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Interaction of the mormyrid fish *Mormyrus kannume* (Forsskål, 1775) reproduction and feeding intensity with the environment in a Nile Delta Canal, Egypt

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ABSTRACT

The effect of environmental factors on the fish biological parameters and their quantification was investigated in this study during the period from January 2005 to January 2006. Bahr Shebeen Canal is a Nile canal that represents a fishery resource in the Delta of Egypt, where *Mormyrus kannume* shows a scanty abundance. During the period from of June to September, there was a chance to examine such interaction. The obtained results revealed that the fish spawn over an extended period, from November till May, with two main peaks of spawning activity namely: November-December and February-April. Consequently, the gonadosomatic index (GSI) could not be correlated significantly with variation in either temperature or photoperiod. In those periods of spawning activity, the fish showed the lowest feeding intensity; i.e., low abundance. This was also quantified mathematically by significant correlations between the seasonal average (excluding winter) of stomachsomatic index (SSI) and either average daily temperature (T) and photoperiod (PP) for females and to a lower extent with males. These relationships were negatively correlated, and more significant among females than males, that was attributed to a higher activity of feeding among females. Also, the fish reproduction and feeding activities were correlated significantly with electrical conductivity and rainfall. This indicated that the fish are subject to the effect of associated environmental parameters interacting with their biology. The susceptibility of this fish species to change in those variables indicates its vulnerability to any adverse climatic change.

The relationship between each of fecundity, egg diameter and gonadosomatic index and the female length or age were also examined and discussed, and the mathematical correlations were presented.

Keywords: *Mormyrus kannume*, environmental effects, reproduction, feeding, ecology, aquatic biology.

INTRODUCTION

As fish represent a very diverse group, different fish species live in highly diverse environments (Volkoff *et al.*, 2009) and experience natural variation in environmental conditions across spatial and temporal scales, but the speed and severity of these changes have recently increased (van der Sluijs *et al.*, 2011). The earth's atmosphere has warmed significantly over the last 50 years, and most of that warming is believed to have been caused by increased levels of carbon dioxide (CO_2) and other heat-trapping gases (Albritton *et al.*, 2001; Cicerone *et al.*, 2001, O'Neal, 2002). This warming could in turn raise the temperature of water in streams, thus altering the habitat of freshwater fish (Meisner *et al.*, 1988; Stefan and Preud'homme, 1993; O'Neal, 2002).

Most fishes are exposed to variations in a wide range of factors, including not only internal factors, such as nutritional/metabolic status and reproductive events but also environmental factors, such as temperature and photoperiod (Volkoff *et al.*, 2009; 2010). Other factors such as water quality are also known to play a major role.

Temperature and photoperiod are two most important factors that influence growth, development and reproduction of aquatic species, including teleost fish (Jin *et al.*, 2010).

Reproduction in fish is rhythmic and timed to guarantee the maximum survival of the offspring. Environmental cues, such as photoperiod and temperature cycles, synchronize the internal timing system that controls breeding (Bromage *et al.*, 2001; Wilkinson *et al.*, 2010; Oliveira *et al.*, 2011). Water temperature does appear to have a more important role in the control of final gamete maturation, ovulation and spawning (Pankhurst *et al.*, 1996). It has a very marked effect on the physiological and biochemical processes in fish, and a raised temperature regime has complex effects on fish reproductive, nerve and endocrine systems (Lukšienė and Svedäng, 1997). Cyclical reproduction of many sub-tropical and tropical fish species are cued by photoperiod and/or temperature (De Vlaming, 1972; Baggerman, 1980; Breton *et al.*, 1980a, 1980b; Billard, 1982; Bromage *et al.*, 2001; Kirschbaum and Schugardt, 2002; Rad *et al.*, 2006). More recently, Taylor *et al.* (2008) identified important relationships between photoperiod, temperature, growth, maturation and a key hormone involved in the coordination of growth (insulin-like growth factor-I [IGF-I]) in rainbow trout (*Oncorhynchus mykiss*).

Changes in feeding behavior can be due not only to variations in intrinsic factors such as nutritional/metabolic or reproductive status, but also to changes in environmental factors, such as temperature and photoperiod (Volkoff *et al.*, 2010). Water temperature and photoperiod have potent influences on feed consumption, metabolic rate and energy expenditure, and thus on growth of poikilothermic vertebrates, including fish (Brett, 1979; Elliott, 1982; Dutta, 1994; Bhikajee and Gobin, 1998; Buentello *et al.*, 2000). Photoperiod acts as a synchronizer, regulating the daily endogenous rhythms in fish (Duston and Saunders, 1990; Biswas *et al.*, 2002), fish growth, locomotor activity, metabolic rates, body pigmentation (Gross *et al.*, 1995; Silva-Garcia, 1996; Boeuf and Le Bail, 1999; Biswas and Takeuchi, 2002; Biswas *et al.*, 2002; Trippel and Neil, 2002; El-Sayed and Kawanna, 2004) and is generally accepted as the most important factor synchronizing sexual maturation and reproduction in fish (Bromage *et al.*, 2001; Biswas *et al.*, 2005a).

In the wild, one must note the importance of the synergistic effects of temperature and photoperiod: generally these two factors change concomitantly (Boeuf and Le Bail, 1999). Therefore, the effects of these environmental factors on fish reproduction and feeding warrant thorough investigation.

Mormyrid fishes are considered to be bio-indicators (Hay *et al.*, 1996; Hugueny *et al.*, 1996) as they are among those fishes that react first to environmental changes (Kouamélan *et al.*, 1999). The ability of this family of freshwater fishes as potential rapid indicators of water quality fluctuations has already been studied and indicates enhanced sensitivity when compared with other fish systems (Lewis *et al.* 1992a, 1992b, 1993, 1994, 1995). So, the mormyrid species *Mormyrus kannume* was chosen to carry out this study in order to assess the effects of environmental variables on reproduction and food intensity of freshwater fishes.

The mormyrid species *Mormyrus kannume* (Elephant-snout fish) (Fig. 1a) has a wide distribution in Africa, found in Uganda, Nigeria, Blue Nile and Lake Victoria, and other African lakes and rivers (Hugh Copley, 1958; Scott, 1974; Bishai and

Khalil, 1997; Khallaf and Authman, 2010). It was reported to be distributed in the River Nile and Lake Nasser, and it was described as a common species but gradually decreasing (El-Etreby, 1985; Bishai and Khalil, 1997). This fish is commonly caught in rapidly flowing water of the River Nile mainly by trammel nets (Latif, 1974). *M. kannume* spends the day on the bottom, but after nightfall it becomes very active, searching for food, i.e. nocturnal, associated with rocks (Bishai and Khalil, 1997; Khallaf and Authman, 2010). It possesses electric organs lying on either side of the terminal portion of the tail (Hugh Copley, 1958; Webb *et al.*, 1981) and well grown fish can give quite an electrical shock (Boulenger 1907; Bishai and Khalil, 1997). This organ produces an often species-specific discharge for electro-location and communication (Hopkins, 1981). From a reproductive perspective, this fish spawns over rocks, emerging from the mud in deep water (Hugh Copley, 1958; Khallaf and Authman, 2010). *M. kannume* is a rare species in the commercial catch from Bahr Shebeen Nile Canal (BSC).

BSC (Fig. 1b), is an important irrigation water and fishery resource, running about 80 km throughout three governorates in the Egyptian Delta. It is a semi-independent water ecosystem from the Nile but connected to it by a major canal (Alrayah Almenoufi) near the Barrage (14 kms north to Cairo), its depth ranges between 2 to 3 m, and its width is about 30 m (Khallaf, 2002; Khallaf and Authman, 2010).

Previous studies on the reproduction and food of *M. kannume* are scarce, but mainly restricted to the reproductive cycle of the fish (Scott, 1974; El-Etreby, 1985, 1986; Ashour *et al.*, 1990a,b; Zaher *et al.*, 1991; Fawole, 2002; Authman and Khallaf, 2009; Khallaf and Authman, 2009) and stomach contents analysis (Aly, 1993; Soliman, 1994; Hassan, 2007). However, fewer studies dealt with the effect of environmental factors on the fish biology in the Nile system (e.g., Gosse, 1984; Khallaf and Alne-na-ei, 1987, 1993; Khallaf *et al.*, 2003).

