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Morpho-Physiological, Blood Biochemistry And Health Status In Wild Yellow Snapper *Lutjanus Argentiventris* (Peters, 1869)

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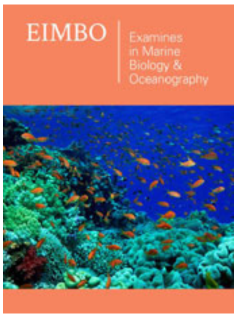

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Abstract

Length-weight relationships, morpho-physiological index and blood biochemical parameters are frequently used to determine the health status of wild and cultured fish. Between December 2013 and July 2015, a total of 123 yellow snappers (*L. argentiventris*) were captured with gillnets in the Macapule Lagoon and blood samples were taken. All the blood biochemical parameter varied significantly among sampling seasons. The total proteins, triglycerides, and cholesterol values were significantly highs in December 2013 (cold season). We found significant differences intra and inter-correlations between morpho-physiological and blood biochemical parameters in bout seasons. The equation parameters (a & b) of the length-weight relationship in each of the seasons indicated that the growth of yellow snapper showed important variations over time between year 1 and year 2. Among the morpho-physiological index, only the Hepatosomatic Index (HIS) and Gastric Repletion Index (GRI) varied significantly among the seasons ($P<0.01$); and they were positively correlated with water temperature. In conclusion, the morpho-physiological and blood biochemical examinations determined for the first time for yellow snapper in Macapule Lagoon, showed a wide temporal variation and were related to environmental changes between seasons. This new data can be used as a reference to compare health conditions between wild and captive yellow snapper (*L. argentiventris*) and other fishes.

Keywords: Hematological variables; Biochemical variables; Warm water; Cold water; Environmental changes; Fish health

Abbreviations: pH: hydrogen Potential; Mg dL^{-1}: Milligrams per deciliter; mL: Milliliters; g: Relative centrifugal force; log x+1: Logarithm of one to base ten; ANOVA: Variance Analysis; r^s: Spearman's correlation coefficient

Introduction

The worldwide marine environment is affected by global warming, as a result, we have climate change that affects physicochemical variables in the water and the internal fish physiology. Indeed, due to fish are ectothermic animals, variables as temperature, oxygen dissolved and pH, affect its physiology, metabolism and behavior (Pörtner 2008; Sampaio 2019). These physicochemical variables, singly, or combined, impose different morpho-physiological stress in fish and impair their health Adams [1]. The different types of stress and health condition in fish have been evaluated using several approaches: e.g., hepatosomatic index, condition factor, gastric repletion index, natural season, origin, sex, size Cabrera [2] and reproductive status Martínez [3], Santamaría [4].

In addition, studies in stress and health condition in fish, also shown how variations in environmental conditions can cause important internal physiologic modifications in blood biochemistry and hematological status (Alvarado [5], Valenzuela [6], Pedro [7], Román [8]). These variation can be observed in the total protein, cholesterol, triglycerides, and glucose levels in blood, which also have been used as physiological indicators to infer the environmental effect on fish Quintana [9]. However, studies on how the warm and cold season in coastal water can affect the natural hematological characteristics in wild fish populations had not been explored.

In general, in fisheries and aquaculture field, the fish health condition has been evaluated using fish growth as a principal reference. Under this worldwide global warming situation (Alfonso et al., 2020), water temperature changes would significantly impair juvenile recruitment in the estuaries and commercial fishing may be impaired shortly.

Belong to the Lutjanidae family, yellow snapper is one of the most important fishery resources along the Mexican Pacific coast. The commercial landings of this species have a total yield of 385.83 metric tons in 2014 (CONAPESCA 2016). Yellow snapper fishery is mostly artisanal, given that the fish lives in the mangroves of coastal lagoons during its juvenile phase (González [10]) and migrates offshore as an adult, where it remains in reef zones down to 60m depth (Fischer [11]). Research on yellow snapper has focused mainly on determining its natural growth rate and age structure in different coastal areas ([Rojas [12], Garcia [13], Ibañez [14], Gómez [15], Ramírez [16]), as well as its feeding habits and reproductive cycle (Santamaría [17], Piñón [18], Flores [19]). However, no information is currently available about the health condition of wild yellow snapper populations. Therefore, the objective of this study was to evaluate the natural health condition in populations of yellow snapper (*L. argentiventris*) inhabiting the coastal lagoon of the Gulf of California, subject to a wide variation in temperatures throughout the year. The new knowledge will be of great importance to compare health condition between wild snapper or different species of cultivated fish worldwide.

