

Reproductive dynamics, biometrics and biochemical composition of the oyster *crassostrea corteziensis* (Hertlein, 1951) in the Pacific of Panama

Dinámica reproductiva, biometría y composición bioquímica de la ostra *crassostrea corteziensis* (Hertlein, 1951) en el Pacífico de Panamá

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Abstract

This study examines the reproductive dynamics, biometric relationships, and biochemical composition of the oyster *Crassostrea corteziensis* in the Panamanian Pacific. From February to December, specimens collected in Puerto Caimito were monitored using a suspended culture system at Naos Island. The results indicate that the species exhibits a continuous reproductive cycle with synchronous maturity peaks during the dry season (February–April) and a secondary phase during the rainy season (July–October). Shell growth in length was found to be more accelerated in juvenile stages during the dry season, coinciding with coastal upwelling and higher chlorophyll availability (0.91 mg/m^3). Biochemical analysis identified the digestive gland-gonad and the adductor muscle as the primary storage centers for energy substrates (proteins and lipids), which are mobilized to support gametogenesis. Carbohydrate levels peaked in February (82.5% in the mantle) and decreased sharply during the March spawning period, confirming their role as a rapid energy source for gamete release. It is concluded that environmental fluctuations in temperature and salinity regulate energy storage efficiency and reproductive success for this species within the estuarine ecosystem of the Gulf of Panama.

Keywords: Biometrics, biochemical composition, *Ostrea corteziensis*, gonadic cycle, upwelling, Panama

Resumen

Este estudio analiza la dinámica reproductiva, las relaciones biométricas y la composición bioquímica de la ostra *Crassostrea corteziensis* en el Pacífico de Panamá. Entre febrero y diciembre, se monitorearon ejemplares en un sistema de cultivo suspendido en Isla Naos, tras su colecta en Puerto Caimito. Los resultados indican que la especie presenta un ciclo reproductivo continuo con picos de madurez sincrónica durante la temporada seca (febrero-abril) y una fase secundaria en la temporada lluviosa (julio-octubre). Se observó que el crecimiento en longitud es más acelerado en etapas juveniles durante la época seca, coincidiendo con el afloramiento costero y una mayor disponibilidad de clorofila *a* (0.91 mg/m^3). El análisis bioquímico identificó a la glándula digestiva-gónada y al músculo aductor como los principales centros de almacenamiento de sustratos energéticos (proteínas y lípidos), los cuales son movilizados para sostener la gametogénesis. Los niveles de carbohidratos alcanzaron su máximo en febrero (82.5% en el manto), descendiendo drásticamente durante el desove de marzo, lo que confirma su uso como fuente de energía rápida para la liberación de gametos. Se concluye que las

fluctuaciones ambientales de temperatura y salinidad regulan la eficiencia del almacenamiento energético y el éxito reproductivo de la especie en el ecosistema estuarino del Golfo de Panamá.

Palabras clave: Biometría, composición bioquímica, *Ostrea corteziensis*, ciclo gonádico, afloramiento, Panamá

Introduction

The natural resources traditionally exploited show a certain depletion, as demand increases alongside the human population, creating an imbalance between available resources and consuming organisms (especially humans). Consequently, we are compelled to seek alternatives to address this urgency. This highlights the nutritional, economic, ecological, and even medical importance that certain marine resources, such as mollusks, have generated since humans first utilized an interest that grows every day.

Countries with technological advancements and greater economic resources for research, such as Japan, the United States, and Spain, have successfully ventured into experimenting with these resources, particularly bivalves (Odum, 1971). When evaluating the possibilities in our country, which faces significant limitations in this research field, enormous challenges remain, beginning with the awareness needed to manage this aquaculture potential as a scientific and technological opportunity.

Above all, economic demand was the primary driver for increasing oyster production in estuarine waters through highly efficient and productive aquaculture techniques (Odum, 1968; Odum, 1971). Consequently, the reproductive biology of oysters in temperate zones has been the subject of numerous studies, most notably those conducted on the American oyster *Crassostrea virginica* (Gmelin, 1791) and the Japanese oyster *Crassostrea gigas* (Thunberg, 1793) (Hopkins, 1937; Loosanoff, 1942; Bargenton, 1943; Imai & Sakai, 1961; Kennedy & Battle, 1964; LeDantec, 1968; Dinamani, 1974).

In our tropical waters, one species gaining commercial importance is *Crassostrea rhizophorae* (Guilding, 1828), distributed along the Caribbean coast (Mattox, 1949; Sáenz, 1965; Bacon, 1971; Angel, 1972; Vélez, 1976). Studies on this species provide insight into oysters from tropical and subtropical waters.

