1973

Estimated growth functions and size-age relationships of the hard clam, Mercenaria mercenaria, in the York River, Virginia

Joseph G. Loesch

Dexter S. Haven

Estimated Growth Functions and Size-Age Relationships of the Hard Clam, *Mercenaria mercenaria*, in the York River, Virginia[1]

BY

JOSEPH G. LOESCH AND DEXTER S. HAVEN

Virginia Institute of Marine Science, Gloucester Point, Virginia 23062

(3 Text figures)

INTRODUCTION

A STUDY OF THE HARD CLAM[2], *Mercenaria mercenaria* (Linnaeus, 1758) resources of Virginia is currently being conducted. One important aspect, their growth in this region, has been limited to the study of small juveniles (HAVEN & ANDREWS, 1957). Our objectives were to demonstrate that *M. mercenaria* growth functions could readily be derived and statistically contrasted, and, subsequently, the age-size relationship could be estimated.

Growth functions in the present study were derived by the Walford transformation (WALFORD, 1946) .The method has been widely used in finfish growth studies but has been applied only to a limited extent in bivalve growth estimates. ANSELL (1968) applied the method to hard clams when he adjusted existing hard clam data from numerous sources to a standard size. His use of the method is dubious, however, since many of the data were from studies in which very limited size ranges were available or chosen. Some of the possible complications arising from the use of restricted size ranges and age groups have been discussed by KOHLER (1963), HANCOCK (1965) and KNIGHT (1968). In addition, to obtain a measure of the instantaneous rate of growth of Virginia hard clams, ANSELL (1968) transformed the data of HAVEN & ANDREWS (1957), and also the North Carolina hard clam data of CHESTNUT, FAHY & PORTER (1957), by using the findings of MENZEL (1963) for similar Milford stock grown in Alligator Harbor, Florida. The validity of the transformation rests upon the assumption of equality of growth rates among sub-groups of a common stock grown in different geographical regions.

This report does not review the extensive literature on hard clam growth. However, past investigators, in general, were concerned with comparative growth rates over relatively short periods of time. A selected size group was generally used, and, moreover, some investigators confined their experimental units to trays or sediment boxes for the duration of their experiments. Under the latter condition, growth rate estimates for wild populations in natural substrates were precluded even though the trays were filled with substrate common to the area.

HASKIN (1949, 1952 and 1954) graphically presented curves for the first 8 to 10 years of *Mercenaria mercenaria* growth derived from average weight increments to arbitrary size intervals. While one might concede that large estimated differences among locations or years were real, his presentation did not allow for statistical analysis of lesser differences.

MATERIALS AND METHODS

The annual increment to shell length, where length is defined as the longest linear dimension, was used to estimate growth.

Hard clams from the smallest size practical for marking through the larger sizes (approximately 30 to 90mm) were measured, code-marked, and planted in the substrate. Clams were marked initially with a Mark-Tex-Tech-Pen and enamel but an indelible Felt Riter pen was later employed. Code marks were applied more readily with the latter pen, dried faster, and have persisted up-

[1] Contribution No. 497 from the Virginia Institute of Marine Science, Gloucester Point, Virginia 23062

[2] The term 'hard clam' is used as a synonym for *Mercenaria mercenaria* in this paper