Material and Method

Site selected to collect fish and blood samples

Fish samples were collected in the Macapule Lagoon. This lagoon has fluctuations in temperature values, the maximum temperature in summer is 27 ºC and the minimum is 13 ºC during the winter. Coastal ecosystems like Macapule Lagoon support diverse and important fisheries in the Gulf of California and are reservoirs of great biological diversity. In addition, the Northern of Sinaloa State population has grown, and its urban development has increased the necessity for recreation areas, as well as the pollution, has substantially increased putting up the pressure on marine resources. Macapule lagoon is part of the San Ignacio-Navachiste system, located in the southern region of the Gulf of California 25º 21' and 25º 24' N; 108º 30' and 108º 45' W (Figure 1). In 2008, San Ignacio-Navachiste-Macapule lagoon system was declared an "Area of Reserve and Refuge for Migratory Birds and Wildlife - Gulf of California Islands" MEX-111 and 1826-RAMSAR, 79 87302, February 02, 2008. Due to its location, this lagoon has a high primary productive ambient (first links in the production chain) (Cota [20]. To see if the natural variation of physio-chemical variables as water temperature, dissolved oxygen, pH, and salinity an influence in health condition of yellow snapper (*L. argentiventris*) have, they were measured each time and in each place that we collected fish blood samples, using a YSI (55-12FT) probe and a portable refractometer (RHS-10ATC).

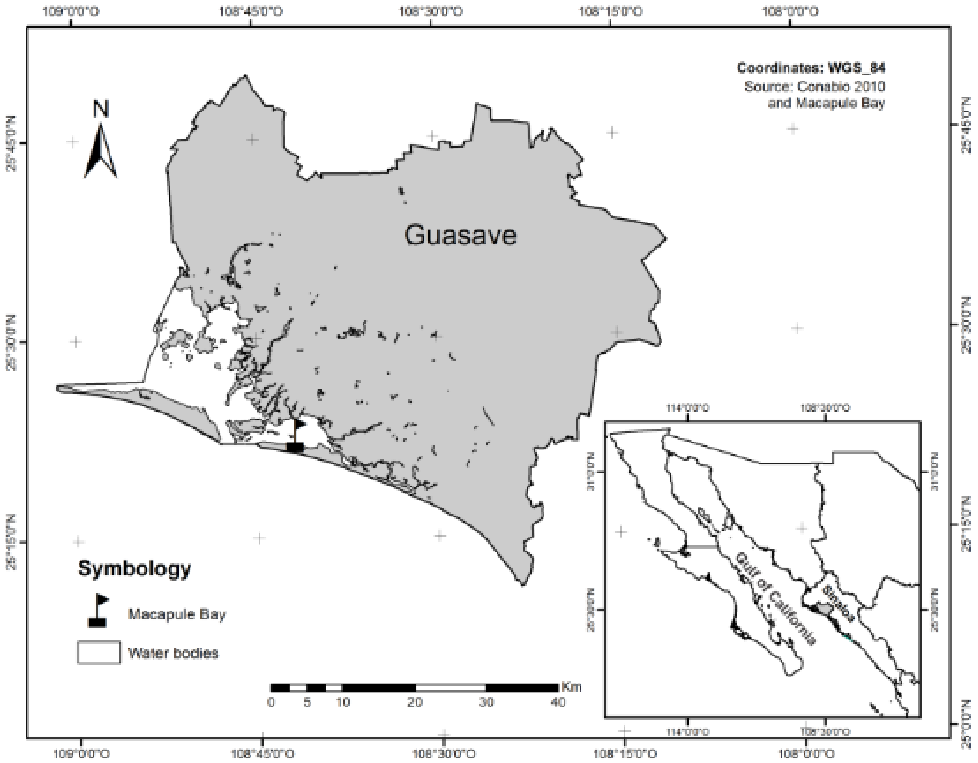

Figure 1: The study area. The Macapule Lagoon is located in the Gulf of California, Mexico.

