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Full Length Research Paper

Examination of liver and muscle glycogen and blood glucose levels of *Capoeta umbla* (Heckel, 1843) living in Hazar Lake and Keban Dam Lake (Elazig, Turkey)

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This study was conducted between December 2006 and November 2007 on *Capoeta umbla* fish species obtained from Hazar Lake and Keban Dam Lake (Elazig, Turkey). It was determined that the GSI values reached maximum in May and started decreasing after this month; the liver glycogen and condition factor values started decreasing after May when gonadal development is maximum. This decrease continued until June and then started increasing again. It was also determined that blood glucose values reached maximum when energy requirement is high and start to decrease after May when reproduction starts. In the summer, it was determined that glycogen and glucose reserves were at low levels when temperature is high. But they were at high levels at autumn and winter when the temperature is lower. Glycogen and glucose reserves generally showed parallel changes with oxygen reserves.

Key words: *Capoeta umbla*, Hazar Lake, Keban Dam Lake, liver glycogen, muscle glycogen, blood glucose.

INTRODUCTION

Carbohydrates or saccharides are necessary nutrition materials for vital activities in animals and plants. In fishes, liver is the main store of carbohydrates that are the biggest source of blood glucose. The ratio of the carbohydrate utilization in fish varies according to feeding habits of fish. Generally, omnivores and herbivores utilize carbohydrate better than carnivores. Glucose has an important place in carbohydrate metabolism (Koedprang et al., 2002). The basic energy reserves glycogens consist 1% of the total body weight. This source is sufficient to provide the energy need for a short time, but not for a long time. The glycogen amount stored in liver depends on the physical, chemical and biological factors faced by the fish. Rapid movement, stress factors or environmental hypoxia causes carbohydrate reserves to diminish (first glycogen in liver and muscles). It has also been determined by various studies that the hormonal changes in fish affect the conversion of liver glycogen into blood glucose.

The glycogen level in muscle may reflect the glycogen level in liver which is the main storage place for glycogen. The glycogen stocks in striated muscles of fish have an important role. However, its amount is lower than the reserves in liver. After physical activity, the glycogen in muscle is converted into lactic acid and causes the pH of the muscle to decrease. In mammals, the rapidly formed lactic acid is carried to the liver for reconfiguration but this generally does not happen in fish, and lactic acid is kept in muscles (Hall, 1997).

Serum glucose level is one of the most important signs of stress situation in fish. When glucose level increases, it means that fish is under a stress condition and is using energy reserves such as glycogen in muscles and liver. The blood glucose level in fish varies according to season and the main reason for this difference is the reproduction activities (Hoar et al., 1992).

It is reported that by taking advantage of the blood

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Formulae: GSI = [Gonad weight/(Body weight–Gonad weight)]*100; **C.F.** = [(Body weight–Gonad weight)/Fish length^3]*100.

Figure 1. Hazar and Keban Dam Lake.

glucose level changes in fish, gonad development, estimation of reproduction season and separating the non-breeding individuals in population could be determined (Johnson and Casillas, 1991).

The aim of this study was to research the change of carbohydrate reserves (especially due to reproduction activities) of *Capoeta umbla* which is an economic species for both Hazar Lake and Keban Dam Lake.

MATERIALS AND METHODS

Fish samples were monthly caught from Hazar Lake and Keban Dam Lake (Elaziğ, Turkey) between December 2006 and November 2007 by using of gill nets with various mesh size (20 to 120 mm). Ages of fish were determined by using otoliths (Öztürk et al., 2000; Aydin and Şen, 2002). Sexes of the fish were determined by opening their abdominal region and examining their gonads macroscopically and if necessary microscopically. GSI = [Gonad weight/(Body weight–Gonad weight)]*100 formula for determination of the reproduction period and C.F. = [(Body weight–Gonad weight)/Fish length^3]*100 formula for the determination of the condition factor used (Avsar, 2005).Temperature (T, °C) and dissolved oxygen (DO, mg/l) values were measured with YSI 52 oxygen meter.

Sampling areas

Hazar Lake is a tectonic lake, located about 25 km south of Elaziğ province, altitude 1248 m and surface area of 86 km^2, 20 km in length 4.5 km in width and coordinated as 38°29′ N and 39°24′ E (Figure 1) (Anonymous, 1995). In terms of trophic status, Hazar Lake could be classified as oligotrophic lake. Hazar Lake is a brackish water with high NaCl level (NaCl = 728.60 mg/l, Na_2CO_3 = 726.10 mg/l). In addition, lake water has a high pH value (8.8) and qualified as hard water (Cici, 1995).

Keban Dam is located 45 km northwest of Elaziğ province and 65 km to the northeast of Malatya and coordinated as 38°37′ and 39°20′ N, 38°15′ and 39°52′ E. The surface area is maximum 687.31 km^2 and the storage volume is maximum 30.6 billion m^3 (Figure 1) (Anonymous, 1994).

