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Artículos Científicos

Relaciones talla-peso y factor de condición de la tilapia Orecochromis niloticus en cinco cuerpos de agua del estado de Jalisco, México

Size-weight relationship and condition factor of tilapia Orecochromis niloticus in five water bodies of Jalisco State, Mexico

Razões altura / peso e fator de condição de Orecochromis niloticus tilapia em cinco massas de água no estado de Jalisco, México

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Resumen

En este trabajo se analizaron las relaciones talla-peso y factor de condición de 3606 individuos de *Oreochromis niloticus* colectados desde enero hasta diciembre de 2010 en cinco cuerpos de agua: dos lagos endorreicos, conocidos como lagunas de Zapotlán y de Cajititlán, y tres embalses artificiales de capacidades similares, denominados presas Calderón, El Salto y Basilio Vadillo. También se exploraron las relaciones entre las variables morfométricas mencionadas con variables de calidad del hábitat como temperatura, oxígeno, pH, potencial óxido reducción (ORP) y sólidos disueltos totales (TDS). El análisis del estado nutricional de los individuos medido a través del índice factor de condición demuestra que los peces que habitan los lagos de Zapotlán y Cajititlán son significativamente más pequeños y con una condición más pobre que los que se hallan en las presas Calderón y El Salto, con la excepción de B. Vadillo, la cual presenta valores semejantes a los lagos. Los valores bajos del factor de condición en los lagos se asocian con niveles bajos de temperatura y concentración de oxígeno disuelto, valores altos de pH y sólidos disueltos, así como un valor bajo en el potencial de óxido reducción, atribuidos a la descarga de aguas residuales de las áreas urbanas adyacentes, con una carga orgánica que afecta la calidad del hábitat acuático e impacta la condición de los individuos. En contraste, las tilapias de mejor talla-peso y condición se capturaron en las presas de El Salto y Calderón, donde los niveles de oxígeno son más elevados, pH cercano al neutro, menor cantidad de sólidos disueltos y potencial óxido reductor positivo. Se asume que talla, peso y factor de condición (K) de los individuos de *Orechromis niloticus* varían en función de la calidad del hábitat.

Palabras clave: aspectos bioecológicos, hidrología, oreochromis niloticus.

Abstract

Variations of size -weight relationships and condition factor of 3,606 individuals of Oreochromis niloticus, collected from January to December 2010, in five water bodies, of Jalisco Mexico, were analyzed. Water bodies include two endorrheic lakes, known as “Laguna: de Zapotlán” and “Laguna de Cajititlán”, and three artificial reservoirs of similar capacities, known as Calderón, El Salto and Basilio Vadillo dams. Relationships between the mentioned morphometric variables and habitat quality variables, such as temperature, oxygen, pH, oxide reduction potential (ORP) and total dissolved solids (TDS) were also

explored. Analysis of the nutritional status of the individuals measured through the condition factor index, indicates that fish that inhabit Zapotlán and Cajititlán lakes are significantly smaller and with a poorer condition than those that live in the Calderón and El Salto dams, with the exception of Basilio Vadillo that presents values similar to lakes. Low values of the condition factor in the lakes are associated with low values of temperature and dissolved oxygen, high values for pH and dissolved solids,and low oxide reduction potential, attributed to the discharge of wastewater from the adjacent urban areas, whose organic load affects the quality of the aquatic habitat and impacts the condition of the individuals. In contrast, greater tilapia sizes, of better weight and condition, were captured in El Salto and Calderón dams, where oxygen levels are higher, pH close to neutral, fewer dissolved solids and a positive oxide reductive potential. It is assumed that size, weight and condition factor (K) of the individuals of Orechromis niloticus, vary depending on the quality of the habitat.

Keywords: bio-ecological aspects, multivariate analysis, hydrology, oreochromis niloticus.

Resumo

Neste trabalho, foram analisadas as relações altura-peso e fator de condição de 3606 indivíduos de Oreochromis niloticus coletados de janeiro a dezembro de 2010 em cinco corpos d'água: dois lagos endorréicos, conhecidos como lagoas de Zapotlan e Cajititlán, e três reservatórios artificiais de capacidades similares, denominadas barragens de Calderón, El Salto e Basilio Vadillo. Também foram exploradas as relações entre as variáveis morfométricas mencionadas e as variáveis de qualidade do habitat, como temperatura, oxigênio, pH, redução potencial de óxido (ORP) e sólidos totais dissolvidos (TDS). A análise do estado nutricional dos indivíduos medidos pelo índice de fator de condição mostra que os peixes que habitam os lagos de Zapotlán e Cajititlán são significativamente menores e com uma condição mais pobre do que os encontrados nas barragens de Calderón e El Salto , com exceção de B. Vadillo, que apresenta valores semelhantes aos dos lagos. Os baixos valores do fator de condição nos lagos estão associados a baixos níveis de temperatura e concentração de oxigênio dissolvido, altos valores de pH e sólidos dissolvidos, além de um baixo valor no potencial de redução de óxido, atribuído à descarga de águas residuais de áreas urbanas adjacentes, com uma carga orgânica que afeta a qualidade do habitat aquático e afeta a condição dos indivíduos. Por outro lado, foram capturadas tilápias com melhor altura e condição nas barragens de El Salto e Calderón, onde os níveis de oxigênio são mais altos, pH

