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Seasonal changes in the gonadal state of the oysters *Crassostrea iridescens* and *Crassostrea corteziensis* (Filibranchia: Ostreidae) in the Northwest coast of Mexico

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Abstract: The reproductive cycle in oysters has been the object of several studies in temperate zones. However, little information is available for tropical and subtropical species. This study shows the seasonal changes in the gonadal index (GI) of two species of oysters, *Crassostrea iridescens* and *Crassostrea corteziensis*, which differ markedly in their hábitat and time of reproduction. Both oysters were sampled at 45 days intervals in the Northwest coast of Mexico between November 1989 and October 1990. Gonadal and somatic tissue per individual were dried for three days at 90°C, weighed and recorded. The gonadal index (GI) applied in this work was calculated from: GI = Wg/Ws. Where Wg is the average gonadal tissue dry weight, and Ws is the average somatic tissue dry weight. Seasonal variations in the gonadal state were evident for the two species. *C. iridescens* exhibited only a single maximum in the year, while *C. corteziensis* two peaks. This situation is presumably related to the contrastable environmental conditions that prevail in the sites where each species inhabit.

Key words: *C. iridescens, C. corteziensis,* reproductive cycle, temperature, oyster.

Typically, marine benthic bivalves have a cyclic pattern of reproduction which can be divided into three phases (Newell *et al.* 1982): (a) gametogenesis and vitellogenesis. (b) spawning and fertilization. and (c) larval development and growth. The main factors that influence this reproductive cycle, according to Galtsoff (1964) are water temperature, depth, salinity, food availability, and pollution.

Water temperature is the most important factor that influence in the gonadal state of oysters, e. g. *Crassostrea virginica* (Sastry 1975, Hayes and Menzel 1981, Gauthier and Soniat 1989), *Ostrea edulis* (Ruiz *et al.* 1992). Mann (1979) found that gametogenesis in *Crassostrea gigas* was dependent on water temperature and period of exposure. Muranaka and Lannan (1984) observed during conditioning of *C. gigas* in Oregon (USA) that the overall rate of gonadal development increased at temperatures from 16 to 22 °C.

The reproductive cycle in oysters has been the object of several studies in temperate zones (e.g. Coe 1932, Hopkins *et al.* 1953, Galtsoff 1964, Morales-Alamo and Mann 1989). Comparatively little information is available for tropical and subtropical species. Three species of wild oysters are found predominantly along the Pacific coast of Mexico. *Crassostrea iridescens* (Hanley 1854), *Crassostrea* *corteziensis* (Hertlein 1951) and *Crassostrea palmula* (Carpenter 1857) (Páez-Osuna *et al.* 1993). *C. iridescens* and *C. corteziensis* are of particular concern because they are used for human consumption. The rock oyster, *C. iridescens,* is associated with rocky substrata, inhabiting subtidal areas. Geographically, it is distributed from La Paz, Gulf of California to Northern Perú (Keen 1971). The mangrove oyster, *C. corteziensis,* is a brackish species (Stuardo and Martínez-Guerrero 1975) which occurs associated with the roots of the red mangrove *Rhizophora mangle*. Its distribution ranges from the Gulf of California to Panamá (Keen 1971). This work describes quantitatively the seasonal changes in the somatic and gonadic tissue weight of *C. iridescens* and *C. corteziensis* related to variations in water temperature.

MATERIAL AND METHODS

Oysters were collected in the Northwest coast of Mexico, between November 1989 and October 1990. Both species were sampled eight times at intervals of forty-five days between each sampling period. *C. iridescens* was collected from the rock substratum by scuba diving in one site (2-5 m depth water), near the inlet of "San Cristobal" estuary (105° 17' 31.2" W and 21° 31' 30" N), Nayarit state. and *C. corteziensis* was collected from the roots of the red mangrove *R. mangle* in the intertidal zone in one site selected near of the estuary inlet (105° 17' 21" W and 21° 32' 24" N). Temperature fluctuations at each site were not determined, instead temperatures were obtained with a laboratory mercury thermometer at a single site of the estuary inlet. Because the short distance between two collection sites (2 km), we assumed that the water temperature in the estuary inlet is the same as the water temperature in the site where *C. corteziensis* was collected.