Determining the blood glucose

Blood samples were taken from caudal peduncle of each fish in a tube with EDTA and then brought to the laboratory. Blood samples were then centrifuged at 3500 rpm for 10 min to obtain serum samples for the analysis of blood glucose (BG). The glucose levels in the serum samples were analysed using the O-toluidine technique. In order to apply this technique, 50 µl serum samples were added to glass tubes and 3.5 ml of O-toluidine reagent was added to each tube and then all the tubes were kept in a hot water bath (100°C) for 10 min. The glucose levels in cooled samples were measured spectrophotometrically (Wedemeyer and Yasutake, 1977; Cicik and Engin, 2005).

Determining the liver and muscle glycogen

The muscle (muscle glycogen: MG) and liver (liver glycogen: LG) tissues to be analysed for glycogen levels were first wet weighed and then placed into centrifuge tubes containing 3 ml of KOH solution (30%). The centrifuge tubes were kept in a hot water bath for 20 min. Then 0.5 ml of saturated Na_2SO_4 and 3 ml of ethyl alcohol (95% pure) were added, followed by boiling for a further 15 min. After being cooled, all samples were centrifuged at 3500 rpm and the supernatants were discarded. The precipitations in the tubes were dissolved in 2 ml of distilled water followed by the addition of 2.5 ml of ethyl alcohol (95% pure). The tubes were then centrifuged at 3500 rpm for a further 10 min and the supernatants were discarded again. The final precipitations in the tubes free of lipid and protein were then dissolved in 2 ml of HCl (5 M) and neutralised with 0.5 M NaOH followed by dilution to 50 ml with distilled water before analysis (Wedemeyer and Yasutake, 1977; Cicik and Engin, 2005). The glycogen levels in the samples were determined by Anthron method (Plummer, 1971).

Statistical analysis

In each sex, the significance of differences between liver glycogen values, muscle glycogen values and blood glucose values were determined by using "Duncan test" depending on age groups and months. In addition, the significance of differences between liver glycogen values, muscle glycogen values and blood glucose values in Hazar Lake and Keban Dam Lake populations was determined by using "t test" for each two areas in the same sex groups depending on age groups and months.

RESULTS AND DISCUSSION

Changes depending on age

In both Hazar and Keban Dam Lakes, it was determined that the liver and muscle glycogen levels of both sexes of *C. umbla* populations were increased with age. The lowest average liver glycogen value in fish from Hazar Lake was determined in III age group for males and in II age group for females. The highest average liver glycogen value was determined in VII age group for both sexes. In the same region, the lowest average muscle glycogen level was determined in II age group for both sexes, while the highest average value was determined in VII age group (Table 1).

The lowest average liver and muscle glycogen value in Keban Dam Lake was determined in II age group for both sexes. The highest average liver glycogen value was determined in VII age group for males and in VI age group for females. The highest average muscle glycogen value was determined in VII age group for both sexes.

In many studies, it is stated that glycogen amount increases with liver size increases. As liver gets bigger in fish due to age, liver glycogen amount also increases (Shahidi and Dujanski, 1993). Mayer et al. (1994) determined the highest liver glycogen values as 35 mg/g in 1 year old and 50 mg/g in 2 years old of *Salmo salar.* Heinimaa (2004) stated that liver glycogen values of Atlantic salmon consists 0.5 to 9.5% of the liver weight. Ali and Jauncey (2005) stated that liver glycogen values in *Clarias gariepinus* is 8.45 mg/g in 2 years old individuals, while Ezike and Ufodike (2008), stated the glycogen values was 1.03±0.03 mg/g in 1 year old individuals of the same species.

Muscle glycogen that is the main source of energy for swimming is variable amount. Its amount depends on the nutrition situation of the environment, the ability of the fish to feed, its physiological status, sexual maturity, reproduction activity and environmental stress factors (Norton and MacFarlane, 1995). The stored glycogen in the muscles of fish decreased during rapid movement. The muscle glycogen amount of an escaping fish can decrease to half in 15 s (Hall, 1997). As the fish used in the study are caught, their muscle glycogen values may not reflect the real values. Guillaume et al. (2001) stated that the muscle glycogen level increased with age, that its amount depends on species and environmental conditions and that it varies between 40 and 200 mg/100 g.

In both Hazar and Keban Dam Lakes, it was determined that blood glucose levels of both sexes of *C. umbla* populations increased by age. The lowest average blood glucose value in both lakes was determined in VII age group for both sexes. The highest blood glucose value was determined in II age group for both sexes (Table 1). Some other studies on *Capoeta capoeta capoeta* (Aydin et al., 2000); on *Leuciscus cephalus orientalis* (Erdogan et al., 2000); on *Capoeta capoeta umbla* (Turkmen et al., 2000) and on *Capoeta tinca* (Yildirim et al., 2000) have observed that blood glucose levels decreased by age.

