

VARIATION OF THE CONDITION, MUSCLE YIELD AND MANTLE INDICES IN *Atrina maura* (SOWERBY, 1835) (BIVALVIA: PINNIDAE) IN THE ENSENADA DE LA PAZ, B.C.S., MEXICO

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ABSTRACT. During 2007 the seasonal variations in the condition (CI), muscle yield (MYI) and mantle indices (MI) in *Atrina maura* were analyzed at Ensenada de La Paz, B.C.S., México. A total of 264 specimens measuring 11 cm to 29 cm were collected. Both CI and MYI increased during winter, spring and summer, in parallel with gonad development, and significantly decreased during autumn, when a considerable proportion of spawning organisms were found along with the highest water temperatures. MI showed no significant seasonal differences (>0.05). From these findings, we suggest that this resource may be exploited during spring and summer.

Keywords: Physiological condition, reproduction, pen shell.

VARIACIÓN DE LOS ÍNDICES DE CONDICIÓN, DE RENDIMIENTO MUSCULAR Y DEL MANTO DE *Atrina maura* (SOWERBY, 1835) (BIVALVIA: PINNIDAE) EN LA ENSENADA DE LA PAZ, B.C.S., MÉXICO

RESUMEN. Durante 2007 se analizó la variación estacional de los índices de condición (IC), de rendimiento muscular (IRM) y del manto (IM) de *Atrina maura* de la Ensenada de La Paz, B.C.S., México. Se recolectaron un total de 264 organismos que midieron entre 11 cm y 29 cm. Se encontró que tanto el IC como el IRM aumentaron durante invierno, primavera y verano, en concordancia con el desarrollo gonádico, y disminuyeron significativamente durante el otoño, cuando se encontraron altas proporciones de organismos en desove y las temperaturas del agua más altas. El IM no presentó diferencias significativas (>0.05) estacionales. Se sugiere que la captura comercial de este recurso se lleve a cabo durante primavera y verano.

Palabras clave: Condición fisiológica, reproducción, hacha china.

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INTRODUCTION

The pen shell *Atrina maura* is a bivalve of commercial importance in the coasts of Baja California Sur (B.C.S.), México. Along with *Pinna rugosa*, during 1990-2000 the mean annual catch in this State yielded 45 tons of fresh muscle (Singh-Cabanillas & Michel-Guerrero, 2002). The regional, national and international demand of *A. maura* adductor muscle ("callo") is considerable, reaching up to \$20 USD/Kg locally. This has led to an intensive and unregulated commercial fishing that has resulted in a decline of the population density in various water bodies of Baja California (Vélez-Barajas & Fajardo-León, 1996; Cardoza-Velasco & Maeda-Martínez, 1997). Despite its importance as a fishing resource, studies on this spe-

cies are scarce, focusing mainly on field growth methods (Cardoza-Velasco & Maeda-Martínez, 1997), estimations on its tolerance to temperature and salinity variations, and the determination of its optimal growth temperature (Leyva-Valencia *et al.*, 2001), as well as the evaluation of microalgal diets (Lora-Vilchis *et al.*, 2004). Some aspects about the reproduction of this bivalve have also been analyzed (Aguilar-Ibarra, 1964; Soria-Padilla, 1989; Rodríguez-Jaramillo *et al.*, 2001; Ahumada-Sempoal *et al.*, 2002; Enríquez-Díaz *et al.*, 2003; Barrios-Ruíz, 2005; Rodríguez-Jaramillo, 2004; Ángel-Pérez *et al.*, 2007; Angel-Dapa, 2008). However, no studies on *A. maura* have been conducted for Ensenada de La Paz, B.C.S.