Most of the previous studies of the effects of environmental factors on fishes; especially weakly electric fish; were obtained from laboratory investigations (Kirschbaum, 1987; Huber and Bengtson, 1999; Kouamélan *et al.*, 1999; Buentello *et al.*, 2000; Bolliet *et al.*, 2001; Kirschbaum and Schugardt, 2002; El-Sayed and Kawanna, 2004; Schugardt and Kirschbaum, 2004; Biswas *et al.*, 2005a,b; Rad *et al.*, 2006; Taylor *et al.*, 2006; Ballagh *et al.*, 2008; Volkoff *et al.*, 2009, 2010; Jin *et al.*, 2010; Wilkinson *et al.*, 2010; Oliveira *et al.*, 2011). Field investigations of these effects on fish are sparsely.

In Bahr Shebeen canal, *M. kannume* shows rarity in the commercial catch of this canal most of the year months, but abundant only during June to September, every year, that represents a riddle needing to be solved. Therefore, this study is carried out to examine:

1. The possible reasons of that variation, by investigating the fish reproductive characteristics and feeding intensity interaction with the daily photoperiod and temperature.
2. Quantifying the relationship of the biological parameters with the variation of some environmental factors.
3. Are mormyrids susceptible to the effect of climatic change?

MATERIAL AND METHODS

(1) Samples collection

M. kannume specimens were caught monthly by fishermen, using commercial fishing gears (trammel nets) during the day, between 6 am to 2 pm, at various localities within 25 km of BSC during consecutive months between January 2005 and January 2006. The fish were transposed back after catching to the laboratory for dissection. In the laboratory, for each fish, the date of capture, total and standard lengths (to the nearest mm), and total weight (to the nearest mg) were recorded. Fish were dissected out to determine sex and maturity stages. Fish gonads and stomachs were carefully removed, weighed to the nearest mg and preserved in either Bouin's fluid or 10% formalin solution for further analysis of reproduction characteristics and in order to preserve the stomach contents for a separate study. In the present study, a total of 134 males ranging from 15.9 to 57.9 cm in total length and from 31.10 to 1613.00 g in weight, and a total of 116 females ranging from 15.50 to 52.80 cm in total length and from 29.80 to 1255.00 g in weight, were collected.

(2) Reproduction Characteristics

A- Maturity stages

This fish species has only one left ovary or testes in the dorsal side of the abdominal cavity, while the second right one is greatly reduced in size. Six maturity stages of ovary and testes were identified and distinguished according to Authman and Khallaf (2009) and Khallaf and Authman (2009) as follows:

Stage I (Immature): Gonads are very small. Ovary is translucent, triangular-shaped and the small sized eggs cannot be distinguished by the naked eye. Testis is very small, thin, narrow thread-like with no sign of development, flattened and transparent.

Stage II (Maturing): Gonads are still small and occupy 1/3 of the body cavity. Ovary is opaque and yellowish or cream-yellow in colour; no oocytes are visible through the ovary wall. Testis is slightly thickened with developing white colour.

Stage III (Nearly-ripe or developing): Gonads begin to develop and occupy 50-60 % of the abdominal cavity. Ovary is yellow in colour and the tiny oocytes are visible through the ovary wall by the naked eye. Testis is broader, thicker, more soft and becomes whitish in colour.

Stage IV (Ripe or highly developing, Pre-spawning): Gonads nearly occupy the entire length of the body cavity. Ovary appears swollen, whitish-creamy or pale yellow in colour and well developed oocytes are visible through the ovary wall. Testis shows maximum development in thickness and width, whitish or creamy in colour and milt extrudes by pressure on the belly.

Stage V (Spawning): Ovary becomes broader, completely turgid, firm and granular. Large translucent, yellow and sticky oocytes are visible through the ovary wall and the eggs can be released with a slight abdominal pressure. Testis is flat and of whitish-creamy opaque colour and the milt discharges by a gentle pressing on the abdomen.

Stage VI (Spent and Atretic): Ovary is severely shrunken, flaccid, reduced in size. Testis is reduced in length, width and thickness and is pinkish bloody in colour and flaccid.

B- The gonadosomatic index (GSI)

The gonadosomatic index (GSI) was calculated to evaluate the state of maturity of the gonads **(Khallaf and Authman, 2010)** for each specimen using the following equation:

$$GSI = GW \times 100 / W$$

Where GW is weight of gonads (ovary or testis) in grams and W is total body weight of fish in grams.

C- Fecundity

Fecundity is the number of mature, or ripe eggs per ovary of fish according to **Bagenal (1978)** and **Bagenal and Tesch (1978)**. One to three samples per ovary were cut and weighed and then the eggs were counted. This number of eggs is then multiplied by the ratio of ovary weight to that of the sample as follows:

F = Number of opaque eggs in a sample X weight of ovary /weight of sample.

Egg count was carried out by the naked eye and fecundity was calculated as the average number of eggs per female fish length or age.

Nineteen ovaries were found with opaque eggs, distributed in the whole period of the present study, and chosen for fecundity analysis.

D- Egg diameter

Egg diameter was measured to the nearest mm by an occular micrometer fixed in an eye-piece of a light microscope.

(3) Stomach fullness (stomachsomatic) index (SSI)

Weight of the stomach (mg) was divided by the fish weight (g) and multiplied by a hundred **(Khallaf and Alne-na-ei, 1987; Authman, 1990; Khallaf and Authman, 1992)**.

(4) Ageing

Fish were assigned to an age-group according to the number of complete annuli on its vertebrae, obtained right behind the skull and right below the dorsal fin, by means of light microscope at *X* 4 magnification. Growth analysis was not the concern of this paper, and data were only used for correlations.

(5) Environmental measurements

Water temperature (°C) and electrical conductivity (µmhos/cm) of the water column were measured at five stations of BSC, 5 Km each, by using an electronic portable Cond. WTW 330i Meter (WTW Wissenschaftlich-Technische Werkstätten GmbH, Weilheim, Germany). Average daily photoperiod and dark period (hrs.) per month were based upon a national calendar table of sunrise to sunset time. Monthly air temperature (°C) and rainfall (mm) were obtained from national weather records.

(6) Statistical analyses

All statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS Inc.) program for Windows (Version 17.0).

RESULTS

1. Environmental factors

The monthly averages of environmental factors of BSC are shown in Table (1). For air temperature (AT), the maximum average value was measured during August (37.35 °C), while the lowest average was recorded in December (20.05 °C). The minimum average water temperature (WT) was recorded during January (16.73 °C), while the maximum one was observed during August (28.94 °C). The higher average value of electrical conductivity (EC) was recorded during August (472 µmhos/cm), while the lower (328 µmhos/cm) during March. The monthly variations of rainfall show that the lower values were recorded during June-September period (0.00 mm) while the higher values during February-April period (8.50-12.60 mm). The minimum value of photoperiod was recorded during December (10.26 hrs) and the maximum value during June (14.03 hrs). On the other hand, the dark period values fluctuated from 9.97 to 13.74 hrs during June and December, respectively. It is worth to mention that the period of April to November was the highest in average temperature and photoperiod.

Table 1: Monthly variations of some environmental factors at Bahr Shebeen Canal.

Months	Air Temperature (°C) (AT)						Water Temperature (°C) (WT)						Electrical conductivity (µmhos/cm) (EC)						Average rainfall (mm) (R)	Photoperiod (hrs) (PP)	Dark period (hrs) (DP)
	Range			average	±	SE	Range			average	±	SD	Range			average	±	SD			
January	13.10	-	31.60	22.35	±	9.25	10.30	-	22.18	16.73	±	0.07	388	-	408	398	±	5.56	0.80	10.49	13.51
February	11.80	-	36.40	24.10	±	12.30	12.05	-	25.56	17.05	±	0.09	382	-	400	389	±	3.48	10.80	11.13	12.87
March	13.30	-	39.40	26.35	±	13.05	12.41	-	26.18	22.31	±	0.11	322	-	346	328	±	6.39	12.60	12.02	11.98
April	18.20	-	43.40	30.80	±	12.60	16.20	-	30.00	26.73	±	1.85	343	-	372	359	±	6.84	8.50	12.89	11.11
May	19.20	-	44.40	31.80	±	12.60	18.50	-	28.00	27.15	±	1.26	375	-	396	385	±	5.21	0.10	13.66	10.34
June	23.40	-	48.00	35.70	±	12.30	22.00	-	30.20	27.68	±	0.98	401	-	424	412	±	5.57	0.00	14.03	9.97
July	27.30	-	44.20	35.75	±	8.45	22.91	-	31.34	28.36	±	0.69	429	-	453	441	±	5.96	0.00	13.87	10.13
August	28.30	-	46.40	37.35	±	9.05	23.36	-	31.75	28.94	±	0.71	459	-	485	472	±	6.38	0.00	13.21	10.79
September	26.90	-	45.70	36.30	±	9.40	20.74	-	28.76	26.58	±	0.16	450	-	475	462	±	6.25	0.00	12.34	11.66
October	26.90	-	41.80	34.35	±	7.45	18.80	-	26.13	24.10	±	0.10	441	-	466	453	±	6.37	0.70	11.48	12.52
November	14.10	-	35.30	24.70	±	10.60	15.11	-	24.58	19.37	±	0.08	419	-	443	430	±	6.06	3.80	10.66	13.34
December	11.50	-	28.60	20.05	±	8.55	11.21	-	19.12	16.93	±	0.04	398	-	420	409	±	5.75	2.60	10.26	13.74

SE = standard error.
SD = standard deviation.