A total of 20 *C. iridescens* (10±2 cm shell height) and sixty, (5±1 cm) of *C. corteziensis* were selected in each sampling period. Emphasis was placed on oysters of nearly equal height. This way, we hoped to limit as much as possible differences due to size and age (NAS 1980). In the laboratory, the oysters were measured for shell height and freed of their shells to separate gonadic from somatic tissue. The gonadal index (GI) applied in this work was calculated from:

GI = Wg/Ws (Latouche and Mix 1981) where Wg is the average gonadal tissue dry weight, and Ws is the average somatic tissue dry weight.

In both species the gonad is associated with the crystalline style sac, so that physical separation of the two tissues is sometimes difficult. Therefore, the gonad and portions of the style sac were considered to represent the gonadal tissue, while the remaining tissues were considered as somatic or nongonadal. Additionally, in *C. iridescens* (Páez-Osuna *et al.* 1995) and *C. corteziensis* as in the mussel *Mytilus edulis* (Lobel and Wright 1982), the gonad develops within the mantle in the last stage of the reproductive cycle so physical separation of both tissues is also difficult. In these cases, the gonad and portions of mantle were taken to represent the gonadal tissue. Gonadal and somatic samples tissue per individual were dried for three days at 90 °C, weighed and recorded with an analytical balance.

RESULTS

Temperatures ranged from 20.1°C in February 1990 to 30.9°C in September 1990 (Fig. 1). The mean 1.5 monthly gonadal index (GI ± standard deviation) per species in Fig. 1, shows that mean GI values in *C. iridescens* increased slowly from November to April (0.44 ± 0.14) achieving a rapid peak value in May (1.84 ± 0.57) when the temperature reached 27.3°C. GI values decreased when water temperature reached 30.6°C in July. For *C. corteziensis,* a slight increase of GI occurred from November to January, attaining a maximum of 0.54 ± 0.30 in April when presumably the temperature reached 23.8°C.

Mean GI value decreased to 0.23 ± 0.04 in May, increased to 0.37 ± 0.02 in July, decreasing later until October.

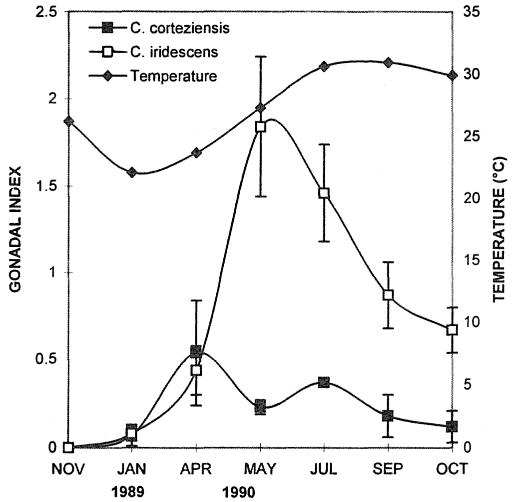

Fig. 1. Water temperature variations and gonadal index values (mean ± standard deviation) for *Crassostrea corteziensis* and *Crassostrea iridescens* during the study period.

DISCUSSION

The principal characteristics of the seasonal reproduction of *C. iridescens* and *C. corteziensis* have been described by Stuardo and Martínez-Guerrero (1975) and Cuevas-Guevara and Martínez-Guerrero (1979): the oyster *C. corteziensis* shows an undifferentiated sex stage from November to April, gametogenesis in February, maturation during March-August. spawning during May-September when the water temperature is higher than 25.5°C, and postspawning in November-December. *C. iridescens* follows a markedly different behavior consisting of a gonadal resting phase from October to May (maximum in January). Gametogenesis and maturation occurs during February-June and June-August, respectively. Spawning, which is relatively short in *C. iridescens* takes place mainly during August and September. However, quantitative measurements in the gonad weight were not considered for these oysters in the studies mentioned. According to Brousseau (1978) and Morales-Alamo and Mann (1989) the quantitative estimates are preferred to describe gonadal stage characterization because they eliminate the subjectivity and semantic problems associated with descriptive methods.

Gonadal index in *C. corteziensis* in this study did not increase from November to January because the organisms were in the resting phase with a mean GI of 0.07. The oysters then develop quickly until April, reaching during this period the gametogenesis phase (GI= 0.54 ± 0.30). From April to May the gonadal index dropped (GI= 0.23 ± 0.04). Possibly, this gonadal tissue weight reduction is related to spawning. Soniat and Ray (1985) found that with the onset of spawning, the percent lipid and the gonadal index of the oysters decline as sexual products are released. This minimum value observed in May, occurred when the water temperature increased almost 4°C presumably stimulating spawning. Numerous ecological observations have shown that under natural conditions, oysters spawn during rising temperatures (Galtsoff 1964). Sastry (1975) and Hayes and Menzel (1981) found that the reproductive state of bivalves such as *Crassostrea virginica* depends on a number of endogenous and exogenous factors, most importantly the water temperature.

