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Age Determination in the Sand Dollar *Mellita tenuis*

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Mellita tenuis were collected from six locations along the Florida gulf coast from March 1997 through Sep. 1998. The anterior–posterior length of the test was measured, and growth lines in the interambulacral plates near the ambitus on the aboral surface (which are oldest) were counted. The number of growth lines is size independent as would be expected if seasonality of growth and growth rate were uncoupled. However, a collection of small individuals had many more growth lines and one of the large individuals had many less than would be anticipated. Lines near the ambitus are difficult to count because they are compressed. In addition, gray growth lines occur between the light and dark ones. The number of plates in the petal increases with body size to an asymptote and cannot be used to age _M. tenuis_.

The ability to age individuals in populations is important because it establishes time of recruitment, rate of growth, age at maturity, and longevity. The use of growth lines to age echinoids is controversial (Pearse and Pearse, 1975; Ebert, 1988). It requires major annual changes in the environment (e.g., temperature or food) or in the physiology of the individual (e.g., reproduction). Growth lines have been used to age the sand dollars *Echinarachnius parma* (Durham, 1955), *Dendraster excentricus* (Birkeland and Chia, 1971; Timko, 1975), *Laganum depressum* (Saunders, 1986), and *Mellita tenuis* (Lane and Lawrence, 1980).

Durham (1955) reported that, although the number of ambulacral plates on the aboral surface outside the petal in *D. excentricus* did not vary, the number of plates inside the petal, as indicated by the number of pore pairs, increased with size. Because the number of plates did not always correspond to the body size, he suggested the variation might result from differences in food supply or other factors affecting growth rate and the number of plates inside the petals might be a better indicator of age than size.

Enormous populations of three species of the genus *Mellita* (Harold and Telford, 1990) occur along the Atlantic coasts of North and South America, the Caribbean Sea, and the Gulf of Mexico (Salsman and Tolbert, 1965; Weihe and Gray, 1968; Bell and Frey, 1969; Lane and Lawrence, 1980; Frazer et al., 1991; Borzone, 1992/1993; Penchaszadeh and Molinet, 1994; Kurz, 1995; Tavares and Borzone, 1998) and undoubtedly have an important ecological role (Bell and Frey, 1969). It would be extremely useful if it were possible to establish the age of individuals in the field.

Harold and Telford (1990) revised the genus *Mellita* so that the species occurring on the west coast of Florida is *M. tenuis* Clark, 1940, and not *Mellita quinquiesperforata* (Leske, 1778). Although the study of Lane and Lawrence (1980) indicated growth lines of *M. tenuis* near Tampa Bay were annual, we asked whether a generalization of this relation is possible. We also investigated Durham's (1955) proposal that the number of plates in the petal could be used to age sand dollars. Consequently, we sampled populations of *M. tenuis* at different sites along the Florida gulf coast, including that used by Lane and Lawrence (1980), to test these two methods.

MATERIALS AND METHODS

Mellita tenuis were collected from six locations along the Florida gulf coast (Fig. 1) from March 1997 through Sep. 1998: St. Joseph Bay at Florida Panhandle (29°40′N, 85°21′W; n = 10), Mullet Key North Beach (27°37′N, 82°44′W; n = 48), Mullet Key East Beach (n = 20), Gulf site (27°49′N, 82°53′W; n = 21), Gasparilla Island (28°46′N, 82°16′W; n = 17), and Naples (26°08′N, 81°47′W; n = 9). The Mullet Key sites and the Gulf site are at the mouth of Tampa Bay.

The outermost interambulacral plates were chosen for growth-line analysis because their number is fixed by the time of metamorphosis or soon thereafter and thus have been present throughout the life of the individual (Durham, 1955). Growth lines were observed by a method modified from Jensen (1969a) and Pearse and Pearse (1975). The largest individuals of the collections were chosen for growth-line analysis. At Mullet Key North Beach, small individuals were also used for comparison with the data of Lane and Lawrence (1980). The anterior–posterior length of each individual was measured and recorded. Tests were placed in water for at least 2 wk to facilitate removal

