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Water Quality Assessment using Monogenean Gill Parasites of Fish in Kenyir Lake, Malaysia

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ABSTRACT

Parasitological studies on monogenean parasites was carried out on the gills of two fish species *Hampala macrolepidoti* (N = 292) and *Hemibagrus nemurus* (N = 292). The study was carried out in six different locations on Lake Kenyir (4°43’N to 5° 15’N and 102°30’E to 102°55’E) in Terengganu State, Malaysia between 2009 and 2011. In total six monogenean species were detected from the gills of the examined fishes, viz: *Dactylogyrus hampali*, *Dactylogyrus quadribrachiatus*, *Dactylogyrus macrolepidoti* from *Hampala macrolepidota* and *Cornudiscoides malayensis*, *Cornudiscoides sundanensis*, and *Bifurcohaptor baungi* from *Hemibagrus nemurus*. There was significant correlation ($P < 0.01$) between the prevalence of monogenean and some water quality (e. g. temperature and dissolved oxygen) parameters in all the fishes examined. Results also revealed highest prevalence rate (100 %) of monogeneans infection during the dry season – Non-Monsoon (March to July) and the lowest rate (57 %) during monsoon (November to February The positive correlation exists between the monogeneans infection and water quality variables in the two basic seasons of the country have led to the conclusion that ectoparasitic monogeneans are good biological tools in assessing the water quality in Lakes.

Key words: *Hampala macrolepidota,* Monogeneans, Bioindicator, Water quality

INTRODUCTION

Monogeneans, a group of helminths or flatworms are common ectoparasites of fish; they have a direct life cycle and considered to be a good bioindicators candidate as comparison to those having multiple life cycles (MacKenzie *et al*., 1995). Recognition of monogenean parasites as useful bioindicators of environmental pollution has captured the minds of several researchers (MacKenzie *et al*., 1995; Lafferty, 1997; Marcogliese and Cone 1997; Landsberg *et al*., 1998; Galli *et al*., 2001; Marcogliese, 2005; Sanchez-Ramirez *et al*., 2007; Bayoumy *et al*., 2008) because of their predictable numerical response to most of the water quality variables (Khan and Thulin, 1991). Their occurrence or abundance can describe the situation of the environment (Sanchez-Ramirez, 2007; Palm and Ruckert, 2009). Monogeneans tend to increase in number when subjected to low and medium pollutant concentrations, but decrease ordisappear at high concentration (Marcogliese *et al*., 1998). Increasing industrialization, agricultural modernization and enhancement of human distraction lead to rising levels of contaminants in our aquatic ecosystem. Therefore there is need for a permanent monitoring of the presence and effects of these pollutants. Conventional use of chemical analysis to find out environmental distress, which sometimes does not reflect the true concentration of most contaminants in aquatic systems, multiple bioindicators

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can provide evidence of chronic exposure of fish to sub-lethal levels (Khan, 2009). Bioindicators organisms are those species that reflect environmental impact because they respond to habitat alterations with changes in physiology or chemical composition (Vidal-Martinez *et al*., 2009). Moreover, bioindicators can be either accumulation or effect indicators (Sures, 2004).

However, several research has been done on fish parasites in relation to water variables in the marine environment (Poulin, 1992; Landsberg *et al*., 1998; Sures *et al.*, 1999; MacKenzie, 1999; Sures, 2004; Marcogliese, 2005; Vidal-Martinez *ea al*, 2009; Bayoumy *et al*., 2008) but, little or less attention was paid in the freshwater ecosystem, especially in this part of Peninsular Malaysia (Prof. Faizah, Pers. Comm). In this study, the comparison made between parasites and water quality variable references to their level of monogenean infestation on two different fish species can go a long way to provide some useful information in understanding the early warning in the lake. However, the question now is how these parasites will indicate any changes of the water quality parameters of the lake? Are there any significant changes of the monogenean prevalence and mean intensity between the seasons and the sampling locations? The current study expects to provide information on these issues.

The objective of this study is to establish the relationship between seasonal of monogenean parasites infection and water quality parameters in the Kenyir Lake.