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In bivalves both the relative amount of meat (condition index) and muscle weight (muscle yield index) have been used to estimate their fishing and consumption value (Prieto-Arcas *et al.*, 2001). Both parameters, as well as mantle weight are influenced by environmental factors and, as they function as nutrient reservoirs (carbohydrate, protein and lipid); their variation is also influenced by reproductive activity (Arellano-Martínez *et al.*, 2004; Sahin *et al.*, 2006). This variation may occur in parallel with either gonad development (Aldrich & Crowley, 1986; Sahin *et al.*, 2006) or inverse oscillation cycles, suggesting that the storage and transference of energy reserves comes from somatic tissues to the gonad (Epp *et al.*, 1988; Gabbott, 1975; Bayne, 1976; Barber & Blake, 1991; Park *et al.*, 2001; Arellano-Martínez *et al.*, 2004), which depends on the particular species and study area.

The aim of this investigation was to analyze the physiological condition of *A. maura* in Ensenada de La Paz, B.C.S., through the condition, muscle yield and mantle indices, as well as their relationship with the morphochromatic reproductive stage.

MATERIALS AND METHODS

During 2007, approximately 20 adult specimens of *A. maura* were collected monthly in Ensenada de La Paz, Baja California Sur, Mexico (20° 06" N - 24° 11" N and 110° 18" W - 110° 26" W) through semi-autonomous diving. Shell length, total weight, wet weight without shell, adductor muscle weight and mantle weight were recorded for each specimen. Water temperature was recorded at the time of specimen collection.

The condition index (CI) was estimated as the percentage of meat weight relative to total weight (Villalejo-Fuerte & Ceballos-Vázquez, 1996). The muscle yield index (MYI= adductor muscle weight*100/ wet weight without shell) and the mantle index (MI= mantle weight*100/ wet weight without shell) were obtained accordingly with Villalejo-Fuerte & Ceballos-Vázquez (1996).

The gonad evaluation can be given at several levels, depending on the information that

is desired to obtain. Among these, the use of morphochromatic scales of maturity is traditional since it is believed that the sexual maturity stage can be recognized through the gonad's external characteristics (Noguera & Gómez-Aguirre, 1972). However, although scales are not definitive, they can be used like general indicators of the maturity degree. For example, in a production hatchery the morphochromatic method is a fast and reliable alternative for selecting the spawning broodstock (Monsalvo-Spencer *et al.*, 1997). In this sense, reproductive maturity scales has been developed and applied in bivalves (Sastry, 1963; Tripp-Quezada, 1985). According with these morphochromatic scales and personal observations (gonad morphological features such as color and consistency), the gonad development was then characterized into three stages: developing, ripe, and spawning. Hence, the reproductive cycle was described through the stage's monthly frequencies.

In order to detect significant differences in CI, MYI and MI between seasons, one-way Analyses of Variance (ANOVA) were conducted (four levels: spring, summer, autumn and winter); when statistically significant differences appeared, *a posteriori* analyses using Tukey's test were performed. The arcsine transformation (arc-sine \sqrt{p}) (Zar, 1996) was applied to the data from CI, MYI, and MI before the statistical analyses to reduce the dependence of the sample variance on the mean and to normalize the data distribution. Also, a Pearson's correlation analysis was conducted to investigate the relationship between CI and both MYI and MI. The level of significance was preset at $P < 0.05$ for all analyses.

RESULTS

Shell length varied from 11 cm to 29 cm (mean = 22 cm SL; std = 2.95).

The gonad's macroscopic observations revealed that, during winter, spring and almost all summer, bivalve gonads were undergoing the developing and ripe stages. However, by late summer and during autumn a high proportion of specimens displayed gonads in the spawning stage (Fig. 1).

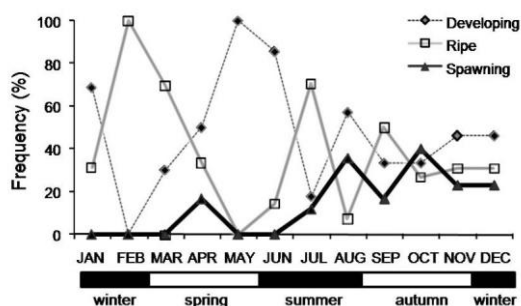


Figure 1. Seasonal variation of the morphochromatic reproductive stages frequencies of *Atrina maura* in Ensenada de La Paz, B.C.S., México.

