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Original article

Seasonal Variation of Zooplankton Abundance and Their Relation to Physical Factors of Ain-Zayanah Lagoon, Benghazi

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ABSTRACT

Background and aims. *The physical parameters and the occurrence and abundance of zooplankton in Ain-Zayanah lagoon, Benghazi, Libya, were studied from August, 2005 – July, 2006, as a part of detailed investigation on the feasibility of converting the lagoon into an aquaculture farm for captive breeding and culturing of different economically important edible fish, fish fry, molluscan and crustacean animals, and for culturing the zooplankton which form the food of these organisms.* ***Methods****. Five different sites located near to the shore were selected in the lagoon for water and zooplankton monthly sampling and analyses. The physical parameters of the water included air and water temperatures, transparency, electrical conductivity, total dissolved solids, pH, dissolved oxygen and total hardness; they were analysed using standard methods. Various differences were revealed in the relationships of these parameters in and between sites, months and seasons.* ***Results****. Seven major groups of zooplankton inhabited Ain-Zayanah lagoon; rotifers formed the dominant one (40.50%), followed by rhabtida (21.61%), crustacean larva (14.55%), foraminifera (13.23%), ostracoda (5.97%), copepoda (4.13%) and cladocera (0.01%). Air and water temperatures, pH, DO, electrical conductivity, TDS and hardness had different relationships with the seven zooplankton groups in Ain-Zayanah lagoon.* ***Conclusion****. The results obtained were discussed extensively in the light of available literature in the fields, and suitable conclusions, suggestions and precautions to be taken were given in connection with the establishment of Aquaculture farm in Ain-Zayanah lagoon.*

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INTRODUCTION

Ecological and economic interests in coastal marine ecosystems have increased in the recent decades since they play important role in sustainable development. Estuaries, bays and lagoons are situated between terrestrial and pelagic environments, constituting ecotones that are strongly affected directly or indirectly by human activities, changing the functioning of these ecosystems [1]. Coastal lagoons have peculiar functional and structural characteristics. They generally have large temporal and spatial variations in hydro chemical characteristics and biological diversity [2]. Their shallowness promotes a short nutrient turnover resulting in high primary productivity [3], and they are subjected to strong anthropogenic pressure, where they receive mineral nutrients derived from urban, agricultural and domestic sewage [4]. Thus, studying the structure and function of coastal lagoons can furnish information useful in sustainable management of these sensitive ecosystems.

Along the Libyan coast few sites are considered as lagoon; these are Farwa (close to Tunisia in the west), Ain-Zayanah (Benghazi), Khalij Bumba and Ain-Elghazala (both in Darnah). Moreover, smaller lagoons and estuarine ponds are found impounded behind sand bars at the mouths and at the lower reaches of numbers of narrow wadi channels along the Libyan Mediterranean coastline [5].

Ain Zayanah is the largest spring in Libya, located in the northern part of Benghazi (east of Libya), flowing into natural basin and joining the sea as blue lagoon [6]. Recently it showed fluctuations in its characteristics such as decrease in water level and increase in water salinity, due to the construction of a barrage between spring and blue lagoon which led to a decrease of groundwater discharge into the blue lagoon leading to an increase in water salinity due to inflow of seawater into the lagoon.

As part of the assessment of aquatic ecosystems, biological parameters are routinely measured [7]. Phytoplankton and zooplankton are two common biological parameters employed since they form the base of the aquatic food web and influence other aspects of the ecosystems including color and clarity of the water and fish production [8]. Phytoplankton represents important group of groups that converts sun energy into living tissues and support all life [9]. Zooplankton are invertebrate animals that live as free-swimming or suspended in the water column; they can be classified based on their size as Picoplankton, Microplankton or Mesoplankton; some of them such as *physalia sp*. are quite big in size and are referred to as Macroplankton. Moreover, they can be classified according to their lifestyles as Meroplankton (spend some of their stages as plankton such as larvae of benthic invertebrates) and holoplankton (spend their entire life as plankton such as microcrustacea).

Zooplankton are primary consumers of phytoplankton and bacteria and in turn are eaten as food by higher organism including fish. Thus, knowledge of the species composition and abundance of zooplankton communities help to assess the food supply available for economically important edible organisms (e.g. fish). Typically, they have short life cycles, respond quickly to environmental changes, and are used as useful tools in assessing water quality. Therefore, the standing crop and species composition of zooplankton community reflects the quality of water in which they live (water pollution control federation, 1985) which is a major criterion for selection of aquaculture farms. Every animal need defined physical, chemical and biological environmental factors to survive, but small organisms like zooplankton which are intimately dependent on their environment, are the best indicators of water properties.

Numerous lagoons and wetlands characterize the Mediterranean basin and rich literature exists on the environmental parameters and zooplankton community of these ecosystems. Among them, Italian lakes and lagoons are the best investigated ones; special mention has to be made on Venice lagoon [10,11], Guardian lagoon [12] and Lake Apnnine [13]. Coming to eastern Mediterranean, much the work on the hadrochemical parameters and plankton in the region were done by Egyptian scientist. Thus, some studies gave an account on the zooplankton community of lake Qarun [14,15]. A detailed description on the physico-chemical and biological parameters of north African wetlands and eastern coastal Mediterranean Sea was furnished [16] and the same coastal waters of Gulf Aqaba were examined [17].

Regarding Libya, a qualitative and quantitative analysis of zooplankton in eastern shore of Mediterranean Sea including Libya was furnished [18,19]. Regarding Ain-Zayanah, limited studies were conducted on the physico-chemical factors and on the occurrence and distribution of biological organisms of the lagoon [20,21], but the information on the zooplankton communities are not known in detail. Therefore, the present study provides some information on the zooplankton abundance and its distribution in Ain-Zayanah lagoon.

The objective of the study was to identify the occurrence of zooplankton and their temporal variation, and to evaluate the hydrological features that influence their distribution. The information gathered in the present study will be a useful tool in evaluating the feasibility of converting the lagoon in an aquaculture farm in future to tap the ocean wealth for the benefit of Libyan population.

METHODS

General characteristics of Ain-Zayanah lagoon

Ain Zayanah (Figure 1) is an important karastic spring formed during the eocenemeocene period [6] and is located approximately 12 Km north-east of Benghazi (32º 10’N, 20º 06’E), Libya, with a total area of about 25 ha; the biggest feature, the blue lagoon, is 0.5 – 3m deep in the coastal area, increasing up to 5 – 6m in the centre. An outlet channel of the lagoon to the sea exists in the north. There are small freshwater channels which originate from the land and join the lagoon, and the influx of freshwater is maximum during the rainy season (November – March).

Ain-Zayanah is a tourist spot where people flock to enjoy the pleasant sea breeze and it has a fish landing site also. It experiences Mediterranean climate with warm summers and mild winters.

Description of the sampling sites of water and zooplankton:

To study physical parameters and the diversity of zooplankton populations in Ain-Zayanah lagoon, Monthly field studies were started in August, 2005 and continued till July, 2006. The time of sampling was between 10.00 and 12.00 a.m., during the last week of every month. Five sites located on the coastal region of the lagoon (Figure 1) were selected for sampling. Site 1 (LS1) is located on the south-west direction of the lagoon. The water is 1-3m deep and the bottom is partly sandy and rocky. LS1 has a fish landing area. The leakage of gasoline from the boats which anchor on the site and the washing of utensils and throwing of fish wastes and other anthropogenic activities make the water turbid. The growth of algae and periphyton on the submerged rocks are evident.

