Journal of Shellfish Research, Vol. 18, No. 2, 415–418, 1999.

TEMPORAL COINCIDENCE OF THE ANNUAL EELGRASS *ZOSTERA MARINA* AND JUVENILE SCALLOPS *ARGOPECTEN VENTRICOSUS* (SOWERBY II, 1842) IN BAHÍA CONCEPCÍON, MEXICO

NOÉ A. SANTAMARÍA,[1] ESTEBAN F. FÉLIX-PICO,[2] JOSÉ LUIS SÁNCHEZ-LIZASO,[1] J. RICARDO PALOMARES-GARCÍA,[2] AND MANUEL MAZÓN-SUÁSTEGUI[2]

[1]*Unidad de Biología Marina. Universidad de Alicante. Ap. 99 E-03080, Alicante, Spain*

[2]*Centro Interdisciplinario de Ciencias Marinas-IPN. Apdo. Postal 592. C.P. 23000, La Paz, B.C.S., Mexico.*

ABSTRACT The possibility that meadows of annual eelgrass *Zostera marina* L. in Bahía Concepción serve as a nursery habitat for Pacific calico scallop *Argopecten ventricosus* has been evaluated. Scallop reproduction occurs mainly in the coldest season of the year, just when annual eelgrass is present. In this study, it was observed that the highest abundance of pectinid larvae was in early March, and scallop spat on artificial collectors was higher in late March. The highest above-ground biomass of eelgrass occurred between February and April and declined in May, just when scallops detach themselves from substrata and settle to the bottom. Our results indicate a high coincidence in timing of the analyzed processes and suggest the possibility that eelgrass beds could be used as nursery grounds by Pacific calico scallop.

KEY WORDS: annual eelgrass, scallop spat, nursery habitat, *Zostera marina, Argopecten ventricosus*

INTRODUCTION

The Pacific calico scallop *Argopecten ventricosus* (=*circularis*) (Sowerby II, 1842) supports an important fishery in the state of Baja California Sur, Mexico. Between 1986 and 1991, scallop harvest in Bahía Concepción, the most productive bay for this fishery, had a very high production (up to 5531 t fresh weight in 1989), but there have been large fluctuations in landings since 1991, moving toward critical levels in 1993 (100 t) and 1994 when the fishery was closed. That depletion has prompted increased interest in the factors that affect scallop recruitment and survival (Félix-Pico et al. 1997).

During their early life history, Pacific calico scallops, as well as other pectinids, settle and attach to substrates that elevate them above the bottom (Félix-Pico et al. 1989). These substrates are usually submerged vegetation or even artificial materials, but eelgrass *Zostera marina* L. appears to be the main natural substratum for bay scallop, *Argopecten irradians* (L.) (Thayer and Stuart 1974). Eelgrass beds not only provide juvenile bay scallops with a settlement substrate but also help scallops avoid benthic predators, which results in higher scallop recruitment and survival (Ekman 1987, Peterson et al. 1989, Pohle et al. 1991, García-Esquivel and Bricelj 1993).

Juvenile bay scallops undergo an ontogenic shift in habitat. Scallops often attach themselves in the eelgrass canopy in their earlier life stage until they reach a size of 20–30 mm, after which juvenile scallops settle to the bottom. At this size they have achieved a refuge from some of their major crustaceans predators (García-Esquivel and Bricelj 1993).

Little is known about the association of Pacific calico scallops and eelgrass beds in spite of the fact there are extensive eelgrass meadows in almost all the lagoons of Baja California Sur where scallops occur (Félix-Pico et al. 1989).

Z. marina is a widely distributed, temperate seagrass species that occurs in some subtropical regions, such as the Gulf of California (Phillips and Meñez 1988). Although this species commonly forms perennial beds, in the Gulf of California eelgrass forms only annual beds, which appear in late autumn as seeds, and disappear in mid-spring when all the plants die (Phillips and Backman 1983, Santamaría 1996).

As Pacific calico scallops reproduce mainly in the coolest part of the year, January to March (Villalejo-Fuerte and Ochoa-Báez 1993, Félix-Pico et al. 1997), it is possible to suppose that annual eelgrass beds serve as nursery habitat for juvenile Pacific calico scallops. For this, it is first necessary that spat settlement coincide with the maximum eelgrass standing crop and that scallops reach a sufficient size to be a free living form before eelgrass beds disappear. Direct evaluation of the settlement of juvenile scallops on eelgrass in Bahía Concepción was not possible because scallops were very scarce throughout the bay during the year of study. Thus, the objective of the present study was to determine the timing of *Z. marina* bed presence, pectinid larval abundance, and juvenile scallop settlement on artificial collectors and to determine if eelgrass meadows in Bahía Concepción appear in the time when they could potentially provide scallops with a mechanism to increase survival.