próximo ao neutro, menor quantidade de sólidos dissolvidos e potencial redução de óxido positivo. Supõe-se que tamanho, peso e fator de condição (K) de indivíduos de Orechromis niloticus variam de acordo com a qualidade do habitat.

Palavras-chave: aspectos bioecológicos, hidrologia, oreochromis niloticus.

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Introduction

The exploration of biometric relationships, particularly those that refer to length-weight and condition factor (K), are descriptors of great interest in population biology (Valencia-Santana and Valencia-Santana, 2015), about all of ectothermal organisms such as fish, since these due to their condition (dependent on environmental factors) are very susceptible to variations and changes, which can provide fundamental information about their growth and their nutritional and reproductive status. Likewise, they are widely used parameters to compare the condition of populations that live in aquatic systems with different degrees of disturbance (Cifuentes et al., 2012). Therefore, knowing the basic comparative information of these aquatic populations that inhabit pristine or disturbed ecosystems is very important to understand the dynamics of changes or effects on other species subject to anthropogenic impacts.

On the other hand, and as for the basins, it can be said that they represent natural divisions of the landscape whose ecohydrological functioning is sustained in a fragile and dynamic equilibrium, so any alteration in some of its components will modify the dynamics of the hydrological cycles and biogeochemicals, which will be reflected in the ecological condition of the fish and in the environmental quality of the bodies of water. According to a recent diagnosis (Cotler, 2010), in 66% of the basins of the country the alteration of its dynamics has produced a deterioration from high to extreme in its operation, among which are those of Zapotlán, Cajititlán, as well as those of the Basilio Vadillo, El Salto and Calderón dams, where the analyzed Oreochromis populations live.

However, Nile tilapia (Oreochromis niloticus) is an exotic species with high yields for commercial and local consumption fisheries, hence it is an economic and nutritional

alternative for rural communities in Mexico. In addition, due to its high tolerance and adaptive strategies, it has been introduced and proliferated in more than 100 countries.

For these reasons, the objective of this work is to explore the height-weight biometric relationships to determine how the factor of physiological condition or well-being of tilapia is affected by the variation in the environmental conditions of these five bodies of water.

Study Area

Lerma-Chapala-Santiago Basin

The five bodies of water in the study area are located in the VIII Lerma-Santiago-Pacific hydrological region, in the Armería-Coahuayana hydrological subregion (figure 1). This area is constituted by two natural lakes (Zapotlán and Cajititlán, whose characteristics are endorheic) and three artificial reservoirs or dams (Basilio Badillo, Calderón and El Salto, with exorreic characteristics). The comparative study was considered relevant, since they are satellite bodies of water from the Lerma-Chapala-Santiago and Ayuquila-Armeria regions, indicated as priorities for requiring urgent measures to recover their ecohydrological functioning (Cotler, 2010).

Figura 1. Área de estudio (localización de los cinco cuerpos de agua)

Fuente: Elaboración propia

Zapotlan Lake (known as Zapotlán Lagoon) is located south of Jalisco, in western Mexico. This belongs to the sub-basin of the same name and has an approximate extension of 499 km2, with an average depth of 4.75 m and an annual average evaporation of 17.7 mm3 (Jalisco State Water Commission [CEA], 2015).

Lake Cajititlán (also known as Laguna) is located within the metropolitan area of Guadalajara; It is 9 km long, 2 km wide and a maximum depth of 4 m. Its estimated storage capacity is 54,400 mm3 in an area of 1700 hectares.

The Basilio Badillo dam is located in the municipality of Ejutla, Jalisco, about 25 km northeast of the town of El Grullo, and has a water mirror of 500 ha, with two vertices in length (4.67 and 5.55) and widths of 2.06 km and 0.89 km, with capacity for 85 000 mm^3.

Elías González Chávez Dam (known as Calderón Dam) is located in the municipality of Zapotlanejo, in Jalisco. It has a water mirror of 382 ha, with a length of 6.15 km, 1.56 km wide and 80 000 mm3 capacity.

