

Influence of Physicochemical Features of Aquatic Habitat on Biodiversity Indices of Gill Ectoparasitic Microfauna of Two Sympatric, Cohabitant Cichlid Hosts Refuging in Burullus Lake and Nourishing Streams

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ABSTRACT

This study tested the null hypothesis that sympatric and cohabiting cichlid species with similar ecological and phylogenetic traits host comparable helminthic microfauna, and that habitat characteristics significantly influence the structure of their parasitic communities. We conducted a comparative analysis of two parasitic taxa, Monogenea (*Cichlidogyrus*, *Scutogyrus*, *Gyrodactylus*) and Digenea (*Centrocestis formosanus*) infesting the gills of *Oreochromis niloticus* and *Sarotherodon galilaeus* in Burullus Lake and adjacent nourishing streams (Egypt) during 2023. Sampled habitats included Burullus Bay (lake outlet), Shakhlouba ecotourism zone (southern lake region), and Drain-7 (agricultural stream). Among 460 examined fish (248 of *O. niloticus* and 212 of *S. galilaeus*), 3,038 gill parasites were identified (1,448 monogeneans, 1,590 digenean cysts). The Shakhlouba zone showed the highest parasite prevalence (40.42%), followed by Drain-7 (31.27%) and Burullus Bay (28.31%). Monogeneans dominated in Shakhlouba, particularly *C. halli typicus* (66.30%), *C. thurstonae* (70.41%), and *G. cichlidarum* (49.07%), whereas digenean cysts were least abundant there (20.50%). In contrast, Burullus Bay hosted the highest digenean cyst count (41.38%). Canonical correspondence analysis (CCA) revealed that digenean cyst prevalence correlated positively with salinity (EC, TDS, Cl⁻) and minerals (Na⁺, K⁺, N) but negatively with water turbidity and temperature. Simpson's diversity index ($D = 0.914$, $1-D = 0.086$, $1/D = 1.09$) indicated low parasite diversity. A variance-to-mean ratio >1 suggested clumped parasite distribution. Results supported the null hypothesis: both cichlid species exhibited species-poor, similar helminthic communities, and parasite assemblages were shaped by habitat features (water volume, turbidity, vegetation, flow regime). The study highlighted how environmental factors driven by human activity and climate change affect parasite transmission in sympatric hosts.

INTRODUCTION

The environment of Burullus Lake, which is regarded as the second largest lagoon in the North coast of Egypt, has been deteriorated in physical, chemical, biological nature

and geological means. This water resource is highly degrading due to its strategic placement in the Nile Delta, the most amazing geopolitical landscape of Egypt. Burullus Lake is the destination point of many dirty watercourses invading the Nile Delta and receives tremendous amounts of drainage water of industrial, domestic and agricultural origin (**Hany *et al.*, 2022; Younis *et al.*, 2024**). According to **Sheta (2019)**, the drainage water is mainly nutrient-rich and is spoiled by heavy metals and fertilizers. Based on the trophic state index (**El-Sayed *et al.*, 2019**), Burullus Lake is phytoplankton- and organic matter-rich lagoon; it is classified as a hypereutrophic ecosystem with poor and deteriorating water quality. **Adrian (2009)** hypothesized that lake dwellers are sentinels of climate change (i.e. organisms utilized to detect risks by rendering advance warning of a venture or an environmental hazard).

Despite the ecological importance of the Egyptian lakes, many are subjected to significant discharges of both inorganic and organic pollutants stemming from industrial operations, agriculture, sewage, and both treated and untreated effluent from densely populated areas (**Mohsen *et al.*, 2018**). These pollutants are characterized by their non-biodegradable, persistent, toxic, and carcinogenic properties, which can pose serious risks to the food web (**Chaoua *et al.*, 2019; Poustie *et al.*, 2020**). Additionally, they present potential hazards to the environment, biota, and human health due to their toxicity, longevity, and ability to bioaccumulate within aquatic ecosystems (**Ogidi & Akpan, 2022**). The prevalent use of untreated wastewater, which contains a variety of fertilizers, pesticides, and heavy metal contaminants in agriculture, significantly contributes to water pollution (**Lwimbo *et al.*, 2019; Srivastav, 2020; Varol & Tokatli, 2022**). Furthermore, heavy metals are discharged in substantial quantities on a daily basis (**Zhang *et al.*, 2020; Aydin *et al.*, 2021**).

Family Cichlidae are primarily freshwater fish that thrive in warm climates and inhabit diverse aquatic environments across Africa, Central and South America, and Asia (**Matschiner *et al.*, 2020**). Cichlids, which are known for their remarkable variety in size, color, and pattern, predominantly exist in Africa, where nearly 2,000 species have been identified in its lakes alone (**Thatcher, 2006**). Central and South America is home to 560 recognized species, with cichlids adapting to various habitats, including streamlined forms in sandy offshore areas and rock-dwelling species along rocky shores (**Möller, 1987; Catalano *et al.*, 2005**). Freshwater cichlids could have extended to diverse landmasses by oceanic dispersal (**Matschiner, 2019**) or they could have experienced several transitions from marine to freshwater to colonize each landmass independently (**Abate & Noakes, 2021**). Cichlids play an important role in their societies.

Cichlid fish play a significant socioeconomic role in aquaculture, fisheries, and the decorative trade. The vast variety of cichlid forms makes it difficult for researchers to combine novel methods for classifying species, creating phylogenies, and assessing species diversity; their thorough investigation has greatly aided evolution models (**Abate & Noakes, 2021**).

The present research aimed to illustrate the biodiversity of gill ectoparasitic helminth microfauna of two sympatric (i.e. sharing the same geographical area) cichlid hosts, namely *Oreochromis niloticus* and *Sarotherodon galillaeus* residing in Burullus Lake and nourishing streams (network of Drain-7) in the Nile Delta, North Egypt. This involved an analysis of the community structure of gill parasitic microfauna in these two sympatric cichlids, focusing on their diversity, abundance, and similarities among the parasitic populations, while also correlating these indices with habitat characteristics. The hypothesis of this study postulated that sympatric fish species, sharing similar ecological traits and close phylogenetic perspectives, will exhibit comparable helminthic microfauna. The hypothesis of this study also assumed that habitat features can play an important role in shaping the populations of gill microorganisms.

MATERIALS AND METHODS

1. Burullus Lake and nourishing streams

The explored ecosystems exist at the north region of the Nile Delta, close to the Mediterranean Coast (Fig. 1A, B, C). The Nile Delta is a fertile landscape, with overgrowing population and critical geopolitical and socioeconomic worth for Egypt. The current study was done throughout four sequential seasons (2023). Three aquatic ecosystems with varying water quality regimes were explored, namely Burullus Bay (Fig. 1B) (coordinates: 31.57907533856282, 30.976486990850756), Shakhlouba ecotourism zone (Figs. 1C, 1D and 1E) (coordinates: 31.40296082479885, 30.75881721856754), and a nourishing stream joining the lake at the southern sector, namely Drain-7 which is merely an agricultural watercourse (Fig. 1C) (coordinates: 31.40392892446864, 30.77444568047246). Shakhlouba ecotourism zone is characterized by intensive vegetation cover (Fig. 1E), ecotourism (Fig. 1D) and a limited human population (Fig. 1C). The lake showed intervals of marked water shrinkage (Fig. 1F) throughout the study period. Drain-7 serves thousands of hectares of agricultural lands providing the community with essential food supply.

2. Water sampling and analysis

On seasonal basis, at 50cm depth, subsurface water samples were collected from each habitat in 1L polyethylene bottle, which were kept at 8°C. Thereafter, water samples were analyzed in order to evaluate an array of abiotic factors (physicochemical factors). The water temperature (T), hydrogen ion concentration (pH), electrical conductivity (EC), and dissolved oxygen (DO) were measured by Multi-parameter Analyzer model YK-22DO and a numerical pH-meter (Orion Research Model PTI20). Water samples were analyzed according to the procedures illustrated by **Mashaly *et al.* (2020)**.

3. Community structure of gill ectoparasitic helminth microfauna

The community structure indices included dominance, prevalence, mean intensity and abundance. The dominance of helminth parasite species was calculated according to **Roohi *et al.* (2016)** as follows:

$$D = N_{\max} / N_{\text{total}}$$

N_{maximum} = total number of individuals belonging to the dominant species,

N_{total} = total number of individuals of different species in the community.

Simpson's Diversity Index (D):

$$D = \sum n_i(n_i-1) / N(N-1)$$

n_i : is the number of organisms that belong to species i

N : is the total number of organisms

Variance to mean ratio was calculated to estimate the dispersion of the parasite populations. Values > 1 indicate clumped distribution (spatial or temporal), while values < 1 indicate even or uniform distribution. The following rank was proposed to discriminate among core, common (com), secondary (sec) and satellite or rare species according to their prevalence values: $> 60\%$ = core, 40-60% = common, 15-40% = secondary and $< 15\%$ = rare or satellite species.

3.1. Sorenson's Coefficient (coefficient of community)

The scale of Sorenson's coefficient ranges between 0 and 1. As the value of this coefficient comes close to zero, there is a complete dissimilarity between the two communities. In contrast, as the value of this coefficient approaches 1, there is an overlapping between two communities. This coefficient is estimated according to the following formula:

$$S_s = 2c / (S_1 + S_2)$$

S_s = Sorensen's similarity coefficient.

c = number of parasite species shared by both communities.

S_1 = number of parasite species unique to the first community.

S_2 = number of parasite species unique to the second community.

3.2. Jaccard's index (Jaccard coefficient of similarity)

This is a measure used to compare the similarity and diversity of two populations or communities (binary data) (**Jaccard, 1901**). Jaccard's index principally relies on the local absence or presence of living organisms. Jaccard's equation is designed as follows:

$$S_J = 100 c / (a + b - c)$$

S_J = Jaccard's coefficient of similarity.

c = number of monogenean species common to both communities.

a = number of parasite species specified to the first community.

b = number of parasite species specified to the second community.

