent sea water of Gulf of Suez. Belt transects perpendicular to the shore were established at the study area versus two reference stations (away from hot springs) to the north and south of the target area. The benthic biota and associated fishes were quantitatively assessed by snorkeling and SCUBA diving. The results showed that the pattern of fluctuation in temperature, salinity, pH and oxygen content in sea water near shore (around hot springs) was not significantly different from water at the offshore end of transects and/or reference stations (with temperature 25°C, salinity of 43‰, pH of 7.6 and oxygen content of 5.5 mg L⁻¹). The recorded biodiversity was low consisted of seaweeds which were dominated by floating *Sargassum lantifolium* and *Padina pavonica* covering 30% of small rocks patches near shore, invertebrates with dominant species of echinoderms, which were sea heart *Lovenia elongata* and sand dollar *Echinodiscus bisperforatus* and fishes, which represented by Arabian pinfish *Diplodus noct*, mullet *Liza carinata*, bristly buffer *Arothron hispidus* and slender lizardfish *Saurida gracilis*. According to these results, it could be concluded that seepage of hot springs of Hamam Pharaon to the marine environment does not affect the physicochemical parameters (temperature, salinity, pH and oxygen concentration) and/or the ecology of benthic communities and associated fishes of the surrounding marine environment receiving their outflows.

Key words: Hamam Pharaon, hot springs, marine ecology, south sinai, Gulf of suez, Red Sea, Egypt

INTRODUCTION

Hot springs or hydrothermal vents are places where warm or hot groundwater issues from the earth on a regular basis for at least a predictable part of the year and is significantly above the ambient ground temperature. The water issuing from a hot spring is heated by geothermal heat, essentially heat from the Earth's interior, or volcanic activity (Gresh-Young, 2003). In general, the temperature of rocks within the earth increases with depth. The rate of temperature increases with depth is known as the geothermal gradient. If water percolates deeply enough into the crust, it will be heated as it comes into contact with hot rocks. The water from hot springs in non-volcanic areas is heated in this manner (Gresh-Young, 2004). However, in volcanic zones water may be heated by coming into contact with magma (molten rock). The high temperature gradient near magma causes water to be heated enough that it boils or becomes superheated (Woodsworth, 1999).

In hot springs, or marine hydrothermal vents, hot fluids emitted from underground floor create some of the most extreme environment on earth, sometimes unstable for life. Most scientific work on hot springs is dealing with microbial ecology (Sonipong *et al.*, 2005; Bonny and Jones, 2007; Jones and Renaut, 2007) and geochemical process (Sanada *et al.*, 2006; Bonny and Jones, 2007). In shallow water, venting is characterized typically by massive free gas release and hot water efflux and extends from the intertidal down to more than 200 m water depth (Dando *et al.*, 1995). Temperatures at hot springs in intertidal areas or hot vents in shallow water, due to the lower boiling point, are not as high as in the widely studied deep sea vents which can exceed 300°C (Tunnicliffe *et al.*, 1990) but sediment temperature over 120°C had been recorded (Dando *et al.*, 1995). Venting temperature is one of the most important environmental factors could affect the distribution of biological communities (Chevaldonné *et al.*, 1991) leading to some changes in their composition and distribution (Tunnicliffe *et al.*, 1990; Dando *et al.*, 1995; De Biasi and Aliani, 2003). Although dilution rates of the heat are poorly known (Johnson *et al.*, 1988; Chevaldonné *et al.*, 1991), the consequences of hot venting on the surrounding habitat are remarkable in many cases (Tarasov *et al.*, 1999).

The aim of the present study, which carried out at hot springs of Hamam Pharaon along the eastern coast of Gulf of Suez, Red Sea, is to investigate effect of hot water seepage on benthic communities and associated fishes of adjacent marine environment and the ecological parameters controlling their distribution. It will assess the physicochemical parameters (temperature, salinity, oxygen concentration, nutrients, sediment grain size and organic matter content), the species composition of marine biota (seaweeds, invertebrates and fishes) and their distribution over the marine area receiving the seepage of hot springs versus reference sites to the north and south of hot vents.