Blood samples extractions and biological index

Yellow snappers were captured using a cast net (mesh size 17.8mm, net length 2.8m, maximum net diameter 4.0m). The fishing cruises were made at least 3 times per month or until getting 30 organisms by month. The syringes with anticoagulants were prepared before the fishing cruise trip. All the blood samples were drawn from the fish as soon as possible to avoid any type of fish stress. Briefly, blood samples of 1±0.1mL were extracted (only of fish larger than 10cm total length) by caudal puncture with a disposable plastic syringe containing 0.5mL of heparinized solution (Sigma-Aldrich) and place in ice until analysis. After one hour in ice, the blood samples were centrifuged at 9,500 g at 4 ºC for 10 minutes to separate the blood cells from the plasma. To determine total protein concentrations in the blood we follow Bradford's method (1976), which is based on the reaction of the amino groups with the dye Coomassie Blue G-250. While triglycerides, glucose, and cholesterol concentrations were determined with colorimetric commercial kits Randox UK Molina [17], and the concentration was registered as mg dL^{-1}. The measure of absorbance was determined with a microplate reader (Multiskan Go, Thermo Scientific UV, United States) and concentrations of triglycerides, glucose, and cholesterol were calculated from a standard solution of substrates.

After blood samples were taken, we registered the biological data from each fish collected. Briefly, total length was measured using an ictiometer (pentair®, 50cm) and the fish were weighed with a scale (Ohaus-202 Scout Pro). Organs as liver, stomach, and gutted weight were weighed and the data were used to calculate the morpho-physiological indices: 1) Fulton's Condition Factor (CF): $CF = W_t/L_t^3 * 100$, where W_t = total weight and L_t = total length; 2) the Hepatosomatic Index (HSI): $HSI = W_h/W_t*100$, where W_h = liver weight and W_t = total weight of the individual; and 3) the Gastric Repletion Index (GRI): $GRI = W_s/W_t *100$, where W_s = stomach weight and W_t = total weight. In addition, The length-weight relationship and the condition factor are parameters used to compare the condition of populations that inhabit aquatic systems with different degrees of anthropic intervention, to calculate length-weight relationship, 123 unsexed fish were measured for their TL to the nearest 1mm and weighed to the nearest 1g.

Parameters of the length-weight relationship of yellow snapper (*L. argentiventris*) were estimated using the equation: $W = aL^b$, where W = weight of the fish (g), L = total length (cm), a = y-intercept or the initial growth coefficient, b = slope or the growth coefficient. On the other hand, the nutrient concentrations as nitrate, ammonium, and phosphate were determined from water samples taken at each site of fish blood samples collected. The water samples were taken using falcon tubes of 50mL and transported in a cooler with frozen gels. One time in the laboratory, the concentration of the nutrient was determined follow the method described by Strickland & Parsons (1972).

Statistical analysis

All data were subject to normality distribution Kolmogorov-Smirnov test using the Lilliefors (1967) approach and the equality of variances were tested using Bartlet test [21]. In the case of the normality test failed, the data were log-transformed (log x+1) e.g., morphophysiological index, whose results are expressed in percentages. Differences in the biochemical blood samples (total protein, triglycerides, cholesterol, and glucose) parameters and the morpho-physiological (CF, HSI, and GRI) between sampling months were evaluated using a Generalized Linear Model (GLM), with the parameters as dependent variables, month as the predictor variable, and the total length of fish as a covariance. While a one-way ANOVA was used to evaluate differences in physical-chemical parameters (temperature, dissolved oxygen, pH, and salinity) and nutrient concentrations between sampling months. A meta-analysis was develop using discriminant analyses based on Mahalanobis distances to identify differences in morpho-physiological and biochemical parameters between months, sampling was analyzed with analyses of variance after testing them for normality and homogeneity using Statistics® version 5.5.

Result and Discussion

Biochemical blood analyses

Table 1: Blood biochemical parameters of *Lutjanus argentiventris* during the sampling months in Macapule Lagoon. Significantly different values (p<0.05) are different small letter.