MATERIALS AND METHODS

Study area

Lake Kenyir, the largest man-made lake in Southeast Asia, was impounded in 1985 for the purpose of hydroelectric generation. The lake is situated between coordinate 4°43'N to 5° 15'N and 102°30'E to 102°55'E in Terengganu on the east coast of Peninsula Malaysia (Rouf, 2010). The lake has an area of 36,900 ha with a maximum depth of 145m and an average depth of 37m. The lake had more than 340 Islands scattered within the Lake. The main source of the lake is originated from two Sungai viz: Sungai Terengganu and Terengan Sungai (Furtado *et al.,* 1997). Among the two, Sungai Terengganu is the largest, with draining area of 458,000 ha (35% of the State land area) which flow south and south-east to join the other Sungai and finally turned east to joins the sea at Terengganu, the State capital (Yusoff *et al*., 1995). Moreso, some tributaries also drain into the lake viz: Sungai Lawit, Sungai Ketiar, Sungai Lasir, Sungai Petang, Sungai Lepar, Sungai Genong, Sungai Pertang, Sungai Cacing, and Sungai Terengganu (FFRC, 1995). The nature and structure of the lake is irregular and dendrite in shape. Under the present study, six different locations were surveyed and each station was visited at least twice (Fig. 1). These sites were Station I Sungai Tembat (5° 12" 48.88' N 102° 40' 33.14" E), II *Sungai Kiang* (5° 07' 09.17" N 102° 44' 42.63" E), III *Sungai Ketiar* (5° 04' 49.85" N 102° 34' 25.38" E), IV *Petang Island* Sungai (4° 59' 30.76" N 102° 47' 16.49" E), V Tanjung Mentong Sungai (4° 53' 48. 32" N 102° 44' 06.45" E) and VI Sungai Cacing (4° 49' 41.11" N 102° 46' 04.59" E).

Fish and Parasites collection

Fish hosts (*Hampala macrolepidota* N = 292) ranging in weight between 50 and 600 g and total length 15-38 cm and (*Hemibagrus nemurus* N = 292) size range between 150 and 650 g and body length 18-48 cm (total length) were collected from the six sampling locations.

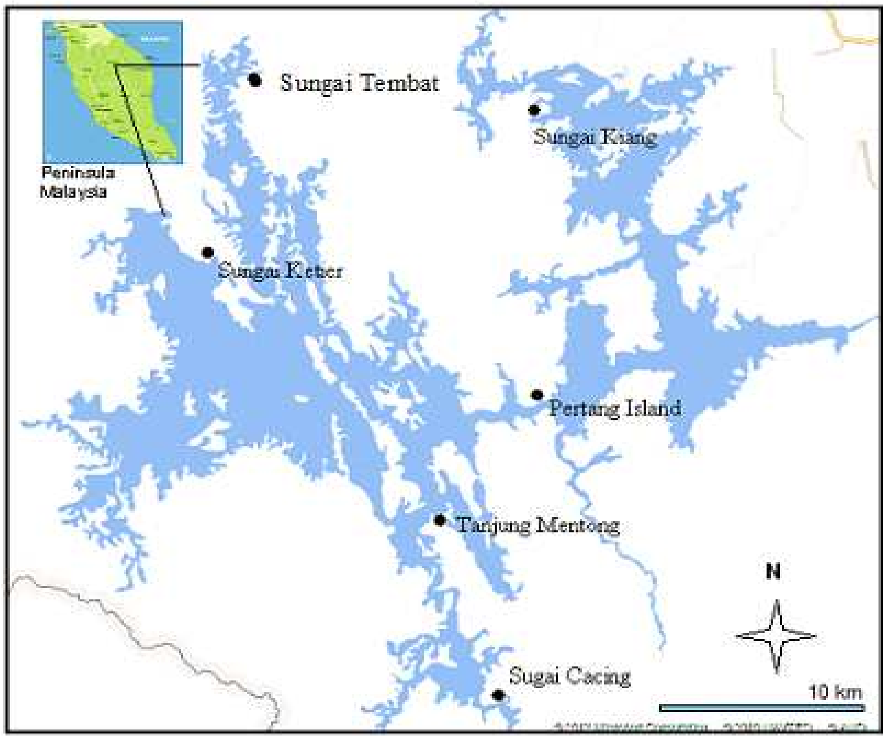

Figure: 1. Map of Kenyir Lake showing the six sampling locations in this work (Source: Google Earth).

