1976

Effects of substratum on growth of the bivalve Rangia cuneata, Gray, 1831

Richard K. Peddicord
Virginia Institute of Marine Science

Recommended Citation

Peddicord, Richard K., Effects of substratum on growth of the bivalve Rangia cuneata, Gray, 1831 (1976). *Veliger*, 18(4), 398-404.
https://scholarworks.wm.edu/vimsarticles/2142

Effects of Substratum on Growth of the Bivalve *Rangia cuneata* Gray, 1831

BY

RICHARD K. PEDDICORD

Virginia Institute of Marine Science, Gloucester Point, Virginia 23062

(4 Text figures)

INTRODUCTION

THE BRACKISH WATER bivalve *Rangia cuneata* Gray, 1831, a member of the family Mactridae, has been reported from Virginia estuaries in the past few years. This species, until recently common only along the Gulf Coast, occurred in estuaries from New Jersey to Mexico during the Pleistocene (RICHARDS, 1938), and now seems to be reoccupying its former range. Live *R. cuneata* on the east coast were first reported from North Carolina in 1955 (WELLS, 1961), Florida in 1961 (WOODBURN, 1962), Virginia in 1960 (WASS, 1972), the Potomac River in 1964 (PFITZENMEYER & DROBECK, 1964), upper Chesapeake Bay in 1966 (PFITZENMEYER, 1970), and the Elk River, Maryland, in 1968 (GALLAGHER & WELLS, 1969). The most common explanations of the range extension of *R. cuneata* have been reviewed by HOPKINS & ANDREWS (1970).

The literature on the growth of *Rangia cuneata* is meager. The larval development was studied by CHANLEY (1965) who reported termination of the straight-hinge stage at about 130 μm length. In a study of environmental effects on the reproductive cycle and larval development, CAIN (1973) reported the greatest growth of larvae at 27 - 32° C and 10 - 20‰ salinity.

Growth of adult *Rangia cuneata* was first studied by FAIRBANKS (1963), who correlated biological and physical factors in Lake Pontchartrain, Louisiana, with length, weight and population density. He attributed differences in abundance, size and growth to physical and chemical properties of the sediments. Growth, as indicated by annuli, was faster in sandy areas, with clams reaching 15 - 20 mm in length the first year and adding 5 - 10 mm the second and 4 - 5 mm the third year. *Rangia cuneata* were generally more numerous but smaller and slower growing in muddy areas.

WOLFE & PETTEWAY (1968) constructed a hypothetical von Bertalanffy growth curve based on data from clams collected over a two-year period at one station in North Carolina. They estimated that *Rangia cuneata* required 10 years to reach its asymptotic length of 75 mm in the area sampled. This is in general agreement with the estimates of FAIRBANKS (1963) and PFITZENMEYER & DROBECK (1964). No mention was made of the substratum or salinity regime from which these clams were collected.

TENORE, HORTON & DUKE (1968) found clay-silt sediments with high concentrations of phosphate or organic matter to be least favorable for growth, while sand with high nutrient levels was the most favorable. Uptake of radionuclide labeled detrital material indicated that *Rangia cuneata*, although morphologically a typical filter-feeder, can obtain organic matter and phosphate from the sediments, either by direct ingestion or by feeding on bacteria associated with these materials.

GODWIN'S (1968) distributional analysis of *Rangia cuneata* beds in the Altamaha River, Georgia, indicated no effect of salinity or substrate on size. However, he felt that salinity was the most important limiting factor governing the occurrence of *R. cuneata* and bottom type was a major factor controlling its distribution and density.

METHODS AND MATERIALS

The experimental sites for this study were around Hog Island in the oligohaline section of the James River, Virginia. Sampling was conducted in 4 areas, labeled A, B, C, and D, each area having having one station (m) in a mud bottom about 3 m deep and one (s) in a sand bottom about 1 m deep (Figure 1). The sand stations were

---

[1] Virginia Institute of Marine Science Contribution No. 704

[2] Current address: University of California, Bodega Marine Laboratory, Bodega Bay, California 94923

located on the submerged portions of beaches where the sandy bottoms probably resulted from wave turbulence rather than high current velocity. The sampling sites were chosen so that the areas differed mainly in salinity and stations within an area differed primarily in type of substratum.

