Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(5): 149 – 160 (2022)
www.ejabf.journals.ekb.eg

Bacterial Load of Tilapia Fish Residing El-Ramla and Abu Simbel Khors, Lake Nasser, Egypt

Sayeda M. Ali
National Institute of Oceanography and Fisheries, NIOF, Egypt.
malisayeda@yahoo.com

ARTICLE INFO
Article History:
Received: June 30, 2022
Accepted: Aug. 17, 2022
Online: Sept. 8, 2022

Keywords:
Lake Nasser,
Microbial load,
Oreochromis niloticus,
Sarotherodon galilaeus,
Tilapia zilli
pathogenic bacteria

ABSTRACT

Fishes are affected by the bacterial load and species present in the surrounding area. Therefore, bacterial load on/in fishes can be used as an indicator of aquatic pollution. Bacterial load was estimated in fish tissues of different tilapia species (*Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zilli*) collected from the entrance and middle El-Ramla and Abu Simbel Khors. Results indicated that fishes of Abu Simbel Khor recorded higher bacterial loads than those of El-Ramla Khor, also fishes of entrance khors recorded higher bacterial loads than the middle. *Salmonella* sp. and *Escherichia coli* were detected in fish samples collected from Abu Simbel Khor more than fishes collected from El Ramla Khor. *Vibrio chorella* was detected in fish samples collected from El Ramla Khor more than those collected from Abu Simbel Khor. The results reflect the exposure of Lake Nasser Khors to various pollutions, especially in its southern part. Here, it is necessary to follow up fishing and tourism boats, also coastal farms around the Khors, to reduce or prevent the causes of pollution of Lake Nasser and its Khors.

INTRODUCTION

Lake Nasser is located at the southern border of Aswan governorate, Egypt. It is considered one of the most important sources of fish wealth for the Egyptians, especially tilapia (bolti fishes), as the most favorite fishes for Egyptians in general and Aswan people in particular **(Habib *et al.*, 2014)**.

In Lake Nasser, there are six species of fishes (*Oreochromis niloticus* (Linnaeus, 1758), *Sarothrodon galilaeus* (Linnaeus, 1758), *Coptodon zillii* (Gervais, 1848), *Lates niloticus* (Linnaeus, 1758), *Alestes dentex* (Linnaeus, 1758), and *Hydrocynus forskalii* (Cuvier, 1819)) that have economic value **(El-Haweet *et al.*, 2008)**. In addition, the southern part of Lake Nasser is more productive for fishes **(Halls *et al.*, 2015)**. Also, khors (the side entrances or extensions of Lake Nasser) are essential fishing areas because they are shallow and contain abundant phytoplankton and limited water currents **(Van Zwieten *et al.*, 2011; Habib *et al.*, 2014)**.

Some researchers and authorities are concerned about assessing fish stock in Lake Nasser **(Halls *et al*., 2015 and GAFRD, 2015)**. Moreover, other researchers have studied the relationships between water quality and fish abundance **(Adams and Ryon, 1994 and Zaki *et al*., 2014)**. Where all fish species are sensitive to aquatic pollutants, and there is a negative relationship between fish health and pollutants, for example, increased concentrations of heavy metals in the ecosystem causes damage to the fish organs **(Authman *et al*., 2008)**. This is because fishes cannot escape from the dangerous effects of water pollutants **(Whitfield and Elliott 2002)**.

Microorganisms can be used as an indicator of environmental pollution because they affect and influence the surrounding environment **(Hans *et al*., 2003 and Ali *et al*., 2015)**. Fish is affected by the bacterial load and the bacterial species that are present in the ecosystem, where **Ali *et al*. (2015)** showed that fishes collected from polluted sites (drainage) recorded higher bacterial loads (in different fish organs) than fishes collected from non-polluted sites. This is because microorganisms are located at the beginning of the aquatic food chain, while fishes are at the end.

In this study, several species of tilapia (*O. niloticus*, *S. galilaeus* and *T. zilli*) were collected from the entrance and middle of two Khors of Lake Nasser (El-Ramla Khor and Abu Simbel Khor, located in the northwest and southeast of Lake Nasser, respectively). The bacterial load in fish tissues was estimated as an indicator of aquatic pollution, and consequently evaluation of Lake Nasser.

MATERIALS AND METHODS

1. The study area

Fish samples were collected from the entrance and middle of two khors of Lake Nasser, one is located in the northwest of Lake Nasser (El-Ramla Khor) and the other in the southeast of Lake Nasser (Abu Simbel Khor) during March 2019 (Figure 1).

