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ABSTRACT

We examined growth rings in red sea urchins collected from Barkley Sound, British Columbia, in order to evaluate their usefulness in determining individual age. In order to estimate the ages of individuals we examined, we used both a previous study and size frequencies observed during this study. The number of growth rings produced each year appears to be highly variable and greater than two, so that growth rings are not useful in ageing this species. Our data indicate a slower growth rate at our study site than the previously published study.

INTRODUCTION

Since 1970, several small companies have been harvesting the red sea urchin, Strongylocentrotus franciscanus, in British Columbia (Hudnall 1970). The gonads of both sexes, called 'roe', are shipped fresh, frozen or canned to Japan, where they are used in 'sushi' and in seafood paste (Kato 1972; Motohiro 1974). In order to manage this small fishery effectively, it is necessary to know growth rates, as well as recruitment and natural mortality rates, so that potential yields can be estimated.

Ebert (1975), in a review of the existing literature on sea urchin growth rates, list four methods for measuring growth: caging, marking, examining size frequencies, and examining growth rings found in the plates of the test. Each of the first three methods either has intrinsic problems or is difficult to apply to S. franciscanus.

Swan (1961) held four Strongylocentrotus species, including S. franciscanus, in cages supplied with Nereocystis luetkeana for 1 yr. However, growth rates obtained this way may be unnatural. Sea urchin growth is dependent on food supply and on the physical conditions (Ebert 1968) which are experienced. Sea urchins held in cages have access to an unlimited food supply, which is almost certainly not true in nature, and the cage itself constitutes an unnatural habitat. In any case, caging experiments are difficult except with the smallest S. franciscanus, because of the large size of the adult.

Sea urchins are difficult to mark, except for short periods. Fuji (1962) and Ebert (1965) describe marking techniques which involve drilling holes through the test and attaching a tag by means of wire or line through the holes. Although this method has been used to measure growth (Ebert 1967, 1968; Lees 1968; Baker 1973), the tags may retard growth (Fuji 1963; Lees 1970) and cause high mortality (Dix 1970). T-bar tags attached to sea urchins also result in reduced gonad growth and lower feeding rates (Dix 1970). Tags applied to spines are useful for short periods only, as the marked spines are shed within 2 or 3 mo (Pace 1975; Vacquier 1965).

Size frequencies of S. franciscanus in British Columbia (Bernard and Miller 1973; Miller 1974; our unpublished data) show that annual recruitment is highly variable and may even be zero in some years. Populations normally consist, therefore, mostly of 1 or 2 modal size classes. For this reason, growth rates cannot be estimated simply by determining modes in a size-frequency distribution. Bernard and Miller (1973) followed changes in the size spectrum over 1 yr at Amphitrite Pt., Barkley Sound, where many year-classes occurred together. From this they were able to estimate growth rate. This method is tedious, requiring repeated sampling, and cannot be carried out except where several year-classes occur together.

The fourth alternative is the use of growth rings to estimate age. After collecting one sample, this would allow construction of an age-size relation; and natural mortality could also be calculated from changes in density and age structure measured at two separate times. An excellent discussion of the development of growth rings, techniques for observing them, and their potential uses is given by Pearse and Pearse (1975).

When sea urchin plates are cleaned, dried, and cleared, alternating translucent and opaque bands (which appear as dark and light respectively under reflected light) can be observed. Pearse and Pearse caution that these rings should not be assumed to be annual rings without either corroboration from examination of animals whose age is known, or comparison of growth-ring data with size-frequency data. Several authors have done this: examples include Moore (1935); Dix (1972), who found that Evichinus chloroticus produces one ring per year; Sumich and McCauley (1973), who concluded from their comparison with size frequencies in Allocentrotus fragilis that two rings are laid down each year; and Brykov (1975), who found one ring per year in S. nudus and three species of sand dollars. Birkeland and Chia (1971) followed the first cohort of a sand dollar through 1 yr and were able to conclude that the growth rings are annual.

In this publication we discuss the elucidation of growth rings in S. franciscanus, the rate at which new plates are added to the test, the rate of production of growth rings, and their significance.