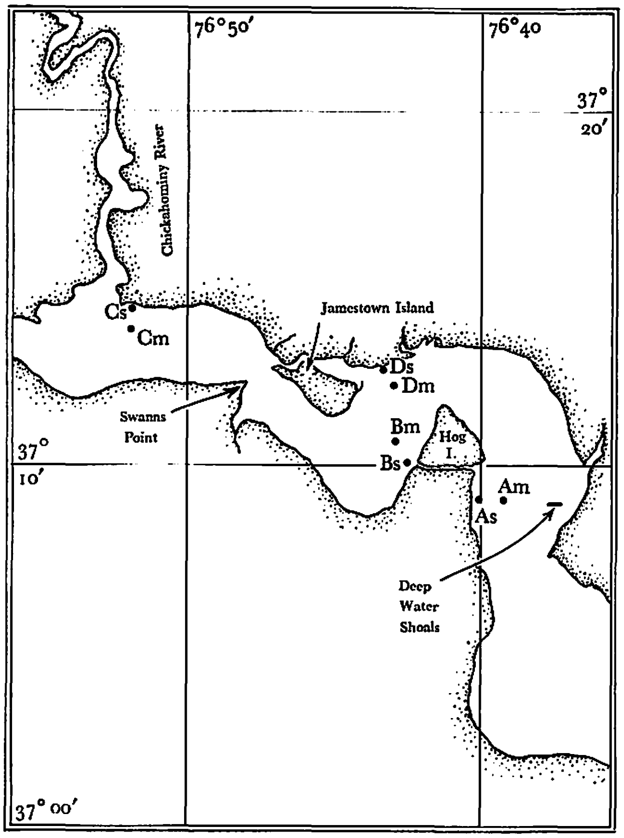

Figure 1

Location of Growth Stations in the James River Estuary, Virginia

Area A, about 25 nautical miles (46 km) above the river mouth, was located in what appeared to be the most seaward well established population of *Rangia cuneata*. Areas B and D were on opposite sides of the estuary at about river mile 32 (51 km). Area C, at mile 40 (64 km) near the mouth of the Chickahominy River, was in an upper estuarine population of *R. cuneata*. Although the clam is found another 40 km upstream, this region is typically tidal fresh water and was not considered in the present study.

Bottom water samples were taken bi-weekly at each station. For all samples temperature was measured immediately with a mercury thermometer while dissolved oxygen samples were fixed and returned to the laboratory for analysis by the Winkler method. Salinity was determined in the laboratory with an induction salinometer. At stations Ds and Dm current velocity, suspended solids concentration, salinity and dissolved oxygen data were collected every hour over a full tidal cycle on September 22, 1972, beginning just after low slack water. Current velocity 25 cm above the bottom was measured with an impeller-type meter, and water samples, integrating conditions between 5 cm and 16 cm above the bottom, were taken with a horizontal Van Dorn bottle. Suspended solids samples were stored on ice overnight, then a measured volume was vacuum filtered through a pre-weighed 0.80 μm filter pad, washed with distilled water and dried at 100° C for 24 hours. After cooling in a desiccator, they were weighed twice and the mean weights were converted to mg/*l*.

Particle size distribution in the top 5 cm of sediment at the 8 stations was determined from 2 samples, taken at the beginning and end of the study. All samples were treated with sodium hexametaphosphate to disperse aggregates. The sand fraction was separated by wet screening and the mud fraction was analyzed by the standard pipette technique. The results of the 2 sediment samplings, being very similar, were averaged and presented as the particle size distribution characterizing each station during the experiment.