2. Monthly variation of maturity stages, GSI and SSI of *M. kannume*

The variation of maturity stages is shown in Table (2). From that Table, it appears that stages of different maturity grades occur in various months. However, stages IV and V were chosen because they represent the state of higher spawning activity (Fig. 2). From that figure, it is noted that males gonads of stages IV and V were conspicuously present during February to April and November-December periods, where males with stage VI gonads were present in January, May and August-October.

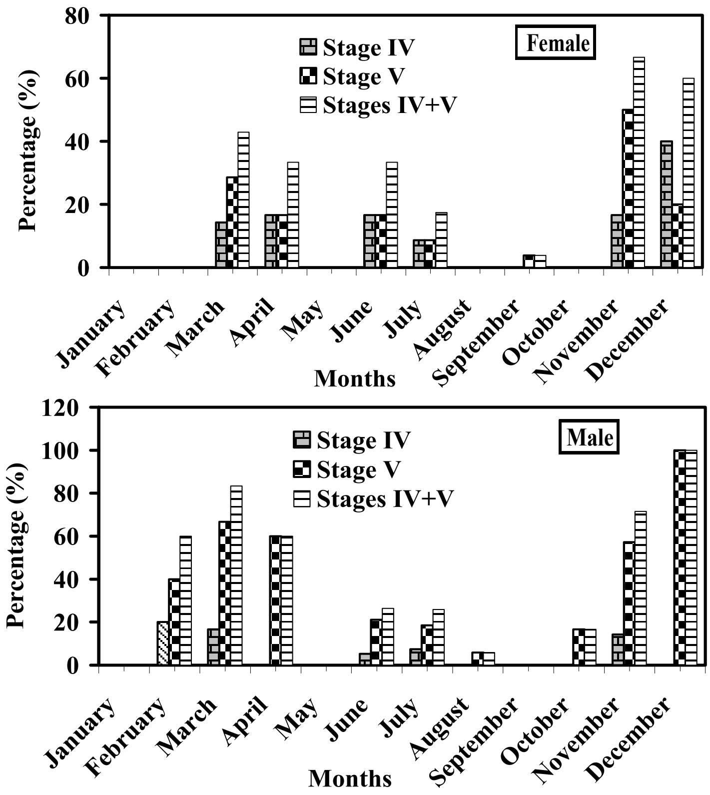


Fig. 2: Monthly variations of the percentage of occurrence of maturity stages IV, V and IV+V of males and females of *M. kannume*.

Table 2: Monthly frequency distribution of gonad maturity stages of males and females *M. kannume* from Bahr Shebeen Nilotic canal.

Month	No. of fishes	Total length (cm)	% Maturity Stages						
			I	II	III	IV	V	IV + V	VI
Male									
January	5	19.0 - 31.5	40.00	20.00	20.00	0.00	0.00	0.00	20.00
February	5	23.8 - 42.5	20.00	0.00	20.00	20.00	40.00	60.00	0.00
March	6	31.5 - 46.4	0.00	0.00	16.67	16.67	66.67	83.34	0.00
April	5	19.0 - 42.5	20.00	20.00	0.00	0.00	60.00	60.00	0.00
May	7	21.0 - 31.8	71.43	14.29	0.00	0.00	0.00	0.00	14.29
June	19	21.3 - 50.7	63.16	5.26	5.26	5.26	21.05	26.31	0.00
July	27	21.0 - 56.5	74.07	0.00	0.00	7.41	18.52	25.93	0.00
August	17	20.9 - 45.0	29.41	52.94	0.00	0.00	5.88	5.88	11.76
September	21	15.9 - 37.8	52.38	28.57	9.52	0.00	0.00	0.00	9.52
October	6	21.6 - 42.3	33.33	16.67	0.00	0.00	16.67	16.67	33.33
November	7	29.8 - 55.5	14.29	0.00	14.29	14.29	57.14	71.43	0.00
December	9	45.0 - 57.9	0.00	0.00	0.00	0.00	100.00	100.00	0.00
Total	134								
Female									
January	5	20.7 - 33.6	40.00	40.00	0.00	0.00	0.00	0.00	20.00
February	5	23.1 - 33.5	40.00	40.00	0.00	0.00	0.00	0.00	20.00
March	7	21.1 - 38.2	28.57	28.57	0.00	14.29	28.57	42.86	0.00
April	6	22.7 - 40.2	33.33	33.33	0.00	16.67	16.67	33.34	0.00
May	5	26.1 - 35.4	40.00	40.00	0.00	0.00	0.00	0.00	20.00
June	6	21.1 - 37.9	33.33	33.33	0.00	16.67	16.67	33.34	0.00
July	23	20.7 - 43.0	52.17	26.09	4.35	8.70	8.70	17.40	0.00
August	11	21.0 - 33.3	54.55	27.27	0.00	0.00	0.00	0.00	18.18
September	26	15.5 - 41.0	57.69	11.54	23.08	0.00	3.85	3.85	3.85
October	11	21.5 - 33.5	54.55	18.18	18.18	0.00	0.00	0.00	9.09
November	6	21.6 - 43.7	33.33	0.00	0.00	16.67	50.00	66.67	0.00
December	5	28.1 - 52.8	0.00	20.00	20.00	40.00	20.00	60.00	0.00
Total	116								

* Maturity stages (After Authman and Khallaf, 2009, and Khallaf and Authman, 2009): I Immature; II Mature; III Developing, IV Highly developing; V Spawning; VI Spent.

On the other hand, females with stages IV and V gonads were high during March-April, June-July, September and November-December. Females with stage VI gonads were shown to appear in the periods of January-February, May, and August-October. It is worth to mention that, the relationships between monthly stages IV and V of fish males and females and the different environmental factors are not significantly correlated.

GSI and SSI varied monthly for both males and females, as indicated in table (3) and fig. (3).

Thus, males GSI values were comparable but with slightly higher activity during February-April and November-December periods. On the other hand, females GSI values peaked conspicuously in March, in addition to slightly higher values in June and November-December period.

On considering the SSI, males have their highest feeding intensity during the months of May to September, with a similar higher activity during January. In those months, males GSI values were low as compared to the rest of the year months. However, females SSI values were comparable, but showed higher values in the period of June to October, while GSI values were lower during July to October months.

When sex ratio was taken into account (Table 2), males and females were comparable during the year months, but males outnumbered females during May-August and December.

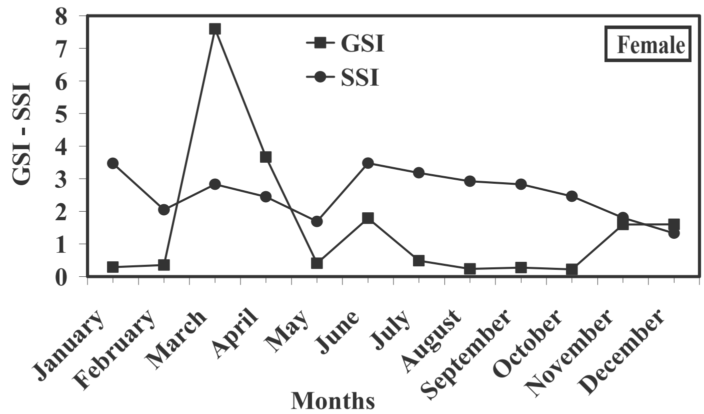
The monthly average of males GSI was significantly negatively correlated with male SSI (Table 3) (r= -0.7682, *F*=14.4018, *P*<0.01). It was also found that, male GSI was significantly correlated with female GSI (r= 0.7187, *F*=10.6817, *P*<0.01). On the other hand, no correlation could be obtained between female GSI and SSI (r= 0.0378, *F*=0.0143, P>0.05).