METHODS

For examination of growth rings, we collected sea urchins of less than 100 mm test diameter from Ohiat Island, Barkley Sound, on three occasions in April, July and August 1976. The site was chosen because of the abundance of juveniles. Spines were scraped away with a knife, and the test was cleaned with a coarse brush and measured. Complete series of interambulacral plates were dissected from the test and then either cleaned in a solution of 25% sodium hypochlorite (laundry bleach) for 15 to 30 min and stored for shipment in ethanol, or simply dried for shipment. With larger specimens, the inner surfaces of the plates were scrubbed with a toothbrush to help remove the inner layer of callus. At the laboratory, dried material was cleaned in hypochlorite; material stored in ethanol was rinsed in water. The intact interambulacral series were dried for 12 to 16 hr at 75 C. Clearing was carried out with xylene, cedar oil or a mixture of terpineol and methyl benzoate, as described by Ebert (1968). We counted the number of plates per vertical column in each individual and counted the dark rings in each plate under reflected light, using a binocular microscope.

We measured as many as possible of those sea urchins under 70 mm test diameter at Ohiat Island in May and again in August, 1976, using specially designed calipers and working underwater. The size-frequency distributions were constructed from these data.

RESULTS

From results of our experiments with preparing test plates, we developed a standard method of preparation.

Cleaning the test in hypochlorite made reading the rings considerably easier. We found that the interambulacral series could be simply washed in water in the field, then dried until they could be cleaned in hypochlorite at the laboratory. We found variation in results with drying time and temperature. Charring the plates in an alcohol flame gave very poor results, and we used a drying oven exclusively. Plates dried for too long a period as well as too short were illegible; at temperatures greater than 85 C our samples were also illegible (this may have been caused by drying for too long at the higher temperature). We found xylene, cedar oil and terpineol-methyl benzoate to be equally effective in clearing, but cedar oil was the least noxious to work with. Sanding the inner surface of the test plates with emery cloth or grinding with a hand-held grinder had no effect on the clarity of individual plates. Growth rings did not become more visible after grinding; and illegible plates were never improved by such treatment.

Even in batches of plates treated together, in which most were legible, some were not legible, or were obviously only partly clear. Partly cleared plates usually displayed rings only in the central portion, and only a few plates in the vertical column were legible. These series were not read, because the number of rings obtained would be artificially low.

The relation between test diameter and the number of plates in one column of the interambulacrum is shown in Fig. 1. The relation appears to be linear. Swan (1966) reported that an individual of S. franciscanus with a test diameter of 162 mm possessed 20.5 plates per row. This value would conform well with extrapolation of our observations. S. franciscanus appears to add new plates at a much slower rate than the other members of its genus: at 55 mm test diameter S. franciscanus possesses 12 or 13 plates, while S. purpuratus contains about 20 (Pearse and Pearse 1975) and S. droebachiensis 31 to 35 (Swan 1958). It is interesting that the species which attains the largest final size has the fewest plates. Because sea urchins grow by plate addition as well as by plate growth, not all test plates are the same age, and thus they show different numbers of rings. Plates are produced by the genital plate at the aboral pole. The number of growth rings observed per plate increases from the aboral region towards the oral region (Fig. 2). The maximum number of rings that can be counted is normally found at, or just below, the ambitus (point of greatest test diameter). In the region below the ambitus, plates become less clear, and the lowest few cannot be read.

If the maximum number of rings is found at the ambitus, but the ambital plate does not contain as many rings as lower, older plates, an error is introduced into this method of ageing. We tried to estimate the magnitude of this error in the following way. Fig. 3 shows the relation between test diameter and the position of the ambitus relative to the series of plates. It can be seen that an individual of 25-mm diameter, which we estimate to be 1-yr-old (Bernard and Miller 1973), possesses 10 test plates. In the largest individual that we examined, 100-mm test diameter, the ambital plate was 1 of the 10 oldest plates, and so had been present in the 1-yr-old individual. The error introduced by the illegibility of the oldest test plates thus is less than 1 yr in those animals that we examined.

The maximum number of rings varied widely in animals of the same size (Fig. 4). In Fig. 4 we have also shown the sizes that represent ages

1 through 4, obtained from the growth curve presented by Bernard and Miller (1973). If that growth curve is approximately correct, it appears that sea urchins produce an average of 4 to 5 rings per year.

The size-frequency distribution of juvenile sea urchins measured at Ohiat Island on two occasions is shown in Fig. 5. One possible interpretation is also shown. This indicates that growth may be slower than Bernard and Miller (1973) observed at Amphitrite Pt. Using our data, the annual number of growth rings added by sea urchins is about 3. However, more data are needed to confirm these growth rates at Ohiat Island.