MATERIALS AND METHODS

Bahía Concepción is located in the Gulf of California on the east coast of the Baja California Peninsula at approximately lat 26°45′N, long 111°45′W (Fig. 1). Usually, the surface water temperature in the Bay varies from 18 °C to 32 °C, but a surface temperature of 16 °C was observed in February 1989 (Villalejo-Fuerte and Ochoa-Báez 1993).

To evaluate the *Z. marina* bed as potential habitat for scallops, data on eelgrass abundance were taken at Punta Arena, Bahía Concepción, during one season of eelgrass development, from December 1994 to July 1995. Samples were taken every 3 weeks via scuba diving. Eelgrass shoot density was measured in 25 × 25 cm quadrats, with 4 to 10 random replicates. Shoot abundance was

Figure. 1. Study area: Bahía Concepción. Sampling sites, Punta Arena and El Coloradito, are indicated by arrows.

extrapolated per m². Percentage cover was examined in 20-m transects, with 4 replicates. Thirty shoots were sampled to determine above-ground biomass and the total height of plants. Plant biomass evaluation was measured by drying individual shoots at 60 °C to constant weight. To evaluate the potential habitat provided by the eelgrass bed, height of the canopy was estimated as the mean height of plants.

Simultaneously, to evaluate abundance of D-veliger (2 to 9 days old), umbonated (10 to 13 days old), and pediveliger (14 to 18 days old) scallop larvae (Avilés-Quevedo 1990, Monsalvo-Spencer 1998), we sampled zooplankton at Punta El Coloradito weekly, using a water-pump and two sieves of 63 and 132 μm mesh. For zooplankton analysis, subsamples were taken by a Folsom Divider. All D-veliger, umbonated, and pediveliger larvae found in both sieves were counted, and the data were standardized per m³.

To test the timing of spat settlement in Bahía Concepción, artificial collectors were used due to the low levels of scallop abundance here during this study. Collectors were built with onion sacks filled with 300 g of polypropylene nets. They were hung from a longline, held by buoys and anchors, at 1- and 3-m depth. Ten collectors were installed weekly, 5 at each depth, to monitor spat settlement during the time when scallop spawning was anticipated to occur, from 19 January to 30 March. Each set of collectors was removed from water 2 months after it was installed. Collectors were dried before juvenile scallops were separated through a 5-mm sieve and Pacific calico scallops counted. Mean spat size and number of scallops settled per collector were recorded. Previous data showed that no significant differences were found in collector efficiency between Punta Arena and El Coloradito in 1991 and 1992 (Félix-Pico et al. 1997). Surface seawater temperature was measured at each sampling date.

RESULTS

The *Z. marina* bed at Punta Arena appeared in early December as seedlings, then all eelgrass plants suddenly died in late May and the meadow disappeared. In July, there were no eelgrass plants, only seeds in the sediment. Shoot density in the bed was about 1,400 shoots per m² from December to April when shoot density started to decrease. Highest values of above-ground biomass occurred between February and March 1995 (Fig. 2a), particularly from 15 to 30 March (218 and 235 g DW/m², respectively). There was a decrease in biomass by early March, but this coincided with the highest mean plant height, 71 cm (Fig. 2a), and we suppose that it could be caused by variation in plant morphology. However, shoot density and height of eelgrass bed showed consistently high values from February to May, suggesting that canopy habitat was high during this period.

There were some pectinid larvae in the water column at El Coloradito, on 16 February and 2 March, 95 and 40 larvae/m³, respectively, but the maximum concentrations were observed on 9 and 16 March: 400 and 290 larvae/m³, respectively (Fig. 2b). Thereafter, larvae were almost absent. Spat caught on collectors were most abundant in collectors installed from 16 to 23 March, averaging 35.5 and 20 individuals per collector, respectively (Fig.