MATERIALS AND METHODS

This study was carried out off Hamam Pharaon hot springs and surrounding marine environment (Fig. 1), receiving the seepage of hot springs, which located at the eastern shore of Gulf of Suez

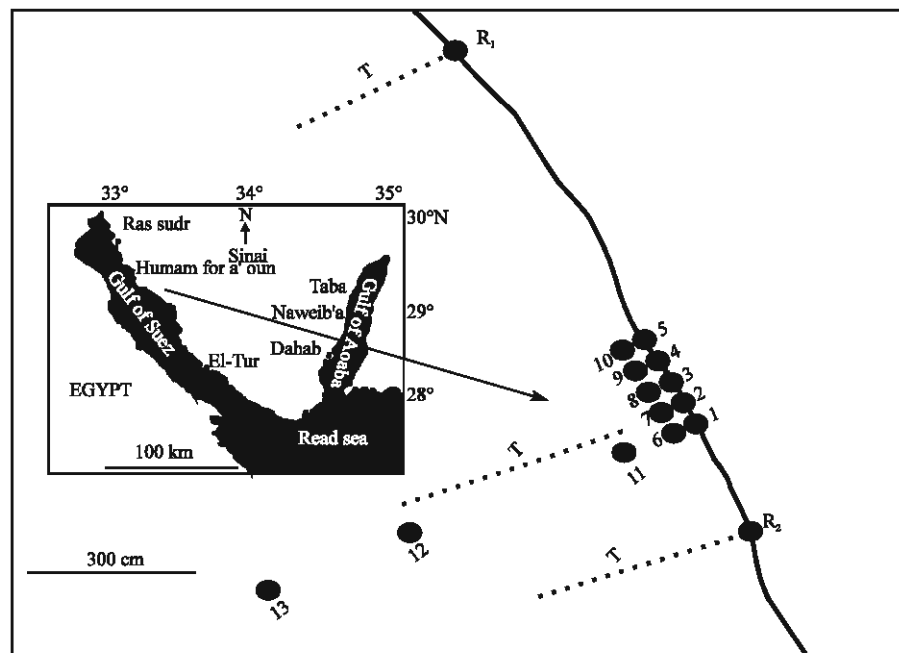


Fig. 1: Sampling stations at Hamam Pharaon, Red Sea, Egypt, showed on a map of Sinai Peninsula
• Stations --- Transects



Fig. 2: Photographs showing site of study and reference sites (A) Hamam Pharaon springs, (B) Blue green algae grown on high mark of hot springs, (C) Terrestrial plant, especially *Phragmites australis*, growing around saprings, (D) The grass *Cynodon dactylon* growing around hot springs, (E) Reference station 1, further north to hot springs and (F) Reference station 2, further north to hot springs

(Fig. 2A). At the area of study, Jabel Pharaon mountain descends to the sea, with very narrow plain strip, leading to the coast. The investigated area is characterized by sedimentary coast. Hot gaseo-hydrothermal springs coming out off the sandy bottom sustain a peculiar ecosystem based on chemosynthetic bacteria (Evenari *et al.*, 1985). The sediment temperature at these springs can be extremely high ($\sim 70^{\circ}\text{C}$) and even putting hands in these vents could produce skin burn. The sampling program was carried out in 2006. A total of 13 stations were selected to cover the entire area along of hot springs and the sea environment (Fig. 1). Some information relevant to their status is summarized in Table 1.

