

Growth and Longevity of Some Calcareous Fouling Organisms, Monterey Bay, California¹

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A KNOWLEDGE of the lifespan of an organism is of value in understanding its life history. Ecological succession, including rates and characteristics of marine fouling, may be related to organism longevity. Organic production can be evaluated from growth and longevity data (e.g., Thorson, 1957). Our longevity analysis was undertaken as part of an evaluation of rates of biogenic sediment production by calcareous organisms.

Such growth and longevity data are scarce for benthic marine invertebrates. Mollusks, particularly the commercially exploited varieties, have been extensively investigated in this regard (as summarized, for example, by Comfort, 1957), but less is known about the growth and lifespan of other marine organisms.

Other writers have calculated organism growth rates from fouling panel data (e.g., Woods Hole Oceanographic Institution, 1952), but the data are not ordinarily used for longevity estimates. Haderlie (1968) studied organisms settling on fouling panels in Monterey Bay, California. We have calculated both growth rate and longevity for 13 of the more common calcareous organisms which settled on those fouling panels.

METHODS

Plywood fouling panels used during this investigation have been described by Haderlie (1968). The panels were placed at five different positions in Monterey Bay (lighted, intertidal, shallow, deep, and floating). One series of panels at each station was designated "tem-

porary." These temporary panels were replaced monthly. A second series of panels was designated "permanent." At each station, beginning in October 1966, permanent panels were left in the water for 3, 6, 9, and 12 months. Two years' data have been gathered for both temporary and permanent panels.

Settling of organisms was too irregular to permit a separate growth analysis for each station. Therefore, for each organism considered, all available data have been considered together. The justification for such a procedure is that, while the presence or absence of an organism may be determined by the station characteristics (light, depth, tidal exposure, etc.), a given species will grow at a relatively constant rate at all stations where it is present at all. Qualitatively, the data appear to support this procedure.

Our approach to estimating longevity is as follows: There are published accounts of the maximum size to which the organisms in question will grow on the Pacific coast of North America. An extrapolation of a growth curve gives a time at which the organism will reach that maximum size (here termed maximum size cutoff). The time required to reach this maximum size cutoff is a measure of the longevity of the organism. Any curve approaching this maximum size asymptotically (e.g., a von Bertalanffy growth curve) is unsatisfactory unless one uses the time required to achieve some set percentage of the maximum size rather than the maximum size itself. This latter approach would correspond to defining the $A_{.95}$ of Taylor (1959). $A_{.95}$ is the age at which an organism reaches 95 percent of its maximum size.

We have calculated a linear approximation to the growth curve and have used this approximation to extrapolate to the maximum size for longevity estimates. Our data do not justify the calculation of more complex functions.

As graphic presentation (Figs. 1 to 3) the

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longevity is represented by the intersection on a size-time diagram of the growth curve (oblique line) with the maximum size cutoff line (horizontal line). Longevity so calculated is the time required for the organism to attain its maximum size.

The largest size of a particular organism on each panel is plotted on a size-time diagram, and a decision whether or not to use that data point is reached as follows: At each time period for which there are data, only the maximum organism size is used. For a particular time even the maximum size is not used if that size is smaller than the maximum size at a previous entry. The X's and O's in Figures 1 to 3 represent all the data; the O's represent the data used. Such a complex procedure of acceptance or rejection is justified because apparent growth

rate on a fouling panel may be a serious underestimation of true growth rate; an organism may have begun its growth any time between immersion and removal of the panel.

The growth curve is represented by the best-fitting straight line through the origin of the size-time diagram. The slope for such a line is given by the formula:

$$\frac{\Delta S}{\Delta T} = \frac{\sum_{i=1}^n T_i \times S_i}{\sum_{i=1}^n (T_i)^2}$$

where T is time and S is size, summed over each of n observations.