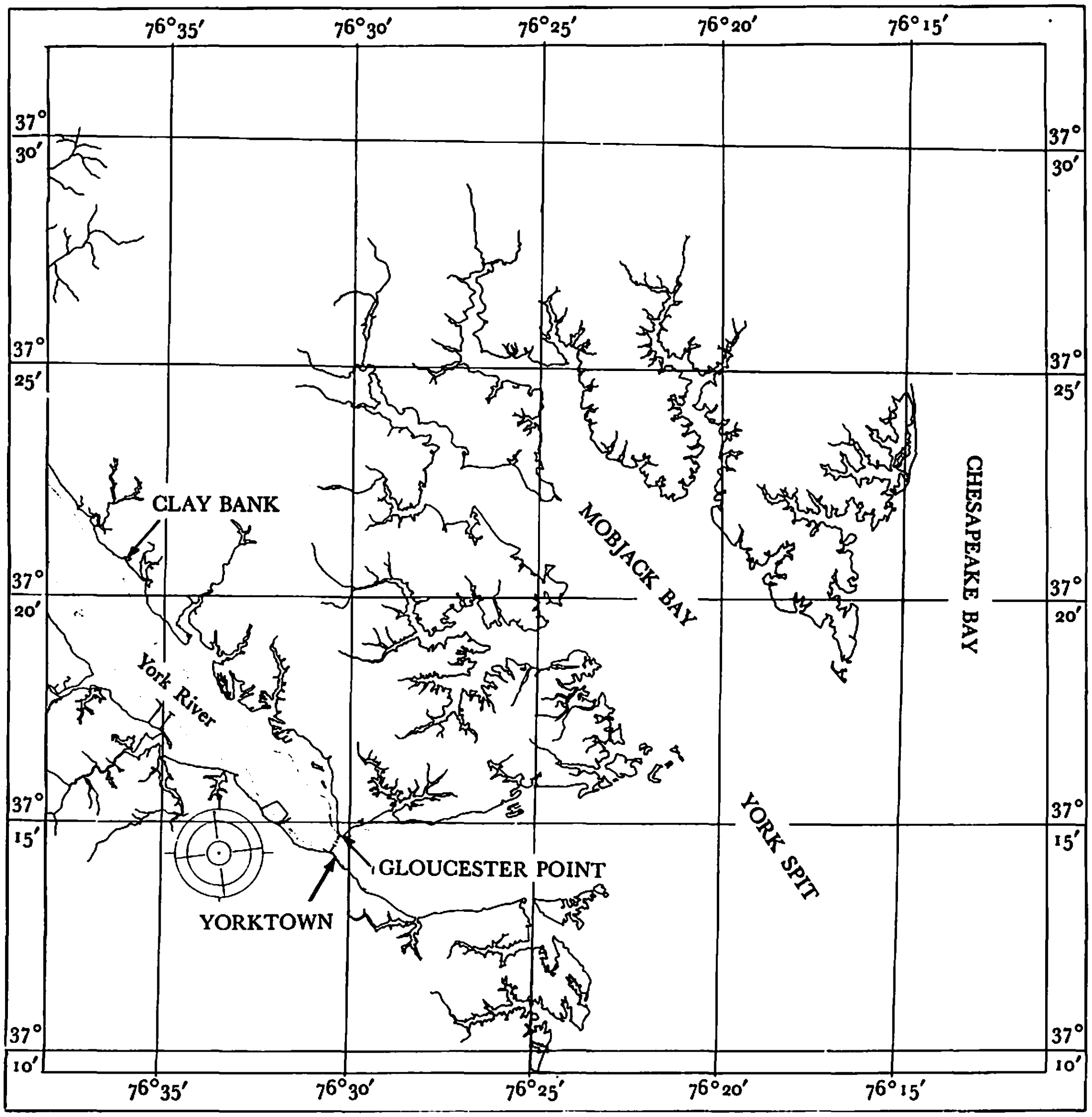

Figure 1

Locations of the experimental plots (Gloucester Point and Yorktown), source of the hard clams (York Spit) and the limit of their upriver distribution (Clay Bank)

wards of three years. An experimental plot was established in the York River adjacent to the Virginia Institute of Marine Science laboratory at Gloucester Point in mid-September, 1967 and another plot was established near the opposite shore at Yorktown, Virginia in mid-November, 1968 (Figure 1). The two groups were formed from native stock obtained from the York Spit area at the mouth of the York River. SCUBA was used for the placement and recovery of the hard clams. After recovery at approximately yearly intervals, the hard clams were measured to the nearest 0.1 mm and replanted. Salinity on the Gloucester Point side seasonally ranges from about 19 to 20‰; on the opposite side salinity is generally 1 to 2‰ lower. A sand-mud substrate with scattered shell and a depth of about 7 feet (MLW) are common to both plots.