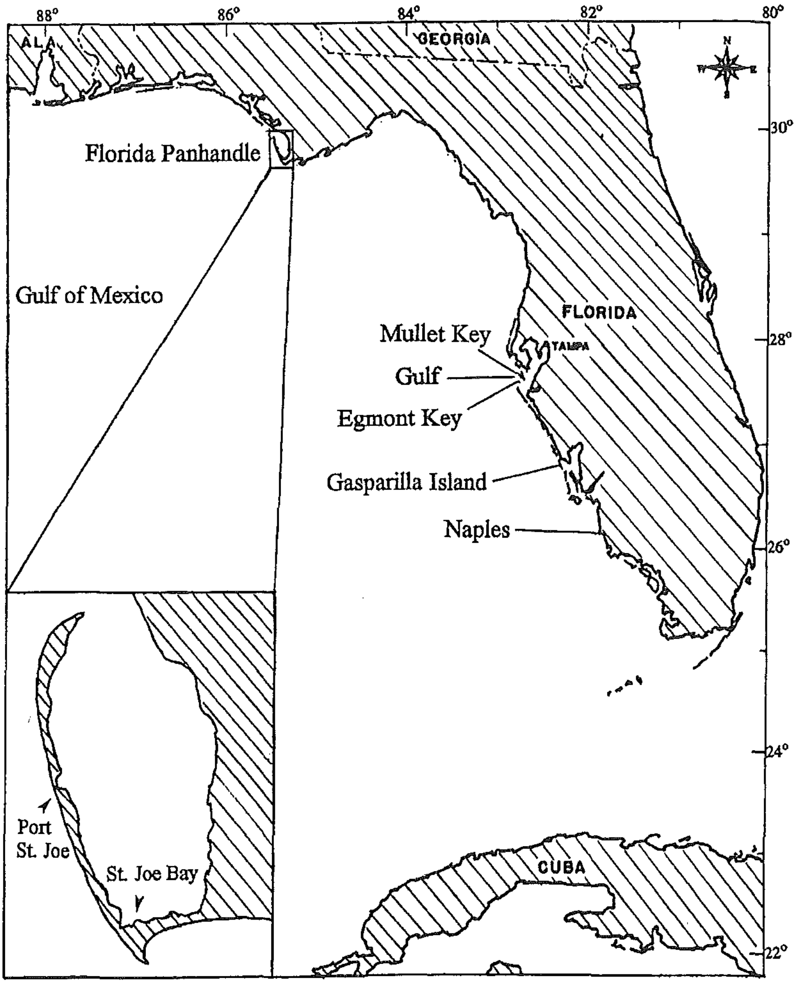

Fig. 1. Map of Florida showing the collection sites.

of the spines. The spines were removed completely with a brush. Tests were air dried and then charred at 350 C in a preheated muffle furnace for 5 min. Concentric dark and light bands appeared immediately when the test plates were placed in xylene. One dark and one light band were considered a complete growth line. An unpaired dark or light band was considered half a growth line.

The number of plates in petal Ib were counted as done by Durham (1955) for three size ranges of individuals from different localities: <13 mm (n = 14, Port St. Joe), 14–33 mm (n = 24, Mullet Key North Beach), and 53–120 mm (n = 33, Gasparilla Island).

Results

Growth lines in skeletal plates of *M. tenuis* are shown in Figure 2. Plates near the edge of the test have relatively broader zones in the center and narrow indistinct lines near the border, especially for individuals with many lines (usually more than four lines, i.e., four dark and four light zones). Lines near the edge of the plate are compressed and thus are not easily distinguished. Besides dark and light bands, intermediate gray bands were also found in some individuals.

The test length and number of growth lines at each location are shown in Figure 3. Specimens from St. Joe Bay (70–100 mm in length) had 2.5–6.5 growth lines. Only the smallest specimen (26 mm) from Mullet Key North Beach had one line (one dark and one light band). The others from this location had 1.5–3.5 lines. Five individuals ranging from 90–120 mm in length had two or less lines. Plates with five or more growth lines were found in only six specimens. Specimens at Gasparilla Island

