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Growth Rates of the Freshwater Mussel, Anodonta imbecillis Say 1829, in Five West Virginia Wildlife Station Ponds

JEFF L. HARMON AND JAMES E. JOY
Department of Biological Sciences, Marshall University, Huntington, West Virginia 25701

ABSTRACT.—Growth rates of a thin-shelled, freshwater bivalve mollusc, *Anodonta imbecillis* Say 1829, were studied for 3 yr (May 1984 through June 1987). A total of 487 *A. imbecillis* individuals were collected from five ponds at the McClintic Wildlife Station (Mason County, West Virginia). Mussels were measured for initial shell length, numbered and replaced in their respective ponds. Summer growth was determined from the recovery of 139 individuals, and annual growth was calculated for 81 recovered mussels. Increase in shell length was inversely correlated with initial shell length (r-values of −0.827 and −0.851 for summer and annual increases, respectively). A 10-yr length-age growth curve, based on annual data, was calculated for this mussel species. Growth is rapid over the 1st 4 yr; after the 4th yr, increases in shell length are slight. One of the study ponds (Pond 12) was contaminated with waterborne nitroaromatic residues. Growth of mussels from this pond was noticeably lower than that of mussels in noncontaminated ponds.

INTRODUCTION

Studies on the growth rates of native freshwater bivalve molluscs can be traced to early part of this century. In general, it was established that shell growth slows \ increasing age, and thin-shelled species grow more rapidly than thick-shelled ones (Lef and Curtis, 1912; Grier, 1922; Howard, 1922; Isley, 1913, 1931; Chamberlain, 19 Most of these reports suffered from small sample sizes. Isley (1913), whose work w notable exception, recovered nearly 100 individuals from an original sample of 900 ma mussels placed in several locations in Oklahoma streams. He found that growth rates v highly variable for individuals of a single species even in the same stream, and obse that juveniles grew much faster than adults. More recently, inverse relationships betw initial size and growth have been documented for the introduced Asian clam, *Corbi fluminea* (*see* Joy, 1985, for citations).

Early studies of unionid growth were undertaken in response to economic quest concerning the pearl button industry. Extensive study of the Asian clam has been du its importance as a biofouling organism (Mattice, 1979). Another reason for studying grc in bivalves is their potential use in biological monitoring of streams, lakes and coastal wa (Bedford *et al.*, 1968; Leard *et al.*, 1980; Johnson and Hartley, 1981). However, be investigators can measure the effects of pollutants upon growth of mussels they must possess some knowledge of "normal" or expected growth rates. The primary goal of study was to establish baseline data on growth rates of *Anodonta imbecillis* Say 1829, a t shelled, freshwater bivalve mollusc, observed in situ.

MATERIALS AND METHODS

This research was carried out at the Clifton F. McClintic Wildlife Station in Ma County, West Virginia (USGS Topographic Map; Cheshire, Ohio Quadrangle). The 2 acre station is owned by the state and managed by the West Virginia Department of Nat Resources. The station has 35 ponds, constructed in the early 1950s, six of which, po 6, 12, 14, 15, 27 and 30, harbor populations of *Anodonta imbecillis*, the only endemic uni