Table 3: Monthly variation of gonadosomatic (GSI) and stomachsomatic (SSI) indices for males and females *M. kannume* from Bahr Shebeen Nilotic canal.

Months	Male					Female				
	No. of fishes	GSI		SSI		No. of fishes	GSI		SSI	
		Range	Mean ± S.E.	Range	Mean ± S.E.		Range	Mean ± S.E.	Range	Mean ± S.E.
January	5	0.027 - 0.241	0.086 ± 0.039^{a}	1.160-3.950	2.834 ± 0.535^{bc}	5	0.132 - 0.509	0.287 ± 0.068^{a}	1.160-5.560	3.468 ± 0.848^{d}
February	5	0.083 - 0.461	0.293 ± 0.071^{bcd}	1.030-3.480	2.138 ± 0.439^{abc}	5	0.119 - 0.690	0.348 ± 0.101^{a}	1.13-3.67	2.048 ± 0.497^{abcd}
March	6	0.234 - 0.529	0.363 ± 0.052^{d}	0.922-2.000	1.270 ± 0.169^{a}	7	0.069 - 17.918	7.596 ± 2.813^{b}	1.63-5.634	2.825 ± 0.696^{bcd}
April	5	0.048 - 0.521	0.271 ± 0.095^{bcd}	0.830-1.508	1.204 ± 0.131^{a}	6	0.121 - 6.947	3.661 ± 1.127^{a}	1.016-3.810	2.447 ± 0.469^{abcd}
May	7	0.022 - 0.193	0.141 ± 0.023^{a}	1.027-4.286	3.195 ± 0.413^{c}	5	0.209 - 0.922	0.406 ± 0.130^{a}	0.667-2.976	1.687 ± 0.406^{ab}
June	19	0.023 - 0.765	0.200 ± 0.051^{abcd}	0.896-6.579	3.061 ± 0.361^{bc}	6	0.184 - 9.058	1.787 ± 1.458^{a}	1.714-5.634	3.473 ± 0.668^{d}
July	27	0.016 - 0.530	0.130 ± 0.031^{ab}	0.966-5.385	3.00 ± 0.255^{bc}	23	0.118 - 4.428	0.486 ± 0.196^{a}	1.205-5.556	3.183 ± 0.222^{cd}
August	17	0.031 - 0.557	0.134 ± 0.031^{ab}	0.857-3.810	2.165 ± 0.239^{abc}	11	0.152 - 0.375	0.235 ± 0.019^{a}	1.875-4.118	2.923 ± 0.250^{bcd}
September	21	0.008 - 0.244	0.097 ± 0.015^{a}	1.136-5.764	2.793 ± 0.285^{bc}	26	0.059 - 1.766	0.277 ± 0.062^{a}	0.667-5.714	2.832 ± 0.226^{bcd}
October	6	0.040 - 0.387	0.161 ± 0.057^{abc}	1.122-3.500	1.811 ± 0.365^{ab}	11	0.146 - 0.307	0.217 ± 0.018^{a}	1.194-3.478	2.462 ± 0.211^{abcd}
November	7	0.036 - 0.448	0.268 ± 0.060^{bcd}	0.560-1.442	1.073 ± 0.101^{a}	6	0.127 - 2.273	1.591 ± 0.349^{a}	0.880-3.947	1.803 ± 0.496^{abc}
December	9	0.172 - 0.439	0.310 ± 0.031^{cd}	0.868-1.602	1.146 ± 0.098^{a}	5	0.069 - 2.504	1.602 ± 0.457^{a}	0.857-1.736	1.327 ± 0.176^{a}
Total	134					116				
F-ratio (Sig.)			3.66** (0.000)		4.856** (0.000)			2.62** (0.005)		2.381* (0.011)

Relationship	a	b	SE (b)	r	r^2	SEE	*F-value*	(Sig.)
MGSI (*X*) *vs.* MSSI (*Y*)	3.5360	-6.8294	1.7996	-0.7682	0.5902	0.5538	14.4018	0.004**
MGSI (*X*) *vs.* FGSI (*Y*)	-1.8909	16.7889	5.1369	0.7187	0.5165	1.5807	10.6817	0.009**
FGSI (*X*) *vs.* FSSI (*Y*)	2.5211	0.0123	0.1025	0.0378	0.0014	0.7371	0.0143	0.907
FGSI (*X*) *vs.* MGSI (*Y*)	0.1570	0.0308	0.0094	0.7187	0.5165	0.0677	10.6817	0.009**

S.E. = standard error. (Sig.) = significance level.
*Significant (*P*<0.05). **Highly significant (*P*<0.01). (*X*) = Independent variable. (*Y*) = Dependent variable.
a = Constant. b = Slope. SE (b) = Standard error of "b".
r = Correlation coefficient. r^2 = Coefficient of determination. SEE = Standard Error of the Estimate.
Means with the same letter for each parameter are not significantly different (*P*>0.05); otherwise, they do **(Duncan's multiple range test, 1955)**.



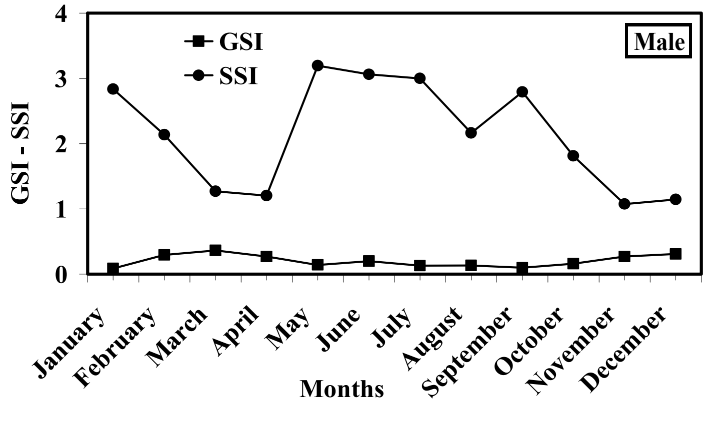


Fig. 3: Monthly variations of gonadosomatic index (GSI) and stomachsomatic index (SSI) of males and females of *M. kannume*.

3. Absolute fecundity and egg diameter

Variation of absolute fecundity (Table 4) indicates that its values ranged between 393 and 10078 with an average of 4288 eggs. Fecundity, as number of opaque eggs, variation correlates (Table 4) significantly with the variation of either fish total length (r= 0.8047, F=12.8581, P<0.01) or age (r= 0.9331, F=33.6853, P<0.01) (Fig. 4B). However, there are insignificant correlations between the fish total length, but over the range of 37 cm, and GSI (r= 0.6906, F=2.7354, P>0.05) and egg diameter (r= 0.7961, F=5.1929, P>0.05) of the fecund fish (Table 4).

The age of *M. kannume* fecund fish correlates insignificantly with the variation of GSI (r= 0.6666, F=3.9976, P>0.05) and significantly with the variation of egg diameter (r= 0.8677, F=15.2335, P<0.05) (Figs. 4A, 4C).

Table 4: Variations of gonadosomatic index (GSI), fecundity (F) and egg diameter (ED) with length and age of the fecund *M. kannume* fish.

