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POPULATION STRUCTURE OF THE ARKSHELL CLAMS, *NOETIA PONDEROSA* AND *ANADARA OVALIS*, IN THE OCEANSIDE LAGOONS AND TIDAL CREEKS OF VIRGINIA AND IMPLICATIONS FOR FISHERIES MANAGEMENT

by

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I. ABSTRACT

Two species of arkshell (blood) clams, *Noetia ponderosa* and *Anadara ovalis*, have recently been targeted by watermen on the Eastern Shore of Virginia for sale to east coast markets. Until 1991 fishermen caught both species in conjunction with the harvest of oysters and hard clams and considered them of little value. Very little is known about either species, and preliminary data from our pilot study in 1993 indicated that blood clams were being over-fished. In September, 1994 we conducted a survey in the oceanside lagoon system along the Eastern Shore and collected data on density, abundance, habitat preference, and mortality rates for both species of blood clams, as well as some ancillary data on the hard clam, *Mercenaria mercenaria*. The study provides baseline data for establishing management practices and regulations for the bloodclam fishery. Mean clam density for all species in the study area was 1.26 clams per m^2, with the majority of clams occurring in shell/mud substrate. The total estimated abundance in the study area was about 15.2 million *Noetia*, 9.6 million *Anadara*, and 62.2 million *Mercenaria*. Of the clams taken in commercial catches on the oceanside of the Eastern Shore, *Mercenaria* constitutes approximately 84%, *Noetia* 14.7%, and *Anadara* 1.4%. Length-frequency data from both the field survey and commercial catches indicate that blood clam stocks are being depleted. We also studied relationships between size and age of blood clams using the acetate peel method. These data, along with growth studies, show that *Anadara* grows about twice as fast as *Noetia* and that market-size *Noetia* (approximately 56 mm in height) may be 8 years old or more. We also

present information on mortality rates and morphometric relationships for both species of blood clams, and recommendations for maintaining and enhancing the fishery.

II. EXECUTIVE SUMMARY

We conducted this study of *Noetia ponderosa* and *Anadara ovalis* in the oceanside lagoon system of the Eastern Shore of Virginia because very little is known about these two species, which now constitute a small but growing commercial fishery. Data gathered from our field survey in September 1994 showed that *Mercenaria* was the most abundant species (71.6% of the total catch), followed by *Noetia* (17.2%) and *Anadara* (11%). These results compare favorably to commercial catch samples in which *Mercenaria* comprised about 60 - 70% of the catch, Noetia 20- 30%, and *Anadara* 10%.

Densities for all species combined averaged 1.26 clams per m^2, or 12,600 clams per hectare, and were highest in shell/mud substrate (3.61 clams per m^2, or 36,000 clams per hectare). We estimated total abundance (all species combined) in the study area to be about 87 million clams.

Very few small *Noetia* occurred in survey samples, indicating that recruitment may be low and/or that mortality rates are high during the first year after settlement. This contrasted markedly with the mostly small *Anadara* taken in samples, which were 0+ - 2 years old. Average heights were 42.6 mm for *Noetia* and 25.1 mm for *Anadara*.

We estimated annual mortality rates using articulated shells. Mortality rates for the 0+ - 1 year class were about 89% and 86% for *Noetia* and *Anadara*, respectively. There is

some evidence that the very strong byssus attachment by *Noetia* to other shells may offer some survival value from both predation and sedimentation, and mortality drops abruptly for 2+ - 5+ year class *Noetia*. During this time the shell thickness of *Noetia* clams increases substantially and shell weight constitutes about 77% of the total weight of the clam, compared to 66% of total weight for *Anadara*.

A combination of growth studies and age-height relationships for both *Noetia* and *Anadara* show that *Anadara* grows about twice as fast as *Noetia* and that growth increments in *Noetia* are very small after the first 3-4 years. In addition, age-size calculations show that the average age and size of *Noetia* presently being sent to markets is 6+ years old and about 45 mm in height. This is a decided decrease in average size from 56 mm in 1993 fishery samples and indicate that over-fishing is occurring. We propose several remedies to reduce the current rate of exploitation of *Noetia*, and possibly a shift in the emphasis of the fishery to *Anadara*. One of these suggestions is to utilize *Anadara* more fully in clam aquaculture on the Eastern Shore.

III. PROJECT PURPOSE

A. Statement of Problem

Since 1991 two species of arkshell or "blood" clams, *Noetia ponderosa* (ponderous ark) and *Anadara ovalis* (blood ark) have been targeted by watermen on the Eastern shore in Virginia for sale to markets in Washington D.C., New York City, Los Angeles and Chicago. Long considered a useless incidental catch in the harvest of the hard clam, *Mercenaria mercenaria*, and oysters, *Crassostrea virginica*, the arkshell clams now constitute a rapidly growing fishery with potential for future development. However, except for preliminary investigations conducted during 1992-1993 by McGraw and Castagna (1993), there is no information on the life history of either of these species. The intensive harvesting of blood clams and paucity of data on important factors such as distribution, densities, growth rates, and survival present a problem for management of the fishery.

At this time no official data on landings or exploitation rates are available (pers. com., Knur 1992), but some estimates from watermen and Virginia Institute of Marine Science (VIMS) biologists are in the range of 6,000 - 10,000 clams harvested per day from the oceanside lagoon system of the Eastern Shore of Virginia. Most of the blood clams harvested along the Eastern Shore of Virginia are *N. ponderosa*; however, some *A. ovalis* are also included. Virginia state fishery regulations concerning the harvest of arkshell clams are currently the same as for hard shell clams, which prohibit dredging from April 1 through December 1. Harvest by mechanical tongs, however, is not currently regulated by a season, and that method is used to continue some harvesting during the closed dredging season. Clam fishermen would like to harvest the clams year-round to provide consistent supplies to the markets they have developed; they requested a variance to permit dredging the arkshell clams during the normally closed season (Terry 1991). However, the Virginia Marine Resources Commission (VMRC) denied the request until more information is gathered on which to base management practices and regulations.

The number of clams sold in retail markets in different regions is not available, but two seafood dealers in Washington, D.C., offered some rough estimates for their stores. One sells 3,000 - 5,000 per week at a price of $ 2.50 - $ 3.00 per dozen (pers. com., V. Pruitt 1993). Another company sells about 2,000 blood clams per week from about November through March and charges $ 3.00 - $ 4.00 per dozen (pers. com., S.K. Martin 1993). Watermen report receiving from $ 0.07 to $ 0.25 per whole clam, depending on the size and demand; one reportedly received $0.50 per clam by selling the clams directly from his boat (pers. com., V. Annis, 1993).

The blood clams are sold primarily in ethnic markets. Both species have a somewhat bitter taste and contain the blood pigment hemoglobin, which gives the flesh a blood-red color (Yonge and Thompson 1976; Abbott 1968). These attributes may explain why they are not usually eaten in the U.S.; however, various ark species constitute significant fisheries in many other parts of the world. For example, Japan imports 23,000 metric tons (MT) of blood clams per year from Korea, in addition to domestic landings of about 90,000 MT (DuPaul 1992). Species of *Anadara* are also harvested and/or cultured for food in India, Thailand, Malasia, and Taiwan (Narasimham 1988, 1969; Ismail 1986; Bae 1986; Sahavacharin et al. 1988; Wong and Lim 1985; Ting 1981). Prior to 1950 there were also substantial harvests of *Arca noae* (up to 685 tons per year) from the Adriatic Sea (Hrs-Brenko 1980).

The ponderous ark (*N. pondersosa*) is ubiquitous along the Eastern Shore, but aggregates in shell debris or "shell hash", where juveniles attach by a prominent byssus to whole shells and pieces of shell (McGraw and Castagna 1993). Because they have no siphons, as some other clams do, they are found at the substrate surface, making them very accessible to dredges and tongs. *Anadara ovalis* occurs both in shell and muddy substrates, but, according to several watermen, densities around the Eastern Shore seem to be far less than *Noetia*. More intensive harvesting of arkshell clams of both species presents a problem for management of the fishery because very little is known about the basic biology and life history of these species, particularly recruitment and mortality rates, and the age, size, and distribution of harvestable stocks. The market size for *N. ponderosa* may include animals over six years of age (McGraw and Castagna 1993). The slow growth rate, with insufficient recruitment, could eventually lead to overharvest of the resource if present practices persist.

Preliminary investigations indicate (Table 1) that *Anadara ovalis* grows about twice as fast as *Noetia ponderosa* during the first year after settlement (a total average height of about 17 mm for *A. ovalis* vs. 9 mm for *N. ponderosa* in one year, respectively). A sample of commercially harvested *Noetia* taken in 1993 indicated that the average size (height) is about 56 mm (Fig. 1); however some data from non-fisheries samples obtained from Parting Creek, Virginia, a previously fished area, indicated that almost all large clams have been removed in that location (Fig. 2).

The apparent slow growth rate of *Noetia*, and depletion in some places, may indicate overfishing is occurring, but there is very little information on which the VMRC can base management decisions. More extensive investigations are needed so that informed decisions can be made with regard to this previously unexploited resource. The primary purpose of this research was to gather data on the sizes, ages, densities and abundance, and survival of blood clams on the Eastern Shore, and to make these data available to management agencies.

B. Project Objectives.

The project objectives are the following:

1. Gather data on the size-frequency and density distributions of blood clams in the oceanside lagoon system of the Eastern Shore of Virginia.

2. Establish size-age relationships of blood clams using the acetate peel technique.

3. Estimate mortality rates of blood clams from survey data.

4. Obtain some information on size distribution and species composition of blood clams in local commercial clam catch.

5. Provide information to the Virginia Marine Resources Commission (VMRC) in the form of a report containing findings of the project, with recommendations and suggestions for managing the fishery.

Table 1 . Growth data for *Noetia ponderosa* and *Anadara ovalis*, 1992 - 1994.

MEAN HEIGHT (MM) (± S.D.)

Species	Oct. 1992*	Feb. 1993	June 1993	Sept. 1994	Total Growth
A. ovalis (numbered)					
Sta. 1	20.3 (1.4) n=50	20.3 (1.4) n=47	22.0 (1.8) n=26	X	
Sta. 2	19.6 (1.1) n=50	19.8 (1.3) n=41	21.7 (1.4) n=38	X	
A. ovalis (subsample of all sizes)					
Sta. 1	14.5 (3.3) n=50	14.2 (3.2) n=30	16.6 (3.4) n=50	28.2 (2.9) n=38	13.7
Sta. 2	14.4 (3.4) n=50	14.4 (3.5) n=30	17.1 (3.1) n=50	32.3 (5.3) n=14**	17.9
N. ponderosa (subsample of all sizes)					
Sta. 1	6.2 (1.2) n=50	8.1 (1.7) n=50	8.5 (1.5) n=50	17.5 (1.4) n=88	11.3
Sta. 2	6.4 (1.5) n=50	8.3 (1.4) n=50	9.5 (1.4) n=50	18.4 (1.4) n=11 **	12.0

A. ovalis (approx. 1 yr. old) from raft behind Revel Island 8/20/93: Mean = 10.7 (4.4); n = 82)

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* Blood clams were obtained from a raft in an oceanside lagoon in Oct. 1992, and are believed to have recruited on the raft in July 1992. Larger *Anadara ovalis* were numbered and measured and placed in two different locations for a growth study. A subsample of additional (smaller) *Anadara* and *Noetia* were measured and also placed in trays at the two locations. Subsequent measurements were taken in Feb. and June 1993 and Sept.1994. The growth study is still in progress.