The species under study, *Crassostrea corteziensis* (Hertlein, 1951), morphologically possesses an elongated, somewhat triangular, slightly curved shell with a compact ligament area and a posterior adductor muscle that attaches the valve to the center. The shell lacks projection or "ear" and is attached by the external surface of the left valve to rocks, mangrove roots, or similar surfaces; the interior of the shell is white and slightly pearly. Its average size is 150 mm in length by 100 mm in width, resembling *Ostrea chilensis* Küster, 1844 (Philippi, 1984). Its geographic distribution ranges from the upper Gulf of California, USA, to Panama (Keen, 1971).

Given its morphological, physiological, and reproductive conditions, this oyster could be considered for study in the cultivation and exploitation industry if managed properly, as it is currently harvested by coastal inhabitants of the Pacific for consumption and trade.

According to Sastry (1975), the biological characteristics of marine invertebrates like oysters indicate that their reproduction is linked to a physiological-cyclic phenomenon related to external environmental changes and feeding, from the onset of gametogenesis to maturity.

Based on these studies, regarding oyster nutrition, these organisms are generally classified as benthic organisms without swimming capacity; from the larval stage, they feed on suspended particles and organic detritus. It is essential to recognize the sedentary life of oysters to compare various energy sources, such as phytoplankton, which can meet the energy requirements for reproduction and allow them to utilize their own energy substrates: proteins, carbohydrates, and lipids, subject to environmental variations such as temperature and salinity.

Global literature highlights various studies on the reproductive cycle and its relationship with external factors, larval settlement, growth, and feeding in species such as *C. rhizophorae* (Angel, 1972), *Magallana bilineata* (Röding, 1798) (Stephen, 1980), *C. corteziensis* (Ruiz, 1980), and *Ostrea puelchana* A. d'Orbigny, 1842 (Fernández and Mattio, 1987).

In this regard, this work aims to expand the knowledge of these bivalve mollusks using the species *C. corteziensis* from the Panamanian Pacific, which has not been studied regarding its physiology and

reproduction, despite an initial study on the gonadal cycle by Ruiz (1980).

Material and methods

Description of the Study Area: Collection Area: Oysters were collected in Puerto Caimito, located in the La Chorrera district on the Pacific coast of the Gulf of Panama (8°51'05" - 8°52'05" N and 79°42' - 79°43' W), approximately 30 km from the experimental site. This area features an estuarine system where the Caimito River discharges.

Experimental Area: The study was conducted at the marine laboratories of the University of Panama on Naos Island, Panama Bay (8°54' - 8°56' N and 79°32' - 79°33' W). The Smithsonian Tropical Research Institute (S.T.R.I.) pier facilities were used to place the samples.

Field Methodology: In February 1992, 600 oysters (*C. corteziensis*) were collected and transferred to the marine laboratories. They were placed in tanks with filtered, recycled, and aerated seawater for 48 hours for acclimation and depuration. Subsequently, they were placed in lantern nets and moved to the pier. Each net (1.70 m long, 0.50 m diameter) was divided into five sections containing nylon baskets with 20 specimens each. The nets were maintained at a depth of 3 to 4 meters, ensuring 6 hours of exposure during low tide and 6 hours of immersion during high tide.

Weekly measurements were taken for temperature, salinity, and chlorophyll *a*. Temperature was measured with a mercury thermometer (-4 °C to 100 °C), salinity (‰) with an American Optical Scientific Instruments field refractometer, and chlorophyll *a* following the methodology of Strickland and Parsons (1972).

Laboratory Methodology: Thirty oysters were sampled during the last week of each month for biomass, biochemical components, and histology. Each test required 10 individuals. Before sacrifice, biometric measurements (length, width, and thickness) were taken, and specimens were weighed on a Mettler PC 2000 balance (0.01 g precision). Shell and soft tissue weights (wet weight) were recorded.

Biomass Analysis: For this test, 10 individuals were dissected into compartments: muscle, mantle,

gills, and digestive gland-gonad. Wet weight and dry weight (oven-dried at 80 °C–90 °C until constant weight) were determined. Tissues were placed in pre-weighed crucibles and calcined in a muffle furnace at 450 °C for one hour to obtain ash weight, following Jorgensen (1976). Shells were analyzed similarly, though drying took 30 to 40 days.

Biochemical Analysis: Ten individuals were used to determine concentrations of proteins, carbohydrates, and total lipids in the compartments. Tissues were homogenized, and aliquots were taken for each test.