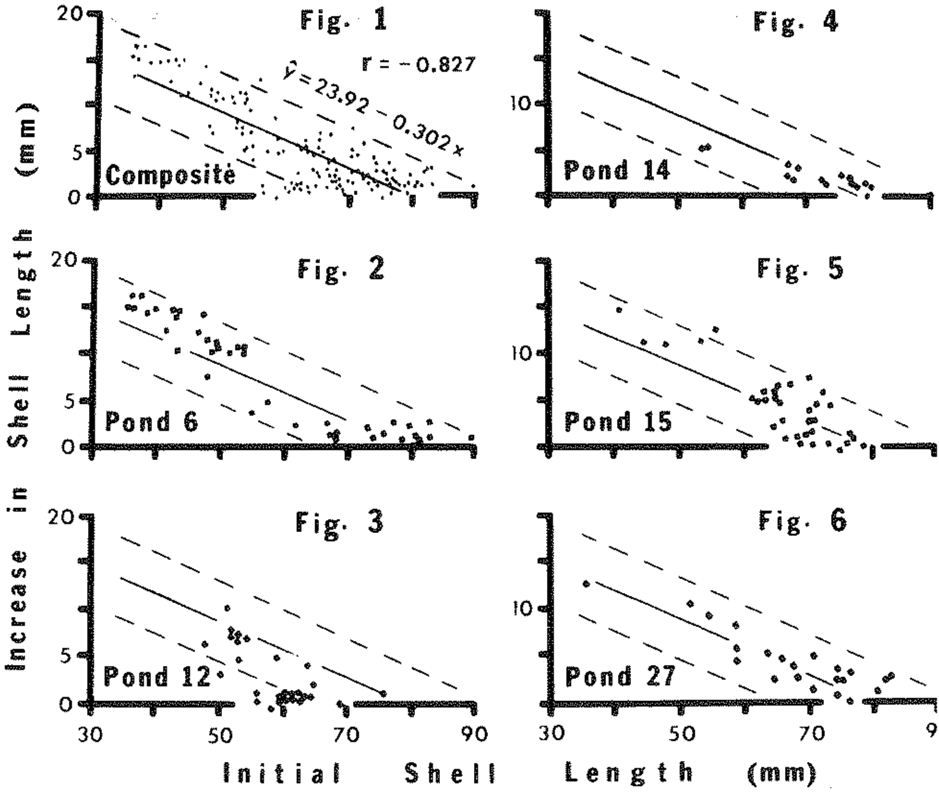
TABLE 1.—Capture/recapture schedule for *Anodonta imbecillis* at five McClintic study ponds. derlined numbers indicate number of individuals in initial capture marked for release. Number parentheses ( ) indicate number of marked individuals recovered after summer growth period. Num in brackets [ ] indicate number of marked individuals recovered after a 1-yr growth period. Ac date (month/day) of collection, or recovery, appears below numbers

Pond	1984 Spring	1984 Fall	1985 Spring	1985 Fall	1986 Spring	1986 Fall	1987 Spring	Total Marked	Recapturec Sum	Recapturec Ann
6	50 5/24	(11) 9/14		[1] 9/28	60 5/18	(29) 9/15	[12] 5/18	110	40	18
							[5] 5/18			
12			60 6/3	(12) 9/22	[5] 6/1			120	27	18
					[10] 6/1		[1] 6/2			
					60 6/1	(15) 9/28	[2] 6/2			
14					43 5/6	(15) 9/6	[6] 5/26	43	15	8
							[2] 5/26			
15			60 6/2	(21) 9/22		[13] 9/5		89	35	22
					29 5/6	(14) 9/5	[5] 5/26			
							[4] 5/26			
27			60 6/9	(19) 9/28	[8] 6/7			125	22	15
					[7] 6/7					
					65 5/2	(3) 8/30				
							Totals	487	139	81

species. Ponds containing mussels were relatively small (0.75–1.25 ha) and shallow (m imum depth 2.0 m). Ponds 6, 12, 14 and 15 had soft silty substrates with an abundanc rooted aquatic vegetation, primarily "coon-tail" (*Ceratophyllum demersum*). Ponds 27 30 had similar substrates, but were virtually devoid of coon-tail. The water of Pond 12 contaminated with nitroaromatic compounds (two isomers of dinitrotoluene, and trini benzene) (Keirn *et al.*, 1986).

Data collection.—Populations of *Anodonta imbecillis* in five study ponds were exami for summer and annual growth rates by means of a capture, mark, release and recap procedure. Pond 30 was omitted from this study because none of the marked individ were recovered. Mussels were initially marked in May or June (April on one occasion 1984, 1985 and 1986 (Table 1). Attempts were made to capture mussels with a wide ra in shell lengths. Captured individuals were cleaned and dried with soft toweling. They v then measured for total length (the anterior–posterior axis) to the nearest 0.1 mm u vernier calipers.