The ecoparasitological indices abundance, mean intensity and prevalence (percentage of infection) of the studied gill ectoparasitic helminth microfauna were calculated according to **Bush *et al.* (1997)**. Prevalence (%) is regarded as a fundamental ecological concept representing the number of organisms in a specific population infested

by a parasite species at a particular time interval (P). Mean intensity (MI) is the total number of individuals of a certain parasite species divided by the number of hosts invaded by that parasite. Abundance (A) means the total number of organisms of a certain monogenean species divided by the total number of examined hosts (parasite-loaded and parasite-free host individuals); these parameters are computed according to the following formulae:

$$\text{Prevalence (P\%)} = \frac{\text{Total number of fish infected}}{\text{Total number of examined fish}} \times 100$$

$$\text{Mean Intensity (MI)} = \frac{\text{Total number of single parasite species}}{\text{Total number of infected fish}}$$

$$\text{Abundance (A)} = \frac{\text{Total number of single parasite species}}{\text{Total number of examined fish}}$$

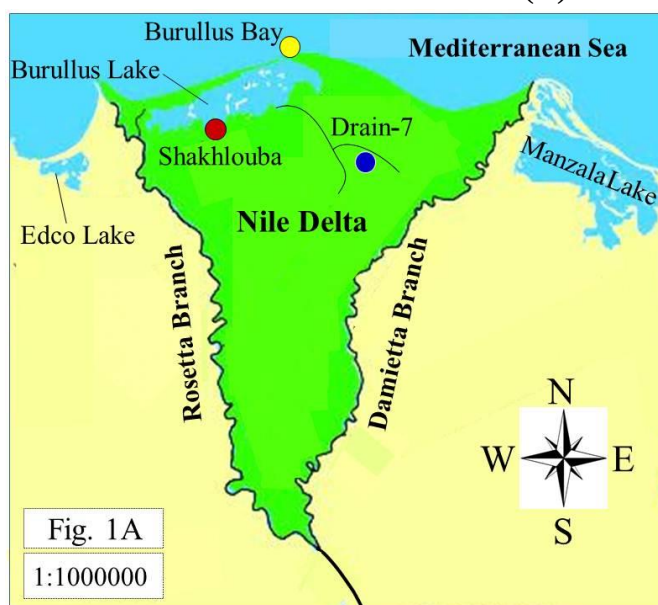


Fig. 1A. Map of the Nile Delta, showing: Burullus Lake, Burullus Bay (yellow circle), Shakhlouba ecotourism area (red circle) and Drain-7, primarily agricultural drainage system (blue circle). Note that the ground bright green color in the map reflects the fertility of this magic landscape (Nile Delta) which is squeezed by the Damietta and Rosetta branches of the River Nile, while the ground yellow color reflects the barren landscapes of the eastern and western desert in the vicinity of the Nile Delta.

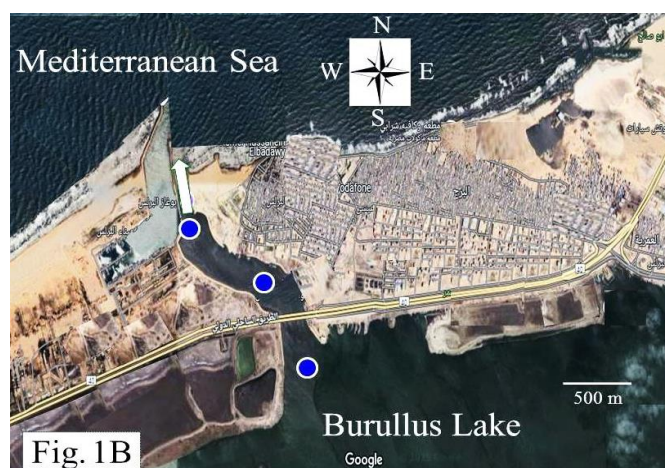


Fig. 1B. Google Earth map showing Burullus Bay (blue solid circle) which joins Burullus Lake to Mediterranean Sea (white arrow). Identify the directions according to the compass. Scale bar = 500 m.

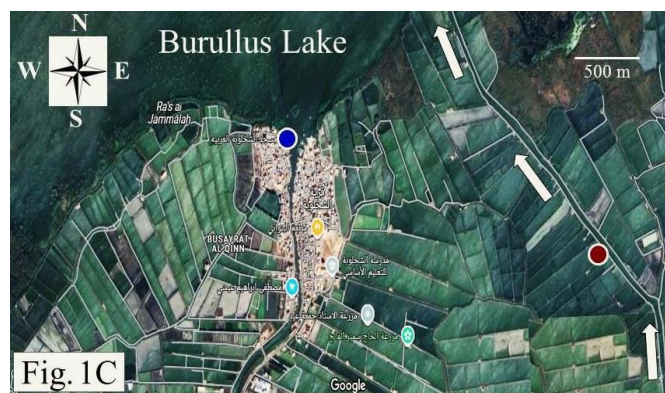


Fig. 1C. Google Earth map showing Shakhlouba ecotourism area (blue solid circle) located at the



Fig. 1D

Fig. 1D. Mobile photograph showing one of the magic islands of Shakhlouba (intermittent arrow) at the southern region of Manzala Lake. Note the heavy vegetation cover at the eastern border of Shakhlouba (red solid circle). Note also the kingfisher, *Ceryx rudis* hovering above water to monitor fish preys. Scale bar = 5 m.



Fig. 1E

Fig. 1E. Mobile photograph showing heavy vegetation cover, one of the specific features of Shakhlouba ecotourism zone at the southern region of Burullus Lake. The plant cover (mainly water hyacinth: *Eichhornia crassipes*) likely provides more sheltered habitat for fish and other aquatic organisms as well. Scale bar = 5 m.

southern region of Burullus Lake, and Drain-7 (red solid circle) which flows from south to north across Nile Delta (white arrow) and terminates in the water body of the lake. Note: the green ground occupying the map reflects the vast agricultural lands shaping this sophisticated geographical area. Identify the directions according to the compass. Scale bar = 500 m.



Fig. 1F

Fig. 1F. Mobile photograph showing shrinkage of the water body of Burullus Lake nearby Burullus Bay. Note the projection of the muddy sediment of the benthic zone and delay of the fishing activity during water cessation periods (intermittent arrow). Scale bar = 5 m.

4. Data analysis

Every record was presented as Mean $\pm$ SD. Kruskal-Wallis One-way ANOVA analysis of variance was also directed to test for variances in the infestation factors of surveyed microorganisms on *Oreochromis niloticus* and *Sarotherodon galilaeus* as well

as water quality criteria among the three studied ecosystems. On the other hand, Mann-Whitney U-test was employed to test for variances in the infestation factors of inspected monogeneans or physicochemical factors among habitat pairs. The following probability values were chosen: Significant $P \leq 0.05$, highly significant $P \leq 0.01$, and very highly significant $P \leq 0.001$. P values > 0.05 , however, were regarded as non-significant. Canonical correspondence analysis (CCA) was employed according to the ordination technique (CCA-biplot) using CANOCO, in which the relationships between the prevalence, mean intensity and abundance records of monogenean and digenean species in each explored ecosystem and physicochemical factors can be indicated on the ordination diagram where points represent the explored habitats at diverse seasons and arrows represent physical and chemical water variables.

RESULTS

1. Parasite community structure

Out of 460 individuals of the cichlid fish hosts (248 *Oreochromis niloticus* and 212 *Sarotherodon galillaeus*), a total of 3038 microorganisms (monogenea and digenea) were isolated and identified from the gills of these hosts inhabiting Burullus Lake and nourishing streams during the period from winter to autumn (2023). The investigated habitats comprised Burullus Bay (an outlet of the lake to the Mediterranean Sea), Shakhlouba ecotourism zone (an ecotourism area in the southern region of the lake), and an agricultural stream, namely Drain-7 which services thousands of hectares at Kafr El-Sheikh Governorate, north Egypt. The viviparous monogenean *Gyrodactylus cichlidarum* was only encountered on the gills of *O. niloticus*, while the oviparous monogenean *Scutogyrus longicornis longicornis* was only encountered on the gills of *S. galillaeus* inhabiting Burullus Bay and Shakhlouba ecotourism zone.

As shown in Fig. (2), regarding the overall parasite assemblages from different habitats and the two cichlid hosts, the digenean taxon (comprising a single species, namely *Centrocestis formosanus*) fairly surpassed the monogenean taxon (comprising 4 species, namely *Cichlidogyrus halli typicus*, *Cichlidogyrus thurstonae*, *Scutogyrus longicornis longicornis* and *Gyrodactylus cichlidrum*). At the species level (Fig. 3), the digenean *C. formosanus* was the most dominant, followed by *C. halli typicus* and *G. cichlidarum*. However, *S. l. longicornis* was satellite or rare species (0.40%).

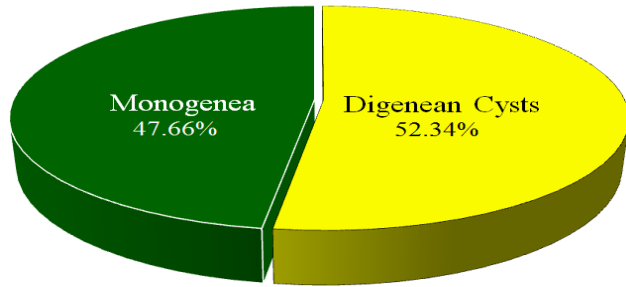


Fig. 2. Pie chart showing ratios of the total skin and gill parasitic load of the catfish, *Clarias gariepinus*

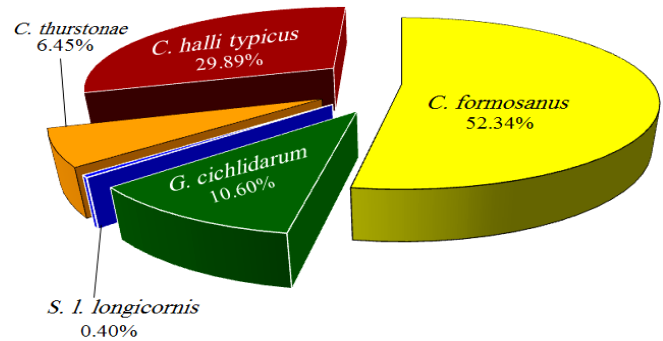


Fig. 3. Pie-Cake chart showing sharing ratios of individual parasite species from the gills of *Oreochromis niloticus* and *Sarotherodon galillaues* (data pooled from the three investigated habitats)

Fig. (4) shows the overall parasite assemblage from the two sympatric cichlid hosts in relation to habitat type. It is clear that fish hosts from Shakhoulouba ecotourism zone harbored the highest ectoparasitic load (40.42%), compared to Drain-7 (31.27%) and Burullus Bay (28.31%). Fig. (5) shows the overall parasite assemblage from different habitats in relation to the cichlid host type. It can be noticed that *O. niloticus* harbored slightly higher numbers of ectoparasitic microfauna in comparison with the sympatric cichlid *S. galillaues*.