** Blood clams from mesh bags hanging from VIMS dock.

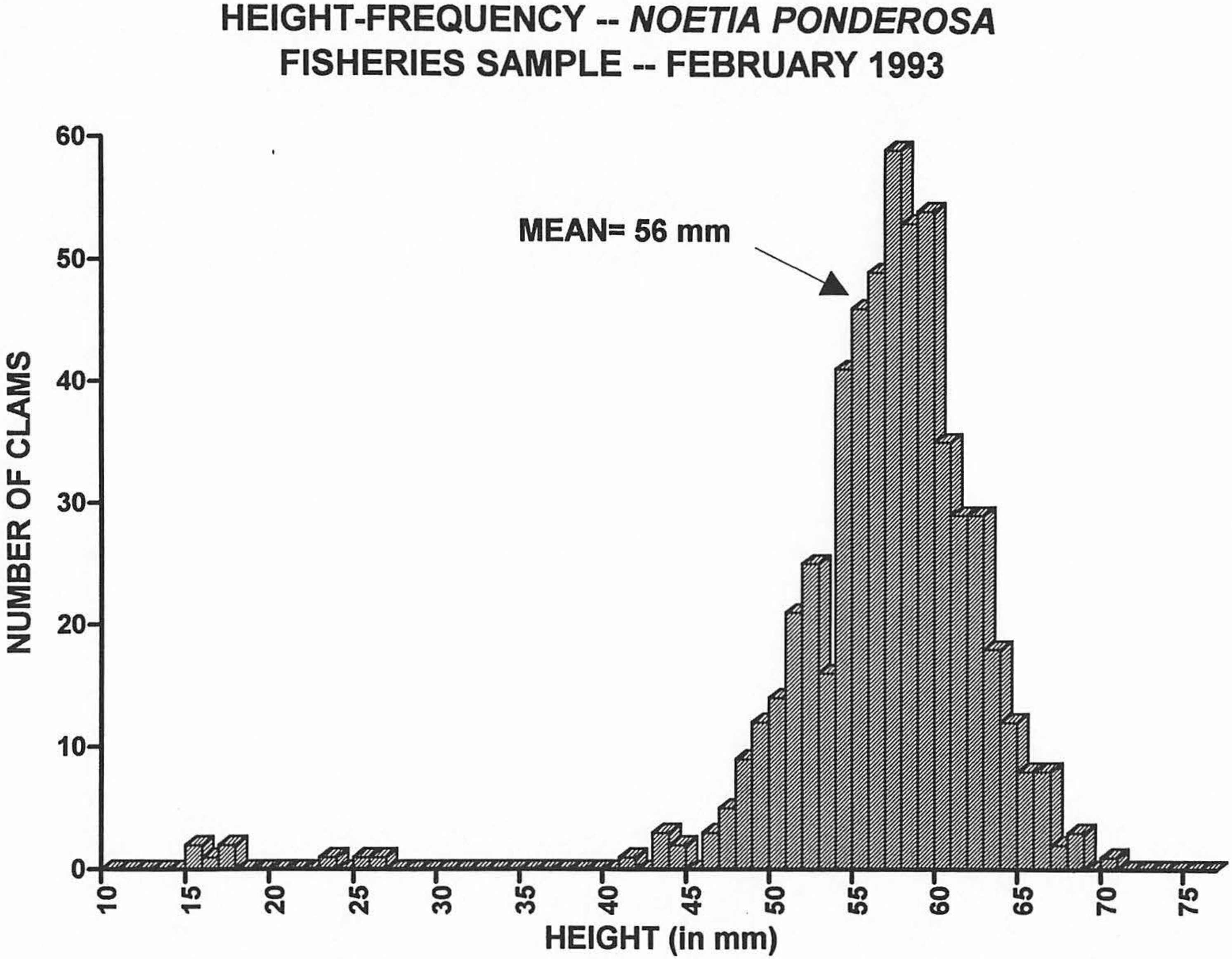


Figure 1. Height-frequency distribution for *Noetia ponderosa* from fisheries sample, 2/93.

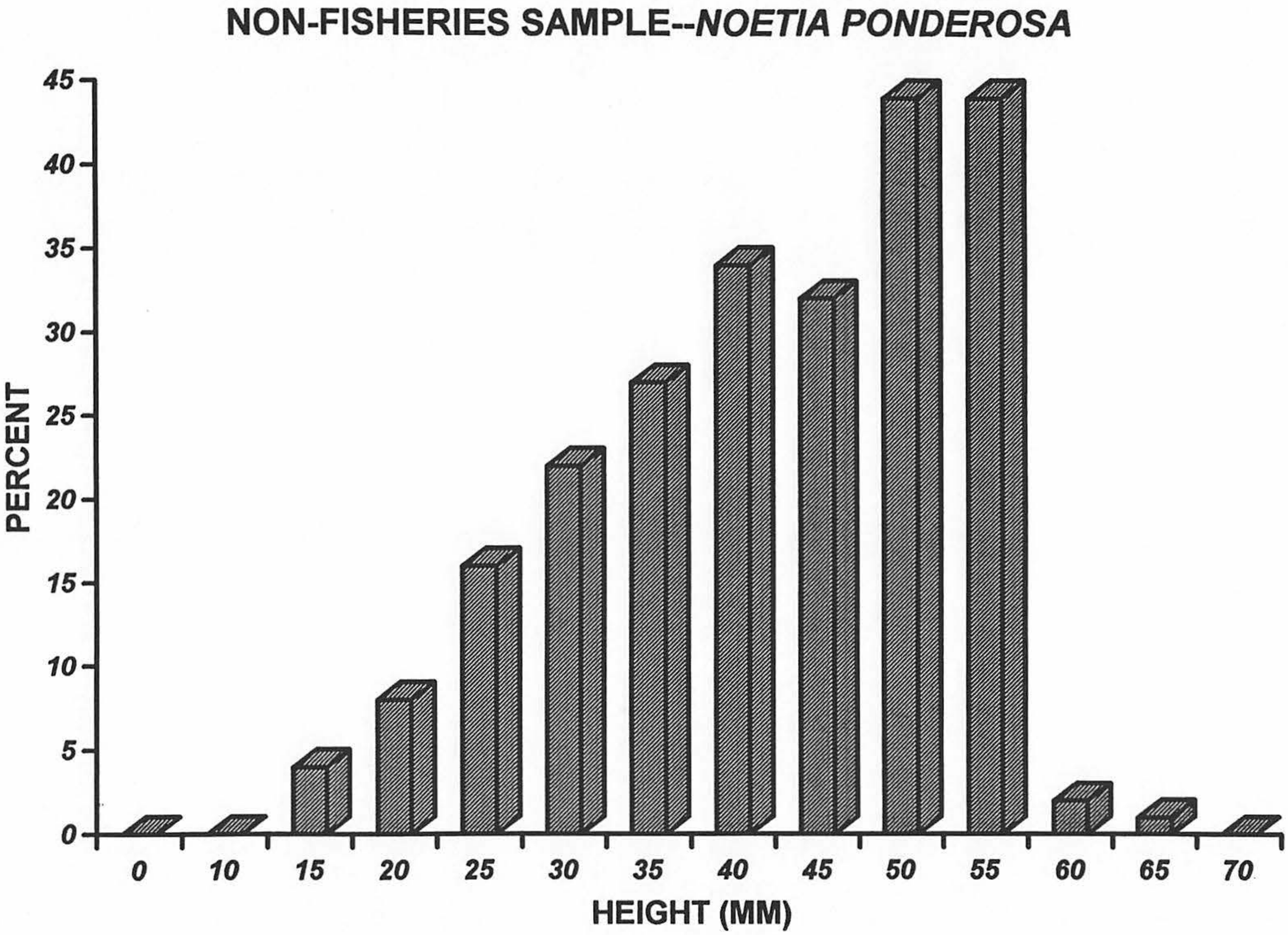


Figure 2. Non-fisheries sample from Parting Creek (Machipongo River), 6/93.

IV. APPROACH

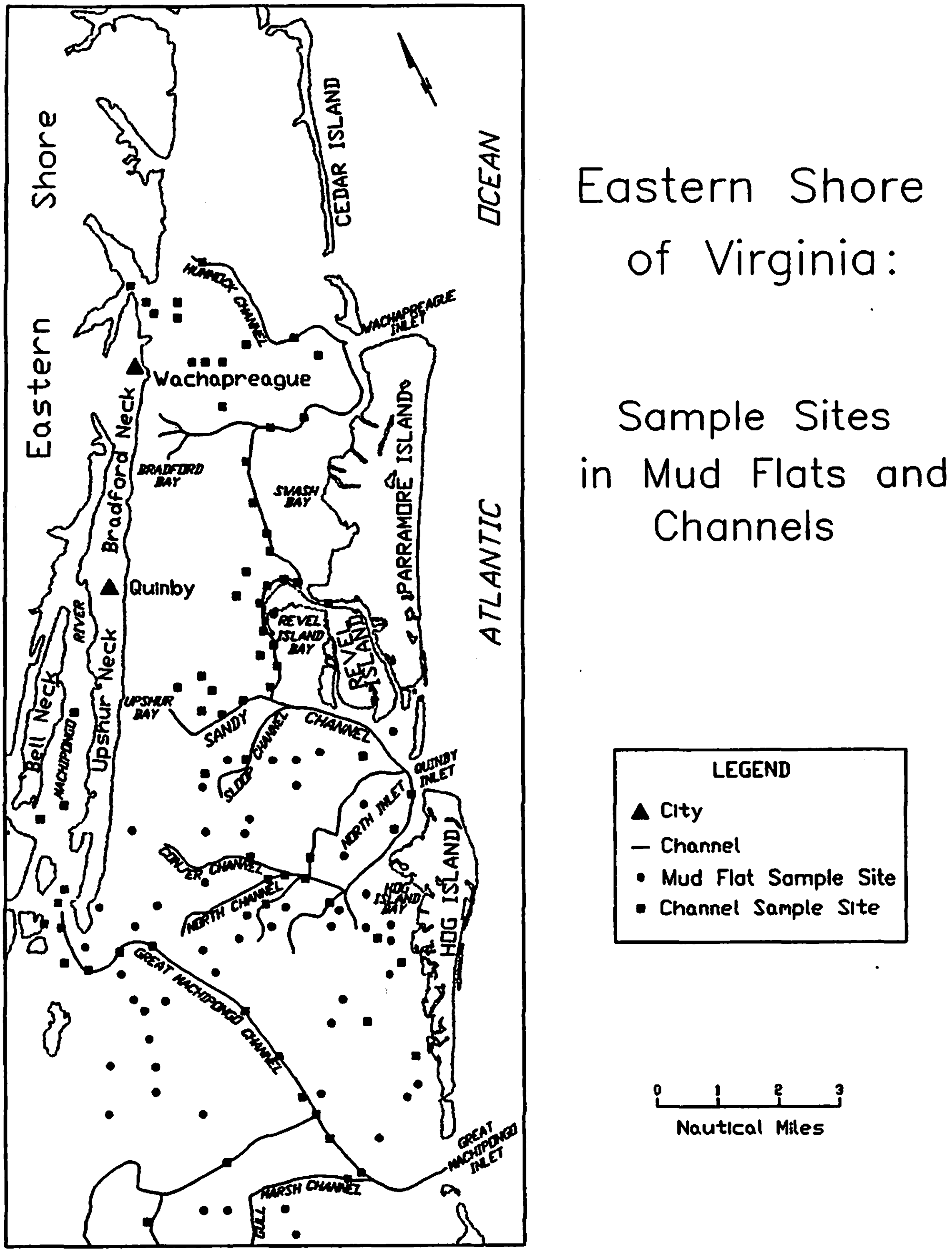
A. Description of Work Performed

The research consisted of three main parts: 1) conducting a field survey to obtain data on densities, substrate preference, distribution, abundance, and mortality rates in the tidal lagoons of the Eastern Shore of Virginia; 2) determining age-size relationships using the acetate peel technique; and 3) collecting fisheries catch data from local watermen. Although the primary emphasis of the study was on blood clams, we also collected some data on the hard clam, and that information is included in this report, as well as some ancillary data on growth rates.