WALFORD (1946) graphically estimated growth parameters from linear expressions obtained by plotting the average length of known age groups against the average length of the next youngest age group. His coordinates, therefore, were derived from different groups. In the present study, coordinates were determined for each individual clam and yearly growth expressions derived by the method of least squares. MANSER & TAYLOR (1947) first employed individual measurements to graphically estimate the rate of growth of English sole, *Parophrys vetulus* Girard, 1854, while LINDER (1953) utilized growth increments in the shrimp, *Penaeus setiferus* (Linnaeus, 1767), to demonstrate the applicability of least squares.

The derived expressions have the general linear form:

$$Y = a + bX$$

but following the more definite notation of RICKER (1958) this becomes:

$$l_{t+1} = l_\infty (1-k) + kl_t$$

Here, $X = l_t$, the length at time t; $Y = l_{t+1}$, the length at the end of a constant time interval (one year in this study); $a = l_\infty(1-k)$, the Y-intercept from which l_∞, the **average** maximum or asymptotic size, can be estimated, and $b = k$, the slope of the Walford regression line. Asymptotic size may also be graphically estimated from the intersection of the regression line and a 45° line; further, it is the "nature" of k that the smaller its value, the greater the rate at which l_∞ is approached (cf. WALFORD, 1946).

Growth functions are often expressed in terms of the growth equation presented by VON BERTALANFFY (1938), in which asymptotic size is but one parameter. The asymptotic size derived by the Walford line is generally a preliminary estimate and may be modified (cf. BEVERTON, 1954; RICKER, 1958). Modification requires an independent estimate of the length-age relationship, as for example, that obtained from back calculations of growth obtained from fish scales. In the present situation with hard clams, lacking the independent estimate, the Walford regression line was employed without modification.

The Walford transformation can be used to estimate growth independently of age. Subsequently, the average size of at least one age group must be known in order to relate size to age. To estimate this relationship two methods were employed. First, young clams spawned at this laboratory were planted in sediment trays and, in turn, the trays were placed in the York River substrate adjacent to the laboratory. These clams were too small (approximately 5 mm) to be marked individually, therefore, the average size of clams in replicate trays was recorded at yearly intervals for three years. The second method was based upon observations at this laboratory, and previously reported by LOOSANOFF, DAVIS & CHANLEY (1966), that hard clams at age zero, the time when the larvae settle to become part of the benthic community, are about 210 µm in length. The value was substituted into the derived growth function to obtain an estimate of length at age one, age one size was then substituted into the equation to estimate size at age two, and so on. It was assumed that clam spat growth is post-inflection-point with respect to an asymmetrical sigmoidal growth curve.

Regression lines were analyzed by covariance and significance is reported in terms of the probability (P) due to chance of obtaining a deviation $\geqslant$ that observed.

RESULTS AND DISCUSSION

Estimated growth functions are presented in Table 1. Analysis of covariance indicated significant difference among the 5 growth rates ($P < 0.001$). It is obvious by inspection that the 1968-69 growth expressions for clams in both locations are similar, and superior to the others. When these data are removed no significant differences could be ascertained among the remaining 3 expressions ($P > 0.75$ for both the estimated growth rates and the adjusted means). Similarly, no significant difference could be detected between the two growth expressions for the 1968-69 growth year ($P > 0.05$). Thus, it appears that growth in the observed yearly intervals did not vary between the two locations, but environmental conditions for growth were more favorable during the 1968-69 period. Estimates of asymptotic size ranged from 79 to 82 mm. This variation may be sampling error because it is not associated with a given plot location or growth year.

Table 1

Estimated Growth Equations for Hard Clams in Two York River Experimental Plots

Plot Location	Growth Year	Number of clams	Growth Functions	Asymptotic Size (mm)
Gloucester Point	1967-68	187	$Y = 12.1 + 0.848X$	80
	1968-69	117	$Y = 19.2 + 0.762X$	81
	1969-70	302	$Y = 12.6 + 0.846X$	82
Yorktown	1968-69	156	$Y = 18.2 + 0.770X$	79
	1969-70	144	$Y = 12.1 + 0.852X$	82

The separate growth functions discussed above were suitable for comparing growth between experimental plots and among years. An estimate of the "average" growth function derived from the pooled data of the growth years common to both plots is shown in Figure 2.