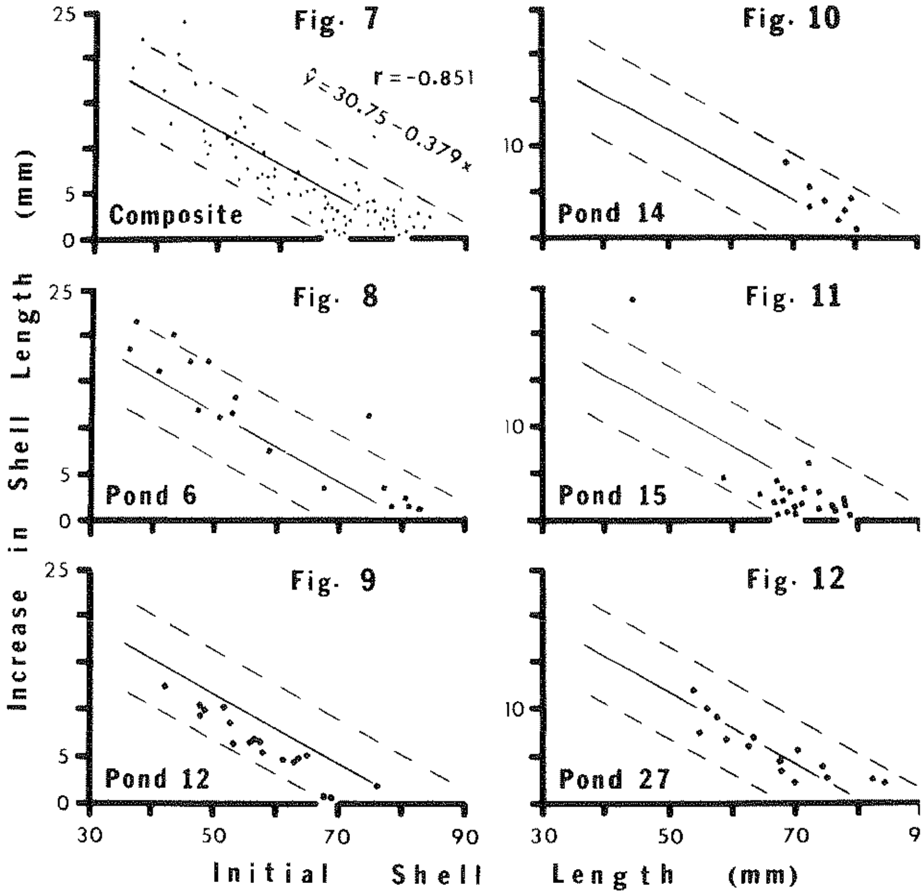
Each mussel was sequentially numbered for identification by scratching a number



FIGS. 1–6.—(1) Summer growth composite baseline regression curve (solid line) calculated for she length increases of 139 *Anodonta imbecillis* individuals. Dashed lines paralleling regression cur represent 90% prediction bands. Each point represents a mussel recovered after approximately 12 days growth during the summer of 1984, 1985 or 1986. Some points may lie directly over other point (2–6) Summer shell length increases of *Anodonta imbecillis* individuals from five study ponds supe imposed against summer growth composite baseline regression curve and 90% prediction bands. Leger same as for Figure 1

the shell with a #60 scalpel blade. Care was taken not to penetrate to the underlying mantl Numbered individuals were released in the pond from which they were taken. Approximate 120 days later, a recapture effort was made to assess summer growth. Recaptured individua were cleaned, dried, measured and returned to their respective ponds. This process w repeated approximately 1 yr after the initial marking date. Thus growth data were obtain for periods of 4 summer mo and a full calendar year (Table 1).

Data analysis.—To address the problem of assessing growth rates for mussels with differe initial shell lengths, we developed a "composite baseline" linear regression curve. This curv plotting initial shell length (x-axis) vs. increase in shell length (y-axis), was calculate using the least squares method, for all 139 mussels recovered from the five ponds duri the summers of 1984, 1985 and 1986 (Fig. 1). The rationale of this approach was th variations in "good" growth summers (or "good" growth ponds) would be evened out l "poorer" summers (or ponds) and thus yield a regression line with a more representati predictive value than one developed from growth data based upon a single summer, or pon



FIGS. 7–12.—(7) Annual growth composite baseline regression curve (solid line) calculated for s length increases of 81 *Anodonta imbecillis* individuals. Dashed lines paralleling regression curve : resent 90% prediction bands. Each point represents a mussel recovered after approximately 1 growth during 1984, 1985 or 1986. (8–12) Annual shell length increases of *Anodonta imbe* individuals from five study ponds superimposed against annual growth composite baseline regres curve and 90% prediction bands. Legend same as for Figure 7

We carried this baseline regression concept one step further by adding 90% prediction ba: after the procedure outlined by Ott (1984). Thus one could compare growth rates of ; length class in one pond to the same class in any other pond (Figs. 2–6).

A second baseline regression curve, with accompanying prediction bands, was calcula for all 81 mussels recovered after a one year growth period (Fig. 7). In this case, comparis of growth in different length classes of different ponds could be made on an annual rat than summer basis (Figs. 8–12).

