Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(1): 1 – 25 (2023)
www.ejabf.journals.ekb.eg

Biodiversity of Zooplankton as Bio-Indicator for Water Criteria at Jazan Coastal Areas

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ARTICLE INFO

Article History:
Received: Aug. 20, 2022
Accepted: Nov. 29, 2022
Online: Jan. 7, 2023

Keywords:
Zooplankton,
Water criteria,
Bioindicator,
Biodiversity,
Sandy shore,
Mangrove

ABSTRACT

Zooplankton is important as a major source of fish food. This study dealt with the spatial and temporal distribution of zooplankton in Al Salwa beach, Jazan sandy shore, the muddy shore of Baish coast, and the sandy coasts of Al-Shuqiq, Al-Moassum, and Farasan. Water properties were determined, including water temperature, pH, conductivity, dissolved oxygen, and total dissolved solids. Species richness, population abundance, relative abundance, and Shannon-Weiner diversity index (H^-) were studied. 11 species were identified; ciliates, free-living nematodes, calanoid copepod, nauplius larva, gnathostomulida, water mite, *Meliola*, medusa, Polychaeta, zoaea larva, and Tardigrada. The highest species abundance was for ciliates on Al-Shuqiq sandy shore, while the lowest was for water mites on Jazan sandy shore coast. Shannon-Weiner diversity index (H) was 1.05 on the sandy coast of the Jazan region and 0.39 on the mangrove coast of Baish. The regression analysis between water criteria and the zooplankton abundance showed a significant relationship of water temperature (P<0.05) with ciliates. Data were discussed to highlight the factors affecting zooplankton distribution in marine habitats.

INTRODUCTION

Zooplanktons are the principal source of nutrition for larvae of marine fish and other marine animals. **(Siddika *et al*., 2012)**. They are considered as vital source of food as they contain proteins, minerals, fatty acids and fats. **(Kribia *et al*., 1997; Al-Ghanim, 2012)**. The marine plankton was classified into two types: Phytoplankton (photosynthesis plankton) and Zooplankton (animal plankton**) (Lee & Stokes, 2006).** According to the duration of planktonic life, zooplanktons are classified into two groups; namely, holoplanktons and meroplanktons. Holoplanktons survived all life span as planktons, while meroplanktons are temporary members of the zooplanktons living as planktons for only a part of their life cycle.

Zooplanktons are the most valuable indicator of trophic status **(Kovalev *et al*., 1999)**. They can also be used as "bioindicators" in water pollution studies since their occurrence and responses change under different environmental conditions **(Hao, 1996)**. Zooplankton may help marine systems function as generators or sinks of CO2 and other greenhouse gases. When eating, zooplankton mixes tiny settled particles with bigger ones (fecal pellets) that can reach the bottom before recycling, allowing biogenic carbon to be stored in the sediment and delaying the return of CO_2 **(Alcaraz & Calbet, 2003)**. The identification of zooplankton in Jazan has been poorly studied. Farasan report stated the presence of copepod as zooplankton in surface seawater **(AbuZinada, 2001)**. Zooplankton were studied as food source for bream fish in Jizan.

Calanoid and Euphausiid zooplankton are the most important zooplanktons in the Red Sea **(ObuidAllah *et al*., 2005)**.

The present study was concerned with investigating the seasonal distribution of zooplanktons at some sandy and muddy shores along Jazan coast and Farasan Islands. The relationship between physical and chemical water criteria and the abundance of zooplankton was examined through statistical analysis so as to study the factors controlling the distribution of zooplankton along Jazan marine habitats.

MATERIALS AND METHODS

2.1. Study site

The current study was conducted on the coast of Jazan region southwest of Saudi Arabia. Five sites were selected for the present work; Al Salwa beach, Jazan coast (sandy shore), Baish Turfa tree mangrove (muddy shore) coast about 40km to the north of the Jazan region. Al-Shuqiq is at 150km in the north-west of the Jazan region. Al-Moassum region is in the south of Jazan, Farasan Island 50 km west of Jazan.(Fig 1). Coordinates of the studied sites are shown in Table (1).