Total length (cm)	Sample size	GSI		Fecundity (F)		Egg Diameter (mm)	
		Range	Mean± S.E.	Range	Mean± S.E.	Range	Mean± S.E.
29	3	0.697 – 1.002	0.874 ± 0.091	807 – 1195	1054 ± 124	0.640 – 1.152	0.842 ± 0.018^{bc}
31	1	0.999 – 0.999	0.999 ± —	1115 – 1115	1115 ± —	0.640 – 0.768	0.691 ± 0.017^{ab}
33	2	0.308 – 0.817	0.562 ± 0.255	830 – 1419	1125 ± 295	0.640 – 1.152	0.876 ± 0.025^{bc}
35	1	0.286 – 0.286	0.286 ± —	393 – 393	393 ± —	0.512 – 0.640	0.572 ± 0.017^{a}
37	2	9.058 – 17.918	13.488 ± 4.430	7491 – 8454	7973 ± 482	1.280 – 2.176	1.886 ± 0.042^{g}
39	2	1.728 – 12.585	7.156 ± 5.428	3701 – 11218	7460 ± 3759	0.640 – 2.304	1.323 ± 0.088^{e}
41	4	1.766 – 6.947	4.391 ± 1.058	2528 – 5879	4661 ± 749	0.640 – 2.304	1.636 ± 0.067^{f}
43	3	1.432 – 2.273	1.787 ± 0.251	2427 – 6979	4734 ± 1314	0.768 – 1.792	1.158 ± 0.045^{de}
53	1	2.504 – 2.504	2.504 ± —	10078 – 10078	10078 ± —	0.768 – 1.152	0.990 ± 0.029^{cd}
Total	19						
F-ratio (Sig.)		3.257* (0.042)		4.301* (0.017)		53.24** (0.000)	

Total length (X)-GSI, Fecundity and Egg Diameter (Y) relationship equations parameters

Relationship	a	b	SE (b)	r	r^2	SEE	*F-value*	(Sig.)
GSI *vs*. Length	28.2532	-0.5255	0.3178	0.6906	0.4769	3.9586	2.7354	0.197
Fecundity *vs*. Length	-10737.9247	396.5816	110.5973	0.8047	0.6475	2279.7243	12.8581	0.009**
Egg Diameter *vs*. Length	3.3702	-0.0463	0.0203	0.7961	0.6338	0.2530	5.1929	0.1071

Age-groups	Sample size	GSI		Fecundity (F)		Egg Diameter (mm)	
		Range	Mean± S.E.	Range	Mean± S.E.	Range	Mean± S.E.
I	2	0.697–1.002	0.850±0.152^{ab}	807–1161	984±177^{a}	0.640–1.024	0.811±0.020^{ab}
II	3	0.286–0.999	0.531±0.234^{a}	393–1115	779±210^{a}	0.512–0.896	0.694±0.019^{a}
III	3	0.817–1.728	1.155±0.288^{ab}	1195–3701	2105±801^{a}	0.640–1.152	0.911±0.022^{b}
IV	4	1.657–4.428	2.531±0.646^{ab}	2427–6979	4357±1127^{ab}	0.640–2.048	1.289±0.053^{c}
V	3	1.432–12.585	7.691±3.291^{bc}	4795–11218	7835±1862^{b}	0.768–2.304	1.508±0.072^{d}
VI	2	6.947–17.918	12.432±5.485^{c}	5879–8454	7167±1288^{b}	1.536–2.304	1.958±0.040^{e}
VII	2	2.504–4.421	3.463±0.959^{ab}	4746–10078	7412±2666^{b}	0.768–2.304	1.468±0.092^{d}
Total	19						
F-ratio (Sig.)		4.09* (0.018)		5.09** (0.008)		65.82** (0.000)	

Age (X)-GSI, Fecundity and Egg Diameter (Y) relationship equations parameters

Relationship	a	b	SE (b)	r	r^2	SEE	*F-value*	(Sig.)
GSI *vs*. Age	-1.3606	1.3635	0.6819	0.6666	0.4443	3.6085	3.9976	0.102
Fecundity *vs*. Age	-1021.5714	1349.6429	232.5407	0.9331	0.8708	1230.4895	33.6853	0.002**
Egg Diameter *vs*. Age	0.5061	0.1820	0.0466	0.8677	0.7529	0.2468	15.2335	0.011*

S.E. = standard error. (Sig.) = significance level. *Significant (P<0.05). **Highly significant (P<0.01). (X) = Independent variable.
(Y) = Dependent variable. a = Constant. b = Slope. SE (b) = Standard error of "b". r = Correlation coefficient. r^2 = Coefficient of determination. SEE = Standard Error of the Estimate.
Means with the same letter for each parameter are not significantly different (P>0.05); otherwise, they do **(Duncan's multiple range test, 1955)**.

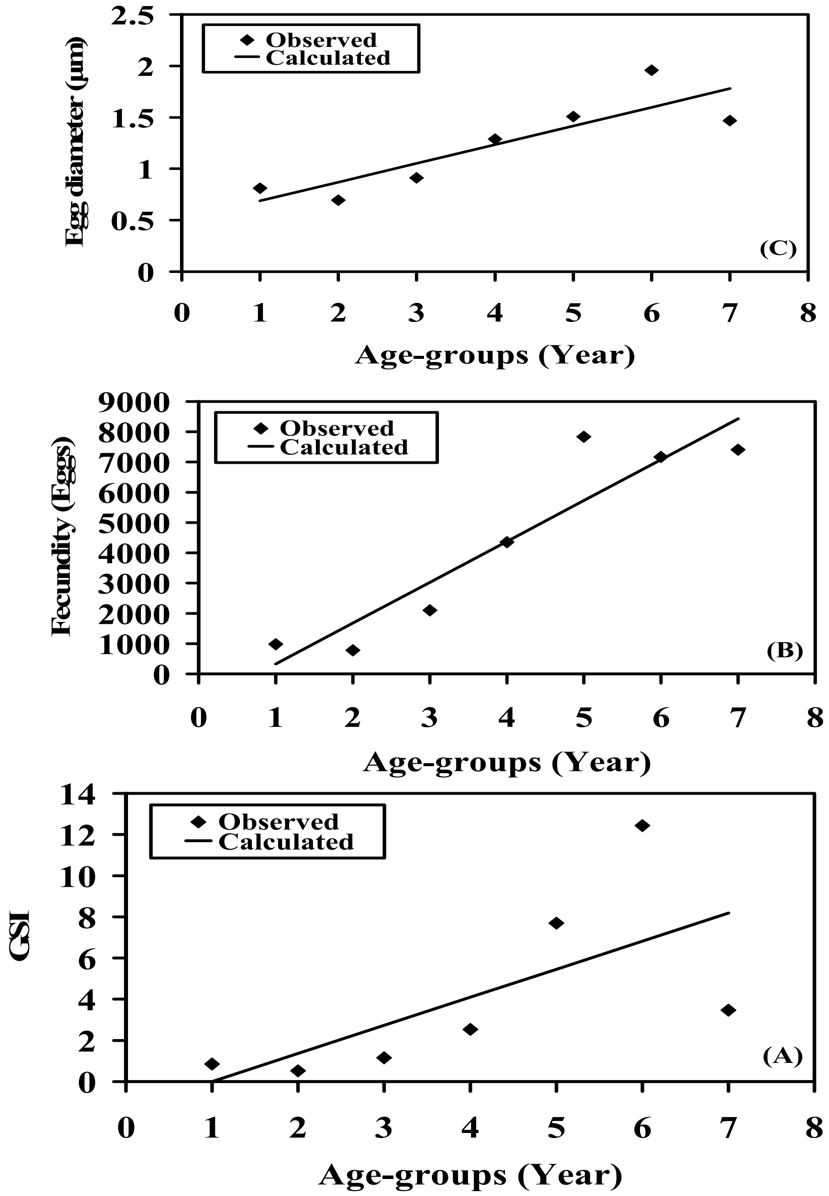


Fig. 4: (A) Variations of GSI, (B) fecundity and (C) egg diameter with age-groups variations of *M. kannume*.

4. Interaction of monthly average GSI, SSI, fecundity (F) and egg diameter (ED) with environmental factors of BSC

There was no clear trend in the variation of those biological parameters and either photoperiod or temperature. The regression of the fish GSI against air or water temperature or daily light and dark periods, revealed insignificant correlation ($P>0.05$), while the male SSI correlated significantly ($P<0.05$) with these environmental factors. However, on considering multivariate analyses (Table 5), those biological parameters correlated significantly ($P<0.05$) and in many cases highly significantly ($P<0.01$) with these environmental factors, in addition to conductivity and rainfall.

Table 5: Univariate and multivariate regression analysis of gonadosomatic (GSI) and stomachsomatic (SSI) indices [dependent variable, Y] against air (AT) and water (WT) temperature, electrical conductivity (EC), rainfall (**R**), daily photoperiod (PP) and dark period (DP) [independent variable, X].

Univariate regression analysis (Y = a + bX)

Interaction	a	b	SE (b)	r	r^2	SEE	*F*	*P*
MGSI *vs.* EC	0.7782	-0.0014	0.0005	-0.645	0.416	0.074	7.129	0.024^{*}
MGSI *vs.* R	0.1497	0.0165	0.0035	0.824	0.679	0.055	21.103	0.001^{**}
MSSI *vs.* R	2.4926	-0.1060	0.0450	-0.597	0.357	0.694	5.542	0.040^{*}
FGSI *vs.* EC	17.1936	-0.0380	0.0105	-0.753	0.568	1.495	13.124	0.005^{**}
FGSI *vs.* R	0.4240	0.3360	0.1024	0.720	0.518	1.578	10.761	0.008^{**}

Multivariate regression analysis ($Y = a + b_1X_1 + b_2X_2 + b_3X_3$ ... etc.)