Plenty of fish are found in LS1. Site 2 (LS2) is a rocky shore area located on the southern direction of the lagoon with many scattered rocks and stones, partly or fully submerged in water. The water is 0.5 to 2m deep. The inflow of sewage and other domestic wastes and the mixing of freshwater flowing from the land into LS2, make the water turbid, slightly blackish in colour with occasional foul smelling. Abundant growth of algae and periphyton, most of which are pollution tolerant and indicators, were located in LS2.

Fishes are comparatively less in the area. Site 3 (LS3) is located on the eastern part of the lagoon. The water is 0.5 to 4m deep; LS3 experiences strong winds which make the water foamy. It is comparatively a clean site with rocks and limestones forming the bottom. The growth of floating and submerged algae, periphyton and plants and occasionally schools of fish are visible. The mixing of freshwater in LS3, brought through channels, takes place during monsoon period. Site 4 (LS4) is located on the bank of a canal which connects the lagoon with the sea on the north. Because of the wave action and the mixing of sea water with lagoon water, the currents and circulation are higher in LS4 as compared with the other sites. It has a sandy bottom and the depth of the canal varies depending on the influx and outflow of water into and out of the canal. Many estuarine fishes as seen here. Site 5 (LS5) is located on the north – west direction of the lagoon and is 1 to 4m deep. The water is clean and schools of fishes and floating diatoms and occasionally algae are noticed. The bottom is sandy. The lashing of strong winds and rapid circulation of water are occasionally noticed.

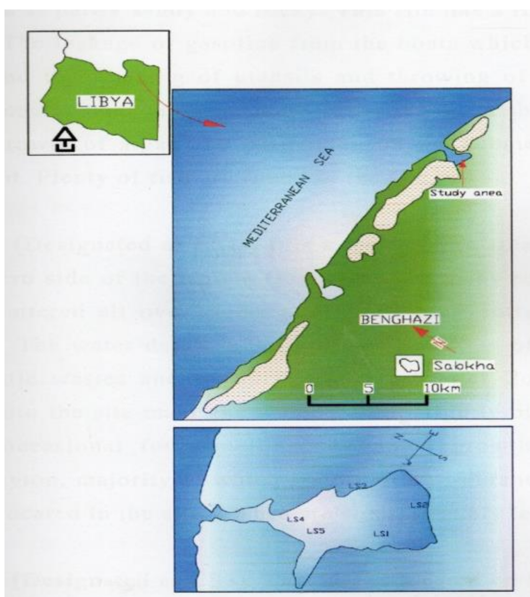

Figure 1. Map of Ain-Zayanah lagoon showing its location and different sites for sampling water and zooplankton

Sampling methods

Water

To evaluate the physical parameters and water quality of Ain-Zayanah lagoon, water samples were collected from the five sites using water sampler. The cylindrical glass sampler which could accommodate one litre water was lowered in the water column with both upper and lower lids open and after immersing it into the designated depth, a messenger was sent down

through the rope which held the sampler, and the weight of the messenger forced the lids to shut and the water sampler containing water was taken out from that point of immersion.
Like this, a total of 3 samples were collected from five different locations in each site/month. This procedure and sampling continued for 12 months, from August, 2005 to July, 2006. The water from the water sampler was transferred slowly to wide mouthed brown glass bottles through the outlet nozzles fixed below the lower lid of sampler. Every care was taken to see that no air bubble got trapped in the sampled water while transferring. The bottles were labelled properly affixing the details of the name of site, time, date, month and year of collection. They were brought to the laboratory for further analysis.

Zooplankton
Zooplankton were sampled from all the five sites once in a month from August, 2005 to July, 2006. The samples were collected using a 55µm mesh plankton net. The net was hauled in each site horizontally touching one end of the frame of the mouth of the net on the water surface and the other end below the water column, keeping 10 minutes time as a constant factor.
Apart from the above, nets were also hauled vertically and planktons were sampled from 1m below the surface column. After the respective hauls were made, the inner surface of the net was rinsed with tap water to drive organisms sticking their into the collecting tube attached at the lower end of the net.
The plankton collected in the tube was transferred into small glass bottles and preserved in Lugol's solution, a fixative and preservative staining solution for zooplankton. For every 100ml of zooplankton samples, 1 ml of Lugol's solution was added and mixed [22].

Field analyses of the physical parameters of water
All the physical parameters of lagoon water were measured three times/ month, from the sampled waters of each site, their values were pooled and the means taken. These parameters were measured in the site of collection itself.
Air temperature of different sites was measured using an ordinary thermometer (0–100^{oC}). The bulb of the thermometer was kept 1m above the water surface for 10 minutes and the reading was noted.
Water temperature of different sites was measured using the thermometer attached inside the water sampler. The temperature readings were recorded after collecting the water inside the sampler with both lids closed. Five minutes time was allowed to elapse before taking the readings after the water samples was lifted out of the water column, to ensure uniformity in temperature of the water inside the sampler.
Electrical conductivity (E.C.) and total dissolved solids (T.D.S.): The E.C. (ms/cm) and T.D.S. (g/l) of water were determined using Hanna Autoranging Microprocessor (HI 9835 EC/TDS meter).
Hydrogen ion concentration (pH) of water was measured using Hanna pH meter.
Dissolved oxygen (DO) (ppm) of water of different sites was measured using Guard Portable Oxygen Meter (handy MKI and MKII).
Transparency (m) was measured using Seechi disc (20 cm dia). The disc was slowly lowered in water and the depth at which the disc disappeared from the surface water column was noted, later the disc was slowly lifted and the depth at which the disc reappeared again was measured. The average of the two readings was recorded as the transparency of water. The transparency measurements were made in the field from December, 2005 to July 2006. (Seechi disks were not available in the first four months of the study)
The laboratory analyses of water included the analysis of total hardness of lagoon water sampled from different sites during the period from August, 2005 to July, 2006.
Total hardness (ppm) was estimated by titrating water samples with standard solution of EDTA (Ethylene Diamine Tetra Acetic acid) after the addition of 3 or 4 drops of Eriochrome Black T indicator at pH 10, and the titration continued until the colour of the solution changed from wine to purple blue (end point colour). The volume of EDTA added was recorded and hardness of water was calculated based on the equation:

T.H=50 x T x N x 1000/V where:
50= equivalent weight of calcium carbonate
T= ml titration of sample
N= Normality of (EDTA) 0.02N.
V= Sample volume in ml.

Analyses of zooplankton

Identification of zooplankton: most of the zooplanktons sampled from different sites of Ain-Zayanah lagoon were identified up to generic levels using taxonomic keys. Rotifera, Foraminifera, Rhabtida and Ostracoda were identified following the description given by different resources [23-26]; respectively. Copepods and Amphipods were identified with the help of scientists of the Institute of Marine Sciences and Marine Biology, Venice, Italy. Cladocerans were identified only up to family level.

Abundance of zooplankton: Zooplankton abundance in different sites of Ain Zayanah lagoon was estimated following the procedures described [27] and mentioned in the third ICES/HELCOM workshop on "Quality Assurance of Biological Measurements" available on http://www.io.warnemuende.de/research/helcom. zp/documents.qa. za.part.P.D.F. The following steps were adopted in the present study for calculating the zooplankton abundance.

