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REGULAR ARTICLE

Assessment of climate change effects on predation activity and growth of largemouth bass, *Micropterus salmoides* (Lacepède, 1802) by water temperature variations

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ABSTRACT

Water temperature influences the life of species in aquatic ecosystems. Our study was carried out in Deroua Fish farm hatchery (Fkih Ben Salah, Morocco) to assess the effect of climate change effects on predation activity and growth of largemouth bass, *Micropterus salmoides.* It was conducted in six circular tanks (1.5m^3) each one receives five specimens of largemouth bass with a weight ranging from 64g to 185g. To carry out this experience we choose two different ranges of water temperature. The first range was water natural temperature; the second range was thermo-regulated by using an electric heating system. The largemouth daily consumption of prey is 5.1% per day of its fresh weight at a temperature range of 16-18°C and 8.7% per day of its fresh weight at a temperature range of 21-24°C. The duration consumption of the same quantity of prey at the temperature range of 21-24°C it is twice more than at a temperature range of 16-18°C but the daily mean growth rate of largemouth bass at a temperature range of 16-18°C is 0.935g/day, while it reaches 2.11g/day at a temperature range of 21-24°C. Fish farm approach following the waters variations demonstrated an increase of the amount of final product of largemouth bass, highlighting the prediction of long-term specie-specific responses to climate change.

Keywords: Climate change; Largemouth bass; *Micropterus salmoides*; Temperature; Predation; Growth

INTRODUCTION

Concern about the potential effects of climate change is increasing in the last decades. Based on these premises, most published projections of natural resources responses to climate change indicate that there will be large changes in the spatial biodistribution that can be monitored using identification and enrichment of database or by new promising stress biomarkers (Di Finizio et al., 2007; Mazzeo et al., 2008; Guerriero et al., 2017a-c; D'Errico et al., 2018; Guerriero et al., 2018). Indeed, given the importance of species sustainability and of feeding the growing world population we focus our attention on how temperature may influence the life of species in aquatic ecosystems. The effects of chemical interactions such as the relationship between temperature and the quantity of dissolved oxygen in water, pH, concentration of nitrite, nitrate, orthophosphate and other chemical elements (Hasnaoui et al., 2001, 2002a; Guerriero et al., 2002; Hasnaoui and Droussi, 2017; Pecoraro et al., 2017, 2018), on the biological phenomena of species: reproduction, growth, diet (Guerriero et al., 2003-2005a,b; Kumar et al., 2011; Farid et al., 2017; Ouaissa et al., 2017; Ouizgane et al., 2016-2017; Fan et al., 2018) on biochemical and hormonal phenomena (Guerriero 2007; Guerriero et al., 2009; Saei-Dehkordi et al., 2010; Chung et al., 2013; Kumar Juin, 2017, Piscopo et al., 2018) are extensively reported to date. As known, the research on the ichtyofauna of Moroccans inland waters have not known a great development and focused only on the systematic and spatial distribution. The study carried out by Pellegrin in 1921 about the North Africa fish of water bodies remained the only basic monograph fish reference, and it was not

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until the 1980s that research began, with those relating to the non-native fish introduction (see for review, Khodari, 1983). Other research teams have subsequently realized a multidisciplinary research on the warm water fish and their environments in barbel (Cherghou, 2002), carps (Hasnaoui, 2001; Hasnaoui et al., 2002b; Kharroubi et al., 2002; Hasnaoui et al., 2007; Farid et al., 2014; Farid et al., 2017), tilapia (Adey et al., 2014) and largemouth bass and brochet (Ouizgane et al., 2016, 2017).