Table 1: Sampling stations, their location, ecological status and GPS position

Station	Location and status	Latitude (N)	Longitude (E)
1	Hot springs, H ₂ S release, hot water efflux	29° 11' 47.2"	32° 57' 22.6"
2	Hot springs, H ₂ S release, hot water efflux	29° 11' 50.1"	32° 57' 20.7"
3	Hot springs, H ₂ S release, hot water efflux	29° 11' 50.5"	32° 57' 20.2"
4	Hot springs, H ₂ S release, hot water efflux	29° 11' 51.1"	32° 57' 19.8"
5	Hot springs, H ₂ S release, hot water efflux	29° 11' 51.2"	32° 57' 19.2"
6	Seawater close to shore line, where discharge of hot seepage	29° 11' 46.9"	32° 57' 21.4"
7	Seawater close to shore line, where discharge of hot seepage	29° 11' 48.7"	32° 57' 21.0"
8	Seawater close to shore line, where discharge of hot seepage	29° 11' 49.8"	32° 57' 20.2"
9	Seawater close to shore line, where discharge of hot seepage	29° 11' 50.3"	32° 57' 19.7"
10	Seawater close to shore line, where discharge of hot seepage,	29° 11' 50.2"	32° 57' 19.2"
11	100 m offshore water, away from discharge of hot water	29° 11' 45.15"	32° 57' 18.61"
12	500 m offshore water, away from discharge of hot water	29° 11' 39.48"	32° 57' 06.13"
13	800 m offshore water, away from discharge of hot water	29° 11' 35.81"	32° 56' 59.54"
Reference station 1	Further north of study area, away from discharge of hot water	29° 12' 08.5"	32° 57' 08.7"
Reference station 2	Further south of study area, away from discharge of hot water	29° 11' 40.7"	32° 57' 25.8"

Spatial series of water temperature (°C), salinity (‰), pH, oxygen concentrations (mg L⁻¹), nutrients (µg at L⁻¹) and chlorophyll a (mg m⁻³) at hot springs outflows and surrounding sea water were recorded *in situ* at stations from 1 to 13. Parallel control measurements of the above mentioned parameters were recorded at reference stations 1 and 2 (Fig. 2 E and F). Water samples were collected from different stations for measuring nutrients (phosphate, nitrite, nitrate and silicate) and chlorophyll a concentrations according to Parsons *et al.* (1984).

Samples of sediment collected from investigated stations were dry sieved and particle size analysis was determined. Also, a sediment portion was analyzed for Total Organic Carbon (TOC) according to Byers *et al.* (1978).

To investigate benthic communities and associated fishes at coastal stations, three 10 m wide belt-transects (T1-T3) perpendiculars to the shore-line were established at target and reference sites. Snorkeling and SCUBA diving was carried out along transect to describe the major habitats (bottom type, living substrates and their community structure) at the study area. Qualitative and quantitative ecological data were taken to assess the distribution of benthic biota, in 3×3 m⁻² quadrats along belt-transects. Samples of benthos were collected for further confirmation of the identification at the lab. Density of fishes through 5 min snorkeling with constant speed along transects was recorded. Also, sediment samples were taken from all stations and each sample was preserved directly after collection in 1:500 mixture of Rose Bengal (0.5 g L⁻¹) and buffered seawater formaline (5%). Meiofauna were extracted by a combination of shaking, decanting and finally concentrated on 63 µm sieves. Each sample was washed from the sieve into counting trays and the meiofauna were enumerated and identified to the major taxon. Identification was followed Tarjan (1980) and Platt and Warwick (1983), while the counts were related to unit area and expressed as number of individuals (1000 cm⁻³).

Data Analysis

Means and standard deviations of the means were calculated for replicate determinations of various parameters monitored. Analysis of variance (one-way ANOVA) test was used to evaluate the significance of differences between groups of measured parameters at different stations with a level of significant set to p≤0.05.

RESULTS

Physico-chemical Parameters

No extreme values of temperature, salinity, pH and oxygen concentration were recorded along the spatial series at sea environment. The parameters were similar to each other at various stations versus reference sites as well. However, most physico-chemical parameters of hot springs were very characteristics, with significant differences to the sea water, which receiving their outflows of hot water (Table 2 and 3).