2. Fish samples

Oreochromis niloticus, Linnaeus, 1758 (19.4 ± 0.5 cm and 249.1 ± 7.3 g), *Sarotherodon galilaeus*, Linnaeus, 1758 (19.5 ± 1.8 cm and 227.3 ± 21.3 g) and *Tilapia zilli*, Gervais 1848 (19.3 ± 1.9 cm and 148.2 ± 43.1 g) were collected from entrance and middle of El-Ramla khor. As well as *O. niloticus* (24.9 ± 2.8 cm and 319.7 ± 100.2 g) and *S. galilaeus* (22.7 ± 1.2 cm and 264.0 ± 31.9 g) were collected from entrance and middle of Abu Simbel khor. Fishes were collected alive and transported to laboratory in an ice-box. After dissecting the fish, 10 g of each organ (skin, gills, gut and dorsal muscles) were transferred aseptically to 90 ml of 0.85% sterile saline, homogenised and left to stand for 15 minutes at room temperature, then tenfold serial dilutions were performed up to 10^7.

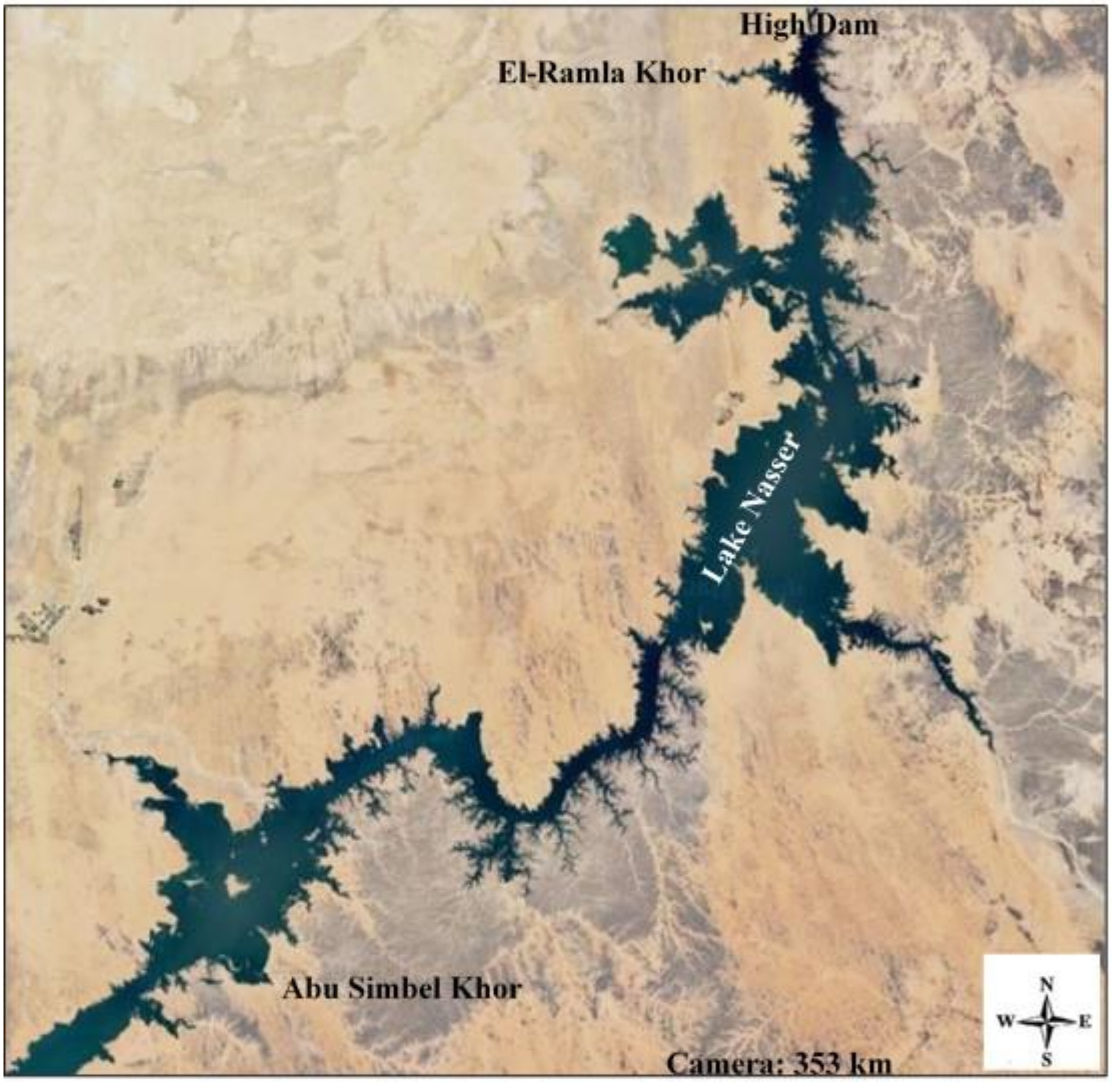

Fig. 1. Satellite image locating El-Ramla Khor and Abu Simbel Khor in Lake Nasser. (El-Ramla Khor and Abu Simbel Khor are located northwest and southeast of Lake Nasser respectively).
(https://earth.google.com/web/search/high+dam,+aswan/@23.06213554,32.32294319,341.02856194a,352570.07629238d,35y,359.63506326h,0t,0r/data=CigiJgokCdUPKV1V4ChAEVNmM_yDbyfAGRy5827-vVBAIfifpyrDPCZA)

3. Bacteriological analyses

Various groups of microorganisms were enumerated in skin, gills, gut and muscles for several species of tilapia fish collected from the experimental sites.