The liver glycogen amount difference between the males of Hazar and Keban Dam Lakes populations was found to be insignificant for VI age groups ($p > 0.05$), but significant for other age groups ($p < 0.05$). The liver glycogen amount difference between females of two populations was found to be insignificant for V and VI age groups ($p > 0.05$), but significant for other age groups ($p < 0.05$). The muscle glycogen amount difference was found to be significant for IV and V age groups between males and for II, III and V age groups between females of two populations ($p < 0.05$). The blood glucose difference was found to be significant for II, III and V age groups between males and for all age groups between females of two populations ($p < 0.05$).

Changes depending on months

It was determined that liver and muscle glycogen values were low during summer for both sexes of Hazar and Keban Dam Lakes populations. The liver glycogen values in fish from Hazar Lake were the lowest in June (70.55 mg/g) and the highest in March (101.08 mg/g). Liver glycogen values in fish from Keban Dam Lake were the lowest in June (83.75 mg/g) and the highest in February (117.16 mg/g). The muscle glycogen values in fish from Hazar Lake were the lowest in June (4.24 mg/g) and the highest in September (6.54 mg/g). Muscle glycogen values in fish from Keban Dam Lake were the lowest in April (5.09 mg/g) and the highest in November (6.91 mg/g). The blood glucose values in fish from Hazar Lake were the lowest in August (64.94 mg/dl) and the highest in April (126.67 mg/dl). Blood glucose values in fish from Keban Dam Lake were the lowest in July (91.41 mg/dl) and the highest in April (163.19 mg/dl) (Table 2).

The relation between changes (depending on months) of liver and muscle glycogen with blood glucose

Table 1. The distribution of liver glycogen (LG, mg/g), muscle glycogen (MG, mg/g) and blood glucose (BG, mg/dl) values of *C. umbla* populations from Hazar Lake and Keban Dam Lake according to age and sex groups ($\bar{x}$: Mean, S.e.: Standart error).

Areas	Sexes	Parameters		Age groups II	III	IV	V	VI	VII
Hazar Lake	♀	LG	$\bar{x}$ ±S.e.	85,64±4,98[a]	83,44±2,68[a]	87,77±1,97[b]	97,14±2,60[bc]	103,40±6,78[cd]	105,05±6,30[d]
		MG		2,94±1,03[ab]	4,87±0,63[a]	6,95±0,35[ab]	7,75±0,69[bc]	9,52±1,11[c]	10,16±1,19[d]
		BG		162,50±21,43[a]	147,01±8,91[a]	129,93±6,77[a]	115,66±8,21[a]	102,09±21,41[a]	95,65±45,65[a]
			N	12	29	57	26	6	2
	♂	LG	$\bar{x}$ ±S.e.	73,29±5,24[a]	75,02±3,62[a]	83,98±2,94[b]	100,56±2,89[c]	108,89±1,89[d]	108,52
		MG		2,97±0,81[a]	4,53±0,57[a]	6,48±0,40[b]	8,65±0,67[c]	7,52±2,23[c]	9,87
		BG		187,39±14,21[c]	133,24±6,21[abc]	122,75±4,66[ab]	103,65±4,33[a]	88,65±11,19[bc]	43,89
			N	7	20	39	22	7	1
	♀+♂	LG	$\bar{x}$ ±S.e.	79,46±3,64[a]	79,23±2,15[a]	85,87±1,66[b]	98,85±1,94[c]	106,14±3,82[d]	106,78±8,62[d]
		MG		2,08±0,83[ab]	4,71±0,44[a]	6,46±0,26[b]	8,42±0,49[c]	8,75±1,28[c]	10,06±2,02[d]
		BG		174,90±14,21[a]	140,13±5,81[a]	126,84±4,44[a]	109,66±4,94[a]	95,37±12,33[a]	69,77±31,50[a]
			N	19	49	96	48	13	3
Keban Dam Lake	♀	LG	$\bar{x}$ ±S.e.	100,27±2,03[a]	105,37±9,86[a]	105,14±1,74[a]	108,34±2,64[ab]	120,75±5,28[b]	113,75
		MG		3,48±0,61[a]	5,06±0,56[a]	6,80±0,42[b]	8,43±0,55[c]	10,15±0,81[d]	10,75
		BG		167,72±15,00[c]	130,77±10,51[b]	113,82±8,33[a]	101,20±9,26[a]	106,94±48,32[a]	84,56
			N	14	16	50	32	10	1
	♂	LG	$\bar{x}$ ±S.e.	81,67±7,75[a]	93,81±3,67[ab]	101,71±2,27[bc]	107,05±2,90[bc]	116,67±2,34[c]	115,82±12,22[c]
		MG		3,37±0,49[a]	5,29±0,68[a]	6,86±0,51[ab]	7,85±0,85[abc]	9,99±1,19[c]	11,02±1,74[bc]
		BG		204,43±17,22[d]	140,81±9,75[c]	115,01±8,71[bc]	116,16±10,18[b]	82,10±8,99[a]	74,58±8,94[a]
			N	10	21	33	24	16	5
	♀+♂	LG	$\bar{x}$ ±S.e.	90,97±3,75[a]	99,59±2,47[ab]	103,43±1,38[b]	107,69±1,94[bc]	116,67±2,42[c]	115,48±9,98[c]
		MG		3,43±0,42[a]	5,41±0,45[ab]	6,31±0,33[b]	8,47±0,52[c]	10,12±0,84[c]	10,48±2,03[c]
		BG		186,58±11,58[e]	135,79±7,08[d]	114,41±6,08[c]	108,68±6,83[bc]	94,52±8,65[ab]	79,57±27,32[a]
			N	24	37	83	56	26	6

a,b,c,d,e,f: Same letters in the same line are not statistically important ($p>0.05$).