Figure 2 shows the variations in CI, MYI and MI over the year. CI remained between 34% and 37% in the winter, rising towards late spring and reaching a peak in the summer (45%); a significant decline in the CI (29%) was observed during the autumn ($P = 0.016$) (Fig. 2a). The MYI displayed significant differences ($P = 0.01$) between seasons. This index ranged between 13% and 16% in the winter, which increased during the spring to reach a peak towards late summer (27%). Afterwards, MYI decreased significantly (14%) during au-

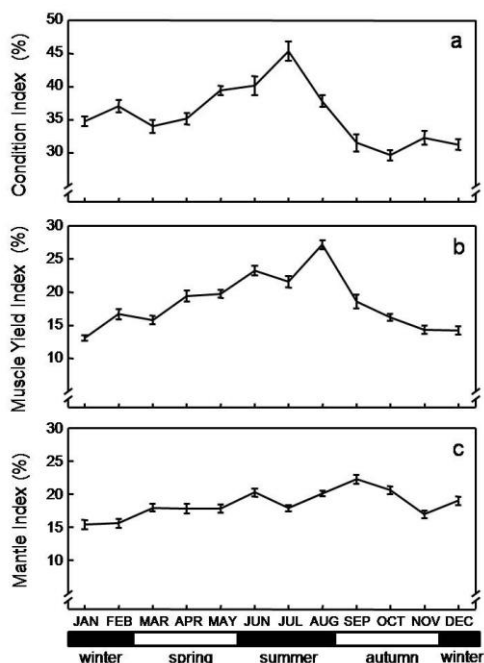


Figure 2. Seasonal variation of: a) condition index, b) muscle yield index, c) mantle index of *Atrina maura* in Ensenada de La Paz, B.C.S., México. Bars correspond to standard error.

tumn ($P < 0.01$) (Fig. 2b). The MI ranged between 15% and 20%, and no significant differences between seasons were detected ($P > 0.05$) (Fig. 2c). The CI was significantly correlated with the MYI ($r = 0.62$, $P < 0.05$), but not with MI ($r = -0.22$, $P > 0.05$).

Water temperature varied throughout the seasons, attaining the lowest levels in winter (mean = 20.9 °C). Temperature rose steadily during the spring and summer, reaching peak levels in late summer and early autumn (29 °C). Afterwards, by late autumn, temperature decreased to reach a minimum in early winter (22.1 °C) (Fig. 3).

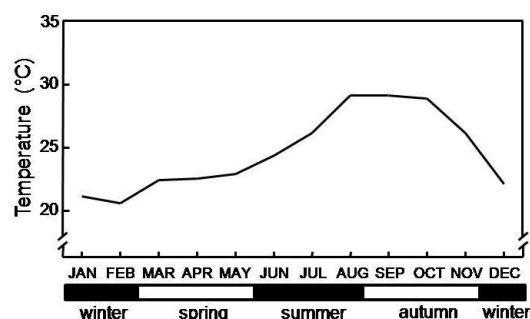


Figure 3. Seasonal variation of water temperature in Ensenada de La Paz, B.C.S. during the study period.

DISCUSSION

The condition index is considered sensitive to changes in reproductive development (Ojea *et al.*, 2004; Peharda *et al.*, 2006). In this study the physiological condition of *A. maura* increased from late spring, reaching a maximum in the summer, in agreement with specimens in developing and ripe stages. On this basis, a good physiological condition has been considered an indicator of nutrient accumulation (mainly glycogen and protein) in many bivalves (Nishida *et al.*, 2006), as well as of yolk buildup within oocytes (Aldrich & Crowley, 1986; Sahin *et al.*, 2006). This index experienced a substantial drop by the end of the summer and throughout autumn, which coincides with a high proportion of organisms in spawning stage (40%). This leads to the assumption that weight losses derive from gamete release, a fact that has also been reported for other species (Sahin *et al.*, 2006). The above demonstrates the strong influence of gonad tis-