Table 2: Distribution of temperature, salinity, pH, dissolved oxygen, nutrient salts and chlorophyll a along different stations

Station No.	Temperature (°C)	Salinity (‰)	pH	Oxyg (mg L ⁻¹)	Nitrit (µg-at L ⁻¹)	Nitrat. (µg-at L ⁻¹)	Phosphate (µg-at L ⁻¹)	Silicat (µg-at L ⁻¹)	Chlo. rophyua (mg m ⁻³)
Hot springs stations									
1	62.0	15	6.5	0.2	0.12	1.92	0.07	6.7	0.00
2	72.0	09	6.4	0.1	0.13	0.83	0.07	6.7	0.00
3	62.0	11	6.7	0.9	0.14	0.96	0.07	6.6	0.00
4	68.0	10	6.3	0.3	0.13	0.29	0.07	6.4	0.00
5	68.0	10	6.4	0.3	0.13	0.65	0.07	6.5	0.00
Mean±SD	66.4±4.33	11±2.35	6.46±0.15	0.36±0.31	0.13±0.01	0.93±0.60	0.07±0.00	6.58±0.13	0.00
Shore line stations									
6	25.6	43	7.6	7.3	0.11	0.18	0.08	0.77	0.21
7	26.5	42	7.5	5.9	0.11	0.18	0.06	0.90	0.19
8	23.8	42	7.5	6.6	0.12	0.19	0.07	0.65	0.18
9	25.5	42	7.5	6.1	0.11	0.31	0.07	0.67	0.20
10	26.0	42	7.4	8.2	0.12	0.18	0.07	0.67	0.19
Mean±SD	25.48±1.02	42.2±0.44	7.5±0.07	6.82±0.94	0.114±0.01	0.208±0.06	0.07±0.01	0.73±0.10	0.194±0.011
Offshore stations									
11	25	42	7.5	6.5	0.12	0.17	0.07	0.70	0.17
12	25	42	7.5	6.5	0.11	0.17	0.07	0.71	0.18
13	25	42	7.5	6.5	0.12	0.17	0.07	0.70	0.17
Mean±SD	25±0.00	42±0.00	7.5±0.00	6.5±0.00	0.115±0.01	0.17±0.00	0.07±0.00	0.703±0.006	0.173±0.006
Reference stations									
Ref. st.1	25	42	7.6	6.7	0.11	0.16	0.08	0.75	0.16
Ref. st. 2	25	42	7.5	6.6	0.13	0.17	0.07	0.72	0.17
Mean±SD	25±0.00	42±0.00	7.55±0.07	6.65±0.07	0.12±0.01	0.165±0.01	0.075±0.007	0.735±0.021	0.165±0.007

Table 3: One way analysis of variance for various physico-chemical parameters between different stations of sea and hot springs of Hamam Pharaon

Source of variation	df	Mean square	F-value	p-value
Temperature (°C)	14	1882.576	260.981	0.000
Salinity (‰)	14	1074.711	518.501	0.000
pH	14	1.205	107.144	0.000
Oxygen (mg L ⁻¹)	14	44.586	124.322	0.000
Nitrite (µg at L ⁻¹)	14	0.000	5.083	0.019
Nitrate (µg at L ⁻¹)	14	0.613	4.520	0.027
Phosphate (µg at L ⁻¹)	14	0.000	0.636	0.607
Silicate (µg at L ⁻¹)	14	38.143	3741.249	0.000
Chlorophyll a (mg m ⁻³)	14	0.038	650.805	0.000

Variables are significantly different at $p \leq 0.05$

Table 4: One way analysis of variance for various physico-chemical parameters between different stations of sea at Hamam Pharaon area