The gonadal index peaked again (0.37 ± 0.02) in *C. corteziensis* from May to July although its magnitude was less than the April peak. Rogers and García-Cubas (1981) in a study with *C. virginica* observed that the gametogenesis phase was evident during almost two continuos years of research because of the conditions prevailing in the hydrologic system. Gunter (1951) observed that oysters grow more rapidly at higher temperatures, and U.S. Southern oysters apparently accumulate enough gonadal tissue for multiple spawns per year (Gauthier and Soniat 1989). Subsequently and until the end of the study period, another drop in the gonadal index value was observed in October (GI= 0.12 ± 0.09), presumably because of a second spawning. A similar tendency has been observed by Hopkins *et al.* (1953) who reported that U.S. Southern Atlantic oysters have two major spawnings per year. Soniat and Ray (1985) in Galveston Bay, found that *C. virginica* had two peaks in the gonadal index during its reproductive cycle, which probably represented two separate spawnings.

When water temperature increased from 23.8°C to 27.3°C, *C. iridescens* entered a gametogenesis phase, and showed a rapid development until May, when maximum GI values occurred (GI= 1.84 ± 0.57), possibly due to the factors discussed above. According to Soniat and Ray (1985), during maturation, the gonadal index is at its peak. In July and September, when water temperature reached 30°C (30.6 and 30.9°C, respectively) the value of gonadal index decreased, suggesting that the population began to spawn. In October *C. iridescens* showed the minimum gonadal index value (GI= 0.67 ± 0.13), indicating probably a continuous spawning.

The coefficient of variation of GI (SD¥100/mean) for the two oysters were relatively high most of the year. Although, the coefficient variation values of *C. corteziensis* in most cases were higher than those of *C. iridescens*, this may be interpreted as a result of higher gametogenic variation in the mangrove oysters than the rock oysters. Stuardo and Martinez-Guerrero (1975) reported that the maturation phase is evident during almost all the year in *C. corteziensis*. Littlewood and Gordon (1988) found that the mangrove oyster *Crassostrea rhizophorae* (in Jamaica), shows a continuous spawning during all year. This type of behavior appears to be characteristic of oyster species inhabiting tropical and subtropical lagoon-estuarine environments.

A general conclusion is that water temperature seemed to be a significant factor determining the gonad index and gametogenic state of the Mexican Pacific oysters *C. iridescens* and *C. corteziensis*. Unfortunately in the present study and in both oysters, significant correlations (p= 0.05) were not found between the GI and temperature, which may be due to the influence of other variables not measured (e.g. salinity, food availability). However, this study confirms the characteristics of the seasonally of reproduction of these bivalves described previously. A markedly different behavior was observed for the gonad index in the two species, thus, while *C. iridescens* exhibited only a single maximum in the year, *C. corteziensis* two peaks. This situation is presumably related to the contrastable environmental conditions that prevail in the two sites where each species inhabit and which must be measured. *C. iridescens* occurs in coastal marine waters where the prevalent hydrologic conditions are more stable. *C. corteziensis* inhabits estuaries where the conditions are more dynamic and the salinity is related to the tidal cycle and season (fresh-water input) of the year.

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RESUMEN

El ciclo reproductivo en ostras ha sido objeto de varios estudios en zonas templadas. Sin embargo, poca información está disponible para especies tropicales y subtropicales. Este estudio describe los cambios estacionales en el índice gonádico (GI) de dos especies de ostras, *Crassostrea iridescens* y *Crassostrea corteziensis*, las cuales difieren significativamente en su hábitat y tiempo de reproducción. Ambas ostras fueron muestreadas a intervalos de 45 días cada uno en la costa noroeste de México entre noviembre de 1989 y octubre de 1990. El tejido gonádico y somático por organismo fue secado por tres días a 90°C, pesados y registrados. El índice gonádico (GI) usado en este trabajo fue calculado de: GI= Wg/Ws. Donde Wg es el peso seco promedio del tejido gonádico, y Ws el peso seco promedio del tejido somático. Las variaciones estacionales en el estado gonádico fueron evidentes para las dos especies. *C. iridescens* presentó sólo un máximo en el año, mientras que *C. corteziensis* presentó dos máximos. Posiblemente esta situación es relacionada con las contrastables condicones ambientales que prevalecen donde cada especie habita.

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