3.1. Total bacterial count: Nutrient agar and pour plate technique was used for enumeration of total bacterial counts after incubation at 37°C for 24 hours **(APHA, 1999)**

3.2. Total Enterobacteriaceae group count: using eosin methylene blue agar media **(Atlas, 1946)**, 0.2 ml suspension was spread over eosin methylene blue agar media and incubated at 37°C for 24 hours **(APHA, 1999)**.

3.3. Detection of some pathogenic bacteria

Some pathogenic bacteria were detected according to **APHA (1999)**.

- **Detection of Salmonella sp.** using spread plate technique and S-S agar (*Salmonella* and *Shigella* agar) medium at 35°C incubation temperature for 24 hrs. Black colonies refers to a positive result.
- **Detection of Escherichia coli** using spread plate technique and eosin methylene blue agar medium at 44.5 °C incubation temperature for 24 hrs. Green metallic sheen refers to a positive result.
- **Detection of Vibrio sp.** using spread plate technique and TCBS (Thiosulfate Citrate Bile salts Sucrose) agar medium at 37 °C incubation temperature for 48 hrs. Yellow colonies refer to a positive result for *Vibrio cholera* and green colonies refers to a positive result for *Vibrio parahaemolyticus*.

4. Statistical analysis

Data obtained were statistically analysed using STATISTICA 10 (StatSoft, Inc., Tulsa, USA). Analysis of variance (ANOVA) was used to examine the independent effects.

RESULTS

Results of microbial loads (total count of bacteria and total count of Enterobacteriaceae spp.) for fish samples collected from the entrance and middle of El-Ramla and Abu Simbel khors are shown in Figure (2). Total bacterial count and total Enterobacteriaceae group varied depending upon sampling site (El-Ramla and Abu Simbel Khors) or (entrance and middle of each Khor) and species of fishes (*O. niloticus*, *S. galilaeus* and *T. zilli*). Total bacteria and total Enterobacteriaceae spp. counts ranged from 1.2 to 8.1 Log No. g^{-1} and 1.4 to 7.5 Log No. g^{-1} respectively for fishes of El-Ramla Khor and from 6.2 to 8.1 Log No. g^{-1} and 0.0 to 7.8 Log No. g^{-1} respectively for fishes of Abu Simbel Khor.

In general, combined statistical analysis for the microbial load of *O. niloticus* and *S. galilaeus* collected from entrance and middle of El-Ramla and Abu Simbel Khors are illustrated in Figure (3). The sensitivity of fishes to pollutants varied and depended on fish species where *O. niloticus* recorded higher microbial load than *S. galilaeus*, except fishes collected from the middle of El-Ramla Khor where *S. galilaeus* recorded higher microbial load than *O. niloticus* (Figure 3A).