Source of variation	df	Mean square	F-value	p-value
Temperature (°C)	12	0.288	0.486	0.634
Salinity (‰)	12	0.050	0.438	0.662
pH	12	0.004	0.921	0.441
Oxygen (mg L ⁻¹)	12	0.098	0.193	0.829
Nitrite (µg at L ⁻¹)	12	0.000	0.573	0.588
Nitrate (µg at L ⁻¹)	12	0.002	1.074	0.392
Phosphate (µg at L ⁻¹)	12	0.000	0.560	0.595
Silicate (µg at L ⁻¹)	12	0.001	0.122	0.887
Chlorophyll a (mg m ⁻³)	12	0.001	7.550	0.018

Variables are significantly different at $p \leq 0.05$

Temperature

Records of temperature at hot springs and sea are given in Table 2. At hot springs, water temperature ranged from 62 to 72°C, with a mean of 66.4°C. In sea water, close to shore, it recorded normal ranges (23.8-26.5 °C) with a mean of 25.5°C. However, at offshore stations, temperature was 25°C. No significant difference was recorded between sea stations and reference stations (Table 4).

Salinity, pH and Dissolved Oxygen

Records of salinity, pH and dissolved oxygen at hot springs and sea are given in Table 2. Measured salinity at hot springs ranged from 9 to 15‰, with a mean of 11‰. In sea water, close to shore, it ranged from 42 to 43‰ with a mean of 42.2‰. However, at offshore stations, salinity was 42‰. The pH of hot springs was slightly acidic ranged from 6.3 to 6.5, with a mean of 6.46. In sea water, it ranged from 7.4 to 7.6, with a mean of 7.55 (Table 2).

Dissolved oxygen concentration at hot springs was very low. It ranged from 0.1 to 0.9 mg L⁻¹ with a mean of 0.36 mg L⁻¹, while at sea, it ranged from 5.9 to 8.2 mg L⁻¹, with a mean of 6.02 mg L⁻¹ close to shore and 6.65 mg L⁻¹ offshore (Table 2). The low concentration of oxygen at hot springs is mainly related to the high temperature of water. No significant differences were recorded between sea stations and reference stations for the above measured parameters (Table 4).

Nutrient Salts and Primary Productivity

The concentrations of nutrient salts (phosphate, nitrite, nitrate and silicate) are given in Table 2. In general, the highest levels of nutrient salts were found high at hot springs, especially for nitrite, nitrate and silicate, while sea stations had the normal levels, recorded at Gulf of Suez. The mean concentrations of nutrients were 0.13, 0.11, 0.12, 0.12 µg-at L⁻¹ for nitrite; 0.93, 0.21, 0.17, 0.165 µg-at L⁻¹ for nitrate; 0.07, 0.07, 0.07, 0.07, 0.075 µg-at L⁻¹ for phosphate; and 6.58, 0.73, 0.71, 0.74 µg-at L⁻¹ for silicate at hot springs, near shore, offshore and reference sites, respectively. The high levels of nutrients at hot springs usually lead to high productivity of blue greens on sediment around hot springs. However, primary productivity of hot springs water was very low or null, due to the absence of any algae in that very hot water, while at sea water, it was in normal range of Gulf of Suez, with a range of 0.165-0.194 mg m⁻³. No significant differences were recorded between sea stations and reference stations, for nutrient salts and chlorophyll a (Table 4).

Sediment and Total Organic Matter Content

Shore of study area is sedimentary, gently sloping. According to Wentworth scale, the sediments of the investigated hot springs, marine stations were sandy. At hot springs and near-shore stations, sediments were mainly fine sand, while, offshore stations, showed the predominance of very fine sand (Table 5). Total organic matter content showed an increase at marine stations than hot springs, which had very low content of organic matter, ranged from 0.02 to 0.14% of sediment weight (Table 5). This organic matter could be produced by bacteria uses sulfur compounds to produce organic material through the process of chemosynthesis. However, marine stations had a relatively high range of organic matter content of 1.0-2.6% of sediment weight (Table 5), with highest records at coastal stations than offshore ones and this due to the accumulation of organic matter of the drifted seaweed *Sargassum lantifolium* at the high water mark of the intertidal region by the wave action.