The largemouth bass present a socio-economical and sport fishing interest in Morocco. It is a fresh and warm water fish; it prefers marshy environments and shallow lakes (Lorenzoni et al., 2002). This fish, considered as a noble fish, has shown a good ability to acclimate to Moroccan conditions. Following regular introduction of fry by the National Center for Hydrobiology and Fisheries, the largemouth bass is currently present in a large number of dam reservoirs and water bodies attracting the interest of fishermen. Therefore, a thorough understanding of the biological, ecological and population dynamics of the largemouth bass under Moroccan environmental conditions is necessary to achieve the objectives of sustainable resources management of this species. This can only be carried out through a better understanding of the biology of this species, its feeding behavior and its mode of interaction with other fish species present in the environment. The largemouth bass is a eurythermal fish. It can grow in water temperatures between 10°C and 32°C, its thermal preferendum was being situated between 27.2 and 30°C (Flouhr and Mary, 2010; Bartiromo et al., 2013). Its tolerance with regard to the minimum and maximum temperature is very high. It supports water temperatures as low as to 2°C and maximum temperatures up to 39°C (Flouhr and Mary, 2010). The current study, addresses two important factors (growth and predation activity) aiming to understand how the climate change can have effect on the largemouth bass culture by the water temperature changes. Subsequently data to follow the behavior of largemouth bass in Moroccan aquatic ecosystems and the adaptations it has developed.

MATERIAL AND METHODS

Study area

The Deroua Fisheries Farm is located in a semi-arid climate, 25 km to the west of Beni-Mellal city (center of Morocco). It is based on plio-quaternary clay-limestone formations (Emberger, 1930). Its main mission is the production of warm water fish seeds to be stocked in Moroccan aquatic environments in order to improve their fish productivities and to control the eutrophication phenomenon observed in the Moroccan dams (introduction of Chinese carps).

Experimental design

This study was carried out from December 07, 2016 to January 21, 2017. The largemouth bass specimens used are produced in the growing ponds of the Deroua Fisheries Farm. The experiments were conducted at the farm's hatchery, where six circular tanks of 1.5 m^3 each were stocked with five specimens with an individual weight ranging between 64g and 185g. The fish stocked has almost at the same age. Table 1 shows the distribution of these individuals in the rearing tanks.

The rearing tanks are supplied with water from the groundwater at a rate of 5L/1min in an open circulating system. Two temperature ranges were adopted; 16-18°Crange, which is the natural temperature of ground water and 21-24°C range, thermo-regulated by using an electrical heating system installed in the hatchery.

Physicals and chemicals parameters of groundwater were monitored, mainly the pH (field pH meter, type: Bioblock Scientific 93301), temperature (Thermometer-combined with a sonde), dissolved oxygen (Field oximeter type ORION 3 STAR), electrical conductivity (Field Conductivity meter, type WTW) as well as nitrite (Afnor, 1983), nitrate (Rodier, 2009) and orthophosphate (Afnor, 1983).

During our experiment, forage fish were distributed at progressive rates of 10%, 20%, 25% and 30% of the total biomass of the largemouth bass specimens reared in the tanks in order to determine the time needed to the total consumption of prey by the largemouth bass and therefore determine the predation rates. The prey distributed were mainly tilapia and gambusia and fingerlings of 3 to 5cm total length.

The total biomass of the five predators placed in each tank was noted at the beginning and the end of the experiments for each temperature range.

Ichthyological balance

The ichthyological balance was quantified by the Swingle coefficient: Cs= F/C where F: forage fish biomass and C: carnivorous fish biomass (Swingle, 1950).

Table 1: Distribution of weight (g) of the largemouth bass in the rearing the tanks

Tank	Individual weight (g)					Total weight (g)	Mean weight (g)
D_1	80	105	92	88	73	438	87.6±11.32
D_2	72	68	68	68	79	355	71.0±4.8
B_1	88	75	71	65	64	363	72.6±9.7
B_2	105	160	116	185	128	694	138.8±33
B_3	176	128	105	144	129	682	136.4±26.2
D_3	150	134	172	123	126	705	141±20.2

Statistical analysis

The statistical analyses were performed using ANOVA one-way analysis.

THE RESULTS

Groundwater quality

The results presented in Table 2 show that the water of groundwater is slightly alkaline but well mineralized with a conductivity of more than 1080 μS/cm and a high nitrate concentration.

Dissolved oxygen in the water tanks

The dissolved oxygen levels in the tanks varied from 4.66mg/L to 7mg/L. These values are within the range of optimal growth of largemouth bass and were homogeneous in all the six tanks. Table 3 shows the average value of the dissolved oxygen recorded in each tank.

