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Growth Bands in Test Plates of the Sea Urchins *Arbacia punctulata* and *Lytechinus variegatus* (Echinodermata) on the Central Florida Gulf Coast Shelf

SOPHIE K. HILL, JASON B. ARAGONA, AND JOHN M. LAWRENCE

Growth bands in test plates provide information about the biology and ecology of sea urchins. We documented the bands in the test plates of *Arbacia punctulata* and *Lytechinus variegatus* at different seasons and locations on the central Florida Gulf Coast shelf. The number of growth bands in test plates is significantly correlated with test diameter for *A. punctulata*. The number of growth bands is not significantly correlated with test diameter for *L. variegatus*. The condition of the outermost growth band was recorded along with the month and reproductive state to investigate the effect of variation in reproduction and temperature on growth. Growth bands in *A. punctulata* are well defined and appear to be related to the reproductive cycle. Growth bands in *L. variegatus* are less well defined and may be more closely related to food availability.

Growth bands in the test plates of sea urchins represent alternating periods of fast and slow growth and have been used for many years to age individuals (Pearse and Cameron, 1991). These authors pointed out the uncertainty of the assumption that the bands are reliable chronometers as they may simply be correlated with size or reflect any fluctuation in food supply, seasonal or not. Abiotic changes sufficient to disrupt physiological processes and differential seasonal gonadal and test growth can also have a similar effect (J. S. Pearse and V. B. Pearse, 1975).

Arbacia punctulata (Arbaciidae) and *Lytechinus variegatus* (Toxopneustidae) are abundant on the Florida Gulf Coast shelf (Serafy, 1979). *Arbacia punctulata* and *L. variegatus* can coexist on the shelf but occupy different microhabitats (Hill and Lawrence, 2003). The effect of temperature and starvation on feeding, respiration, and production differs for the two species (Hill and Lawrence, 1999), suggesting fundamental differences in their biology. Growth bands have been reported in the test of the European *Arbacia lixula* but not for *A. punctulata*. Growth bands in the test have not been described for *L. variegatus*, although Beddingfield and McClintock (2000) reported growth bands in the teeth of the Aristotle's lantern. Because of the potential use of growth bands as indicators of the biological and ecological conditions of individuals, we investigated the growth bands of different populations of the two species on the central Florida Gulf Coast shelf.

MATERIALS AND METHODS

Specimens were collected by scuba diving at six sites in the Gulf of Mexico between Feb. 1998 and May 1999. The characteristics of the sites are given in Table 1. The test diameter was measured, and the specimens were weighed. The gonads were removed and weighed, and the gonad index was calculated as (gonad wet weight/body wet weight) × 100.

Tests were placed in bleach for 20 min to remove spines and dried in an oven at 60 C for 48 hr. The tests were then charred in a muffle furnace at 300 C for 30 sec for *A. punctulata* and 45 sec for *L. variegatus*. The tests were immersed in xylene, the numbers of light and dark growth bands of plates from the ambitus were counted with a dissecting microscope, and the condition (light or dark) of the outermost band was recorded.

RESULTS

The light and dark bands of the test plates are shown in Figure 1. The growth bands of *A. punctulata* were clear and easily identifiable. Growth bands of *L. variegatus* were much harder to distinguish, often with multiple, closely spaced bands within a major band. The r^2 was significant for the regression between test diameter and number of growth bands for *A. punctulata* ($P < 0.001$) but not for *L. variegatus* ($P = 0.094$) (Figs. 2, 3). Each growth band class in *A. punctulata* encompassed a 20- to 30-mm range.

Most individuals always had a light outer-

TABLE 1. *Arbacia punctulata* and *Lytechinus variegatus*: location, depth, and distance from shore of collection sites, dates of collection, and characteristics of collection sites.