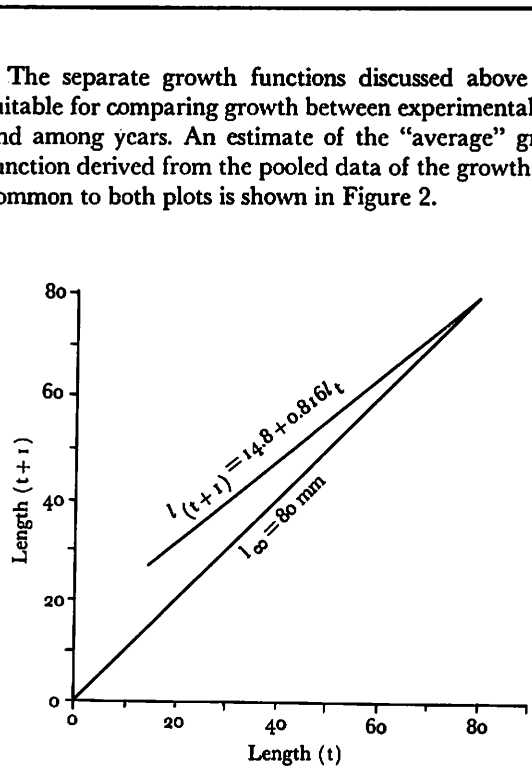

Figure 2

Estimated growth equation derived from the pooled data for the 1968-69 and 1969-70 growth years

The age-length relationship was determined by substituting age zero length, 0.21 mm, into the common growth function (Table 2). The estimate of age one size obtained from clams in sediment trays was not used because of suspected stunting. Average one-year-old sizes attained in 5 trays used over 3 years ranged from 7.8 to 11.7 mm with an overall average of 8.7 mm. This value is only 58% of the predicted one-year-old mean size of 15 mm derived from the growth function. Growth data of two-year-old clams in trays were ambiguous; clams in 3 trays averaged 25.9 mm when the densities were only 12, 15 and 29 clams per tray; however, 200 clams in a fourth tray exhibited no average length increment between the first and second years. Recent growth data (unpublished) of young hard clams in a gravel substrate at Gloucester Point also indicate that the 8.7 mm is an unrealistically low estimate of one-year-old length. Menzel (personal communication) noted retarded growth when young clams were retained in sediment filled trays and transplanted the clams to a natural bottom when they were about 25 mm in length (MENZEL, 1963).

An asymptotic size of 80 mm was estimated from the pooled data. This relatively low value may reflect the limited number of observational years, the use of age zero length, or the inability to adjust the asymptotic estimate. Sampling of hard clams in relatively shoal depths similar to the experimental plots (about 5 to 10 feeet MLW) in the lower-and-upper part of their York River range, however, indicated that a small maximum size is attained because the clams tend to blunt. Blunting is defined as a form of stunting in which the free edges of the valves, the ventral margin, thicken and recurve inward. Observations of marked blunted hard clams indicated that growth in length ceases and in some individuals length may decrease; SALOMAN & TAYLOR (1969) reported this phenomenon for *Mercenaria campechiensis* (Gmelin, 1791). Blunted clams comprised 37.9% of 1 016 clams in 7 samples taken between Yorktown and Clay Bank (Figure 1). In contrast, in 2 shoal-water samples each at Poquoson and Hampton Flats outside the mouth of the York River only 4 of 502 clams (0.8%) were blunted. There were intergrades between sharp-edge and blunt-edge clams but only those having the entire ventral margin affected were designated as blunt clams and the above percentages are minimal. The potential stunting effects of a limited food supply and unfavorable conditions of salinity, temperature, oxygen, turbidity and other factors upon aquatic organisms have been reviewed by HALLAM (1965). Environmental factors were not monitored in the present study but relatively low salinity in these shoal water experimental sites is suspect as a major limiting growth factor.