Concerning the monogenean occurrence (Fig. 6), the oviparous *C. halli typicus* was the most dominant, followed by the viviparous *G. cichlidarum* and the oviparous *C. thurstonae*. In contrast, the oviparous scutogryid monogenean *S. l. longicornis* was a satellite or rare candidate. Regarding habitat differences in the distribution of *C. halli typicus* collectively from the two cichlid hosts, Shakhoulouba ecotourism zone exhibited the highest load of the this monogenean (66.30%), compared to Drain-7 (30.18%) and Burullus Bay (3.52%) (Fig. 7).

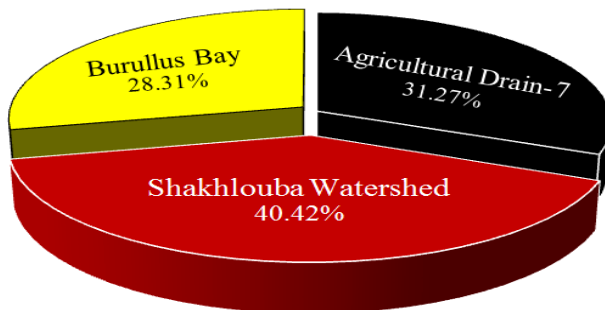


Fig. 4. Pie-Cake chart showing sharing ratios of the overall parasite assemblage from the gills of *Oreochromis niloticus* and *Sarotherodon galillaues* inhabiting the three investigated habitats

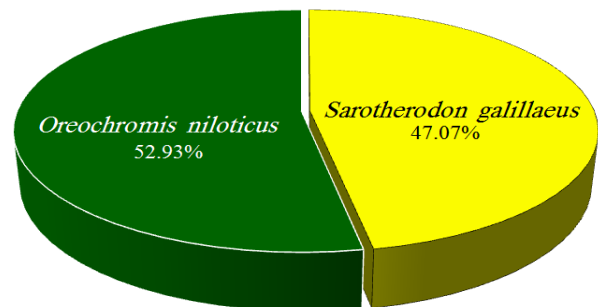


Fig. 5. Pie-Cake chart showing percentage distribution of the overall parasite assemblage between the two cichlid hosts (data pooled from the three investigated habitats)

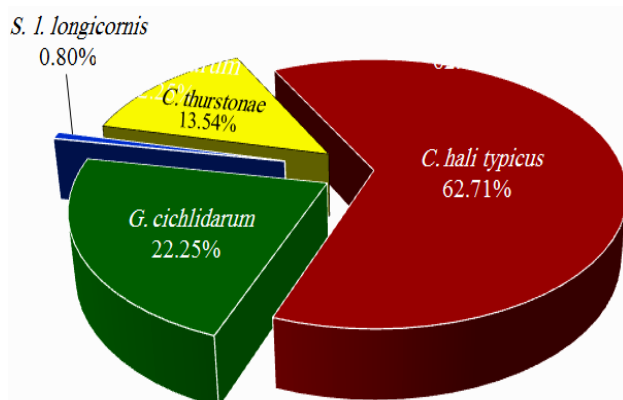


Fig. 6. Pie-Cake chart showing percentage distribution of individual species structuring the gill monogenean microfauna (data pooled from the two cichlid hosts and the three investigated habitats)

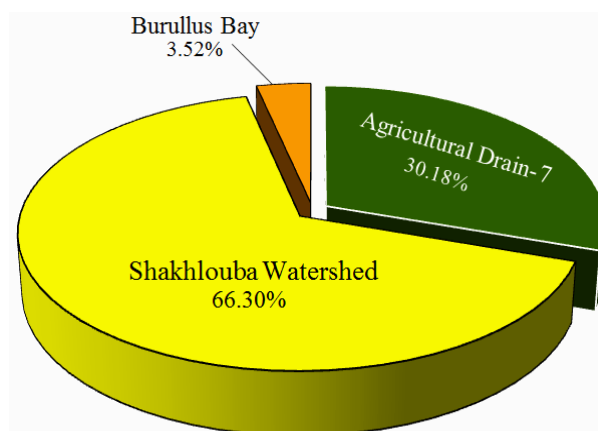


Fig. 7. Pie-Cake chart showing percentage distribution of the gill monogenean *Cichlidogyrus halli typicus* at different habitats (data pooled from the two cichlid hosts)

With respect to habitat differences in the distribution of *C. thurstonae* collected from the two cichlid hosts, Shakhlouba ecotourism zone exhibited the highest load of this monogenean (70.41%), compared to Drain-7 (27.55%) and Burullus Bay (2.04%) (Fig. 8). Concerning habitat differences in the distribution of *G. cichlidarum* collectively from the two cichlid hosts, Shakhlouba ecotourism zone and Burullus Bay exhibited the highest load of this monogenean (49.07%), while Drain-7 showed the lowest load (1.86%) (Fig. 9). For *S. l. longicornis*, Burullus Bay exhibited the highest load of this monogenean (66.67%), while Shakhlouba ecotourism zone showed the lowest load (33.33%) (Fig. 10). As illustrated in Fig. (11), Burullus Bay exhibited the highest load of the digenean *C. formosanus* (41.38%), followed by Drain-7 (38.12%). However, Shakhlouba ecotourism zone exhibited the lowest load (20.50%).

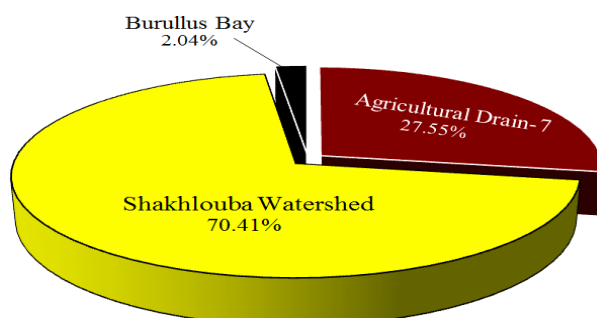


Fig. 8. Pie-Cake chart showing percentage distribution of the gill monogenean *Cichlidogyrus thurstonae* at different habitats (data pooled from the two cichlid hosts)

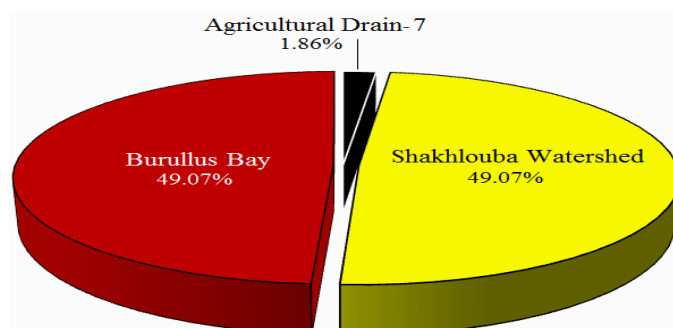


Fig. 9. Pie-Cake chart showing percentage distribution of the gill monogenean *Gyrodactylus cichlidarum* at different habitats (data pooled from the two cichlid hosts)

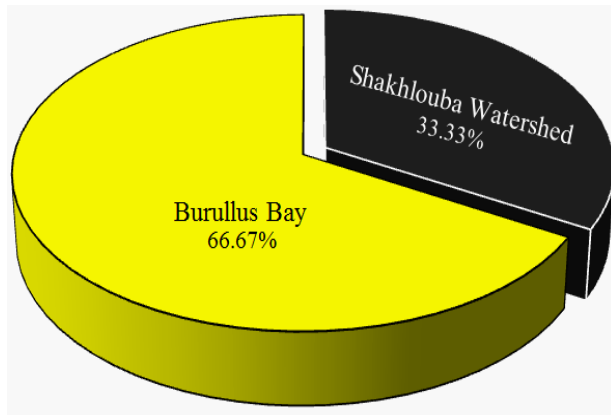


Fig. 10. Pie-Cake chart showing percentage distribution of the gill monogenean *Scutogyrus longicornis longicornis* at different habitats (data pooled from the two cichlid hosts)

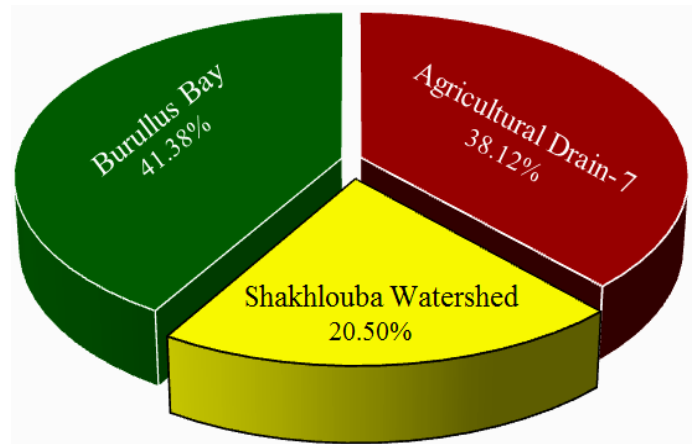


Fig. 11. Pie-Cake chart showing percentage distribution of the gill digenean *Centrocestis formosanus* at different habitats (data pooled from the two cichlid hosts)

Regarding the gill ectoparasitic helminth microfauna of *Oreochromis niloticus* (Table 1), obviously high overall percentage of infection (prevalence) was obtained at Shakhlouba ecotourism zone and Drain-7 (95.00 and 89.25%, respectively). On the other hand, the corresponding level at Burullus Bay was 58.33% (Table 1). The mean intensity and mean abundance levels of these microorganisms were relatively lower than corresponding levels in *O. niloticus* (9.53 and 4.84, 8.68 and 8.18, and 7.25 and 6.50, respectively, in Burullus Bay, Shakhlouba ecotourism zone and Drain-7).