The organisms were mixed thoroughly in sample jar and 1ml of sub-sample was taken with a wide mouth volumetric pipette. Sub-samples were transferred to a small petri dish and the zooplanktons present were identified and counted. This procedure was repeated 10 times.

The zooplankton abundance (number/m^3) was calculated using the formula: N (Ind/m^3) = k x m/vf Where,

N = counted part of sample
K = Vs/Vsb, where Vs = volume of sample, and Vsb = volume of sub-sample
m = number of counted organisms (Individuals)
vf = volume of filtered water (m^3) calculated using the equation vf = 3.14 x r^2d, where r = radius of net surface,
d = depth to which the net was lowered.

Statistical analysis

Numerical data are presented as Mean (± SD) for water variables and Mean (± SE) for zooplankton. The differences in water variables between sites, between seasons, and between sites and seasons; and the differences in zooplankton abundance between sites and months were subjected to two-way analysis of variance (ANOVA). The respected levels of significance were $p<0.05$ (5%) and $p<0.01$ (1%).

The correlation between water quality variables and zooplankton abundance was carried out using 2 – tailed Pearson correlation and the accepted levels of significance were * $p<0.05$ and ** $p<0.01$. All the analysis were carried out using the statistical package for science.

RESULTS

General observations

During the study period (August 2005 – July 2006), fluctuations in the water levels of the lagoon were noticed, and noticeable decrease in water level was discernible during summer and also during the opening of the canal that links the lagoon with the adjoining Mediterranean Sea.

The mixing of the tidal waves from the sea with the lagoon water at LS4 (located near the bar mouth of the sea) and at LS5, and the presence of limestones at the bottom at LS3 together with strong winds lashing at times at these sites made the water foamy. On the other hand, huge growth of submerged plants and rooted algae were present at LS1 (fish landing site), whereas floating plankton, algae and periphyton made the water greenish in colour at LS2 (located south of lagoon).

At LS3, the sudden disappearance of submerged plants was noted after August/September, 2005. The pollution indicator organisms (both phyto and zooplankton) were present at LS2 throughout, whereas they were occasionally observed at LS1 and LS3.

Physical parameters of water of Ain-Zayanah lagoon

The values (Mean ± SD) of various physical parameters of water except that of transparency of the five sites of Ain Zayanah lagoon for the study period (clubbed together) are given in Table 1.

In the case of transparency, dates were collected from December, 2005 to July, 2006. The univariate analysis of variance of different physical factors between sites and between seasons (Fall season: August, September, October; Winter season: November, December, January; Spring season: February, March, April; Summer Season: May, June, July) and between sites x seasons interactions, their levels of significance, and also the multiple comparison of each factor between sites and between seasons are presented in Table 2. The observations made are described below.

Table 1. Physical parameters (Mean ± SD) of five different sites of Ain-Zayanah lagoon (for period August, 2005 to July, 2006)

Parameters	LS1	LS2	LS3	LS4	LS5
Air temperature (oC)	22.7+6.6	23.2+5.0	23.6+4.1	23.3+3.9	23.7+4.4
Water temperature (oC)	21.2+2.6	21.9+1.6	21.4+3.8	21.5+2.7	21.2+2.4
Electrical conductivity (ms/cm)	32.6+3.6	32.7+4.3	32.7+4.3	33.3+5.7	32.6+3.8
Hydrogen ion concentration	8.5+0.3	8.2+0.3	8.5+0.3	8.5+0.2	8.5+0.2
Dissolved oxygen (ppm)	5.8+2.1	5.5+2.0	6.3+1.8	6.2+2.0	5.8+2.0
Transparency (m)	0.12+0.02	0.28+0.05	0.52+0.05	1.3+0.5	0.2+0.03
Total hardness (ppm)	2750.8+1992.6	2514.9+790.9	2482.4+956.9	2925.4+309	2819.4+210.3

Table 2. Levels of significance (P-value) of physical parameters in Ain-Zayanah lagoon (differences) with regard to sites, seasons, and sites *seasons

Source of differences	P-value							
	Air temperature	**Water temperature**	**Transparency**	**Electrical conductivity**	**TDS**	**Hydrogen ion concentration**	**Dissolved oxygen**	**Total hardness**
Sites	0.509	0.27	0.00 *	0.990	0.993	0.00 *	0.071	0.187
Seasons	0.00 *	0.00 *	0.061	0.00 *	0.00 *	0.00 *	0.00 *	0.00 *
Sites x Seasons	0.003 *	0.00 *	0.00 *	0.363	0.417	0.089	0.088	0.137

The mean annual (August 2005 – July 2006) values of air temperature in different sites ranged from 22.7ºC in LS1 to 23.7ºC in LS5 (Table 1). Regarding monthly fluctuations, the minimum (16.7ºC) and maximum (31.2ºC) air temperatures of in the lagoon area were recorded in February, 2006 and May, 2006, respectively. The differences in air temperatures between sites ($F=0.827$; $p>0.05$) were insignificant, whereas such a difference existed between seasons ($F=198.894$; $p<0.01$) and between sites x seasons interactions ($F=2.568$; $p<0.05$) (Table 2).

The water temperatures recorded were slightly lower when compared with the values of air temperatures. The mean annual values of water temperatures recorded in different sites of Ain Zayanah lagoon were 21.2ºC in LS1, 21.9ºC in LS2, 21.4ºC in LS3, 21.5ºC in LS4 and 21.2ºC in LS5 (Table 1). The monthly variations of water temperatures in 5 sites clubbed together ranged from 17.3ºC recorded in February, 2006 to 27ºC recorded in August, 2005. The differences in water temperatures between sites ($F=1.302$; $p>0.05$) were insignificant whereas significant differences of this factor existed between seasons ($F=170.175$; $p<0.01$) and between sites x seasons interactions ($F=3.490$; $p<0.01$) (Table 2).

The transparency values between December, 2005 – July, 2006, showed wide differences between different sites of lagoon. LS1 and LS2 recorded the lowest values of 0.12 and 0.28m respectively whereas LS4 recorded the highest (1.3m) (Table 1). Monthly variations in transparency in 5 sites clubbed together showed the minimum (0.2m) in April 2006 and the maximum (0.9mm) in March, 2006. A highly significant difference existed in transparency between different sites ($F=71.641$; $p<0.01$) and between sites x seasons interactions ($F=6.738$; $p<0.01$) whereas such a difference was not discernible between seasons ($F=2.853$); $p>0.05$) (Table 2).

The electrical conductivity reflected the total amount of ionized materials in water. There were not wide variations in values of electrical conductivity between sites (32.6 ms/cm in LS1 and LS5 to 33.3 ms/cm in LS4) (Table 1). However, monthly variations were not uniform, where the minimum (27.3 ms/cm) and maximum (39.6 ms/cm) values were recorded in January, 2006 and September, 2005, respectively. A significant difference in this factor was discernible only between seasons ($F = 78.924$; $p<0.01$) (Table 2).

An almost uniform values of total dissolved solids (26.1 g/L in LS1, LS3, LS2, 26.2 g/L in LS5 to 26.6 g/L in LS4) were noted in different sites of the lagoon during the period of study (Table 1). Monthly variations in TDS, however, showed fluctuations with the minimum (21.7 g/L) and maximum (31.7 g/L) values recorded in January, 2006 and September, 2005, respectively. A significant difference in TDS was discernible between seasons ($F=77.290$; $p<0.01$) whereas such a difference did not exist between sites ($F=0.06$; $p>0.05$) and between sites x seasons interactions ($F=1.036$; $p>0.05$) (Table 2).