The El Salto dam is located in the municipality of Valle de Guadalupe, in Los Altos de Jalisco, 12 km away from the municipal capital; with a water mirror of 959 ha, length of 8.58 km and variable widths (between 3.73 km, 2.20 km and 1.76 km) and a capacity of 85 000 mm3.

From the analysis of the microbasins where the five studied sites are located, it was determined that the three dams are exorheic microbasins, while those of the lakes are of the endorheic type. In addition, although the catchment areas and lengths of the main channels related to the three dams are different, their storage volumes are similar (Calderón 80,000 dam, while Basilio Vadillo and El Salto 85,000 mm3). On the other hand, natural lakes have different storage capacities (Cajititlán 54 400 mm3 and Zapotlán 27 000 mm3).

The concentration times related to the length and average slope of the riverbed are relatively short, not exceeding 4 hours in natural lakes, while for reservoirs they range between 8 and 19.4 hours. Likewise, there are certain similarities in the total catchment areas between the Zapotlán lagoon basins and the Calderón dam, although the storage capacity of said “lagoon” is the smallest of the five water bodies. If the storage volume (mm3) / surface (ha) ratio is considered, the dams studied are deeper, since they have values ranging from 88-209, while the lakes are more shallow, with a range of values of only 27-32.

The populations near the studied lakes have a profound influence on the deterioration of their aquatic environment, since both lakes (Zapotlán and Cajititlán) receive direct discharges of wastewater. This has seriously affected the environmental variables of water, the BOD / COD ratio, which has favored the proliferation of aquatic weeds (such as lily Eichornia crassipes) that block aquatic photosynthesis, increase evapotranspiration and cause loss of habitat quality. for aquatic organisms. This eutrophication / dystrophy affects fishing, navigation and tourism, which generates large economic losses. Regarding the presence of superficial aquatic weeds, the lakes had similar lily coverage, with annual averages between 14% and 17%.

Materials and methods

Biometric data (size, total length and weight) were measured in 3606 fresh specimens of O. niloticus tilapia (Linnaeus 1758) from commercial catches in the five bodies of water mentioned. The capture was made with 3.5-inch gillnets, between January and December of 2010. For the physical-chemical characterization of the water in the five reservoirs, six variables were measured using a YSI-556 probe, in 4-8 georeferenced stations and three depths deep (-20 cm), half water and surface (-20 cm). The variables were temperature (° C), hydrogen potential (pH), dissolved oxygen [mg / l], oxide-reduction potential (ORP), total dissolved solids (DST) and salinity.

Analysis of data

Fulton condition factor (K)

The condition factor (K) is used in fish to measure the volumetric ratio as a function of weight, since it allows not only to compare fish of the same lengths, but also to determine the degree of well-being or robustness (Martínez, 1987). This is estimated by the following expression:

$$k = 100*WL^3$$

As *W* is the wet body weight in grams and L the length in centimeters. The monthly variation between the water bodies of the K factor was analyzed using an Anova test.

Relationship between length and weight

To define the relationship between weight and length, the data were adjusted using a power model calculated by the least squares method.

$$W = A*Lb$$

As *W* It is the weight in grams and L the length in centimeters (Da Costa and Gerson, 2003). The coefficient b provides information about the type of growth that the species exhibits; if $b = 3$, the growth is isometric, and when $b \neq 3$, it is allometric (Bagenal and Tesch, 1978; Ricker, 1975). When $b > 3$, individuals of greater size increase their weight in greater proportion than their length (positive allometry); when $b < 3$, the length is preferentially increased more than its weight (negative allometry); In addition, isometric growth species that fluctuate within the values are considered $b = 2.5$ y $b = 3.5$ (Carlander, 1969; Froese, 2006).

Results

The size composition in the tilapia capture has a bias due to the selectivity of the networks that were used in the sample captures. Specifically, 92.48% of the catch is based on sizes 18 cm to 24 cm in total length, that is, adult individuals (table 1). The averages of weight and height measured in the five bodies of water ($p < 0.005$) exhibit statistically significant differences ($p < 0.5$), in the data grouped by seasons (quarters).