Interaction	a	b_1	b_2	b_3	r	r^2	SEE	*F*	*P*
MGSI *vs.* AT and R	0.2507	-0.0031	0.0145	-	0.844	0.712	0.055	11.126	0.004^{**}
MGSI *vs.* WT and R	0.2071	-0.0023	0.0155	-	0.831	0.691	0.057	10.048	0.005^{**}
MGSI *vs.* EC and R	0.1960	-0.0001	0.0157	-	0.824	0.680	0.058	9.542	0.006^{**}
MGSI *vs.* AT and WT and R	0.2476	-0.0102	0.0093	0.0137	0.859	0.739	0.056	7.533	0.010^{*}
MGSI *vs.* WT and EC and R	0.2529	-0.0023	-0.0001	0.0148	0.832	0.692	0.060	5.983	0.019^{*}
MGSI *vs.* WT and R and PP	0.2103	-0.0022	0.0156	-0.0006	0.831	0.691	0.061	5.955	0.020^{*}
MGSI *vs.* WT and R and DP	0.1966	-0.0022	0.0156	0.0006	0.831	0.691	0.061	5.955	0.020^{*}
MSSI *vs.* AT and WT and PP	-5.8161	0.1988	-0.4279	0.9904	0.784	0.615	0.600	4.253	0.045^{*}
MSSI *vs.* AT and WT and DP	17.9526	0.1988	-0.4279	-0.9904	0.784	0.615	0.600	4.253	0.045^{*}
MSSI *vs.* WT and EC and PP	-10.5926	-0.2690	0.0114	1.1807	0.784	0.614	0.601	4.243	0.045^{*}
MSSI *vs.* WT and EC and DP	17.7452	-0.2690	0.0114	-1.1807	0.784	0.614	0.601	4.243	0.045^{*}
MSSI *vs.* WT and R and PP	-3.6874	-0.2157	-0.1161	0.9269	0.852	0.726	0.506	7.073	0.012^{*}
MSSI *vs.* WT and R and DP	18.5579	-0.2157	-0.1161	-0.9269	0.852	0.726	0.506	7.073	0.012^{*}
MGSI *vs.* MSSI and AT	0.4668	-0.0735	-0.0035	-	0.794	0.631	0.062	7.695	0.011^{*}
MGSI *vs.* MSSI and WT	0.4323	-0.0808	-0.0023	-	0.776	0.602	0.065	6.816	0.016^{*}
MGSI *vs.* MSSI and AT and WT	0.4482	-0.0692	-0.0122	0.0115	0.820	0.673	0.062	5.482	0.024^{*}
MGSI *vs.* MSSI and AT and EC	0.7666	-0.0710	-0.0001	-0.0010	0.886	0.784	0.051	9.693	0.005^{**}
MGSI *vs.* MSSI and AT and R	0.3100	-0.0446	-0.0015	0.0108	0.897	0.804	0.048	10.969	0.003^{**}
MGSI *vs.* MSSI and AT and PP	0.1180	-0.0909	-0.0119	0.0525	0.898	0.807	0.048	11.140	0.003^{**}
MGSI *vs.* MSSI and AT and DP	1.3769	-0.0909	-0.0119	-0.0525	0.898	0.807	0.048	11.140	0.003^{**}
MGSI *vs.* MSSI and WT and EC	0.7718	-0.0703	-0.0005	-0.0010	0.886	0.785	0.051	9.722	0.005^{**}
MGSI *vs.* MSSI and WT and R	0.2814	-0.0474	-0.0005	0.0112	0.893	0.798	0.049	10.523	0.004^{**}
MGSI *vs.* MSSI and WT and PP	-0.2324	-0.1206	-0.0295	0.1140	0.955	0.912	0.032	27.768	0.0001^{**}
MGSI *vs.* MSSI and WT and DP	2.5036	-0.1206	-0.0295	-0.1140	0.955	0.912	0.032	27.768	0.0001^{**}
MGSI *vs.* FGSI and AT	0.3480	0.0266	-0.0062	-	0.821	0.674	0.059	9.294	0.006^{**}
MGSI *vs.* FGSI and WT	0.3349	0.0301	-0.0075	-	0.817	0.668	0.059	9.046	0.007^{**}
MGSI *vs.* FGSI and AT and WT	0.3476	0.0276	-0.0045	-0.0022	0.822	0.675	0.062	5.536	0.024^{*}
MGSI *vs.* FGSI and AT and EC	0.2651	0.0297	-0.0067	0.0002	0.823	0.677	0.062	5.599	0.023^{*}
MGSI *vs.* FGSI and AT and R	0.2666	0.0136	-0.0038	0.0010	0.871	0.759	0.053	8.405	0.007^{**}
MGSI *vs.* FGSI and AT and PP	0.3391	0.0264	-0.0064	0.0014	0.821	0.674	0.062	5.511	0.024^{*}
MGSI *vs.* FGSI and AT and DP	0.3736	0.0264	-0.0064	-0.0014	0.821	0.674	0.062	5.511	0.024^{*}
MGSI *vs.* FGSI and WT and EC	0.3392	0.0299	-0.0075	-0.00001	0.817	0.668	0.063	5.361	0.026^{*}
MGSI *vs.* FGSI and WT and R	0.2492	0.0158	-0.0043	0.0095	0.865	0.747	0.055	7.889	0.009^{**}
MGSI *vs.* FGSI and WT and PP	0.2512	0.0297	-0.0112	0.0141	0.821	0.674	0.062	5.515	0.024^{*}
MGSI *vs.* FGSI and WT and DP	0.5895	0.0297	-0.0112	-0.0141	0.821	0.674	0.062	5.515	0.024^{*}
FGSI *vs.* AT and EC	17.2194	0.0724	-0.0434	-	0.774	0.599	1.518	6.710	0.017^{*}
FGSI *vs.* AT and R	-1.1661	0.0496	0.3674	-	0.731	0.534	1.637	5.148	0.032^{*}
FGSI *vs.* WT and EC	16.3096	0.0884	-0.0409	-	0.776	0.603	1.511	6.822	0.016^{*}
FGSI *vs.* WT and R	-2.6679	0.1246	0.3855	-	0.764	0.583	1.547	6.296	0.019^{*}
FGSI *vs.* AT and WT and R	-1.3357	-0.3365	0.5058	0.3237	0.824	0.678	1.442	5.618	0.023^{*}
FGSI *vs.* WT and EC and R	8.0587	0.1250	-0.0247	0.2127	0.828	0.685	1.426	5.800	0.021^{*}
FGSI *vs.* WT and EC and PP	30.1354	0.5548	-0.0520	-1.6640	0.849	0.721	1.343	6.879	0.013^{*}
FGSI *vs.* WT and EC and DP	-9.8010	0.5548	-0.0520	1.6640	0.849	0.721	1.343	6.879	0.013^{*}
FGSI *vs.* FSSI and EC	16.4809	0.4355	-0.0390	-	0.766	0.587	1.540	6.400	0.019^{*}
FGSI *vs.* FSSI and R	-1.2306	0.6247	0.3564	-	0.747	0.558	1.594	5.670	0.026^{*}
FGSI *vs.* FSSI and WT and EC	16.0246	0.2607	0.0742	-0.0410	0.780	0.609	1.590	4.148	0.048^{*}
FGSI *vs.* FSSI and EC and R	9.3167	0.5793	-0.0240	0.1870	0.808	0.653	1.496	5.026	0.030^{*}

MGSI = Male gonadosomatic index.
MSSI = Male stomachsomatic index.
FGSI = Female gonadosomatic index.
FSSI = Female stomachsomatic index.
a = Constant.
b = Slope.
SE (b) = Standard error of "b".
r = Correlation coefficient.
r^2 = Coefficient of determination.
SEE = Standard Error of the Estimate.
F = F-value.
P = Significance level.
* = Correlation is significant at the 0.05 level (2-tailed).
** = Correlation is significant at the 0.01 level (2-tailed).

By correlating them seasonally, SSI showed a negatively significant variation, especially for females than males, with either photoperiod or water temperature, when winter season was excluded. The relationships for these parameters appeared as follows:

For females:

$$SSI= 4.3446 -0.0688\ WT\ (r^2 = 0.974),$$
$$SSI= 4.7708 – 0.1622\ PP\ (r^2 = 0.996);$$

And for males:

$$SSI= 7.0773 – 0.2138\ WT\ \ (r^2 = 0.3648),$$
$$SSI= 10.1449 – 0.6532\ PP\ \ (r^2 = 0.5898).$$

Where WT= water temperature in centigrade, and PP= photoperiod in hours.