Site and species	Location, depth, distance from shore	Dates	Characteristics
1. *Arbacia punctulata*	28°08.56N 83°08.82W, 20 m, ca. 19 km	Feb. 1998 Nov. 1998 March 1999	Rubble (10 cm high) with some macroalgae and sponges. Homogeneous habitat
2. *Lytechinus variegatus*	28°07.40N 82°59.70W, 13 m, ca. 19 km	Nov. 1998 March 1999	Bare sand. Homogeneous habitat
3. *Arbacia punctulata* and *Lytechinus variegatus*	28°07.56N 82°59.70W, 13 m, ca. 19 km	Feb. 1998 Nov. 1998 March 1999	Patches of rock and rubble (10–50 cm high) surrounded by bare sand. Rubble patches distinct from sand. Rubble covered with macroalgae, sponges, and ascidians. Heterogeneous habitat. *Arbacia punctulata* occurs on the rock–rubble; *Lytechinus variegatus* occurs on the sand
4. *Arbacia punctulata* and *Lytechinus variegatus*	28°07.45N 82°59.70W, 13 m, ca. 19 km	Nov. 1998 March 1999	Patches of rubble (10 cm high) surrounded by bare sand. Rubble patches merge into sand. Rubble covered with macroalage. Heterogeneous habitat. *Arbacia punctulata* occurs on the rubble; *Lytechinus variegatus* occurs primarily on the sand, occasionally on the rubble
5. *Arbacia punctulata* and *Lytechinus variegatus*	27°07N 82°27W, 7 m, ca. 0.3 km	April 1998 May 1998 June 1998 July 1998 Nov. 1998 Jan. 1999 March 1999 May 1999	Patches of rubble (10 cm high) surrounded by bare sand. Rubble patches merge into sand. Rubble covered with macroalgae. Heterogeneous habitat. Both *Arbacia punctulata* and *Lytechinus variegatus* occur on the rubble; *L. variegatus* occurs on the sand
6. *Lytechinus variegatus*	27°38N 82°43W, 5 m, ca. 0.1 km	Jan. 1999	Bare sand. Homogeneous habitat

most band regardless of reproductive condition (Figs. 4, 5; Tables 2, 3). Exceptions were in June 1998 and May 1999 for *A. punctulata*. In June 1998, 53% of the individuals had a dark outermost band and a gonad index of 12.3 ± 2.8. However, in April 1998, the gonad index was at a similar peak (12.0 ± 2.5) and 100% of the individuals had a light outermost band. In May 1999, 90% of individuals had a dark outermost band and a gonad index of 2.1 ± 0.8. In July 1998, the gonad index was 1.7 ± 0.7 and 67% of the individuals had a light outermost band. The percentage of individuals with a last light band decreased with higher water temperature (Fig. 4; Tables 2, 3). In June 1998 and May 1999, individuals with a last dark band outnumbered those with a last light band and water temperature was at a peak (28 C and 27 C, respectively). Gonad index also reached a peak in June 1998 (12.3 ± 2.7) but not in May 1999 (2.1 ± 0.8).

DISCUSSION

Statistical analysis indicates that test diameter is a good predictor of the number of growth bands for *A. punctulata* but not for *L. variegatus*. Although statistically significant, the r^2 value for *A. punctulata* is low and, therefore, of questionable biological meaning. For a species with a maximum size of 70 mm (Hill and Lawrence, 2003), the 20- to 30-mm range in test diameter for each growth band class in *A. punctulata* is very large; therefore, the predictive value of these data is questionable.

Arbacia punctulata has a well-defined repro-

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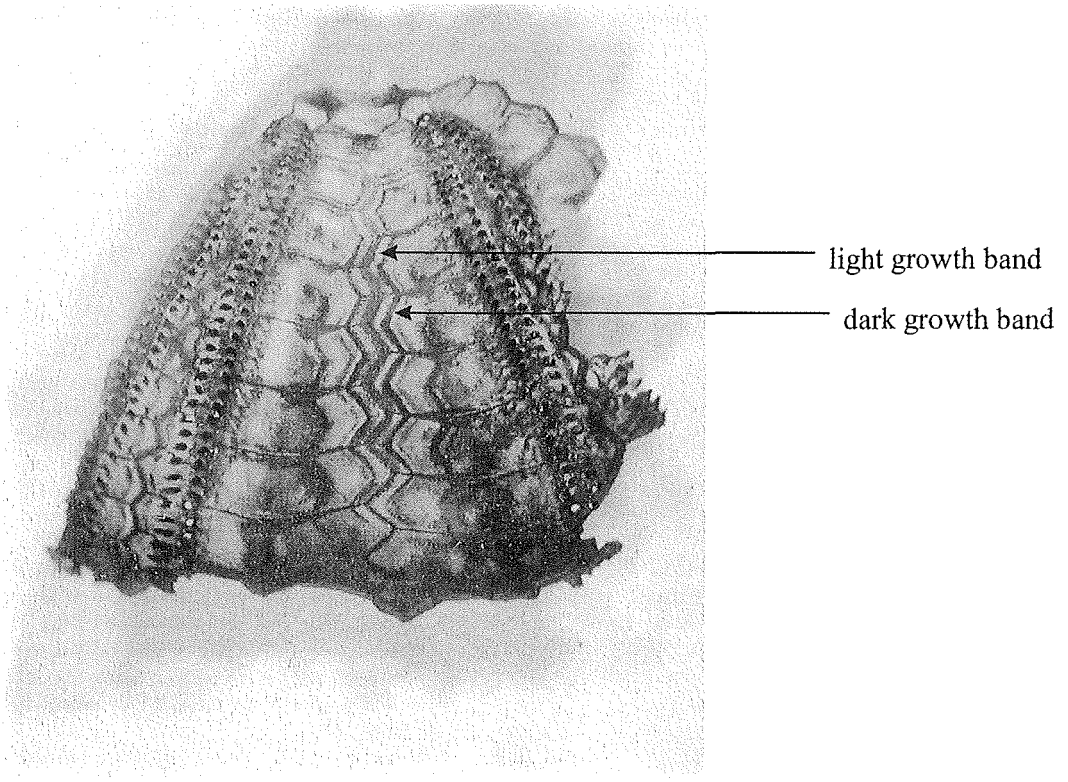