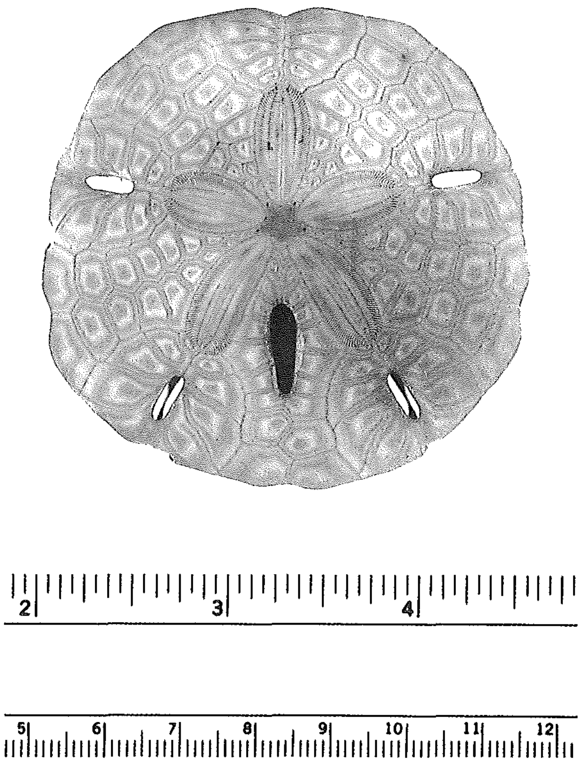

Fig. 2. *Mellita tenuis.* Growth lines in aboral skeletal plates.

(~80 mm in length) had from two to four growth lines.

The petals on the aboral surface showing the pore pairs can be seen in Figure 4. The regressions of the number of plates in the petal with body size of three populations (Fig. 5) differ significantly from one another ($P < 0.001$). The number increases most rapidly with increase in body size in the smallest individuals from Port St. Joe and least rapidly in the largest individuals from Gasparilla Island. The correlation coefficient between number of plates and body was greatest in the collection of smallest individuals from Port St. Joe and least in that of the largest individuals from Gasparilla Island.

Discussion

We found that plates near the edge of the test have relatively broader zones in the center and narrow indistinct lines near the border, especially for individuals with many lines (usually more than four lines, i.e., four dark and four light zones). Lines near the edge of the plate are compressed, particularly in the larger individuals, possibly due to slowdown or ceasing of growth in older plates, thus they are not easily distinguished. Gage (1992) noted this in the sea urchin *Echinus esculentus.* Besides dark and light bands, intermediate gray bands were also found in some individuals, which makes counting lines more complicated. Others also have noted indistinct growth lines indicate minor growth periods in sea urchins (Ebert, 1966; Jensen, 1969a, 1969b; Pearse and Pearse, 1975).

Most individuals were 37–129 mm in length and had two or three growth lines. This would be predicted if seasonality of growth was uncoupled from growth rate. The range in number of growth lines of large individuals, as at St. Joe Bay, could result from the merging of different cohorts into the larger sizes. However, some incongruities occur. The individuals at Mullet Key North Beach ranged in size from 29–75 mm in length. According to the study at this same site in 1973 (Lane and Lawrence, 1980), these would be first-year individuals. Yet the number of growth lines ranged from 1 to 3.5. Four individuals >120 mm in length from the Gulf site and Mullet Key East Beach had only 1.5 or 2 growth lines. This would require extremely rapid growth because Lane and Lawrence (1980) reported an average diameter of 88 mm and a maximum value of 111 mm

