Observations on Shell Deformities, Ultrastructure, and Increment Formation in the Bay Scallop *Argopecten irradians*

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Abstract

Shell morphology and ultrastructure were examined in the bay scallop *Argopecten irradians*, cultured in recirculating seawater systems under various conditions of feeding, lighting, and handling. On a unialgal diet of *Thalassiosira pseudonana*, scallop growth ranged from 120 to 183 µm d\(^{-1}\) at 20°C in the laboratory, about two-thirds of the growth rate found in the field. However, shell deposited in the laboratory differed from that in the field in several ways. In the field, scallops formed costae as an unpigmented, corrugated marginal shell layer; shell deposited in the laboratory lacked this layer and was therefore darker. Also, microstructure of the exterior shell surface of field scallops was coarsely granular, while that of cultured scallops was relatively smooth. Excessive handling of scallops in the laboratory resulted in marginal thickening of valves, a deformity which was completely arrested by a change from daily to weekly handling. Scallops cultured in the same tank with oysters developed shell-thickening on the interior of the valves. It is postulated that shell abnormalities in bivalves result from disruption of complex behavioral processes associated with shell deposition and may be elicited by a variety of natural and experimental irritants. Under natural lighting regimes and optimal conditions for growth, scallops deposited exactly one shell increment per day, but under continuous lighting, deposition of growth increments often became aphasic. In one 28-d experiment, there was a strong correlation between number of growth increments formed and increase in shell height, suggesting that shell ridge formation occurred intermittently, rather than daily, when shell growth rates fell below approximately 150 µm d\(^{-1}\).

Introduction

Study of shells of molluscs cultured in the laboratory or in well-monitored field conditions has been helpful in understanding a number of basic physiological processes, including ionic transport (Wheeler et al., 1975), growth (Rhoads and Pannella, 1970), reproduction (Jones et al., 1978), and autophasing (Clark, 1975; Thompson, 1975; Gordon and Carriker, 1978). For culturists, growth increments inscribed in shell can be used to assess the effect of microenvironmental conditions on growth (Rhoads and Pannella, 1970; Clark, 1977; Palmer and Carriker, 1979).

Although shell structure and shell increments have often been used as indicators of underlying physiological processes, the effects of various environmental conditions on shell deposition in bivalves are poorly understood. Environmental conditions may not only affect periodicity of increment formation (Broom and Mason, 1978), but also shell structure itself. For example, Rhoads and Pannella (1970) found that specimens of *Astarte castanea* and *Mercenaria mercenaria*, when transplanted to the laboratory, showed changes in size, arrangement, and orientation of both crystalline and periostracal structures in the shell. Changes such as these are of considerable theoretical interest to the physiologist, and may have practical significance to the culturist, particularly if abnormalities appear in shell deposited under laboratory conditions. Epifanio (1976), for instance, found that scallops (*Argopecten irradians*) cultured in a recirculating seawater system developed a thickening at the shell margins which prevented closure of the shell. This abnormality co-occurred with slow growth and severe mortality. Many specimens of *A. irradians* cultured in flowing seawater with oysters (*Crassostrea virginica*) developed a shell deformity similar to that described by Epifanio (1976), and these laboratory-reared scallops also had high mortality rates (Mann and Taylor, 1977). None of these workers positively identified the cause of these abnormalities or

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indicated whether they could be reversed by manipulation of cultural conditions.

Shell abnormalities apparently occur under laboratory conditions in several families of bivalves and in several types of calcium carbonate shell structures. Deformities similar to those described by Epifanio (1976) for *Argopecten irradians*, whose shell is composed of foliated calcite, have also been observed in *Mercenaria mercenaria* (C. E. Epifanio, personal communication) and in *Tapes japonica* (S. Laurence, personal communication). The growing margin in the latter two species is composed of composite prismatic aragonite (Taylor et al., 1973).

Little is known about differences in morphology and ultrastructure of shell from bivalves cultured in field, in contrast to laboratory conditions, or about causes of shell abnormalities in cultured bivalves. Objectives of this study were: (1) to compare the structure of shell deposited under field conditions by the bay scallop *Argopecten irradians* with that produced under laboratory conditions; (2) to describe the microscopic structure of shell deformities associated with laboratory culture of this organism; and (3) to delineate environmental conditions associated with both initiation and reversal of these abnormalities. Observations are also presented on shell increment formation under various environmental conditions and on the potential value of these increments to growth studies.

**Methods and Materials**

**Environmental Conditions**

Three groups of scallops were maintained in aquaria with recirculating seawater at the University of Delaware, Lewes, Delaware, USA between September, 1977, and December, 1978. Diets, lighting regimes, and handling procedures for the 3 groups were manipulated in an attempt to clarify associations between various environmental conditions and concomitant shell growth rates on the one hand, and shell structure on the other (Tables 1, 2).

The first group (*Argopecten irradians irradians* Lamark) was hatchery-reared at the National Marine Fisheries Service, Milford Laboratory, Milford, Connecticut. In Delaware, 6 scallops (initial mean shell height: 21 mm) were maintained in each of five 40-l aquaria; feeding was, however, continued on a daily schedule, and feces and pseudofeces were siphoned from the aquarium daily.

The third group of scallops (*Argopecten irradians concentricus*) also came from the Wachapreague, Virginia laboratory. In Delaware, 10 of these scallops (initial mean shell height: 41.6 mm) were maintained in an 80-l aquarium under a continuous addition of *Thalassiosira pseudonana* at the rate of 2.5 x 10^8 cells g^-1 day^-1. The aquarium was cleaned weekly.

Seawater (30%o) for algal culture and for the recirculating aquaria was collected at high tide at Indian River Inlet, Delaware, and passed through two 5 μm, two 1 μm, and one 0.5 μm cartridge filters before use. Procedures used in the culture of *Thalassiosira pseudonana* are given by Epifanio (1979).

**Preparation of Shells**

At the end of each growing period, scallop shells were cleaned of soft tissues and immersed in 20% chlorox (about 1% sodium hypochlorite) for 5 min. Organic material on the surface of the shell was then gently removed with a camel’s-hair brush, and the valves were rinsed in tap water and then air dried. Growth increments were counted and measured on the left valves only, using a Wild M-5 stereomicroscope with calibrated ocular micrometer.