Date Sampling	Total Proteins (g/dL)	Triglycerides (mg/dL)	Cholesterol (mg/dL)	Glucose (mg/dL)
Year 1				
Dec. 2013	10.7 ± 2.2a	51. 1 ± 23.0a	43.0 ± 18.4a	27.7 ± 19.3a
Jul. 2014	7.7 ± 1.0b	33.8 ± 19.1b	26.2 ± 14.8b	38.6 ± 24.3b
Year 2				
Dec. 2014	8.8 ± 1.5b	25.9 ± 17.0b	8.0 ± 10.5c	27.1 ± 20.7a
Jul. 2015	7.9 ± 1.2b	12.9 ± 10.4c	8.7 ± 7.3c	17.7 ± 11.4a

For blood samples extractions a total of 123 yellow snapper were sampled (December 2013, [n=32]; June 2014, [n=34]; December 2014 [n=30], and July 2015 [n=27]). All the blood biochemical parameters varied significantly among sampling months. The total proteins, triglycerides, and cholesterol values were significantly higher in December 2013 (ANOVA, $F_{3,122}$ = 25.8, 29.3, and 47.8, respectively, P<0.01), while the highest glucose value was recorded in July 2014 (ANOVA, $F_{3,122}$ = 4.5, P<0.01) (Table 1). We found significant differences intra and inter-correlations between morpho-physiological and biochemical blood biochemical parameters (Table 2). On the other hand, the total length was positively correlated with weight, while the CF also was positively correlated with the HSI, and so was the GRI with the HSI (Table 2). The total protein concentration in fish blood was the only blood biochemical parameter that correlated with one of the morpho-physiological parameters (GRI). Total protein concentration was also positively correlated with Triglycerides Cholesterol, and Glucose biochemical parameters (Table 2). The blood total protein concentrations recorded in yellow snapper *L. argentiventris* were higher than those reported by Román [8] and García [22] for *L. peru* in Mexican coastal waters or for the serranids *Acantopagrus latus* and *Epinephelus coioides* (Akbary [23]). The variation recorded in blood total protein concentrations across the sampling months for this study might be due to changes in feeding behavior (about the type of prey consumed). In agreement with Table 2, it could be inferred that this yellow snapper population from Macupale Lagoon has not yet entered in the reproductive phase and all the protein they get is used for growth and welfare (García [24]) as has been suggested for other lutjanids species (García [22], Román [8]).

Table 2: Correlation coefficients (rs) among the morpho-physiological and blood biochemical parameters of *Lutjanus argentiventris* during the sampling months in Macapule Lagoon.

	Length	Weight	HSI	CF	GRI	Total Proteins	Triglycerides	Cholesterol
Weight	0.983							
HSI	0.099	0.145						
CF	-0.095	0.055	0.243					
GRI	0.045	0.031	0.226	-0.034				
Total Proteins	-0.135	-0.136	-0.098	0.088	-0.209			
Triglycerides	-0.097	-0.11	0.16	0.144	0.02	0.607		
Cholesterol	-0.083	-0.121	0.187	-0.15	0.159	0.533	0.739	
Glucose	-0.016	-0.03	0.063	-0.042	0.073	0.221	0.391	0.35

HSI = hepatosomatic index, CF = Fulton’s condition factor, GRI = gastric repletion index.

The levels of triglycerides and cholesterol are proportional at liver weight, as indicated by the positive correlation between cholesterol and HSI values (Table 3). Lipid concentrations decrease in the blood plasma after spawning and during periods of fasting, but after that, they increase periodically with feeding during the non-reproductive season (García [24]). The ranges of triglycerides and cholesterol levels in yellow snapper were very wide (Table 2), although the highest mean values were similar to those reported by Román [18] in *L. peru*. However, the concentrations recorded for *L. argentiventris* and *L. peru* are lower than those reported for other marine species, e.g., *Acantopagrus latus* (Akbary [23]) or Lates calcarifer (Satheesh [25]). In this study, we observe significant differences in the glucose concentration of the blood from fish obtained in July 2014 (Table 2) showing a direct relationship with dissolved oxygen concentration in the water (Table 1) and it could be that the organisms at the time of capture were more susceptible to acute stress after the capture (Molina [17]). Triglycerides and cholesterol levels are related to the age and reproductive stage in fish. For example, cholesterol concentrations increase with fish body size. The fish examined in the Macapule Lagoon, as well as those examined by Román [18], were juvenile organisms; therefore, the low concentrations recorded can be mainly attributed to their younger age. On the other hand, the triglycerides and cholesterol levels decreased steadily across the sampling (Table 2). The composition of the food ingested by yellow snapper has not been analyzed during this study; however, the higher levels of triglycerides and cholesterol recorded during the first two samplings (Table 2) can be attributed to a higher proportion of abdominal fat in the fish. However, it could be inferred that the population in the Macapule Lagoon has already started the reproductive phase and all stored nutrients are used for this new biological process.