Terrestrial and Marine Biota

Overall diversity of biota at study area is very low, due to sandy nature of study area and oligotrophic characteristics of its water. Species of macro-benthic biota collected from different investigated stations are given in Table 6. A total of 13 species were identified (Table 6). All the species of the reference sites were recorded at the target, except blue greens and terrestrial plants *Phragmites australis* and the grass *Cynodon dactylon* which were recorded around hot springs only (Fig. 2B, C, D), where the fresh or brackish water coming out. The list includes besides terrestrial plants and blue greens; seaweeds, invertebrates and fishes. Seaweeds mainly include 4 species which were *Dictyota dichotoma*, *Jania rubens*, *Padina pavonica*, covering 30% of small scattered rocks patches near shore and floating *Sargassum lantifolium*. The relatively abundant species was *Padina pavonica*. Invertebrates included hydrozoan *Holocordyle disticha*, echinoderms, sea heart

Table 5: Distribution of grain size (mm), total organic carbon (%) in sediment of the different sampling stations

Site	>2 mm G	>1 mm VCS	>0.5 mm CS	>0.25 mm MS	>0.125 mm FS	>0.063 mm VFS	>0.031 mm SC	>0.0156 mm SF	<0.0156 mm Cl	Org. mat.(%)
1	0.01	11.91	9.60	11.91	19.77	39.68	7.01	0.10	0.01	0.02
2	4.84	02.90	3.15	09.80	60.39	17.82	1.03	0.40	0.03	0.08
3	1.80	05.10	5.30	18.50	32.55	33.15	3.10	0.20	0.30	0.08
4	0.02	01.20	1.86	11.90	43.46	38.58	2.86	0.10	0.02	0.11
5	8.90	05.66	5.98	12.63	42.32	22.83	1.62	0.03	0.03	0.14
Shore line stations										
6	0.00	0.00	0.03	0.36	52.78	44.76	2.01	0.02	0.04	0.26
7	7.61	1.31	1.09	2.34	31.90	48.30	6.84	0.39	0.22	0.10
8	0.54	0.13	0.10	1.21	49.49	43.58	4.22	0.43	0.30	0.19
9	0.11	0.26	0.03	0.92	51.50	45.30	1.53	0.30	0.05	0.16
10	7.39	0.06	0.19	0.75	43.79	45.90	1.87	0.02	0.03	0.13
Offshore stations										
11	0.00	0.00	0.01	0.35	49.41	48.57	01.60	0.05	0.01	0.13
12	0.00	0.19	0.09	7.45	33.90	36.27	21.59	0.36	0.15	0.19
13	0.00	0.00	0.06	1.74	37.74	54.90	05.49	0.04	0.03	0.17
Reference stations										
Ref.1	0.00	0.00	0.70	4.50	40.50	50.00	3.50	0.50	0.30	0.19
Ref.2	0.00	0.14	1.06	6.70	37.50	45.50	6.20	2.50	0.40	0.18

G = Granule, VCS = Very coarse sand, CS = Coarse sand, MS = Medium sand, FS = Fine sand, VFS = Very fine sand, SC = Coarse silt, SF = Fine silt, Cl = Clay

Table 6: The recorded biota and their density at the site of study and reference sites

Taxa station	Site of hamam pharaon	Reference station 1	Reference station 2
Terrestrial plants			
<i>Fragmites australis</i>	+	-	-
<i>Cynodon dactylon</i>	+	-	-
Blue green algae	Mats around springs	-	-
Sea weeds			
<i>Dictyota dichotoma</i>	++	++	++
<i>Padina pavonica</i>	+++	++	++
<i>Jania rubens</i>	+	+	+
<i>Sargassum lantifolium</i>	Drifted and floating	Drifted and floating	Drifted and floating
Invertebrates			
<i>Holocordyle disticha</i>	+	+	+
<i>Lovenia elongata</i>	+++ (25±5)	+++ (22±4)	+++ (20±4)
<i>Echinodiscus bisperforatus</i>	++ (15±6)	++ (16±5)	++ 17±4)
Fishes			
<i>Arothron hispidus</i>	+++ (60±10)	+++ (65±9)	+++ (66±9)
<i>Saurida gracilis</i>	+++ (100±15)	+++ (91±13)	+++ (89±12)
<i>Diplodus noct</i>	+(10±3)	+(11±5)	+(9±4)
<i>Liza carinata</i>	+(15±6)	+(14±4)	+(12±6)