Tabla 1. Valores descriptivos de los peces

Lugar	Sexo		Media	Desv. típ.
Zapotlán	Macho	L total	22.71	1.17
		Peso	203.82	81.21
	Hembra	L_total	22.51	1.18
		Peso	200.12	29.28
Basilio Vadillo	Macho	L_total	24.57	1.76
		Peso	267.33	61.71
	Hembra	L_total	23.70	1.48
		Peso	250.41	45.20
El Salto	Macho	L_total	26.71	2.46
		Peso	375.53	100.61
	Hembra	L_total	26.56	2.14
		Peso	378.09	87.28
Calderón	Macho	L_total	28.72	2.64
		Peso	486.78	123.33
	Hembra	L_total	30.71	4.30
		Peso	589.45	240.64
Cajititlán	Macho	L_total	20.81	2.40
		Peso	183.80	45.03
	Hembra	L total	21.05	1.96
		Peso	186.67	36.81

Fuente: Elaboración propia

Length-to-weight ratio

The analysis of height-to-weight relationships was better defined by the potential model of the form $W = A L^b$. Table 2 shows the determination values (R2) F value, degrees of freedom, significance and the parameters a and b of the equations for each body of water.

Tabla 2. Parámetros de las ecuaciones del modelo talla-peso por cuerpo de agua

Sitios	Resumen del modelo				Parámetros	
	R^2	F	gl	Sig	a	b
Zapotlán	0.63	1770.21	1040	0.000	0.244	2.14
Basilio Vadillo	0.644	1422.64	785	0.000	0.136	2.36
El Salto	0.83	2514.91	514	0.000	0.042	2.78
Calderón	0.875	4900.11	699	0.000	0.08	2.59
Cajititlán	0.735	1610.51	580	0.000	0.314	2.1

Fuente: Elaboración propia

For all the bodies of water the coefficients of determination were low, since they vary from 0.875 for Calderón to 0.630 for Zapotlán. The lowest values correspond to Zapotlán, B. Vadillo and Cajititlán, with 0.63, 0.644 and 0.735, respectively (two natural lakes and one dam). Only El Salto and Calderón dams had determinations greater than 0.8, with 0.830 and 0.875, respectively.

Parameter b is the basis for the interpretation of the model and represents the form of growth for each population: isometric (2.5> b <3.5), positive allometric (b> 3), negative allometric (b <3). According to the values found for b, all water bodies fall within the range of negative allometry (b> 3) and in only two cases isometry was presented, that is, values greater than 2.5, which correspond again to the dams. Salto and Calderón (with 2.78 and 2.59, respectively), while the lowest values were for the lakes Cajititlán, Zapotlán and the dam B. Vadillo, with 2.10, 2.13 and 2.36, respectively.

Physicochemical variables

In the five bodies of water the average temperature was 22.75 ° C and intervals of 16.54 to 28.53. The maximum values were presented in July-September and the minimum values in November-January. Particularly, with an average of 25 ° C, the Basilio Vadillo dam turned out to be the warmest, with variations of more than 2 degrees in almost all cases, followed by Calderón, Zapotlán, Cajititlán and El Salto (natural lakes did not show significant differences among them).

The site with the highest concentration of dissolved oxygen in the water was Calderón. Likewise, El Salto and B. Vadillo stand out for their wide variations, while the lakes remained more or less stable in relation to this factor and without significant differences. Pearson's correlation analysis between oxygen concentrations and temperatures, although low, were reversed in all cases: that is, high oxygen concentrations are related to low temperatures. The correlation values (r) for each body of water were -0.44, -0.12, -0.04, -0.63, -0.78, in Zapotlán, B. Vadillo, El Salto, Calderón and Cajititlán, respectively, and only in El Salto la relationship was not significant.

Another factor that was high (that is, alkaline) in all the analyzed sites was the pH, since the variations were wide in the three dams, while in the lakes it varied little. Significant differences were found between B. Vadillo and the lakes. Total dissolved solids showed an average of 0.32 g / l, with a minimum of 0.13 and a maximum of 0.69 g / l. The averages of the bodies of water reached significant differences ($p < 0.5$) and the highest for this factor were 0.63 and 0.4 g / l, which correspond to the Zapotlán and Cajititlán lakes, respectively. Suspended solids can increase turbidity and also decrease oxygen concentration. For the oxide-reduction potential only in Calderón, both individual and average (although low) positive values were presented, while in the other bodies of water the averages were close to zero in B. Vadillo and negative in the remaining sites (figure 2).