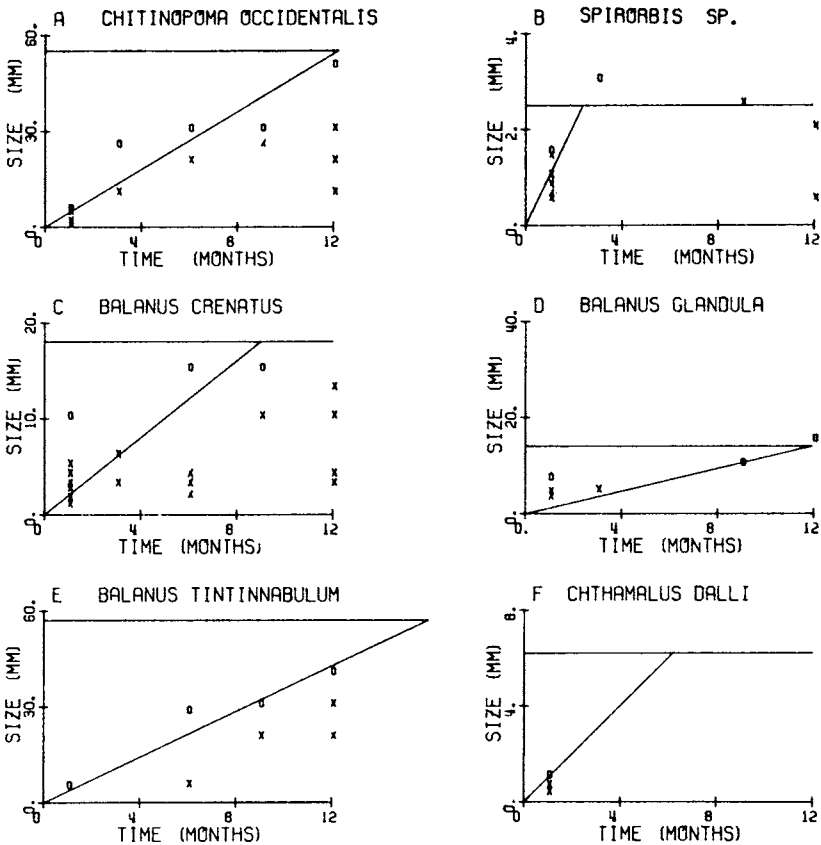


FIG. 1. Longevity calculated from growth rates for two species of annelids (A and B) and four species of barnacles (C-F). The longevity is represented by the intersection of the growth curve (oblique line) with the maximum size cutoff (horizontal line).

RESULTS

Annelida

Two genera of serpulids were considered: *Chitinopoma occidentalis* and *Spirorbis* sp. *Chitinopoma*, which grows to about 55 mm, appears to have a lifespan of about one year, while *Spirorbis* (maximum size 1 to 4 mm) apparently lives about 2 months. The following observations on the habitats of these organisms agrees with these estimates. *Spirorbis* commonly encrusts blades of the giant kelp, *Macrocystis*, while *Chitinopoma* rarely if ever does so. These kelp blades last only a few months (North, 1964), and so it appears that *Spirorbis*, but not *Chitinopoma*, can complete the benthic portion of its life cycle on this short-lived substratum.

Arthropoda

Four species of barnacles were common on

fouling panels. The maximum size cutoffs used are from Johnson and Snook (1927). Three species of *Balanus* were examined. *B. crenatus* (Fig. 1C) lives 9 months according to our estimates. *B. glandula* (Fig. 1D) lives a year, and *B. tintinnabulum* (Fig. 1D) about 16 months. *Chthamalus dalli* (Fig. 1F) lives about 6 months; since it was present only on the one-month panels, however, the estimate of its longevity is unreliable.