Fig. 1. Growth bands for *Arbacia punctulata.*

ductive cycle in the populations sampled, with distinct peaks in March–April and June–July (Hill, 2000). Therefore, the occurrence of well-defined growth bands could be related to the reproductive cycle. In May 1999, the slow down in test growth could have resulted from the allocation of limited resources to reproduction. As there are two reproductive peaks within a year in these populations, it would need to be determined whether the growth bands are annual and test growth slows down between March and July, or whether more than one growth band is laid down each year.

The occurrence of multiple, closely spaced bands within major bands in *L. variegatus* is similar to those Gage (1991) described in

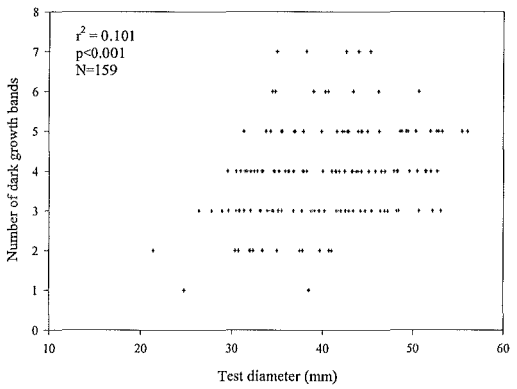

Fig. 2. Number of dark growth bands against test diameter for *Arbacia punctulata.*

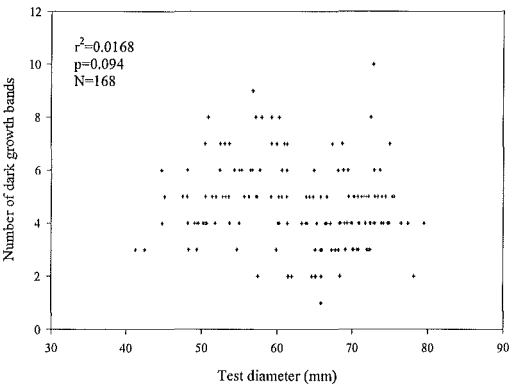

Fig. 3. Number of dark growth bands against test diameter for *Lytechinus variegatus.*

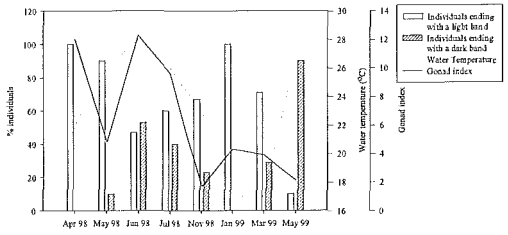

Fig. 4. Monthly reproductive state, water temperature, and growth band data for *Arbacia punctulata* at site 5.

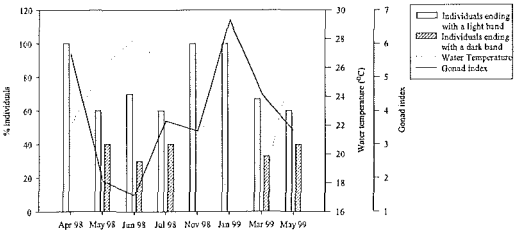

Fig. 5. Monthly reproductive state, water temperature, and growth band data for *Lytechinus variegatus* at site 5.