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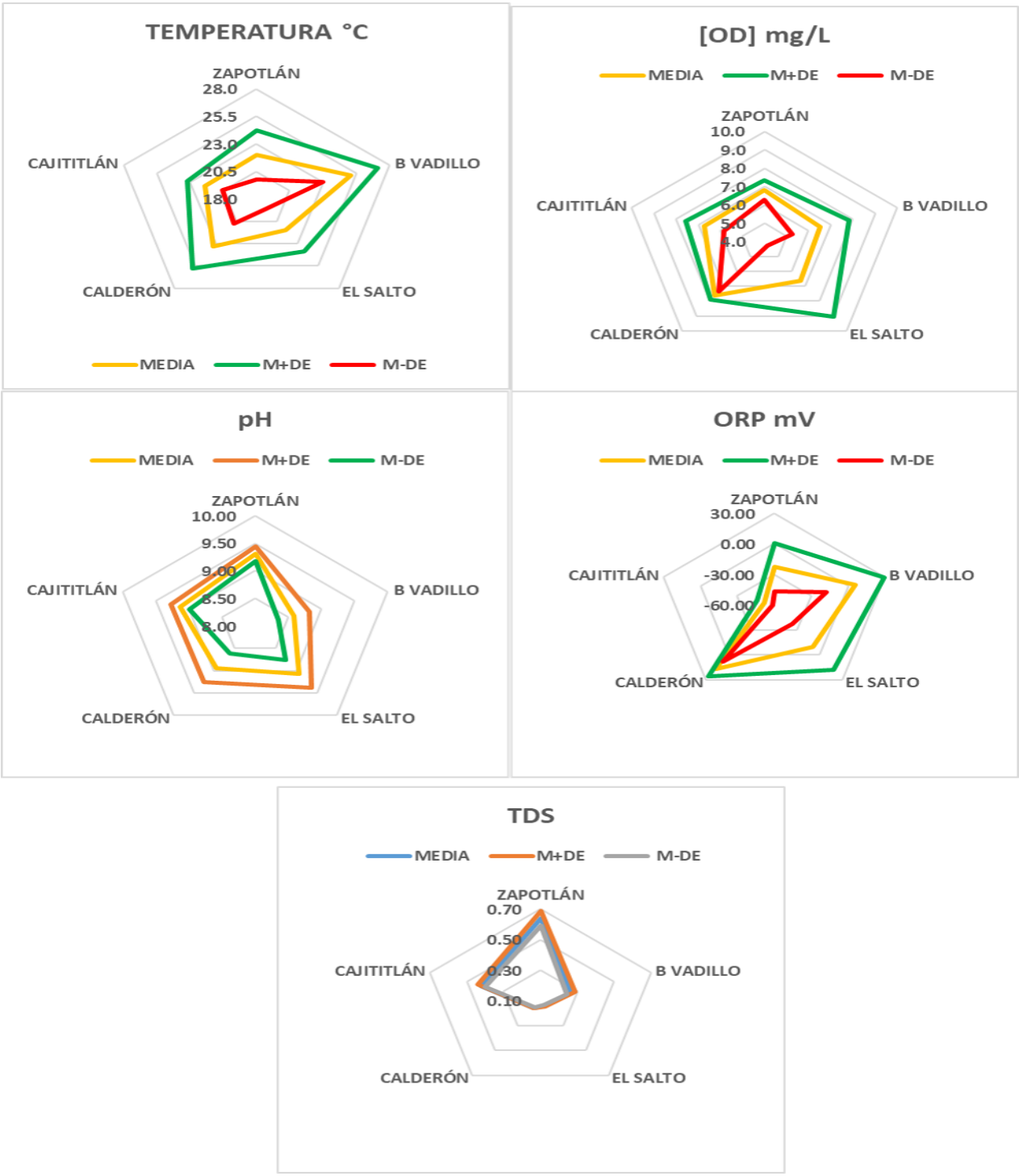
Figura 2. Representación de los promedios ± desviación de las variables ambientales



Fuente: Elaboración propia

Fulton condition factor (K)

The average values of the condition factor in all months were quite variable and with significant differences in time and body of water ($p < 0.01$) (table 3).

Tabla 3. Prueba posthoc para factor de condición

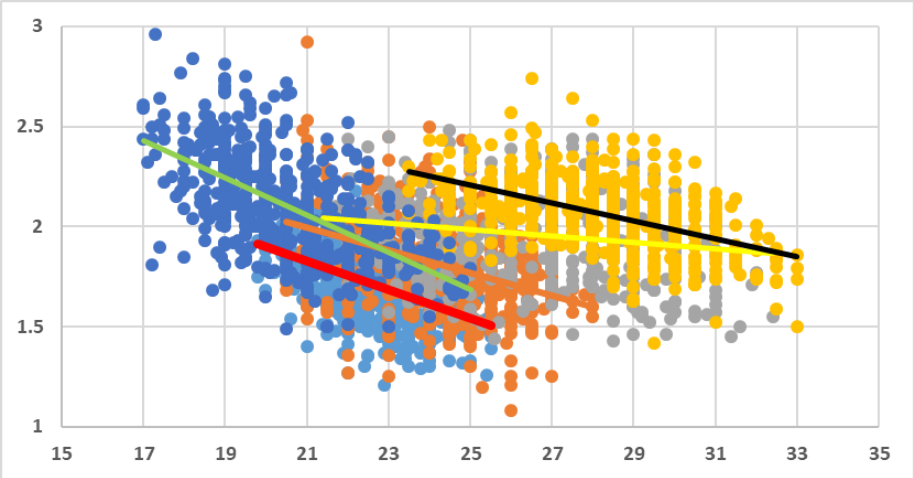
k_Fulton						
	Lugar	Subconjunto para alfa = .05				
HSD de Tukey (a,b)	Zapotlán	1.716				
	B. Vadillo		1.813			
	El Salto			1.959		
	Calderón				2.063	
	Cajititlán					2.101