Growth studies were begun in July, 1971. All experimental *Rangia cuneata* 30 mm to 40 mm long were collected by dredge at station Bm, while those 40 mm to 50 mm long and 50 mm to 60 mm long were collected by hand at Bs and Ds, respectively. Approximately 125 clams in each 10-mm length interval between 30 mm and 60 mm were returned to the laboratory where they were brushed clean, measured, weighed and numbered for planting.

Ten clams were selected randomly from a size class, towel dried, weighed to 0.1 g and length and width were measured to 0.1 mm. These clams were set aside and the procedure repeated until 100 clams had been selected from that size class. By this time the shells had evaporated to complete dryness and an identifying number was painted on each clam using Marktex Tech-Pen and Ink (Mark-Tex Corp., Englewood, New Jersey). Fifty clams of each size class were selected to be planted in sand and 50 in mud in each study area.

Planting beds had been previously prepared at all 8 stations using SCUBA gear, which was also employed in planting and recovering marked clams. At each station clams within a marked area about 1.5 meters square were removed. By the time the numbered clams were ready for planting, the currents had reworked the sediment in the planting beds until they were indistinguishable from the surrounding sediment. The clams were distributed evenly over the cleared area and pushed into the substrate in approximately the natural orientation. One hundred and fifty clams between 30 and 60mm long were planted at each of the 8 stations. In addition, 50 clams 20 to 30 mm long were planted at both Ds and Dm on August 19, 1971, and on September 1, 1971, about 30 clams less than 20mm long were planted at these stations.

Clams were recovered 1 year ± 2 days after planting, and were returned to the laboratory, dried, weighed and measured as before planting.

Although clams of the same sizes had been planted at all 8 stations, size-related biases may have occurred in the subsamples recovered at some stations. This was tested by an analysis of variance comparing the lengths at the time of planting of those clams which were recovered at each station.

The growth of the clams at the various stations was compared by constructing Walford plots for each station (Lindner, 1953; Walford, 1946; Wolfe & Petteway, 1968). This method plots length at time t (at planting) on the X axis and length at time t + 1 (at recovery 1 year later) on the Y axis. The result is a linear "transformation" of the data. An analysis of covariance was then performed to compare the least squares regression lines obtained from the data for each station. Contrasts among the adjusted means of the regression lines were made by Scheffe's method (Guenther, 1965) at the 0.05 level. No acceptable multiple contrast method was available for contrasting the slopes of the lines; therefore, visual inspection was employed to establish apparently homogeneous groupings of regression lines. Then covariance was used to test the identity of the lines within each group and to compare the pooled data for each group to lines outside the group. The author was aware that with such a multiple use of "F" the probability level decreases at an undetermined rate. However, the change is slight for a small number of comparisons and can be offset by the use of a lower alpha level.

RESULTS

Water temperature ranged seasonally from about 4°C to 29°C, with daily and tidal temperature variations at a station as great as differences between stations on the same day. Dissolved oxygen was usually somewhat below saturation, ranging from 12mg/l in winter to about 6 mg/l in autumn at all stations. All mud stations usually had slightly higher salinity and lower dissolved oxygen than the shallower sand stations. Salinity was highly variable seasonally with most areas showing measurable salinity in late summer, and even area A becoming fresh during periods of high runoff. Area A was the highest salinity area investigated, with a range of 0.2‰ to over 17.1‰ between August, 1970, and March, 1972. Salinities in area B ranged from 0.1 to 14.4‰ while those in area D were usually 0.1 to 0.5‰ higher. In contrast to the other areas, C does not experience salinity every year. In October, 1970, salinity reached 9.4‰ at Cm and after mid-November, 1970, did not exceed 1‰. The temperature, salinity and dissolved oxygen conditions at each station are presented in detail in Peddicord (1973).

The results of the sediment particle size analysis for all 8 stations are presented in Table 1. All sand stations had very similar particle size distributions, while the mud stations showed more variability. Station Dm had more sand than the other mud stations, but did not approach the sand content of the sand stations. All mud stations had approximately 80% or greater silt-clay content.