The pH of water of the lagoon was alkaline and it ranged from 8.2 in LS2 to 8.5 in the remaining sites (Table 1). The monthly variations in pH showed minimum and maximum values of 8.0 and 8.9 in July, 2006 and March, 2006. A highly

significant difference in pH ($p<0.01$) existed between sites ($F=16.532$) and between seasons ($F=67.314$) but their interactions did not reveal any significant variation ($F=1.613$; $p>0.05$) (Table 2).
An annual mean moderate value of dissolved oxygen (>5.5 ppm) was discernible in all the five sites and it ranged from 5.5 ppm in LS2 to 6.3 ppm in LS3 (Table 1). The monthly fluctuations of this parameter revealed that the lowest (2.8 ppm) and highest (8.8 ppm) values were recorded in August, 2005 and January 2006, respectively. The variations in dissolved oxygen levels in the lagoon water between seasons were significant ($F=112.638$; $p<0.01$) whereas such a phenomenon was not observed between sites ($F=2.536$; $p>0.05$) and between sites x seasons interactions ($F=2.068$; $p>0.05$) (Table 2).
The total hardness values of Ain Zayanah lagoon were moderately high. The highest (2925.4 ppm) and lowest (2482.4 ppm) values were recorded in LS4 and LS3, respectively (Table 1). Monthly variations showed almost uniform values (>1750 ppm) between December, 2005 to May, 2006, and the highest value of this parameter (7904.6 ppm) was recorded in August, 2005. However, ANOVA evaluation revealed a significant difference in total hardness between seasons ($F=45.392$; $p<0.01$) only, and not between sites ($F=1.558$; $p>0.05$) and between sites x seasons interactions ($F=1.470$; $p>0.05$) (Table 2).

Zooplankton

Occurrence of zooplankton in Ain-Zayanah lagoon

Ain Zayanah lagoon is inhabited by different groups of zooplankton. The taxa of zooplankton present in the lagoon were broadly divided into seven major groups: (1) Foraminifera (2) Rotifera (3) Rhabtida (4) Ostracoda (5) Copepoda (6) Crustacean larva, and (7) Cladocera. Apart from the above, small groups of gastropoda, amphipoda and polychaeta were also present. Since their densities were low, they were not subjected to detailed studies.

Abundance of zooplankton

The percentage of annual abundance of zooplankton in the five sites of Ain-Zayanah lagoon clubbed together during the period August, 2005 – July 2006 is presented in Figure 2. Among the seven groups, rotifers formed the dominant one constituting 40.50% of all the groups sampled, followed by rhabtida (21.61%), crustacean larva (14.55%) and foraminifera (13.23%). The values of the remaining groups were less than 10%. Thus, ostracoda formed 5.97%, copepoda (4.13%) and cladocera (0.01%).

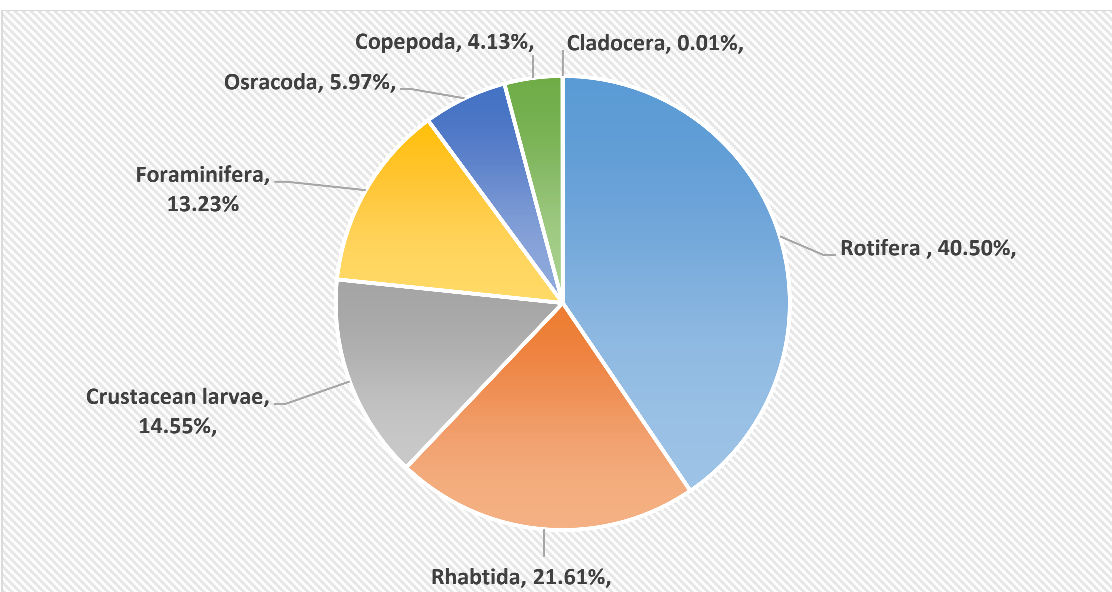

Figure 2. The annual percentage abundance of zooplankton in Ain-Zayanah lagoon during the period from August, 2005 to July, 2006

Distribution of zooplankton

The mean annual density of seven zooplankton groups in five sites of Ain-Zayanah lagoon during August, 2005 to July, 2006, is presented in Table 3. The monthly variations of different groups of zooplankton in 5 sites grouped together during the same period is shown in Table 4. The seasonal variations in the different zooplankton groups in 5 sites of Ain Zayanah lagoon clubbed together are given in Table 5. The results of the statistical analyses in densities of each group tabulated between sites and between seasons (Fall season: August, September, October; Winter season: November, December, January; Spring season: February, March, April; Summer season: May, June, July), their 'p' values (levels of significance) are presented in Table 6.

Table 3. The mean annual density (±SE) of zooplankton groups (ind/m^3) in 5 different sites of Ain-Zayanah lagoon during the period August, 2005 to July, 2006.

Zooplankton groups	LS1(near the fishers landing area)	LS2(south of the lagoon)	LS3(east of the lagoon)	LS4(near the sea)	LS5(north west of the lagoon)
Foraminifera	2265.8+592.9	1281.8+459.9	1846.2+699.1	1837.8+506.4	2034.1+458.3
Rotifers	815.4+335.4	14536.4+1017.7	3409.2+214.2	698.9+242.8	782.3+293.7
Rhabtida	222.7+43.5	589.9+199.9	195.5+57.9	152.9+33.1	159.5+27.9
Ostracoda	466.4+148.1	330.9+105.9	321.9+81.3	494.4+115.6	389.7+109.7
Copepods	234.7+46.9	327.9+80.9	207.6+55.9	413.5+196.6	198.6+37.1
Crustacean larvae	809.4+164.8	1116.3+312.9	3377.2+214.4	1540.1+455.9	1369.09+413.9
Cladocera	99.3+80.3	69.2+36.5	48.1+18.8	30.1+26.1	39.12+11.1

Table 4. The monthly variation (Mean+SD) of different zooplankton groups (ind/m3) in 5 sites of Ain-Zayanah lagoon during the period August, 2005 to July, 2006.