Fish were caught with gill net (2.5-6.5 cm mesh). Fish were identified according to Moshin and Ambak (1983) while parasites isolation was followed procedure using the explained by Berland, (2005). The investigation was carried out between November 2009 and July 2011.

Fish were killed (by pithing) and monogeneans found on the gills were removed by sucking out with fine modified glass pipette (Berland, 2005). Worms were then placed on a clean glass slide containing a drop of water and cover-slip was placed on top. Four corners of the cover-slips were glued with nail vanish (Řehulková and Gelnar, 2006) later ammonium-picrate-glycerine or alcohol-formalin-acetic acid were added to the edge of the cover slip to fix and clear the monogenean for further study. Parasites were identified based on their haptor (hamuli, connective bars, and hooklets) and reproductive organs (copulatory organ and vaginal armament) according to (Gusev, 1985).

Water sampling and water quality analysis

Water samples were collected monthly from all the sites at a depth of 3 metres from the Lake with the aid of the Niskin water sampler. Water samples collected were placed into a bottle (500ml) and acidified (H_2SO_4) to stop microbial activities before further analysis. Samples were then placed in a cool box containing ice. Physical parameters (Dissolved oxygen, pH, water transparency and temperature) of waters were determined onsite using YSI meter (Model 556), while chemical parameters such as ammonia (TAN), un-ionized ammonia, nitrite, and alkalinity were from water sampled collected from the lake following the procedures laid out in APHA, (1985), Kislaya, (2007) and Khanna and Bhutaina, (2008). Frozen water samples collected from the lake were defrosted at room temperature in a water sink in the laboratory by running tap water upon the bottles. Immediately samples were then de-acidified with 4% sodium hydroxide (NaOH) solution to neutralize with careful adjustment of the pH to neutral.

Data analysis

Following Bush *et al*. (1997) and Rózsa *et al*. (2000) parasitological terms such as prevalence (P) and mean intensity (MI) of monogenean infections was calculated for both fish species. Where the prevalence (P) = Number of infected fish in a population/Total number of fish examined x 100, Mean intensity (MI) = Total number of parasite species of host/Number of infected hosts. The data were subjected to Pearson correlation using SPSS statistical software, version 16 to evaluate between the environmental factors and parasites prevalence. In Malaysia, two basic climates have been identified: Monsoon (September – February) and Non-monsoon (March – August) Rouf (2010). These climatic conditions are used to correlate the parasites prevalence in respect to the water quality parameters of the lake.

RESULTS

Parasitological examination

Six monogenean species were detected from the gills of the examined fishes. They were: *Dactylogyrus hampali* (DH), *Dactylogyrus quadribrachiatus* (DQ) *and Dactylogyrus macrolepidoti* (DM) in the gills of *Hampala macrolepidota*; *Cornudiscoides malayensis* (CM), *Cornudiscoides sundanensis* (CS) and *Bifurcohaptor baungi* (BB) from *Hemibagrus nemurus*. The prevalence and mean intensity of the six different monogenean species in two host fishes from the six different locations have been depicted in Table 1 and Table 2 respectively. It is clear that prevalence of monogeneans infection changes with water quality changes and incidence of infection reflects with seasona in both fishes; higher during the non-monsoon (March – July) and lower during November. –February which is monsoon (table 3).

Table1: The prevalence of monogenean species recorded from two fish species at six locations in Kenyir Lake for the period of November, 2009 – July, 2011(N = 19 fish/month)

Locations	Date	Fish Species					
		H. macrolepidota (N = 292)			*H. nemurus* (N = 292)		
		Monogenean species					
		DH	DM	DQ	CM	CS	BB
STB[1]	Nov. 09	45	50	39	42	33	0
STB[2]	Nov. 10	45	55	35	75	50	0
STB[3]	Apr. 11	53	66	53	87	87	0
SKG[1]	Jan. 10	42	57	57	44	44	0
SKG[2]	Jun. 10	93	87	87	80	73	0
SKG[3]	Dec.10	45	45	40	55	45	0
SKG[4]	Jan. 11	47	53	46	53	60	0
SKG[5]	May.11	87	93	73	80	87	0
SKG[6]	Jun. 11	70	80	60	80	87	0
PIL[1]	Feb. 10	47	53	40	67	53	0
PIL[2]	Jul. 10	82	88	71	88	82	0
SKT[1]	Mar. 10	67	73	67	80	73	60
SKT[2]	May.10	100	100	100	93	86	86
SKT[3]	Feb. 11	53	60	47	57	48	0
SMT[1]	Apr. 10	73	80	67	87	80	0
SMT[2]	Mar. 11	65	74	74	77	86	0
SCC[1]	Oct. 10	69	69	69	75	81	0
SCC[2]	Jul. 11	85	95	75	86	93	0