Previous observations (McGraw and Castagna 1993) indicated that *N. ponderosa* is found almost exclusively in areas with shell and shell debris; however, random survey samples taken in oceanside lagoons contained varying substrates, which permitted some evaluation of habitat preferences for *N. ponderosa* and *A. ovalis* as well as *M. mercenaria.*

1. Field Surveys

We conducted field surveys during September 1994 aboard a contract vessel rigged with mechanical tongs. After discussion with several watermen, and examining NOAA charts and others prepared by Haven et al. (1981), we chose Hog Island Bay (Fig. 3) as the main focus for sampling and set up a grid overlay of the area (NOAA chart #1221) using 800 meter x 800 meter squares. The dimensions of the sampling grid were chosen because of the large area to be sampled, the scale of the NOAA charts, and the absence of GPS (Global Positioning Satellite) receiver or Loran on the vessel to precisely determine (within a few meters) location. However, the use of navigational aids in the channels, in addition to



Base Map Source: U.S. Department of Commerce, NOAA, 1972.
Julia Thompson
Radford University

Figure 3. Map of study area for clam survey, September 1994. Dots indicate sample sites on mud flats. Blocks indicate sample sites in channels.

investigators' knowledge of the area, and notations on the chart, provided ample accuracy of location.

Random number tables were used to determine which squares would be sampled, with 3 samples being taken at each station within a block. Stations which were deemed too shallow were eliminated and additional random numbers were selected. A total of 119 stations were sampled.

Mechanical tongs were used for sampling instead of a dredge because they permit more discreet samples to be obtained and retain more substrate when retrieved from the bottom. The tongs were lined with 1 centimeter square mesh to prevent loss of substrate and smaller clams. The area covered by the tongs in sampling is 1.12 m^2, with a penetration into the substrate of about 15 cm. Area is a more pertinent measurement for assessing densities of blood clams than volume because the clams inhabit the upper 6 - 8 cm of substrate and are easily caught with tongs.

In addition to the blocks chosen by random numbers, portions of some of the following tidal creeks and channels were included in the sampling plan: Swash Creek, Sandy Creek, Sloop Channel, Parting Creek, Machipongo River, Great Machipongo Channel, Quinby Inlet, Sand Island Channel, Millstone creek, and Wachapreague Inlet. Samples in tidal creeks and channels were taken approximately every .5 miles or 900 m. (in the immediate vicinity of channel markers), to more precisely locate positions on navigation charts. Channel samples also were usually done along transects across the channel, with the three samples spanning the channel or creek (i.e., each side and the middle).

Substrate material in each sample was qualitatively assessed into the categories used by Haven et al. (1981), who identified portions of the public (oyster) grounds within the lagoon systems as containing several types of substrate and provided areal estimates of each. Samples (or subsamples) were placed in plastic bags or buckets and later sorted on land.

The volume of substrate in some samples dictated that only portions of samples (i.e., subsamples) be retained for sorting. In those instances, subsample proportions were noted, along with other data, and factored into the density calculations during data analyses. Density estimates for the areas sampled are based on the number of clams obtained per sample and surface area covered by the sampling device (i.e., approximately 1.12 m^2).

All samples (or subsamples) were transported to the VIMS lab and carefully sorted using 1 cm mesh screens and water hoses. Blood clams and hard clams found in samples were counted and measured (height) to the nearest mm) with vernier calipers. Length and depth, or thickness were also measured for many clams. Height is defined here as the distance between the dorsal hinge and the ventral lip of the clam (Fig. 4), and length is the distance from the anterior end to the posterior end. Depth or thickness is the greatest distance between the right and left valves.

Analysis of catch data showed that the general distribution of clams was clustered or aggregated (i.e., non-normally distributed), as evidenced by coefficients of dispersion much greater than 1 (Sokal and Rohlf, 1969). This was caused by the large numbers of zeroes (i.e., samples with no clams). Therefore, data were transformed using log(X+1) transformation according to the method discussed in Zar (1974) and Sokal and Rohlf (1969) before ANOVA or other tests were used (e.g., to test for differences between mean densities among substrate types). After transformation, mean densities of clams found in the various substrates were tested using analysis of variance (ANOVA) (Sokal and Rolf 1969) to determine if significant differences exist (i.e., mean density x substrate type), indicating substrate preference (or perhaps differential survival rates in different substrates) for one or more species of clams. A Student-Newman-Keuls (SNK) test was employed (Zar 1974) to determine which means were significantly different ($\alpha = 0.05$).

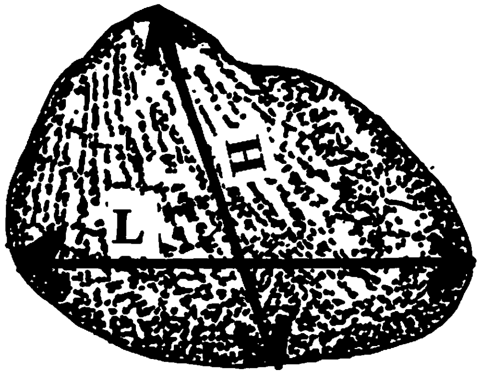


Figure 4. Shell dimensions for *Noetia ponderosa* (H = height); L = length). Dimensions are similar for *Anadara ovalis*.

Morphometric data were used to construct size-frequency distributions for the three species of clams. Relationships between height, length, and depth were determined for *Noetia* and *Anadara*. Weights were taken for a subset of clams, and correlations determined for height and whole weight of clams and wet meat weight (= whole weight - shell weight).

2. *Shell aging.*

A shell aging technique (acetate peel) was used on different sizes of blood clams to determine age more precisely and to estimate the maximum longevity of the clams. The acetate peel technique has long been used by paleontologists (Rigby and Clark 1965), but has proven effective in age determination for several species of bivalves (Ropes and O'Brien 1979; Ropes 1984, 1987; Kennish et al 1980; Richardson 1987, 1988). We specifically employed the method described by Farrow (1971), which eliminates the step of embedding shells in epoxy resin.

Shell microgrowth patterns have been discussed in detail by several authors, including Panella and MacClintock (1968), Rhoads and Panella (1970), and Lutz and Rhoads (1980). Age and size data can be applied to size distribution data through back-calculation procedures to create age frequency distributions, thus providing a better understanding of the population structure. Similar applications are found in fisheries literature (Robson and Chapman 1961; Gulland 1966; Ricker 1975).

Various sizes of *Noetia* and *Anadara* were processed and age determinations were made using a compound microscope at 40X (total magnification). All blood clams from the field survey were aged, supplemented by additional clams purchased from local watermen and previous data. The extra clams increased the sample size and therefore the accuracy of predictions.

3. Mortality rates

Some bivalves remain articulated for a time after death before the hinge ligament deteriorates and the valves separate, and these can be used to help estimate natural mortality (Dickie 1955; Buckner 1984). Although our sampling yielded relatively few clams in samples, we obtained enough to calculate some age-specific annual natural mortality rates (i.e., by dividing the number of articulated shells by the sum of live clams plus articulated clams for different size/age groups). as well as instantaneous mortality rates (Z). Instantaneous mortality rates were computed using the following equation: $Z = -\log E(1-A)$, where $A=$ the number of living clams in an age group and $E = 2.71828183$, the base of natural logarithms.

4. Fisheries catch data

Mr. David Bishop, of Oakhall, VA, a waterman on the Eastern Shore of Virginia, collected and recorded data on the proportion of blood clams from many of his catches over a 3 month period, from September through November, 1994. He also provided additional clams for measurements and age determinations. Those data are discussed in the findings section of the report.

B. Project management

Dr. Kay A. McGraw, Mr. Michael Castagna, and Dr. Sally D. Dennis were the project investigators. Dr. McGraw, the Project Investigator, was responsible for the day-to-day overall coordination of the project, preparing contract materials, assisting with procurement matters, pricing and ordering equipment, writing quarterly and final reports, and conferring with Co-PIs regarding sampling strategy, data analyses, data entry, obtaining and sorting samples, and primary supervision of students working on various aspects of the project. Mr. Castagna acted as liaison with the local watermen and processors, and was singularly instrumental in finding a waterman and vessel (Mr. David Bishop) to conduct the field surveys. He was the navigator for the survey and participated fully in sampling and sorting, as well as providing expertise on sample areas. Dr. Dennis participated in field sampling and sorting, assisted with processing shells for shell aging, and also helped supervise student workers on the project.

Jean Watkinson and Rudy Cashwell, VIMS Eastern Shore Laboratory, assisted with sampling and sample sorting. Reed Bonniwell maintained and repaired various pieces of gear and equipment during the study.

Several Radford University students participated in portions of the study. Kacey Gray, Regina Dumouchelle, and Yvonne Buswell assisted in shell preparations for age determinations. James Hardy and Julia Thompson digitized area charts and prepared maps for inclusion in the report. Janet Hahn, Rhea Epstein,and Sara Underwood, Office of Sponsored Programs, Radford University, and Jane Lopez, Office of Sponsored Programs, Virginia Institute of Marine Science, prepared documentation for the proposal and provided administrative support throughout the project.

V. FINDINGS

A. Field Survey Results:

Sampling began in Hog Island Bay on September 7, 1994, and continued for approximately 3 weeks. During that time, 119 stations were sampled (Fig. 3) and all hard clams (*Mercenaria mercenaria*) and blood clams (*Noetia ponderosa* and *Anadara ovalis*) taken in samples were counted and measured. Of the clams taken in survey samples and subsamples, there were 43 *Noetia*, 29 *Anadara*, and 146 *Mercenaria*. Adjusting for the proportions of substrate in subsamples, this equates to a total of 86 *Noetia*, 55 *Anadara*, and 358 *Mercenaria*. Therefore, *Mercenaria* constituted approximately 71.6 % of the total catch, *Noetia* 17.2 %, and *Anadara* 11%.

1. Density.

After data transformation, clam densities were estimated for all species combined and for each of the three species by dividing the total number of clams caught in each sample by the area covered by the mechanical tongs (i.e., 1.12 m^2). They were further analyzed according to substrate type and water depth (i.e., channels or mud flats/shallow areas). The different kinds of substrates noted in field surveys included mud, sand, shell, shell/mud, shell/sand, and sand/mud .

The average densities (Table 2) of *Noetia ponderosa*, *Anadara ovalis*, and in the areas sampled were: 0.22 (± 1.11), 0.14 (± 1.01), and 0.90 (± 2.31) per m^2, respectively. Total average clam density (all 3 species combined) was 1.26 clams (± 3.03) per m^2, or about 12,600 clams per hectare (ha).

Clam densities varied among substrate types and species. For example, mean densities of *Noetia* and *Mercenaria* in shell/mud substrate were 0.92 and 2.70 clams/m^2, respectively, whereas *Anadara* densities were highest in shell substrate (Table 2 and Fig. 5). Mean densities for all three species combined were highest in shell/mud substrate ($\overline{X} = 3.61$ clams/m^2, or 36,000 clams/ha) and shell substrate ($\overline{X} = 2.3$ clams/m^2, or 23,000 clams/ha).

Clam densities for the six substrate types were compared using ANOVA after data transformation (i.e., log [X+1]). ANOVA results showed that there was a significant difference in mean clam densities among substrates (Table 3). We then applied the Student-

Table 2. Densities of clams (# / m^2) by species and substrate types.