Table 1

Percentage composition by weight of the sediment at each of the 8 growth stations. Values given are the mean of two determinations.

Station	% fine clay <0.49μm	% coarse clay 0.49-3.9μm	% silt 3.9-62.5μm	% sand >62.5μm
As	1.80	4.84	7.64	85.73
Bs	0.85	5.67	12.33	81.16
Cs	2.72	4.81	10.68	81.79
Ds	0.58	4.50	12.19	82.73
Am	18.67	17.19	57.67	6.47
Bm	23.86	26.23	47.64	2.27
Cm	29.71	33.02	30.22	7.06
Dm	16.62	18.33	42.28	21.77

Additional differences between the sand and mud stations were indicated by the study of suspended solids and current velocity in area D. The salinity at both stations varied about 1.5‰ over the tidal cycle and was generally lower at Ds than at Dm. Dissolved oxygen patterns were similar at both stations, but more variable at Ds. The duration of the ebb and flood currents at Ds and Dm was equal. Flooding currents reached 0.7 knot (1.3 km per hour) at both stations but the ebb current at Ds only reached 0.5 knot (0.9 km/hr), while at Dm the ebb current exceeded 0.5 knot for 4 hours and reached 0.75 knot (1.35 km/hr). The most striking difference between the 2 stations was in suspended solids content in the water a few centimeters above the bottom (Figure 2). At Dm suspended solids content varied with current velocity, exceeding 500 mg/*l* on the maximum flood and ebb currents and falling to around 100 mg/*l* at periods of slack tide. In contrast, Ds showed a suspended solids peak only slightly above 200 mg/*l* on the maximum flood current and thereafter stayed very close to 100 mg/*l*. Although quantitative variability over time undoubtedly exists within and among areas, it seems reasonable that the pattern observed in area D of higher suspended solids at the mud station than at the sand station would be generally applicable to the other sampling areas as well.

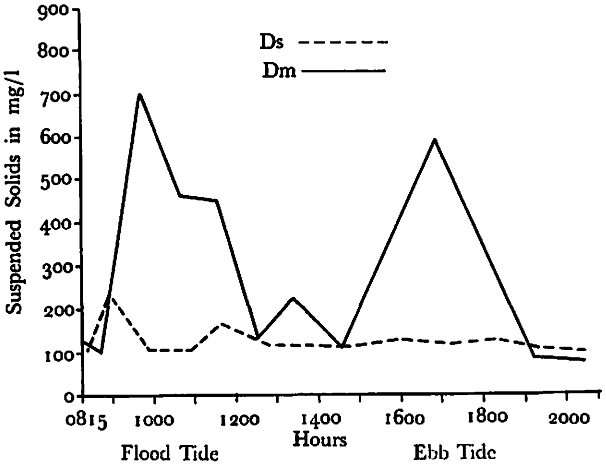

Figure 2

Suspended Solids Content (mg/l) in the Bottom Water at Stations Ds and Dm over a Tidal Cycle on September 22, 1972

Rangia cuneata living in muddy bottoms were generally smaller and more numerous than those in sandy areas. Clams in silt-clay substrata rarely exceeded 45 mm in length and often occurred in densities of several hundred per square meter. Some areas were found to support clams 38 to 42 mm in length in densities exceeding 1000/m². *Rangia cuneata* from sand bottoms often exceeded 60 mm in length but seldom occurred in greater densities than 50/m². The largest living clam collected (76 mm long) was found at station As and the longest shell (81 mm) was found in a sand bottom near station Bs.

At least 75% of the marked clams 30 to 60 mm long were recovered alive at all stations. Those under 30 mm long planted in area D were not recovered in sufficient numbers to provide reliable information. Although the data permit the evaluation of the relative growth of *Rangia cuneata* at the 8 stations, the biases arising from studying only a selected size range make the prediction of absolute growth from the calculated equations uncertain.

The analysis of variance comparing the lengths at the time of planting of those clams which were recovered at each station gave a non-significant "F" value. Therefore, the clams recovered at all stations had been of equal mean size when planted and any differences at recovery must have been due to differential growth.

