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Surf clam

Spisula solidissima

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Surf clams are found from the Gulf of St. Lawrence to Cape Hatteras (Ropes 1980). In the Middle Atlantic Bight, where the resource is extensive and an active fishery exists, this macruid occurs from the coastal beach zone to depths of over 60 m. Off New England, surf clams are found along nearshore ocean beaches, on shoals off Nantucket and Martha's Vineyard, and on Georges Bank.

Surf clams are of separate sexes, although some individuals are hermaphroditic (Ropes 1982). In the Middle Atlantic Bight, spawning occurs primarily during summer, although some activity has also been documented in autumn (Ropes 1968). Sperm and eggs are released into the environment where fertilization and larval development occur. Full sexual maturity is attained in the second year of life at a shell length of 45 to 85 mm (Ropes 1979). Growth is fairly rapid to about age 7, but diminishes thereafter (Fig. 1). A maximum shell length of 226 mm and longevity estimate of 37 years have been reported for surf clams (Ropes and Jearld 1987).

Belding (1910) reported the earliest age information for surf clams based on observations that rings or bands on the external valve surface probably form annually. Mean shell length at age values were reported for surf clams ≤ 7 years old. The method was extended to studies of surf clams at Prince Edward Island, Canada (Kerswill 1944), off Long Island, New York (Westman and Bidwell 1946), off central New Jersey (W.R. Welch, Maine Dep. Mar. Resour., W. Boothbay Harbor, ME 04575, pers. commun. 1963), off Buctouch, Canada (Caddy and Billard 1976), and off Virginia (Loesch and Ropes 1977). An age of 17 years was the oldest reported in these studies, but none of the shell-length measurements exceeded 163 mm (Ropes 1980). Age was not determined for larger clams, because early rings on the valves were obliterated by erosion, and later rings became too crowded together at the valve margin for definite separation. Since significant numbers of clams >163 mm are found in natural populations (Ropes and Merrill 1976), the method is not generally applicable.

Bivalves have been found to deposit specific internal microstructures annually (Rhoads and Lutz 1980). These are considered to be relatively unaffected by external conditions and can be critically examined by microscopic enlargement. Therefore, methods were developed for exposing and examining such deposits in the shells of surf clams. In 1975, procedures were developed at Oxford, Maryland, for sectioning whole valves from the umbo to valve margin using a diamond-impregnated sawblade. The cut edges were then polished to remove saw marks and enhance the age-growth structures. Distinctive dark lines seen in the cut edges of the valves terminated at external rings. The annual periodicity of these lines was validated by marking experiments (Ropes and Merrill 1970, Jones et al. 1978). Although the method was reliable, age determinations required careful microscopic examination of the cut surface, which, together with the cutting and polishing procedures, proved to be excessively time-consuming.

A more efficient method has been developed based on similarity between the number and relative location of annuli in the valve and chondrophore (Ropes and O'Brien 1979). A linear correspondence has been found between chondrophore and valve growth ($r=0.97$). The preparation of a chondrophore for examination includes excision of the chondrophore from the valve by a pair of diamond-impregnated blades, gluing the excised chondrophore onto a slide, and production of a thin-section (0.25 mm thick) using an Isomet low-speed saw.

Age determinations are conducted under transmitted light at 50-100 \times . Wetting agents on the surface of the sections are unnecessary. A television/microscope monitoring unit also provides

adequate resolution of most sectioned chondrophores and has the advantage of permitting examinations by several viewers. Such devices are invaluable for training age readers and resolving age determinations of difficult specimens. In these examinations, light is transmitted through the translucent age annuli and blocked by the opaque growth increments, producing alternate zones of white and black, respectively. The exact opposite occurs in a photographic print (Fig. 2).

Bivalves may alter construction of their shells to form annular marks because of extrinsic or intrinsic factors (Lutz and Rhoads 1980). Low winter temperatures have been cited as the cause for annulus formation in several bivalves, including Stimpson's surf clam, *S. polynyma* (Feder et al. 1976). For the surf clam, annuli may form in response to spawning stress (Jones et al. 1978). Anaerobic conditions reportedly contribute to annulus formation in the northern quahog, *Mercenaria mercenaria*, and the ocean quahog, *Arctica islandica* (Lutz and Rhoads 1980).

Jones (1980, 1981a) investigated age-growth phenomena of surf clams and examined shells under a scanning electron microscope. He identified specific microstructural elements constituting the age annuli and growth increments in the outer shell layer and found that very fine layers in the shells of surf clams had no subdaily, daily, or tidal periodicity. Only annual layers were formed with a consistent periodicity.