	SUBSTRATE TYPE						TOTAL AVG. DENSITY (N=355)
SPECIES	**SHELL N=23)**	**SHELL/SAND (N=24)**	**SHELL/MUD (N=47)**	**SAND (N=50)**	**MUD (N=133)**	**SAND/MUD (N=78)**	
NOETIA	0.52 (±1.17)	0.22 (± 0.79)	0.92 (± 2.41)	0.00	0.09 (± 0.66)	0.00	**0.22** **(±1.11)**
ANADARA	0.51 (±1.08)	0.00	0.00	0.00	0.26 (± 1.55)	0.05 (± 0.28)	**0.14** **(±1.01)**
MERCENARIA	1.05 (± 1.90)	0.86 (± 1.36)	2.70 (± 3.98)	0.20 (± 1.03)	0.56 (± 1.83)	0.83 (± 2.06)	**0.90** **(± 2.31)**
TOTAL MEAN DENSITY (CLAMS/M2)	2.30 (± 3.06)	1.08 (± 1.61)	3.61 (± 5.13)	0.20 (± 1.03)	0.91 (± 2.73)	0.88 (± 2.06)	**1.26** **(± 3.03)**
CLAMS PER HECTARE	**23,000**	**10,800**	**36,000**	**2,000**	**9,100**	**8,700**	**12,600**
CLAMS PER ACRE	**9,318**	**4,374**	**14,580**	**810**	**3,685**	**3,523**	**5,103**

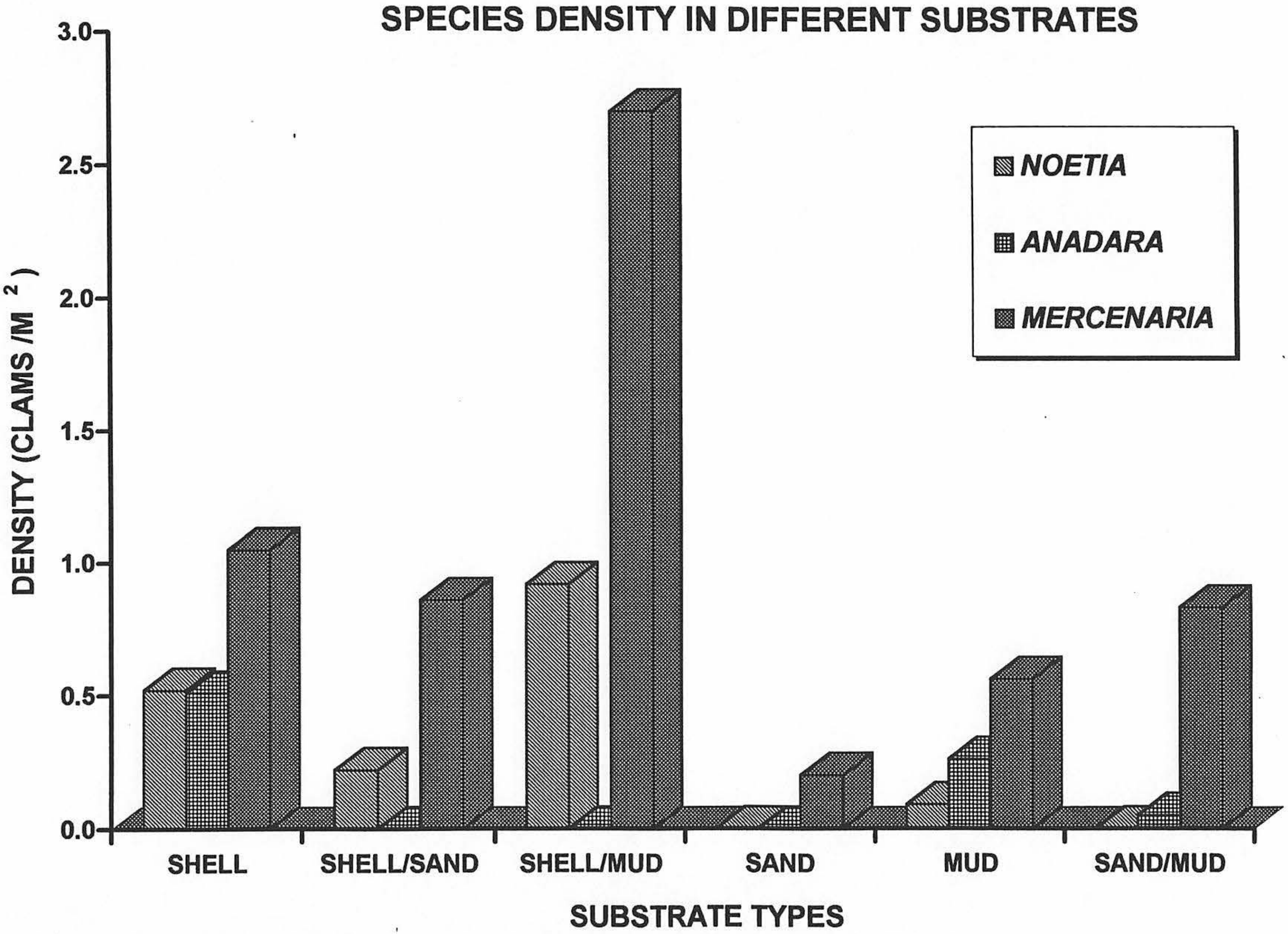


Figure 5. Species densities in different substrate types on the Eastern Shore of Virginia.

Table 3. Analysis of variance of mean clam densities in different substrate types. Data were transformed with log (X+1) transformation before analysis.

ANOVA: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
MUD	133	14.59106	0.109707	0.075432
SAND	50	1.54678	0.030936	0.019016
SAND/MUD	78	10.69572	0.137125	0.069151
SHELL/SAND	24	5.023848	0.209327	0.069518
SHELL	23	7.852287	0.341404	0.116597
SHELL/MUD	47	19.00777	0.404421	0.173367

ANOVA

Source of Variation	SS	df	MS	F	p-VALUE	F-crit
Between Groups	4.822859	5	0.964572	11.8733	1.27E-10	2.239851
Within Groups	28.35231	349	0.081239			
Total	33.17517	354				

Newman-Keuls test to determine which means were different. Results are summarized in Table 4 and as follows: $\mu_1 \mu_2 \mu_3 \mu_4 \mu_5 \mu_6$, where μ_1 = shelly mud, μ_2 = shell, μ_3 = shelly sand, μ_4 = sandy mud, μ_5 = mud, and μ_6 = sand. There were no significant differences in mean densities between muddy shell and shell substrates, or between shell substrate and shelly sand. However, there was a significant difference in mean densities between shelly mud and shelly sand substrates. In general, densities of clams were much higher in shell substrate and a mixture of either shell and sand or shell and mud, pointing out the importance of shell as either an attachment substrate and/or a factor in survival from predation.

Hard clam densities were as high as 10.7/m^2 in samples from Little Sloop Channel, The Swash Channel, and a small slough in Revel Island Bay. Densities of *Noetia* were highest (13.4 clams/m^2) in a sample taken in the vicinity of Channel Marker 1 in the Great

Table 4. Student-Newman Keuls test of mean densities among substrate types.

Comparison	Order of means	N	Difference in means	SE	q	p	qα,ν,p	Conclusion
SHELLY MUD VS	0.404421	47						
SHELL	0.341404	23	0.06301697	0.051	1.235627	2	2.77	Accept Ho
SHELLY SAND	0.209327	24	0.19509373	0.051	3.825367	3	3.35	Reject Ho
SANDY MUD	0.137125	78	0.26729612	0.037	7.22422	4	3.6	Reject Ho
MUD	0.109707	133	0.29471348	0.034	8.668044	5	3.85	Reject Ho
SAND	0.030936	50	0.37348513	0.041	9.109393	6	4	Reject Ho
SHELL VS	0.341404	23						
SHELLY SAND	0.209327	24	0.13207676	0.059	2.238589	2	2.77	Accept Ho
SANDY MUD	0.137125	78	0.20427916	0.048	4.255816	3	3.35	Reject Ho
MUD	0.109707	133	0.23169651	0.045	5.148811	4	3.6	Reject Ho
SAND	0.030936	50	0.31046816	0.051	6.087611	5	3.85	Reject Ho
SHELLY SAND	0.209327	24						
SANDY MUD	0.137125	78	0.07220239	0.047	1.536221	2	2.77	Accept Ho
MUD	0.109707	133	0.09961975	0.045	2.213772	3	3.35	Accept Ho
SAND	0.030936	50	0.1783914	0.05	3.567828	4	3.6	Accept Ho
SANDY MUD	0.137125	78						
MUD	0.109707	133	0.02741736	0.029	0.945426	2	2.77	Accept Ho
SAND	0.030936	50	0.106189	0.036	2.949695	3	3.35	Accept Ho
MUD	0.109707	133						
SAND	0.030936	50	0.07877165	0.033	2.38702	2	2.77	Accept Ho

Machipongo Channel (intracoastal waterway). The highest densities of *Anadara* observed were in samples at a station in the Deeps Channel. Those three samples had densities of 15.0, 7.16, and 4.3 *Anadara*/m^2 and contained almost half of the *Anadara* obtained during the field survey (i.e., 11 of the total 29).

Of the 355 samples taken, 201 were in channels and 154 were from shallower areas (mud flats). After log transformation , the total average clam density (all species) for channel samples was .20 (± .33) clams/m^2, and .12 (±.26) clams/m^2 in shallow areas. Comparison of means with a Student's t-test showed that mean clam densities were significantly different between channel stations and shallower stations ($p \leq .001$).

Densities of clams in various substrates are presented in Table 2. Using these, we estimated the abundance of clams with substrate data from Haven et al. (1981) by multiplying the density of clams found in various substrates by the number of acres of that substrate for the study area (Tables 5 and 6). That is, $A_t = \sum (Ds \times h)$, where A_t = the total abundance of clams in the study area; Ds= the total mean density of clams in a given type of substrate; and h = number of hectares of a given substrate in the study area. The total estimated clam abundance in the study area (Hog Island Bay, Burton's Bay, and Bradford Bay) is 12,600 clams per ha (all species combined) X 7,470 hectares (= 18,451.3 acres), or about 87 million clams. Total estimated abundance for the different species is: *Noetia*, about 15.2 million; *Anadara*, about 9.6 million; and for *Mercenaria*, about 62.2 million clams. The proportions are based on those from the field survey, in which *Noetia* had an average density of 0.22 clams/m^2, *Anadara* 0.14 clams/m^2, and *Mercenaria*, 0.90 clams/m^2.

Table 5. Estimated acreage of substrate types in the study area (Haven et al. 1981).

	SUBSTRATE TYPE						
LOCATION	SHELL	SHELL/SAND	SHELL/MUD	SAND	MUD	SAND/MUD	TOTAL ACRES
Burton's Bay	13.4	505.4	105.4	289.5	476.4	——	1,390.1
Bradford Bay/ Swash Bay	74.8	301.1	105.8	155.7	586.3	——	1,223.7
Upshur Bay, Major Hole Bay Revel Island Bay	21.9	649.9	286.1	1,535.6	334.8	99.3	2,927.6
Hog Island Bay (above North Channel)	60.7	149.0	425.6	565.1	2,956.5	156.7	4,313.6
Hog Island Bay (below North Channel)	83.3	459.7	1,072.3	1,208.7	1,541.8	1,721.5	6,087.3
Ramshorn Bay to Sand Shoal Channel	32.3	5.1	479.7	8.4	1,350.2	633.3	2,509.0
TOTAL ACRES	286.4	2,070.2	2,474.9	3,763.0	7,246.0	2,610.8	18,451.3
TOTAL HECTARES	116.0	838.1	1,002.0	1,523.5	2,933.6	1,057.0	7,470.2

Table 6. Estimated clam abundance of selected areas of the Eastern Shore of Virginia based on clam densities from 1994 survey and estimated acreage of substrate types in the study area (from Haven et al., 1981).

	SUBSTRATE TYPE												
	SHELL		SHELL/SAND		SHELL/MUD		SAND		MUD		SAND/MUD		EST.
LOCATION	ACRES	CLAMS	ACRES	CLAMS	ACRES	CLAMS	ACRES	CLAMS	ACRES	CLAMS	ACRES	CLAMS	CLAMS
Burton's Bay	13.4	**124,861**	505.4	**2,210,620**	105.4	**1,536,732**	289.5	**234,495**	476.4	**1,755,534**	—	**0**	**5,862,242**
Bradford Bay/ Swash Bay	74.8	**696,986**	301.1	**1,317,011**	105.8	**1,542,564**	155.7	**126,117**	586.3	**2,160,516**	—	**0**	**5,843,194**
Upshur Bay, Major Hole Bay Revel Island Bay	21.9	**204,064**	649.9	**2,842,663**	286.1	**4,171,338**	1,535.6	**1,243,836**	334.8	**1,233,738**	99.3	**349,834**	**10,045,473**
Hog Island Bay (above North Channel)	60.7	**565,603**	149.0	**651,726**	425.6	**6,205,248**	565.1	**457,731**	2,956.5	**10,894,703**	156.7	**552,054**	**19,327,064**
Hog Island Bay (below North Channel)	83.3	**776,189**	459.7	**2,010,728**	1,072.3	**15,634,134**	1,208.7	**979,047**	1,541.8	**5,681,533**	1,721.5	**6,064,845**	**31,146,476**
Ramshorn Bay to Sand Shoal Channel	32.3	**300,971**	5.1	**22,307**	479.7	**6,994,026**	8.4	**6,804**	1,350.2	**4,975,487**	633.3	**2,231,116**	**14,530,712**
TOTAL ACREAGE/ ABUNDANCE	286.4	**2,668,675**	2,070.2	**9,055,055**	2,474.9	**36,084,042**	3,763.0	**3,048,030**	7,246.0	**26,701,510**	2,610.8	**9,197,848**	**86,755,160**
TOTAL HECTARES/ ABUNDANCE	116.0		838.1		1,002.0		1,523.5		2,933.6		1,057.0		**86,755,160**

2. *Size-frequency*

Average sizes (i.e., height measured from the umbo to the shell margin) for the three species were: *Noetia*, 42.6 mm (± 14.3, n=43); *Anadara*, 25.1 mm (± 6.6, n=29); and *Mercenaria*, 75.3 mm (± 14.3, n=146). Height-frequency data are shown in Figs 6 - 8. The relatively few small *Noetia* taken in survey samples suggest that recruitment may be relatively low and/or that mortality rates may be quite high during the first year after settlement. In contrast, most of the *Anadara* were 0+ to 2 years old, with very few older, larger clams in samples. The *Mercenaria* height frequency distribution appeared to be skewed toward the larger sized clams, and contains probably 3 juvenile year classes, with a decided lack of small clams.