When the Walford growth lines obtained from the analysis of covariance were plotted, the lines for stations As, Bs, and Ds were superimposed and thus considered homogeneous. The lines for stations Am, Bm, and Dm were nearly as close but had a slope obviously different from the sand stations. Another analysis of covariance performed on the data from stations Am, Bm, and Dm showed their slopes to be equal and they were pooled into one line. Thus the slopes of the more closely grouped lines for stations As, Bs, and Ds were assumed to be equal, and they were also pooled. The analysis did show the adjusted means of the mud station regression lines to be statistically different, but the actual difference was less than 1.5% and was considered biologically unimportant. The plotted Walford regression line for Cm fell slightly outside the group of lines for the other mud stations, and Cs fell between the mud and sand groups. The slopes for the 2 stations in area C were compared by covariance and found to be different. Stations Cs and Cm were also shown to differ from the lines derived from pooling the data for the other stations in their respective substrata. Thus, the Walford growth lines for *Rangia cuneata* 30 to 60 mm long at the 8 stations fell into 4 different groups shown in Figure 3. The coefficient of determination (r^2) for all lines was 0.98 or higher, indicating both the success of Walford's linear transformation and the low variability of the data within each group.

When growth of the planted clams was considered in terms of weight gain, the slopes of the lines for all mud stations were found to be equal, and the data were pooled into a single growth line (Figure 4). All the adjusted means differed from each other, although the greatest difference was less than 5% and was considered biologically insignificant. In terms of weight gain the sand stations were divided into 3 groups (Figure 4). Station Cs was the

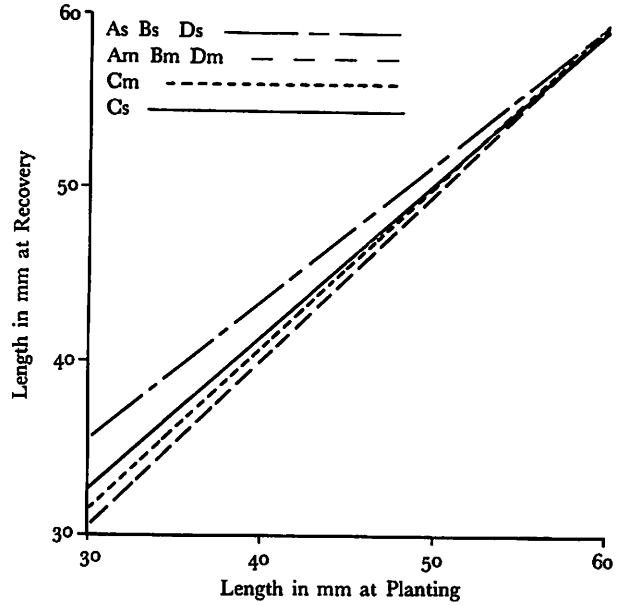

Figure 3

Pooled Walford Growth Lines Illustrating Different Rates of Length Increase at Four Groups of Stations

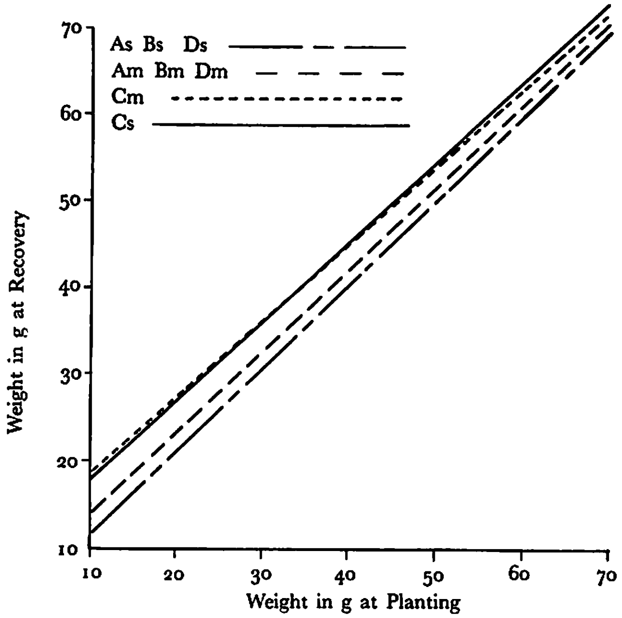

Figure 4

Pooled Walford Growth Lines Illustrating Different Rates of Weight Increase at Four Groups of Stations