parameters of *C. umbla* populations from Hazar and Keban Dam Lakes are examined by the application of t test. The liver glycogen amount difference between males of two populations was found to be significant in all months ($p < 0.05$). The liver glycogen amount difference between females of two populations was found to be significant in January, February and November ($p < 0.05$) and insignificant in all other months ($p >$

Table 2. The distribution of liver glycogen (LG, mg/g), muscle glycogen (MG, mg/g) and blood glucose (BG, mg/dl) values of *C. umbla* populations from Hazar Lake and Keban Dam Lake according to months and sex groups ($\bar{x}$: Mean, S.e.: Standart error).

Areas	Months	$\bar{x}$ ±S.e.											
		♀				♂				♀+♂			
		N	LG	MG	BG	N	LG	MG	BG	N	LG	MG	BG
Hazar Lake	D	10	85,92±5,62^{bcde}	4,92±0,98^{ab}	107,90±11,54^{bcd}	8	92,99±11,05^{bcd}	5,56±1,33^{ab}	98,80±15,02^{bc}	18	89,45±5,62^{cd}	5,74±0,98^{ab}	103,35±11,54^{bcde}
	J	9	90,56±4,59^{bcde}	5,22±0,79^{ab}	96,86±10,32^{cd}	8	82,71±7,51^{abc}	5,64±0,98^{ab}	112,22±8,24^{abc}	17	86,63±4,59^{bcd}	5,64±0,79^{abc}	104,54±10,32^{bcde}
	F	15	101,03±2,74^{f}	5,12±0,77^{ab}	110,73±7,57^{bcd}	8	95,41±4,58^{cd}	4,23±1,52^{a}	111,00±12,45^{abc}	23	98,22±2,74^{ef}	4,98±0,77^{a}	110,37±7,57^{bcde}
	M	12	98,99±4,63^{ef}	6,02±1,42^{b}	114,10±13,09^{cd}	8	103,17±6,53^{d}	7,64±2,76^{b}	114,49±9,87^{bc}	20	101,08±4,63^{f}	6,15±1,42^{c}	114,29±13,09^{de}
	A	11	99,42±4,99^{def}	5,35±0,79^{ab}	124,92±10,02^{d}	7	95,01±8,20^{cd}	6,02±1,14^{ab}	128,42±10,06^{abc}	18	97,21±4,26^{def}	5,87±0,79^{abc}	126,67±11,61^{cde}
	M	11	82,93±4,39^{cdef}	5,61±0,87^{ab}	83,64±11,61^{cd}	9	73,27±8,46^{abc}	4,90±1,33^{ab}	92,98±10,71^{c}	20	78,10±4,39^{cd}	5,05±0,87^{abc}	88,31±10,02^{e}
	J	11	73,24±3,37^{a}	4,51±0,79^{a}	63,38±4,87^{abc}	10	67,87±5,52^{a}	5,31±1,41^{ab}	79,47±6,84^{ab}	21	70,55±3,37^{a}	4,24±0,79^{a}	71,42±4,87^{abc}
	J	13	78,78±2,86^{ab}	4,88±0,61^{ab}	59,51±3,88^{a}	8	72,61±4,93^{ab}	4,44±0,99^{a}	85,77±3,74^{a}	21	75,69±2,86^{ab}	4,88±0,61^{a}	72,64±3,88^{a}
	A	10	88,27±3,77^{cde}	5,64±1,00^{ab}	46,30±3,95^{ab}	6	96,55±6,09^{cd}	4,13±2,51^{ab}	83,58±9,35^{ab}	16	91,41±3,77^{cdef}	4,79±1,00^{abc}	64,94±3,95^{a}