- Carbohydrates: Following a modified protocol by Dubois et al. (1956), 0.5 g of homogenized wet tissue was mixed with 6 ml of distilled water and 3 ml of 15% TCA. After 24 hours, the supernatant was tested using phenol (5%) and sulfuric acid (10 N). Absorbance was read at 490 nm against glucose standards.
- Proteins: Following the BioRad method, 0.1 g of homogenized tissue was digested in NaOH (0.1 M) for 48 hours. Absorbance was read at 595 nm using Bovine Serum Albumin as a standard.
- Total Lipids: Extraction followed Bligh & Dyer (1959) with modifications by Gómez (1991), using a Chloroform/Methanol (2:1) mixture. After separation with NaCl and evaporation with nitrogen, the total lipid weight was determined.

Histological Analysis: Ten individuals were selected monthly. Sections were made at the digestive gland-gonad level and fixed in Davidson's solution for 48 hours. Samples were processed through graded alcohols and embedded in paraffin. 7-micron sections were cut using an American Optical microtome and stained with Ehrlich's hematoxylin and Putt's eosin. Sex and reproductive status were determined according to Ruiz (1980). Linear regression (weight/length) and index/weight correlation between tissues were performed for all specimens.

Results and discussion

Environmental Parameters

- Temperature: During the 1992 dry season (Feb–Apr), temperatures ranged from 22.5 °C to 27.0 °C. During the rainy season, they ranged from 26.4 °C to 29.5 °C. The average temperature was higher in the rainy season (28.2 °C) than in the dry season (24.8 °C).

- Salinity: Highest salinity was recorded in the dry season (33%). In the rainy season, it peaked in June (32%) and dropped to its lowest in October and November (27%).
- Chlorophyll *a*: Values were higher in the dry season (up to 0.91 mg/m³ in March) compared to the rainy season (0.11 mg/m³ in October).

Biometric Relationships

- Shell Length: Average size was 6.8 cm in the dry season and reached a maximum of 7.2 cm in October.
- Length vs. Weight: Regression analysis showed a strong proportional relationship ($r = 0.78$).

Biomass

All tissues (gills, digestive gland-gonad, mantle, and muscle) followed the same pattern: an increase in dry biomass in April and June, followed by a decline toward the end of the year. The digestive gland-gonad showed the highest biomass (up to 10470 mg in June).

Biochemical Analysis

- Proteins: The primary substrate in the digestive gland-gonad and muscle, peaking in August.
- Carbohydrates: Reached a maximum in the mantle in February 82.5%, then decreased significantly, indicating utilization during spawning.
- Lipids: Peaked in the digestive gland-gonad in March 38% (Figure 1).

Histology and Reproductive Dynamics: Of 100 individuals, 91 were sexed (36 males, 55 females). Spawning (Stage IV) was observed throughout the year but was most intense during the dry season February–March (Figure 2). *C. corteziensis* exhibits its most intense reproductive period when temperatures drop below 20 °C and salinity rises due to the upwelling caused by trade winds in the Gulf of Panama.

Figure 1.

Comparative summary of biochemical peak: maximum levels and tissue distributions.