Fuente: Elaboración propia

The lowest averages were presented in Zapotlán and B. Vadillo, while the highest averages in Calderón and Cajititlán. The tendencies to descend temporarily appeared in Calderón and B. Vadillo, to increase in El Salto and Cajititlán and to always remain low in Zapotlán (figure 3).

Although the sizes of the organisms are quite homogeneous, the individual variation of the condition factor exhibits a random pattern ($R2 > 0.33$ in all cases), tending to decrease with the size in the bodies of water (Figure 3), but with slopes “Soft” in El Salto (-0.016) and Calderón (-0.045), regarding steeper slopes in B. Vadillo (-0.056), Zapotlán (-0.072) and Cajititlán (-0.093), respectively (table 4).

Figura 3. Regresión lineal simple entre la talla y el factor de condición de Fulton (K) en cada cuerpo de agua, en orden descendente de acuerdo con la pendiente (b)



Fuente: Elaboración propia

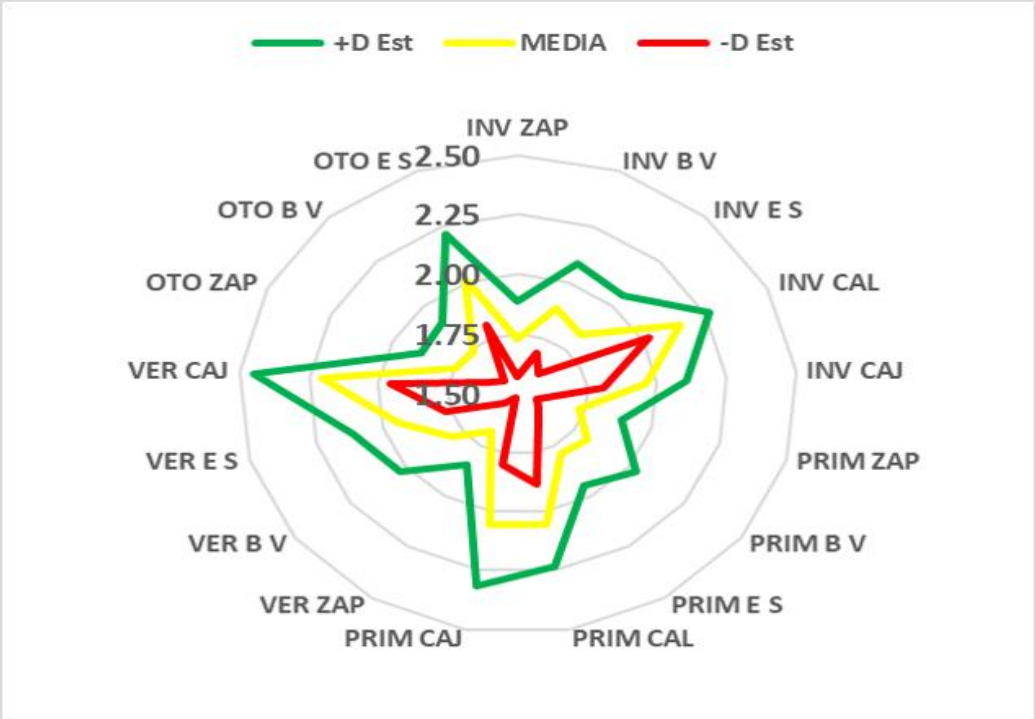
Tabla 4. Parámetros del modelo factor de condición K y talla LT prueba poshoc para factor de condición tabla

Sitio	Modelo lineal	r^2
Cajititlán	K= -0.093LT +4.012	0.331
Zapotlán	K= -0.072LT +3.337	0.242
B. Vadillo	K= -0.056LT +3.180	0.138
Calderón	K= -0.045LT +3.331	0.235
El Salto:	K= -0.016LT +2.389	0.032

Fuente: Elaboración propia

The temporal distribution of the condition factor shows that the lowest values were always presented in Zapotlán; in B. Vadillo there were low pre-floods and post-floods and intermediate rains; for El Salto, intermediate values were also presented in all samples regardless of the season; Calderón recorded the highest values (regardless of the season), while Cajititlán had high post-flood and intermediate values in the remaining samples (Figure 4).

