Population dynamics of the oyster *Crassostrea* cf. *corteziensis* in the Chone River estuary, Ecuador

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Abstract. The oyster *Crassostrea* cf. *corteziensis* is a species that inhabits a sandy-stony area located in the mangrove ecosystem in the estuary of the Chone River, where it is exploited in an artisanal way for commercial and consumption purposes, which generated a decrease in its populations, due to the effect of fisheries. In this study, the growth and mortality of *C.* cf. *corteziensis*, in the locality of Portovelo, in the Chone River estuary, Ecuador, was evaluated. Monthly, between May 2018 and April 2019, different population parameters were estimated, such as: length (L), total weight (Wt), growth parameters (L_∞, K, t0, Tmax), growth index (Ø'), total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate of the resource (E). The population showed a height range between 25 and 170 mm (58.91±1.03 mm) and a total weight from 1.50 to 322.40 g (62.33±2.66 g), dominated by groups of individuals with sizes (L) between 40-70 mm and weights from 25 to 75 g (Wt). The von Bertalanffy growth parameters estimated an asymptotic length (L_∞) of 178.5 mm, with a growth coefficient (K) of 0.50 year^{-1}, t_0 of -0.20 year, Tmax of 6.19 years and a Ø' of 4.20. The relationship between length (L) and total weight (Wt) was represented by the equation $Wt=0.4698*L^{2.2688}$ (R^2=0.7661; n=905) indicating that the species presents a negative allometric growth. A Z of 1.73±0.27 year^{-1}, M of 0.48, F of 1.25 and E of 0.72 indicated that the population is in a state of overexploitation. The *C.* cf. *corteziensis* population structure was analyzed for the first time in the Chone River estuary, supplying necessary information for the evaluation and management of this resource.

Key Words: fishery resource management, growth parameters, mortality, oyster beds.

Introduction. In Ecuador, Mora (1990) described *Crassostrea corteziensis* as elongated, triangular or oval in shape, with a wide ligament area. The upper valve is flat, externally lamellose, pale olive colored and with a border of the same color internally. The lower valve is concave with smooth edges, its internal face is chalky white except for the impression of the posterior adductor muscle, stained pink to light brown, with a length up to 250 mm (Lodeiros et al 2020). It inhabits estuarine zones (mangrove), stony and open beaches, devoid of vegetation, mainly in the intertidal zone. *C. corteziensis*, in Ecuador, has been reported so far in estuarine zones of Esmeraldas, estuary of the Gulf of Guayaquil and Jambelí Archipelago. Galtsoff (1964) pointed out that the high morphological variability of the shell of *Crassostrea* species makes it difficult in many cases to identify them adequately, due to the environment in which they are found or established and to the interspecific relationships in which the species develops (e.g. competition for space). Phylogenetic and genetic studies carried out on populations of *C. corteziensis* show that the high genetic variability of the species is associated with variations in salinity and the selective pressures generated by the different habitats in which they are found (Rodríguez-Romero et al 1988). In this study, the presence of *C. corteziensis* is recorded for the first time in the estuary of the Chone River, Manabí-Ecuador, where there is a natural bank associated with a mangrove ecosystem, dominated by *Rhizophora mangle*, located within the Islas Corazon y Fragatas Wildlife Refuge. The criteria selected to sustain that this species corresponds to *C. corteziensis* are related to morphological characteristics similar to those described by Olsson (1961) and Mora (1990). Although the species has not yet been identified molecularly, it was proposed to name it *Crassostrea* cf. *corteziensis.*

Population ecology studies in mollusks are important because they provide information related to the distribution and structure of the population, allowing a better prediction of the recruitment (García-Delgado & Leones-Zambrano 2016). Therefore, it is necessary to determine structural aspects of bivalve populations of commercial importance, in order to achieve maximum utilization and rational management of natural banks, which will ensure a better management of the resource over time. *C.* cf. *corteziensis*, is extracted in an artisanal way for consumption and commercial purposes by local fishermen from the Chone River estuary, without any type of regulation, constituting a popular feeding alternative due to its easy extraction, so the objective of this study was to evaluate the population dynamics of the oyster *C*. cf. *corteziensis*, information that will serve to implement management plans for this resource in the Chone River estuary and other areas according to its distribution.