	S	9	84,40±4,68^{abcd}	6,40±1,02^{b}	78,52±5,89^{abcd}	9	98,11±7,61^{bcd}	6,68±1,75^{ab}	99,61±9,08^{bc}	18	91,25±4,68^{cd}	6,54±1,02^{bc}	89,07±5,89^{bcde}
	O	10	86,53±4,67^{bcde}	5,64±0,79^{ab}	109,06±10,87^{ab}	8	97,00±6,59^{cd}	6,34±1,29^{ab}	90,85±8,98^{abc}	18	94,52±4,67^{cde}	5,49±0,79^{abc}	99,96±10,87^{ab}
	N	11	88,65±3,96^{abc}	5,57±1,00^{ab}	98,39±10,08^{abcd}	7	88,07±6,97^{abcd}	6,29±1,86^{ab}	104,66±5,37^{ab}	18	88,36±3,96^{bc}	5,75±1,00^{abc}	101,54±10,08^{abcd}
Keban Dam Lake	D	11	115,78±2,69^{cd}	6,32±1,44^{a}	122,07±23,53^{abc}	8	115,49±4,79^{c}	6,50±1,50^{a}	132,00±26,62^{a}	19	115,63±2,48^{d}	6,13±1,02^{ab}	127,03±17,19^{abc}
	J	13	109,35±2,69^{c}	6,22±0,96^{a}	118,20±18,44^{abc}	10	120,99±5,16^{c}	5,81±1,16^{a}	119,89±20,88^{a}	23	115,17±2,91^{d}	6,51±0,73^{ab}	119,50±13,53^{a}
	F	10	117,96±3,55^{cd}	6,76±1,18^{a}	131,57±22,47^{abc}	10	116,36±3,42^{bc}	6,26±1,78^{a}	117,62±18,23^{a}	20	117,16±2,52^{d}	6,51±1,04^{ab}	127,60±14,08^{ab}
	M	10	114,87±2,31^{d}	7,17±1,05^{a}	112,65±18,86^{ab}	10	113,86±2,07^{c}	6,06±0,85^{a}	130,75±24,75^{a}	20	114,86±1,53^{d}	6,11±0,70^{b}	117,70±15,34^{ab}
	A	9	110,85±2,31^{cd}	6,24±1,72^{a}	161,61±20,38^{c}	6	114,79±2,36^{c}	4,46±1,45^{a}	164,73±19,26^{a}	15	112,43±1,70^{d}	5,09±1,15^{ab}	163,19±12,28^{bc}
	M	9	80,98±1,63^{a}	5,34±1,50^{a}	125,47±19,14^{bc}	12	87,93±4,00^{b}	5,15±1,23^{a}	120,27±19,26^{a}	21	84,45±2,68^{c}	5,84±1,00^{ab}	123,08±13,72^{c}
	J	8	84,64±4,73^{a}	6,20±1,28^{a}	101,65±20,73^{abc}	10	82,87±4,19^{a}	4,13±0,81^{a}	101,78±16,83^{a}	18	83,75±3,12^{a}	5,10±0,77^{a}	101,72±12,73^{ab}
	J	8	97,63±2,44^{b}	6,45±1,28^{a}	92,76±24,66^{a}	8	81,11±5,50^{a}	5,23±1,11^{a}	90,56±24,13^{a}	16	89,37±2,87^{a}	5,42±0,82^{ab}	91,41±16,72^{a}
	A	9	106,56±2,72^{c}	6,89±0,84^{a}	95,04±17,97^{a}	8	86,41±3,37^{a}	4,81±0,93^{a}	111,26±21,17^{a}	17	96,48±2,42^{b}	5,64±0,63^{ab}	99,85±13,65^{a}
	S	11	116,38±2,47^{cd}	7,65±1,27^{a}	107,59±14,08^{abc}	9	108,11±4,08^{bc}	5,63±1,67^{a}	88,77±22,97^{a}	20	112,25±2,23^{d}	6,56±1,03^{ab}	98,12±12,73^{a}
	O	13	110,40±2,59^{cd}	6,01±0,95^{a}	118,76±12,91^{abc}	9	109,97±2,52^{c}	6,42±1,29^{a}	114,45±24,52^{a}	22	110,23±1,80^{d}	6,77±0,76^{ab}	116,09±12,30^{ab}
	N	12	118,46±1,52^{cd}	6,54±1,22^{a}	116,27±14,35^{abc}	9	113,85±0,85^{c}	5,67±1,09^{a}	129,70±19,18^{a}	21	116,15±0,92^{d}	6,91±0,84^{ab}	123,08±11,31^{ab}