Table 3: Discriminant analysis classification showing the numbers and percentages of fish assigned to each sampling month (group).

	Dec. 2013	Jul. 2014	Dec. 2014	Jul. 2015	Percent*
Dec. 2013	25	3	3	1	78.1
Jul. 2014	1	33	0	0	97.1
Dec. 2014	2	0	27	1	90
Jul. 2015	1	4	1	21	77.8

Glucose levels may vary greatly due to changes in biological factors, such as the fish length, weight, age, nutritional status, reproduction, and stress level, or due to environmental variations related to changes in temperature and dissolved oxygen concentrations. The blood glucose concentrations of yellow snapper varied up to 46 % (Table 2) between sampling months. Nevertheless, these concentrations were lower than those reported for *L. peru*, *Lates calcarifer*, *Mugil cephalus*, or *Chanos chanos*. The biochemical parameters in the blood can vary greatly among fish species or between different climatic seasons (González [26], Castellanos [27], Bayir [28]). The multivariate analysis confirmed the great variation of these parameters in yellow snapper between different months and between years (Figure 2). The CF index was the only parameter rejected by the statistical model, due to its little variation (Table 2). However, although the health condition of yellow snapper was fairly constant over time, the fish biochemical parameters presented important changes, e.g., fish examined in December 2013 were characterized by higher blood total protein levels, while fish from July 2014 sample showed higher glucose levels (Table 2). On the other hand, yellow snapper examined in December 2014 had the lowest cholesterol concentrations than those sampled in July 2015, where triglyceride levels are more constant (Table 2).

The meta-analysis result in a multivariate model constructed to find differences in morpho-physiological and biochemical variables of yellow snapper between sampling years, the first two discriminant variables explained 90.5% of the variance, contributing 52.3% (eigenvalue = 2.31) and 38.2% (eigenvalue = 1.69), respectively. The third discriminant variables explained only 9.5% of the total variance (eigenvalue = 0.42). A significant overall group effect was observed (Wilks' lambda = 0.79, F_{325}, P<0.001). Individual fish were evenly distributed along the two discriminant axes (Figure 2). Dimensionality tests showed that the two years (December 2013, 2014, and July 2014, 2015) in two years (groups) were significantly separated in both dimensions (χ^2 = 294.51, df = 24, P<0.01) (Figure 2). Each fish was correctly assigned to one of the four groups with an accuracy of 86.2%. Seven fish from December 2013, three from December 2014, six from July 2015, and one fish from July 2014 were erroneously assigned to other groups (Table 3).

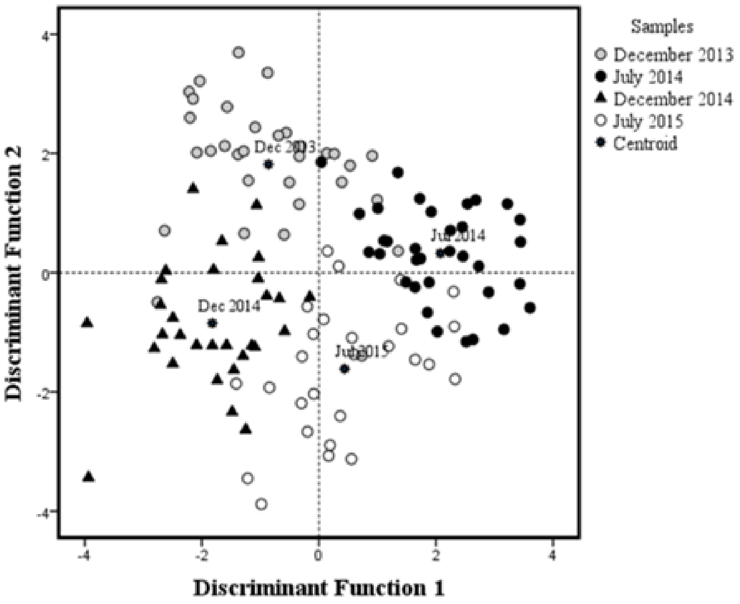

Figure 2: Graphic representation of the multivariate discriminant analysis of *L. argentiventris* samples from Macapule Lagoon. Each fish examined during the sampling months is represented by a symbol. Centroid = mean of the respective group.