lowest but showed over twice the increase of the pooled mud stations. Stations As and Bs gave regression lines not significantly different in terms of either slope or adjusted means and are pooled in Figure 4. Clams at these stations showed the greatest weight gain of the study. The slope of the line for Ds differed from As and Bs and indicated somewhat less weight gain for the larger individuals. All the lines in Figure 4 had coefficients of determination (r^2) greater than 0.98.

Rangia cuneata at stations As and Bs showed the greatest increases in both length and weight, but only slightly exceeded those at Ds. At the 3 down-river sand stations 30m clams increased in length almost 20% during the year. Clams at station Cs had considerably less growth of all sizes than at the other sand stations in terms of length and weight. At stations Am, Bm, and Dm increases in length and weight were slight even for 30mm clams, and almost undetectable for large clams. With respect to weight Cm could not be distinguished from these stations, but length increase at Cm was somewhat greater than at the other mud stations.

DISCUSSION

The relationship of sediment to current velocity was somewhat unusual, in that currents were actually slightly slower over the near-shore sand bottoms than over mud. The sand substratum likely resulted from wave turbulence reaching bottom in the shallow water resuspending any fine material present, which was then carried away by the current. A similar mechanism may have been at least partially responsible for the greater abundance of clams in mud bottoms than in sand. Currents were slow enough that larvae may have set on both bottoms, but many juveniles could have been washed out of the sand bottom by wave action and carried away by the currents soon after setting. This makes it conceivable that the clams occurring naturally in sand bottoms grew from larvae that had an intrinsically high growth rate and were better able to resist the wave action at an early age. If so, their greater maximum size as adults may be due partly to genetic characteristics.

The idea of currents providing more food per unit time over sand bottoms does not apply here, since currents were slightly faster over mud bottoms. There is evidence that under natural conditions, detritus with its associated organisms is an important food source (Darnell, 1961; Tenore *et al.*, 1968). There is an abundant supply of detritus to the upper James estuary, and it seems unlikely that food is seriously limiting.

Pratt & Campbell (1956) found that increased silt-clay content of the sediment was related to reduced growth in the hard clam *Mercenaria mercenaria*. They suggested that some chemical factor associated with fine sediments may have been responsible, but were unable to test this hypothesis satisfactorily. The authors also suggested that the inhalent current dislodged surface sediment particles and their ingestion and expulsion by the clams consumed considerable energy.

A very great difference was shown in the suspended solids content of the water a few centimeters above the bottom at stations Ds and Dm. The suspended solids measured at Ds probably represent primarily the very fine material in more or less permanent suspension. At Dm some clay particles apparently are resuspended by the maximum currents and settle out again near slack tide. In a system as well mixed as the upper James estuary, it is difficult to conceive of significant differences in temperature, salinity, chemical composition or available food between nearby mud and sand stations. However, the very great difference in the suspended solids load just above the two bottom types may well be a major factor contributing to the slower growth of clams in mud bottoms.

Loosanoff (1961) has shown that pumping rate of oysters, *Crassostrea virginica*, varies inversely with suspended silt concentration, with 100 mg/*l* causing an average reduction of 57% compared to clear water. As concentration increased, so did atypical shell movements associated with ejection of pseudofeces. Pumping rate of oysters was also reduced in high concentrations of food cells (Loosanoff & Engle, 1947). The quantity of pseudofeces was roughly proportional to the total amount of food and inert material in suspension, while the amount of true feces was inversely proportional to the total suspended particle concentration. As food cell concentration was increased, volume and rate of ejection of pseudofeces increased; the stomach contained progressively less food, and the crystalline style disappeared, indicating little digestion was taking place. Thus as suspended particle concentration increased, energy intake declined and pseudofecal energy expenditures rose.