a,b,c,d,e,f: Same letters in the same line are not statistically important ($p>0.05$).

0.05). The muscle glycogen amount difference between males of two populations was found to be significant in February and June ($p < 0.05$) and insignificant in all other months ($p > 0.05$) while the muscle glycogen amount difference between females of two populations was found to be insignificant in all months ($p > 0.05$). The blood glucose amount difference between males of two populations was found to be significant in October ($p < 0.05$). The blood glucose amount difference between females of two populations was found to be significant in April, May and November (p <

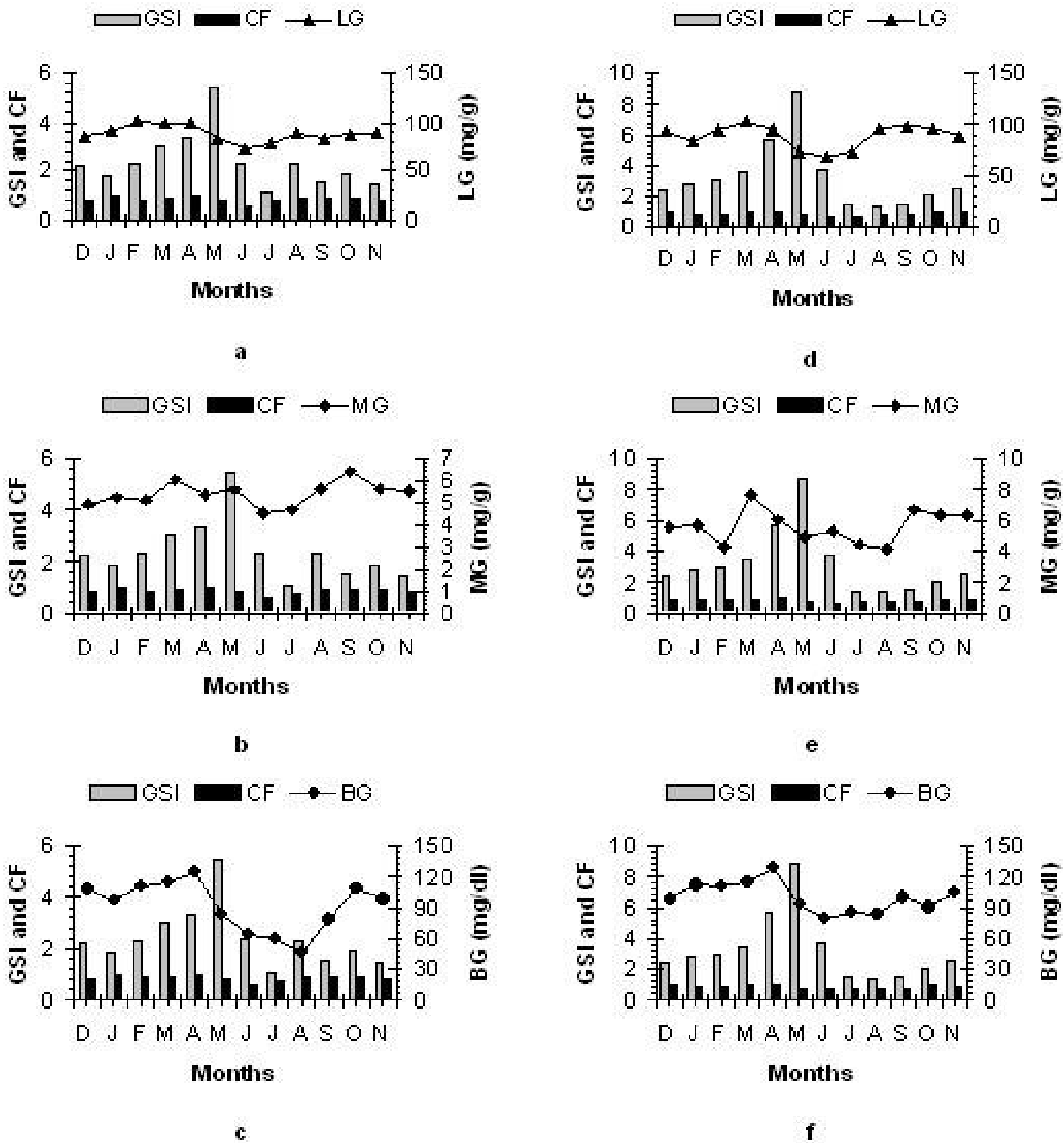

Figure 2. The distribution of liver glycogen (mg/g), muscle glycogen (mg/g), blood glucose (mg/g), GSI and condition factor values of *C. umbla* populations in habiting Hazar Lake according to months and sex groups (a, b, c for male individuals, d, e, f for female individuals).

0.05). The relationships of liver and muscle glycogen amounts and blood glucose amount with repro-duction of *C. umbla* populations from Hazar and Keban Dam Lakes were examined by the appli-cation of GSI and condition factor values.

It is determined that the gonadosomatic index values of *C. umbla* individuals from both popu-lations reached maximum level in May and started decreasing after this month. They laid their sperms and ovaries between May and July. Condition factor value started decreasing in May when gonadal development was at maximum level. It was at minimum level in June when reproduction continues and increased rapidly after this month. The reproduction period of *C. umbla* populations in both lakes was determined to be between May and June (Figures 2 and 3).