Abbreviations of Locations**:** STB = Sungai Tembat; SKG = Sungai Kiang; PIL = Sungai Pertang Island; SKT = Sungai Ketiar; SMT = Sungai Tanjung Mentong; SCC = Sungai Cacing.,Monogenean species: DH = *Dactylogyrus hampali*, DM = *Dactylogyrus macrolepidota,* DQ = *Dactylogyrus quadribrachiatus,* CM = *Cornudiscoides malayensis,* CS = *Cornudiscoides sundanensis,* BB = *Bifurcohaptor baungi***, Numbers in superscript indicate frequencies of visit to sampling locations**.

Table 2: Mean intensity [MI (mean ± SD)] of monogenean species recorded on two fish species at six locations in Kenyir Lake for the period of November 2009 – July 2011.

		Fish Species					
		H. macrolepidota **(N = 292)**		***H. nemurus*** **(N = 292)**			
	Monogenean Sp	**DH**	**DM**	**DQ**	**CM**	**CS**	**BB**
Locations	Date						
STB[1]	Nov. 09	7.5 ± 2.449	18.7±5.574	10 ± 3.437	14 ± 2.739	13 ± 2.986	0
STB[2]	Nov. 10	16 ± 4.604	24 ± 8.192	16 ± 5.707	21 ± 7.093	28 ± 6.538	0
STB[3]	Apr. 11	11 ± 0.518	12 ± 2.319	11 ± 1.685	19 ± 6.875	16 ± 7.005	0
SKG[1]	Jan. 10	3 ± 0.983	10± 6.0850	4 ± 2.682	25 ± 4.077	20 ± 4.967	0
SKG[2]	Jun. 10	9 ± 3.388	17 ± 4.746	5 ± 2.619	19 ± 4.440	17 ± 7.933	0
SKG[3]	Dec.10	15 ± 2.976	28 ± 3.708	15 ± 2.507	23 ± 5.515	24 ± 5.869	0
SKG[4]	Jan. 11	14 ± 4.572	29 ± 4.334	14 ± 4.786	31 ± 7.797	30 ± 7.390	0
SKG[5]	May.11	7± 2.926	12 ± 4.055	7 ± 2.809	13 ± 5.641	10 ± 6.249	0
SKG[6]	Jun. 11	9 ± 6.425	12 ± 8.513	9 ± 5.354	22 ± 7.829	15 ± 6.062	0
PIL[1]	Feb. 10	9 ± 3.035	21 ± 6.164	17 ± 3.564	25 ± 7.975	26 ± 7.416	0
PIL[2]	Jul. 10	12 ± 5.121	27 ± 9.025	9 ± 2.803	20 ± 8.656	19 ± 8.914	0
SKT[1]	Mar. 10	5 ± 2.300	14 ± 7.244	8 ± 4.606	18 ± 7.512	17 ± 4.880	2 ± 1.054
SKT[2]	May.10	20 ± 4.139	28 ± 7.230	6 ± 3.160	23±4.39	17 ± 5.864	4 ± 2.021
SKT[3]	Feb. 11	25 ± 5.273	22± 10.039	18 ± 1.496	29 ± 4.207	31 ± 5.037	0
SMT[1]	Apr. 10	9 ± 3.003	20 ± 9.727	10 ± 6.877	25 ± 8.321	22 ± 9.582	0
SMT[2]	Mar. 11	9 ± 2.208	13 ± 5.263	8 ± 3.962	9 ± 5.522	7 ± 3.763	0
SCC[1]	Oct. 10	8 ± 3.075	14 ± 4.990	7 ± 2.908	12 ± 5.401	9 ± 4.369	0
SCC[2]	Jul. 11	5 ± 2.529	8 ± 2.813	6 ± 2.865	14 ± 8.146	8 ± 6.340	0