The aforementioned research provides the basis for making routine age estimates from thin-sectioned surf clam chondrophores. Since age readers customarily use the term "hyaline zones" for age-mark determinations of other animals, this term is used herein to describe and identify the translucent age annulus or portions of an annulus in surf clam chondrophores. Three types of annuli have been recognized: the first annulus formed near the umbo, those formed during the next 9 years or so, and those formed from the 10th year or so onward. This separation is based on the apparent thickness of hyaline zones and a repetitive accretion of hyaline zones in some annuli. Age readers are instructed to count annuli beginning at the distal growing edge of a chondrophore, since it has been found that counts initiated at the umbo often resulted in an underestimation of age.

Environmental conditions at the sample location may influence the time of annulus formation. Jones (1980) found developing annual marks during late summer-early fall for specimens collected off New Jersey. Our observations confirm these data with the exception that clams from off Delmarva Peninsula form the annulus later in the fall, i.e., from October to December. These geographic differences in time of annulus formation may create confusion in age interpretation. A difficulty arises with the designation of 1 January as the standardized birthdate, since all annuli formed in early fall may show that substantial growth had occurred before the January birthdate. Therefore, caution must be exercised assigning an additional year of age due to finding a hyaline zone at the distal edge of chondrophores collected between the time of annulus formation and 1 January. This procedure assumes an annulus is formed in the first few months after larvae settle to the bottom.

The first annulus is usually a single, relatively narrow hyaline zone (Fig. 2a). Distance from the umbo to the most distal edge of the first hyaline zone is often variable. This may occur from improper technique during the cutting or grinding operations. More typically, variation may result from an annual variation in timing of larval production and settlement due to protracted spawning activity. One to three-month periods of peak spawning activities have been reported by Ropes (1968) and Jones (1981b), with some lower levels of spawning before and afterwards. This interpretation,

however, does not take into account possible differences in growing conditions at the place of settlement.

The second through about the tenth annuli may be characterized by alternating weak and strong hyaline zones separated by narrow opaque bands (Fig. 3). The terms "strong" and "weak" relate to the relative thickness of the hyaline zones and degree of light transmission through the zones. Double hyaline zones comprising an annulus are delimited from preceding and subsequent annuli by wide opaque bands. A reduction and increase in the growth rate during the formation of an annulus are suggested by this alternative pattern of zones and bands.

The hyaline zones and opaque bands of subsequent annuli are greatly compressed, although variation in growth between annuli may occur (Fig. 3). Each distinct hyaline zone is counted as an annuli. The more compressed pattern of these annuli is suggestive of a reduction in the growth rate.

Occasionally chondrophores have incomplete hyaline zones, particularly in the case of annuli formed after the tenth year of life. These are narrow hyaline zones in the middle of a chondrophore that fail to clearly extend to the lateral edges (Fig. 3). They are categorized as growth checks.

Although patterns of annular growth are similar for most areas that have been sampled, others have unique characteristics. Surf clams from Nantucket Shoals have much more diffuse hyaline bands. The bands are not discrete groups sharply delineated by opaque zones but tend to split more frequently and blend together. The dynamic environment of this area may create conditions which are not conducive to consistent deposition of annular material. Inshore and offshore samples along the Middle Atlantic coast also exhibit different growth patterns (Jones et al. 1978) and consequently the annuli pattern varies. In this area, though, the rings are defined well enough to age.

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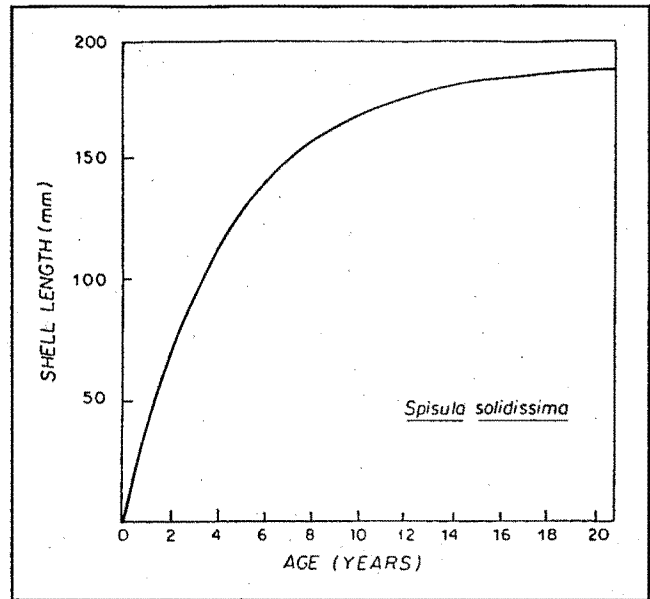


Figure 1

Relationship between age and growth in surf clams.