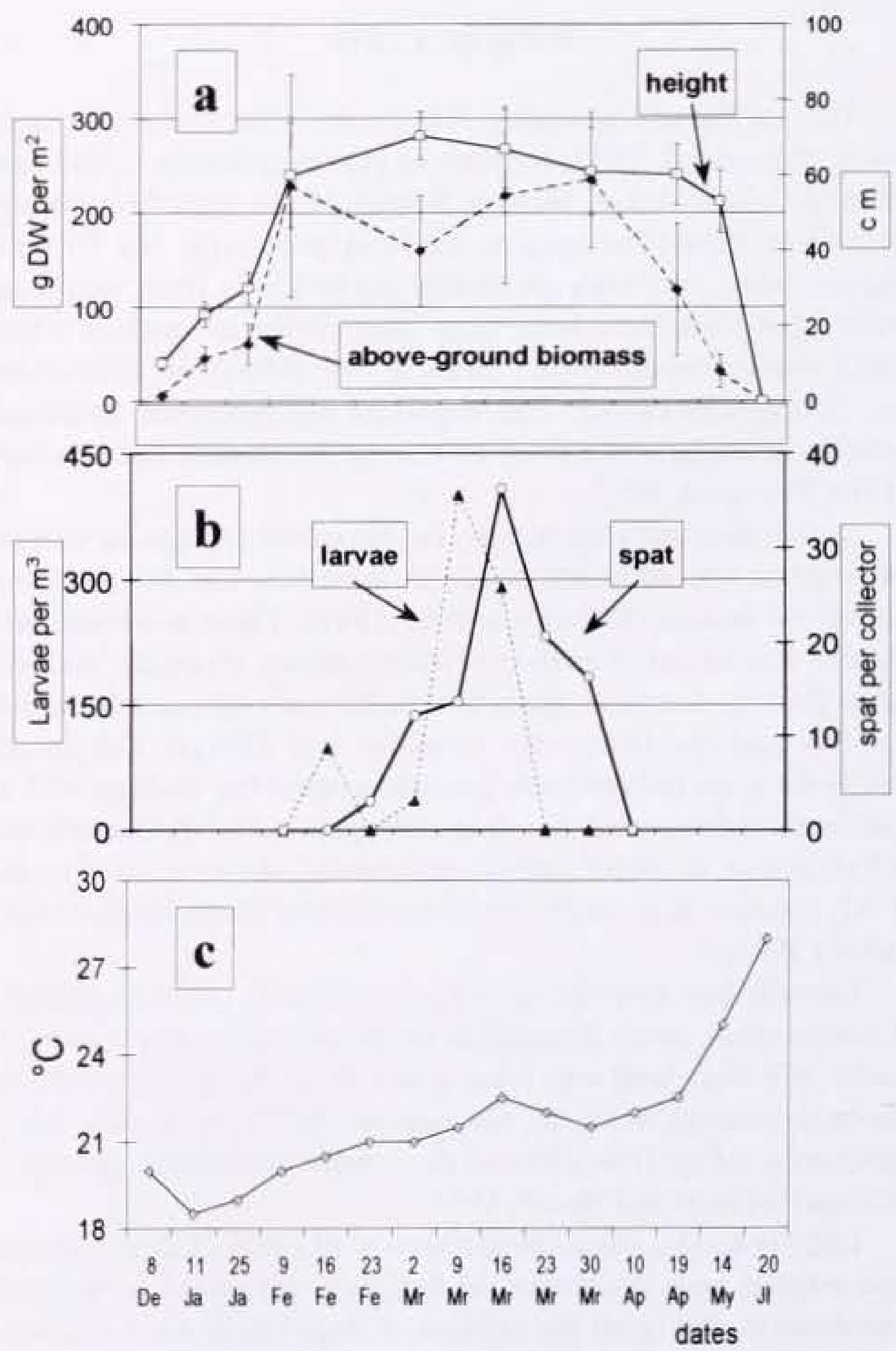

Figure. 2. (a) Mean above-ground biomass of eelgrass bed (left scale) and plant height (right scale); error bars = standard deviation (n = 30), (b) scallop larvae density (left scale) and new spat abundance on collectors per week (right scale), and (c) seawater temperature during sampling period. All data shown are from December 1994 to July 1995.

2b). Spat in collectors were gradually detached when they reached n 20 to 30 mm, from April to May. Sizes of scallops observed in collectors were between 7 and 34 mm.

Seawater temperature was between 18.2 °C in January and 22.5 °C in April, and reached 28 °C in July (Fig. 2c).