Biological index

The equation parameters (a & b) of the length-weight relationship in each one of the samplings indicated that the growth of yellow snapper showed important variations over time between year 1 and year 2 (Table 4). For example, in December 2014 and July 2015, second year, the fish growth in length and weight was more homogeneous (b≈ 3, isometric growth), while in December 2013 and July 2014 first year (b≈ 2.73), the growth showed negative allometry (i.e., the fish grew faster in length than in weight).

Table 4: Length-weight relationships of *Lutjanus argentiventris* during the sampling months in Macapule Lagoon. Length-weight coefficients, y = a + b*x.

Date Sampling	A	B	r^2
Year 1			
Dec-13	0.034	2.726	0.959
Jul. 2014	0.033	2.743	0.946
Year 2			
Dec. 2014	0.018	2.956	0.946
Jul. 2015	0.021	2.912	0.97

Table 5: Morpho-physiological parameters of *Lutjanus argentiventris* during the sampling months in Macapule Lagoon. HSI = hepatosomatic index, CF = Fulton's condition factor, GRI = gastric repletion index.

Date Sampling	HIS	CF	GRI
Year 1			
Dec-13	1.2 ± 0.4a	1.6 ± 0.2	1.8 ± 0.9a
Jul. 2014	1.7 ± 0.4b	1.5 ± 0.1	3.7 ± 1.8b
Year 2			
Dec. 2014	1.2 ± 0.3a	1.6 ± 0.1	1.4 ± 0.4a
Jul. 2015	1.4 ± 0.5a	1.6 ± 0.1	2.6 ± 1.7c

Among the morpho-physiological parameters (Table 5), only the HIS and GRI varied significantly among the sampling of the years mainly HIS and GRI (P<0.01); and they were positively correlated with water temperature (r_s = 0.294 and 0.441, respectively, P<0.01). A significantly higher value of the HIS (1.7±0.4) was recorded in July 2014 (ANOVA, $F_{3,122}$ = 9.28, P<0.01), while the GRI was significantly higher in July 2014 and 2015 (ANOVA, $F_{3,122}$ = 21.1, P<0.01). The importance of each morpho-physiological or biochemical parameter in distinguishing between sampling months in two years (groups), was evaluated as the contribution of each variable to the total sum of Mahalanobis distances, indicating that the weight of the fish and the blood total protein concentration were the most important parameters to identify the December 2013 group (Table 6). The length of the fish, the HSI, the GRI and glucose values were the most important parameters to differentiate the July 2014 group, while the cholesterol concentration was the most important parameter for the December 2014 group. Finally, the triglycerides defined July 2015 group (Table 6) and only the CF index was rejected by the model due to its larger Wilks' lambda P-value.<0.001.

Table 6: Coefficients of discriminant functions of morpho-physiological and biochemical variables that allow establishing differences (in bold) between sampling in two years (groups) of *Lutjanus argentiventris* in Macapule Lagoon.

	Dec. 2013	Jul. 2014	Dec. 2014	Jul. 2015
Weight	-4272.4	-4266.8	-4236.92	-4228.82
Length	12849.7	12856.89	12752.05	12756.37
HIS	537.09	551.56	535.79	543.98
GRI	100.17	109.88	97.71	104.37
Total Protein	1163.79	1127.64	1158.86	1148.65
Triglycerides	-41.87	-44.9	-39.63	-50.05
Cholesterol	-44.92	-43.64	-54.67	-48.01
Glucose	81.79	86.16	84.26	85.16

In addition, the morpho-physiological indices have been considered, for a long time, an appropriate method to evaluate the physiological condition of fish (Tyler [29]). Variations in the GRI and HSI (Table 2) were related to significant temperature fluctuations during the sampling months. The temperature was considered an environmental parameter with important effects on the physiology and behavior of fish in the Macapule Lagoon. For example, the metabolic rate as well as several metabolic processes tend to increase as temperature increases(Vázquez [30]) The positive correlation between temperature and the HSI and the GRI indicated that feeding activity and storage of energy reserves in the liver of yellow snapper increased with higher water temperature. The increase in food uptake during the high-temperature months July 2014 and 2015, (Table 1) was also reflected in an increase in liver energy reserves (higher values of HSI), given that the liver is an important organ for energy storage in benthic and demersal fish species (Drazen [31]).