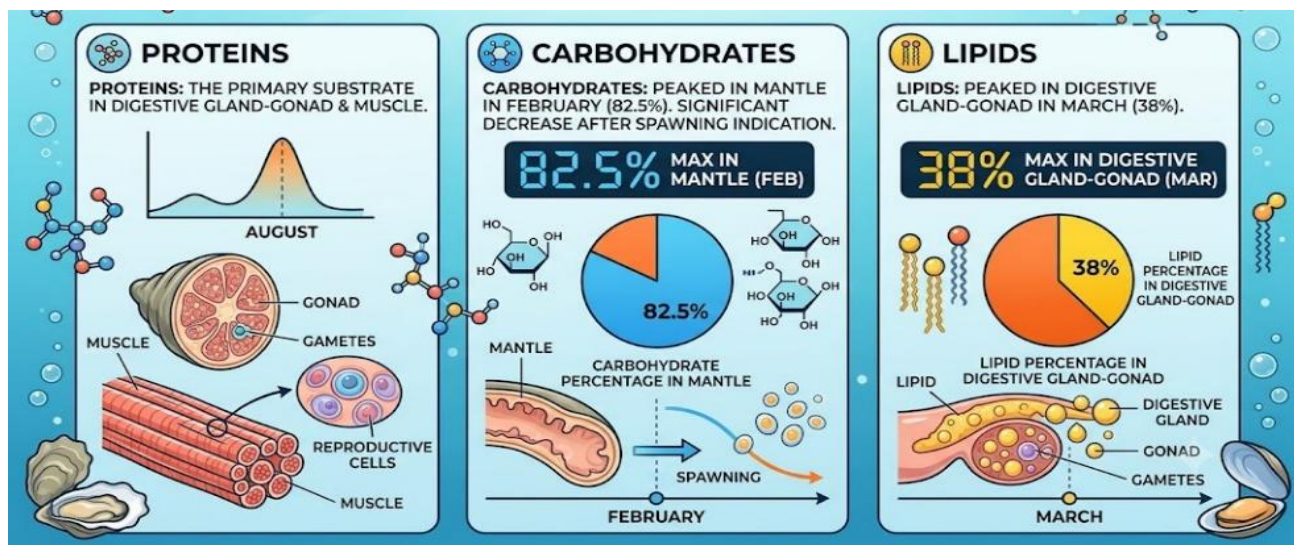
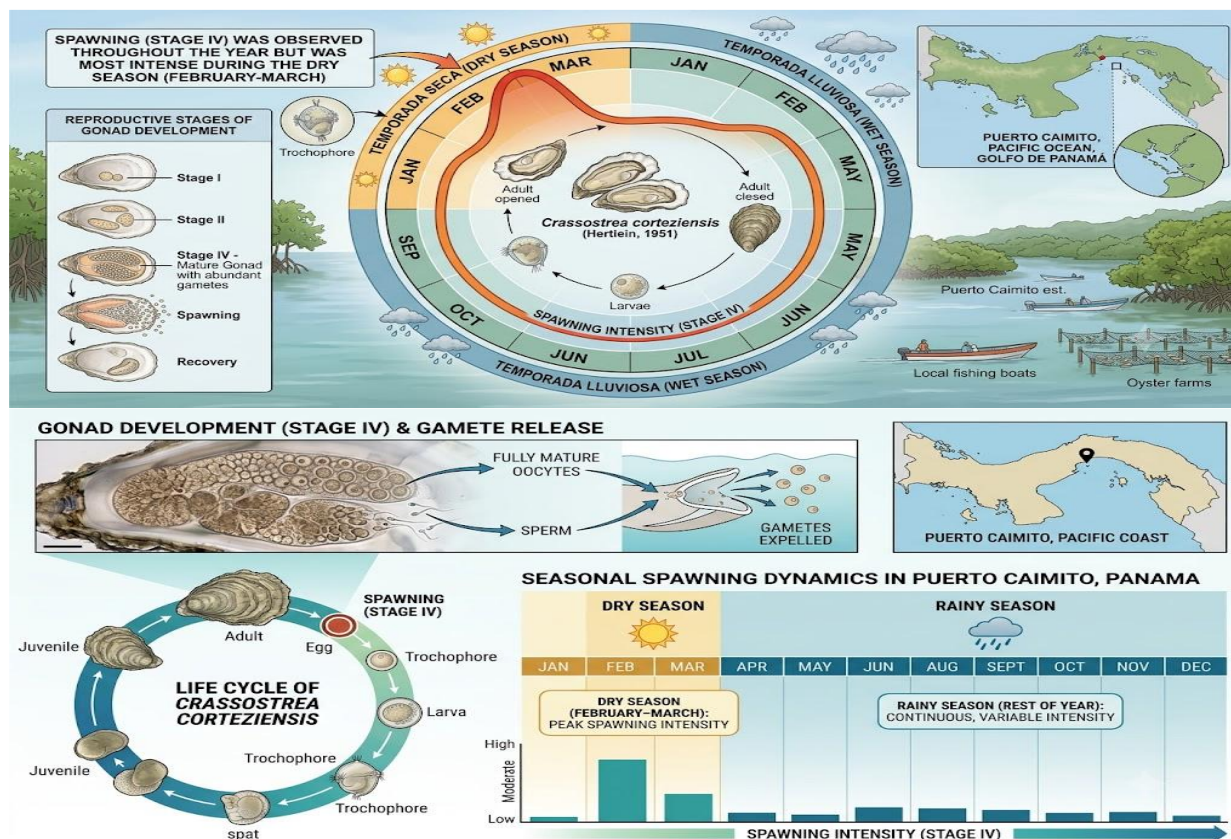


Figure 2.

Most intense breeding period of *Crassostrea corteziensis* in Puerto Caimito, Chorrera, in the Pacific of Panama.



Conclusions

Digestive gland and the adductor muscle are the primary nutrient storage structures for *C. corteziensis*. There is a direct relationship between these two organs in the reproductive process. During the summer upwelling, the abundance of nutrients allows the oysters to reach their maximum reproductive development. In the rainy season, while the muscle accumulates energy, the digestive gland-gonad maintains low nutrient levels, suggesting the construction of new reproductive tissue while storing energy for the final stages of reproduction.

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