DISCUSSION

Our data show a high coincidence in timing of scallop spawning, spat abundance, and the permanence of eelgrass beds. Spat abundance peaked in collectors installed one week after we observed peak in larval abundance on 9 March, therefore, it can be inferred that individuals in collectors came from the same cohort as the sampled larvae, because there were no more larvae in the water after that. Efficiency of collectors decreases rapidly after they have been installed, probably due to epibiosis. On the other hand, scallops take about 2 months to reach 20 to 30 mm, when they are able to become a free-living form, but scallop spat are able to detach themselves after reaching about 15 mm (García-Esquivel and Bricelj 1993).

During the time when the scallop spat in Bahía Concepción need to be fixed, the eelgrass bed was present. The height of the eelgrass canopy remained at high levels until plant death, but above-ground biomass began to decline in late March. Previously, it has been observed that most juvenile scallops detach themselves from the substrate to begin a free-living form before all the plants die in May (Félix-Pico et al. 1997). Similarly, populations of *Argopecten irradians* on the east coast of the United States reproduce mainly in the season of major development of eelgrass meadows, although those beds are not annuals but perennials, and it occurs in summer, from July to September (Churchill and Riner 1978, Roman and Able 1988, Garcia-Esquivel and Bricelj 1993).

The absence of juvenile scallops attached to eelgrass shoots in Bahía Concepción during the sampling period was considered to be due to low adult scallop abundance, and spat abundance observed in collectors was also low. Normal levels of spat collections are consistent annual yields of 6,000 spat per collector. In 1994, spat collections were 41 to 852 spat per bag (Félix-Pico et al. 1997), but 2 years later, in spring 1997, a great quantity (about 500 spats/m^2) of scallop spat were found together with plants sampled in April. Unfortunately it was not possible to quantify the density because distribution inside the bed is very contagious and systematic sampling was not done.

Other types of submerged macrophytes in Bahía Concepción must not be ignored, such as *Sargassum* spp. stands, which are the most abundant macroalgae in the Bay and may also serve as a substratum to scallop spat. However, the main development of *Sargassum* is in June to July (Casas-Valdez et al. 1993) when scallop spat presence is not significant.

In 1989, an unusually high eelgrass abundance coincided with the lowest temperature recorded in the Bay (Castro-Ortíz pers. comm.), and a boom in catches of scallops was also observed that year (Félix-Pico et al. 1997). As annual eelgrass in the Gulf of California develops in the coolest season of the year because it is a temperate species living in a subtropical locality (Phillips and Backman 1983, Phillips and Meñez 1988, Santamaría 1996), and the main scallop spawning period in Bahía Concepción also coincides with the coolest months of the year (Villalejo-Fuerte and Ochoa-Báez 1993), temperature probably plays a significant role in Pacific calico scallop recruitment and survival. However, other environmental factors that could also affect the abundance of eelgrass beds in their year-to-year variation must be considered in future studies.

Findings obtained in this study are limited and more research is necessary to confirm and evaluate the relation of Pacific calico scallop spat to eelgrass beds, both in the laboratory and field. However, with these results it is possible to propose some suggestions for a better exploitation of Pacific calico scallop. If our hypothesis is confirmed, the protection of eelgrass beds would be necessary to preserve high abundance of scallop populations. Besides, with absolute certainty, eelgrass beds accomplish several other ecological tasks in the Bay (Phillips and Meñez 1988). Avoidance of trawl fishing over the meadows is an urgent matter that should be addressed to protect the meadows. This activity, as we could see during field work in Bahía Concepción, causes severe damage to the eelgrass coverage. Seagrass meadows in other localities have been already protected successfully from trawl fishing (Guillén-Nieto et al. 1994) with benefits for artisanal fisheries (Martínez 1997).

AKNOWLEDGMENTS

This research was supported by the "Biología y cultivo de la almeja catarina, y algunos invertebrados de importancia económica" project, under number 923460 (DEPI) for CICIMAR IPN. The first author was supported by the scholarships CONACyT and COFFA-IPN. Second and third authors had scholarships from COFFA-IPN and Desempeño Académico. Special thanks to Armando Naranjo Mariscal and MASAVI S.A. for its collaboration on collector installation and all CICIMAR personnel who worked on this project.

LITERATURE CITED

Avilés-Quevedo, M. A. 1990. Crecimiento de la almeja catarina (*Argopecten circularis*) en función del alimento, con anotaciones sobre su biología y desarrollo. Tesis de Maestría. CICIMAR-IPN. La Paz, B.C.S. México. 64 pp.