Bryozoa

The maximum size cutoffs for the five species of bryozoans considered are taken from Osburn's papers (1950, 1952, 1953) on bryozoans of the Pacific coast of North America. All species can reach these maximum sizes within 6 months or less. Both *Crisulipora occidentalis* (Fig. 2A) and *Tubulipora pacifica* (Fig. 2B) can grow to

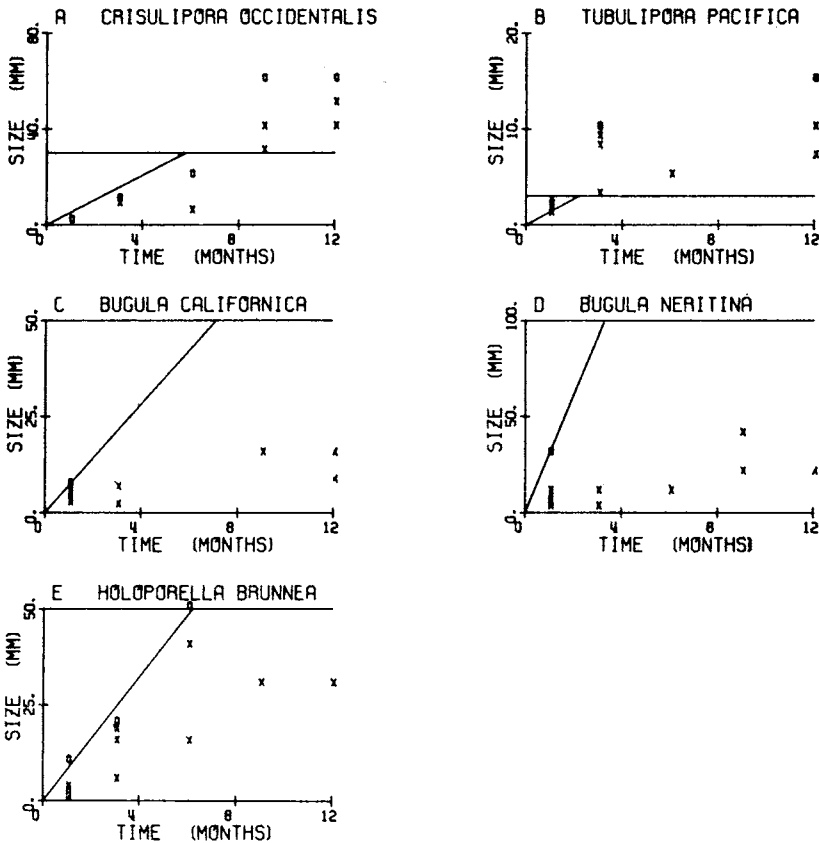


FIG. 2. Longevity calculated from growth rates for five species of bryozoans. The longevity is represented by the intersection of the growth curve (oblique line) with the maximum size cutoff (horizontal line).

sizes significantly larger than the Osburn maxima and thus perhaps can live longer than 6 months. Probably, however, they ordinarily complete their life cycles within 6 months.

A departure from the outlined procedure of data manipulation was taken with the two species of *Bugula* (Figs. 2C and 2D). Only the 1-month data were used because the data for longer periods would give lifespans of several years. As Grove (1933) observed that *Bugula flabellata* lives less than a year on the Atlantic coast of North America, it appears likely that the apparent slow growth of *Bugula* on our 9- and 12-month panels resulted from late settling rather than long lifespan.

The fifth bryozoan species considered is *Holoporella brunnea* (Fig. 2E) which lives about 6 months according to our calculation.

Porifera

DeLaubenfels (1932) reported that *Leuconia heathi* grows to about 110 mm in diameter. The estimated longevity is therefore about 17 months (Fig. 3A).

Mollusca

Mytilus edulis can grow to about 100 mm (Fitch, 1953). Such a size can be achieved in

approximately 20 months (Fig. 3B). Data from Coe and Fitch (1950) suggest that 3 years might be a better estimate of longevity. The discrepancy between our estimate and theirs could be explained by deviation of *Mytilus edulis* growth from our linear approximation after a year.

DISCUSSION

In the absence of more rigorous methods of estimating longevity, we suggest that linear approximations like those we have made can give a reasonable idea of longevity. However, major errors can arise from lengthy extrapolations (as with *Mytilus*), but even with such an error the estimate appears to be within a factor of two of the correct age. We suggest that our linear approximation in this instance would have attained approximately Taylor's (1959) $A_{.95}$, the age of reaching 95 percent of the maximum size. For many purposes this magnitude of error is acceptable.