That a real difference can exist between the amounts of pseudofeces ejected by hard clams, *Mercenaria mercenaria*, in different substrata was shown by Pratt & Campbell (1956). Clams in aquaria with a substrate of 10% silt and clay had a mean of 9.5 ejections/hour, and 107 ejections/hour in a substrate of 40% silt-clay content. This is more than an order of magnitude increase and probably represents a considerable increase in energy consumed in ciliary and muscular action and mucous secretion, as well as a loss of some utilizable food due to imperfect sorting. The silt-clay content was over 70% at station Dm and almost 100% at Bm, compared to a maximum of 40% in their study.

Johnson (1971) studied the growth of the filter-feeding gastropod *Crepidula fornicata* in trays 0, 45 and 75 cm above a bottom characterized by the resuspension of sediments by tidal currents. Growth was least in the bottom tray and increased significantly in each progressively higher tray as suspended sediment concentration decreased. A series of trays was also placed in a clear and a relatively more turbid environment. The greatest growth (top tray) in the turbid environment was equaled by the least growth (bottom tray) in the clear environment. In the laboratory, filtration rate was shown to vary inversely with suspended sediment concentration, with the rate at 600 mg/*l* approximately 20% of that at 150 mg/*l*. Rhoads & Young (1970) placed small *Mercenaria mercenaria* in a similar set of trays over a silt-clay bottom resuspended by tidal currents. Growth in the most turbid environment nearest the bottom was significantly less than in the upper trays in clearer water.

A study of the condition index of *Rangia cuneata* (Peddicord, in preparation) conducted in conjunction with the present research, showed condition to be highest at the stations supporting fastest growth, and lowest at the slowest growth stations. A reciprocal transplant experiment in area D showed that low condition was due to some factor associated with the water overlying the mud bottom, rather than characteristics of the substratum itself. It was suggested that this water-associated factor may have been the high suspended solids concentrations found over the mud bottom.

Although none of the above studies conclusively demonstrate that suspended sediments significantly inhibit the growth of *Rangia cuneata* in natural situations, their combined implications make this a reasonable hypothesis. It is suggested that the suspended sediment concentrations occurring at station Dm with maximum currents may result in reduced pumping and ingestion rates and increased ejection of pseudofeces. This would increase energy consumption and reduce energy intake through lower ingestion rate and loss of potentially utilizable food due to imperfect sorting. The cumulative effect of these conditions may be that *R. cuneata* in mud bottoms are unable to exceed the demands of their environment sufficiently to support rapid growth in addition to other necessary biological activities.

ACKNOWLEDGMENTS

I am indebted to many people at the Virginia Institute of Marine Science, particularly Dr. Marvin Wass for his valuable guidance and reading of the manuscript. Dr. Thomas Cain assisted in sampling and offered many valuable suggestions. Financial support during the research was provided by Dr. Morris Brehmer under a research assistantship to the Virginia Institute of Marine Science by Virginia Electric and Power Company.