Material and Method

Sampling and data collection. Samples were obtained off Isla Corazon, in the Chone River estuary (0°38'25.9 "S, 80°21'34.2 "W) located in the central part of the coastal zone of the province of Manabí, Ecuador. The oyster was randomly sampled in the middle of each month from May 2018 to April 2019, using a hammer and a chisel. The oysters were detached from the rocks during the lowest diurnal tide, in a sandy-stony area associated with *R. mangle*, at a depth between 0.5 and 1 m. Approximately 80 specimens were obtained per month. The samples were transported in isothermal containers to the laboratory where the grouped individuals were separated, and cleaned of the sediment and epifauna adhering to their shells by brushing and washing. The length (anterior-posterior axis) of the oyster shells was taken with a 0.01 mm precision Vernier. The total weight of each specimen was taken with a 0.01 g precision CAS electronic balance.

Growth parameters. Frequency histograms with 10 mm intervals were constructed for growth analysis. Estimates of the Von Bertalanffy growth parameters L_∞ (Asymptotic length) and K (Growth rate or curvature parameter) were elaborated by combining the length-frequency samples (Pauly 1983). To the Lt data, the computer program FISAT II was applied, using Shepherd's (1987) method of Length Composition Analysis (SLCA), to obtain estimates of the parameters of von Bertalanffy's growth equation:

$$Lt = L_\infty \left(1 - e^{-K(t-t_0)}\right)$$

Where:
Lt - expected length of oyster at age t (mm);
L_∞ - maximum length the population can reach (mm);
K - growth constant;
t_0 - estimated theoretical age of oyster at zero length.

To determine the value of t_0, which represents the time in which the organism is zero millimeters long, the following equation was used, according to Pauly (1983):

$$\mathbf{Log_{10}\,(-t_0) = -0.3922 - 0.2752 * Log_{10}(L_\infty) - 1.038 * Log_{10}(K)}$$

The maximum possible age or longevity was calculated with the expression, considering that the largest size observed in nature corresponds to approximately 95% of L∞ according to Taylor (1962) and Beverton (1963).

$$\mathbf{T_{max}} = \left(\frac{\mathbf{2.966}}{\mathbf{K}}\right) + \mathbf{t_0}$$

The growth index (Ø') was estimated according to the equation established by Pauly and Munro (1984):

$$Ø' = \mathrm{Log}_{10}\,(K) + 2\,\mathrm{Log}_{10}\,(L_\infty)$$

The relationship between total weight and length was determined according to the potential relationship:

$$W_t = a * L^b$$

Where:
Wt - total weight (g);
L - length (mm);
a - intercept;
b - slope.

Mortality. The total mortality (Z) of the population was estimated through linear relationship between natural logarithm from the change in amount of oyster per time of growth to i^{th} class with age, known as length converted catch curve (Pauly 1984; Pauly 1990) with the formula:

$$\mathbf{Ln}\left(\mathbf{N}\,\Delta\mathbf{t^{-1}}\right) = \mathbf{a} + \mathbf{bt}$$

Where:
N - number of oysters in length class i;
Δt - time needed for oyster to grow in length class to i;
t - age (or relative age, calculated with t_0= 0) related to median value of i^{th} class;
b - slope as the value of Z.

The processing of this information was supported by means of the FISAT II program, where length-frequency data with constant class sizes, and the parameters L_∞ and K (t_0 is optional) were used as defined in the equation of von Bertalanffy (1938).

Instantaneous natural mortality (M) was estimated according to Taylor (Taylor, 1958; Taylor 1962), who establishes that the maximum age (Tmax) occurs when 95% of a cohort reaches the asymptotic height.

$$\mathbf{M} = \left(\frac{\mathbf{2.966}}{\mathbf{A_{0.95}}}\right) \quad \mathbf{A_{0.95}} = \left(\frac{\mathbf{2.966}}{\mathbf{K}}\right) + \mathbf{t_0}$$

$A_{0.95}$: Age at which 95% of L_∞ is reached.

Results

Size-frequency distribution. Population structure of a total of 905 *C.* cf. *corteziensis* organisms were analyzed. Their length ranged from 25 to 170 mm (Figure 1A), with an average of 58.91±1.03 mm, and their total weight ranged from 1.50 to 322.40 g (Figure 1B), with a mean of 62.33±2.66 g. Organisms with a length from 40 to 70 mm represented 86.52% of the sample, having a total weight ranging from 25 to 75 g.