3. *Articulated Shells and Mortality.*

Articulated shells were used to estimate annual age specific mortality rates and instantaneous mortality rates for *Noetia* and *Anadara*. Age-length data from acetate peels were applied to the size distribution of living and articulated clams and the number of clams in each age-size class was determined. Then the number of articulated shells in a given age-size category was divided by the number of live clams taken in the survey to arrive at an age specific or annual mortality rate expressed as a percentage (Table 7). Instantaneous mortality rates were also computed. The annual mortality rate for 0+ - 1 yr. class *Anadara* is 86.4%, then decreases to 30.4% for the 1+ -2 year class, rising abruptly again to 80% the following year. No articulated shells greater than 50 mm occurred in samples (Fig. 9); therefore, the mortality rate for the 3+ year class *Anadara* was 0. The sharp increase for older clams seems unusual, and may be due to senescence or to the small sample size for live *Anadara*.

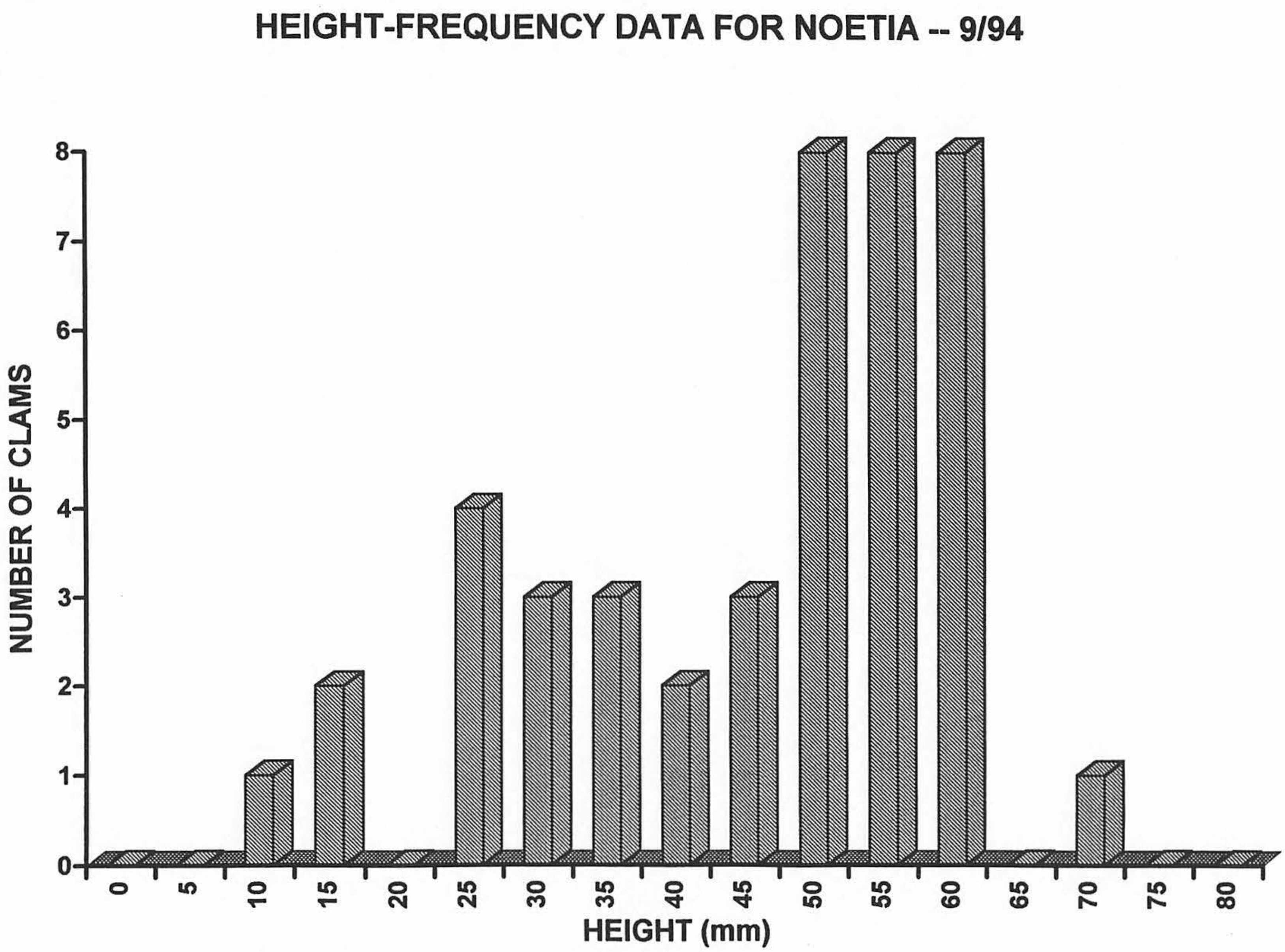


Figure 6. Height-frequency data for *Noetia ponderosa* from Eastern Shore clam survey, 9/94 (mean height= 42.6 mm; n=43).

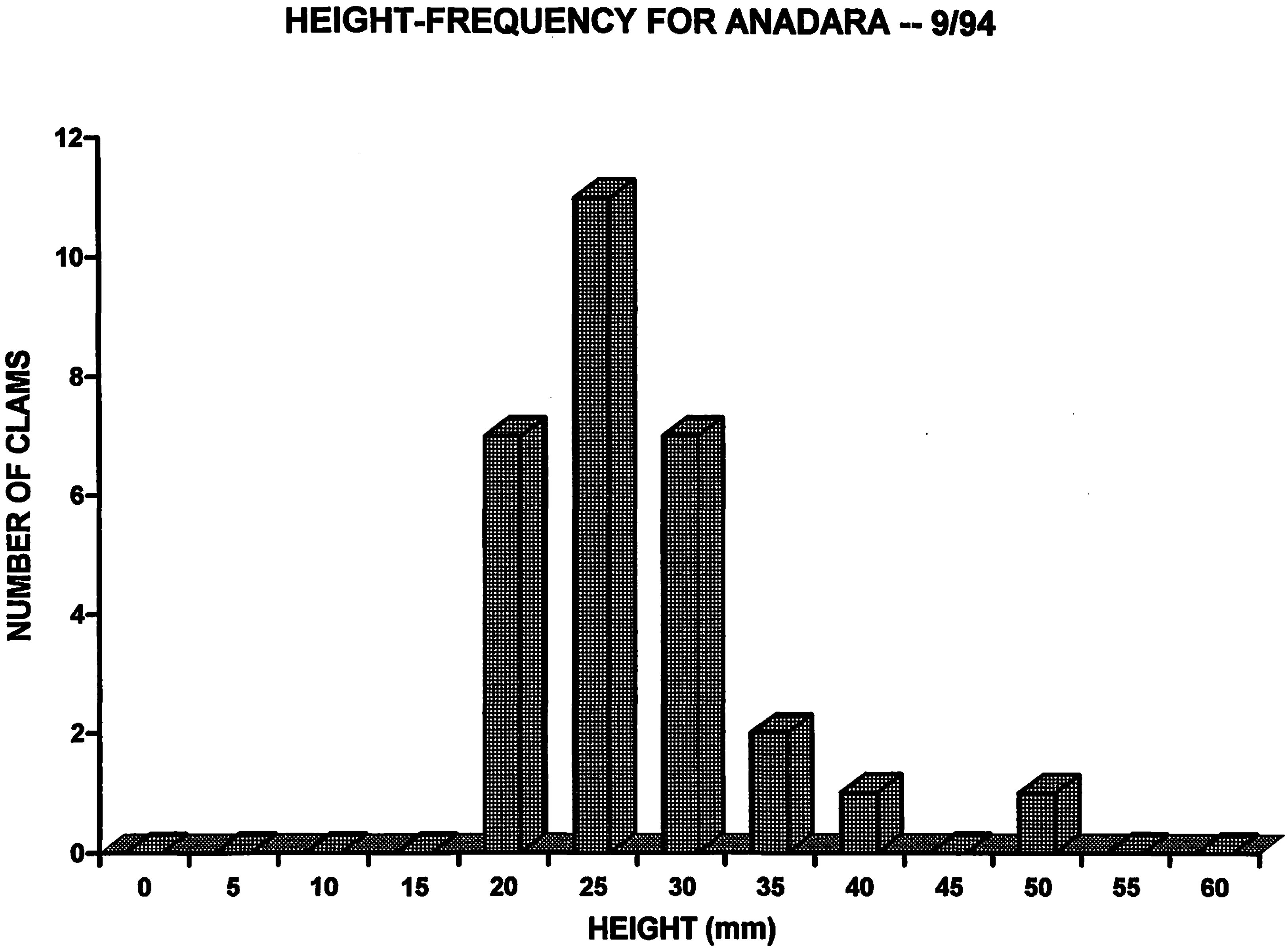


Figure 7. Height-frequency for *Anadara ovalis* from Eastern Shore clam survey, 9/94 (mean height =25.1; n=29).