The CF did not vary significantly among the sampling months (Table 2), indicating that the adverse conditions that occurred during given sampling periods, such as in July 2014 when the oxygen concentration was very low and salinity very high, had no negative effect on the fish (Table 1). The CFs obtained during the sampling months were similar to those of *L. argentimaculatus* (Daliri [32]) and *L. peru* (Garduño [22]), but lower than those reported for *L. malabaricus* . Concerning the growth in yellow snapper, the b values were b<3 during the first two samplings, suggesting a negative allometric growth (Table 4). By contrast, b was ~3 in the last two samples, second-year indicating an isometric growth. Vázquez [30] and Gómez [11] recorded an isometric growth (b = 3.04 and 3.07, respectively) in yellow snapper from 21.5 to 58cm total length. Allometric growth, either positive (b > 3) or negative (b < 3), has been reported for many marine fish species. For example, Marzouqi [33] noted that allometric growth is a recurrent pattern among many carangid species. A study of 43 marine species of the families Carangidae, Lutjanidae, and Haemulidae from the central Mexican Pacific reported at least 26 allometric negative and 7 allometric positive length-weight relationships. Therefore, is possible that the growth for yellow snapper tends to be isometric in larger individuals. Species present an allometric growth pattern that could lead to important adaptive advantages associated with the use of benthic habitat Cifuentes [34].

Physico chemical variables

The physicochemical variables (Table 7) shown significant changes between the sampling, the concentrations of the three examined nutrients also showed significant variation between the years, such as Ammonium and Nitrates. As it generally happens, through the seasons we observed how at a lower temperature, higher dissolved oxygen was recorded in the sampling areas. Finally, the environmental parameters recorded in Macapule Lagoon showed a significant variation throughout the sampling months. This remarkable environmental variation can be due to the strong influence of the California Current on this coastal lagoon, causing important changes in the physicochemical parameters and nutrient concentrations Magaña [35], [36-40].

Table 7: Physico-chemical parameters and nutrient concentrations during the sampling months in Macapule Lagoon. PSU = practical salinity unit. Means not sharing the same superscripts are significantly different.

Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	PSU	Ammonium (mg L)	Nitrates (mg L)	Phosphates (mg L)
Year 1							
Dec. 2013	28.4±0.166b	5.30±0.057a	7.9±0.033c	37.13±0.067a	1.2±0.017a	1.30±0.100a	0.21
Jul. 2014	31.0±0.145a	2.90±0.057b	7.5±0.033b	41.07±0.067d	1.1±0.427a	2.80±0.865a	0.07
Year 2							
Dec. 2014	20.4±0.058c	7.10±0.052c	6.7±0.050a	38.03±0.033b	0.1±0.020b	1.28±0.061a	0.1
Jul. 2015	31.4±0.755a	5.43±0.065a	7.5±0.088b	39.67±0.333c	0.1±0.019b	9.60±0.306b	0.17

The maximum total length reported for yellow snapper from the Mexican Pacific coast ranges from 66 (Fischer [11], [41-43]) to 70cm Rojas [12], while the size of first sexual maturity has been estimated between 31.5 and 32.6cm (Piñón [18], Ramírez [16], [44,45]). The fish of the Macapule Lagoon measured between 18.8±3.7 and 21.7±2.7cm (Table 8), indicating that they were juvenile, approximately one-year-old organisms (Rojas [12], [46-50]).

Table 8: Length and weight of *Lutjanus argentiventris* during the sampling months in Macapule Lagoon.

Date Sampling	No. of fish	Total length (cm)	Total weight (g)
Year 1			
Dec. 2013	32	18.8 ± 3.7a	112.5±69.1a
Jul. 2014	34	20.3 ± 2.2a	131.9±44.4a
Year 2			
Dec. 2014	30	19.0 ± 1.6a	113.5±32.0a
Jul. 2015	27	21.7 ± 2.7b	170.2±62.8b

Conclusion

The morpho-physiological and biochemical parameters, determined for the first time for yellow snapper in Macapule Lagoon, showed a wide temporal variation. The variability in these parameters was related to environmental changes, such as fluctuations in water temperature, changes in feeding behavior, and the type of prey consumed over time. In further research, the blood biochemical parameters determined for the present research could be employed as a reference tool to compare the health condition between wild and captive yellow snapper.

Summary

The discovery in the blood biochemical parameters of *Lutjanus argentiventris*, could be employed as a useful tool to monitor the health condition in populations of fish.

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