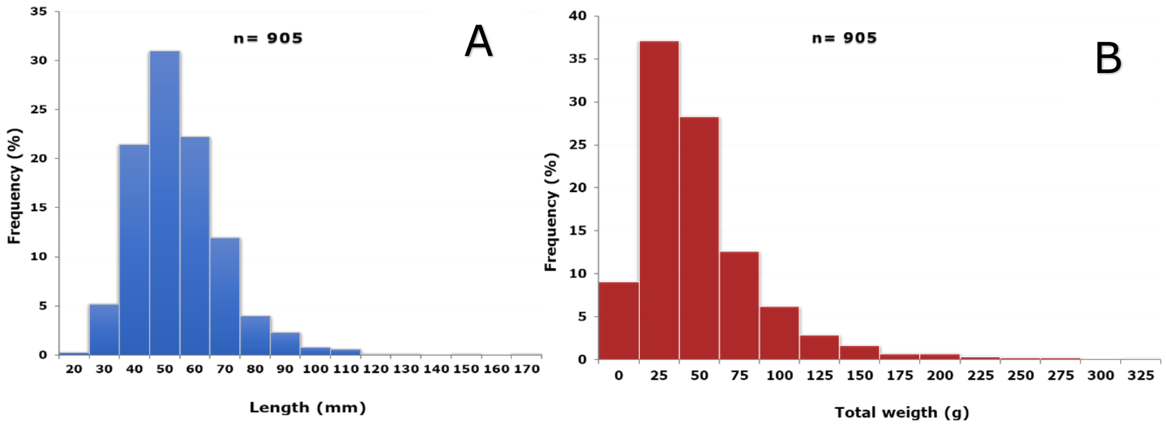

Figure 1. Frequency distribution (%) of length (mm) (A) and total weight (g) (B) of the oyster *Crassostrea* cf. *corteziensis*, in the Chone River estuary.

Growth parameters. The growth parameters of *C.* cf. *corteziensis* were determined from size frequency distributions grouped into 10 mm length classes describing a population of an asymptotic length (L_∞) of 178.5 mm, with a growth coefficient (K) of 0.50 $year^{-1}$, a t_0 of -0.20 $year^{-1}$, a Tmax of 6.19 years and a growth index of 4.20. The final growth expression can be represented by the following equation: L_∞= 178.50 [1 - $e^{-0.50\ (t+0.20)}$] (Figure 2).

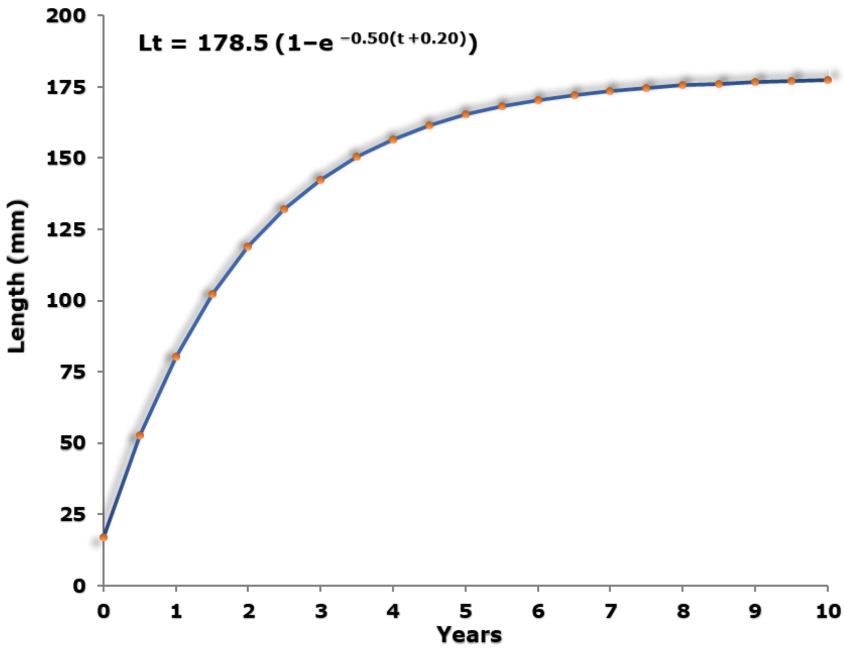

Figure 2. The von Bertalanffy growth curve in length in the oyster *Crassostrea* cf. *corteziensis.*

The relationship between length (L) and total weight (Wt), of the oyster *C.* cf. *corteziensis* in the population studied, was represented by the equation Wt= 0.4698*$L^{2,2688}$ (R^2= 0.7661; n=905) (Figure 4), showing values for the allometry coefficient (b) between 2.19 and 2.35, significantly lower than 3, thus presenting a negative allometric growth (t= 54.39; p<0.0001, with a 95% confidence interval) (Figure 3).