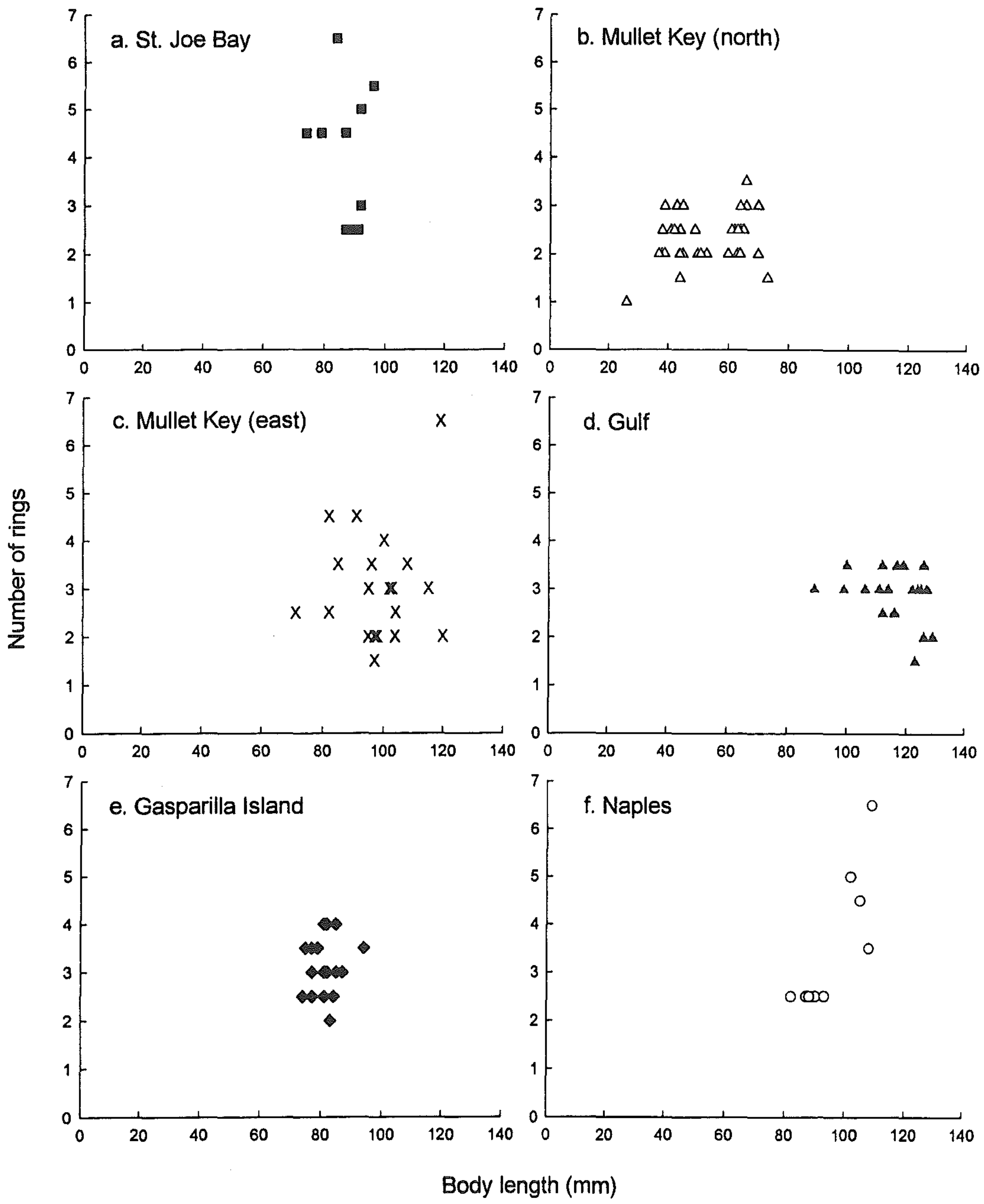

Fig. 3. *Mellita tenuis.* Body length and number of growth lines in specimens collected from six sites along the Florida gulf coast (Fig. 1): St. Joseph Bay (n = 10), Mullet Key North Beach (n = 48), Mullet Key East Beach (n = 20), Gulf site (n = 21), Gasparilla Island (n = 17), and Naples (n = 9).

for individuals 1–2 yr after settlement. Individuals with more than five lines in our study might be >5 yr old if the growth lines are annual. On the other hand, they could be younger if more than one line was formed each year. This is possible because gonadal growth in *M. tenuis* can occur in both winter and summer months (Lane and Lawrence, 1979b) and somatic growth is lowest in the fall (Lawrence and Lane, 1980). Ebert (1988) found that two or sometimes three lines were added per year to the skeletal plates of rapidly growing sea urchins.

Annual periodicity in growth lines requires

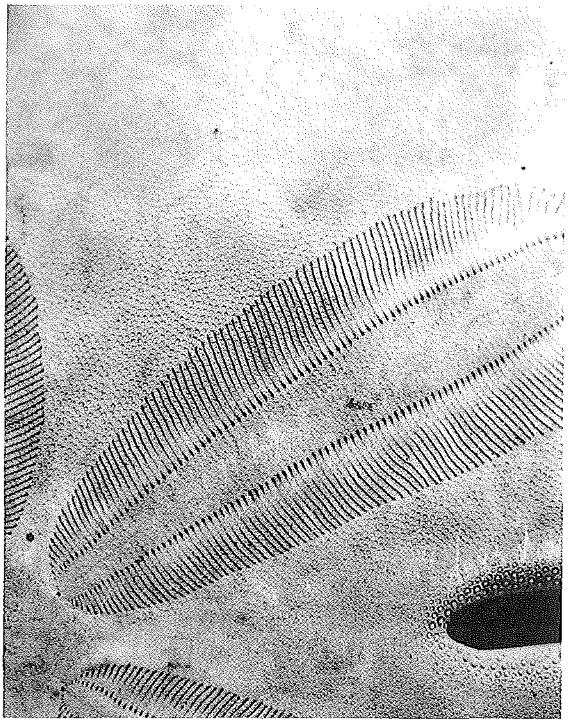

Fig. 4. *Mellita tenuis.* Petals on the aboral surface showing the pore pairs.