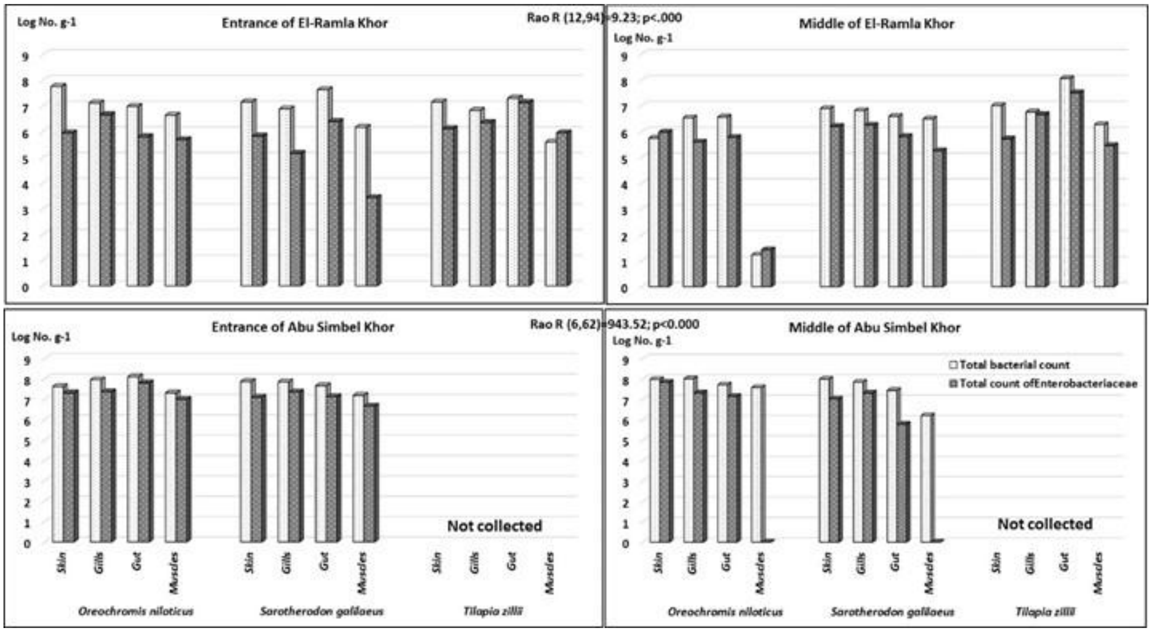

Fig. 2. Microbial loads of the different organs of *Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zilli* collected from entrance and middle of El-Ramla khor, as well as *Oreochromis niloticus* and *Sarotherodon galilaeus* collected from entrance and middle of Abu Simbel khor.

Also, combined statistical analysis shows that fishes of Abu Simbel Khor recorded a higher bacterial load than fishes of El-Ramla Khor, as shown in Figure (3A, B, C). Where fishes collected from the entrance and middle of Abu Simbel Khor recorded 7.7 and 7.6 Log No. g^{-1} respectively, compared to 7.1 and 5.7 Log No. g^{-1} for fishes collected from entrance and middle of El-Ramla Khor, respectively (Figure 3B). Also, fishes collected from the entrance for each Khors recorded higher counts of bacteria and total Enterobacteriaceae spp. than fishes collected from the middle (Figure 3B).

In addition, combined statistical analysis shows that the highest microbial load for various fish organs was recorded at Abu Simbel Khor and followed the order: gills>skin>gut>muscles for total bacterial count, and gills≥skin≥gut>muscles for total count of Enterobacteriaceae spp. (Figure 3C).