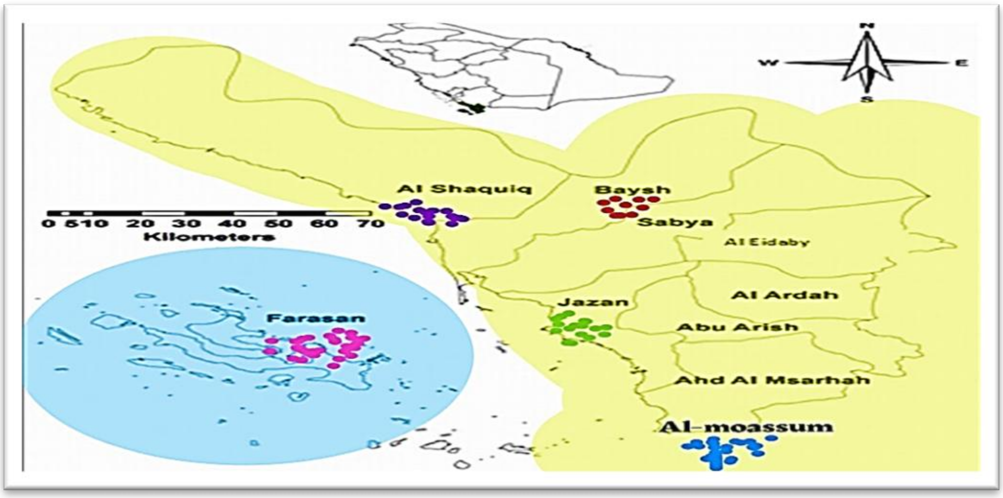

Fig. 1. Map showing the studied sites

Table 1. Coordinates of the investigated sites

Site	The location coordinates
Al Salwa beach, Jazan coast (sandy shore).	16°50'19.9"N 42°34'19.7"E
Baish Turfa tree mangrove (muddy shore)	17°22'41.1"N 42°19'14.3"E
AL- Shuqiq	17°41'45.0"N 42°01'08.5"E
AL-Moassum	16°28'58.4"N 42°46'03.3"E
Farasan	16°41'36.3"N 41°55'35.8"E

2.2. Sampling

Samples were collected during September 2020 - January 2021 from the selected sites for the present study. The samples were collected using the plankton network (Plate 1) after 10m and repeated three times per region.

2. 3. Water criteria determination

Water criteria including pH (Ohaus), conductivity (µs/cm) (Jen way 4510 conductivity meter), water temperature (ºC) (using Thermometer), dissolved oxygen (mg/L) (Hanna H19142) and total dissolved solids in water (TDS g/ l) (Hanna digital instrument H19034) were measured. Three replicates of water sampling readings were taken to measure the water criteria in studied locations and record the mean and standard deviation.

2.4. Abundance and relative abundance of zooplankton

Three droplets of rose bengal stain (5%) was added to water sample in 9cm- petri dish to detect Zooplankton under Zeiss research microscope with magnification 10X. Zooplanktons were identified according to **Lee and Stock (2006)** and **Hickman *et al.* (2011)**. Population abundance was determined examining the number of individuals in 10ml water sample. 30 readings were determined; the arithmetic mean, and the standard deviation were calculated for zooplanktons defined at each studied site. The ratio of population abundance of each planktonic group to total densities of all examined groups were the calculated relative abundance.

2.5. Species richness

Species richness (R) quantifies how many different types the dataset of interest contains **(Jost, 2006; Tuomisto, 2010)**. It calculated the number of different invertebrate species in each study area.

2.6. Shannon-Weiner diversity index (H´)

Diversity of zooplankton species in the studied coastal area was compared using Shannon Weiner diversity index formula **(Shannon, 1951)** as follows:

$H' = -\sum p_i \log p_i$,

Where, p_i is the relative abundance (percentage composition) of each zooplankton species.

2.7. Statistical analysis

SPSS 22 statistical software program was used. Two factor ANOVA (analysis of variance) was analyzed to determine the importance of the temporal and spatial distribution of plankton organisms in the area under investigation. The Tukey test was conducted to compare the abundance of common species in all studied locations and compare the common species population abundance in summer and winter. The regression analysis was applied to analyze the relationship between the physical and chemical water standards detected and the abundance of zooplankton in the studied coastal areas.

RESULTS

3.1. Water criteria

Surface water temperature, pH, conductivity, dissolved oxygen and total dissolved solids (TDS) were measured at the study sites. The highest value of water temperature was recorded for Al-Shuqiq (31.9ºC), while the lowest value was for Jazan (27ºC); the pH recorded the highest value in Farasan (7.39) and the lowest in Al-Shuqiq (7.04). The highest conductivity value was for Al-Shuqiq region (1404µs/ cm), while the lowest value was for Farasan (1326µs/ cm). Oxygen concentration (DO) showed the highest value in Farasan (14.8mg/ l) and the lowest in Al-Shuqiq (11.05mg/ l). The highest value of the total dissolved solids TDS was recorded in Al-Shuqiq (87.9g/ l), while the lowest was in Baish (84.1g/ l).

Table 2. Water criteria (mean±SD) recorded at the selected study sites

	Water temperature (°C)	pH	Conductivity µs/cm	DO mg/L	TDS g/l
Al Salwa beach	**27±2**	**7.34±0.02**	**1401.5±4.5**	**12.3±8**	**85.2±2.08**
Baish	**31.5±4.8**	**7.37±0.03**	**1403±2**	**13.5±0.6**	**84.1±2.3**
AL-Shuqiq	**31.9±8**	**7.04±0.05**	**1404±8**	**11.05±1.9**	**87.9±6.4**
Al-Moassum	**28±5**	**7.34±0.01**	**1401±2**	**11.45±3.1**	**84.3±0.9**
Farasan	**30.9±12**	**7.39±0.06**	**1326±8**	**14.8 ±1**	**86.2±0.4**

- DO; dissolved oxygen.
-TDS, Total dissolved solids.