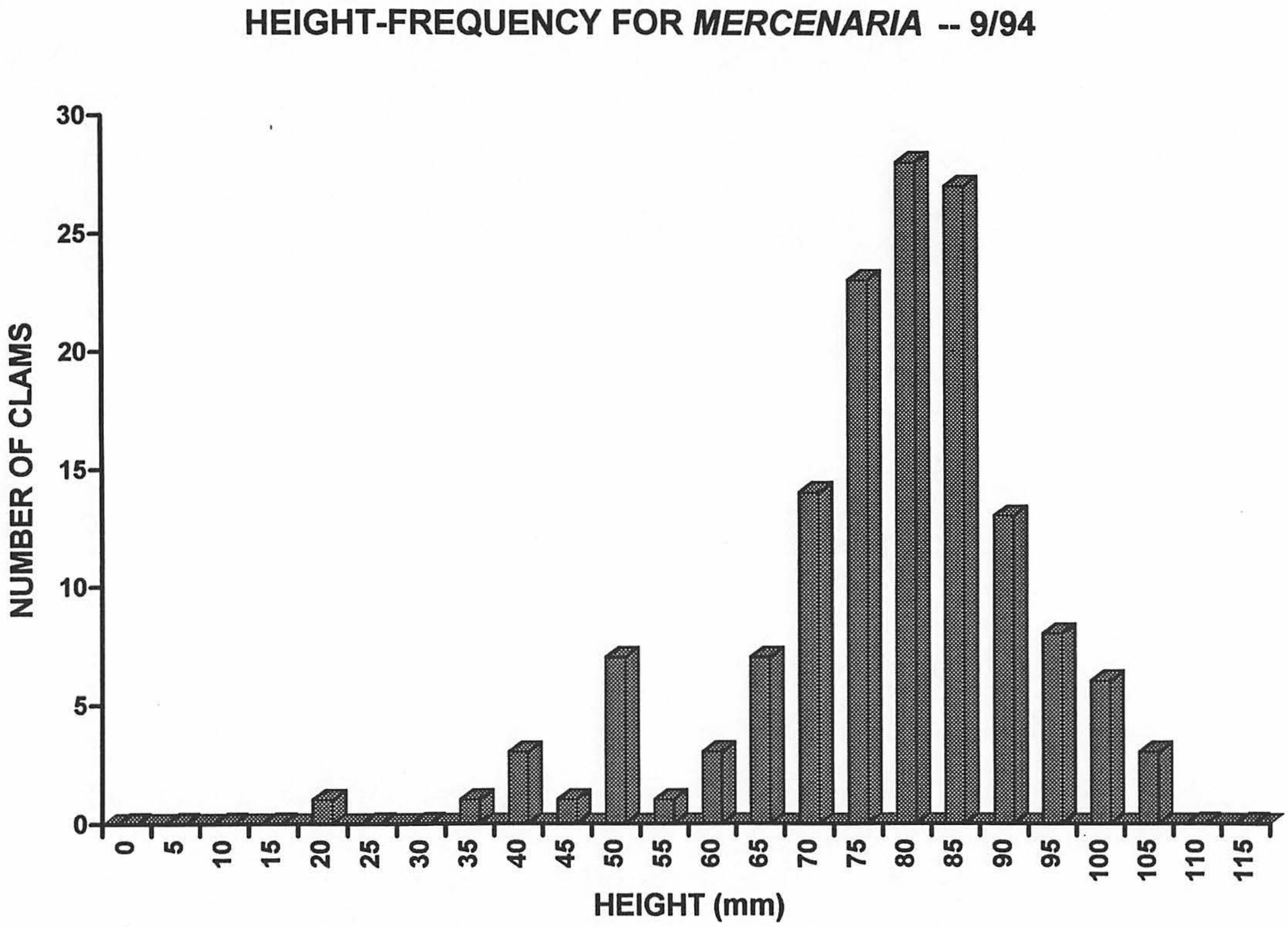


Figure 8. Height-frequency for *Mercenaria mercenaria* from Eastern Shore clam survey, 9/94 (mean height = 75.3; n=146).

However, it may reflect the actual situation, since few large *Anadara* are taken in commercial clam catches, and most seem to die before reaching 5 years of age. A similar phenomenon has been observed for the bay scallop, *Argopecten irradians*, in which about 80% of scallops die between months 13 to 16 (Castagna 1975; Castagna and Duggin 1971).

Table 7. Mortality rates (%) and instantaneous mortality rates (Z) for *Noetia ponderosa* and *Anadara ovalis*, based on articulated clam shells.

Noetia ponderosa

Year Class	# Articulated Shells	# Live	Total	% Mortality	Z
0-1	8	1	9	88.9%	2.2
1+ - 2	3	2	5	60.0%	0.916
2+ - 3	0	9	9	0.0%	0
3+ -4	0	3	3	0.0%	0
4+ -5	0	3	3	0.0%	0
5+ - 10	6	11	17	35.3%	0.086
10+ - 15	5	14	19	26.3%	0.061

Anadara ovalis

Year Class	# Articulated Shells	# Live	Total	% Mortality	Z
0-1	70	11	81	86.4%	1.995
1+ - 2	7	16	23	30.4%	0.362
2+ - 3	0	1	1	0.0%	1.61
>3+	4	1	5	80.0%	0

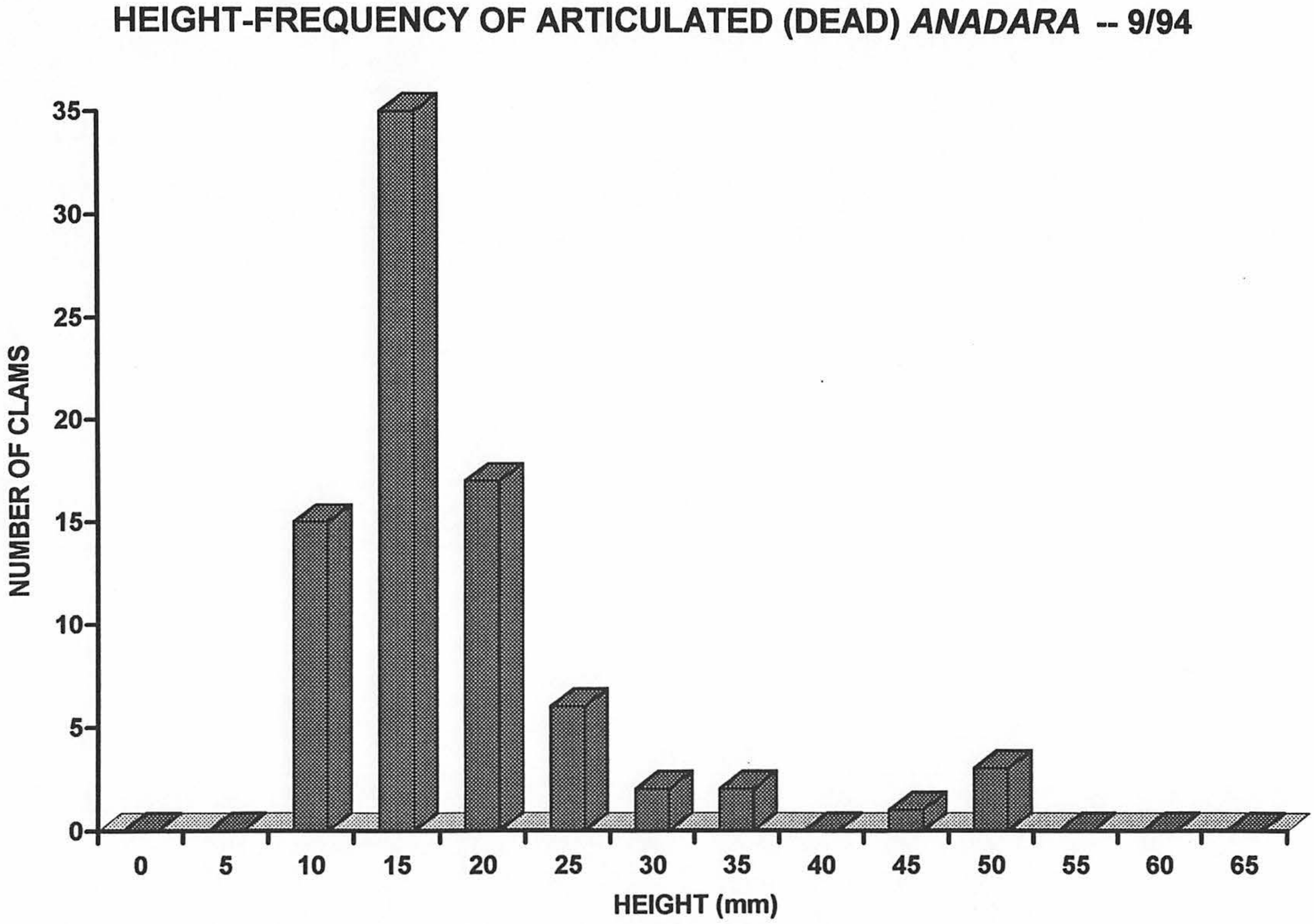


Figure 9. Height-frequency for articulated (dead) *Anadara ovalis* shells from clam survey on Eastern Shore of Virginia, 9/94.

Annual mortality rates for *Noetia* (Table 7 and Fig. 10) were highest for the 0+ to 2 year old groups (88.9% and 60%, respectively). Because incremental increases in shell height are very small for clams 5 year old and above, we grouped the 5+ to 10 year classes and 10+ to 15 year old clams to determine mortality rates. The annual mortality rate for the 5+ to 10 year old group was 35% over the 5 years, or 7% per year; for the 10+ to 15 year old clams, it was 26.3%, or 5.3% per year. No articulated clams were obtained in samples for the 2+ to 5 year age classes. Again, this may be attributed to sampling variation, but could also suggest decreasing predation for these age classes as a function of increasing size and shell thickness, concurrent with whatever protection accrues from the strong byssal attachment to shells. The byssus in *Noetia* is extremely strong and resembles a ligament, which can be torn away only with considerable force. When live *Noetia* are kept in tanks, they attach firmly to the sides of containers and, after removal, the remaining byssus portions cannot be washed off, but must be removed with hydrochloric acid.

Increases in mortality rates for age 5+ - 15 year old *Noetia* may reflect increasing senescence and, perhaps, the effects of dredges in some areas, causing smothering. Future field studies using various sizes of clams may help in discerning natural mortality and fishing mortality.

4. Attached Noetia.

Some *Noetia* taken in samples were attached by a very strong byssus to other pieces of shell, primarily old *Noetia* shells. We also noted that the attachment site was usually the concave (i.e., inside) portion of the old shell. Of the 46 *Noetia* obtained in samples, 15 , or 33% were attached. Attached *Noetia* averaged 28.5 mm in height and ranged in size from 6-

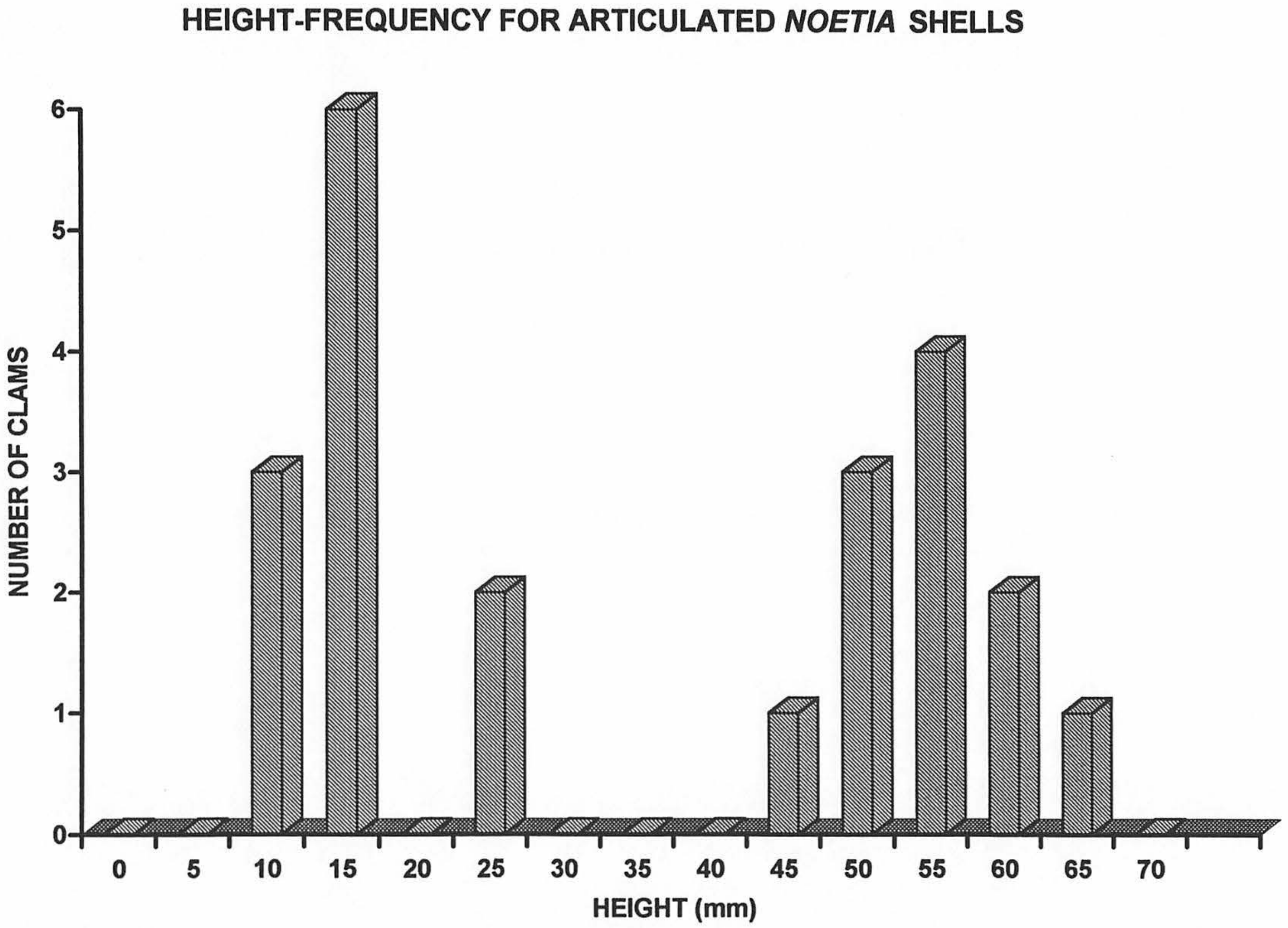


Figure 10. Height-frequency for articulated (dead) *Noetia* shells from Eastern Shore clam survey, 9/94.