Months	Foraminifera	Rotifera	Rhabtids	Ostracods	Copepods	Crustacean larvae	Cladocera
Aug	609.1±127.1	741.4±210.9	346.6±106.4	370.7±142.2	565.7±101.6	1567±401.8	488.7±127.8
Sep	256.4±54.9	0.00±0.00	234.7±94.9	94.8±36.3	375.5±63.2	1368.3±168.3	21.7±14.4
Oct	1009.4±179	1516.2±790.3	234.3±30.2	331.4±96.5	272.1±48.2	1496.5±340.9	14.4±4.4
Nov	613.7±129.8	873.8±669.2	127.6±22.4	113.1±56.2	221.5±67.1	1227.7±187.3	28.9±11.1
Dec	558.5±201.6	24777.2±1066.5	221.5±60.9	74.6±34.9	185.4±27.6	2144.8±451.5	7.2±1.2
Jan	4405.2±1303.1	767.9±122.9	293.7±70.2	382.7±68.1	209.4±41.8	755.9±116.2	43.3±18.9
Feb	3230.5±972.8	382.7±331.3	122.8±14.4	1165.1±394.3	235.9±65.8	464.6±110.1	14.4±6.8
Mar	2438.5±243.6	12125.1±11593.3	178.1±19.9	286.9±69.1	226.3±75.5	1156.3±419.7	0.00±0.00
Apr	4029.6±625.9	1239.7±106.5	291.1±208.6	695.7±89.6	122.8±33.5	370.7±90.1	0.00±0.00
May	1870.7±953.9	0.00±0.00	86.±731.1	178.2±95.1	94.5±28.5	437.9±134.7	0.00±0.00
Jun	1731.8±745.4	69.5±7.7	630.1±181.9	542.1±155.9	115.6±38.7	724.9±144.1	7.2±1.4
Jul	1398.9±381.5	6087.8±507.5	423.7±81.9	572.9±53.1	693.3±175.7	7994.3±1816.2	60.2±24.1

Table 5. The seasonal variations (Mean values) in different zooplankton groups (ind/m3) in 5 sites of Ain-Zayanah lagoon during the period August, 2005 to July, 2006.

Season	Months	Foraminifera	Rotifera	Rhabtida	Ostracoda	Copepoda	Crustacean larvae	Cladocera
Fall	Aug Sep Oct	625	753	272	266	404	1477	175
Winter	Nov Dec Jan	1859	8807	214	190	205	1376	26
Spring	Feb Mar Apr	3233	4583	197	716	195	664	5
Summer	May Jun Jul	1667	2052	380	431	301	3052	22

Foraminifera
The mean annual density of foraminifera in five sites of Ain-Zayanah lagoon ranged between 1281.8 ind/m^3 in LS2 to 2265.8 ind/m^3 in LS1. In LS3, LS4 and LS5, the numbers varied between 1800 to more than 2000 ind/m^3 (Table 3). As far as monthly variations of this group were concerned, the highest (4405.2 ind/m^3) and lowest (256.4 ind/m^3) numbers of foraminifera were recorded in January, 2006 and September, 2005, respectively (Table 4). When the monthly variation data was transformed into seasonal variation ones, the lowest (625 ind/m^3) and highest (3233 ind/m^3) numbers were recorded in fall and spring seasons, respectively (Table 5). A significant difference ($p<0.05$) in the densities of foraminifera was discernible between seasons, whereas such a no difference was observed between different sites and between sites x seasons interactions (Table 6). The dominant group of forminifera present in the Ain-Zayanah lagoon belonged to the genus Ammonia sp.

Rotifera
Some interesting observations were made on the mean annual density of rotifers in 5 sites of Ain Zayanah lagoon. Not much variations in density (698.9 to 815.4 ind/m^3) of rotifers were discernible between LS1, LS4 and LS5, whereas a phenomenal increase in their numbers was recorded in LS3 (3409.2 ind/m^3) followed by a more than 3 times increase (14536.4 ind/m^3) as compared with LS3, was noted in LS2 (Table 3). The monthly variations in their numbers showed their total absence in all the five sites during September, 2005 and May, 2006. The highest number of rotifers (24777.2 ind/m^3) was recorded in December, 2005, and the second highest (12125.1 ind/m^3) in March, 2006. During other months, moderate fluctuations in their numbers were recorded. (Table 4). The seasonal variations of rotifer population registered the highest (8807 ind/m^3) and lowest (753 ind/m^3) during winter and fall seasons, respectively (Table 5). No significant difference was found in the densities of rotifers between sites, between seasons and between sites x seasons interactions (Table 6). The rotifers of Aim Zayanah lagoon were dominated by Brachionus Synchaeta sp followed by Asplenchna sp.

Rhabtida
The rhabtida population recorded its highest density (589.9 ind/m^3) in LS2 followed by in LS1 (222.7 ind/m^3). In the remaining sites the density of this population was slightly lower and it ranged from 152.9 ind/m^3 in LS4 to 195.5 ind/m^3 in LS3 (Table 3). The monthly variations in numbers in rhabtida showed only moderate fluctuations from August, 2005 to April, 2006 (127.6 ind/m^3 in November, 2005 to 346.6 ind/m^3 in August, 2005), but in May, 2006, a sudden decline in its number (86.7 ind/m^3) was observed followed by an exponential increase to 630.1 ind/m^3 in June, 2006, with a decrease thereafter (Table 4). Rhabtida populations were more (380 ind/m^3) in summer and less (197 ind/m^3) in spring (Table 5). A significant difference in rhabtid populations between sites ($p<0.01$) and between sites x seasons interactions ($p<0.05$) were discernible, whereas seasonal differences of the same were insignificant (Table 6). Rhabtids in Ain-Zayanah was mainly represented by Rhabdolaimus sp.

Ostracoda
Not much difference in the density of ostracods were observed in five sites of Ain Zayanah lagoon. The densities of this population ranged from 321.9 ind/m^3 in LS3 to 494.4 ind/m^3 in LS4 (Table 3). The monthly variations of ostracods during the period August, 2005 to July, 2006, showed the minimum during September, 2005 (94.8 ind/m^3) and the maximum during February, 2006 (1165.1 ind/m^3) (Table 4). The ostracods were present more during spring season (716 ind/m^3) whereas they were comparatively less during winter season (190 ind/m^3) (Table 5). A significant difference in ostracod population existed between seasons ($p<0.05$) whereas their differences in density between sites and between sites x seasons interactions were insignificant ($p>0.05$) (Table 6) Majority of ostracods sampled in the present study belonged to Candona sp.

Copepoda
The mean annual density of copepod population revealed some differences between sites; the minimum (198.6 ind/m^3) and the maximum (413.5 ind/m^3) were recorded in LS5 and LS4, respectively (Table 3). They're existed wide monthly fluctuations in their numbers present in the lagoon. During May, 2006, their numbers were low (94.5 ind/m^3) and during July, 2006, it peaked to a high of 693.3 ind/m^3 (Table 4). Seasonal variations in their densities revealed the highest (404 ind/m^3) and the lowest (195 ind/m^3 in fall and spring seasons, respectively (Table 5). The differences in the densities of copepods between sites, between seasons and between sites x seasons interactions were statistically found to be insignificant (Table 6). The copepods in Ain-Zayanah lagoon were dominated by the members of the orders Harpaeticoidea and Cyclopoidea. Members of the order Calanoidea were also encountered, but their numbers were few. Among the

Harpacticoides, members of the families Harpacticoidae and Ectinostomatidae formed the majority. Microseletta sp, a member of Ectinostomatidae were frequently encountered in the zooplankton samplings. Order cyclopoidea was represented by the families (1) Oithonidae, genus Oithona sp and (2) Cyclopoidae, genus Acnathocyclops sp. The order Calanoidea is represented by two families, Calanoidae (genus Calanus sp) and Acratiidae (genus Acartia sp).

