Notes on the growth, survival, and reproduction of the lion's paw scallop *Nodipecten subnodosus* maintained in a suspended culture

Notas sobre el crecimiento, sobrevivencia y reproducción de la almeja mano de león *Nodipecten subnodosus* en cultivo en suspensión

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Abstract. The study was conducted from March 1999 to November 2002 in a suspended culture located in Bahía Juncalito, Gulf of California, Mexico. *Nodipecten subnodosus* (Sowerby, 1835) is a species with fast growth (ø=3.91) and alometric, with a seasonality of 0.78 and an amplitude of 0.8. Its growth was described by the von Bertalanffy model. An average growth rate of 4 mm/month was estimated for the first 16 months of the study. Then, it decreased to 1.3 mm/month until the end of the experiment. The survival was high (≥ 89 %) and did not change substantially until November 2001 when it decrease to 40%. In Bahía Juncalito, *N. subnodosus* attain its first spawn at nearly 2-years old with a mean shell height of 72 mm.

Key words: Pectinidae, scallops, culture, Gulf of California.

Resumen. El estudio se llevó a cabo entre marzo 1999 y noviembre de 2002 en un cultivo en suspensión localizado en Bahía Juncalito, Golfo de California, México. Se encontró que *Nodipecten subnodosus* (Sowerby, 1835) es una especie con crecimiento rápido (ø=3.91), y alométrico, con una estacionalidad de 0.78 y una amplitud de 0.8. Su crecimiento se describe por el modelo de von Bertalanffy. Se estimó una tasa de crecimiento promedio de 4 mm/mes para los primeros 16 meses de estudio. Posteriormente disminuyó a 1.3 mm/mes hasta el final del estudio. La supervivencia fue alta (≥ 89 %) y no hubo cambio sustancial hasta noviembre de 2001 cuando disminuyó hasta 40%. En Bahía Juncalito *N. subnodosus* tuvo su primer desove a una edad de aproximadamente 2 años con una altura media de la concha de 72 mm.

Palabras clave: Pectinidae, pectinidos, cultivo, Golfo de California

The lion's paw scallop *N. subnodosus* (Sowerby, 1835) is distributed from the Laguna Guerrero Negro, Baja California Sur, Mexico (including the Gulf of California) to Peru (Keen, 1971). It is the largest of all pectinid species, reaching a maximum length of 218 mm (Félix-Pico *et al.*, 1999). In Mexico, the lion's paw scallop is commercially exploited because its large adductor muscle locally named "callo", is appreciated for human consumption. The "callo" production is exported chiefly to the United States of America. However, commercial exploitation takes place only at the scallop's northern range (Laguna Ojo de Liebre, in the Pacific Ocean) because its abundance is low in other areas. Since 1997 an increasing interest in this species has arisen due to its high potential for aquaculture.

Studies focused on the biology of the lion's paw scallop are scarce. Research on the seasonality of spat settlement was undertaken at the Laguna Ojo de Liebre (García-Domínguez *et al.*, 1992). In Baja California Sur, Mexico, the growth of juveniles in a suspended culture has been evaluated at Laguna Ojo de Liebre (García-Domínguez *et al.*, 1992), Bahía de La Paz (Barrios *et al.*,1997), and Bahía Magdalena (Racotta *et al.*, 2003). Furthermore, studies on gonadic maturity, spawning, and seed production have been conducted (Morales-Hernández and Cáceres-Martínez, 1996; Villavicencio-Peralta, 1997; García-Pámanes *et al.*, 1994), as well as research on embryonic development (Villavicencio-Peralta, 1997) and the reproductive cycle (Reinecke-Reyes, 1996). Nevertheless, no studies on the biology of the *N.*

subnodosus population in Bahía Juncalito have been previously conducted.

The objective of the present study was evaluate the growth, survival, and reproduction of lion's paw scallop juveniles in a long-line culture system.

Lion's paw scallop juveniles (4 months old and ≈20 mm in shell height) produced with techniques previously established (Robles-Mungaray *et al.*, 1999) at the hatchery of the Centro de Investigaciones Biológicas del Noroeste (CIBNOR) in La Paz, Baja California Sur, Mexico, were placed in Bahía Juncalito, Gulf of California (26°49' y 111°20') in February 1999 and maintained in 2.0 mm mesh bags within Nestier trays (50 x 50 x 10 cm). Trays were suspended 1 m above the bottom (during ebb tide) from a long polyethylene line (10 m long and 0.5 inch diameter). This system was placed 300 m offshore, suspended with floats (30 x 20 x 25 cm) and anchored at 10 m deep. One month later, juveniles were released from the bags into the Nestier trays. As scallops grew, the density was adjusted to maintain 50% of the tray bottom free.