Figura 4. Representación del factor de condición por lugar y temporada



Fuente: Elaboración propia

Relations between environmental and morphometric factors

The correlation analysis between environmental and morphometric variables showed significant direct relationships between height and weight ($r^2 = 0.933$), size with ORP (0.505), and inverses between size and TDS ($r^2 = -0.656$). The weight being highly related to height also showed significant relationships with TDS and ORP (with r2 = -0.71 and 0.496, respectively). On the other hand, although the condition factor depends on the size and weight variables, it only exhibits an inverse relationship, very weak with TDS r2 = -0.447. Regarding environmental factors, the pH was directly related to TDS and inverse to ORP, while between TDS and ORP it was inverse (table 5).

Tabla 5. Análisis de correlación de Pearson entre variables morfométricas y ambientales

	L_Total	Peso	K_Fulton	Temp	DO	pH	TDS	ORP
L_Total	---	**0.933**	-0.036	0.128	0.016	-0.235	**-0.656**	**0.505**
Peso	0.0000	---	0.299	0.082	0.04	-0.208	**-0.710**	**0.496**
K_Fulton	0.037	0.0000	---	-0.099	0.101	-0.091	**-0.447**	0.134
Temp	0.0000	0.0000	0.0000	---	-0.115	-0.111	-0.143	-0.032
DO	0.377	0.027	0.0000	0.0000	---	0.234	-0.112	0.095
pH	0.0000	0.0000	0.0000	0.0000	0.0000	---	**0.496**	**-0.482**
TDS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	---	**-0.491**
ORP	0.0000	0.0000	0.0000	0.076	0.0000	0.0000	0.0000	---

Fuente: Elaboración propia

Discussion

Tilapia is an exotic fish of tropical origin that has wide tolerance and adaptability, with thermal optimum ranging from 25-28 ° C to 32 ° C (National Fisheries Institute [Inapesca], 2011). Therefore, if it drops to 20 ° C, they stop eating; and if they show sudden changes of 5 ° C or decreases to <12 ° C, they can cause mortality (Inapesca, 2011).

However, in all cases - with the exception of the dam B. Vadillo - minimums were registered <20 ° C, which indicates - according to the average temperature values - that the analyzed water bodies do not reach the optimum values for their development .

Oxygen is essential in aquatic systems because it conditions the distribution, behavior and growth of organisms (Wetzel, 2001). Oreochromis niloticus is also tolerant at low concentrations of oxygen> 3mg / l, although temperatures above 30 ° C increase its consumption, while concentrations below 5 mg / l and 6 mg / l decrease metabolism, food consumption and satiety, so that individual growth slows down (Inapesca, 2011; Pandit and Nakamura, 2010). Therefore, this is likely to have occurred at least in the B. Vadillo and El Salto dams.

In the case of Oreochromis that is under cultivation, it is recommended to maintain dissolved oxygen concentrations higher than 5 ppm or 5 mg / l (Bautista and Ruiz-Velasco, 2011), since under experimental conditions, concentrations below 3mg / l they have as a response a lower food intake; In addition, there is a direct relationship between body size and demand or consumption (smaller organisms consume more oxygen). Likewise, consumption is also related to feeding behaviors: organisms at 3 mg / l consume more food in the morning,

while at 5.6 mg / l they do more in the afternoon (Tran, Ben, Dam and Schrama, 2008). In the case of the water bodies object of this study, only El Salto showed values close to 4 mg / l, while all others were relatively normal, that is, above 5 mg / l.

The assessment of the quality of the aquatic habitat from physical-chemical variables (which have a direct effect on the physiological behavior of organisms, such as those used in this study) is a very useful tool to demonstrate anthropogenic impacts on the bodies of Water. The temperature measurement that established suboptimal levels of this factor for the species, standard concentrations of dissolved oxygen, quite alkaline pH deviated from the basic, high organic loads that modify the total suspended solids and the potential reducing oxide in the water bodies provide information of the degree of alteration in all the cases studied in the aquatic habitat (Orozco, Pérez, Gonzáles, Rodríguez and Alfayate, 2015); On the other hand, the bioecological indexes provide this information, but do not indicate anything about the factors responsible, so it is advisable to use both in the evaluation. One of the advantages of physical-chemical methods is their speed, so they can be monitored more frequently, unlike biological methods, which require massive observations and precise measurements of quite uncertain processes and wide variation that beings exhibit alive (Samboni, Escobar and Escobar, 2007), as documented in this study.