DISCUSSION

We must conclude that the growth rings which can be observed in S. franciscanus are neither annual nor semi-annual. The average number of rings produced is open to question, depending on whether our size-frequency data or those of Bernard and Miller (1973) are used to estimate ages of the animals we examined. In both cases, however, the average number of rings produced annually is greater than two.

Furthermore, the number of rings produced by individuals of similar size varies widely. This might result from an actual variation in growth-ring deposition among individuals; or from wide variation in growth rate, in turn resulting in variations in age among animals of similar size. Whatever the cause of this variation, it is evident that growth rings can be of limited use at present in determining the age of individuals of this species.

It has been clearly demonstrated that growth rings may be influenced by the availability of food (Pearse and Pearse 1975). Translucent zones form when food is scarce. It may also be that the beginning of annual reproductive activity, when energy resources are diverted to gonadal rather than somatic growth, has the same effect on plate growth as decreased food supply; and that a translucent ring is formed (eg. Sumich and McCauley 1973). S. franciscanus in British Columbia shows only 1 cycle of spawning per year (Kramer and Nordin 1975; Bernard, personal communication), so reproduction can account for only one of the several dark translucent rings produced each year.

The food supply of red sea urchins consists of both attached algae and drifting pieces of large algae. Standing crops of the two major producers of drifting algae, Macrocystis integrifolia and Nereocystis luetkeana (an annual) begin to increase in spring, reach a maximum in late summer and then decline. This pattern is true of shallow subtidal algal communities as a whole (Neushul 1967; Vadas 1968). Although the general pattern of algal abundance seems to be a simple yearly cycle, the actual availability of food to sea urchins may not be as simple. Sea urchins are usually found in a dense band which begins below the algal zone, at a depth which increases as the degree of wave exposure decreases (Low 1975; Pace 1975). Little attached algae is directly available to sea urchins, although there may be upward migration into the algal zone in the fall (Pace 1975; cf. Silver and Brierton 1974). The pattern of drift algal abundance may be more complex than the pattern of standing crop. In addition, sea urchins consume zooplankton and benthic diatoms (Leighton 1967). Fluctuations in these food supplies on a short-term basis, even in the summer when the standing crop of algae is high, might therefore account for both the average number of rings produced per year and the variation between individuals.

The apparent difference between the growth rate estimated from size frequencies at Ohiat and that reported by Bernard and Miller (1973) is not surprising. Several authors have reported that growth rate and final size vary with both food supply and physical factors in the environment, such as the degree of exposure (Ebert 1968; Leighton and Jones 1968; Lees 1970). Although we have not made a comparison of Ohiat Island and Amphitrite Pt., differences accounting for the discrepancy in growth rates may easily exist. Food availability also varies from year to year (Ebert 1975), which may further account for the difference. Finally, the identification of year-classes in size frequency data is highly subjective, and our interpretation may not be correct. The degree of overlap shown among size-classes in Fig. 5 underlines the need for a better method of measuring growth rate in different locations.

The measurement of size frequencies of juveniles at Ohiat Island is continuing in an attempt to obtain better data on the age of those animals that we have examined. In addition, we are now experimenting with tetracycline labelling of test plates as a means of measuring plate growth.

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REFERENCES

Baker, S. L. 1973. Growth of the red sea urchin (Strongylocentrotus franciscanus (Agassiz) in two natural habitats. M.Sc. Thesis, California State University, San Diego. 83 p.

Baker, S. L., and D. C. Miller. 1973. Preliminary investigation on the red sea urchin resources of British Columbia (Strongylocentrotus franciscanus [Agassiz]). Fish. Res. Board Can. Tech. Rep. 400: 37 p.

Birkeland, C., and F. S. Chia. 1971. Recruitment risk, growth, age and predation in two populations of sand dollars, Dendraster excentricus (Eschscholtz). J. Exp. Mar. Biol. Ecol. 6: 265-278.

Brykov, V. A. 1975. Individual age and life duration of some sea urchins from the Sea of Japan. Biol. Morya (Vladivost) 2: 39-44. (Abstract seen only)

Dix, T. G. 1970. Biology of Evechinus chloroticus (Echinoidea: Echinometridae) from different localities. 2. Movement. N.Z. J. Mar. Freshwater Res. 4(3): 267-277.

1972. Biology of Evechinus chloroticus (Echinoidea: Echinometridae) from different localities. 4. Age, growth and size. N.Z. J. Mar. Freshwater Res. 6: 48-68.