3.2. Population abundance and relative abundance

3.2.1. Al Salwa beach, Jazan sandy shore

Species richness for zooplankton was 7. The following zooplankton groups were defined; ciliates, nematodes, calanoid copepods, nauplius larva, gnathostomulaida, *Meliola* and water mite (Table 3). Based on mean abundance, the arranged zooplankton was: Ciliates> Free living nematodes> Calanoid copepods> Nauplius larva> Gnathostomulaida> *Meliola* > Water mite. Ciliates recorded highest abundance (288.50±173.5), and lowest abundance was for water mite (12.50±4.4) (Fig. 2).The highest relative abundance was recorded for ciliates (52.2%), while water mite recorded the lowest relative abundance (2.26%) (Fig. 3). Total defined zooplankton abundance was 552.5. Shannon-Weiner diversity index (**H**́) for Zooplankton was 1.05.

Table 3. Mean abundance, relative abundance and Shannon-Weiner diversity index (H ́) in Al Salwa beach and Jazan sandy shore

Species	Abundance (Mean±SD)	Relative abundance (Pi%)	Log pi	Pi log Pi
Ciliates	**288.50±173.5**	**52.2**	**-1.28**	**0.66**
Free living nematodes	**159.50±137.9**	**35.3**	**0.45-**	**0.15**
Calanoid copepods	**39.50±26.6**	**7.14**	**-1.14**	**0.08**
Nauplius larva	**19.50±10.5**	**3.52**	**-1.45**	**0.05**
Gnathostomulaida	**17±7.3**	**3.07**	**-1.52**	**0.045**
Meliola	**14±5.9**	**2.53**	**-1.60**	**0.04**
Water mite	**12.50±4.4**	**2.26**	**-1.65**	**0.03**
Total	**552.5**			
Shannon-Weiner diversity index (H ́)		**1.05**		

3.2.2. Baish mangrove trees area

The species richness of zooplankton was seven. Defined zooplankton groups were: ciliates, nematodes, gnathostomulida, calanoid copepods, Zoaea larva, nauplius larva and polychaeta. Based on mean abundance, zooplankton has been arranged as follows: ciliate > free living nematodes > calanoid copepods> nauplius larva > gnathostomulida> zoaea larva> polychaeta (Table 3). Ciliates recorded highest population abundance (697.50±173.5) while polychaeta showed lowest population abundance (13±4.4) (Fig. 4). It was the highest relative abundance for ciliates (63.52%) and was the lowest relative abundance for polychaeta (1.18%). Shannon-Weiner diversity index (**H ́**) for zooplankton was 0.39.

Table 4. Mean abundance, relative abundance and Shannon-Weiner diversity index (H ́) in Baish mangrove trees area

Species	Abundance (Mean±SD)	Relative abundance (Pi%)	Log pi	Pi log Pi
Ciliates	**697.50±173.5**	**63.52**	**-0.20**	**0.12**
Free living nematodes	**318.50±137.9**	**29**	**-0.53**	**0.15**
Calanoid copepods	**16±26.6**	**1.45**	**-1.83**	**0.026**
Nauplius larva	**15.50±10.5**	**1.41**	**-1.85**	**0.02**
Gnathostomulaida	**21.50±7.3**	**1.95**	**-1.72**	**0.03**
Zoaea larva	**16±5.9**	**1.45**	**-1.83**	**0.026**
Polychaeta	**13±4.4**	**1.18**	**-1.95**	**0.021**
Total	**1098**			
Shannon-Weiner diversity index (H ́)		**0.39**		

3.2.3. Al-Shuqiq sandy shore

This group of zooplankton has been identified, (ciliates, free living nematodes, calanoid copepods, nauplius larva, gnathostomulida, zoaea larva, polychaetes and Medusa) (Table 5). For species richness, eight different species of zooplankton were recorded. Based on population abundance, zooplankton were arranged as follows (ciliates > nematodes > gnathostomulida > zoaea larva > polychaeta > calanoid copepods > medusa > nauplius larva) (Table 5). Ciliates showed the highest abundance; 732.50±224.94 while nauplius larva had the lowest abundance; 23±15.25_(Fig. 6). The highest relative abundance (61.63%) was recorded for ciliates, while the lowest relative abundance (1.93%) was for nauplius larva. Total defined zooplankton abundance was 1188.5. Shannon-Weiner diversity index (H´) for zooplankton was 0.47.

Table 5. Mean abundance, relative abundance and Shannon-Weiner diversity index (H´) in Al-Shuqiq sandy shore

Species	Abundance (Mean± SD)	Relative abundance (Pi%)	Log pi	Pi log Pi
Ciliates	**732.50± 224.94**	**61.63**	**-0.21**	**0.12**
Free living nematodes	**296.50± 262.94**	**24.94**	**-0.60**	**0.14**
Calanoid copepods	**26±14.29**	**2.18**	**-1.67**	**0.035**
Nauplius larva	**23±15.25**	**1.93**	**-1.72**	**0.032**
Gnathostomulaida	**32.50±28.63**	**2.73**	**-1.56**	**0.04**
Zoaea larva	**28±19.35**	**2.35**	**-1.61**	**0.037**
Polychaeta	**26.50±17.55**	**2.22**	**-1.65**	**0.036**
Medusa	**23.50±16.31**	**1.97**	**1.72**	**0.032**
Total	**1188.5**			
	Shannon-Weiner diversity index (H´) 0.472			