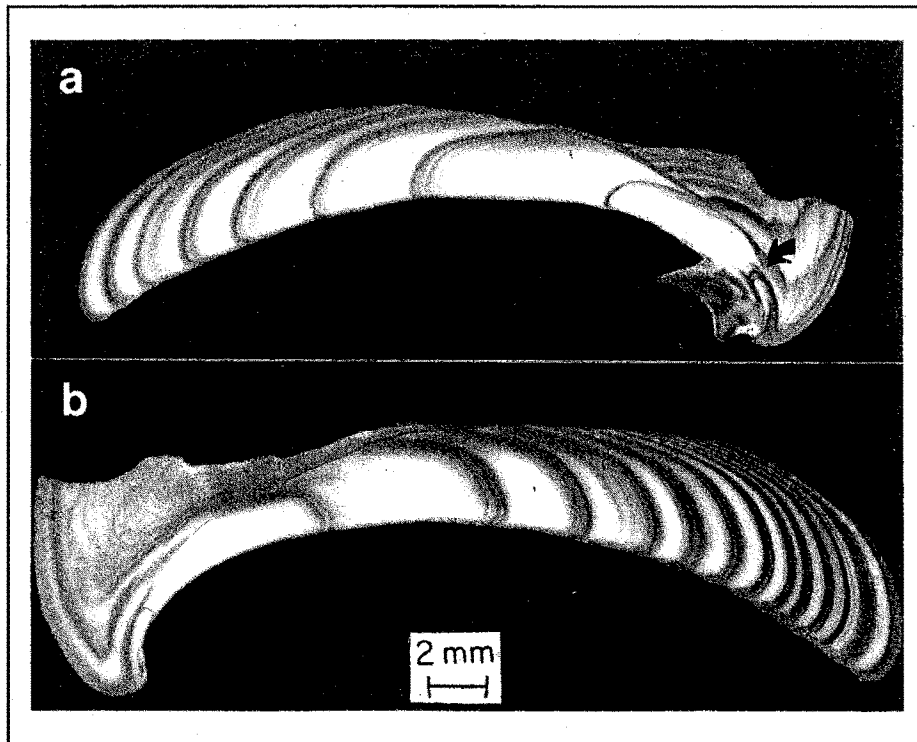


Figure 2

Photographic enlargements of thin-sectioned chondrophores from surf clams: (a) 139 mm (shell length), age 8; and (b) 137 mm (shell length), age 13. The first annulus formed in the life of a surf clam is sometimes faint (arrow indicates a bold annulus in the chondrophore of the upper clam). The most recent annulus at the marginal edge of these chondrophores was not completely formed.

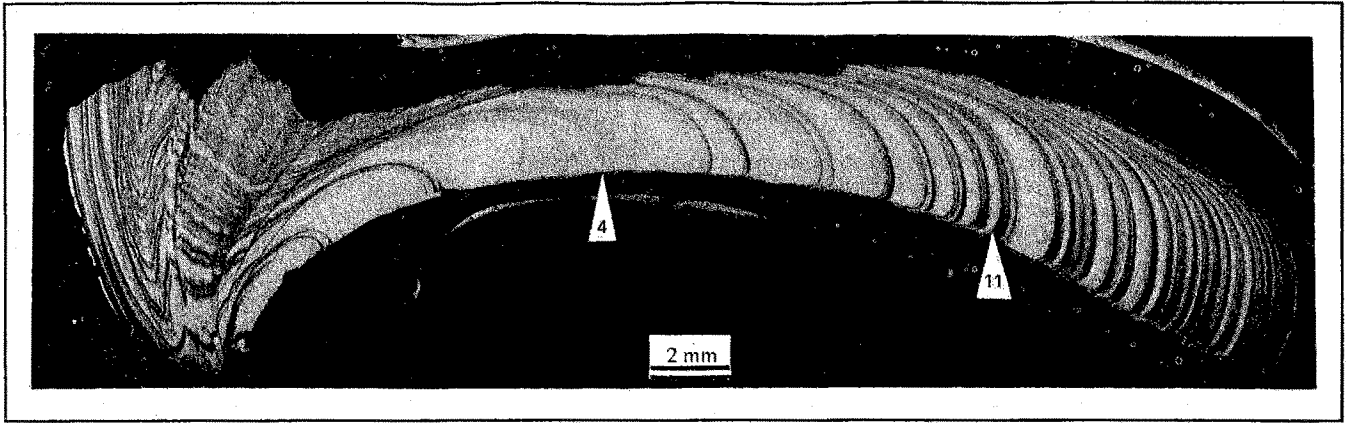


Figure 3
Photographic enlargement of the thin-sectioned chondrophore of a 175-mm (shell length), age-32 surf clam.