Ebert, T. A. 1965. A technique for the individual marking of sea urchins. Ecol. 46: 193-194.

1967. Negative growth and longevity in the purple sea urchin Strongylocentrotus purpuratus (Stimpson). Science 157: 557-558.

1968. Growth rates of the sea urchin Strongylocentrotus purpuratus related to food availability and spine abrasion. Ecol. 49: 1075-1091.

1975. Growth and mortality of post-larval echinoids. Am. Zool. 15: 755-775.

Fuji, A. R. 1962. A new tagging method for the sea urchin, Hemicentrotus pulcherrimus (A. Agassiz). Aqui Culture 10(1), 10: 11-14 (Japanese).

1963. On the growth of the sea urchin, Hemicentrotus pulcherrimus (A. Agassiz). Bull. Jpn. Soc. Sci. Fish 29: 118-126.

Hudnall, J. 1970. Sea urchins. New industry for Tofino. West. Fish. 16-17 p.

Kato, S. 1972. Sea urchins: a new fishery develops in California. Mar. Fish. Rev. 34: 23-30.

Kramer, D. D., and D. M. A. Nordin. 1975. Physical data from a study of size, weight, and gonad quality for the red sea urchin (Strongylocentrotus franciscanus [Agassiz]) over a one-year period. Fish. Res. Board Can. MS Rep. 1372: 91 p.

Lees, D. C. 1968. Tagging subtidal echinoderms. Underwater Nat. 5: 16-19.

1970. The relationship between movement and available food in the sea urchins Strongylocentrotus franciscanus and Strongylocentrotus purpuratus. M.Sci. Thesis, San Diego State College, San Diego. 119 p.

Leighton, D. L. 1967. Ecological investigations of sea urchin populations along the Palos Verdes Peninsula. Kelp Habitat Improvement Project Annu. Rep. 1966. 67: 41-54.

Leighton, D. L., and L. G. Jones. 1968. Ecological investigations of sea urchin populations along the Palos Verdes Peninsula. Kelp Habitat Improvement Project Annu. Rep. 1967. 68: 39-62.

Low, C. J. 1975. The effect of grouping in Strongylocentrotus franciscanus, the giant red sea urchin, on its population biology. Ph.D. Thesis, University of British Columbia, Vancouver. 160 p.

Miller, D. C. 1974. Abalone and sea urchin survey 1974. Federal-Provincial Cost-Shared Project, supported by the Marine Resources Branch, Department of Recreation and Conservation, and Industrial Development Branch, Fisheries and Marine Service, Environment Canada. Unpubl. Rep: 53 p.

Moore, H. B. 1935. A comparison of the biology of Echinus esculentus in different habitats. Part II. J. Mar. Biol. Assoc. U.K. 20: 109-128.

Motohiro, T. 1974. The catches and utilization of shellfish in Japan, p. 172-176. In R. Kreuzer [ed.] Fishery products. Fishing News (Books) Ltd., Surrey.

Neushul, M. 1967. Studies of subtidal marine vegetation in western Washington. Ecol. 48: 83-94.

Pace, D. R. 1975. Environmental control of red sea urchin (Strongylocentrotus franciscanus) vertical distribution in Barkley Sound, British Columbia. Ph.D. Thesis, Simon Fraser University, Burnaby. 98 p.

Pearse, J. S., and V. B. Pearse. 1975. Growth rings in the echinoid skeleton. Am. Zool. 15: 731-753.

Silver, G. R., and A. Brierton. 1974. Some indicators which suggest that vertical movement does not occur in Strongylocentrotus franciscanus (Agassiz). Lambda 1: 15-18.

Sumich, J. L., and J. E. McCauley. 1973. Growth of a sea urchin, Allocentrotus fragilis, off the Oregon coast. Pac. Sci. 27: 156-167.

Swan, E. F. 1958. Growth and variation in sea urchins of York, Maine. J. Mar. Res. 17: 505-521.

1961. Some observations on the growth rate of sea urchins in the genus Strongylocentrotus. Biol. Bull. (Woods Hole) 120: 420-427.

Swan, E. F. 1966. Growth, autotomy and regeneration, p. 397-434. In R. A. Boolootian [ed.] Physiology of Echinodermata. John Wiley and Sons Ltd., New York.

Vacquier, V. D. 1965. Studies of urchin movements. Kelp Habitat Improvement Project, Annu. Rep. 1964. 65: 55-56.