A total of 12 samplings were conducted between March 1999 and November 2001 (Table 1). Shell height (distance between the dorsal hinge and the ventral margin), was measured to the nearest 0.01 mm in randomly selected scallops, and the number of living and dead individuals were noted. No scallop mortality occurred during transportation. Survival was 100% during the first three months (March to May 1999). In June, survival decreased to 90%. In September no survival records were available because of the loss of one module due to the environmental conditions. Survival was 89% in October and did not change substantially until November 2001 when it declined to 40%. Scallop survival during this experiment was high and comparable with reports for the same species in similar experiments (88-91%) (Carvajal-Rascón, 1987; Félix-Pico *et al.*, 1999). Although high mortalities have been related to reproductive activity (Freites 1995), or to dinoflagellate blooms (Lodeiros *et al.*, 1998), in our study the high mortality observed in November 2001 was a consequence of the effects of hurricane Juliette occurred in October.

Additionally, 5 scallops were sampled randomly each time to determine the weight of the soft tissue, adductor muscle, and total wet weights (to the nearest 0.01g). Gonads of these scallops were fixed in a 10% formalin solution prepared with seawater for histological analysis. The gonads were later dehydrated in a series of progressive increasing ethanol concentrations, cleared in toluene, and embedded in paraplast X-Tra tissue-embedding medium. Serial sections measuring 7 µm thick were obtained with a rotary microtome and stained with hematoxilyn-eosin (Humason, 1979).

The histological analyses show that gonad development started in February 2000, when mean shell height was 57 mm, at this time gonads were translucent with a pale pink color. Mature scallops were present in June-July 2000 when the scallops measured 68-72 mm in shell height. Gonads were turgid, not translucent, with an intense orange color in the female portion and a creamy color in the male portion. Spawning occurred in October 2000, when scallops were two years old, with a mean shell height of 72 mm, and gonads were flaccid and opaque. In 2001, no histological analysis was conducted but the tendency in the appearance of gonads in development, maturity and spawning was similar to those presented in 2000, and another spawning event was observed in November. Although there were not samples in all months, the tendency observed in the reproductive cycle was accord with the reproductive cycle reported for *N. subnodosus* in other localities of Baja California Sur (Reinecke-Reyes, 1996; Racotta *et al.*, 2003; Arellano-Martínez *et al.*, 2004).

In relation with the growth, in the study area the lion's paw scallops reached mean shell heights of 57 mm in 12 months and 93 mm in 32 months (Table 1). However, at the end of the 32-month growth experiment shell height ranged from 70 to 105 mm. Total weight (TW), soft tissue weight (STW), and adductor-muscle weight (AMW) were fitted to a potential model in relation to shell height (H) (n=93).

$$TW = 0.00073H^{2.72} \qquad r = 0.96$$
$$STW = 0.00019H^{2.68} \qquad r = 0.96$$
$$AMW = 0.00003H^{2.87} \qquad r = 0.96$$

In order to determine if the growth may be considered isometric or not, a t-student test was applied with the null hypothesis ß = 3. Thus, the results indicated that the growth in TW, STW and AMW of *N. subnodosus* is alometric ($P < 0.025$). Additionally, a one-way ANOVA followed by a mean comparison post hoc Tukey test were made to assess significant differences in TW, STW and AMW among shell-height classes. In all cases, significant differences were observed at >60 mm H ($P < 0.001$).

To calculate the amplitude and seasonality of growth, the mean growth values (for shell-height modal classes) were obtained by the Bhattacharya modal separation method (Sparre and Venema, 1991), and plotted (Fig. 1). From the resulting graph, the amplitude and seasonality of growth were determined according to Gulland and Holt's method (Gayanilo *et al.*, 1995). In this way, the seasonality was determined at 0.78 with an amplitude of 0.8. A clear seasonality in growth rate was observed in April and October. An average growth rate of 4 mm/month (0.13mm/day) from the start of the experiment on March 1999 until July 2000 (16 months on suspended culture and 19-month old scallops) was estimated. From this point, a decline in growth rate to 1.3 mm/month (0.04 mm/day) was observed until the end of the experiment. Racotta *et al.*, (2003) also reported a decrease in the growth rate of *N. subnodosus* in the second year of culture. The decrease in the growth rate

Table 1. Data on sampling periodicity, number of scallops sampled (n), age, and shell height (mean and standard deviation)of lion-paw scallop *Nodipecten subnodosus*

Sampling date Day/month/year	n	Age (month)	Mean Height (mm)	Standard deviation (mm)
06/03/99	33	4	20.0	4.1
02/04/99	89	5	17.3	4.9
23/06/99	257	7	25.5	7.1
03/09/99	187	9	42.5	7.3
02/10/99	154	10	42.5	6.1
27/11/99	89	11	46.5	6.4
24/02/00	67	14	57.0	4.0
04/06/00	138	19	68.4	7.0
15/07/00	140	20	72.0	6.0
22/11/00	107	24	74.1	5.9
21/04/01	49	29	84.6	9.3
02/11/01	36	36	93.4	8.6

observed may be a consequence of the start of gonadal development. Gonadal growth is a factor that may negatively affect somatic growth of *N. nodosus* (Acosta *et al.*, 2000) and *Pinna cornea* (Narváez *et al.*, 2000).