Crustacean larva

The density of crustacean larvae showed their peak (3377.2 ind/m^3) in east of lagoon (LS3) and they were comparatively less (809.4 ind/m^3) in LS1 (Table 3). They were maximum during July, 2006 (7994.3 ind/m^3) and minimum during April, 2006 (370.7 ind/m^3) (Table 4). Seasonal variations in their densities also revealed the same trends of monthly variations, with the highest (3052 ind/m^3) recording during summer, and the lowest (664 ind/m^3) during spring (Table 5). No significant difference was found in the density of crustacean larvae between the different sites, between seasons, and between sites x seasons interactions ($p>0.05$) (Table 6). The crustacean larvae in Ain-Zayahan lagoon were dominated by nauplii and among them, the majority belonged to copepoda. The presence of crustancean larvae in good numbers in Ain-Zayanah lagoon is a positive indication on the viability of this lagoon to be converted into an aquaculture farm.

Cladocera

Cladocerans were comparatively less in density in Ain Zayanah lagoon when compared with the other groups sampled. LS4 located near to the bar mouth recorded their minimum (30.1 ind/m^3) and the fish landing site LS1 recorded their maximum (99.3 ind/m^3) occurrence (Table 3). Monthly variations in their densities revealed some interesting phenomena. No cladocerans were sampled in March – May, 2006. In other months, their numbers were limited to one or two figures whereas during August, 2005, a phenomenal increase (488.7 ind/m^3) in their density was discernible (Table 4). Seasonal variations in their densities recorded the lowest (5 ind/m^3) and highest (175 ind/m^3) in spring and in fall seasons, respectively (Table 5). A significant difference ($p<0.05$) in density of Cladocerans between seasons was noted, whereas such a difference was not discernible in their densities between sites, and between sites x seasons interactions (Table 6).

Table 6. Levels of significance (P-value) of zooplankton densities in Ain-Zayanah lagoon (differences) with regard to sites, seasons, and sites*seasons

Source of differences	P-value						
	Foraminifera	Rotifera	Rhabtida	Ostracoda	Copepoda	Crustacean larvae	Cladosera
Sites	0.718	0.212	0.001	0.852	0.555	0.455	0.836
Seasons	0.002	0.572	0.283	0.018	0.371	0.335	0.02
Sites*Seasons	0.696	0.682	0.005	0.496	0.766	0.7	0.66

The relationships between zooplankton abundance and physical factors

Effects of physical parameters of Ain-Zayanah lagoon on the abundance of each group of zooplankton present were investigated during the study period from August, 2005 to July, 2006. Foraminifera showed different relationships with physical factors. Their density revealed positive correlations with pH ($r=0.26$; $p<0.05$), and dissolved oxygen ($r=0.344$; $p<0.01$) and showed significant negative correlations with air temperature ($r=403$; $p<0.01$), water temperature ($r=0.31$; $p<0.05$), electrical conductivity ($r=0.46$; $p<0.01$) and TDS ($r=0.43$; $p<0.01$).

Density of copepoda showed a clear positive correlation with water temperature ($r=0.327$; $p<0.05$), whereas density of ostracoda revealed a negative correlation with electrical conductivity ($r=0.327$; $p<0.05$).

Density of Rhabtida showed significant positive correlation with total hardness ($r=0.449$; $p<0.01$), and revealed negative correlation with hydrogen ion concentration ($r=0.341$; $p<0.01$).

The crustacean larvae present in the lagoon showed positive relationship of their density with electrical conductivity ($r=0.255$; $p<0.05$), TDS ($r=0.258$; $p<0.05$) of lagoon water. However, a negative correlation ($r=0.261$; $p<0.05$) of pH of lagoon water with density of larval population was discernible.

Cladocerans, even though few in number when compared with other groups present in the lagoon, established only significant positive correlations with air temperature ($r=0.31$; $p<0.05$), electrical conductivity ($r=0.298$; $p<0.05$) and TDS ($r=0.282$; $p<0.05$).

DISCUSSION

Ain-Zayanah lagoon is a very prominent one on the eastern part of Libya, located slightly away from the Benghazi city proper. The present study on the physical factors and zooplankton abundance of this lagoon formed a part of the feasibility studies on the possibility of converting it into an aquaculture farm.

The importance of Ain-Zayanah lagoon should be viewed from a study which states that the saline ecosystems and lagoons have greatly declined in area and have been severely degraded in recent decades particularly in the Mediterranean region due to various engineering schemes [28]. The lagoons are of great ecological, economic and social interests. Coastal lagoons are highly variable systems where changes in the water circulation patterns and fluctuations of land influences (rivers, sewage flow etc.) induce high temporal variability on scale ranging from months to seasons and the variability may be reflected in the dynamics of the populations particularly planktonic ones thriving in coastal systems [29]. Thus, it is highly desirable to conduct water quality studies of the Ain-Zayanah lagoon by monitoring the physical, chemical and biological factors of the water body and a knowledge of their response to land use variations and environmental changes. The above-mentioned aspect has also been stressed by other studies while making investigations on various coastal lagoons in Europe and in Americas [30,31].

Regarding the physical parameters of Ain-Zayanah lagoon, some important, informative and valuable data were gathered during the present study. The mean air temperature in five different sites for the period August, 2005 to July, 2006, ranged between 22.7 to 23.7ºC and that of water temperature between 21.2 to 21.9ºC, which coincided with the normal Mediterranean coastal climatic pattern. The small differences in air and water temperatures between sites were statistically insignificant, whereas a clear significant difference in these factors between seasons and between sites x seasons interactions were evident. Water temperature has a great effect on the vital activities of the living organisms and it influences the total standing crop of phytoplankton where it decreases during winter and regains its maximum during spring and summer [32]. Water temperature also exerts a strong influence on the growth rates of zooplankton and is often thought of more important than food availability for limiting the growth rates of bacteria and zooplankton [33].

Transparency can be considered as an indicator for the penetration of light passing through the water. In this study, the maximum and minimum transparency of 0.12 and 1.3m were measured in LS4 (adjacent to the sea) and LS1 (fish landing area having turbid bottom and phytoplankton bloom), respectively.

A significant difference in transparency between sites, and between sites and seasons interactions was discernible, whereas such a difference in this factor between seasons was not evident. Shallowness and continuous disturbance of the mud bottom by wind action leading to the agitation of the bottom sediments reduces transparency [10]. Low transparency can also be attributed to the continuous blooming of phytoplankton [32]. Area near to the lagoon-sea connection is more transparent and this may be due to the high depth in comparison with other areas of the lagoon [10] [32].

The total dissolved solids in different sites in Ain-Zayanah lagoon were more than 26 g/L and the minor differences of this factor between sites and between sites x seasons interactions were insignificant. However, a significant difference in TDS between seasons was evident. One study opined that the TDS in lagoon water is affected by various factors, the most important of which are the continuous discharge of drainage water and the frequent in rush of seawater through lagoon-sea connection [32]. This aspect needs further careful study in Ain-Zayanah also because of draining in of water from the land and the rush of sea water into the lagoon took place during certain seasons. The same author observed further that the evaporation accelerated by high summer temperature as well as rain water are other factors influencing the TDS in lagoon.