Vadas, R. L. 1968. The ecology of Agarum and the kelp bed community. Ph.D. Thesis, University of Washington, Seattle, 280 p.

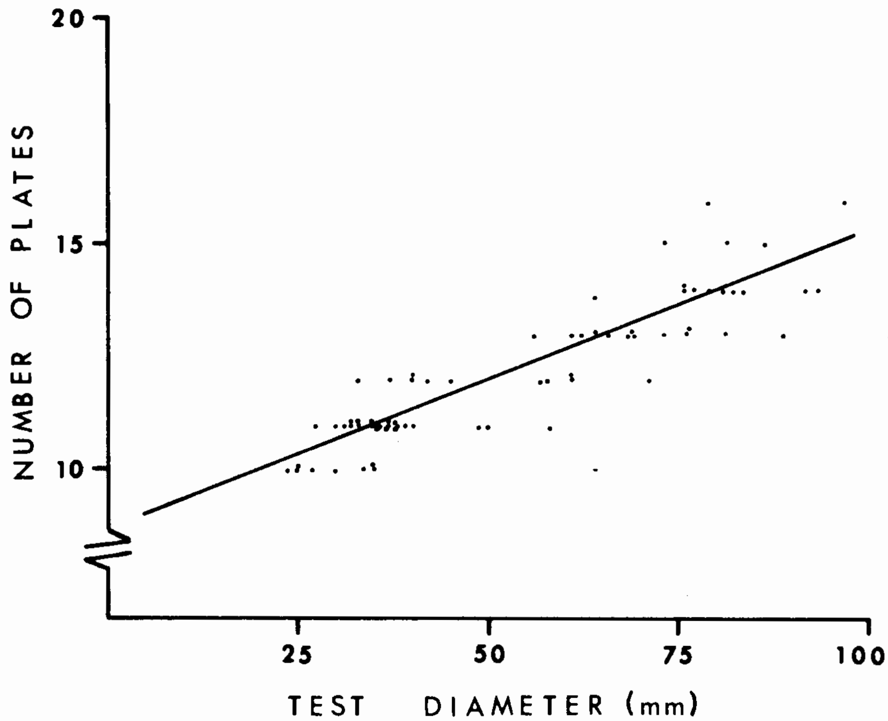


Fig. 1. The relation between test diameter and the number of plates in one vertical column of the interambulacrum. This relation is described by:

$$N = 8.55 + 0.069\ D$$

where N is the number of plates and D is test diameter (mm).

Fig. 2. A series of plates from an individual of 82 mm test diameter.