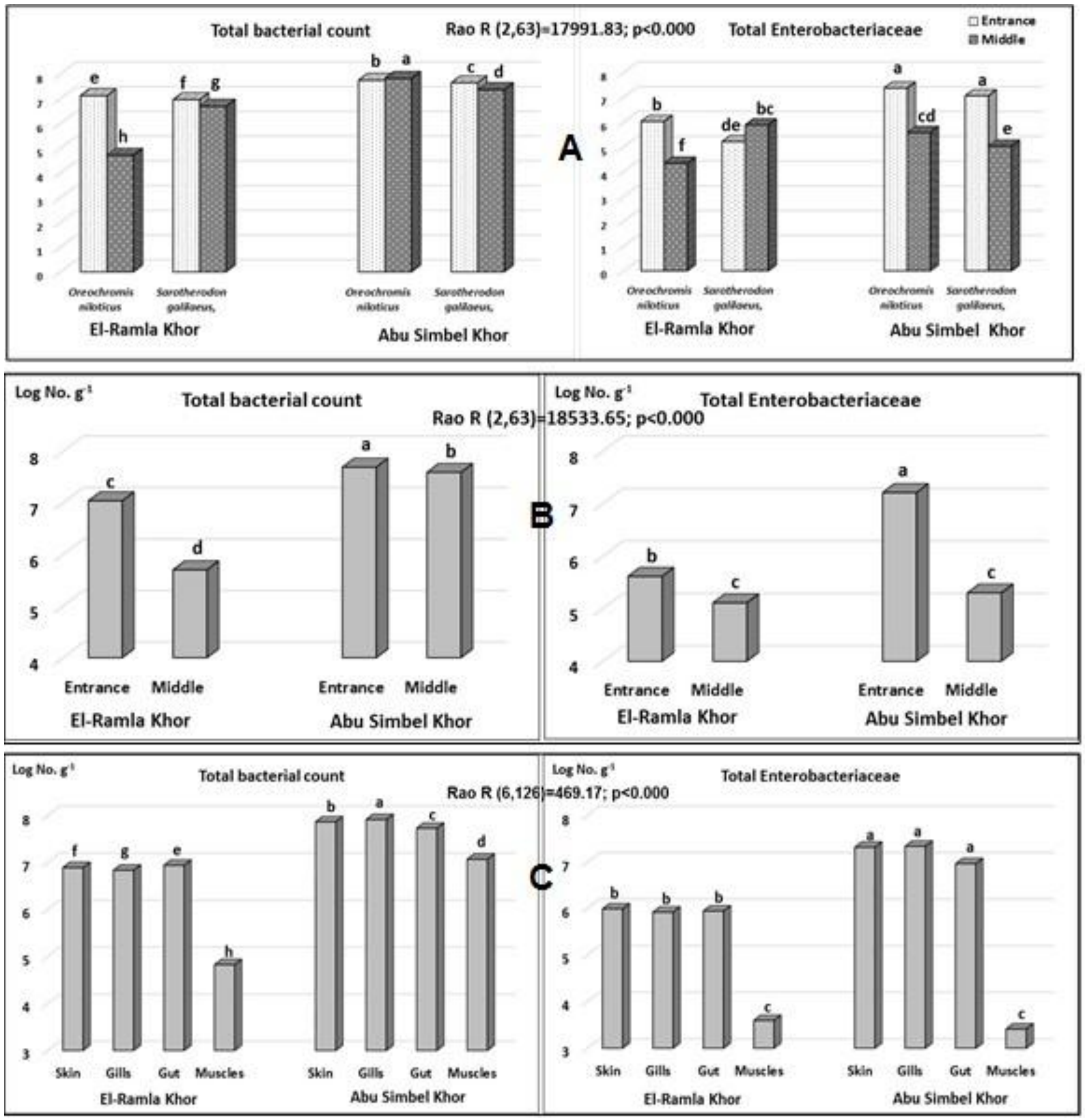

Fig. 3. Combined statistical analysis for microbial loads of *Oreochromis niloticus* and *Sarotherodon galilaeus* collected from entrance and middle of El-Ramla and Abu Simbel khors.

(A): Combined statistical analysis of microbial load for different tilapia fish species with different khors, irrespective of fish organs.

(B): Combined statistical analysis of microbial load for tilapia fishes collected from entrance and middle of El-Ramla and Abu Simbel khors, irrespective of fish species and fish organs.

(C): Combined statistical analysis for microbial load of different fish organs of tilapia fishes, irrespective of fish species and entrance or middle khors.

The different small letters above the column indicate significant differences ($P<0.05$).

Pathogenic bacteria were detected in the organs of the experimental fishes, and the obtained results are presented in Table (1). In general, pathogenic bacteria were detected in greater levels in fishes collected from Khor Abu Simbel than in fishes collected from Khor Al Ramla, where *Salmonella* sp. was not detected in Khor Al Ramla fish samples, while it was present in all skin samples of Khor Abu Simbel fish. Also, *Escherichia coli* was present in all organs of fish samples collected from the entrance and middle of Abu Simbel Khor as 100 and 87% respectively. While *Escherichia coli* was present in 16 and 41% of the fish organ samples collected from the entrance and middle of El Ramla Khor respectively. In addition, *Vibrio cholera* was detected in fish organs collected from El Ramla Khor more than those collected from Abu Simbel Khor. Where *V. chorella* was present at 50 and 42% of fish organs samples collected from the entrance and middle of El Ramla Khor respectively, while the percentage was 37% of fish organ samples collected from the entrance or middle of Abu Simbel Khor. While *Vibrio parahaemolyticus* was present in higher percentage for fish samples of the middle of El Ramla Khor (83%) and the entrance or middle of Abu Simbel Khor (62%), compared to 58% in the fish samples collected from the entrance of El Ramla Khor.

DISCUSSION

Fish is a cold-blooded aquatic vertebrate, and it is essential to a healthy human diet because fish flesh contains high-quality protein, omega-3 fatty acids, and other essential nutrients **(Rhea, 2009)**. Bacteria are found in/on fishes and are beneficial to fish. Bacteria can degrade complex molecules in the digestive tract **(MacDonald *et al*., 1986)** and produce vitamins **(Sugita *et al*., 1991)**.

Fishes are sensitive to any environmental change. Therefore, many researchers use fishes as a biological indicator for toxicological metal pollution in the aquatic systems **(Rashed 2001 and Abumourad *et al*., 2014)**. Also, researchers studied interactions between fish and bacteria **(Olafsen, 2001, Austin 2002 and Rhea, 2009)**. Because fishes are found in water, they are affected by the bacterial load and bacteria species present in water and sediments **(Olafsen, 2001)**. Some researchers reported higher bacterial loads on/in fishes present in polluted waters **(Zmyslowska *et al*., 2001 and Ali *et al*., 2015)**. It is difficult to differentiate between the indigenous microflora and transient microflora on/in fish, which could be present in the water film around fish **(Austin, 2002)**, moreover extraneous bacteria are capable of surviving in fish **(Del Rio Rodriguez *et al*., 1997)**.

Results of the present study recorded higher bacterial load in/on fishes collected from Abu Simbel and El Ramla Khors. Also, gills and gut show that the highest bacterial load than skin and muscles. This is because microorganisms may enter the digestive tract through the mouth, and natural inhibitory compounds or microflora present on the surface

Table 1. Detection of some pathogenic bacteria in different organs of *Oreochromis niloticus, Sarotherodon galilaeus* and *Tilapia zilli* collected from entrance and middle of El-Ramla khor, as well as *Oreochromis niloticus* and *Sarotherodon galilaeus* collected from entrance and middle of Abu Simbel khor in March 2019.