As indicated in Table (5), the univariate regression of monthly male GSI values and electrical conductivity (EC) was found to be negatively correlated ($P<0.05$). In addition, highly significant relationship ($P< 0.01$) was obtained using the univariate analysis of male GSI versus rainfall. The male SSI was negatively significantly correlated ($P<0.05$) with rainfall. Also, highly significant negative relationship ($P< 0.01$) was obtained using the univariate analysis of female GSI versus electrical conductivity (EC). Highly significant relationship ($P< 0.01$) was obtained between female GSI and rainfall.

DISCUSSION

Similar to other vertebrates, many fish species are subject to a number of environmental challenges, which might have led to a number of feeding adaptations, such as coping with long-term fasting. In addition, seasonal changes in feeding often coincide with spawning, migration and reproduction, suggesting a link between nutrition and the reproductive axis (Volkoff *et al.*, 2009). The spawning of a fish species is a subject to the innate characteristics moderated by the surrounding environmental factors (Khallaf and Al-ne-na-ei, 1987, 1993; Thomaz *et al.* 2007). *M. kannume* is no exception as revealed by the present results.

Thus, on examining GSI, maturity stages variation during the year months, two main distinctive periods were apparent with high activity. These periods extend from February-April and November-December, for either GSI or high occurrence of stage V of maturity for males, and more or less for females. However, since females have their peak in March that may be an indication that males stay active longer time than females till they commence spawning. Females also are found to have stage V of maturity during June, July and September, which is an indication of extended readiness to spawn most of the year months. Mature specimens (in stages IV and V) of both sexes were encountered throughout the months of the study period. This agreed with the findings of Scott (1974) and Fawole (2002) that most of the species of the family Mormyridae spawn more or less, throughout the year. Present results revealed that, there are no significant correlations between stage IV and V of both sexes and environmental factors. This is in agreement with the study of Kirschbaum (1987), on *Pollimyrus isidori*, that the relationship of the different stages of oocyte growth to the environmental changes could not be determined.

The feeding intensity of males that covered the months of May to September, and the slight rise in SSI of females indicate that the fish show low feeding activity at the times of spawning. The negative significant correlation ($P<0.01$) (Table 3) between male GSI and SSI confirms this. Toguyeni *et al.* (1997) found that *Oreochromis niloticus* males increase their social interactions during sexual maturation, which could affect food intake. Bratton and Kramer (1989) mentioned that, in the male mormyrid fish, *Pollimyrus isidori* builds the nest, patrols his territory while searching for more nest materials and nudging the nest. Lamml and Kramer (2005) and Baier *et al.* (2006) reported that, in some mormyrids, reproduction was always indicated by highly conspicuous behaviours in male, such as marked territorial behaviour and nest building. In the African cichlid fish *Astatotilapia (Haplochromis) burtoni*, reproductively active territorial males spend all their time and energy in territory maintenance and mate attraction as well as sperm production (Hofmann *et al.*, 1999; Hofmann, 2003). In addition, a decline in feeding is often seen during spawning, migrations or other reproductive behaviors (e.g., spawning, guarding) (van Ginneken and Maes, 2005; Volkoff *et al.*, 2010). In both Atlantic cod (Fordham and Trippel, 1999) and winter flounder (Scott and Scott, 1988; MacDonald and Volkoff, 2009), feeding is suppressed in both sexes during the spawning period and increases after spawning.

The rise of occurrence of stage VI maturity of males during May, October and January, and January-February, May and August for females, is another proof that spawning occurs in the above mentioned periods. In accordance, Scott (1974), working on the same species in Uganda, indicated that *M. kannume* reproduction extends most of the year but with a conspicuous period of November to January, while ripe fish caught from October till June. However, Odoul (1986) from Kenya, defined the periods of April-May and November-December as the main spawning period for *M. kannume*. Similar findings were reported by El-Etreby (1985) on the fish from Lake Nasser and Aly (1993) on the fish from the High Dam reservoir. The previous studies of Authman and Khallaf (2009) and Khallaf and Authman (2009) on the spermatogenesis and oogenesis of *M. kannume*, respectively, from BSC, are a further confirmation of the present results.

Males outnumbered females during May-August and December, and that could be attributed to that females are busy in a post spawning activity.

It is worth to mention that the temperature values of present study are higher than those recorded previously in BSC by Authman (1990), Elewa and Authman (1991) and Alne-na-ei (1999). Previously, Ashour *et al.* (1990a) suggested that the spawning of *M. kannume* is influenced by water temperature. The spawning behavior of *M. kannume*, as described in this study made it difficult to predict any significant correlation with either monthly average daily photoperiod or temperature (Table 5). Consequently, the coefficient of determination was negative and below 60%. This is understandable, since the fish spawn in two main periods, one during summer and the second in winter that could be due to that *M. kannume* is a nocturnal fish (Hopkins, 1986; Kramer, 1990; Moller, 1995) and spawns during night (Kirschbaum and Schugardt, 2002). This was confirmed by the negative correlation between male GSI and photoperiod, while the negative correlation between female GSI and dark period is questionable. Previously, Khallaf *et al.* (1986) found some significant correlations between GSI of *Tilapia nilotica* and *Tilapia zillii* in BSC and water temperature and photoperiod.

On examining the relationship of SSI and the two examined environmental factors seasonally, females had a higher coefficient of determination ($r^2 = > 0.97$) than males ($r^2 = < 0.59$). This is attributed to the higher feeding intensity of females than males. As males become busy with spawning activity when daily temperature and photoperiod increase in most of the warmer and longer days, and hence they slow their feeding. There are positive correlations between male and female SSI and photoperiod and negative correlations between male and female SSI and dark period.

This may be attributed to the fact that some fish appear to display a great plasticity in circadian rhythms as individual fish can be diurnal at first, then switch between diurnal and nocturnal activity (Reebs, 2002). Therefore, climate change when occurs, will have an eminent effect on that fish species reproduction and feeding.

The GSI of the fecund fish did not correlate significantly with either fish length (r^2=0.48), or age (r^2=0.44), due to the prolonged spawning season. During that period, females and males stay with different stages of maturity most of the time. That is understandable, since the fish mature at a length of 34 cm for females, and 36 cm for males, and 50 % of the fish become mature at the length of 28 cm (2.33 years) and 30 (2.75 years) for females and males, respectively, as indicated by Khallaf and Authman (2010), while the fish length ranged from 29 to 53 cm. It was also noted that fecundity and egg diameter correlate significantly with variation of length (r^2= 0.65) or age of the fish (r^2= 0. 87), since those parameters are related to the ripe ova, while GSI is based on the weight of all immature and mature ova, thus variable.

The fish fecundity ranged between 393 and 10078 eggs with an average egg diameter of 1.96 mm, while Fawole (2002), showed that the same species in Nigeria, produced between 741 and 6000 eggs, which can be attributed to variation in geographical differences. Adebisi (1987) found that, the fecundity of *Marcusenius senegalensis* in Ogun River, Nigeria, ranged between 830 and 1490 eggs, and the average egg diameter was 1.35 mm, and he related the relatively low fecundities and large sizes of eggs of mormyrids to the existence of some degree of parental care. Albaret (1982) asserted that mormyrids of the rivers of Ivory Coast with low fecundities tend to hide their eggs in nests. Likewise, Coates (1988) suggested that the yolk content of fish eggs and hence their sizes, are closely linked to the degree of parental care accorded to the eggs and/or young.