-: Absent, +: Present, ++: Common, +++: Abundant

Lovenia elongata and sand dollar *Echinodiscus bisperforatus* which usually bury themselves in clear sand and represented by mean densities of 25 and 15 individuals (9 m)⁻², respectively. The first species of echinoderms, usually found at a depth more than 1 m at distance of about 500 m offshore, while the other species usually found at a depth of 0.5 to 1 m, from shore up to 500 m off. Fishes were represented by 4 species which were bristly buffer *Arothron hispidus*, slender lizardfish *Saurida gracilis*, Arabian pinfish *Diplodus noct* and mullet *Liza carinata*. These fish species are detritivores, feeding on some detrital particles found in sand and had densities of 60, 100, 10 and 15 fish (5 min⁻¹) snorkeling observations, respectively.

For meiofauna, 7 species were recorded in sediment of sea water; however, none were recorded in sediment of hot springs (Table 7). Most of the recorded meiofauna were nematodes, which were *Oncholaimus campylocercides*, *Oncholaimus oxyrius*, *Metaoncholaimus* sp., *Ptycholiamellus ponticus*. Other groups, included copepods, polychaetes and oligochaetes, were represented by one species for each group. They were *Harpacticus littoralis*, *Stygocapitella subterranea* and *Aktedrilus* sp.,

Table 7: Spatial distribution and density of different major taxa of meiobenthos (individuals (1000 cm)⁻³) at different sampling stations

Site/taxa	Nematodes	Copepodes	Polychaetes	Oligochaetes	Total No. 1000 cm ⁻³
Hot vents	00	00	00	00	00
Shore line	195±20	22±7	00	13±4	230±30
100 m Offshore	213±25	10±4	12±5	18±6	243±28
800 m Offshore	225±33	70±12	14±4	11±4	310±33
Reference station 1	220±14	75±15	15±4	13±4	323±37
Reference station 2	230±20	65±13	14±3	14±3	323±39
Species recorded	<i>Oncholaimus</i> <i>campylocerides</i> , <i>Oncholaimus</i> <i>oxyrius</i> <i>Metaoncholaimus</i> sp. <i>Ptycholaimellus</i> <i>ponticus</i>	<i>Harpacticus</i> <i>littoralis</i>	<i>Stygocapitella</i> <i>subterranea</i>	<i>Akteodrillus</i> sp.	

Table 8: One way analysis of variance summary for various taxa recorded between spatial sea stations and reference stations at Hamam Pharaon

Source of variation	df	Mean square	F-value	p-value
Nematodes	14	230.400	4.608	0.327
Copepodes	14	1190.400	23.808	0.149
Polychaetes	14	51.833	103.667	0.072
Oligochaetes	14	8.767	17.533	0.173
Invertebrates	14	4.167	8.33	0.212
Fishes	14	8.167	0.135	0.776

Variables are significantly different at $p \leq 0.05$

respectively. Nematodes were the most abundant group with highest density, followed by copepods. No significant differences were recorded between different major taxa at various sea stations and reference stations (Table 8).

DISCUSSION

Sea coasts are highly variable ecosystems due to the interaction of local physical, geological, chemical and biological factors. Given their position at the sea-land interface, coasts are prime sites for human impacts e.g. industry, marine transportation, fisheries and tourism (Dauvin *et al.*, 2006) or natural impacts such as seepage of hot springs.