Table(2) shows the overall percentage of infection (prevalence), mean intensity and abundance of gill ectoparasitic helminth microfauna of *Sarotherodon galillaeus* inhabiting Burullus Bay, Shakhlouba ecotourism zone and Drain-7. The overall mean prevalence values were 7.74, 82.50 and 76.75% in the studied habitats, respectively. The overall mean intensity levels were 0.75, 5.67 and 3.25 in the investigated habitats, respectively. On the other hand, the overall mean abundances were 0.10, 4.67 and 2.50, respectively. As documented in Table (2), all examined individuals of *S. galillaeus* were infested by an ectoparasitic load (prevalence =100%) during winter in Shakhlouba and Drain-7, and (prevalence =80%) during spring in Shakhlouba ecotourism zone. Table (1) indicates that all examined individuals of *O. niloticus* were infested by an ectoparasitic load (prevalence =100%) during winter in all localities.

Table 1. Seasonal changes in the overall prevalence, mean intensity and abundance of the monogeneans microorganisms from the gills of *Oreochromis niloticus* dwelling Burullus Bay, Shakhlouba ecotourism zone and Drain -7 at the Nile Delta

Season	Burullus Bay			Shakhlouba			Drain No. 7		
	Prevalence	Mean intensity	Abundance	Prevalence	Mean intensity	Abundance	Prevalence	Mean intensity	Abundance
Winter	100.00	4.71	4.71	100.00	8.73	8.73	100.00	6.00	6.00
Spring	33.33	11.00	3.53	100.00	9.00	9.00	82.00	7.00	6.00
Summer	50.00	14.00	6.92	90.00	8.00	7.00	89.00	2.00	2.00
Autumn	50.00	8.40	4.20	90.00	9.00	8.00	86.00	14.00	12.00
Mean	58.33	9.53	4.84	95.00	8.68	8.18	89.25	7.25	6.50
±SD	25.00	3.94	1.47	5.00	0.47	0.89	6.68	4.99	4.12

Table 2. Seasonal changes in the overall prevalence, mean intensity and abundance of the monogeneans microorganisms from the gills of *Sarotherodon galilaeus* dwelling Burullus Bay, Shakhlouba ecotourism zone and Drain -7 study at the Nile Delta

Season	Burullus Bay			Shakhlouba			Drain No. 7		
	Prevalence	Mean intensity	Abundance	Prevalence	Mean intensity	Abundance	Prevalence	Mean intensity	Abundance
Winter	14.29	1.00	0.14	100.00	4.67	4.67	100.00	3.00	3.00
Spring	0.00	0.00	0.00	80.00	8.00	6.00	82.00	5.00	4.00
Summer	16.67	2.00	0.25	90.00	7.00	6.00	89.00	2.00	2.00
Autumn	0.00	0.00	0.00	60.00	3.00	2.00	36.00	3.00	1.00
Mean	7.74	0.75	0.10	82.50	5.67	4.67	76.75	3.25	2.50
±SD	8.99	0.96	0.12	17.08	2.26	1.89	28.16	1.26	1.29

Calculations of Simpson's diversity index showed $D = 0.914$, $1-D = 0.086$ and $1/D = 1.09$, indicating low diversity order in the present gill ectoparasitic model. Sorensen's similarity coefficient revealed complete overlapping between parasite species from Burullus Bay and Shakhlouba ecotourism zone ($S_s = 1$), and partial overlapping between Burullus Bay and Drain-7 ($S_s = 0.93$) as well as Shakhlouba ecotourism zone and Drain-7 ($S_s = 0.93$). Jaccard's similarity coefficient revealed complete overlapping between parasite species from Burullus Bay and Shakhlouba ecotourism zone ($S_J = 100\%$), and partial overlapping between Burullus Bay and Drain-7 ($S_J = 87.5\%$) as well as Shakhlouba ecotourism zone and Drain-7 ($S_J = 87.5\%$). Variance to mean ratio attained a value of 332210.24 (>1) indicating clumped distribution of this gill ectoparasitic helminth assemblage.

2. Physicochemical parameters of subsurface water

The mean water temperature levels at Burullus Bay, Shakhlouba ecotourism zone and Drain-7 were $23.23 \pm 4.46^\circ\text{C}$, $22.05 \pm 5.50^\circ\text{C}$ and $22.05 \pm 6.18^\circ\text{C}$, respectively. The mean water pH values at Burullus Bay, Shakhlouba ecotourism zone and Drain-7 were 8.69 ± 0.56 , 8.62 ± 0.22 and 8.54 ± 0.45 , respectively. The electrical conductivity in water from Burullus Bay is markedly higher than those in water from Shakhlouba ecotourism zone and Drain-7, with mean values of 4.99 ± 2.05 dS/m, 3.17 ± 1.07 dS/m and 1.67 ± 0.16

dS/m, respectively. A similar output was relevant for total dissolved solids (3190.50 ± 1312.40 mg/L, 1875.2 ± 831.16 mg/L and 1217.6 ± 266.54 mg/L, respectively). The bicarbonates amounts at Burullus Bay were markedly higher than those at Shakhlouba ecotourism zone and Drain-7, with mean values of (376.38 ± 213.66 mg/L, 270.84 ± 116.49 mg/L and 126.42 ± 133.93 mg/L, respectively). A similar output was relevant for sulphates (631.92 ± 458.36 mg/L, 524.95 ± 203.87 mg/L and 256.62 ± 131.58 mg/L, respectively) and chlorides (2182.46 ± 719.69 mg/L, 1229.84 ± 692.38 mg/L and 670.67 ± 136.80 mg/L, respectively). The water at Burullus Bay, Shakhlouba ecotourism zone and Drain-7 were relatively oxygenated, with mean values of 6.90 ± 0.70 mg/L, 6.30 ± 1.65 mg/L and 6.63 ± 1.70 mg/L, respectively. The water depth at Burullus Bay (308.6 ± 72.61 cm) is markedly greater than those at Shakhlouba ecotourism zone (135.20 ± 17.53 cm) and Drain-7 (78.03 ± 17.22 cm). The water body at Drain-7 is more turbid (14.5 ± 5.26 cm) than those at Burullus Bay (15.50 ± 4.20 cm) and Shakhlouba ecotourism zone (36.25 ± 11.09 cm) (Tables 3-5).

Table 3. Seasonal fluctuations of the physicochemical parameters in subsurface water from Burullus Bay, Shakhlouba and Drain - 7 study sites

Season	Burullus Bay				Shakhlouba				Drain No. 7			
	T	pH	EC	TDS	T	pH	EC	TDS	T	pH	EC	TDS
Winter	20.00	8.57	2.94	1882.00	18.30	8.29	4.50	2880.00	18.20	8.70	1.53	979.20
Spring	23.60	8.69	5.75	3680.00	18.40	8.68	1.57	1004.80	17.70	8.63	2.53	1619.20
Summer	29.40	9.42	3.75	2400.00	30.00	8.80	1.94	1241.60	31.00	9.13	1.92	1228.80
Autumn	19.90	8.06	7.5	4800.00	21.50	8.10	3.71	2374.40	21.30	8.29	1.63	1043.20
Mean	23.23	8.69	4.99	3190.50	22.05	8.195	4.105	2627.2	22.05	8.495	1.58	1011.2
±SD	4.46	0.56	2.05	1312.40	5.50	0.13	0.56	357.51	6.18	0.29	0.07	45.26

T=Temperature, pH=hydrogen ion concentration, EC=Electric conductivity, TDS=Total dissolved solids.

Table 4. Seasonal fluctuations of the physicochemical parameters in subsurface water from Burullus Bay, Shakhlouba and Drain - 7 study sites

Season	Burullus Bay				Shakhlouba				Drain No. 7			
	DO ₂	HCO ₃ ⁻	SO ₄ ⁻²	Cl ⁻	DO ₂	HCO ₃ ⁻	SO ₄ ⁻²	Cl ⁻	DO ₂	HCO ₃ ⁻	SO ₄ ⁻²	Cl ⁻
Winter	7.00	70.08	108.34	1704.00	4.80	121.88	544.20	2214.00	6.50	40.04	81.25	857.90
Spring	7.70	541.68	876.92	2261.90	6.60	52.77	400.44	551.59	8.50	270.84	522.80	825.56
Summer	6.00	392.72	412.50	1594.87	5.30	325.01	273.89	588.70	4.40	284.38	267.23	677.19
Autumn	6.90	501.05	1129.90	3169.05	8.50	406.26	765.55	1202.59	7.10	87.84	270.88	684.48
Mean	6.90	376.38	631.92	2182.46	6.30	264.07	654.88	1708.30	6.63	63.94	176.07	771.19
±SD	0.70	213.66	458.36	719.69	1.65	201.09	156.52	715.18	1.70	33.80	134.09	122.63

DO₂=dissolve oxygen, HCO₃⁻ =bicarbonates, Cl⁻ =Chlorides, SO₄⁻²=Sulphates.