Location	Fish	Organs	*Salmonella* sp.	*Escherichia coli*	*Vibrio cholera*	*Vibrio parahaemolytic*
Entrance of El-Ramla khor	*O. niloticus*	Skin	-	-	+	-
		Gills	-	-	-	+
		Gut	-	-	-	+
		Muscles	-	-	-	+
	S. galilaeus	Skin	-	-	+	-
		Gills	-	-	-	-
		Gut	-	-	+	+
		Muscles	-	-	+	-
	T. zilli	Skin	-	+	-	+
		Gills	-	-	+	+
		Gut	-	-	-	+
		Muscles	-	+	+	-
Middle of El-Ramla khor	*O. niloticus*	Skin	-	+	+	-
		Gills	-	+	-	+
		Gut	-	+	-	+
		Muscles	-	+	-	+
	S. galilaeus	Skin	-	-	-	+
		Gills	-	+	-	+
		Gut	-	-	+	-
		Muscles	-	-	-	+
	T. zilli	Skin	-	-	-	+
		Gills	-	-	+	+
		Gut	-	-	+	+
		Muscles	-	-	+	+
Entrance of Abu Simbel khor	*O. niloticus*	Skin	+	+	+	+
		Gills	-	+	-	+
		Gut	-	+	-	+
		Muscles	-	+	-	+
	S. galilaeus	Skin	+	+	+	-
		Gills	-	+	+	-
		Gut	-	+	-	+
		Muscles	-	+	-	-
	T. zilli		**Not collected**			
Middle of Abu Simbel khor	*O. niloticus*	Skin	+	+	-	+
		Gills	-	+	-	+
		Gut	-	+	-	+
		Muscles	-	-	-	-
	S. galilaeus	Skin	+	+	+	-
		Gills	-	+	+	+
		Gut	-	+	-	+
		Muscles	+	+	+	-
	T. zilli		**Not collected**			

+ refer to presence, - refer to absence

of fish act as an inhibitor of microorganisms in contact with the fish surface **(Austin and Austin, 1987)**. These results agree with **Naigaga *et al*. (2011)**, who reported that the distribution and abundance of fish species strongly influenced by water quality.

Fishes collected from the entrance of Abu Simbel Khor recorded a higher total Enterobacteriaceae spp. load than the middle, while the fishes of *S. galilaeus* collected from the middle of El-Ramla Khor recorded higher total counts of Enterobacteriaceae spp. than the entrance which means poor water quality in the entrance of Abu Simbel Khor and middle of El-Ramla Khor. These results agree with **Ali *et al.* (2017)**, who reported that the end of El-Ramla khor is more polluted than the beginning of El-Ramla khor. This is because the end of El-Ramla khor is narrow and far from the main channel of Lake Nasser, as well as increase the activity of fishing inside the khor. Also, increasing fishing activities in the southern part of Lake Nasser, and increased natural fish foods **(El-Shabrawy and Dumont, 2003)** where they found that the zooplankton in the upstream khors (Toushka and Korosko) was richer than the downstream khors (El-Ramla and Kalabsha).

According to the Egyptian Standard **(EOS, 2005)**, which recommended that the total number of aerobic bacteria should not exceed 10^6 CFU g^{-1} and the total coliform bacteria not exceed 100, the results obtained showed that total Enterobacteriaceae spp. number for all studied samples exceeded 100 CFU g^{-1} except muscle samples of *O. niloticus* collected from the middle of Abu Simbel Khor. Although *Escherichia coli* should not be present on fresh-caught fish **(Chattopadhyay, 2000)**, the results indicated pathogenic bacteria in fish organs. Furthermore, pathogenic bacteria were also detected in fish organs collected from Abu Simbel Khor more than fish organs collected from El Ramla Khor. This indicates that the southern part of Lake Nasser is more polluted than the northern part.

Pollution of the ecosystem affects the quality and quantity of fish, evident from Lake Nasser's fishing, which decreased from about 37,700 metric tons in 2009 to 18,400 metric tons in 2016 **(El-Far *et al*., 2020)**. Also, increasing microorganisms around fishes causing accumulation of microorganisms on/in the fishes causes fish damage **(Ali *et al*., 2015)**, reduce fish production **(Halls *et al*., 2015)**, and rapid spoilage of fish **(Novotny *et al*., 2004)**.

Unfortunately, accumulated bacterial load in fish tissues may be transmitted to humans, especially fishermen, through dealing with fish causing chronic or acute diseases **(Novotny *et al*., 2004 and Abumourad *et al*., 2014)**.