Also, the growth index (ø) was calculated using the equation by Pauly and Munro (1984) (ø = log10K + 2log L∞), originally proposed for fishes and regarded as highly appropriate for comparing growth patterns in bivalves (Vakily, 1990; cited by Urban, 1991).The estimated growth index (ø) for juveniles of *N. subnodosus* maintained in a suspended culture in Bahía Juncalito, Gulf of California was 3.91. Comparing this value with that of other species regarded as fast-growing such as *Aulacomya ater* (ø = 3.68), *Gari solida* (ø = 3.71) and *Semele solida* (ø = 3.54) (Urban, 1991), it is evident that *N. subnodosus* may be considered as a fast-growing species.

The growth of *N. subnodosus* was described by the von Bertalanffy model. For the model, L∞ and k were obtained with the FISAT software (Gayanilo *et al.*, 1995); t_0 was calculated from the Von Bertalanffy equation. Thus, the model of growth for juveniles of *N. subnodosus* maintained in a suspended culture in Bahía Juncalito, Gulf of California was: $H = 116(1-e^{-0.61(t-0.22)})$.

The growth of *N. subnodosus* has been evaluated in different localities along the Baja California coast. Although direct comparisons are not always possible or appropriate due to differences in time, localities, origin of spat and broodstock, or records on the onset of growth (Racotta *et al.*, 2003), an interesting finding is evident. The mean shell height reached after one year is similar in localities belong to the Gulf of California: Bahía Juncalito, 57 mm/year, 0.13 mm mm/day (this study) and Bahía de La Paz, 54 mm/year, 0.14 mm/day (Barrios *et al.*, 1997). Whereas, in localities belong to

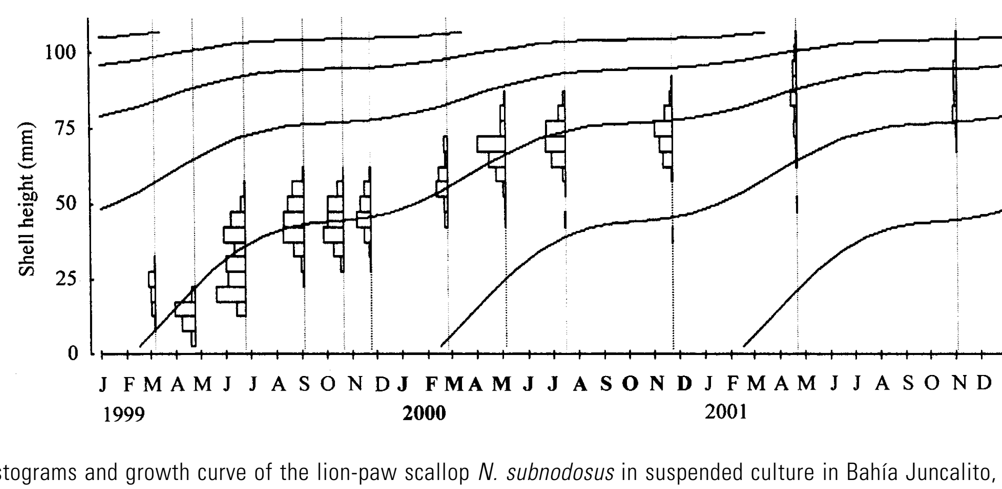

Figure 1. Histograms and growth curve of the lion-paw scallop *N. subnodosus* in suspended culture in Bahía Juncalito, Gulf of California obtained by the Bhattacharya modal separation method.

the Pacific coast the values are larger: Laguna Ojo de Liebre, 76 mm/year, 0.21 mm/day (García-Domínguez *et al.*, 1992) and Bahía Magdalena, 92 mm/year, 0.25 mm/day (Racotta *et al.*, 2003). This suggests that the Pacific coast may be a better location for the culture of lion's paw scallops.

Temperature and food availability have been considered as the more important environmental factors that influence the bivalve growth under suspended culture conditions (Bayne and Newell, 1983; Lodeiros *et al.*, 1998; Lodeiros and Himmelman, 1994, 2000). To this respect, the maximum temperature registered in Bahía Juncalito is 29ºC (Villalejo-Fuerte *et al.*, 2002), whereas the maximum temperatures registered in Laguna Ojo de Liebre (25.2 ºC) (Arellano-Martínez, unpublished data) and Bahía Magdalena (26.6 ºC) (Hernández-Rivas *et al.*, 1993) are lesser. From the above, temperature appears as a factor that no influence so much the growth of *N. subnodosus*, then the difference may be the food availability in each locality, but no data on the food availability are available for comparison. However, the above is supported by the results of Félix-Pico *et al*. (1999) who registered a growth (86.5mm/year, 0.24mm/day) in Bahía de Loreto (into the Gulf of California) similar to the observed in Pacific coast localities.

Bahía de Loreto is near Bahía Juncalito, and then it is possible that the environmental conditions been similar, but the results in growth rate in each locality are very different. Another possibility to explain these differences is that the study by Félix-Pico *et al*. (1999) was conducted with wild seed collected at the study site, whereas in the present study we used laboratory-produced seed, which may be of lower quality.

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