49 mm (Fig. 11). The age-height relationship from acetate peels suggests that these clams are up to 8 years old. Samples obtained in 1993 from Parting Creek also contained 50 attached *Noetia* out of 234 or 21%. In those samples, the average height of attached *Noetia* was 29.1 (±6.3; n=50). Attachment, especially in the concave portion of the shell, may provide some protection from predation, and may also explain the higher density of *Noetia* in shell habitats. Perhaps survival is enhanced for some period of time until the clam is larger and has a thicker shell. In addition, attachment to shells may also help prevent smothering due to siltation, as a clam would be situated higher in the shell hash and less likely to sink or be covered by sediment in water currents. However, the attachment shell will disintegrate over time as a result of various boring organisms (e.g., boring sponge, *Cliona sp.*) and dissolution in water; hence, few very large clams are found attached to empty valves.

5. Morphometrics

The data set used for morphometric relationships is from several sources, including growth studies, fisheries samples, survey samples, and extra clams purchased for shell aging studies. The relationships of several variables were examined: height and length; height and depth; height and whole clam weight; height and wet meat weight (= whole weight - shell weight). The relationship between valve height and length for *Noetia* (Fig. 12) is described by the regression equation: $L = 1.22H + 1.81$, where L = length in mm and H = height in mm. The dimensions of height and length are highly correlated, with a coefficient of determination, $r^2 = .986$. Height and shell depth are also linearly related (Fig. 13) by the regression equation $D = 0.978H - 2.52$, where D = depth of the clam in mm ($r^2 = 1$).

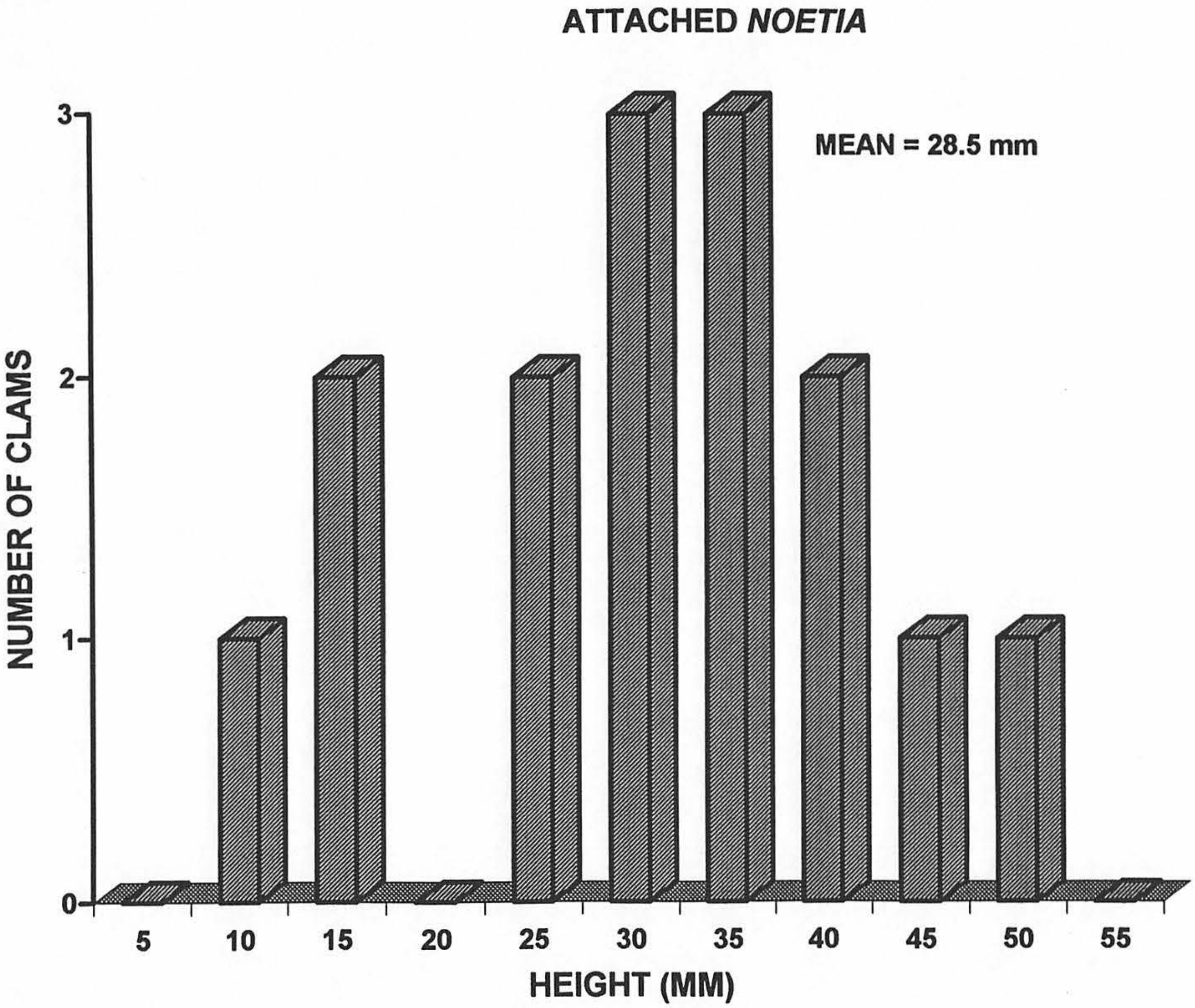


Figure 11. Height-frequency for attached *Noetia ponderosa* from survey samples, 9/94.

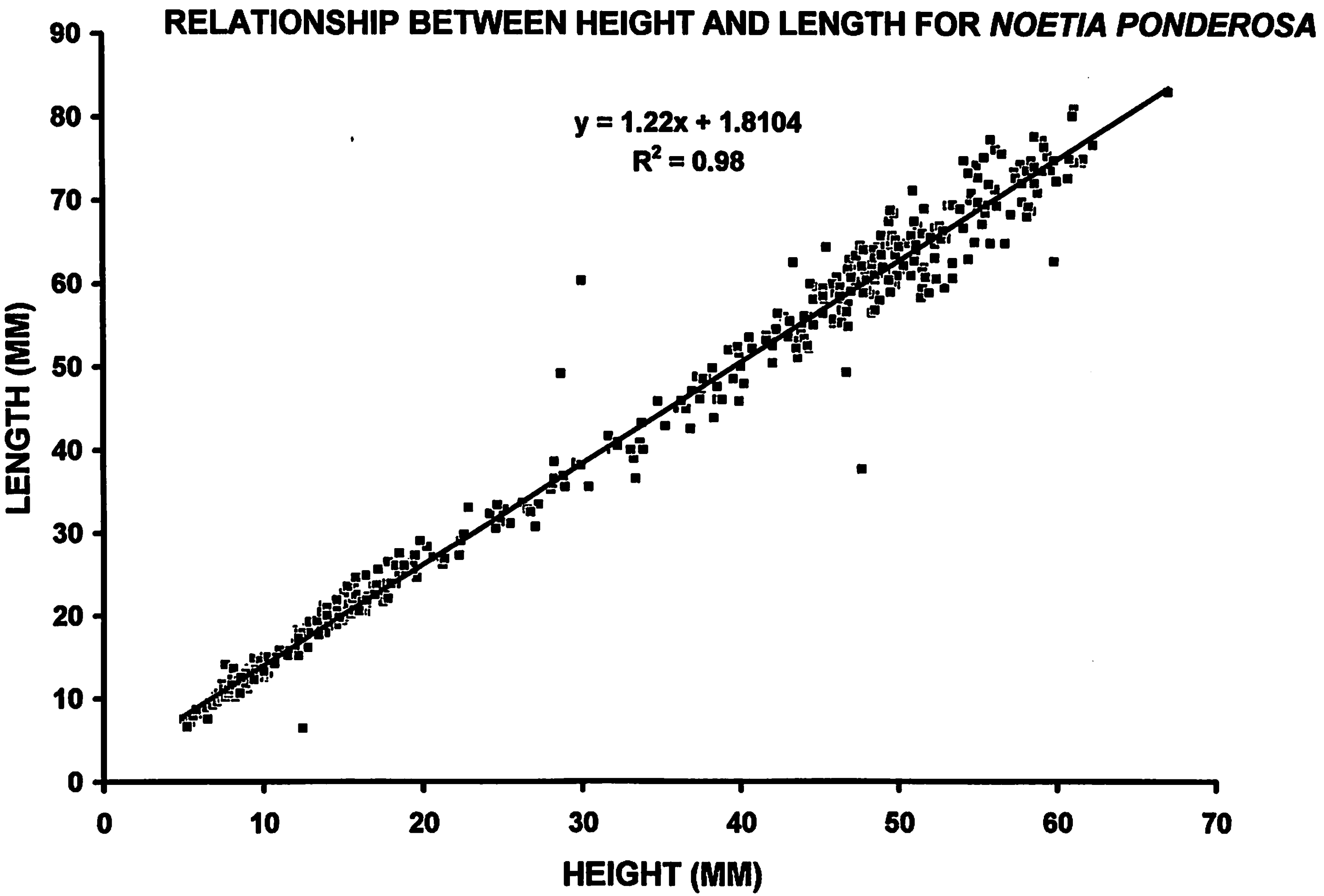


Figure 12. Regression of height vs. length for *Noetia ponderosa*. Data are from several sources, including 1994 survey, commercial samples, and growth studies.