CONCLUSION

Bacterial load on/in fishes often reflects the quality of the surrounding water. Therefore, we can use fishes as an indicator of pollution. Where water contaminants not only affect the quality of fish (increase fish spoilage and reduce shelf life) but also affect the health of fishermen more than consumers because fisherman deals directly with fishes, while the effects on consumers depend on consumption behavior (method of processing and cooking). This study shows that the possibility of using microbiological criteria to assess the quality of fishes and, consequently, the quality of water.

ACKNOWLEDGMENTS

The authoress would like to express her sincere thanks to the team of work in the Lake Nasser project of the National Institute of Oceanography and Fisheries to collect samples.

REFERENCES

Abumourad, I.M.K.; Abbas, W.T.; Authman, M.M.N. and Girgis, S.M. (2014). Environmental impact of heavy metal pollution on metallothionein expression in Nile Tilapia. Research Journal of Pharmaceutical, Biological and Chemical Sciences 5: 998-1005. http://www.rjpbcs.com/pdf/2014_5%282%29/%5B117%5D.pdf

Adams, S.M. and Ryon, M.G.A. (1994). A comparison of health assessment approaches for evaluating the effects of contaminant-related stress on fish populations. Journal of Aquatic Ecosystem Health 3: 15-25. https://doi.org/10.1007/bf00045153

Ali, S.M.; Gaber, H.S. and EL-Kashif, M.M. (2017). Bacteriological, Haematological and Histopathological studies on some fish species inhibiting in El-Ramla Khor, Lake Nasser, Aswan, Egypt. Journal of Advanced Trends in Basic and Applied Science 1: 344-353. https://www.researchgate.net/publication/334119643_Bacteriological_Haematological_and_Histopathological_studies_on_some_fish_species_inhibiting_in_El-Ramla_Khor_Lake_Nasser_Aswan_Egypt

Ali, S.M.; Yones, E.M.; Kenawy, A.M.; Ibrahim, T.B. and Abbas, W.T. (2015). Effect of El-Sail Drain Wastewater on Nile Tilapia (*Oreochromis niloticus*) from River Nile at Aswan, Egypt. Journal of Aquaculture Research & Development 6:294. doi:10.4172/2155-9546.1000294.

APHA, American Public Health Association, (1999) Standard Methods for the Examination of Water and Wastewater (20th ed.). American Public Health Association, Washington DC. http://srjcstaff.santarosa.edu/~oraola/Assets/_APHA_SM_20.pdf

Atlas, Ronald M. (1946). Handbook of microbiological media/Ronald M. Atlas.3rd ed. Boca Raton London New York Washington, D.C, CRC Press, 2004. International Standard Book Number (ISBN) 0-8493-1818-1

Austin, B. (2002). The Bacterial Microflora of Fish. The Scientific World Journal 2: 558-572. https://doi.org/10.1100/tsw.2002.137

Austin, B. and Austin, D.A. (1987). Bacterial fish pathogens: disease in farmed and wild fish. Ellis Horwood Limited, Chichester, England. https://doi.org/10.1017/ s0025315400027399

Authman, M.M.N.; Bayoumy, E.M. and Kenawym A.M. (2008). Heavy metal concentrations and liver histopathology of *Oreochromis niloticus* in relation to aquatic pollution: Global Veterenaria 2: 110-116. https://www. researchgate.net/ publication/313551801

Chattopadhyay, P. (2000). Fish - catching and handling. In: Robinson, R.K., Batt, C.A. and Patel, P.D. 2000. Encyclopedia of Food Microbiology. Academic Press. https://www.worldcat.org/title/encyclopedia-of-food- microbiology/oclc/41581839

Del Rio Rodriguez, R.E.; Inglis, V. and Millar, S.D. (1997). Survival of *Escherichia coli* in the intestine of fish. Aquaculture Research 28: 257-264. https://doi.org/10.1046/j.1365-2109.1997.t01-1-00854.x

El-Far, A.; Aly, W.; El-Haweet, A.E.D.; Nasr-Allah, A. and Karisa, H. (2020). Fisheries management based on gear selectivity of a tropical reservoir, Lake Nasser, Egypt. Egyptian Journal of Aquatic Research 46: 71-77. https://doi.org/10. 1016/ j. ejar. 2020.02.004

El-Haweet, A.; Adam, E.; Sangq, Y. and ElFar, A. (2008). Assessment of Lake Nasser Fisheries. Egyptian Journal of Aquatic Research 34: 285:298. https://www.researchgate.net/publication/265471596_ASSESSMENT_OF_LAKE_ NASSER_FISHERIES

El-Shabrawy, G.M. and Dumont, H.J. (2003). Spatial and seasonal variation of the zooplankton in the coastal zone and main khors of Lake Nasser (Egypt). Hydrobiologia 491: 119–132. https://doi.org/10.1023/a:1024466216214

EOS, Egyptian Organization for Standardization and Quality, Chilled fish (2005). ES No. 3494. https://archive.org/details/es.3494.2005

GAFRD, General Authority for Fishery Resources Development, (2015). Fish Statistics Yearbook 2013. Ministry of Agriculture and Land Reclamation. http://www.gafrd.org/

Habib, O.A.; Nasr Allah, A. and Dickson, M. (2014). Fisheries situation analysis in Aswan. Youth Employment in Aswan Governorate Project.