Longevity of hard clams is not definitely known. Estimates based on counts of growth rings range from 25 years (KERSWILL, 1941) to as high as possibly 40 years (HOPKINS, 1930). In general, determining age from growth rings is unreliable, particularly in older hard clams, when rings produced by environmental and physiological changes are not recognized. This has been confirmed by microscopic investigation of transverse shell sections by PANNELLA & MACCLINTOCK (1968) and RHOADS & PANNELLA (1970).

The asymptotic size based on the present estimated growth rate would not be reached until age 22 (Table 2). This estimate of late attainment of the average maximum size is probably the result of an antagonistic interaction between inherent growth potential and the tendency to blunt. Growth ceases, for all practical purposes, at about age 14 or 15; after this the predicted annual increments are less than 1 mm. Of more importance is the estimate that the young hard clams in this area would not attain Littleneck size until age 4 and Cherrystone size until age 8 (based on local market size definitions). At these ages

Table 2

Estimated Age - Length Relationship for Hard Clams in the Gloucester Point and Yorktown Experimental Plots, derived from the pooled data of the 1968-69 and 1969-70 growth years

Age (Years)	Length (mm)	Age (Years)	Length (mm)	Age (Years)	Length (mm)
1	15	9	68	16	77
2	27	10	70	17	78
3	37	11	72	18	78
4	45	12	73	19	79
5	51	13	75	20	79
6	57	14	76	21	79
7	61	15	77	22	80
8	65				

the hard clams attain about 56 and 81% of their asymptotic size, respectively.

Haven & Andrews (1957) reported that 25 young *Mercenaria mercenaria* held in a suspended sediment tray for 2 years, and others of this group placed in the natural substrate for the second year, attained average lengths of 37mm and 33mm, respectively. These observed lengths exceed the estimated length of 27mm for two-year-old hard clams in the present study. The initial average length of their young hard clams, however, was 11mm, which is 52 times greater than the initial length (0.21mm) substituted into this study's derived growth function. The 11mm length is 73% of the predicted length increment from age zero to age one. A more realistic comparison, therefore, is to contrast the lengths observed by Haven & Andrews (1957) with the predicted length derived from the cumulative growth curve (Figure 3) for approximately a $2\frac{3}{4}$ year old clam in the present study. The latter length is approximately 34mm, and in agreement with the length observed by Haven & Andrews (*op. cit.*).

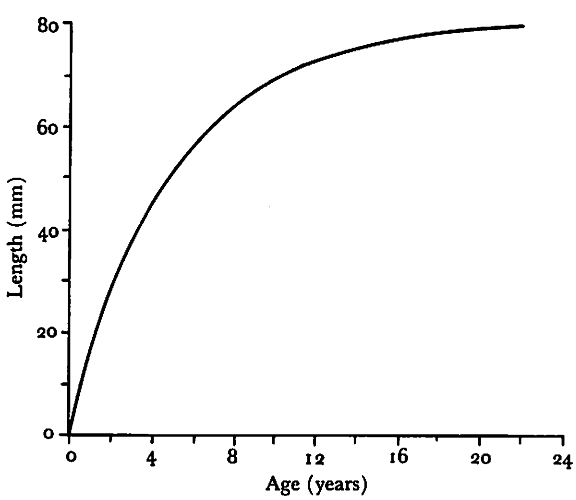

Figure 3

Cumulative growth curve

In summary, the Walford transformation can readily be applied to statistically contrast relative growth among areas and years for hard clams. Derived estimates of the age-size relationship appear reasonable but should be substantiated by microscopic studies of transverse shell sections or by following the growth of young individuals of known age through several growth years.

ACKNOWLEDGMENTS

The authors wish to acknowledge the efforts of Mr. James P. Whitcomb of the Virginia Institute of Marine Science who was responsible for the yearly placement and retrieval of the hard clams.