3.2.4. Al-Moassum sandy shore

Species richness of zooplankton was 7. Defined Zooplankton group were; ciliate, nematodes, calanoid copepods, nauplius larva, Gnathostomulida, water mite and polychaeta (Table 6). Based on abundance data, zooplankton showed the following arrangement; ciliates > free living nematodes > calanoid copepods > nauplius larva > gnathostomulida > water mite >polychaeta (Table 6). Ciliates showed highest abundance of 482.50±309.19 and polychaetes recorded the lowest abundance with 14.50±8.87. Highest relative abundance was for ciliates (64.98%), while polychaeta recorded the lowest relative abundance (1.95%). Total defined zooplankton abundance was 742.5. Shannon-Weiner diversity index (H´) for zooplankton was 0.46.

Table 6. Mean abundance, relative abundance and Shannon-Weiner diversity index (H´) in AL-Moassum sandy shore

Species	Abundance (Mean±SD)	Relative abundance (Pi %)	Log pi	Pi log Pi
Ciliates	**482.50±309.19**	**64.98**	**-0.19**	**0.12**
Free living nematodes	**164±212.04**	**22**	**-0.65**	**0.143**
Calanoid copepods	**25.50±18.77**	**3.43**	**-1.46**	**0.049**
Nauplius larva	**21±12.52**	**2.82**	**-1.55**	**0.043**
Gnathostomulaida	**18±9.51**	**2.42**	**-1.61**	**0.038**
Water mite	**17±9.23**	**2.28**	**-1.65**	**0.036**
Polychaeta	**14.50±8.87**	**1.95**	**-1.72**	**0.032**
Total	**742.5**			
Shannon-Weiner diversity index (H´)		**0.461**		

3.2.5. Farasan Island sandy shore

Species richness for zooplankton was 8. This group of zooplankton was identified as follows: ciliates, free living nematodes, calanoid copepods, nauplius larva, gnathostomulida, zoaea larva, polychaeta and tardigrada (Table 6). Zooplankton were ranked according to their mean abundance; ciliates > nematodes > polychaeta >calanoid copepods >nauplius larva > gnathostomulida> zoaea larva >tardigrada (Table 6). The highest abundance (417±281.76) was for ciliates (417 ± 281.76) and the lowest abundance (19.50±9.44) was for Tardigrada. The highest relative abundance (44%) was recorded for ciliates, while the lowest relative abundance (2.07%) was for tardigrades. Total defined zooplankton abundance was 938.5. Shannon-Weiner diversity index (H´) for zooplankton was determined as 0.52**.**

Table 7. Mean abundance, relative abundance and Shannon-Weiner diversity index (H´) in Farasan sandy shore

Species	Abundance (Mean±SD)	Relative abundance (Pi %)	Log pi	Pi log Pi
Ciliates	**417±281.76**	**44**	**-0.35**	**0.154**
Free living nematodes	**381.50±229.49**	**40.6**	**0.39-**	**0.156**
Calanoid copepods	**29.50±14.68**	**3.14**	**-1.50**	**0.047**
Nauplius larva	**21±14.10**	**2.23**	**-1.65**	**0.03**
Gnathostomulida	**20.50±9.98**	**2.18**	**-1.67**	**0.03**
Zoaea larva	**19.50±9.98**	**2.07**	**-1.69**	**0.033**
Polycheta	**30±15.55**	**3.19**	**-1.50**	**0.047**
Tardigrada	**19.50±9.44**	**2.07**	**-1.69**	**0.03**
Total	**938.5**			
Shannon-Weiner diversity index (H´)			**0.527**	

3.3. Temporal distribution of Zooplankton

3.3.1. Jazan sandy shore

The highest abundance was for ciliates (320±204.22) while the lowest was for water mite (11.66±3.89). Multiple comparison by using Tukey test (Table 8) between abundance of similar species in summer and winter seasons (ciliates, nematodes, calanoid copepods and nauplius larva**)** showed high significant difference between ciliates in summer and winter seasons (*P* <0.01).

Table 8. Mean abundance of summer and winter seasons of Zooplankton in Al Salwa beach, Jazan sandy shore **(**; *P*< 0.001 indicates high significant difference)**

Species	Summer (Mean±SD)	Winter (Mean±SD)
Ciliates	**320±204.22****	**150±67.41**
Free living nematodes	**258.33±114.48**	**187.50±100.28**
Calanoid copepods	**37.50±21.79**	**19.166±7.92**
Nauplius larva	**20±10.44**	**18.33±5.77**
Gnathostomulaida	**20.83±7.92**	**0**
Meliola	**15.83±6.68**	**0**
Water mite	**11.66±3.89**	**0**
Total	**97.73±150.07**	**53.57±86.49**

3.3.2. Baish mangrove trees area

Polychaeta recorded the lowest abundance (15±7.97), while ciliates showed highest abundance (312.50±188.44). Multiple comparison between similar species in summer and winter seasons (ciliates, free living nematodes, calanoid copepods, nauplius larva and gnathostmulida**)** showed significant differences (*P*< 0.05) between nematodes in summer and winter (Table 9).