According to the temperature values found in the El Salto and Calderón dams, as well as in the lakes of Zapotlán and Cajititlán, it allows them to be classified as cold water, while the waters of the B. Vadillo dam are a bit warmer. Unlike the three dams, the lakes of Zapotlán and Cajititlán (of endorheic characteristics) have oxygen concentrations similar to eutrophic lakes. These concentrations are related to very low values of OPR and high values of TDS and pH, as a result of high organic loads, mainly nitrogen, ammonium (NH3) and phosphorus, since they are direct recipients of industrial and urban wastewater from surrounding towns. , in addition to other diffuse sources that result from agricultural activity.

The factors of dissolved oxygen, pH, total dissolved solids (TDS) and potential oxide reduction (ORP) appear to be related to the number of inhabitants in the basin and the distance from urban locations to the sites where the samples were taken: 18 155 inhabitants in the Calderón river basin; 32 220 inhabitants in the basin where the El Salto dam is located and more than 100,000 inhabitants in the basin where Lake Zapotlán is located.

Discharges of both nitrogen and phosphorus constitute a major problem for the survival and ecological and economic sustainability of bodies of water near urban areas (Eugercios-Silva, Álvarez-Cobelas and Montero-González, 2017), since nitrogen In the form of ammonium, it can be toxic to fish, even tilapia, despite its resistance and adaptability. On the other hand, nitrates and phosphates intensify the growth of plants and algae, which accelerates the eutrophication of lakes and reservoirs (Campos-Pulido, Alonso-López, Avalos-de la Cruz, Asiain-Hoyos and Reta-Mendiola 2013), as It is shown by the coverage of the lily Eichornia crassipes documented in the present study (Table 2).

In addition, at low concentrations of dissolved oxygen, fish are more susceptible to diseases, since metabolic activity is limited (Tomalá, Chavarría and Escobar, 2014). In the lakes, the problems are aggravated when considering the endorheic condition, since the only water inlet to the system is of a rain nature (by rain), while its only exit is by evaporation, which gives it a dilution dynamics and temporary concentration, although linked to the annual precipitation cycle (Bernal-Brooks, 2002). In contrast, in the dams this dilution-concentration pattern is related to its management, which explains the differences between the five bodies of water in this study, as well as the individual random variations of the condition factor and the trends of these variations in relationship with size or weight, and / or lake or dam in question.

Finally, it should be emphasized that in the lakes of Cajititlán and Zapotlán, serious problems of environmental deterioration are faced due to the contamination of solid waste and the drag of agrochemicals (Ministry of Environment and Territorial Development [Semadet], 2015). According to estimates, in 2013 in Cajititlán 99.5 l s-1 of wastewater was generated, which was 57.38% (that is, 57.5 l s-1), a percentage that dropped to 50% in 2016 (CEA, 2016); while in Zapotlán only 75% of the wastewater from Guzmán city (Santoyo, own data 2017) was treated, without considering other populations such as Gómez Farías and San Andrés, which also discharged wastewater into the lagoon. Other problems that influence the deterioration of the watershed and the quality of the aquatic habitat of Lake Zapotlan are those caused by the pressures derived from changes in land use - from forestry to urban in the lower basin and from forestry to agricultural (orchards of avocado and livestock) - as well as clandestine logging in the upper basin and even within the snow-capped Colima National Park (Semadet, 2015).

Conclusions

The bodies of water that receive urban wastewater discharges without due treatment showed smaller fish sizes, as well as smaller weight and length, especially in the case of Cajititlán and Zapotlán, which are located in the vicinity of two urban areas (zone Guadalajara metropolitan and southern metropolitan area). In addition, the water bodies of Cajititlán and Zapotlán share two of the lowest average temperatures, the two highest average pH, the two highest salinities, the two most significant TDS and the smallest ORPs. In other words, four of the six variables are in extreme conditions in these reservoirs.

As for the larger tilapia, these were captured in the El Salto and Calderón dams. It is important to mention that the condition factor (K) of the fish varies mainly depending on the weight and length, and in this study it was closely related to the pollution conditions of the bodies of water.

Since the oxygen measurements for this study were diurnal, it is recommended to work with others in the dark part of the day to establish the dynamics of oxygen and its possible implications on fish growth, particularly for the cases of Zapotlán and Cajititlán, which showed high levels of dystrophy.

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