Fouling panel data can be criticized because of the complication introduced by ecologic succession. On the other hand "natural fouling panels" (e.g., fresh surfaces such as new rock surfaces, algal blades, grass, and shells) are frequently made available in benthic communities, and the organisms which we have considered are prominent among the pioneering biota of such naturally occurring fresh surfaces.

Our analysis was undertaken to estimate rates of biogenic sediment production in a temperate-climate, rocky-bottom community. We conclude that the standing crop of calcareous organisms for the fouling panel community examined has the potential for annual or more rapid turnover.

LITERATURE CITED

- COE, W. R., and J. E. FITCH. 1950. Population studies, local growth rates and reproduction of the pismo clam. *Journal of Marine Research*, vol. 9, pp. 188-210.
- COMFORT, A. 1957. The duration of life in molluscs. *Proceedings of the Malacological Society of London*, vol. 32, pp. 219-241.
- DE LAUBENFELS, M. W. 1932. The marine and fresh-water sponges of California. Pro-

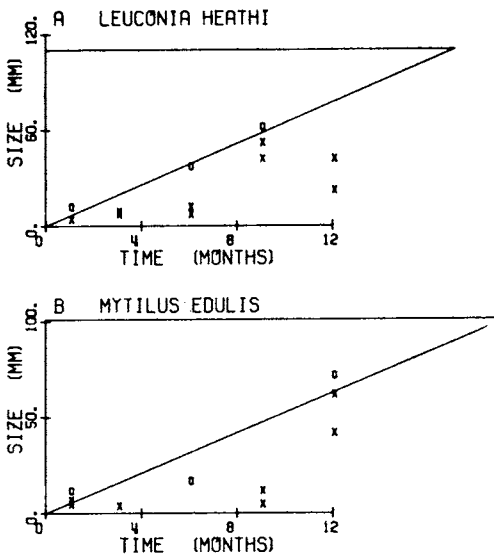


FIG. 3. Longevity calculated from growth rates for a sponge (A) and a pelecypod (B). The longevity is represented by the intersection of the growth curve (oblique line) with the maximum size cutoff (horizontal line).

- ceedings of the U.S. National Museum, vol. 81, pp. 1-140.
- GROVE, B. H. 1933. Rate of growth, age at sexual maturity, and duration of life of certain sessile organisms at Woods Hole, Massachusetts. *Biological Bulletin*, vol. 65, pp. 375-386.
- HADERLIE, E. C. 1968. Marine fouling and boring organisms in Monterey Harbor. *The Veliger*, vol. 10, pp. 327-341.
- JOHNSON, M. E., and H. J. SNOOK. 1927. *Seashore animals of the Pacific coast*. New York, Macmillan Co. 659 pp.
- NORTH, W. J. 1964. An investigation of the effects of discharged wastes on kelp. *The Resources Agency of California, State Water Quality Control Board Publication No. 26*, 124 pp.
- OSBURN, R. C. 1950. *Bryozoa of the Pacific coast of America, Part 1. Cheilostomata-Anasca*. Allan Hancock Pacific Expeditions. Los Angeles, The University of Southern California Press. Pp. 1-269.
- 1952. *Bryozoa of the Pacific coast of America, Part 2. Cheilostomata-Ascophora*. Allan Hancock Pacific Expeditions. Los Angeles, The University of Southern California Press. Pp. 270-611.
- 1953. *Bryozoa of the Pacific coast of America, Part 3. Cyclostomata, Ctenostomata, Entoprocta, and addenda*. Allan Hancock Pacific Expeditions. Los Angeles, The University of Southern California Press. Pp. 612-841.
- TAYLOR, C. C. 1959. Temperature and growth—the Pacific razor clam. *Journal du Conseil International pour l'Exploration de la Mer*, vol. 10, pp. 93-99.
- THORSON, G. 1957. Bottom communities (sublittoral or shallow shelf). *Geological Society of America Memoir 67*, pt. 1, pp. 461-534.
- WOODS HOLE OCEANOGRAPHIC INSTITUTION. 1952. Sequences and biotic successions. In: *Marine fouling and its prevention*. Prepared for the Bureau of Ships, Navy Department. Pp. 42-90.