Table 9. Mean abundance of summer and winter seasons of Baish mangrove trees area **(******;** ***P*****< 0.001 indicates high significant difference)**

Species	Summer (Mean±SD)	Winter (Mean±SD)
Ciliates	**312.50±188.44**	**200±104.44**
Free living nematodes	**254.16±179,50****	**150±156.66**
Calanoid copepods	**19.16±9**	**14.16±6.68**
Nauplius larva	**20.83±7.92**	**16.66±7.78**
Gnathostomulida	**29.16±9.96**	**23.33±11.54**
Zoaea larva	**19.16±7.92**	**0**
Polychaeta	**15±7.97**	**0**
Total	**95.71±229.07**	**80.02±120.19**

3.3.3. Al-Shuqiq sandy shore

Ciliates recorded highest population abundance (641.66±250.30), while calanoid copepods showed the lowest population abundance (17.5±9.65). Multiple comparison was conducted between similar species in summer and winter seasons (ciliates, free living nematodes, calanoid copepods, nauplius larva, gnathostmulida and medusa). High significant difference (*P*< 0.001) was shown between ciliates in summer and winter season (Table 10).

Table 10. Mean abundance of summer and winter seasons of Al-Shuqiq sandy shore **(******;** ***P*****< 0.001 indicates high significant difference)**

Species	Summer (Mean±SD)	Winter (Mean±SD)
Ciliates	**641.66±250.30****	**216.66±169.66**
Free living nematodes	**310±295.69**	**191.66±99.62**
Calanoid copepods	**17.50±9.65**	**12.50±4.52**
Nauplius larva	**19.16±10.85**	**12.50±6.21**
Gnathostomulida	**25±20.22**	**19.16±12.40**
Medusa	**24.16±20.65**	**11.66±3.89**
Zoaea larva	**35±20.95**	**0**
Polychaeta	**32.50±17.64**	**0**
Total	**138.12±250.96**	**58.02±108.53**

3.3.4. Al-Moassum sandy shore

Ciliates showed the highest abundance (470.83±334.70), and Polychaeta had the lowest abundance (17.50±10.55). Multiple comparison was tested between similar species in summer and winter seasons (ciliates, free living nematodes, calanoid copepods and nauplius larva). Significant difference (*P*< 0.05) was found between ciliates in summer and winter (Table 11).

Table 11. Mean abundance in summer and winter seasons for Al-Moassum sandy shore **(**; *P*< 0.001 indicates high significant difference)**

Species	Summer (Mean±SD)	Winter (Mean±SD)
Ciliates	470.83±334.70**	283.33±194.62
Free living nematodes	263.33±252.52	125.83±70.38
Calanoid copepods	30±20.44	17.50±9.65
Nauplius larva	22.50±12.88	15.83±6.68
Gnathostomulida	20.83±9.96	0
Water mite	21.66±9.37	0
Polychaeta	17.50±10.55	0
Total	120.95±225.97	63.21±125

3.3.5. Farasan sandy shore

The highest abundance was for ciliates (552.50±295.05) and lowest abundance was for nauplius larva (18.31±9.37). Comparison between similar species in summer and winter seasons demonstrated high significant difference (*P*< 0.001) between ciliates in summer and winter seasons and free- living nematodes in summer and winter (Table 12).

Table 12. Mean abundance of summer and winter seasons of Farasan sandy **shore (**; *P*< 0.001 indicates high significant difference.**

Species	Summer (Mean±SD)	Winter (Mean±SD)
Ciliates	552.50±295.05**	222.50±88.84
Free living nematodes	350±269.88**	141.66±88.60
Calanoid copepods	35±14.45	18.33±10.29
Nauplius larva	18.31±9.37	13.33±4.92
Gnathostomulida	26.66±7.78	0
Zoaea larva	25±9.04	0
Polychaeta	37.50±14.22	0
Tardigrada	25±7.97	0
Total	133.75±234.88	49.47±90.65

3.4. ANOVA Test comparing zooplankton abundance at different study areas

Table (13) shows ANOVA test comparing zooplankton abundance at the studied sites; significant difference was shown between abundance recorded of defined zooplankton species (F= 114.236, *P*= 0.000). There was significant difference between total zooplankton abundance in different study areas (F= 4.913, *P*= 0.001). The difference between recorded zooplankton species abundance in the studied areas was highly significant (F=3.351, *P*= 0.000).