Psammechinus miliaris. He suggested these were caused by discontinuities in growth. The data suggest that test growth in this species is not tightly coupled to reproductive condition. *Lytechinus variegatus* has a more continuous low level of reproduction (Hill, 2000). Although peaks in gonad index were seen in April 1998 and Jan. 1999, the increase was much less than for *A. punctulata*. Histological examination of the gonad of *L. variegatus* showed there were always individuals in the populations with gametogenic tissue (stage 3) but the final stage of maturity (stage 5) was only observed in May 1998 (Hill, 2000). *Lytechinus variegatus* may continuously reproduce throughout the year if conditions are favorable. The data support the idea of continuous production because more individuals always had a light outermost band. Individuals are constantly allocating energy to reproduction throughout the year; therefore, the reproductive cycle has a much smaller effect on test growth. Food availability may be a more important determinant of growth for *L. variegatus*.

Test diameter cannot be used to predict the number of growth bands in *A. punctulata* and *L. variegatus*. Growth bands in *A. punctulata* were well defined and may be related to the reproductive cycle. For *L. variegatus*, growth bands were less clearly defined and may be more closely related to food availability than to the reproductive cycle.

TABLE 2. Growth band data for *Arbacia punctulata*.

Date sampled	Water temperature (C)	Test diameter (mm) (Mean ± SD)	Gonad index (Mean ± SD)	Percentage with light outermost band	n
Site 1					
Feb. 1998	12	37.2 ± 6.5	3.2 ± 1.8	100	10
Nov. 1998	23	41.8 ± 1.8	0.8 ± 0.2	70	10
March 1999	17	42.6 ± 1.7	2.4 ± 0.7	55	9
Site 3					
Feb. 1998	12	31.6 ± 4.3	1.7 ± 1.0	90	10
Nov. 1998	23	33.7 ± 2.3	0.5 ± 0.3	80	10
March 1999	17	34.5 ± 3.1	1.4 ± 0.3	89	9
Site 4					
Nov. 1998	23	33.4 ± 2.8	0.4 ± 0.2	78	9
March 1999	17	35.8 ± 1.6	2.4 ± 1.5	86	7
Site 5					
April 1998	22	46.8 ± 3.8	12.0 ± 2.5	100	10
May 1998	26	45.7 ± 7.4	4.8 ± 2.2	90	10
June 1998	28	49.1 ± 3.9	12.3 ± 2.7	47	19
July 1998	26	47.5 ± 3.6	9.6 ± 3.5	60	10
Nov. 1998	23	42.2 ± 4.1	1.7 ± 0.7	67	9
Jan. 1999	17	38.6 ± 5.8	4.3 ± 1.3	100	10
March 1999	17	37.6 ± 3.4	3.9 ± 1.6	71	7
May 1999	27	33.4 ± 3.8	2.1 ± 0.8	10	10

TABLE 3. Growth band data for *Lytechinus variegatus*.

Date sampled	Water temperature (C)	Test diameter (mm) (Mean ± SD)	Gonad index (Mean ± SD)	Percentage with light outermost band	n
Site 2					
Nov. 1998	23	66.6 ± 3.7	1.7 ± 1.3	40	10
March 1999	17	72.3 ± 1.6	1.5 ± 0.6	10	10
Site 3					
Feb. 1998	12	69.0 ± 4.6	1.5 ± 0.7	80	10
Nov. 1998	23	69.2 ± 2.0	1.3 ± 0.8	50	10
March 1999	17	73.0 ± 2.0	2.1 ± 0.9	40	10
Site 4					
Nov. 1998	23	71.0 ± 2.9	1.8 ± 1.1	20	10
March 1999	17	73.8 ± 3.5	2.2 ± 0.5	50	10
Site 5					
April 1998	22	58.5 ± 9.8	5.7 ± 1.6	100	9
May 1998	26	53.0 ± 7.9	1.9 ± 0.9	60	10
June 1998	28	49.8 ± 2.6	1.5 ± 0.8	70	10
July 1998	26	54.5 ± 3.2	3.7 ± 1.6	60	10
Nov. 1998	23	64.5 ± 3.6	3.4 ± 1.5	100	10
Jan. 1999	17	59.6 ± 2.1	6.7 ± 1.9	100	10
March 1999	17	56.2 ± 3.1	4.5 ± 0.8	67	9
May 1999	27	62.9 ± 3.0	3.4 ± 0.5	60	10
Site 6					
Jan. 1999	17	54.7 ± 5.8	5.7 ± 2.7	90	20

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