RESULTS

Summer growth data were obtained for 139 individuals recovered from five study po (Table 1; Figs. 1–6). Only three—one from Pond 6 (Figs. 1, 2) and two from Pond

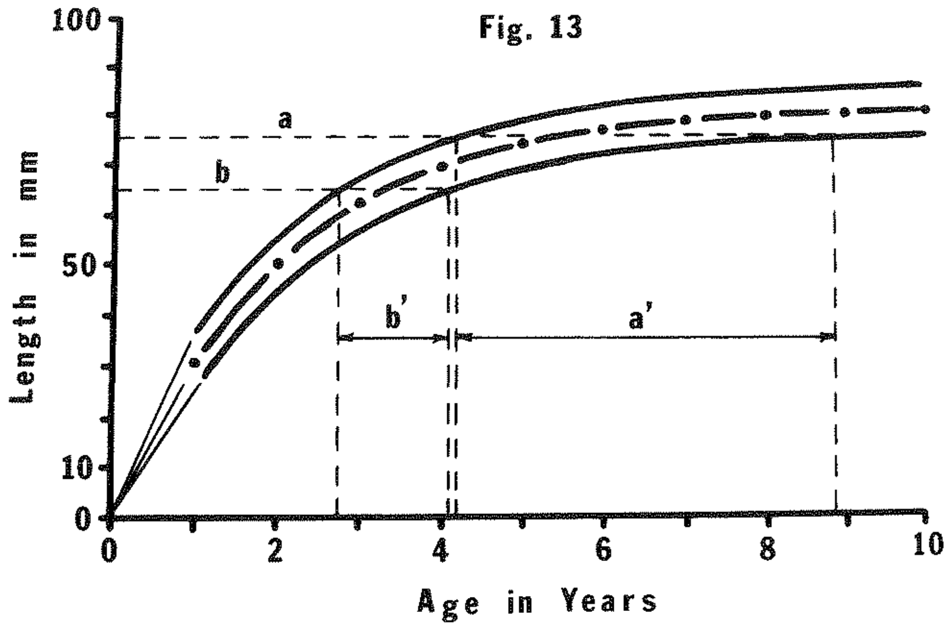


FIG. 13.—Length-age growth curve, with accompanying 90% prediction bands, derived from annu: growth data for 81 *Anodonta imbecillis* individuals. Closed circles indicate one yr increments. Dashe line "a" bisects upper and lower prediction limits to show possible age range (a') for an individu: with a shell length of 75 mm. Dashed line "b" used in the same manner to show possible age ran; (b') for an individual with a shell length of 65 mm

(Figs. 1, 5)—grew at rates exceeding the expected summer value, *i.e.*, with a growth ra falling above the 90% prediction band. Eleven individuals, however, failed to achieve tl minimum expected summer growth rate, *i.e.*, falling below the 90% prediction band (Fig 1, 3).

Annual growth data were obtained for 81 individuals recovered from five study pon (Table 1; Figs. 7–12). Only five—four from Pond 6 (Figs. 7, 8), and one from Pond 1 (Figs. 7, 11)—exceeded the expected value. None fell below the minimum expected lev (Fig. 7). A length-age growth curve derived from the data for these 81 individuals predic the length of members of this species over a 10-yr span (Fig. 13). In addition, 90% predictic bands transform this curve from a standard length-age curve into a very useful comparati tool.

DISCUSSION

The 11 individuals failing to achieve minimum expected summer growth were all locat in Pond 12 (Figs. 1, 3), the study pond with a documented presence of waterborne nitroa omatics. These data suggest an association between lowered growth rates and the presen of nitroaromatic residues.

No individuals fell below the minimum expected annual growth rates (Fig. 7), althou; Pond 12 mussels were unusual in that increases in growth of all but one recovered individu fell below the baseline regression curve (Fig. 9). Conversely, all recovered individuals fro Pond 14 exhibited growth rates above the regression curve (Fig. 10).