Table 13. Two factor ANOVA comparing zooplankton population densities through the studied areas

Factor	SS	DF (n-1)	MS	F-value	P
Zooplankton species	**27252277.64**	**10**	**2725227.764**	**114.236**	**<0.001**
Studied areas	**468839.455**	**4**	**117209.864**	**4.913**	**<0.01**
Zooplankton species X studied areas	**3198080.545**	**40**	**79952.014**	**3.351**	**<0.001**
Error	**2492955**	**1045**	**23856.129**		
Total	**55848852.64**	**1099**			

3.5. Tukey test comparing zooplankton abundance at the studies areas

Multiple comparison (Table 14) between abundance of defined species showed high significant difference between ciliates and calanoid copepods (*P* < 0.01). High significant difference between Ciliates and Nauplius larva, Gnathostomulida, Meliola and Water mite was recorded (*P*< 0.01). The remaining comparisons were not significant. Multiple comparisons between abundance of studied species (Table 15) demonstrated high significant difference (*P*< 0.01) between ciliates and other zooplankton (free living nematodes, calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva and Polychaeta). High significant difference (*P*< 0.01) between nematodes and other groups (calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva and Polychaeta) *P*< 0.01. Other comparison was not significant. Multiple comparisons (Table 16) between species abundance showed high significant difference (*P*< 0.01) between ciliates and other groups (nematodes, calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, polycheta and medusa). High significant difference (*P*<0.01) was recorded between nematodes and other zooplanktons (calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, Polychaeta and Medusa). Remaining comparisons were not significant. Multiple comparisons (Table 17) between species abundance revealed high significant difference (*P*< 0.01) between ciliates and other zooplanktons (nematodes, calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, water mite and Polychaeta). A high significant difference (*P*< 0.01) was detected between free living nematodes and other zooplanktons (calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, water mite and Polychaeta). The remaining comparisons were not significant. Multiple comparisons between the abundance of studied species (Table 15) demonstrated high significant difference ($P< 0.01$) between ciliates and other zooplanktons (nematodes, calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva and Polychaeta). A high significant difference ($P<0.01$) was recorded between free living nematodes and other groups (calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva and Polychaeta) $P< 0.01$. Other comparisons were not significant. Multiple comparisons between species (Table 18) showed high significant difference ($P< 0.01$) between ciliates and nematodes, calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, Polychaeta or Tardigrada. The abundance of nematodes was highly significantly different ($P< 0.01$) with calanoid copepods, nauplius larva, Gnathostomulida, Zoaea larva, Polychaeta or Tardigrada. Other comparisons were not significantly different.

Table 14. Tukey values test comparing zooplankton abundance in Jazan sandy shore **(*P*< 0.001 indicates high significant difference), n.s; non- significant).**

Zooplankton species	Mean	Ciliates	Nematodes	Calanoid copepod	Nauplius larva	Gnathostmiolida	Meliola	Water mite
Ciliates	288.50	*	0.914	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Free living nematodes	159.50		*	n.s	n.s	n.s	n.s	n.s
Calanoid Copepod	39.50			*	n.s	n.s	n.s	n.s
Nauplius larva	19.50				*	n.s	n.s	n.s
Gnathostomulida	17					*	n.s	n.s
Meliola	14						*	n.s
Water mite	12.50							*

Table 15. Tukey values comparing zooplankton abundance in Baish mangrove trees area **(*P*< 0.001 indicates high significant difference), n.s; non- significant).**

zooplankton species	Mean	Ciliates	Nematodes	Calanoid copepod	Nauplius larva	Gnatostomulida	Zoaea larva	Polycheta
Ciliates	697.50	--	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Free living nematodes	318.50		--	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Calanoid Copepod	16			--	n.s	n.s	n.s	n.s
Nauplius larva	15.50				--	n.s	n.s	n.s
Gnatostomulida	21.50					--	n.s	n.s
Zoaea larva	16						--	n.s
Polychaeta	13							--

Table (16) Tukey values test comparing zooplankton abundance in Al-Shuqiq sandy shore (P<0.001 indicate high significant difference), n.s; non- significant).

zooplankton species	Mean	Ciliates	Nematodes	Calanoid copepod	Nauplius larva	Gnatostmiolida	Water mite	Polychaeta
Ciliates	482.50	*	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Nematodes	164		*	n.s	n.s	n.s	n.s	n.s
Calanoid Copepod	25.50			*	n.s	n.s	n.s	n.s
Nauplius larva	21				--	n.s	n.s	n.s
Gnathostomulida	18					*	n.s	n.s
Water mite	17						*	n.s
Polychaeta	14.50							*

Table 17. Tukey values test comparing zooplankton abundance in Al-Moassum sandy shore **(*P*< 0.001 indicates high significant difference), n.s; non- significant).**

Zooplankton species	Mean	Ciliates	Nematodes	Calanoid Copepod	Nauplius larva	Gnatostomulida	Zoaea larva	Polycheta	Tardigrada
Ciliates	**417**	*	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**
Free living nematodes	**381.50**		*	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**
Calanoid Copepod	**29.50**			*	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**
Nauplius larva	**21**				*	**n.s**	**n.s**	**n.s**	**n.s**
Gnathostomulida	**20.50**					*	**n.s**	**n.s**	**n.s**
Zoaea larva	**19.50**						*	**n.s**	**n.s**
Polychaeta	**30**							*	**n.s**
Tardigrada	**19.50**								*

Table (18) Tukey values test comparing zooplankton abundance in Farasan sandy shore (P<0.001 indicate high significant difference), n.s; non significant.