It is evident from the present results that the male and female GSI were significantly negatively correlated with electrical conductivity (EC) (univariate regression). In addition, the multiple regressions of these variables versus EC and other environmental factors revealed a significant relationship with positive correlation coefficients (Table 5). On the other hand, significant positive relationships (P<0.05) were obtained using the univariate and multivariate analyses of male and female GSI versus rainfall. This may lead to the conclusion that, the *M. kannume* GSI in BSC may be affected by the change in both electrical conductivity and the rainfall. Consistent with these observations, Bénech and Quensière (1985) have shown that in the Republic of Chad, the peak of reproduction in *Pollimyrus isidori* is preceded by a substantial decrease of conductivity and increase of water level, caused by the beginning of the rainy season. In that fish, gonadal recrudescence and regression are controlled by three environmental factors namely: conductivity, water level and rain (Kirschbaum, 1987). Schugardt and Kirschbaum (2004) concluded that decreasing conductivity is sufficient to induce complete gonadal maturation in mormyrids in experimental conditions as well as in the wild. Kirschbaum and Schugardt (2002) demonstrated that decrease of conductivity alone is sufficient to provoke complete gonad maturation. Kirschbaum (2000), Kirschbaum and Schugardt (2002) and Moller *et al.* (2004) mentioned that, in African freshwater mormyrid fishes, the environmental factors that control their cyclic reproduction are related to high water conditions, the most important cue being the decrease in water conductivity. Gonadal maturation could be induced by decreasing conductivity, increasing water level and rainfall (high water conditions), while gonadal regression could be caused by increasing conductivity (low water conditions) alone (Schugardt and Kirschbaum, 2004). Which sensory systems would allow mormyrid fishes to measure conductivity changes? There are indications that mormyrids might be able to use their electrosensory system for this purpose (Moller 1995; Schugardt and Kirschbaum, 2004). African freshwater mormyrid fishes generate and perceive electric organ discharges (EODs) that are involved in social contact and communication, territorial behaviour, prey detection, individual recognition, nocturnal courtship and mating (Hopkins, 1986; Kramer, 1990, 1996; Moller 1995; Kramer *et al.*, 2003, 2004).

CONCLUSION

The present results revealed no obvious correlation between fish reproduction, and either temperature or photoperiod. However, under natural conditions, these parameters are difficult to separate, and act collectively with other environmental factors as shown by multivariate analyses. On the other hand, electrical conductivity and rainfall significantly affect on the reproduction of the fish. Therefore, the present data indicate that *M. kannume* is susceptible for global warming effects.

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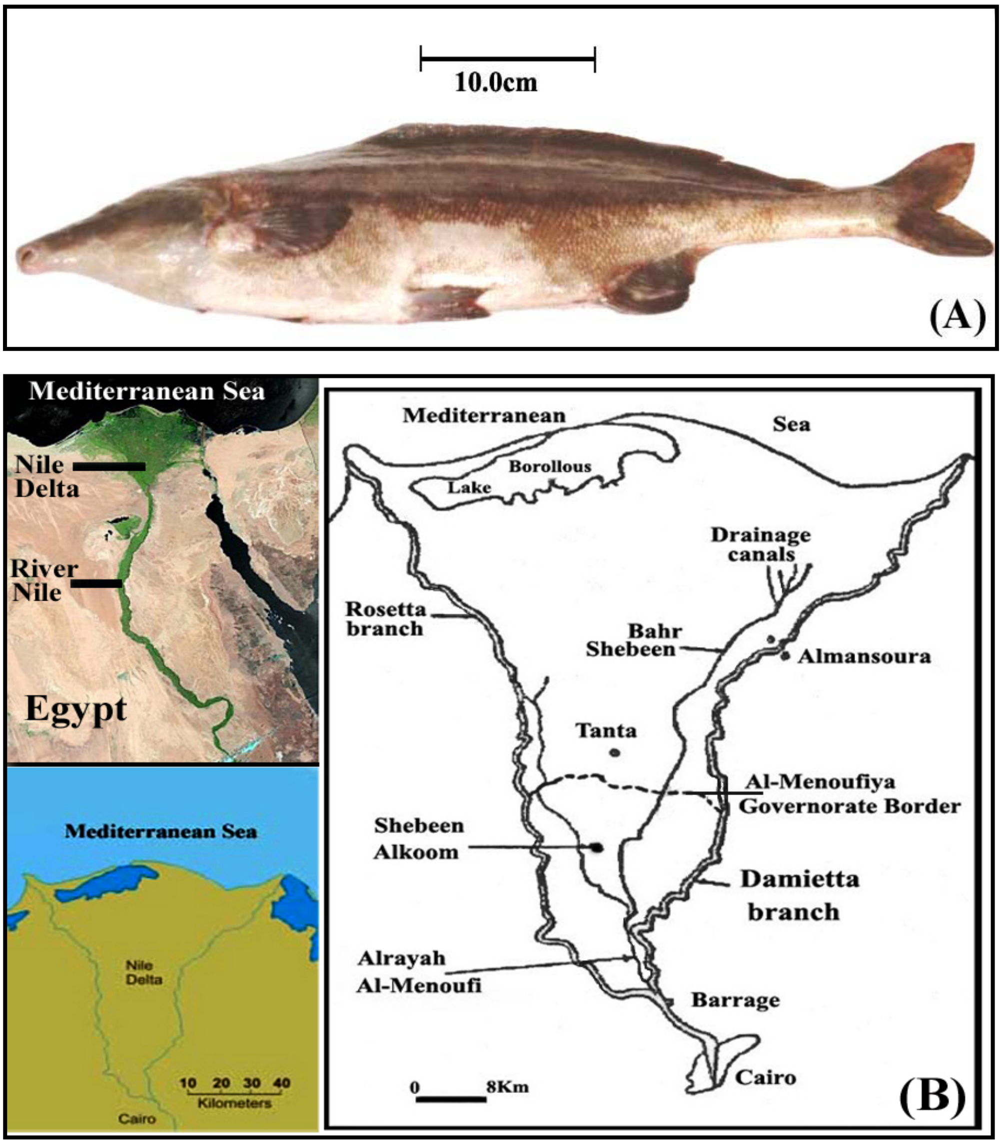

Fig. 1: (A) *M. kannume*, 57.9 cm total length, (B) Map of Nile Delta showing Bahr Shebeen Canal (BSC).

ARABIC SUMMARY

التفاعل بين التكاثر وكثافة الإغتذاء فى أسماك الأنومة *مورميرس كانوم* (فورسكال 1775) و البيئة فى قناة نيلية، مصر

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في هذه الدراسةِ تم دراسة مشكلة تأثيرِ العواملِ البيئيةِ على العوامل البيولوجية للأسماك وقياس مدى هذا التأثير. تعتبر ترعة بحر شبين قناة نيلية، بالإضافة إلى أنها مصدرٍ من مصادر الأسماك في دلتا نهر النيل بمصر، حيث تتوفر أسماك الأنومة النيلية (أنومة أم بويز)، ماعدا أثناء شهورِ يونيو إلى سبتمبر، التى تمثّلَ نموذجاً لفَحْص مثل هذا الإختلافِ. أظهرت نتائجَ هذه الدراسةِ بأنّ الأسماك تتزاوج على مدى فترة ممتدةِ، مِنْ نوفمبر حتى مايو، بفترتين من فترات النشاط الرئيسية للتزاوج؛ ديسمبر- نوفمبر وأبريل – فبراير. وبالتالي ، فأن المعامل المنسلى الجسدى لا يُمْكن أنْ يرتْبَطَ بشكل معنوى مع الإختلافِ أمّا في درجة حرارة الماء أو فترة الإضاءة. وفي تلك الفتراتِ من نشاطِ التزاوج، أظهرت الأسماك إنخفاضاً فى كثافة نشاط الإغتذاء، أي كثافة أقل فى أعداد الأسماك. وحُدّدتْ هذه الحقيقة أيضاً رياضياً بالإرتباطاتِ الهامّةِ بين المعدلِ الموسميِّ (ماعدا الشتاء) لدرجة حرارة الماء أو فترة الضوء اليومى والمعامل المعدى الجسدى للإناث، وإلى حد أقل مَع الذكورِ. وبما أن هذه العِلاقاتِ كانت مرتبطة سلبياً، وأكثر معنوية بين الإناث مِنْ الذكورِ، فأن ذلك يعزى إلى أرتفاع نشاط الإغتذاء بين الإناث. كما وجد أن نشاطات التكاثر وشدة الإغتذاء بين الأسماك ترتبط إرتباطاً معنوياً مع درجة التوصيلة الكهربائة للمياه وكمية هطول الأمطار. ويشيرَ ذلك بأنّ هذه الأسماكَ تخضع للتفاعل بين تأثيرِ العوامل البيئيةِ والعوامل البيولوجية الخاصة بها. وأظهرت الدراسة الحالية مدى حساسية هذا النوع من الأسماك للتَغْيرات البيئية، وتُشيرُ إلى إمكانية تأثرها بالإختلافات المناخية المتنوعة.

كما تم فحص ومناقشة العلاقة بين كل من درجة الخصوبة، أقطار البويضات والمعامل المنسلى الجسدى وطول وعمر إناث هذا النوع من الأسماك، ووَصْف الإرتباطاتِ الرياضيةِ بينها.