Abbreviation of Locations: STB = Sungai Tembat; SKG = Sungai Kiang; PIL = Sungai Pertang Island; SKT = Sungai Ketiar; SMT = Sungai Tanjung Mentong; SCC = Sungai Cacing. Numbers in superscript indicate frequencies of visit to sample locations. **Monogenean species**: DH = *Dactylogyrus hampali*, DM = *D. macrolepidota,* DQ = *D. quadribrachiatus,* CM = *Cornudiscoides malayensis,* CS = *C. sundanensis,* BB = *Bifurcohaptor baungi*

Table 4 showed the correlation matrix between monogenean prevalence and water quality variables of the six study locations. At all locations, significant correlations were observed between water temperature and monogenean prevalence ($p < 0.05$). In the lake, a negative significance was observed between dissolved oxygen and *Dactylogyrus macrolepidoti, Cornudiscoides malayensis* and *Cornudiscoides sundanensis* ($p < 0.05$). A strong negative significance was also detected between the prevalence of *D. macrolepidoti,* and TAN in the lake. Influence of water transparency was highly significant ($p < 0.05$) in all cases of monogenean prevalence. NO_3N was highly significant ($p < 0.05$) with *Cornudiscoides malayensis* and *Cornudiscoides sundanensis*.

Table 3: Physco-chemical parameters measured at six locations in Kenyir Lake for Monsoon and Non-monsoon seasons

Seasons	Locations	Date	T (O^C)	pH	DO	TAN.	NO_2-N	NH_3-N	ALK.	TRSP.	NO_3-N
Monsoon	STB[1]	Nov. 09	25.6	7.3	6.8	0.716	0.049	0.021	80	1.1	0.2
	STB[2]	Nov. 10	29.3	6.9	7.7	0.15	0.064	0.002	29	1.2	0.3
	SKG[3]	Dec.10	28.8	6.9	7.6	0.004	0.004	0	23	1.4	0.2
	SKG[1]	Jan. 10	26.9	6.7	7.4	0.007	0.003	0.001	38	1.4	0.3
	PIL[1]	Feb. 10	29.3	7.4	7.4	0.193	0.011	0.012	49	1.8	0.4
	SKG[4]	Jan. 11	27.3	6.2	8.2	0.056	0.022	0.002	107	1.6	0.3
	SKT[3]	Feb. 11	27.7	6.7	7	0.492	0.002	0.002	63	1.8	0.5
Mean	**--**	**--**	**27.9**	**6.9**	**7.4**	**0.231**	**0.022**	**0.005**	**55.477**	**1.471**	**0.3**
± SD	**--**	**--**	**1.384**	**0.514**	**0.461**	**0.272**	**0.025**	**0.007**	**30.228**	**0.275**	**0.107**
Non Monsoon	SKT[1]	Mar. 10	28.7	6.7	6.9	0.073	0.007	0	48	2	0.6
	SMT[1]	Apr. 10	32.8	7.3	6.1	0.748	0.002	0.024	114	2.1	0.5
	SKT[2]	May.10	31.9	6.9	7.2	0.1	0.028	0.001	80	2.3	0.4
	SKG[2]	Jun. 10	29.9	7.4	7.2	0.021	0	0	117	3.6	0.3
	PIL[2]	Jul. 10	31.5	7.8	6.6	0.032	0.003	0.032	329	3.2	0.4
	SCC[1]	Oct. 10	31.7	6.4	7.9	0.005	0.004	0	23	2.6	0.5
	SMT[2]	Mar. 11	27.5	7.3	6.8	0.767	0.002	0.002	58	1.4	0.3
	STB[3]	Apr. 11	29.3	7.0	5.9	0.008	0.001	0.001	73	1.3	0.4
	SKG[5]	May.11	31.5	7.4	5	0.059	0.006	0.002	261	2	0.3
	SKG[6]	Jun. 11	31.1	7.4	5.1	0.046	0.026	0.001	81	3.7	0.5
	SCC[2]	Jul. 11	25.9	7.7	3.8	0.074	0.023	0.002	108	3.4	0.4
Mean	**--**	**--**	**30.1**	**7.2**	**6.2**	**0.176**	**0.009**	**0.005**	**117**	**2.5**	**0.4**
± SD	**--**	**--**	**2.122**	**0.379**	**1.200**	**0.289**	**0.010**	**0.011**	**93.583**	**0.854**	**0.098**