Zooplankton species	Mean	Ciliates	Nematodes	Calanoid Copepod	Nauplius larva	Gnatostomulida	Zoaea larva	Polycheta	Medusa
Ciliates	732.50	*	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Free living nematodes	296.50		*	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001
Calanoid Copepod	26			*	n.s	n.s	n.s	n.s	n.s
Nauplius larva	23				*	n.s	n.s	n.s	n.s
Gnatostomulida	32.50					*	n.s	n.s	n.s
Zoaea larva	28						*	n.s	n.s
Polychaeta	26.50							*	n.s
Medusa	23.50								*

3.6. Post hoc test comparing abundance of similar zooplankton groups at studied sites

A high significant difference ($P<0.01$) was found between ciliates abundance of Jazan and Baish studied sites. The remaining comparisons were not significant ($P>0.05$). High significant difference ($P<0.01$) was recorded between ciliates of Jazan and those of Al-Shuqiq. The remaining comparisons were not significant ($P> 0.05$). No significant difference was shown between the abundance of similar zooplankton groups ($P> 0.05$). While, high significant difference ($P<0.01$) was found only between nematodes abundance in Jazan and Farasan. The other comparisons were not significantly different ($P> 0.05$). Similar zooplankton abundance showing differences was not significant ($P> 0.05$). Significant difference ($P> 0.05$) was found between ciliates abundance in Baish and Al-Moassum. High significant difference ($P< 0.01$) was shown between ciliates of Baish and Farasan. The rest comparisons recorded no significance ($P> 0.05$). High significant difference ($P< 0.01$) was between ciliates abundance at Al-Shuqiq and Al-Moassum. The other comparisons were of no significance ($P> 0.05$). Abundance of Ciliates at Al-Shuqiq and Farasan were highly significantly different ($P<0.01$). The remaining comparisons were no significant ($P>0.05$). High significant difference ($P<0.01$) was registered between nematodes abundance at Al-Moassum and Farasan. The rest comparisons showed no significance ($P>0.05$).

3.7. Regression analysis between water criteria and zooplankton abundance in study areas

The regression analysis (Table 19) between the mean abundance of zooplankton species and the mean of water temperature was significant. Regression coefficient was 0.978, which indicates a positive significant relationship between the water temperature of the study areas and the abundance of the species. The significance level was 0.004 ($P< 0.01$), indicating a high significant effect of "water temperature" on the ciliates in the study areas. The R squared value (0.957) means that 95.7% of the changes in the species abundance for the study areas were caused by water temperature. Only a significant effect of water temperature was that shown on the abundance of zooplankton species as shown from the regression analysis.

Table 19. Effect of water temperature on abundance of ciliates zooplankton in the study areas

Independent Variable	Regression Coefficient				Determination coefficient	F	Sig
	B	t	Sig.	R	R-square		
(Constant)	223.12	-5.97**	0.009	0.978	0.957	67.03**	P<0.01
Water Temperature	0.21	8.18	0.004				

Regression analysis between zooplankton abundance and other water criteria; pH, conductivity, total dissolved solids TDS or dissolved oxygen DO demonstrates no significant effect ($P > 0.05$) in the studied areas.

DISCUSSION

A marine ecosystem's zooplankton community is made up of holoplankton and meroplankton. **(AbdAllah *et al.*, 2018)**. Zooplankton represent an important component of the food chain. They obtain a lot of energy by feeding on phytoplankton. Carnivorous zooplanktons are a kind of zooplanktons that eat other zooplanktons. Higher trophic level animals that eat zooplankton get the energy they need to do their activities. **(AbdAllah *et al.*, 2018)**. The present study identified zooplanktons inhabiting the studied areas and determined the abundance and the distribution of zooplankton in some sandy and muddy shores along the coast of Jazan to Farasan Islands. In addition, the present findings demonstrate the relationship between zooplankton abundance and the physical and chemical water criteria.

Physico-chemical variables (water temperature, pH, conductivity, dissolved oxygen, and TDS) in water were measured for the studied sites. The most significant environmental variable that affected organisms as well as chemical and biological processes was water temperature **(Abdulmongy *et al.*, 2015; Manickam *et al.*, 2018)**. The current results confirmed the statement and showed a significant regression relationship of water temperature on the abundance of ciliates in the studied areas.

The highest value of water temperature was recorded in Al Shuqaiq region (31.9ºC), while the lowest value was in Jazan region (27ºC), and these results are consistent within the range of temperatures (18 ºC- 31.6ºC) mentioned in the northern part of Gaza, and with the spatial variation of sea water temperature recorded in that area **(Al Safady, 2012)**. This might be attributed to the fact that the sampling sites are located along the coastline and might also be due to the amount of sewage inputs and runoffs. pH is an important environmental factor for aquatic creatures' survival, metabolism, physiology and development, as well as chemical activities. **(Marion *et al.*, 2011; Abdulmongy *et al.*, 2015)**. The present findings revealed that pH was the highest value in Farasan (7.39), and the lowest value was in Al-Shuqiq (7.04). Our results concur with those of **Al Safady (2012)** who reported that, the pH of sea water ranged between 6.5 and 9.5 and added that it was affected by surface water temperature and the activities of living organisms.