Temperature effect of the growth of largemouth bass

The table 4 illustrates the results obtained in each temperature range during this experiment. The temperature showed a noticeable effect on the largemouth bass growth rate, since an increase of 3°C daily average has permitted to double its growth rate. In fact, the daily mean growth rate in the temperature range 16-18°C, is 0.935 g/day, while it reaches 2.11 g/day when the temperature range was set at a range of 21-24°C. Furthermore, this difference in the temperature (3°C) has quadrupled the daily growth rate average of this species in the tanks D_1 and D_2.

Daily growth rates recorded at the beginning of the experiment are low compared to those recorded after. A period of adaptation of the fish to captive conditions has been observed before they start to feed on prey provided for them. This period varied according to the location of the tanks installed at the hatchery. Fish placed in tanks D_1 and D_2, installed near the stairs, where the movement of personnel is quite frequent, required more time to adapt than those installed far from stress conditions.

The statistical analysis of the growth rates average recorded at 16-18 ° C and 21-24°C temperature ranges, performed according to ANOVA in one way, showed that the difference is highly significant (α = 0.003) for two the temperatures ranges. It also showed that the difference of growth in each tank between individuals is statistically insignificant within the same temperature range.

Temperature effect on the rate of predation activity and time needed to total consumption of the prey

The average consumption of the added quantities of forage fish is inversely proportional to the increase in temperature. The averages time needed to the total consumption of forage fish at a feeding rates of 10%, 20% and 30% of largemouth bass biomass was respectively 2; 4.02 and 6.17 days, at a temperature range of 16 - 18°C and 1; 2 and 3.47 days at a temperature range of 21 to 24°C. The average consumption of the equivalent period of 30% of the fresh weight of the largemouth Bass at a temperature of 16-18°C applied for a duration of 8 days in tank B_1 and B_3, while at a temperature of 21-24°C the largemouth bass consumes the same quantity at only 4 days at the tank B_1 and 3.3 days at tank B_3 (Table 5).

The largemouth bass consumes an average quantity of 5.1% per day of its fresh weight at a temperature of 16-18°C. This quantity reaches 8.7% per day of fresh weight at a temperature between 21-24°C (Table 6).

In fact, an individual of 100g consumes 5.1 g/day in the first temperature range and 8.7 g/day in the 2nd temperature range. We also note that the variation in the quantity consumed by the largemouth bass decreases with the increasing of temperature. The mean standard deviation was ± 2.1%) at a temperature range of 16-18°C, while in a temperature range of 21-24°C this parameter has dropped to 1.6%. Therefore, this quantity consumed varied between 3.8% and 5.9% at 16-18, while it varied from 8.1% to 9.7% at a temperature range of 21-24°C. The food conversion rate also was statistically different between the two temperature ranges. The average feed conversion rate at 16 to 18°C was 6.5 while it was 5.2 at 21 to 24°C, indicating that a high temperature range allows to obtain a better food conversion rate.

The ANOVA one-way statistical analysis shows that the effect of temperature on the conversion rate is statistically insignificant (α = 0.458) with a probability level of 5%.

DISCUSSION

The results obtained in this study show that high temperature range has a highly significant effect on the largemouth bass predation activity at a temperature varying between 21 and 24°C. Engle et al. (2013) report that the feeding activity of largemouth bass reaches its optimum at a temperature between 27 and 30°C whereas Flouhr

Table 2: Physical and chemical characteristics of groundwater

pH	Conductivity (μS/cm/)	Dissolved O_2 (mg/L)	T°C	Nitrates (mg/L)	Nitrites (mg/L)	Orthophosphates (mg/L)
7.7	1080	5.63	21.1	5.9	0.09	0.07