Literature Cited

Ansell, Alan David
1968. The rate of growth of the hard clam *Mercenaria mercenaria* (L.) throughout the geographical range. Journ. Cons. perm. int. explor. Mer 31: 364 - 409; 15 figs.; 3 tables

von Bertalanffy, Ludwig
1938. A quantitative theory of organic growth. Human Biol. 10 (2): 181 - 213; 5 figs.; 10 tables

Beverton, R. J. H.
1954. Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. U. S. Fish. Lab., Beaufort, North Carolina, Misc. Contr. no. 2: 159 pp.; 24 figs.; 7 tables

Chestnut, Alphonse F., William E. Fahy & Hugh J. Porter
1957. Growth of young *Venus campechiensis* and their hybrids. Proc. Nat. Shellfish. Assoc. 47: 50 - 56; 1 fig.; 2 tables

Hallam, A.
1965. Environmental causes of stunting in living and fossil marine benthonic invertebrates. Palaeontology 8 (1): 132 - 155; 1 table

Hancock, D. A.
1965. Graphic estimation of growth parameters. Journ. Cons. perm. int. explor. Mer 29: 340 - 351; 4 figs.; 5 tables

Haskin, Harold H.
1949. Growth studies on the quahog, *Venus mercenaria*. Proc. Nat. Shellfish. Assoc. 39: 67 - 75; 5 figs.
1952. Further growth studies on the quahog, *Venus mercenaria*. Proc. Nat. Shellfish. Assoc. 42: 181 - 187; 4 figs.; 1 table
1954. Age determination in molluscs. Trans. New York Acad. Sci. (2) 16: 300 - 304; 7 figs.

Haven, Dexter & Jay D. Andrews
1957. Survival and growth of *Venus mercenaria, Venus campechiensis* and their hybrids in suspended trays and on natural bottoms. Proc. Nat. Shellfish. Assoc. 47: 43 - 49; 2 figs.; 2 tables

Hopkins, Hoyt S.
1930. Age differences and the respiration in muscle tissues of mollusks. Journ. Exp. Zool. 56 (2): 209 - 239; 2 figs.; 1 plt.; 7 tables

Kerswill, Charles James
1941. Some environmental factors limiting growth and distribution of the quahog, *Venus mercenaria* L. Ph. D. thesis, Univ. Toronto; 104 pp.; 18 figs.; 5 tables; 2 appendices

Knight, William
1968. Asymptotic growth: An example of nonsense disguised as mathematics. Journ. Fish. Res. Brd. Canada 25 (6): 1303 - 1307; 3 figs.

Kohler, A. Carl
1963. Use of tagging data in subarea 4 cod growth investigation. Spec. pub. I. C. N. F. no. 4: 66 - 70; 3 figs.; 1 table

LINDER, 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, HARRY CARL DAVIS & PAUL E. CHANLEY
1966. Dimensions and shapes of larvae of some marine bivalve mollusks. Malacologia 4 (2): 351 - 435; 61 text figs. (31 August 1966)

MANZER, JAMES IVAN & FREDERICK HENRY C. TAYLOR
1947. The rate of growth of lemon sole in the Strait of Georgia. Fish. Res. Brd. Canada, Pacific Progr. Reprt. no. 72: 24 - 27; 1 fig.; 1 table

MENZEL, R. WINSTON
1963. Seasonal growth of the northern quahog *Mercenaria mercenaria* and the southern quahog *M. campechiensis* in Alligator Harbor, Florida. Proc. Nat. Shellfish. Assoc. 52: 37 - 46; 3 figs.; 2 tables

PANNELLA, GIORGIO & COPELAND MACCLINTOCK
1968. Biological and environmental rhythms reflected in molluscan shell growth. Mem. Journ. Paleontol. 42: 64 - 79; 9 plts.

RHOADS, DONALD C. & GIORGIO PANNELLA
1970. The use of molluscan shell growth patterns in ecology and paleoecology. Lethaia 3: 143 - 161; 9 figs.; 3 tables

RICHER, WILLIAM EDWIN
1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Brd. Canada, Bull. no. 119: 300 pp.

SALOMAN, CARL H. & JOHN L. TAYLOR
1969. Age and growth of large southern quahogs from a Florida estuary. Proc. Nat. Shellfish. Assoc. 59: 46 - 51; 9 figs.; 5 tables

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.