The current dissolved oxygen ranged between 11.05 & 14.8mg/ l. This result coincides with that of **AbdAllah *et al*. (2018)**. Values of conductivity (1326-1404 µs/ cm) and TDS (84.1-87.9 g/l) in the present study are different those recorded in other studies **(Bhadja & Kundu, 2012; Picapedra *et al*., 2020)** due to the difference in climate and weather.

It is clear from the current study that the distribution of zooplankton in the study areas (Jazan Sandy shore, Baish mangrove trees area, Al-Shuqiq sandy shore, Al-Moassum sandy shore and Farasan sandy shore) was variable, and the increasing population abundance might be attributed to the diversity of study areas along with physical and chemical characteristics, an indication of a healthy marine ecosystem **(AbdAllah *et al*., 2018)**. The presence of organic substances or organic pollutants in some coasts led to the disappearance of some species or reduced the population abundance of others.

The results of the current study showed total zooplankton abundance range (552.5 to 1188.5). These results agree with previous study with ranges fluctuating from 356-1440 **(Hirche & Kosobokova, 2011)**. Nematode essentially inhabited marine sediments. Free living nematodes are characterized by their swimming activity in the marine water column **(Ullberg *et al*., 2003; Derycke *et al*., 2013)**. This might explain the appearance of nematodes with zooplankton during marine water examination.

In this study, species richness of zooplankton species ranged from 7 to 8 in each study area. The total number of species defined at all studied areas was 11, which corresponds to what was found in the study of **Branco *et al*. (2007**), the highest richness of zooplankton was found in Farasan sandy shore (eight species) because it's a protected island where there's no more swimming, no fishing, and fewer organic pollutants. **(Alnashiri *et al*., 2018)**. The results of the current study showed that ciliates, nematodes and copepods were the dominant zooplankton in the surface sea water. The results agree with those of **Alnashiri (2021)**. High abundance (63.52 %) was recorded in Baish Mangrove tree area and (61.63%) in Al-Shuqiq sandy shore. This result is consistent with that of **Alnashiri (2021)** that sandy shore and muddy shore showed the highest abundance. It was followed by nematode, which was the highest abundance in Farasan sandy shore and Baish sandy shore (40.6% and 29%).

Calanoid copepods had the highest abundance in Jazan sandy shore (7.14%). It was less than that recorded in previous studies among which is that of **Alnashiri (2021)**. This might be attributed to sampling times and the environmental conditions changing over the course of the year. The results of the current study showed that the least abundant species was for water mite (2.26%) in Jazan sandy shore, polychaeta (1.18%) (1.95%) in Baish mangrove tree area and Al-Moassum sandy shore. These results differed from those of previous studies and were less than those reported by **Mansour *et al*. (2020)**, nauplius larva (1.93%) in Al-Shuqiq sandy shore. These results differed from previous studies and were more than reported by **Alnashiri (2021)**. This difference may be due to different places and times of sampling as well as climate and soil type, Tardigrada (2.07%) in Farasan sandy shore.

Shannon-Weiner diversity index (H') is a measure of the diversity of zooplankton species within the selected sites. Baish sandy shore (H'=0.39) showed the least diverse Zooplankton species due to the presence of the economic city in this area and the large number of organic and ionic pollutants and other environmental disturbances that can be harmful agents controlling zooplankton biodiversity. The high value of Shannon-Weiner diversity index (H') on the Jazan Sandy Coast (H'=1.05) this results agree with previous study **(Apri and Iskandar, 2020)** where he mentioned that the diversity of species in the water Maspari island was from low to medium. Showed the health value of the marine ecosystem **(AbdAllah, 2018).**

The regression analysis relationship of the current study results showed a relationship positively significant($r=0.978$, $P<0.05$) between Water temperature and abundance of Zooplankton (ciliates). This results agree with a previous study **(AbdAllah *et al.*, 2021)** that mentioned that regression relationship was significant ($r = 0.922$, $P < 0.05$) between variation in surface seawater temperature and zooplankton abundance. No significant ($P>0.05$) effect between conductivity and zooplankton distribution. This results agree with previous study

(AbdAllah *et al*., 2021) that mentioned no significant regression between conductivity and zooplankton abundance.

Dissolved oxygen, pH and TDS had negative effect for zooplankton distribution, this results disagree with other study **(AbdAllah *et al*., 2021)**. This is might be due to different sampling times and locations. Two factor ANOVA test showed significant difference between abundance recorded of defined Zooplankton species ($P<0.001$) and significant difference between total zooplankton abundance at different study area ($P<0.001$). The difference between recorded zooplankton species abundance at studied areas was highly significant $P<0.001$). This finding agreed with previous study by **AbdAllah *et al*. (2021)**.

Further studies of zooplankton are recommended to identify and study the distribution and abundance of zooplankton on different types of Jazan coastal areas and its possible use as bioindicator of marine water quality.

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