and Mary (2009) reveals that when the temperature passes from 10°C to 20°C the largemouth bass trophic activity triples. Our results reinforce data obtained in previous studies showing that at temperature increase of about 3°C, doubles this trophic activity highlighting the challenge and opportunity of such climate change. Indeed, Beamish et al. (2005) highlight that decreasing temperature is the most obvious cause of decreased metabolic activity in this carnivorous species. Through the current study, the time needed to the total consumption of a quantity of forage fish at a temperature of 16-18°C is much greater than that required for the consumption of the same quantity at a temperature range of 21-24°C. The daily average quantity of prey ingested by largemouth bass reaches 5.1% of its fresh weight at a temperature between 16-18 °C and reaches 8.7% at a temperature of 21-24 °C. In fact a specimen of 139 g consumes 7.37g per day, or 53mg.g^{-1} of its fresh weight, at a temperature of 16-18 °C, while between 21 and 24°C, the same specimen consumes 15.23g per day or 97mg.g^{-1}of its fresh weight. Our results obtained in fish farm are in good agreement with Breeggemann et al. (2015) that indicated that the daily feeding behavior of largemouth bass increases with the temperature increase. Our results are similar to those found in rearing ponds of largemouth bass in polyculture with nil tilapia, chinese carp (silver, grass and common carps), blue gill, gambusia where we found that the stomach contents of largemouth bass ranges between 0.1 mg.g^{-1} and 79.4mg.g^{-1} of prey by fresh weight at a water temperature ranging between 19.7 and 32.5°C (Ouizgane et al., 2017). These results seem more informative compared to those obtained by Cochran and Adelman (1982) who showed that the stomach content of largemouth bass at Rebecca Lake varies between 3.6

Table 3: Variation in mean Values of Dissolved Oxygen in tanks

Tank	D_1	D_2	D_3	B_2	B_1	B_3
Dissolved O_2 (mg/L)	6.36	5.21	5.25	5.92	5.66	6.13

Table 4: Growth of the largemouth bass in the two temperature ranges

Tank	16°C- 18°C					21°C-24°C				
	I.B (g)	F.B (g)	G.W (g)	G.W/ind. (g)	D.G (g)	I.B (g)	F.B (g)	G.W (g)	G.W/ind. (g)	D.G (g)
D_1	38	80	42	8.4	0.38	80	693	213	42.6	2.36
D_2	55	40	85	37	1.68	540	711	171	34.2	1.9
B_1	363	56	93	18.6	0.84	56	587	107	21.4	1.18
B_2	694	786	92	18.4	0.83	786	1002	216	43.2	2.9
B_3	682	831	149	29.8	1.35	831	1028	197	39.4	2.18
D_3	705	764	59	11.8	0.53	764	958	194	38.8	2.15
Average				20.66±10.9	0.94±0.5	Average			36.6±8.1	2.11±0.6

W: weight;//WT: total weight;//G.W/ind/g: gain weight/individual/g//D.G/g: Daily growth/g.

Table 5: Average time needed to the total consumption of the quantity of forage fish distributed according to the percentage of the total biomass of the largemouth bass

Tank	Total Biomass (g)	Average duration of consumption per day at 16-18°C			Total weight (g)	Average duration of consumption per day at 21-24°C			
		10%	20%	30%		10%	20%	25%	30%
D_1	438	2	4	6	480	1	2	3	3.6
D_2	355	2	3.3	5	540	1	2	2	3.6
B_1	363	2	5.5	8	456	1	2	2	4
B_2	694	2	4	5	786	1	2	2	3
B_3	682	2	4	8	831	1	2	2	3.3
D_3	705	2	3.3	5	764	1	2	2	3.3
Average		2±0	4.02±0.8	6.17±1.47	Average	1±0	2±0	2.17±0.41	3.47±0.34

Table 6: Quantity of prey (g) consumed at two temperature ranges

	16-18°C					21-24°C				
	TQPD	GTW	Q/d/ind	CR	%	QT	GTW	Q/d/ind	CR	%
D_1	438	42	4.4	10.4	5	696	213	7.3	3.3	7.6
D_2	355	185	4.2	1.9	5.9	783	171	9.2	4.6	8.5
B_1	290.4	93	2.8	3.1	3.8	661.2	107	7.3	6.2	8.1
B_2	664	92	7	7.2	5.3	1139	216	15.22	5.3	9.7
B_3	682	149	6.2	4.6	4.5	1205	197	13.8	6.1	9.1
D_3	705	59	8.3	11.9	5.9	1108	194	13.8	5.7	9.1
Average				6.5±4.03	5.1±0.91	Average			5.2±1.1	8.7±0.77