Table 5. Seasonal fluctuations of the physicochemical parameters in subsurface water from Burullus Bay, Shakhlouba and Drain - 7 study sites

Season	Burullus Bay				Shakhlouba				Drain – 7			
	WT	WD	N	P	WT	WD	N	P	WT	WD	N	P
Winter	20.00	270.08	18.27	0.26	25.00	120.04	14.49	0.14	10.00	100.88	19.81	0.46
Spring	10.00	341.68	9.45	0.50	50.00	150.77	5.04	0.38	20.00	70.84	3.15	0.32
Summer	15.00	392.72	17.64	0.38	40.00	150.01	9.45	0.33	10.00	60.38	8.19	0.30
Autumn	17.00	230.05	14.49	0.57	30.00	120.00	4.41	0.35	18.00	80.00	3.15	0.30
Mean	15.50	308.61	14.96	0.43	36.25	135.20	8.35	0.30	14.50	78.03	8.58	0.34
±SD	4.20	72.61	4.03	0.14	11.09	17.53	4.67	0.11	5.26	17.22	7.86	0.08

WT= Water Transparency, WD= Water Depth, N=Nitrogen, P=Phosphorous.

As documented in Table (6), water from Burullus Bay is richer in the essential minerals sodium, potassium, calcium and magnesium (3055.66 ± 1273.87 mg/L, 16.25 ± 3.84 mg/L, 82.50 ± 31.81 mg/L and 36.11 ± 14.48 mg/L, respectively) than water from Shakhlouba ecotourism zone (973.38 ± 99.85 mg/L, 11.38 ± 0.75 mg/L, 63.80 ± 25.02 mg/L and 18.64 ± 8.52 mg/L, respectively) and Drain-7 (1909.43 ± 755.50 mg/L, 13.63 ± 5.68 mg/L, 75.94 ± 25.68 mg/L and 27.25 ± 2.56 mg/L, respectively). It can be noticed that potassium is the least abundant mineral in water from all localities, while sodium is the most abundant mineral. The mineral sodium attains marked seasonal fluctuations in Burullus Bay and Drain-7. The lowest levels of calcium are detected during winter in all explored habitats.

Table 6. Seasonal fluctuations of the physicochemical parameters in subsurface water from Burullus Bay, Shakhlouba and Drain -7 study sites

Season	Burullus Bay				Shakhlouba				Drain -7			
	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺
Winter	1813.00	14.00	35.20	19.88	928.80	11.00	26.40	12.96	2789.00	22.00	44.16	27.46
Spring	3532.86	14.50	101.20	31.44	899.52	12.50	74.80	17.98	1473.80	11.00	105.60	28.80
Summer	2254.46	14.50	92.40	38.64	1120.50	11.00	79.20	30.88	1117.20	12.00	70.40	29.18
Autumn	4622.32	22.00	101.20	54.48	944.68	11.00	74.80	12.72	2257.73	9.50	83.60	23.57
Mean	3055.66	16.25	82.50	36.11	973.38	11.38	63.80	18.64	1909.43	13.63	75.94	27.25
±SD	1273.87	3.84	31.81	14.48	99.85	0.75	25.02	8.52	755.50	5.68	25.68	2.56

Na⁺= Sodium ions, K⁺= Potassium ions, Ca⁺⁺= Calcium ions, Mg⁺⁺= Magnesium ions.

From Table (3), it is obvious that water temperature increased gradually from winter to summer, followed by a sudden drop during autumn. It is also noticed that the recorded values of EC in water from Burullus Bay were markedly higher during spring and autumn than winter and summer. The highest levels of pH in all localities were measured during summer. As recorded in Table (4), it is clear that bicarbonates, sulphates and chlorides showed marked elevation in water from Burullus Bay between winter and spring, followed by dramatic decline during summer. As documented in Table (5), it can be seen that water depth at Burullus Bay increased gradually from winter to summer before declining again in autumn. In contrast, water depth at Drain-7 decreased gradually from winter to summer before elevating again in autumn. Table (6) shows that the maximum amount of sodium in water from Burullus Bay was obtained during autumn (4622.32 mg/L).

Statistical comparison (Kruskall-Wallis One-Way ANOVA test) revealed significant variation in the EC ($H=6.0385$, Asymp. Sig.: $P \leq 0.05$), TDS ($H=6.0385$, Asymp. Sig.: $P \leq 0.05$), chloride content ($H=5.6985$, Asymp. Sig.: $P \leq 0.05$), water transparency ($H=7.5528$, Asymp. Sig.: $P \leq 0.05$), sodium ($H=7.2692$, Asymp. Sig.: $P \leq 0.01$) and magnesium ($H=7.2692$, Asymp. Sig.: $P \leq 0.01$), but high significant variation in water depth ($H=9.8462$, Asymp. Sig.: $P \leq 0.01$) among Burullus Bay, Shakhlouba ecotourism zone and Drain-7. Further statistical analysis (Mann-Whitney U-test) revealed high significant differences of EC as well as TDS between Burullus Bay and Drain-7 ($Z=2.4515$, $P \leq 0.01$), and water depth between Burullus Bay and Drain-7 ($Z=3.1379$, $P \leq 0.01$). Moreover, Mann-Whitney U-test revealed significant differences of water transparency between Burullus Bay and Shakhlouba ecotourism zone ($Z=2.3248$, $P \leq 0.05$) as well as between Shakhlouba ecotourism zone and Drain-7 ($Z=2.3248$, $P \leq 0.05$). Further statistical analysis (Mann-Whitney U-test) revealed significant differences of chlorides between Burullus Bay and Drain-7 ($Z=2.1573$, $P \leq 0.05$) as well as between Burullus Bay and Shakhlouba ecotourism zone ($Z=1.9652$, $P \leq 0.05$). Highly significant differences were also calculated for sodium between Burullus Bay and Shakhlouba ecotourism zone ($Z=2.6476$, $P \leq 0.01$), and for magnesium between Burullus Bay and Shakhlouba ecotourism zone ($Z=2.5495$, $P \leq 0.01$). On the other hand, a significant variation was obtained for magnesium between Shakhlouba ecotourism zone and Drain-7 ($Z=1.9786$, $P \leq 0.05$). In contrast, other physicochemical factors showed non-significant differences among explored ecosystems (Kruskall-Wallis One-Way ANOVA test: Asymp. Sig.: $P > 0.05$).

3. Relationship between parasite load and physicochemical parameters of subsurface water

Fig. (12) represents a CCA chart showing the relationship between physicochemical parameters of water and percentage of infestation of *Oreochromis niloticus* by gill monogenean and digenean taxa. Fig. (13) represents a CCA chart

Fig. 12. CCA chart showing the relationship between physicochemical parameters and percentage of infection of the cichlid *Oreochromis niloticus* (data pooled from different habitats)

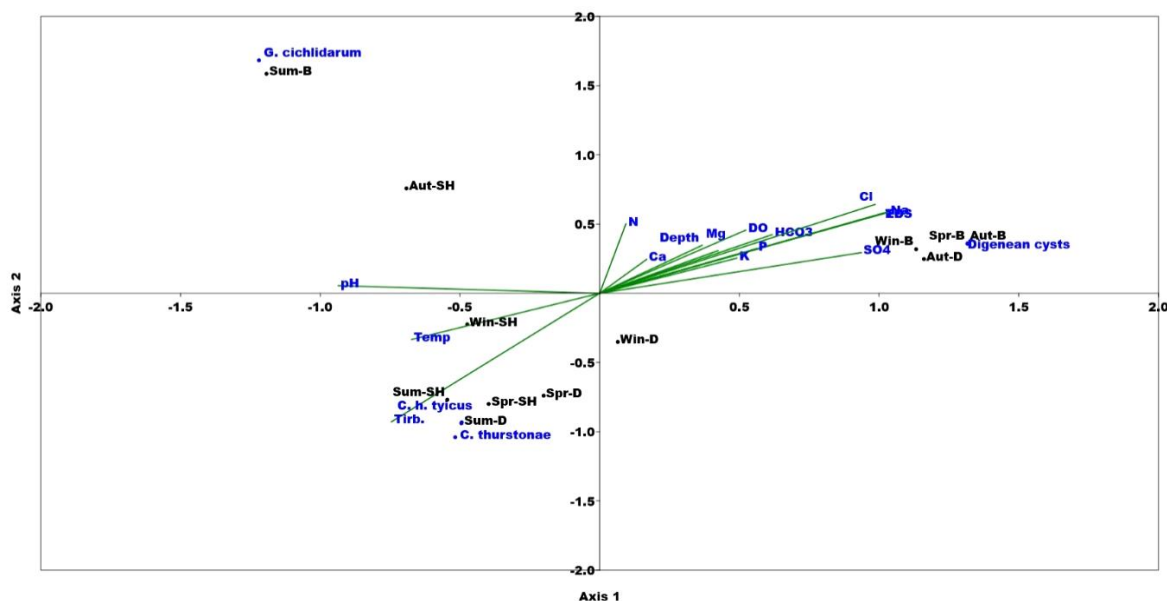


Fig. 13. CCA chart showing the relationship between physicochemical parameters and abundance of parasites of the cichlid *Oreochromis niloticus* (data pooled from different habitats)

Fig. (14) represents a CCA chart showing the relationship between physicochemical parameters of water and percentage of infestation of *Sarotherodon galillaeus* by gill monogenean and digenean taxa. Fig. (15) represents a CCA chart showing the relationship between physicochemical parameters and abundance of parasites (gill monogenean and digenean taxa) of *Sarotherodon galillaeus*. It is evident that the prevalence of the digenean cysts is strongly (positively) affected by salts (EC, TDS and Cl) and minerals (Na, K and N). It is also obvious that the prevalence of the digenean cysts is negatively influenced by water turbidity and water temperature. Fig. (14) indicates that water depth, pH, HCO₃, SO₄, Ca, P and Mg are moderately affected parasite prevalence.