Literature Cited

CAIN, THOMAS D.
1973. The combined effects of temperature and salinity on embryos and larvae of the clam *Rangia cuneata*. Mar. Biol. 21: 1 - 6
CHANLEY, PAUL
1965. Larval development of the brackish water mactrid clam, *Rangia cuneata*. Chesapeake Sci. 6 (4): 209 - 213
DARNELL, REZNEAT M.
1961. Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana. Ecology 42 (3): 553 - 558
FAIRBANKS, LAURENCE D.
1963. Biodemographic studies of the clam *Rangia cuneata* Gray. Tulane Studies Zool. 10 (1): 3 - 47
GALLAGHER, JOHN L. & HARRY W. WELLS
1969. Northern range extension and winter mortality of *Rangia cuneata*. The Nautilus 83 (1): 22 - 25
GODWIN, WALTER F.
1968. The distribution and density of the brackish water clam, *Rangia cuneata*, in the Altamaha River, Georgia. Georgia Game & Fish. Comm., Mar. Fish. Div., Contr. Ser. 5, 10 pp.
GUENTHER, W. C.
1965. Concepts of statistical inference. McGraw-Hill Book Co., New York, 353 pp.
HOPKINS, SEWELL H. & JAY D. ANDREWS
1970. *Rangia cuneata* on the east coast: thousand mile range extension or resurgence? Science 167: 868 - 869
JOHNSON, JOHN KENNETH
1971. Effects of turbidity on the rate of filtration and growth of the slipper limpet, *Crepidula fornicata* Lamarck, 1799. The Veliger 14 (3): 315 - 320; 4 text figs. (1 January 1971)
LINDNER, MILTON J.
1953. Estimation of growth rate in animals by marking experiments. U. S. Fish & Wildlife Serv., Fish. Bull. 78: 65 - 69; 3 figs.
LOOSANOFF, VICTOR LYON
1961. Effects of turbidity on some larval and adult bivalves. Proc. Gulf Carib. Fish. Inst. 14: 80 - 95
LOOSANOFF, VICTOR LYON & JAMES B. ENGLE
1947. Effect of different concentrations of micro-organisms on the feeding of oysters (*O. virginica*). Fish. Bull. U. S. Fish & Wildlife Serv. 51 (42): 31 - 57
PEDDICORD, RICHARD K.
1973. Growth condition of *Rangia cuneata* in the James River, Virginia. Ph. D. thesis, Univ. Virginia, Charlottesville, Va. 117 pp.
in preparation Salinity and substratum effects on the condition of the bivalve *Rangia cuneata*.
PFITZENMEYER, HAYES T.
1970. Project C. Benthos, pp. 26 - 38 *In*: Gross physical and biological effects of overboard spoil disposal in upper Chesapeake Bay. Univ. Maryland Natural Res. Inst. Spec. Reprt. 3
PFITZENMEYER, HAYES T. & K. G. DROBECK
1964. The occurrence of the brackish water clam, *Rangia cuneata*, in the Potomac River, Maryland. Chesapeake Sci. 5 (4): 209 - 215
PRATT, DAVID M. & DONALD A. CAMPBELL
1956. Environmental factors affecting growth in *Venus mercenaria*. Limnol. Oceanogr. 1 (1): 2 - 17
RHOADS, DONALD C. & DAVID K. YOUNG
1970. The influences of deposit-feeding organisms on sediment stability and community trophic structure. Journ. Mar. Res. 28: 150 - 178
RICHARDS, H. G.
1938. Animals of the seashore. Bruce Humphries, Boston, 29 pp.
TENORE, KENNETH R., DONALD B. HORTON & THOMAS W. DUKE
1968. Effects of bottom substrate on the brackish water bivalve *Rangia cuneata*. Chesapeake Sci. 9 (4): 238 - 248
WALFORD, LIONEL A.
1946. A new graphic method of describing the growth of animals. Biol. Bull. mar. biol. lab. Woods Hole 90: 141 - 147; 4 figs.
WASS, MARVIN L.
1972. A checklist of the biota of lower Chesapeake Bay. Va. Inst. Mar. Sci. Spec. Sci. Reprt. No. 65: 290 pp.
WELLS, HARRY WILSON
1961. The fauna of oyster beds, with special reference to the salinity factor. Ecol. Monogr. 31: 239 - 266
WOLFE, DOUGLAS A. & ERNEST N. PETTEWAY
1968. Growth of *Rangia cuneata* Gray. Chesapeake Sci. 9 (2): 99 - 102
WOODBURN, K. D.
1962. Clams and oysters in Charlotte County and vicinity. Florida State Brd. Conserv. Mar. Lab. No. 62-12: 29 pp.