major seasonal changes in the environment (e.g., temperature or food) or in the physiology of the individual (e.g., reproduction) that affect growth. The differences in day length between the summer and winter solstices at Port St. Joe and at Naples are not great (3 hr 50 min and 3 hr 22 min, respectively) (Astronomical Applications Department, 1999). Jor-

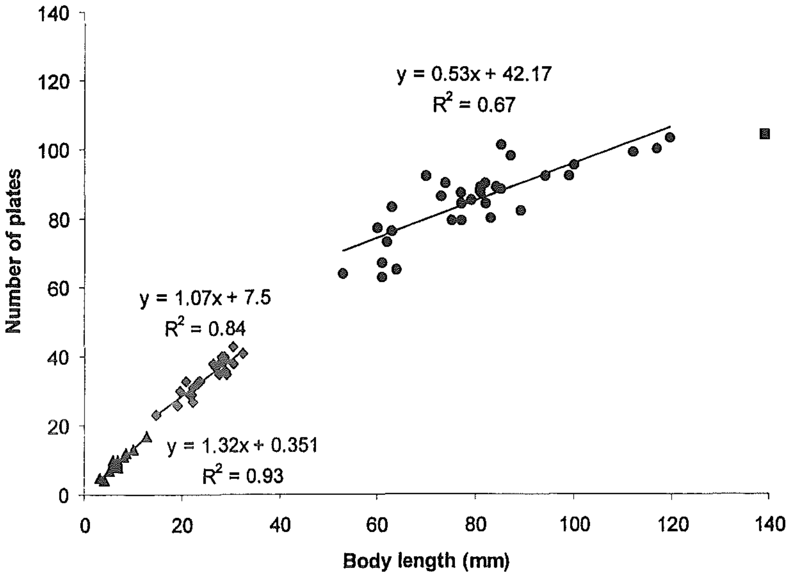

Fig. 5. *Mellita tenuis.* Body length and number of plates in the petals in specimens collected from three sites along the Florida gulf coast (Fig. 1): Port St. Joe (n = 14, triangles), Mullet Key North Beach (n = 24, diamonds), and Gasparilla Island (n = 33, circles).

dan (1973) reported similar summer temperatures at Port St. Joe and Naples (27 C and 28 C, respectively) but different winter temperatures (18 C and 22 C). Lane and Lawrence (1979a) reported summer temperatures of 30–33 C at Mullet Key North Beach. These seasonal changes may affect primary productivity and thus the availability of food. We noticed a greater abundance of benthic diatoms in the summer, but this has not been quantified. Lane and Lawrence (1980) found seasonal growth and distinct, yearly growth lines in *M. tenuis* at Mullet Key North Beach (Lane and Lawrence, 1980). The growth ring counts corroborated yearly mean diameters estimated from size-frequency analysis. However, the maximum number of rings reported was three for individuals 100 mm in diameter. We found individuals with three growth rings at Mullet Key North Beach that were only 40–70 mm in diameter.

The number of plates in the petal increases with body size in *M. tenuis,* as in *D. excentricus, E. parma,* and *L. depressum* (Durham, 1955; Lohavanijaya, 1965; Saunders, 1986, respectively). Because these plates in the petal support the respiratory tube-feet (Smith, 1980), their number should increase with an increase in size of the visceral coelom. Their apparent asymptote in *M. tenuis* and decrease in correlation between number of plates and body length probably indicate that growth beyond a body length of about 60 mm involves little increase in size of the coelom. Durham (1955) suggested the number of plates in the petal probably was a better indication of age than absolute size because he found their number varied with body size. His suggestion that the number of plates in the petal and body size are uncoupled probably resulted from an inadequate sample size.

We conclude that growth lines in *M. tenuis* do reflect changes in growth rate that undoubtedly result from environmental or physiological changes but that the way they affect growth is complex. This difficulty of using growth lines as chronometers is increased because of their compression as the individual approaches asymptotic size as well as the possibility of negative growth. The number of plates in the petal cannot be used as a chronometer because they reflect the size of the individual. Accurate information on the age of individuals in populations will require monitoring cohorts from the time of settlement.

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