The water of Ain-Zayanah lagoon was alkaline and pH of water in all the sites except in LS2 averaged 8.5. However, in LS2, a marginal reduction of pH to 8.2 was discernible. Statistical analysis revealed a significant difference in pH between sites and between seasons. Higher pH is associated with the alkalinity – hardness factors along with calcium, magnesium and conductivity of many saline lagoons [34] and pH has been suggested as a strong species–specific regulating parameter [34] [35]. A rise in pH definitely provides conditions for the existence of more taxa and all processes are dependent on pH [36]. At the same time, it was reported that the feeding rates of certain organisms is inhibited at pH>9.0, which often occurs in many lagoons in early summer [37]. However, such a high rise in pH beyond 9.0 was not observed in the Ain Zayanah lagoon.

Dissolved oxygen in the waters of Ain-Zayanah lagoon averaged more than 5.0 ppm in all the sites with the maximum and minimum of 6.3 and 5.5 ppm recorded in LS3 and LS2, respectively. A significant difference in DO in lagoon water was observed only in between different seasons. Oxygen content in water can be used as an indicator of organic loading, nutrient input and biological activity [38] and if the decomposing matter is in too great proportion, it will absorb much of the DO in water [39]. Lower values of DO in El-Genka area in Egypt were due to the consumption of high rate of oxygen in the decomposition of organic matter discharged in this area [40]. In the present study, the above-mentioned condition prevailed in LS1 and LS2 of Ain-Zayanah lagoon where a sizeable quantity of organic matter was discharged into these sites from the surrounding land and from other anthropogenic activities leading to a reduction in oxygen in water as compared with the values recorded in other sites.

There was not much variation in conductivity and it ranged very marginally between sites. However, a significant difference of the same prevailed between seasons. The spatio – temporal distribution is related to temperature, competition between species and other factors [41]. This is a very important point, and the factor of temperature was well within the tolerance limits of organisms inhabiting Ain-Zayanah lagoon, and the effect of competition between species found in the lagoon needs further detailed studies before conclusions can be arrived on this point.

There did not exist any significant difference in hardness of lagoon water in between sites, but seasonal differences of the same were apparent. Water hardness is affected by levels of minerals like calcium which also affect several species of zooplankton; deficiency in calcium may decrease the concentration of water hardness which may lead to a transition from large crustaceans to smaller organisms [42]. Thus, a constant and continuous monitoring of hardness, calcium and magnesium (the last two were not studied) in Ain Zayanah lagoon water may be useful in assessing the health, sclerotization and distribution of edible organisms inhabiting the lagoon.

Zooplankton is among the most important components of the aquatic ecosystem, playing a major role in energy transfer between the phytoplankton and the various economically important fish populations [43]. The abundance of zooplankton in Ain-Zayanah lagoon depends on various biotic and abiotic factors, which collectively affect individual groups of the zooplankton community. In this study, the zooplankton sampled from the lagoon were broadly divided into seven groups viz. Foraminifera, Rotifera, Rhabtida, Ostracoda, Copepoda, Crustacean larva and Cladocera. Among them, Rotifera formed the dominant group constituting 40.50% of all groups sampled and Cladocera the least forming only 0.01%. Many environmental factors can affect zooplankton assemblages, and many Mediterranean coastal lagoons show a spring – summer increase in zooplankton [16] [44]. The maximum abundance of zooplankton during late spring and summer in west Naubaria canal, Alexandria, Egypt, may be attributed to favourable conditions, such as high temperature, stable water conditions and abundance of food [45]. This aspect had been amply verified and confirmed in the present study. An explanation for the seasonal differences of mesozooplankton in Mediterranean coastal areas can be the particular characteristics of coastal zones and the coastal environments are exposed to different intensities of anthropogenic and land-related influences and the particular condition of each lagoon may strongly influence the phyto and zooplankton annual distribution [46].

Apart from the above, many environmental factors can affect zooplankton assemblages, including water temperature, nutrient concentration and salinity. Increased nutrient concentrations correspond with increased phytoplankton abundance which can affect zooplankton [47] and the response of the zooplankton community to lagoon ecosystem enrichment is related to many factors including changes in abiotic factors, food availability, changes in predation or interspecific competition [48]. Also, in estuarine and coastal lagoon food webs, zooplankton plays an important role in the energy transfer between primary producers and pelagic fish populations and they are key factors influencing fish production [49].

In the present study, the foraminiferans in the lagoon were mainly represented by Ammonia sp; the rotifers by Brachionus sp; Synchaeta sp; and Asplenchna sp; rhabtidans by Rhabdolaimus sp; ostracodans by Candona sp; copepoda by the members of the orders Harpacticoidea, Cyclopoidea and Calanoidea, and genera Microsecletta, Oithona, Calanus, and Acartia; crustacean larvae mainly by the nauplii of copepoda, and cladocera by Daphnia. A significant seasonal difference in the density of Foraminifera, Ostracoda and Cladocera were discernible. Conversely, the differences in density of Rhabtida between sites were significant. However, no significant difference was found in the abundance of Rotifera, Crustacean larva and Copepoda between sites and between seasons.

Among the foraminiferans both micropheric and megalospheric forms were encountered in this study and their density did not significantly vary between sites of the lagoon The abundance and variety of different species of foraminifera in the geological record make them one of the more useful groups of fossils for aging rocks [50]. The nematode Rhabdolaimus sp. sampled in the present study could be correlated with the quality of water of different sites of the lagoon and their density was more in the water of the sites contaminated with sewage and other domestic wastes. The ostracods which formed 5.97% of all the groups sampled did not differ in their density between sites and the member Candona sp. was the dominant one found in Ain-Zayanah. A study conducted in the Gulf of Aqaba and the northern red sea reported that the ostracods rank second to copepods and form a sizeable proportion of the mesozooplankton [51]. The relative abundance of Cladocerans is characterized by the positive correlation with the concentration of nutrients [52].

The density of Rotifera, Copepoda and Crustancean larva in the Ain-Zayanah lagoon did not show a significant difference between sites, between seasons and between sites x seasons interactions. Among the most representative zooplankton species in Mediterranean lagoons, the rotifer Brachionus and the estuarine copepod Acartia are frequently observed [53]. Both the species can potentially produce large populations and occupy different ecological niches to avoid competing for food and space and they are known for their high degree of tolerance to the fluctuating physical and chemical conditions of their habitats [54].

The assemblage structure of rotifers is affected by the geographical position and thermal period and these organisms are trophic links between net microzooplankton and mesozooplankton populations [55]. Brachionus sp. is often the dominant rotifer in moderate saline and alkaline lakes/lagoons and it produces resting eggs to ensure survival during adverse periods [56], while another rotifer Synchaeta sp. are micropredators preferring microflagellates [57]. The decline in rotifer biomass in saline lagoons takes place when nutrient loads from different point and diffuse sources decrease considerably [58]. This aspect needs further studies on the rotifer populations of Ain-Zayanah lagoon. Regarding copepods, they are the most dominant group in many coastal lagoons due to richness of their larvae. The presence of copepod larval stages all the year round indicates the continuous production of copepods all the year. The quantitative structure of copepod community in coastal lagoons illustrates the key role of these zooplankton in Mediterrannean pelagic ecosystems [60].