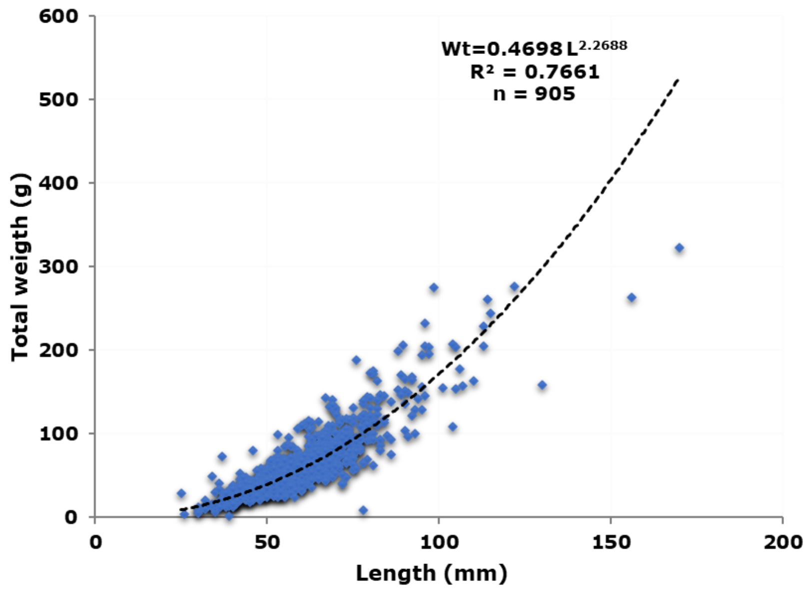

Figure 3. Relationship between shell length and total weight of the oyster *Crassostrea* cf. *corteziensis*, in the Chone River estuary.

Mortality. The total mortality rate obtained for the oyster *C.* cf. *corteziensis* was Z= 1.73±0.27 year^{-1} (Figure 4), the natural mortality rate M calculated by Taylor's method was 0.48, the fishing mortality F was 1.25 and the exploitation rate E was 0.72, indicating that the species is under conditions of overexploitation (Caddy & Csirke 1983).

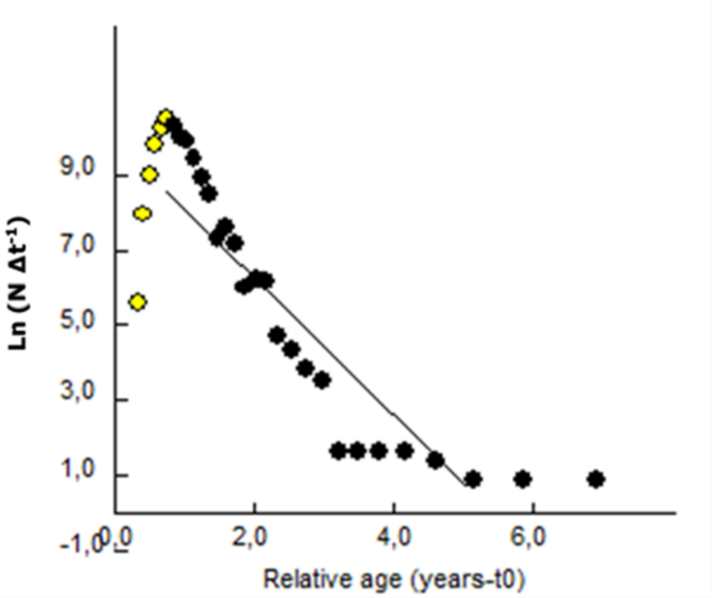

Figure 4. Catch curve converted to length to estimate the total mortality coefficient (Z) of the oyster *Crassostrea* cf. *corteziensis*, in the Chone River estuary.

Discussion. The genus *Crassostrea* includes ecologically and commercially important species. Due to the environments they inhabit, they present a phenotypic plasticity, which generally makes their identification difficult beyond morphological characters. In this sense, it has been found that morphological changes in this species occur in response to environmental conditions, giving rise to confusion in taxonomic classification, and it is very important to resolve the questions through molecular procedures (Rodríguez & Lagos 2007; Lazoski et al 2011; Amaral & Simone 2014).