eys: Locations: STB = Sungai Tembat, SKG = Sungai Kiang, PIL = Petang Island, SKT = Sungai Ketiar, SMT = Sungai Tanjung Mentong, SCC = Sungai Cacing. **Numbers** in superscript indicate frequencies of visit to sampling locations. **Parameters:** Air temp = Air Temperature, W/temp = Water Temperature, TAN = Total Ammonia-Nitrogen, NO_2-N = Nitrite-nitrogen, ALK = Alkalinity, TRSP = Transparency, NO_3-N = Nitrate. Measurement units: with the exceptions of pH, Alkalinity (CaCO3 mg/L), and Water Transparency (m) all units are in mg/L, DO = Dissolved oxygen, pH = Hydrogen ion concentrations.

Table: 4. Pearson correlation matrix between the prevalence of six monogenean species on the gills of two fish species with water quality variables in Kenyir Lake.

Monogenean species						
Parameters	**DH**	**DM**	**DQ**	**CM**	**CS**	**BB**
$T^{O}C$	0.527*	0.700**	0.472*	0.657**	0.552*	0.977**
pH	0.195	0.367	0.184	0.309	0.274	0.301
DO (mg/L)	-0.323	-0.541*	-0.342	-0.477*	-0.636**	-0.301
TAN (mg/L)	-0.151	-0.980*	-0.209	-0.155	-0.135	-0.409
NO_2-N (mg/L)	-0.223	-0.219	-0.297	-0.189	-0.356	-0.038
NH_3-N (mg/L)	0.550	0.058	0.177	0.010	-0.015	-0.248
ALK. (mg/L $CaCO_3$)	0.530*	0.511*	0.344	0.384	0.458	-0.302
TRANSP. (m)	0.700**	0.669**	0.644**	0.531*	0.637**	0.0.171
NO_3-N (mg/L)	0.243	0.258	0.317	0.500*	0.610*	-0.760

***Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 (2-tailed).**

Abbreviations: Monogenean species, DH= *Dactylogyrus hampali*, DM= *Dactylogyrus macrolepidota*, CM= *Cornudiscoides malayensis*, CS= *Cornudiscoides sundanensis*, BB= *Bifurcohaptor baungi*

Parameters: Temp. = Water Temperature, DO= Dissolved oxygen, TAN= Total Ammonia-Nitrogen, NO_2-N = Nitrite, NH_3-N= Un-ionized ammonia, ALK= Total Alkalinity, Transp. = Water transparency, NO_3-N = Nitrate.

DISCUSSION

The results indicated that there were significant differences between the monogenean prevalence and the water quality parameters in the fish gills in respect to the seasons. The highest prevalence recorded during the non-monsoon season were at SKT (May 2010) and SMT (April 2010) in all the species of monogenean parasites. This could be attributed to the higher water quality variable of the lake water principally temperature. However, in the monsoon time, the lake water was constantly diluted by rain and all the flowing tributaries (Sungai) are emptying their contents with lots of debris and other impurities to the lake (Rouf 2010). These conditions can however adversely affect the monogeneans by reducing their occurrence especially the free-swimming delicate oncomiracidium in finding a relevant host for attachment. In terms of prevalence (P), *D. macrolepidoti* on *H. macrolepidota* ($p = > 80\%$) and *C. malayensis* ($p = \geq 75\%$) on *H. nemurus* are the most ecologically invasive, occurring at all six locations with higher prevalence. *B. baungi* parasitizing *H. nemurus* were observed only at SKT with low prevalence (<40%). The prevalence and intensity of these monogenean parasites are governed by the seasons of the year and water quality variables.