Juvenile stages of copepods were the major component of copepod populations in the whole of Egyptian Mediterranean red sea coast [61]. This may be the case in Ain-Zayanah lagoon also, since more than 90% of crustacean larvae sampled belong to nauplii of copepods and they along with adults form a sizeable proportion in the lagoon. It was reported earlier that most of the copepod species found in the Mediterranean coastal lagoons originated from the sea and entered the lagoon, and among them Acartia sp. is an Atlanto– Mediterranean, antilessepsian migrant and it is the most common species in the entire Ponto – Mediterranean province [62].

The relationship between the physical parameters and the abundance and density of different groups of zooplankton in Ain-Zayanah lagoon revealed some interesting trends. A clear positive correlation of water temperature with density of copepod population was observed whereas a negative correlation of this factor with the density of rotifera, foraminifera and rhabtida was discernible. Foraminiferans preferred the lagoon water with moderately high dissolved oxygen whereas cladocerans did not show any such preference. Rotifera, crustacean larva and cladocera were found in the region of high total dissolved solids but foraminifera showed an inverse correlation with this factor. Moderately high pH of water was preferred by foraminiferans whereas crustacean larva and rhabtida preferred low alkaline water. A positive correlation of the density of crustacean larva and cladocera and a negative one of the same of foraminifera and ostracoda with electrical conductivity of the lagoon water were recorded. Crustacean larva preferred a moderate to high hardness in water and rhabtida population showed an inverse correlation with this factor.

There is a strong positive correlation between the cladoceran numbers and the water temperature [63]. Cladocerans show a clear preference for high temperature in the upper layers of estuaries and lagoons [49]. Cladocera are the most abundant organism in September (peak of summer) and they usually develop after cyclops (copepoda) which peak in July/August (early summer). Copepods and rotifers reach lower quantities whereas cladocerans reach very high quantity in September [64]. This aspect has been amply verified and confirmed in the present study. The earlier development of nauplii with respect to cladocera is regarded as a strategy of cyclops for surviving in the presence of cladocera and especially of Daphnia sp. an efficient particle feeder and the strongest competitor [65]. The positive correlation of copepods with temperature indicate that copepods develop better in warmer periods after the mild and moderate winter. This will result in a promotion of fish recruitment because the number of juvenile fish correlate very well with copepod biomass.

The better development of copepods during warmer and rotifers during colder seasons in Ain-Zayanah lagoon coincide with the investigations of similar studies on temperature dependent changes in lagoon plankton [66,67]. pH of lagoon water appears to have an impact on zooplankton community composition. A rise in pH surely provide conditions for the existence of more taxa and all processes are dependent on pH. Effect of low pH on zooplankton physiology are filtering reduction, hemoglobin loss, oxygen and sodium uptake reduction and gill tissue damage. Long term effects are reduced brood size and reproductive capacity and delayed reproduction [36]. Such a situation did not exist in Ain-Zayanah lagoon at present because the pH of lagoon water in all sites were towards higher ranges. Higher pH is associated with the alkalinity – hardness factor along with calcium, magnesium and conductivity of many saline lagoons [34].

CONCLUSION

The physical factors and the zooplankton abundance of Ain-Zayanah lagoon revealed some encouraging aspects for developing the lagoon as an Aquaculture farm for the breeding and culturing of economically important edible fish, crustaceans and mollusks and also of zooplankton which is a major food source to these organisms. The water quality of different sites studied in the lagoon was almost uniform and most of the physical parameters measured were within the maximum permissible limits allowed for these factors. Only the seasonal changes in the water quality were discernible. The abundance of zooplankton revealed some seasonal variations in their density, and all major groups of zooplankton taxa were represented in the lagoon. However, some important precautionary and preventive measures have to be taken and implemented before any changes are made in the lagoon for the establishment of the farm: (1) the boundaries of the lagoon should be well earmarked, demarcated and protected, and no human activities should be allowed which may affect the quality of the water, (2) the inflow of the sewage and other contaminants from the land and surrounding areas into the lagoon should be stopped , and dumping of garbage and other wastes should be prevented, (3) selection of organisms to be cultured in the lagoon should be made with utmost care taking into account the physico-chemical characteristics of the lagoon water and the adaptability of organisms in the medium, (4) detailed studies should be made on the chemical parameters, taxa of phytoplankton and their abundance, and the sediment quality of the lagoon, so that a clear picture on the tropic structure and food chain of the lagoon can be established, which is very vital for the successful culturing of the selected organism, and (5) periodical monitoring on the water quality and of biota will be useful in preventing any contamination of the lagoon water and to keep the healthy conditions of the organisms selected for culturing in the lagoon. The implementing agency is advised to conduct periodic consultations with the scientists and experts working in the field both in Libya and abroad and seek their suggestions and advice in the smooth functioning of the program.

Conflict of interest
There are no financial, personal, or professional conflicts of interest to declare.

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التباين الموسمي لمدى وفرة العوالق الحيوانية وعلاقتها بالعوامل الفيزيائية في بحيرة عين الزيانة، بنغازي

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المستخلص

الخلفية والأهداف. تمت دراســة العوامل الفيزيائية ووجود ووفرة العوالق الحيوانية في بحيرة عين الزيانة، بنغازي، ليبيا، في الفترة من أغســطس 2005 إلى يوليو 2006، كجزء من التحقيق التفصــيلي حول جدوى تحويل البحيرة إلى مزرعة لتربية الأحياء المائية واستزراع الأسماك الصالحة للأكل ذات الأهمية الاقتصادية، وزريعة الأسماك، والرخويات، والقشريات، واستزراع العوالق الحيوانية التي تشكل غذاء هذه الكائنات. **طُرق الدراسة**. تم اختيار خمسة مواقع مختلفة تقع بالقرب من الشاطئ في البحيرة لأخذ عينات وتحليلات شهريا للمياه والعوالق الحيوانية. وشملت المؤشرات الفيزيائية للمياه درجات حرارة الهواء والماء، والشفافية، والتوصيل الكهربائي، والمواد الصلبة الذائبة الكلية، ودرجة الحموضة، والأكسجين المذاب والصلابة الكلية؛ وقد تم تحليلها باستخدام الطرق القياسية. تم الكشف عن اختلافات متنوعة في العلاقات بين هذه المؤشرات داخل وبين المواقع والأشهر والمواسم. **النتائج**. سبع مجموعات رئيسية من العوالق الحيوانية تسكن بحيرة عين الزيانة؛ كانت الدوارات هي السائدة (40.50%)، تليها الرابتيدا (21.61%)، يرقات القشريات (14.55%)، المثقبات (13.23%)، الصدفيات (5.97%)، مجدافيات الأرجل (4.13%) والكلادوسيرا (0.01%). كان لدرجات حرارة الهواء والماء، ودرجة الحموضة، والأكسجين المذاب، والتوصيل الكهربائي، والمواد الصلبة الذائبة والصلابة علاقات مختلفة مع مجموعات العوالق الحيوانية السبع في بحيرة عين الزيانة. **الخاتمة**. وقد تمت مناقشة النتائج التي تم الحصول عليها بشكل مستفيض في ضوء الأبحاث المتوفرة في هذا المجال، وتم تقديم الاستنتاجات والاقتراحات والاحتياطات المناسبة الواجب اتخاذها فيما يتعلق بإنشاء مزرعة الاستزراع المائي في بحيرة عين الزيانة.

الكلمات المفتاحية: بحيرة عين الزيانة، مؤشرات فيزيائية، عوالق حيوانية، مزرعة استزراع مائي.