Halls, A.S.; Habib, O.A.; Nasr-Allah, A. and Dickson, M. (2015). Lake Nasser fisheries: Literature review and situation analysis. Penang, Malaysia: WorldFish. Program Report: 2015-42. http://pubs.iclarm.net/resource_centre/2015-42.pdf

Hans, W.P.; Dyble, J.; Moisander, P.H.; Noble, R.T.; Piehler, M.F.; Pinckney, J.L.; Steppe, T.F.; Twomey, L. and Valdes, L.M. (2003). Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies: FEMS Microbiology Ecology 1: 233-46. DOI: 10.1016/S0168-6496(03)00200-9

MacDonald, N.L.; Stark, J.R. and Austin, B. (1986). Bacterial microflora in the gastro-intestinal tract of Dover Sole (Solea soleal.), with emphasis on the possible role of bacteria in the nutrition of the host. FEMS Microbiology Letters 35: 107-111. https://doi.org/10.1111/j.1574-6968.1986.tb01508.x

Naigaga, I.; Kaiser, H.; Muller, W.J.; Ojok, L.; Mbabazi, D.; Magezi, G. and Muhumuza, E. (2011). Fish as bioindicators in Aquatic Environmental Pollution Assessment: A case study in lake victoria wetlands, Uganda. Physics and Chemistry of the Earth, Parts A/B/C 36: 918-928. https://doi.org/10.1016/j.pce.2011.07.066

Novotny, L.; Dvorska, L.; Lorencova, A.; Beran, V. and Pavlik, I. (2004). Fish: a potential source of bacterial pathogens for human beings. Veterinarni Medicina – Czech 49: 343-358. https://doi.org/10.17221/5715-VETMED

Olafsen, J.A. (2001). Interactions between fish larvae and bacteria in marine aquaculture. Aquaculture 200: 223-247. https://doi.org/10.1016/s0044-8486(01)00702-5

Rashed, M.N. (2001). Monitoring of environmental heavy metals in fish from Nasser Lake. Environment International 27: 27–33. https://doi.org/10.1016/s0160-4120(01) 0050 2

Rhea, F. (2009). Microbiology handbook: Fish and seafood. Leatherhead Food International Ltd. Surrey, UK. ISBN: 978-1-905224-76-0. http://www.ssu.ac.ir /cms/fileadmin/user_upload/Daneshkadaha/dbehdasht/behdasht_imani/book/Microbiology_Handbook_Fish_and_Seafood.pdf

Sugita, H.; Miyajima, C. and Deguchi, Y. (1991). The vitamin B12-producing ability of the intestinal microflora of freshwater fish. Aquaculture 92: 267–276. https://doi.org/10.1016/0044-8486(91)90028-6

Van Zwieten, P.A.M.; Bene, C.; Kolding, J.; Brummett, R. and Valbo-Jorgensen, J. (2011). Review of tropical reservoirs and their fisheries – The cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoirs. FAO Fisheries and Aquaculture Technical Paper No. 557. Rome: Food and Agriculture Organization of the United Nations. ISBN: 9789251067413 https://www.fao.org/publications/card/en/ c/f5837 af0-4f1e-543f-95b0-2a97f92f1888/

Whitfield, A.K. and Elliott, M. (2002). Fishes as indicators of environmental and ecological changes within estuaries: A review of progress and some suggestions for the future. Journal of Fish Biology 61: 229–250. https://doi.org/10.1111/j.1095-8649.2002.tb01773.x

Zaki, M.S.; Authman, M.M.N.; Hammam, A.M.M. and Shalaby, S.I. (2014). Aquatic environmental pollution in the Egyptian countryside and its effect on fish production (Review) Life Science Journal 11: 1024-1029. https://www.lifesciencesite.com/lsj/life1109/150_25681life110914_1024_1029.pdf

Zmyslowska, I.; Lewandowska, D.; Nowakowski, T. and Kozlowski, J. (2001). Occurrence of bacteria in water and in vendace (*Coregonus albula*) during rearing in tanks. Polish Journal of Environmental Studies 10: 51-56. http://www.pjoes. com/ Occurrence-of-bacteria-in-water-and-in-vendace-Coregonus-albula-during-rearing-in,87352,0,2.htm