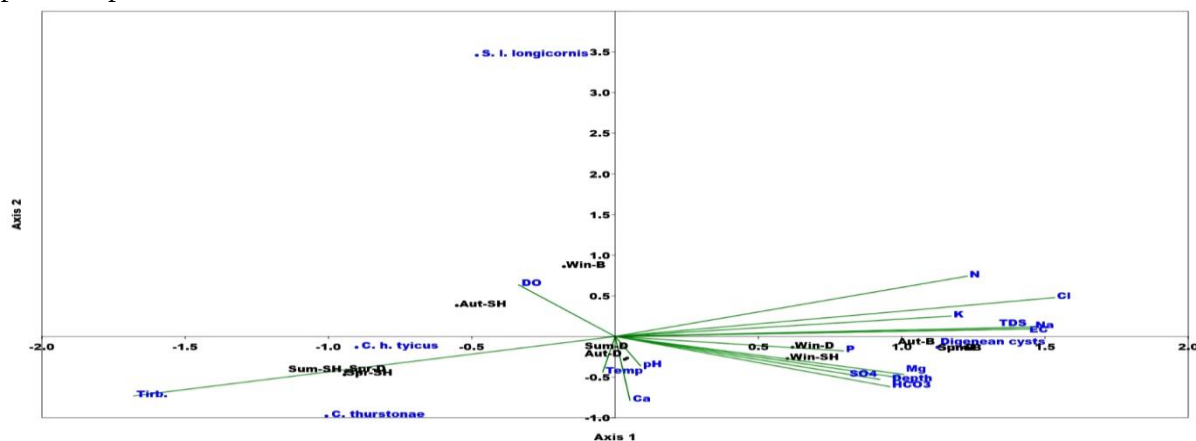


Fig. 14. CCA chart showing the relationship between physicochemical parameters and percentage of infection of the cichlid *Sarotherodon galillaeus* (data pooled from different habitats)

From Fig. (15), the abundance of the monogeneans *Cichlidogyrus halli typicus* and *Cichlidogyrus thurstonae*, and digenean cysts are strongly (positively) influenced by water turbidity, but moderately (positively) affected by DO and Ca. However, the abundance of these gill parasites is negatively affected by other physicochemical parameters. In addition, it can be noticed that the monogenean *Scutogyrus longicornis longicornis* is positively affected by EC, TDS and Cl, HCO₃ and water depth.

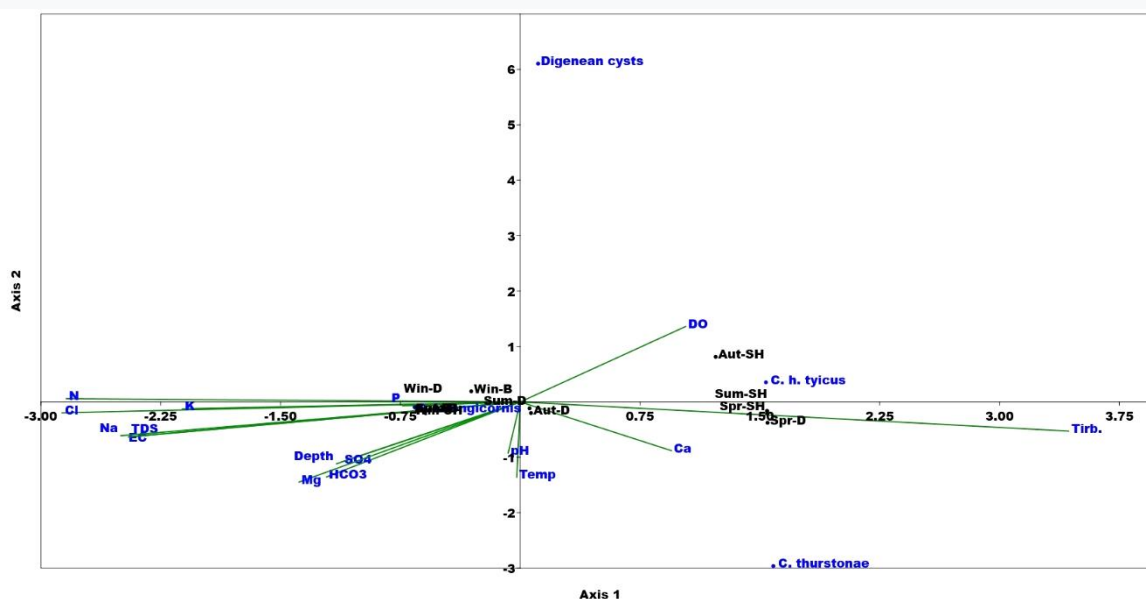


Fig. 15. CCA chart showing the relationship between physicochemical parameters and abundance of parasites of the cichlid *Sarotherodon galillaeus* (data pooled from different habitats)

DISCUSSION

Gill ectoparasitic helminths survey of the two cichlid host revealed that Shakhlouba ecotourism zone was found to be the most favourable and nursery habitat for these inhabitants in *Oreochromis niloticus* and *Sarotherodon galillaeus* (40.42%), compared to Drain-7 (31.27%) and Burullus Bay (28.31%). At the species level, cichlid host resident in Shakhlouba ecotourism zone harbored the highest number of the oviparous monogeneans *C. halli typicus* (66.30%) and *C. thurstonae* (70.41%), and the viviparous monogenean *G. cichlidarum* (49.07%). On the other hand, cichlid host resident in Burullus Bay harbored the highest number of the digenean cysts (41.38%). However, cichlid host from this habitat harbored the lowest numbers of digenean cysts (20.50%). The viviparous monogenean *Gyrodactylus cichlidarum* was only encountered on the gills of *O. niloticus*, while the oviparous monogenean *Scutogyrus longicornis longicornis* was only encountered on the gills of *S. galillaeus* inhabiting Burullus Bay and Shakhlouba ecotourism zone.

Nouman (2024) studied the monthly fluctuations in the prevalence, mean intensity and abundance of *S. l. longicornis* from the gills of *O. niloticus* dwelling the River Nile and one of interconnected quaternary streams at Nile Delta, Egypt from September (2021) to August (2022). The author computed the following infestation parameters for this oviparous monogenean in River Nile habitat: prevalence = 15.37%, mean intensity = 2.03 and abundance = 0.32. On the other hand, the following infestation parameters were recorded in the minor stream habitat: prevalence = 7.91%, mean intensity = 1.13 and abundance = 0.09. These data indicate that *S. l. lomgicornis* is a secondary species, with a relatively low population growth. In line with the report developed by **Nouman (2024)**, the present study showed that *S. l. lomgicornis* existed only on *S. galillaeus* from Burullus Bay and Shakhoulouba ecotourism zone. The following infestation parameters were recorded in Burullus Bay: prevalence = 25.0% (secondary species), mean intensity = 0.33 and abundance = 0.33. These findings indicate that *S. l. lomgicornis* has a limited reproductive potential regardless the habitat type. These calculations are in agreement with those computed by **El-Naggar and Khidr (1986)** and **El-Naggar and El-Tantawy (2003)**. On the other hand, the following infestation parameters were recorded in Shakhoulouba habitat: prevalence = 5.0% (rare species), mean intensity = 0.50 and abundance = 0.10. These data are in line with those computed for this monogenean in *O. niloticus* by **El-Naggar and Khidr (1986)** and in *Tilapia zillii* by **El-Naggar and Khidr (1986)** and **El-Naggar and El-Tantawy (2003)**.

Marcogliese (2005) suggested that a dynamic equilibrium is maintained between hosts and their parasite communities under natural circumstances, possibly demonstrating the most dominant interaction in the biosphere. Aquatic organisms have adapted to thrive at a definite thermal regime; exposure to extremely high or low water temperatures can be fatal (**Dallas, 2008; Glazier, 2012**). Various ecological, physiological, and behavioral traits of aquatic species, such as their reproductive capabilities, metabolic processes, and developmental stages, are influenced by temperature (**Ouellet *et al.*, 2020**). Besides, the process of photosynthesis, which provide the building blocks of the food chains and webs, is augmented by water temperature. Elevated temperature can render pollutants highly toxic (**Ouellet *et al.*, 2020**). Furthermore, amplified water temperatures lead to a decrease in amounts of dissolved oxygen; on the contrary, lower temperatures can increase solubility of oxygen in water.

Wood *et al.* (2023) discovered that protected habitats support populations of parasitic organisms. They proposed that fishing activities may reduce parasite abundance by diminishing the availability of habitats (fish) and limiting access to vital resources. **Cavalcanti *et al.* (2020)** examined the responses of monogenean microfauna from two oviparous genera (*Cichlidogyrus* and *Scutogyrus*) to variations in abiotic (physicochemical) factors in farmed tilapia in Brazil. Their findings indicated that *C. tilapiae*, *C. sclerosus*, *C. thurstone*, and *S. l. longicornis* exhibited positive correlations with electrical conductivity, whereas *C. halli* did not show significant correlations with

any of the physical and chemical parameters measured. They attributed the relationship between *C. halli* and abiotic factors to the low number of parasite specimens observed on the gills of the host. **Cavalcanti et al. (2020)** linked the high prevalence of fish parasites in nutrient-rich, organic matter-laden water to their preference for such habitats, while noting a lower abundance of these pathogens in turbid waters.

Dayoub and Salman (2015) noted that the monogenean *Cichlidogyrus sclerosus* exhibited elevated mean intensity values in *T. zillii* due to reduced dissolved oxygen levels and increased organic matter in Lake 16 Tishreen, Syria. **Buchmann and Lindenstrom (2002)** noted that the attachment of monogeneans to a specific host relies on mechanical adaptations (e.g. musculature, robust hamuli, and minute peripheral hooklets) and biochemical factors (e.g. glandular secretions of parasite origin). Additionally, they indicated that host immune responses include innate and adaptive processes. **Buchmann and Lindenstrom (2002)** suggested that the capacity of monogeneans to evade hostile immune responses may play a significant role in the dynamic of the host-parasite system.