The Kruskal-Wallis (KW) test was performed showing that the size of the sampled population maintained a relatively homogeneous distribution during the sampling period, although with monthly differences (KW=125.10; $p<0.0001$). The size frequency distribution shows the presence of a dominant group between 40 mm and 70 mm length, representing 86.52 % of the total sample in all sampling months. Regarding total weight, *C.* cf. *corteziensis* presented an average of 62.33±2.66 g with significant monthly differences (KW=118.07; $p<0.0001$). These results differ from the study performed by Chávez-Villalba et al (2005) who reported an average length of 71.3±1.9 mm and a total weight of 30.1±1.9 g for *C. corteziensis* under culture conditions. According to these results, it is proposed to initiate culture programs for *C.* cf. *corteziensis* in the Chone River estuary, which would compensate the reduction of its populations due to fishing, and it is suggested that under these conditions the organism would have a higher growth and meat yield, even higher than those reported in previous studies for marine environments.

The growth parameters in this study are the first records obtained for *C.* cf. *corteziensis* in the estuary of the Chone River: L_∞=178.5 mm; K=0.50 year^{-1}; t_0=-0.20 year and Tmax=6.19 years with a growth index of 4.20. Also, these results indicate that in the estuary this species shows an average growth, reaching a length of approximately 80.54 mm at one year after hatching. These values differ from those reported for the same species by Chávez-Villalba et al (2005) (L_∞=114 mm; K=1.1 year^{-1}; t_0=0) and Chávez-Villalba et al (2008) (L_∞=132.2 mm; K=1.08 year^{-1}, t_0=-0.18), in a culture system in the marine environment of the Sea of Cortes (Sonora-Mexico). These values would probably vary due to differences in environmental conditions (temperature, salinity, food availability) of the latitudes or study areas.

The relationships between length-weight are crucial when examining the biology of molluscs since they provide insights into the environmental conditions that bivalves inhabit (Agboola & Anetekhai 2008). Indeed, in fisheries analyses it is required to estimate and determine the population size of a species, since the rate of increase in weight and length reflect the influence of the ecological factors of a habitat and how these affect the organisms (Mohammed & Yassien 2003; Panta-Vélez 2012; Vásquez et al 2015; García-Delgado & Leones-Zambrano 2016; González et al 2015; Góngora-Gómez et al 2018). In this study, the weight/length (W/L) relationship of *C.* cf. *corteziensis* was determined as $Wt=0.4698*L^{2.269}$ (R^2=0.7661), and the b value was found to be less than three. This indicates a negative allometric relationship (b=2.269, b<3) for W/L. Similar findings have been reported by Unnikrishnan & Balakrishnan (1986), who revealed a value of b=0.87 for *C. madrasensis*, Yapi et al (2016) a value of b=2.20 in *C. gasar*, and Aydın et al (2021) a b=2.65 in *M. gigas*. According to these authors, it is suggested that negative allometric growth in these species leads to their shells becoming thinner as they increase in length (Farías-Tafolla et al 2015), indicating that shell length increases more rapidly relative to weight.

Studies of mortality estimates in natural populations are important because they provide predictive information on the loss of organisms, indicating the need to take protective measures to minimize this condition (Jiménez et al 2004; Panta-Vélez 2012). Mortality rate values for *C.* cf. *corteziensis* are the first to be estimated in estuarine environments and are considered useful background information for the evaluation and management of the resource. The total mortality rate estimate obtained was Z=1.73±0.27 year^{-1}, the natural mortality rate was M=0.48, while the fishing mortality was F=1.25 and the exploitation rate was E=0.72. When comparing the results of M and F, it is evident that the individuals that die as a result of extraction by fishing (F=1.25) are twice as many as those dead from natural reasons. According to Caddy & Csirke (1983), a rate of 0.5 is the optimum exploitation rate for a fishery. The exploitation rate obtained was greater than 50% (E=0.72), which indicates that the resource *C.* cf. *corteziensis* in the Chone River estuary is being overexploited.

Conclusions. The size distribution shows a high variability of sizes, compared to a normal distribution. This may be indicative of strong capture pressure on the larger sizes. In the Chone River estuary, *C.* cf. *corteziensis* presents an average growth (K=0.5 year^{-1}) with a maximum age of 6.19 years. The length-total weight relationship showed that *C.* cf. *corteziensis* presents a negative allometric growth, which indicates that the species increases its length faster than its weight. The average growth reached an approximate size of 52.71 mm, 6 months after hatching. The population structure, growth parameters and mortalities are the first estimates for *C*. cf. *corteziensis* in the Chone River estuary, and are considered useful background information for the evaluation and management of this resource. Based on the results obtained, it is recommended that management plans and regulations for *C.* cf. *corteziensis* oyster catches be implemented to reduce fishing pressure on the species, focusing on: (1) maintaining a landing record with the competent authority and (2) oyster farming feasibility in the Chone River estuary, as an alternative to minimize the extraction of this resource.

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Conflict of interest. The authors declare no conflict of interest.

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