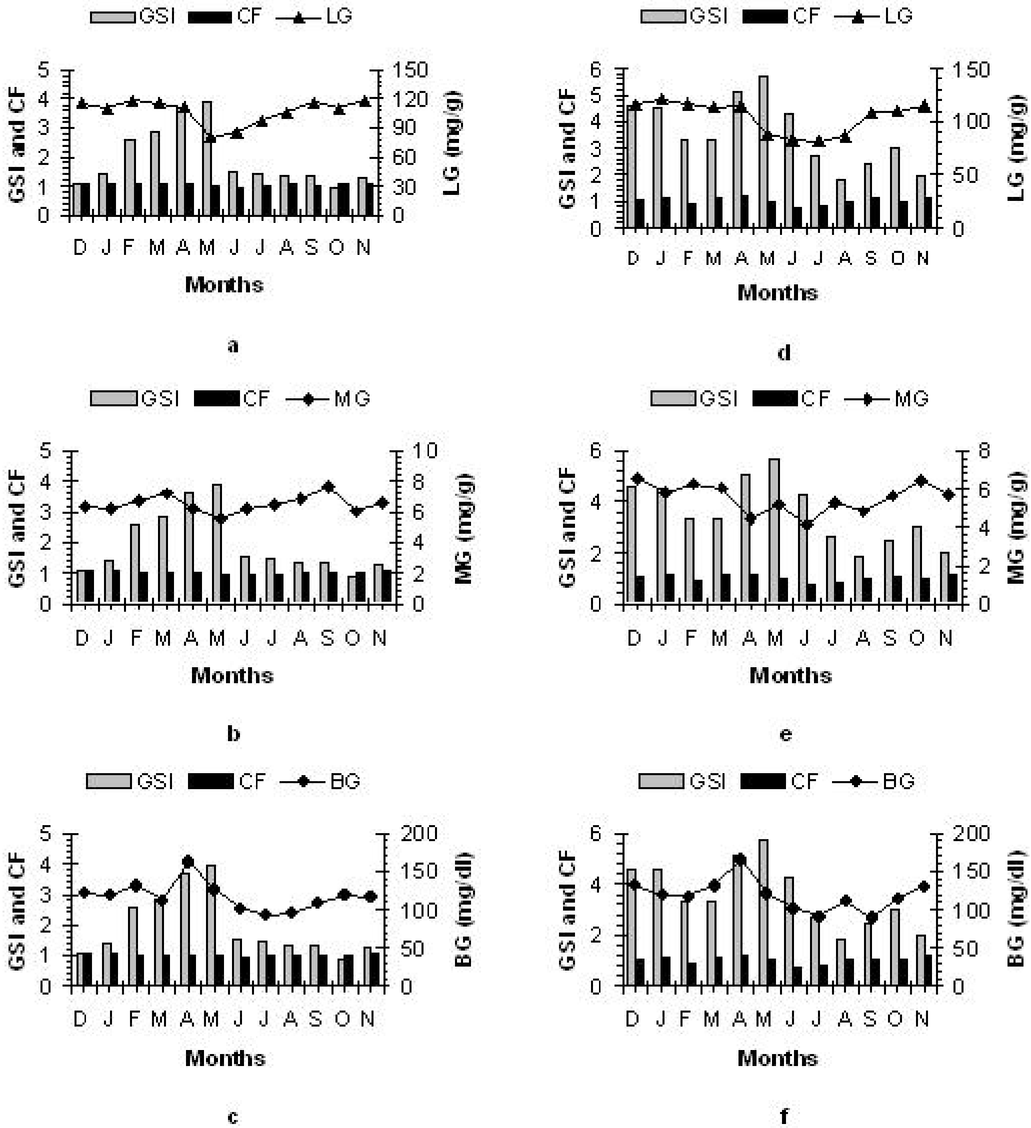

Figure 3. The distribution of liver glycogen (mg/g), muscle glycogen (mg/g), blood glucose (mg/g), GSI and condition factor values of *C. umbla* populations in habiting Keban Dam Lake according to months and sex groups (a, b, c for male individuals, d, e, f for female individuals).

In both regions, liver glycogen and condition factor values started decreasing in May when GSI value was the highest and this decrease pro-ceeded until June (Figures 2a, d and 3a, d). During the period when reproduction activities are low, nutrition reserves such as fat and glycogen accumulate in the body. Relevantly, condition factor in fish tended to increase during this period. In the period, when gonadal development started, the condition factor was very high. Together with the start-up of the gonadal development, reserve materials such as fat and glycogen started to be consumed. The reserve materials in somatic tissues such as liver begin to be transferred to gonads for the formation of oocytes. When ovulation period started, GSI was at the highest level and condition factor was at the lowest level. In this period, the amount of reserve materials in somatic tissues was at the lowest level (Arellano-Martinez and Ceballos-Vazquez, 2001).

The studies on *Gadus morhua* (Lambert and Dutil, 1997), on *Perca fluviatilis* (Girard et al., 1998) and on *Osmerus mordax* (Treberg et al., 2002) have stated that liver glycogen and condition factor were at the lowest level during reproduction and increased after reproduction period. Aas-Hansen et al. (2005) stated that the condition factor (and relevantly liver glycogen values) of *Salvelinus alpinus* which is an anadro-mous fish rapidly decreased during their migration from fresh water to sea.