Casas-Valdez, M. M., I. Sánchez-Rodríguez & G. Hernández-Carmona. 1993. Evaluación del *Sargassum* spp en la costa oeste de Bahía Concepción, B.C.S., México. *Inv. Mar. CICIMAR* 8(2):61–69.

Churchill, A. C. & M. L. Riner. 1978. Anthesis and seed production in *Zostera marina* L. from Great South Bay, New York, U.S.A. *Aquat. Bot.* 4:83–93.

Ekman, J. E. 1987. The role of hydrodynamics in recruitment, growth and survival of *Argopecten irradians* (L.) and *Anomia simplex* (D Orbigny) within eelgrass meadows. *J. Exp. Mar. Biol. Ecol.* 106:165–191.

Félix-Pico, E., A. Tripp-Quezada, J. Castro-Ortíz, G. Serrano-Casillas, P. González-Ramírez, M. Villalejo-Fuerte, R. Palomares-García, F. García-Domínguez, M. Mazón-Suástegui, G. Bojórquez-Verástiga & G. López-García. 1997. Repopulation and culture of the pacific calico scallops in Bahía Concepción, B.C.S., México. *Aquacult. Int.* 5:551–563.

Félix-Pico, E., A. Tripp-Quezada & J. Singh-Cabanillas. 1989. Antecedentes en el cultivo de *Argopecten circularis* (Sowerby) en Baja California Sur, México. *Inv. Mar. CICIMAR* 4:75–92.

García-Esquivel, Z. & M. Bricelj. 1993. Ontogenic changes in microhabitat distribution of juvenile bay scallops, *Argopecten irradians irradians* (L.), in eelgrass beds, and their potential significance to early recruitment. *Biol. Bull.* 185:42–55.

Guillén-Nieto, J. E., A. A. Ramos-Esplá, L. Martínez & J. L. Sánchez-Lizaso. 1994. Antitrawling reefs and the protection of *Posidonia oceanica* (L.) Delile meadows in the western Mediterranean sea: demand and aims. *Bull. Mar. Sci.* 55(2–3):645–650.

Martínez, J. M. 1997. La pesca artesanal de El Campello (Alicante, S.E. Ibérico): caracterización y elementos para una ordenación. PhD Thesis, University of Alicante. 248 pp.

Monsalvo-Spencer, P. 1998. Estudios sobre el cultivo de larvas y juveniles de almeja catarina *Argopecten ventricosus* (= *circularis*) (Sowerby II, 1842) en laboratorio. Tesis de Maestría. CICIMAR-IPN. La Paz, B.C.S. México. 70 pp.

Peterson, C. H., H. C. Summerson, S. R. Feghley & R. C. Prescott. 1989. Timing, intensity and sources of autumn mortality of adult bay scallops *Argopecten irradians concentricus* Say. *J. Exp. Mar. Biol. Ecol.* 127: 121–140.

Phillips, R. C. & T. W. Backman. 1983. Phenology and reproductive biology of eelgrass (*Zostera marina* L.) at Bahia Kino, Sea of Cortez, Mexico. *Aquat. Bot.* 17:85–90.

Phillips, R. C. & E.G. Meñez. 1988. Seagrasses. Smithsonian Contributions to the Marine Sciences. No. 34. Smithsonian Institution Press, Washington. 240 pp.

Pohle, D. G., V. M. Bricelj & Z. García-Esquivel. 1991. The eelgrass canopy: an above-bottom refuge from benthic predators for juvenile bay scallops *Argopecten irradians*. *Mar. Ecol. Prog. Ser.* 74:47–59.

Roman, C. T. & K. W. Able. 1988. Production ecology of eelgrass (*Zostera marina* L.) in a Cape Cod salt marsh-estuarine system, Massachusetts. *Aquat. Bot.* 32:353–363.

Santamaría, N.A. 1996. Ciclo de crecimiento y fenología de la fanerógama *Zostera marina* L. en Punta Arena, Bahía Concepción, B.C.S., México. Tesis de Maestría. CICIMAR-IPN. La Paz, B.C.S. México. 97 pp.

Thayer, G. & H. H. Stuart. 1974. The bay scallop makes its bed of seagrass. *Mar. Fish. Rev.* 36:27–30.

Villalejo-Fuerte, M. & R. I. Ochoa-Báez. 1993. The reproductive cycle of the scallop *Argopecten circularis* (Sowerby, 1835), in relation to temperature and photoperiod, in Bahía Concepción, B.C.S., México. *Ciencias Marinas* 19(2):181–202.