Ecology of hot springs and hydrothermal vents dragged the concern of scientists all over the world. However, no studies have been carried out on hot springs of Red Sea and little work done on hydrothermal vents of its deep water. In 1949, a deep water survey reported anomalously hot brines in the central portions of the Red Sea (Degens, 1969). Later work in the 1960s confirmed the presence of hot, 60°C, saline brines and associated metaliferous muds. The hot solutions were emanating from an active subseafloor rift. The highly saline character of the waters was not hospitable to any living organisms. The brines and associated muds were investigated as a source of mineable precious and base metals (Bäcker, 1981).

The study concluded no patterns of fluctuation or zonation in sea water temperature (where springs emissions) are evident. This is because dilution of vent water in seawater was very strong, due to high capacity of seawater, wave actions, tides and currents. Present data demonstrate clearly that hot springs not involved in any significant increase in sea water temperature at area of study, even at points very near to the seepage of hot springs to sea. Also, despite of seepage water completely has different characteristics (being brackish, acidic, with very low oxygen and high nutrients concentrations) from sea water at the area, or other areas of Gulf of Suez and Red Sea (Sourina, 1977; Klinker *et al.*, 1978; Leavanon-spainer *et al.*, 1979; Dowidar, 1983; Reiss and Hottinger, 1984;

Shaikh *et al.*, 1986; El-Sherbiny, 1997) but it does not have any noticeable effects on physicochemical properties of sea water where other ecological parameters of salinity, nutrients, primary productivity, sediment type and organic matter content are within the normal range as well.

This study rejects the hypothesis about the relationship between hot water seepage of Hamam Pharoan's springs and marine benthic communities and associated fishes of this area. Present list of marine benthos and fishes does not include species recorded only at vent sites and /or have certain distribution or abundance. The species found have been recorded at normal sites in the Gulf of Suez and cannot be called vent-obligate species according to the definition reported by Barry *et al.* (1996). Globally, the work done on the ecology of hydrothermal vents and their related communities both in shallow and deep water has been reviewed by the study of Tarasov *et al.* (2005) which compared hydrothermal vent communities from 76 sites all over the world at depths from 0 to 4100 m and concluded that at depths less than 200 m, vent obligate taxa are absent or their taxonomic rank does not exceed a species. Also, he confirmed that there are no significant differences between the vent and non-vent biogeography both in shallow waters and the deep ocean. Furthermore, he concluded that in shallow water areas, usually the effect of venting is restricted to a very narrow zone in a close proximity to discharge.

From an ecological point of view, Hamam Pharaon is considered as a fragile, sensitive ecosystem, with a limitation of its trophic levels components. Therefore, it is expected that any type of impact on such one of the components of this ecosystem, could damage greatly the marine environment of Hamam Pharaon. As proven from the study, the marine environment is characterized by low eutrophication level, very clear water, white fine sand and low diversity of organisms due to harsh environmental conditions of high salinity and low nutrients, which characterize Gulf of Suez (Morcos, 1970; Edward, 1987). The obtained ecological results could be regarded as newly added data about this specific location, should be significant in contrasting the extent of future impacts and their effects on this area, also, for developing the area on a sustainable manner and conserving its biodiversity and renewable resources, where springs of Hamam Pharaon are regarded now as economically valuable recreational heritage, could support new large areas for future popular tourism and recreational marine activities. As a consequence of national and international importance of the site, significant tourist and medical projects could be established in near future (e.g., rehabilitation clinics for the disables) which may disturb the ecology of this unique environment.

Finally, despite of the study tested and rejected the hypothesis about the relationship between hot water seepage of Hamam Pharoan's springs and marine benthos of this area. It could drag the attention for more studies should be done on their microbial ecology and geochemical processes. Study chemistry of hot springs of Hamam Pharaon, in particular the sulphur cycle will aid in understanding of springs' deposits and their mineralogical and geochemical characterization.

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