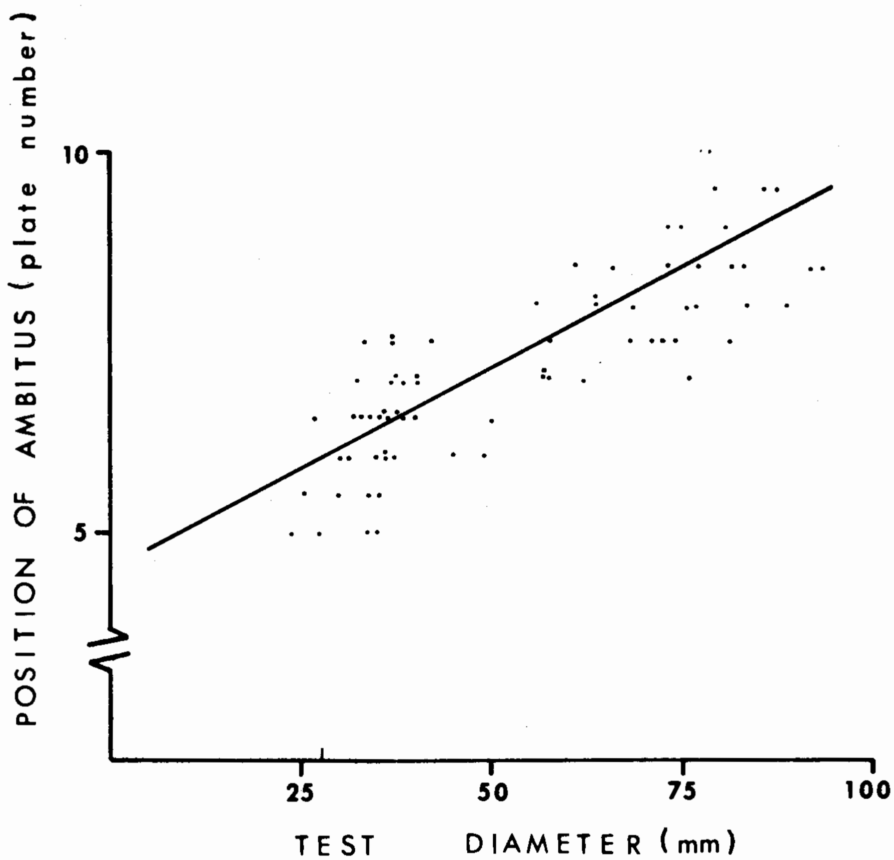


Fig. 3. The position of the ambitus (point of greatest test diameter) related to test diameter. Test plates were numbered beginning at the oral region of the test. The relation is described by:

$$P = 4.72 + 0.046\ D$$

where P is the plate number and D is test diameter (mm).

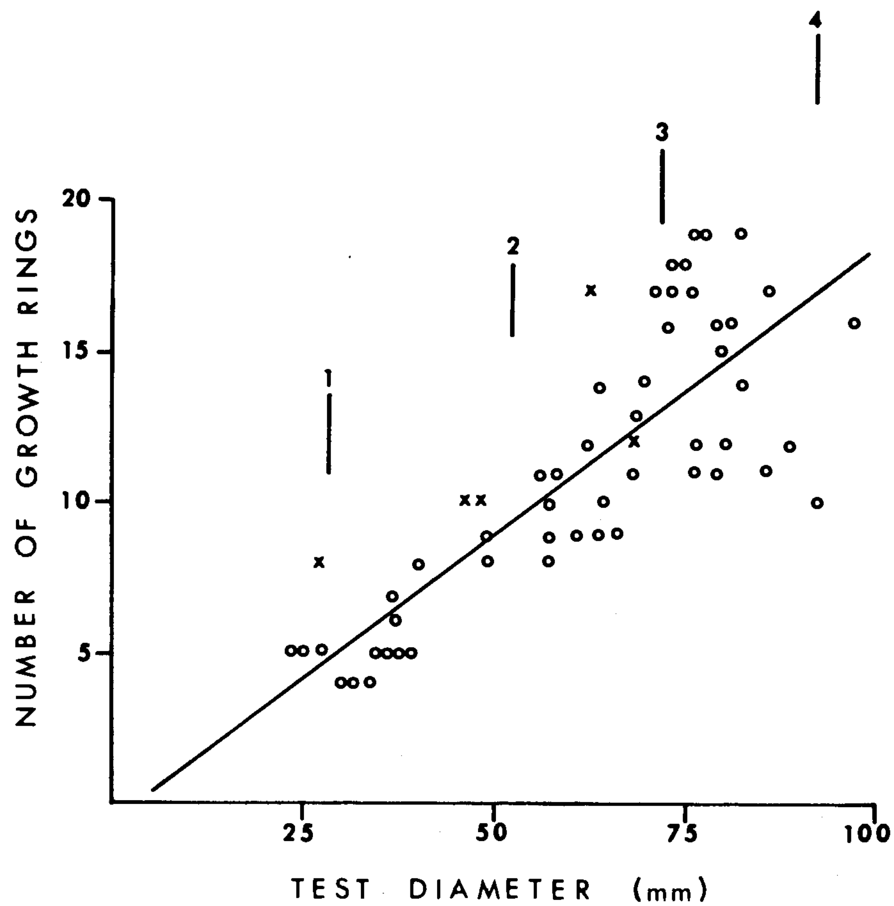
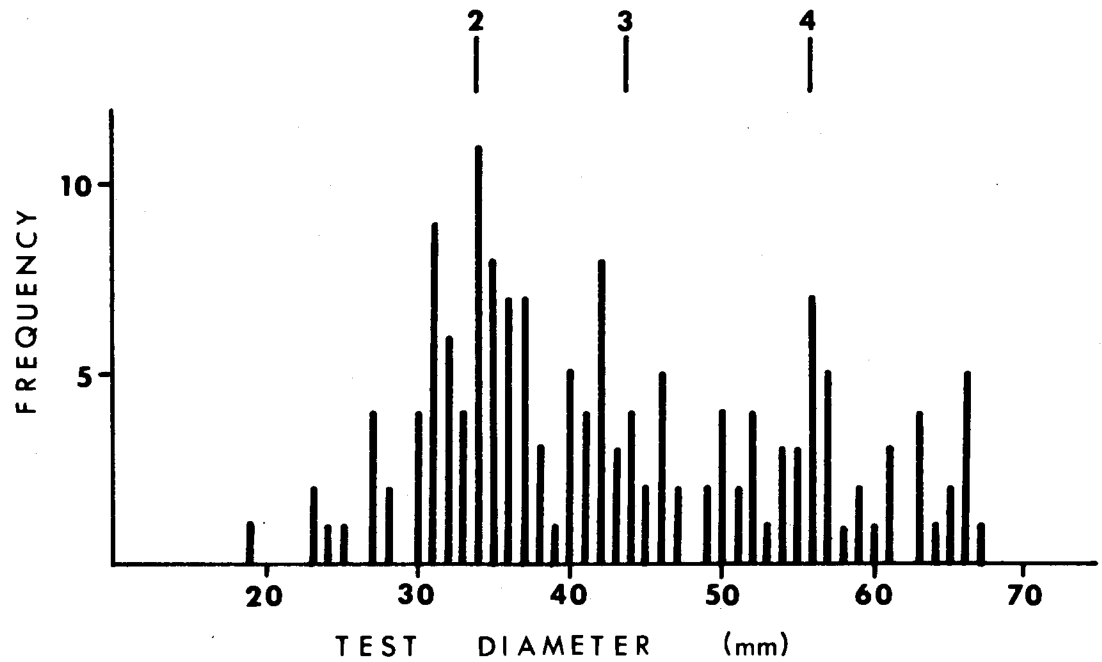