The composite regression equation for annual growth was used to establish a length-ε relationship (Fig. 13). To accomplish this, the length of at least one age group had to known. Hudson and Isom (1984) indicated that the length of a 1–2 day old mature *Anodo imbecillis* glochidium is approximately 0.28 mm. By substituting 0.28 (length in mm at ε 0, or x_0) for x in the annual regression equation, a value for $\hat{y}_1$, the mean amount of grov expected for the 1st yr, was derived. This 1st yr growth ($\hat{y}_1$), added to initial length (x yields a total mean length expected at 1 yr of age (x_1). Substituting the value of 0.28 n (x_0) for x in the prediction band equation of Ott (1984) allows for calculation of 9 prediction limits about the $\hat{y}_1$ estimate. Mean length at age 1 (x_1) was in turn used estimate growth for the 2nd yr ($\hat{y}_2$). The sum of x_1 plus $\hat{y}_2$ yields x_2, mean length at age Prediction limits around $\hat{y}_2$ are then derived by substituting x_1 for x in Ott's prediction ba equation. The value of x_2 is used to estimate $\hat{y}_3$ and x_3, and so on for subsequent yea That maximum shell lengths observed in the field rarely exceeded 85.9 mm (the maxim length of 81.1 mm as predicted by the regression curve plus the upper 90% prediction li of 4.8 mm) attests to the validity of the estimated growth curve. This procedure predi that increases in growth after 4 yr are statistically insignificant, and strengthens the i that shell length-to-age correlates are unreliable for old, large mussels. Actual longevity *Anodonta imbecillis* is predicted by this growth curve to be at least 4 yr.

We believe our approach to the analysis of growth in bivalve molluscs offers a stand for comparing shell growth rates and maximum length potential of this mussel spec throughout its geographic range. Future investigators should be equally successful in scribing "normal" growth patterns for other bivalve species as well.

LITERATURE CITED

BEDFORD, J. W., E. W. ROELOFS AND M. J. ZABIK. 1968. The freshwater mussel as a biologi monitor of pesticide concentrations in a lotic environment. *Limnol. Oceanogr.*, **13**:118–126

CHAMBERLAIN, T. K. 1931. Annual growth of fresh-water mussels. *Bull. U.S. Bur. Fish.*, **46**:71 739.

GRIER, N. M. 1922. Observation on the rate of growth of the shell of lake dwelling fresh wa mussels. *Am. Midl. Nat.*, **13**:129–148.

HOWARD, A. D. 1922. Experiments in the culture of freshwater mussels. *Bull. U.S. Bur. Fish.*, 63–90.

HUDSON, R. G. AND B. G. ISOM. 1984. Rearing juveniles of the freshwater mussels (Unionidae) a laboratory setting. *Nautilus*, **98**:129–135.

ISLEY, F. B. 1913. Experimental study of the growth and migration of fresh-water mussels. A III Rep. U.S. Comm. of Fish., 1–27.

———. 1931. A fifteen year growth record in fresh-water mussels. *Ecology*, **12**:616–619.

JOHNSON, J. B. AND D. M. HARTLEY. 1981. Bivalves as monitors for persistent pollutants in mar and freshwater environments, p. 184–198. *In:* S. M. Somani and F. L. Cavender (ed Environmental toxicology principles and policies. Charles C Thomas, Springfield, Illinoi

JOY, J. E. 1985. A 40-week study on the growth of the Asian Clam, *Corbicula fluminea* (Müll in the Kanawha River, West Virginia. *Nautilus*, **99**:110–116.

KEIRN, M. A., C. D. HENDRY, D. L. KRAUS, W. PANDORF, C. F. POPPELL, W. A. TUCKER AND J. POWELL. 1986. West Virginia Ordnance Works Remedial Investigation, Final Rep AOOA. U.S. Army Toxic and Hazardous Materials Agency Contract No. DAAK11-83- 0007. Aberdeen Proving Ground, Maryland. 1696 p.

LEARD, R. L., B. J. GRANTHAM AND G. F. PESSONEY. 1980. Use of selected freshwater bivalves monitoring organo-chlorine pesticide residues in major Mississippi stream systems, 197 1973. *Pestic. Monit. J.*, **14**:47–52.

LEFEVRE, G. AND W. C. CURTIS. 1912. Studies on the reproduction and artificial propagation freshwater mussels. *Bull. U.S. Bur. Fish.*, **30**:105–201.

MATTICE, J. S. 1979. Interactions of *Corbicula* sp. with power plants, p. 119–138. *In:* J. C. Brit

(ed.). Proceedings, First International *Corbicula* Symposium. Texas Christian Univers Research Foundation, Fort Worth, Texas.
OTT, L. 1984. An introduction to statistical methods and data analysis. PWS Publishers. Bost Mass. 775 p.

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