TQPD: total quantity of prey distributed; GPT: gain total weight; QC/D/ind: Quantity consumed/day/individual; CR: conversion rate; %: percentage of food per fresh weight of largemouth bass.

and 11.4mg.g^{-1}, and the maximum value is reached at the end of summer when the temperature of the lake water reaches 25°C. The differences between predation activities observed in controlled environments (tanks), in polyculture ponds and at natural lakes could be attributed to several factors. In tanks, preys are easily captured by the largemouth bass, whereas at ponds and lakes preys are more likely to escape predation. Indeed, the availability of forage in the natural environment is a factor that influences the quantity of prey consumed and growth of largemouth bass in addition to the effect of temperature variation.

This daily consumption increase of largemouth bass requires a high availability of forage fish so that the ratio Predator/forage keeps its balance and thus enhance the ecosystem ichthyological balance. The lack of forage fish favors the cannibalism phenomenon within the population of in this species therefore impacts its balance. This ichthyological balance, quantified by the Swingle coefficient (Cs= F/C), can be established when the numerical proportion of forage/carnivorous fish is between 3 and 6. This proportion is quantified by the Swingle coefficient: Cs= F/C. where F: forage fish biomass and C: carnivorous fish biomass.

Maintaining this balance in aquatic ecosystems is a real challenge in the future because of the temperature variability related to the climate change. It is therefore necessary to understand and study the predator behavior as temperature increases to predict the future efforts for the conservation and management of the aquatic ecosystems and seafood. Several authors have paid high attention to the fish individual behavior and how they might react with climate change and others have given more attention to interactions between them (predator/prey, prey competition, etc.) (Johnson et al., 2008; Wuellner et al., 2010; Breeggemann et al., 2015).

This study also shows that the temperature has a very significant effect on the largemouth bass growth since the daily growth average rate recorded at a temperature of 21-24 °C is twice higher than that recorded at a temperature of 16-18. °C. This is in agreement with the results obtained by Rodriguez-Sanchez et al. (2009) and Breeggemann et al. (2015). As mentioned above, largemouth bass consumes 8.7%/day of its fresh weight at the first temperature range, while this rate is 5.1%/day at the second temperature range. These results has shown that even with the availability of forage fish with preferred sizes, the growth of largemouth bass seems to be closely dependent on temperature. In fact, the daily mean growth rate average at a temperature of 16 to 18°C is 0.935g/day while it is 2.11 g/day at a temperature of 21 to 24°C. Niimi and Beamish (1974) in their study conducted on the feeding behavior of largemouth bass at a temperature range of 18-30°C claimed that the maximum growth is reached at 25°C and the minimum at 18°C.

The largemouth bass (*Micropterus salmoides* Lacepède, 1802) is a fish from the Southeast of the North American continent. It has become one of the most widespread fish in the world due to the introductions made in several countries from the end of the 19th century to the beginning of the 20th century (Weyl and Hecht 1999; Bernardo et al., 2003; Schulz and Leal, 2005). This fish was introduced to Morocco on 1934 and acclimatized in the lakes of the Middle Atlas (Mouslih, 1989). It seems that this species still keeps its genetic originality since there have been no other introductions since 1934 (Droussi, 2007).The data obtained for largemouth bass in culture about its growth in relation to the temperature can incourage the culture to improve the amount of fish necessary for safe human feeding. The quantities of forage fish requested may not a limit because can be insured by prolific fishes.

CONCLUSIONS

This study has assessed that the predation activity and rate growth of largemouth bass vary considerably with the temperature increasing. The knowledge of these variations in the framework of assessment of climate change effects allow a sustainable management of largemouth bass stocks in the aquatic culture with good security for consumers and higher fish growth production using as natural factor, the water temperature. Furthermore, data obtained on the behavior of largemouth bass help to predict its ability to adapt with biotopes changes. This does not mean that temperature changes in climate change is always favorable, but that catastrophic scenarios generated by some models may be excessively alarmists in relation to the problem of feeding the growing world population.

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