Fig. 4. The relation between test diameter and the maximum number of growth rings that could be counted. Crosses indicate five individuals collected at Hudson Rocks in Georgia Strait. The relation is described by:

$$N = 0.53 + 0.19\ D$$

where N is the number of growth rings and D is test diameter.



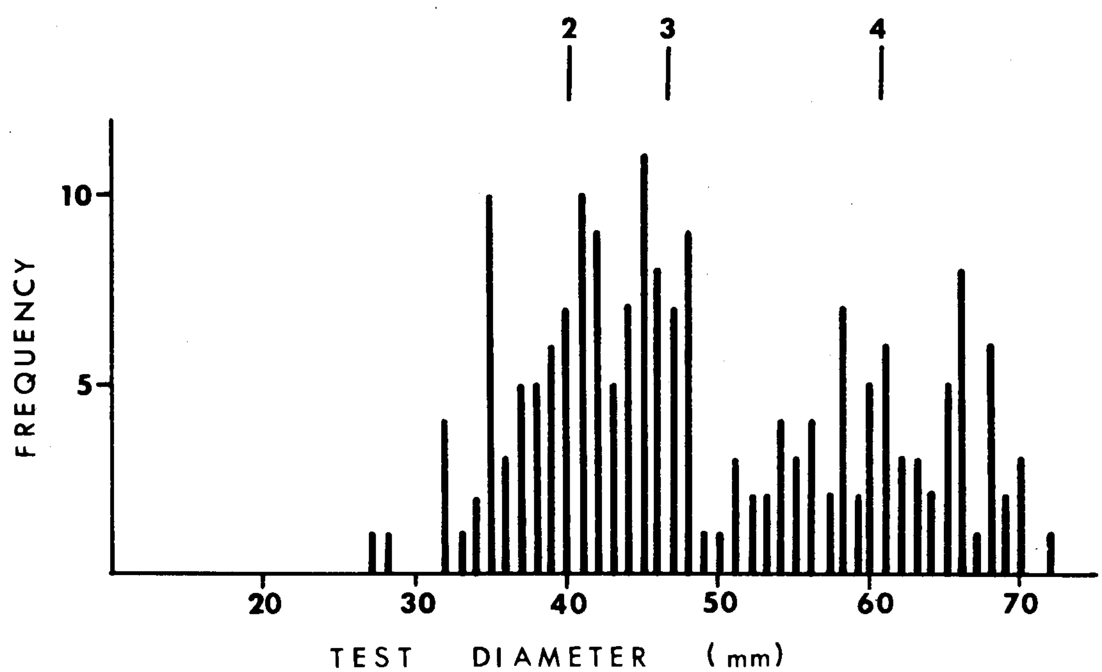


Fig. 5. The size-frequency distribution of sea urchins less than 70 mm test diameter at Ohiat Island on May 6 (above) and August 3 (below), 1976.