Human activities can pose adverse impacts and modify aquatic and terrestrial habitats (**Coscia & Kaiser, 2022; Nartey, 2024**). Drain-7 exhibited stochastic flow of water due to unpredictable filling and emptying works, potentially disturbing aquatic organisms and disrupting energy flow patterns within food chains and webs. Ultimately, these disturbances can lead to an imbalance in the aquatic ecosystem and development of parasitic infections. According to **Al-Zahrani (2025)**, even though Burullus Lake attained the highest turbidity level, the redbelly tilapia residing there harbored the lowest infection rates compared to River Nile and Rayyan Lake. Furthermore, this lake had the highest concentrations of nitrogen, sodium, potassium, calcium, and magnesium, suggesting that the nutrient load of aquatic environment does not drive parasite proliferation. This author found that the core monogenean *C. arthracanthus* and digenean *Centrocestis formosanus* species from the gills of the redbelly tilapia, *Tilapia zillii* inhabiting Burullus Lake experienced a marked decline during summer. This author linked summer population crash of monogenean and digenean species to extensive dredging accomplishments inside the lake. Such human interference may result in removal of the bottom components the lake, along with accompanying biological communities (i.e. fauna and flora), leading to increased water turbidity. This turbidity modifies interaction between fish host and gill ectoparasitic microorganisms. Moreover, light penetrating the water column likely alters thermal stratification of water and subsequently reduces ecosystem productivity and energy flow via food chains and webs. As well, turbidity disrupts thermoreception response in the free-swimming larvae of ectoparasitic organisms (e.g., oncomiracidium of oviparous monogeneans).

Al-Zahrani (2025) suggested that monogenean eggs that temporarily settle on the lakebed may be lost or degenerated. The gill-ventilating water current may be loaded with particulate matter, inducing irritation to resident microorganisms and disturbance in

their normal activities. Furthermore, the degradation of gill can render them resource-poor microhabitats, modify egg hatching rhythm, and change fish behavior due to noise generated by dredging machinery. According to **Ogundiran *et al.* (2009)**, fish gills exhibit a high degree of sensitivity to changes in physical and chemical features of water, and alterations in ambient environment as well. This sensitivity is a significant indicator of the existence of pollutants in water. From both physiological and morphological perspectives, the gill is essential for fish existence; this vital organ regulates water level, balances acid-base, and eliminates nitrogenous waste products such as ammonia and urea (**Shimpei *et al.*, 2008; Pereira & Caetano, 2009**).

Ribeiro *et al.* (2025) indicated that environmental factors, particularly water temperature, significantly affect egg production, larval hatching, and overall life cycle of oncomiracidium in monogeneans. Monogeneans have specific optimal temperature requirements, and sustaining this ideal temperature for a prolonged duration can extend the infection period, resulting in a higher generation of parasites (**Lohmus & Bjorklund, 2015**). The transmission and prevalence of these parasites are typically seasonal, exhibiting variations throughout the year (**Sitja-Bobadilla *et al.*, 2010**). Higher temperatures led to an increased prevalence of *Neobenedenia girellae*, and the egg count from *Seriola dumerili* raised at 30°C surpassed that of those raised at 20 and 25°C (**Hirazawa *et al.*, 2010**). Additionally, *Discocotyle sagittata* showed enhanced egg production with rising temperatures, producing 1.5 eggs per day at 5°C, 7 eggs per day at 13°C, and 12 eggs per day at 20°C (**Rubio-Godoy & Tinsley, 2008**). **Sereno-Uribe *et al.* (2012)** observed that gyrodactylid population growth may depend on abiotic variables such as temperature. These authors monitored the reproductive rate of *Gyrodactylus mexicanus*, a parasite infecting fins of *Girardinichthys multiradiatus*, at three different water temperatures, 10–13, 19–22, and 24°C. The average number of offspring per parasite was 2.0 when averaged across all temperatures. However, the generation time was negatively correlated with temperature. These authors also observed that innate capacity for increase was positively correlated with water temperature: from 0.29 at 13 °C to 0.48 parasite/day at 24°C.

In general, the fecundity and hatching of monogenean eggs, as well as the subsequent growth and development of the parasites following invasion, are significantly augmented by elevated water temperatures; however, the longevity of these parasites exhibits an inverse correlation with temperature (**Tubbs *et al.*, 2005; Buchmann & Bresciani, 2006**). Consequently, investigations conducted in temperate regions typically demonstrate that the transmission of oviparous monogenean gill parasites is positively correlated with temperature (**Buchmann & Bresciani, 2006; Rubio-Godoy & Tinsley, 2008**). In contrast, in areas characterized by tropical and subtropical climates, the influence of temperature on the infection dynamics of oviparous monogenean parasites disseminated through oncomiracidia remains ambiguous. For example, the thermal conditions of water exhibited a positive correlation with the population growth of the gill

parasites *Diplozoon kashmirensis*, which infects *Carassius carassius*, and *Schizothorax niger*, in the region of Kashmir, India (**Shah et al., 2013**); as well as with *Zeuxapta seriola*, which infects *Seriola lalandi* in New Zealand (**Tubbs et al., 2005**). Conversely, temperature demonstrated a negative correlation with the abundance of the gill parasites *Ligictalurus floridanus*, which infects *Ictalurus punctatus*, maintained in floating cages in Tamaulipas, Mexico (**Rabago-Castro et al., 2011**); as well as with *Pseudorhabdosynochus coioides* and *P. serrani*, which infect groupers, *Epinephelus* spp. in the South China Sea (**Luo & Yang, 2010**). While in South Carolina, USA, *Metamicrocotyla macracantha* infecting *Mugil cephalus* (**Baker et al., 2008**) was recorded in addition to *Sparicotyle chrysophrii* infecting *Sparus aurata* in Corsica, France (**Antonelli et al., 2010**). The mean abundance of *Cichlidogyrus tilapia* and *C. sclerosus* infecting *Oreochromis niloticus*, in Uganda (**Akoll et al., 2012**) and *Urocleidoides eremitus* and *Anacanthorus* sp. infecting *Hoplias malabaricus* in Pirassununga, Brazil (**Correa et al., 2013**) did not significantly correlate with temperature.

REFERENCES

- Abate, M. E. and Noakes, D. L. G.** (2021). The Behavior, Ecology and Evolution of Cichlid Fishes. Fish and Fisheries Series (FIFI, volume 40). Springer Nature Link.
- Adrian, R.** (2009). Lakes as sentinels of climate change. Limnol. Oceanogr., (54): 2283–2297.
- Akoll, P.; Fioravanti, M. L.; Konecny, R. and Schiemer, F.** (2012). Infection dynamics of *Cichlidogyrus tilapia* and *C. sclerosus* (Monogenea, Ancyrocephalinae) in Nile tilapia (*Oreochromis niloticus* L.) from Uganda. J. Helminthol., 86(3): 302 – 310.
- Al-Zahrani, H. A.** (2025). Comparative Ecological and Molecular Biology Studies on the Redbelly Cichlid, *Tilapia zillii* (Gervais, 1848) from Open and Closed Aquatic Ecosystems in the Nile Delta – Egypt. PhD Thesis, Zoology Department, Faculty of Sciences, Mansoura University, Egypt.
- Antonelli, L.; Quilichini, Y. and Marchand, B.** (2010). *Sparicotyle chrysophrii* (Van Beneden and Hesse 1863) (Monogenea: Polyopisthocotylea) parasite of cultured Gilthead sea bream *Sparus aurata* (Linnaeus 1758) (Pisces: Teleostei) from Corsica: ecological and morphological study. Parasitol. Res., 107: 389–398.
- Aydin, H.; Ustaoglu, F.; Tepe, Y. and Soylu, E. N.** (2021). Assessment of water quality of streams in northeast Turkey by water quality index and multiple statistical methods. Environ. Forensics, 22 (1-2): 270-287.
- Baker, T. G.; Pante, E.; Levesque, E. M.; Roumillat, W. A. and de Buron, I.** (2008). *Metamicrocotyla macracantha*, a polyopisthocotylid gill parasite of the striped

- mullet, *Mugil cephalus*: population dynamics in South Carolina estuaries. Parasitol. Res. 102:1085–1088.
- Buchmann, K. and Bresciani, J.** (2006). Monogenea (Phylum Platyhelminthes). In: Woo, P.T.K. (Ed.), Fish diseases and disorders. Protozoan and metazoan infections vol. 1. CAB International, Wallingford, pp. 294–341.
- Buchmann, K. and Lindenstrom, T.** (2002). Interaction between monogenean parasites and their fish host. Int. J. Parasitol., 32(3):309-19.
- Bush, A. O.; Lafferty, K. D.; Lotz, J. M. and Shostak, W.** (1997). Parasitology meets ecology on its own terms: Margolis et al. revisited. J. Parasit., 83: 575-583.
- Catalano, S. R.; Whittington, I. D.; Donnellan, S. C. and Gillanders, B. M.** (2005). Parasites as biological tags to assess host population structure: Guidelines, recent genetic advances and comments on a holistic approach. Int J Parasitol Parasites Wildl., 2013 Dec 12;3(2): 220-6. doi: 10.1016/j.ijppaw.2013.11.001.
- Cavalcanti, L. D.; Gouveia, E. J.; Leal, F. C.; Figueiro, C. S. M.; Rojas, S. S. and Russo, M. R.** (2020). Responses of monogenean species to variations in abiotic parameters in tilapiculture. J. Helminthol., 94(e186): 1–7.
- Chaoua, S.; Boussaa, S.; Gharmali, A. and Boumezzough, A.** (2019). Impact of irrigation with wastewater on an accumulation of heavy metals in soil and crops in the region of Marrakech in Morocco. J. Saudi Soc. Agric. Sci., 18(4): 429-436.
- Correa, L. L.; Karling, L. C.; Takemoto, R. M.; Ceccarelli, P. S. and Ueta, M. T.** (2013). Hematological parameters of *Hoplias malabaricus* (Characiformes: Erythrinidae) parasitized by Monogenea in lagoons in Pirassununga, Brazil. Rev. Bras. Parasitol. Vet., 22: 457-462.
- Coscia, I. and Kaiser, M. J.** (2022). The impact of the human activities on aquatic ecosystems. J Fish Biol., 101(2): 331-332.
- Dallas, H.** (2008). Water temperature and riverine ecosystems: an overview of knowledge and approaches for assessing biotic responses, with special reference to South Africa. Water SA, 34: 393–404.
- Dayoub, A. I. and Salman, H. M.** (2015). Study of Using Monogenea Parasites on Free – Living Fishes in the Lake of 16 Tishreen Dam as Bio Indicators of Environment Pollution. IJBECS, 1(1).
- El-Naggar, A. A. and El-Tantawy, S. A.** (2003). The dynamics of gill monogenean communities on cichlid fish hosts inhabiting Damietta Branch of the River Nile: long-term changes in species richness and community structure. J. Basic Appl. Zool., 41(D): 187-220.
- El-Naggar, M. M. and Khidr, A. A.** (1986). Population dynamics of cichlidogryid monogeneans from the gills of three Tilapia spp. From Damietta Branch of the River Nile in Egypt. Proceedings of the Zoological Society of Arab Republic of Egypt, 12: 275-286.