sue on total mass. On the other hand, the adductor muscle weight in *A. maura* represented a high percentage of total mass, so that variations in muscle biomass strongly affected total biomass. Thus, the decrease observed in the CI might also be a result of the significant drop in the MYI through the autumn. This decrease in the MYI weight may derive from energy transfer (mostly carbohydrate and protein) from the muscle to the gonad, as occurs in other bivalves (Barber & Blake, 1981; Epp *et al.*, 1988; Taylor & Venn, 1979; Comely, 1974; Racotta *et al.*, 1998; Martínez, 1991; Racotta *et al.*, 2003; Arellano-Martínez *et al.*, 2004; Vite-García & Saucedo, 2008). These transferred energy reserves may be used as an immediate energy source for spawning (Racotta *et al.*, 1998; Ruíz-Verdugo *et al.*, 2001; Racotta *et al.*, 2003). The general pattern of CI and MYI found in this study contrasts with observations reported by Barrios-Ruiz (2005) for *A. maura* in Laguna San Ignacio, B.C.S. This author states that CI is unrelated to gonad ripening, and reported that MYI was inversely correlated with CI. This disparity may be due to the fact that *A. maura* displays a continuous reproduction pattern at Laguna San Ignacio (Barrios-Ruiz, 2005), whereas this species reproduces following a seasonal pattern in Ensenada de La Paz (this research). A discrepancy in the physiological pattern within the same species living in two localities under different environmental conditions has also been reported for *N. subnodosus* (Arellano-Martínez *et al.*, 2004).

The mantle has been reported to play a secondary role as energy storage and transfer site during gonad development in several Pectinidae species (Epp *et al.*, 1988; de Zwaan & Mathieu, 1992; Lodeiros *et al.*, 2001; Arellano-Martínez *et al.*, 2004) and in the pearl oyster *Pinctada mazatlanica* (Saucedo *et al.*, 2002). However, this study revealed insignificant variations in MI, suggesting little or no participation in energy storage and allocation during reproduction in *A. maura* in the Ensenada de La Paz. A similar finding was reported for the pearl oyster *Pteria sterna* collected from Bahía de La Paz (Cáceres-Puig, 2007; Vite-García & Saucedo, 2008).

On the other hand, two basic types of reproductive patterns have been documented for bivalves in the Gulf of California: species with continuous spawning, and species displaying a seasonal spawning pattern (Ceballos-Vázquez *et al.*, 2000). In this investigation, the macroscopic observation of gonads revealed that, in Ensenada de La Paz, *A. maura* displays a seasonal reproduction pattern characterized by spawning towards the end of the summer and throughout autumn, coinciding with the highest water temperature (29 °C). This seasonal spawning pattern is not consistent with the continuous spawning displayed by *A. maura* in tropical zones, including Acapulco Bay in Guerrero (Aguilar-Ibarra, 1964), the Balsas river mouth, Michoacán (Soria-Padilla, 1989), the Corralero-Alotengo lagoon system, Oaxaca (Ángel-Pérez *et al.*, 2007) and in some temperate zones, such as Bahía San Ignacio, B.C.S. (Barrios-Ruiz, 2005). This result evidences that bivalve reproductive cycles may vary with latitude, and that cycles are related to environmental instability or variations in critical parameters, such as temperature or food availability (Porter, 1964; Hesselman *et al.*, 1989; Cruz & Villalobos, 1993; Rodríguez *et al.*, 1993; Baqueiro & Aldana, 2000), following species-specific adaptations.

Based on the findings reported here, it is suggested that the commercial catch season of this species could comprise spring and summer. This is considered the best period inasmuch the combination of the best physiological condition and muscle weight occurs. However, it is necessary to consider that in August the higher value of MYI was registered, along with a high proportion of organisms in spawning stage. Thus, further studies on *A. maura* distribution, abundance, and reproductive potential in this area are required in order to set adequate catch quotas designed to avoid negative effects on this bivalve's population density.

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