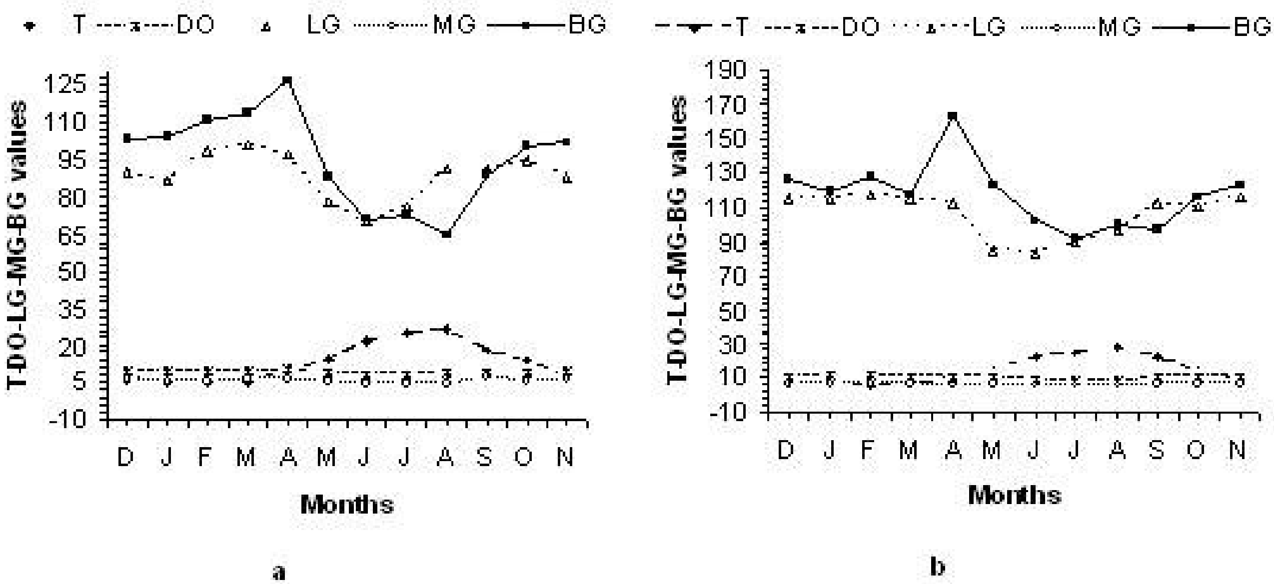

Figure 4. The distribution of liver glycogen (mg/g), muscle glycogen (mg/g), blood glucose (mg/g), temperature and dissolved oxygen values of *C. umbla* populations in habiting Hazar and Keban Dam Lakes according to months and sex groups (a for Hazar Lake; b for Keban Dam Lake).

In most of the seasonal studies (like this one), fish were obtained by hunting, so many resear-chers stated that abnormal changes may occur on the level of muscle glycogen levels. So, the muscle glycogen values may be far away from reflecting the real values. However, in this study, it was determined that muscle glycogen values changed seasonally and were lower during reproduction period (May and July) (Figures 2b, e and 3b, e).

In both regions, it was determined that blood glucose levels increased as a result of increasing energy consumption due to gonadal development and it reached to the highest level in April. GSI was also maximum in April, but it was low in May (when reproduction period starts) and June (when reproduction period continues) (Figures 2c, f and 3c, f). It was determined that blood glucose levels of most fish species decreased when reproduction period started. Various researchers determined that the blood glucose level was high before reproduction and it decreased when repro-duction started (Erdoğan et al., 2000). This decrease may be due to cease of food taking and energy necessary for reproduction consumed from the glucose in blood (Aydin et al., 2000). On the other hand, the blood glucose levels of some fish species was not affected by reproduction activities. This may be due to their different metabolism or feeding habits (Erdoğan et al., 2000).

Some studies on *C. c. capoeta* (Aydin et al., 2000), *C. c. umbla* (Turkmen et al. 2000; Bayir et al., 2007), *C. tinca* (Yildirim et al., 2000) and *Tinca tinca* (Atanasova et al., 2006) stated that blood glucose levels were high just before reproduction, but they decreased after repro-duction started.

Changes depending on temperature and dissolved oxygen

In both Hazar and Keban Dam Lakes, it was determined that the liver and muscle glycogen levels of *C. umbla* populations were very low in summer when temperature was high. They were high in autumn and winter when the temperature is low (Figure 4a, b). The relation between energy reserves (such as glycogen and glucose) and temperature varied according to fish species. These reserves generally increase in cold seasons for fish reproducing in hot seasons and it is just the opposite for fish reproducing in cold seasons. Besides, these values decreased dramatically when temperature exceeded the tolerance limit while they increased parallel to slowing metabolism when temperature decreased below thetolerance limit (Turkmen et al., 2000; Treberg et al., 2002; Bayir et al., 2007; Das et al., 2009).

According to the findings obtained from this study, dissolved oxygen values and glucose values generally showed parallel change. Energy reserves were low dur-ing summer when dissolved oxygen was low and repro-duction took place, while the reserves were high during spring when dissolved oxygen was high (Figure 4a, b). In various studies, it is stated that glucose transportation increased when oxygen was low due to anaerobic ATP production, that liver glycogen amount decreased (with increasing lactate). In low temperatures, energy con-sumption decreased as nutrition, reproduction and swimming activities slowed down or completely stopped (Randall et al., 2004). Therefore, at low temperatures fish have more tolerance against hypoxia and at low temperatures hypoxic conditions, liver glycogen level decrea-ses less (Nilsson, 2004).

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