- El-Sayed, F. A.; Okbah, M. A.; El-Syed, S. M.; Eissa M. A. and Goher M. E.** (2019). Nutrient salts and eutrophication assessment in Northern Delta lakes: Case study Burullus Lake, Egypt. *EJABF*, 23(2): 145–163.
- Glazier, D. S.** (2012). Temperature affects food-chain length and macroinvertebrate species richness in spring ecosystems. *Freshw. Sci.*, 31: 575–585.
- Hany, A.; Akl, F.; Hagra, M. and Balah, A.** (2022). Assessment of recent rehabilitation projects' impact on water quality improvement in Lake Burullus, Egypt. *Ain Shams Eng. J.*, (13): 101-492.
- Hirazawa, N.; Ryoko, T.; Hiroko, H.; Mitsuyo, N. and Minoru, N.** (2010). The influence of different water temperatures on *Neobenedenia girellae* (Monogenea) infection, parasite growth, egg production and emerging second generation on amberjack *Seriola dumerili* (Carangidae) and the histopathological effect of this parasite on fish skin. *Aquaculture*, 299(1-4): 2-7.
- Jaccard, P.** (1901). Distribution de la Flore Alpine Dans le Bassin des Dranses et Dans Quelques Regions Voisines. *Bulletin de la Société Vaudoise des Sciences Naturelles*, 37: 241-272.
- Lohmus, M. and Bjorklund, M.** (2015). Climate Change: What will it Do to Fish Parasite Interactions?. *Biol. J. Linn. Soc.*, 116(2): 397-411.
- Luo, Y. F. and Yang, T. B.** (2010). Seasonal population dynamics of the monogeneans *Pseudorhabdosynochus coioidesis* and *P. serrani* on wild versus cultured groupers in Daya Bay, South China Sea. *Helminthologia*, 47: 241–250.
- Lwimbo, Z. D.; Komakech, H. C. and Muzuka, A. N. N.** (2019). Impacts of emerging agricultural practices on groundwater quality in Kahe catchment, Tanzania. *Water*, 11(11): 2263.
- Marcogliese, D. J.** (2005). Parasites of the Superorganism: Are the Indicators of Ecosystem Health?. *Int. J. Parasitol.*, 35: 705–716.
- Mashaly, M. I., Allam, H. E., El-Naggar, M. M.** (2020). Impacts of physicochemical and heavy metal parameters on infestation level of the monogeneans, *Quadriacanthus* spp. infesting Nile catfish, *Clarias gariepinus* of different water localities in Nile Delta, Egypt *J Parasit Dis*, 44(3): 579–589.
- Matschiner, M.** (2019). Gondwanan vicariance or trans-Atlantic dispersal of cichlid fishes: a review of the molecular evidence. *Hydrobiologia*, 832: 9–37.
- Matschiner, M.; Böhne, A.; Ronco, F. and Salzburger, W.** (2020). The genomic timeline of cichlid fish diversification across continents. *Nat. Commun.*, 11(5895).
- Mohsen, A.; Elshemy, M. and Zeidan, B. A.** (2018). Change detection for Lake Burullus, Egypt using remote sensing and GIS approaches. *ESPR*, (25): 30763–30771.
- Möller, H.** (1987). Pollution and parasitism in the aquatic environment. *Int. J. Parasitol.*, 17: 353–361.

- Nartey, J. N.** (2024). Environmental History: Impact of Human Activity on the Planet. Centre for Sustainable Research and Advocacy (Censura, Ghana).
- Nouman, A. A. N.** (2024). Microecology and Survival of Monogenean Populations Nesting on Some Fishes in Degraded and Fragmented Aquatic Ecosystems of Nile Delta, North Egypt. PhD Thesis, Zoology Department, Faculty of Sciences, Mansoura University, Egypt.
- Ogidi, O. I. and Akpan, U. M.** (2022). Aquatic Biodiversity Loss: Impacts of Pollution and Anthropogenic Activities and Strategies for Conservation. In book: Biodiversity in Africa: Potentials, Threats and Conservation, pp.421-448.
- Ogundiran, M. A.; Fawole, O. O.; Adewoye, S. O. and Ayandiran, T. A.** (2009). Pathologic lesions in the gills of *Clarias gariepinus* exposed to sublethal concentrations of soap and detergent effluents. Anim. Biol., 3(5): 078-082.
- Ouellet, V.; St-Hilaire, A.; Dugdale, S. J.; Hannah, D. M.; Krause, S. and Proulx-Ouellet, S.** (2020). River temperature research and practice: Recent challenges and emerging opportunities for managing thermal habitat conditions in stream ecosystems. Sci. Total Environ., 736: 139679.
- Pereira, B. F. and Caetano, F. H.** (2009). Histochemical technique for the detection of chloride cells in fish. Micron, 40(8): 783-786.
- Poustie, A.; Yang, Y.; Verburg, P.; Pagilla, K. and Hanigan, D.** (2020). Reclaimed wastewater as a viable water source for agricultural irrigation: A review of food crop growth inhibition and promotion in the context of environmental change. Sci. Total Environ., 739: 139756.
- Rabago-Castro, J.; Sanchez-Martínez, J.G.; Loredó-Osti, J.; Gómez-Flores, R.; Tamez-Guerra, P. and Ramirez-Pfeiffer, C.** (2011). Temporal and spatial variations of ectoparasites on cage-reared channel catfish, *Ictalurus punctatus*, in Tamaulipas, Mexico. J. World Aquacult. Soc., 42: 406–411.
- Ribeiro, M.; Lourenço-Marques, C. C.; Baptista, T.; Pousao-Ferreira, P. and Soares, F.** (2025). First Report of *Calceostoma glandulosum* (Monogenea) in *Argyrosomus regius*: Morphological and Molecular Characterization and Temperature Effects on Life Cycle.
- Roohi, J. D.; Ghasemzadeh, K. and Amini, M.** (2016). Occurrence and Intensity of Parasites in Goldfish (*Carassius auratus* L.) from Guilan Province Fish Ponds, North Iran. Croat. J. Fish., 74(1): 20-24.
- Rubio-Godoy, M. and Tinsley, R. C.** (2008). Recruitment and effects of *Discocotyle sagittata* (Monogenea) infection on farmed trout. Aquaculture, 274(1): 15-23.
- Sereno-Urbe, A. L.; Zambrano, L. and Garcia-Varela, M. J.** (2012). Reproduction and Survival under Different Water Temperatures of *Gyrodactylus mexicanus* (Platyhelminthes: Monogenea), a Parasite of *Girardinichthys multiradiatus* in Central Mexico. Parasitology, 98(6): 1105-1108.

- Shah, H. B., Yousuf, A. R., Chishti, M. Z., Ahmad, F.** (2013). Seasonal changes in infrapopulations of *Diplozoon kashmirensis* Kaw, 1950 (Monogenea: Diplozoidae) along a eutrophic gradient. *Parasitol. Res.*, 112: 3347–3356.
- Sheta, B. M.** (2019). Biodiversity and habitat use of wintering and breeding waterbirds in Burullus Lake (Ramsar site), Egypt. *CATRINA*, 19(1): 47–54.
- Shimpei, W.; Osamu, K.; Kishio, H.; Hideo, I.; Kohichi, K. and Yuhsuke, W.** (2008). Proliferative bronchitis associated with pathognomonic, atypical gill epithelial cells in cultured *Plecoglossus altivelis*. *Fish Pathol.*, 43(2): 89-91.
- Sitja-Bobadilla, A.; Redondo, M. J. and Alvarez-Pellitero, P.** (2010). Occurrence of *Sparicotyle chrysophrii* (Monogenea: Polyopisthocotylea) in gilthead sea bream (*Sparus aurata* L.) from different mariculture systems in Spain. *Aquac. Res.*, 41(6): 939-944.
- Srivastav, A. L.** (2020). Chapter 6 - Chemical fertilizers and pesticides: role in groundwater contamination. *Agrochemicals Detection, Treatment and Remediation, Pesticides and Chemical Fertilizers*, pp. 143-159.
- Thatcher, V. E.** (2006). *Amazon Fish Parasites*, 2nd ed.; Pensoft Publishers: Sofia, Bulgaria.
- Tubbs, L. A. ; Poortenaar, C. W.; Sewell, M. A. and Diggles, B. K.** (2005). Effects of temperature on fecundity in vitro, egg hatching and reproductive development of *Benedenia seriola* and *Zeuxapta seriola* (Monogenea) parasitic on yellowtail kingfish *Seriola lalandi*. *Int. J. Parasitol.*, 35: 315–327.
- Varol, M. and Tokatli, C.** (2022). Evaluation of the water quality of a highly polluted stream with water quality indices and health risk assessment methods. *Chemosphere*, 137096.
- Wood, C. L.; Welicky, R. L. and Preisser, W. C.** (2023). A reconstruction of parasite burden reveals one century of climate-associated parasite decline. *NAS*, 120 (3): e2211903120.
- Younis, E. M.; Abuelkasem; S. S.; Mehanny, P. E. and El-Meadawy, S. A.** (2024). The Impacts of Climatic Change on Water Quality and Nile Tilapia (*Oreochromis niloticus*) in Burullus Lake, Egypt. *EJAH*, 4(1): 11-24.
- Zhang, J.; Gao, Y.; Yang, N.; Dai, E.; Yang, M.; Wang, Z. and Geng, Y.** (2020). Ecological risk and source analysis of soil heavy metals pollution in the river irrigation area from Baoji, China.