In this study, water chemistry observed in all the six locations were not varied significantly between the locations with some few exceptions ($p > 0.05$). However, some locations such as SKT and SMT have vegetation cover and are shallow in some parts, these characteristics might induce other water quality parameters to fluctuate suddenly (Koskivaara, 1992). Temperature is one of the most important abiotic factors of the aquatic ecosystem (Hirazawa *et al.*, 2010). All aquatic organisms depend very much on water temperature for their physiological processes. A rise in water temperature accelerates chemical reaction, reduces the solubility of gases, amplifies taste and odour, and elevates the metabolic activity of organisms (Chandrasekhar, 2006). Differences of monogenean prevalence in the present study can be explained by differences in the water temperatures (Modu *et al.*, 2012). Water temperature in the present study significantly correlates with monogenean prevalence in all studied locations. Water temperature according to Koskivaara et al., (1991) and Šimkova *et al*., 2001) is recognized as an important factor controlling the occurrence of monogeneans but different species appear to react in different ways (Koskivaara, 1992). However, it is evident from other field studies (Chubb 1977; Koskivaara *et al.*,1991) that temperature is not the only factor influencing the proliferation of monogenean biomass, other abiotic factors such as pH, dissolved oxygen, ammonia and biotic (fish spawning) might mask the effect of temperature (Rakauskas and Blaevièius, 2010). In this study, highly positive significant correlations were noticed between temperature and the prevalence in all species of the monogeneans.

Dissolve oxygen (DO) in water bodies is one of most important abiotic factors to be considered after temperature. Low DO content in a given aquatic media can jeopardize the life of inhabitants dwelling in it (Molnar, 1994). In the lake where fluctuation in water parameters is obvious, the dissolved oxygen concentrations was relatively low during non-monsoon period and tend to increase towards monsoon time due to continuous mixture and turbulence between air-water interface (Modu *et al.*, 2012). This finding agrees with similar research conducted by Rouf, (2010) in the same lake who found lower concentration of DO in the hot – dry period (non-monsoon) and higher level during rainy season (monsoon). In most sampling sites, concentrations of DO were within the safety value for freshwater fishes in the tropics (admissible values of DO 4.5- 8.5 mg/l) (Boyd, 1982; Molnar, 1994; Chapman, *et al*., 2000). The relatively higher DO concentration in the lake reflects that little or less domestic wastes are entering the lake. Low DO during the dry season (May - July) may be due to rising level of water temperature and probable water evapotranspiration during the day time. This however, will compromise fish immune systems Paperna (1996) and conversely increase the rate of infection. In general, parasites intensities become high on fishes under stress as transmission rates are enhanced when natural immunity is suppressed or low (Landsberg *et al.*, 1998). However, that the seasonal prevalence of *Dactylogyrids* is sometimes more influenced by other abiotic and biotic factors than by temperature; e.g. *D. solidus* is very sensitive to oxygen depletion; in a low DO condition the parasite moves towards the end of the gill filaments and returns to its normal dwelling position when DO improves (Bauer *et al*., 1973).

Unlike oceanic water, where pH is maintain within a narrow range from 8.0 to 8.3 (Hill, 2005) the pH of freshwater ecosystems fluctuate most often and with wide ranges and is governed by several factors such as carbon dioxide (CO_2) concentrations, phytoplankton density and total alkalinity. (Wurts and Durborow, 1992). In the present study, the fluctuation in water pH was dependent on seasonality; pH was observed lowest during monsoon period (November – February.) the highest values were recorded in non-monsoon time (March – July). This showed that the lake was slightly acidic in monsoon period and remains alkaline for the rest of the year. This fluctuation pattern showed some evidence of lower monogenean prevalence in monsoon and higher in dry season.

The nutrient variables measured in this study were quite low in all the locations. TAN recorded was within safe values for tropical fish (< 1 mg/l). The maximum admissible TAN concentration for cyprinids and other related species in freshwater is 0.05 mg/l (Svobodova, *et al*., 1993). Nitrite-nitrogen measured all the tributaries was low, however, the highest value was observed at STB, this site accommodates most of the annual tourist and thus, fishing and other festivity occurred, in return there is an increased nutrient loading by discharge of uneaten food and other materials into the lake. A similar situation was recorded in central Finland Lake receiving effluents from a pulp and paper mill, where a high prevalence and more species diversity of *Dactylogyrus species* were found in the gills of roach, *Rutilus rutilus* due to eutrophication (Koskivaara and Valtonen, 1992).

Finally, the results of this study indicated that there was a strong correlation between monogeneans prevalence and water temperature of the lake ($p < 0.05$). A significant increase or decrease in the abundance of monogeneans observed from the six tributaries of the lake at different seasons also showed evidence that the monogeneans are useful tools in environmental quality assessment. The study further showed that seasonality had a remarkable influence in monogenean life cycle because seasonal fluctuation in certain factors such as water temperature and dissolved oxygen can enhance their proliferation.

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