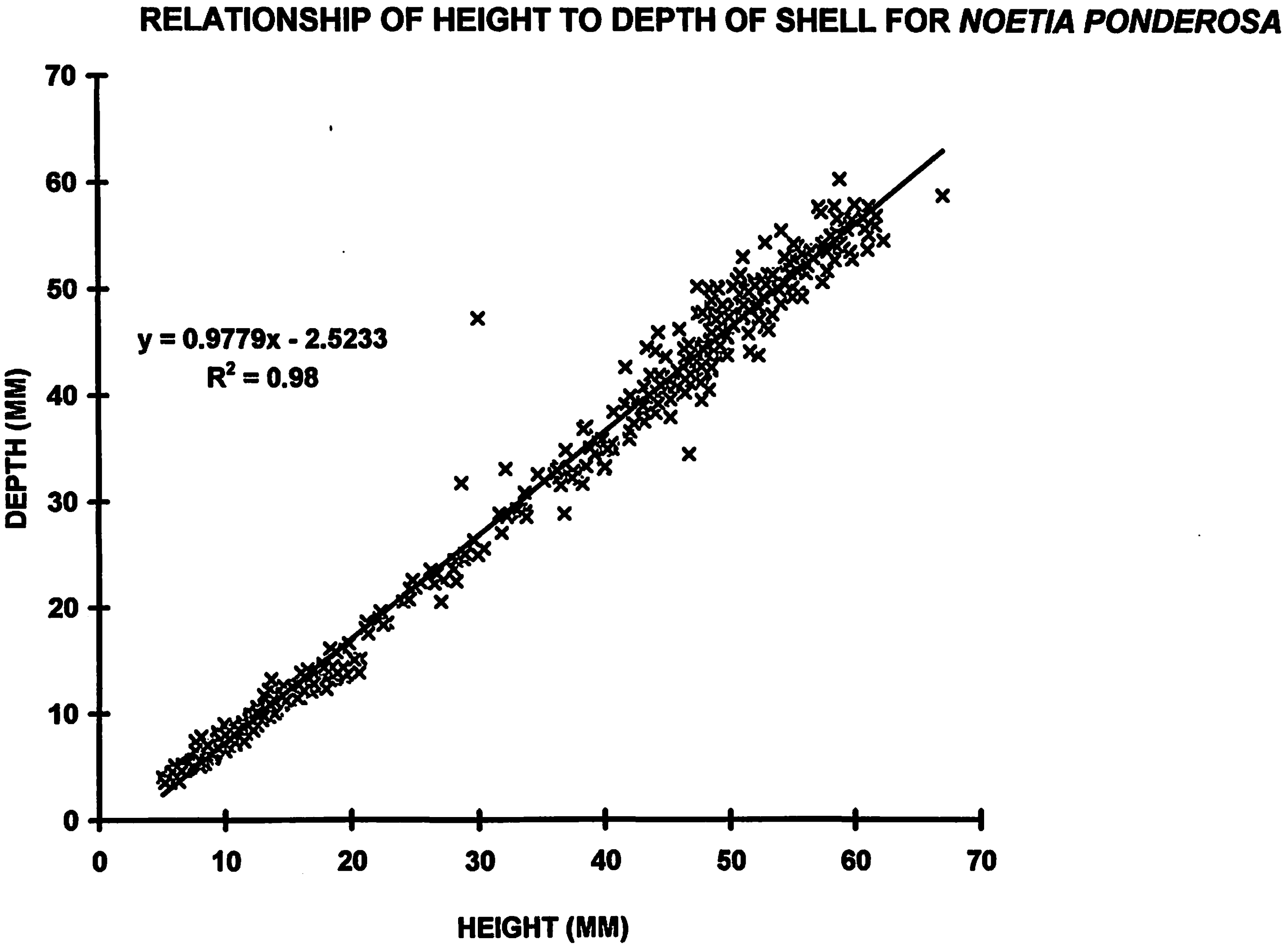


Figure 13. Regression of height vs. depth for *Noetia ponderosa*. Data are from several sources, including 1994 field survey, commercial fishery samples, and growth studies.

Relationships between height and weights (whole and meat weights) were nonlinear (Figs 14 and 15). For example, the relationship of height and whole weight (shell and meat) is described by the allometric equation of the form $W = aH^b$, where W = whole weight of the clam in grams, H = height in mm, and a and b are allometric coefficients (a = .0006 and b = 3.0298). Transformed to the linear form, this equation is: $\log W = b\log H + \log a$. Meat weight (defined as whole weight minus shell weight) and height were likewise nonlinearly related by the equation $M = aHb$, where M = meat weight, H = height of the clam in mm, a = 0.0012, and b = 20469 (Fig. 15). The coefficient of determination, r^2, = .842, is slightly lower than that for height and whole weight; however, meat weight determinations are subject to more sampling error, mostly because of varying amounts of water loss. For the data used, the mean shell weight was 46.8 g. (± 36.3, n = 132), and mean whole wet weight of *Noetia* was 60. 5 grams (± 44.06, n = 132), or approximately 77% of the total weight. Mean meat weight ($\overline{X}$ = 13.6 g) was only about 23% of the total weight of the clams sampled.

The relationships of height and length and height and shell depth for *Anadara* were linear (Figs 16 and 17). Unlike *Noetia*, shell length in *Anadara* changes little in relationship to the height, and most, as the name (*ovalis*) implies, are oval or nearly round. The height-depth relationship (Fig. 17), expressed as $D = 0.739H - 0.885$ ($r^2 = 0.934$), is slightly improved ($r^2 = 0.96$) using a power equation: $D = a\log H^b$, where $a = 0.6612$, b = 1.0143, D = shell depth, and H = shell height. By comparison, increase in shell depth in *Anadara* per increase in shell height is proportionately smaller than that in *Noetia*, in which shell depth is almost equal that of height. For *Anadara*, shell depth is approximately 70% of shell height.

The relationship of whole weight and height in *Anadara* (Fig. 18) is best described by the curvilinear equation: $W = aH^b$, where W = whole weight in grams, H = height in mm, a = .0003, and $b = 3.136$ ($r^2 = 0.967$). As with *Noetia*, meat weight (Fig. 19) was more variable

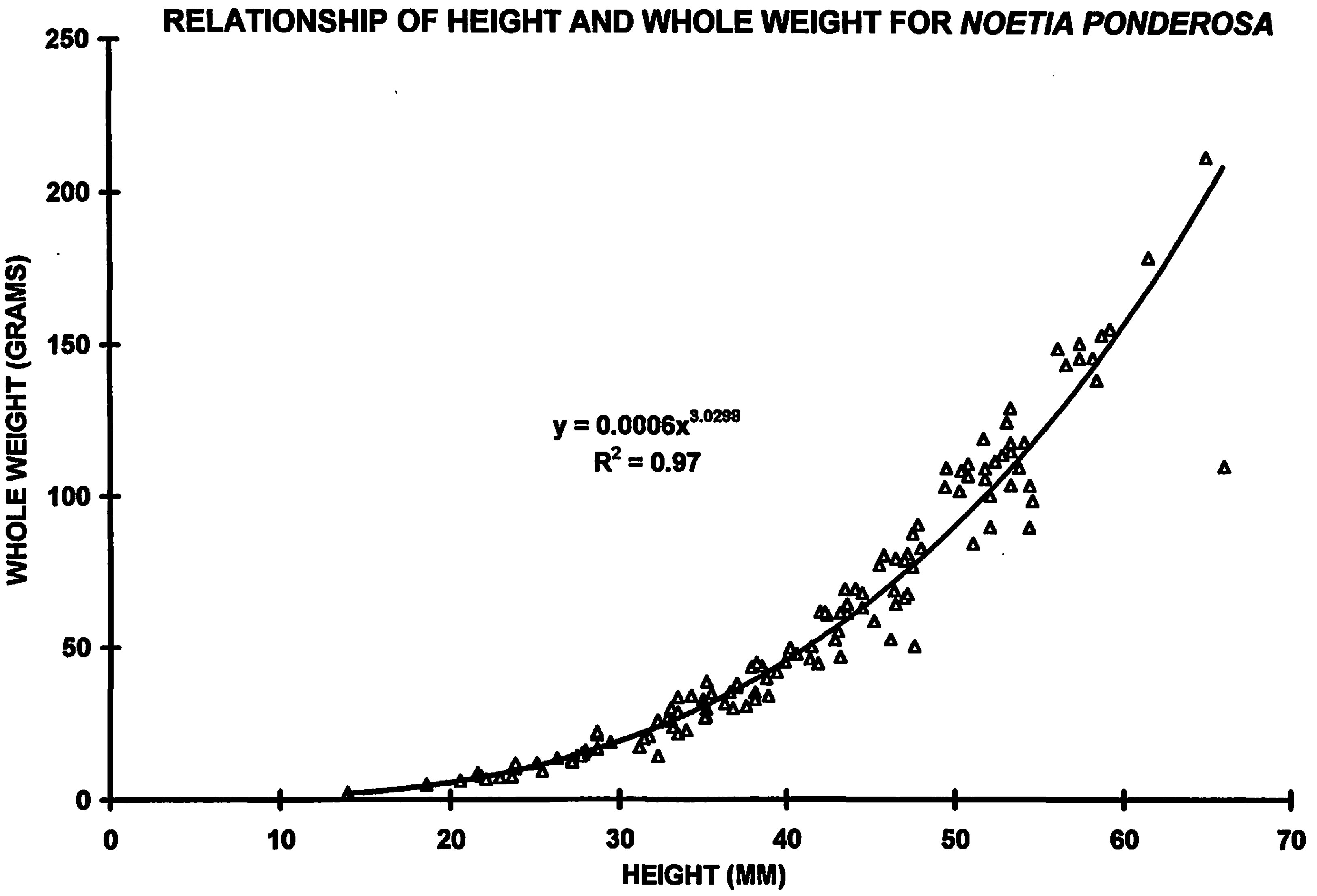


Figure 14. Relationship of height and whole weight for *Noetia ponderosa*. Data are from several sources, including 1994 field survey, commercial fishery samples, and growth studies (n=132).

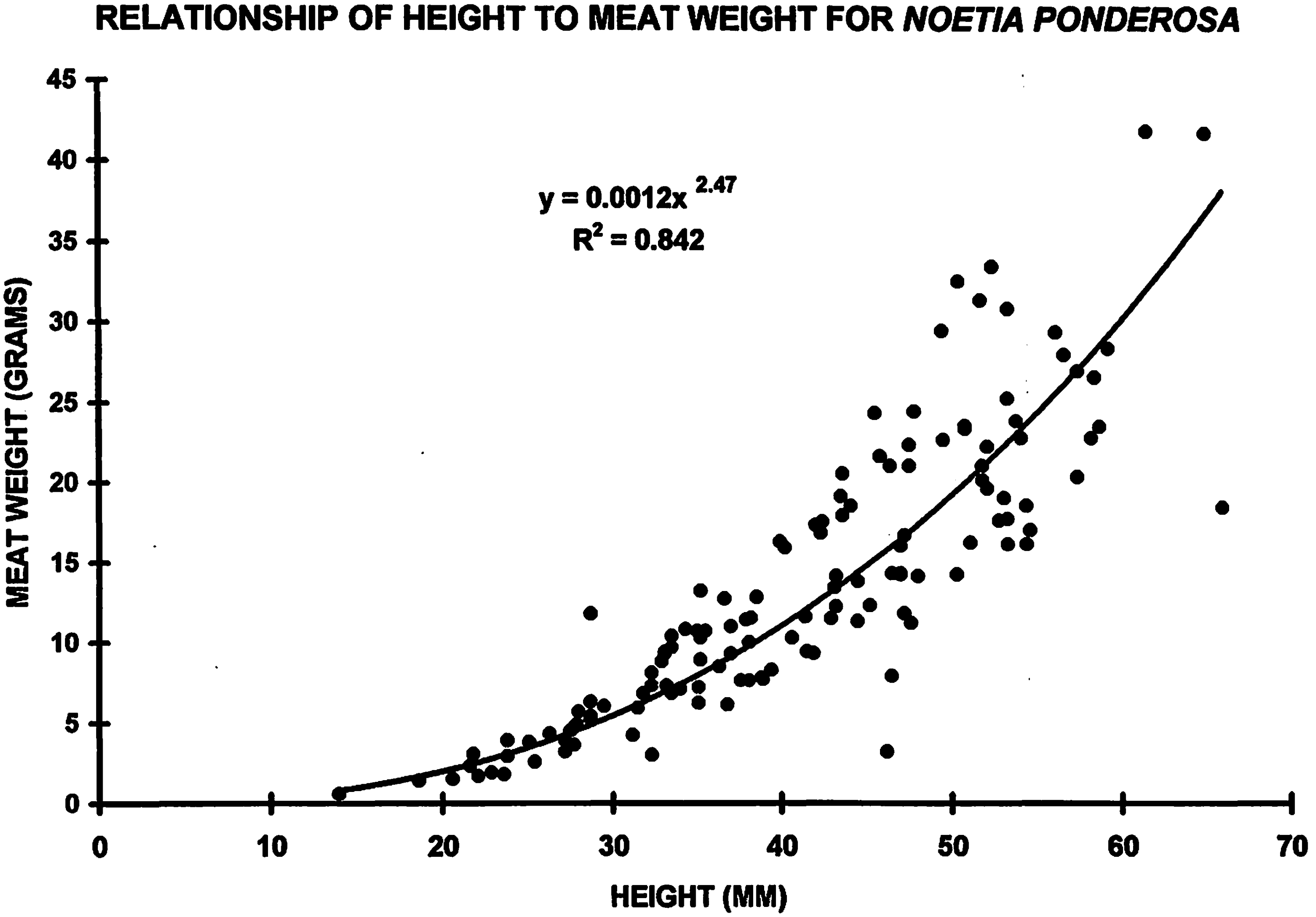


Figure 15. Relationship of height to wet meat weight in *Noetia ponderosa.* Data are from several sources, including 1994 field survey, commercial fisheries samples, and growth studies (n=132).

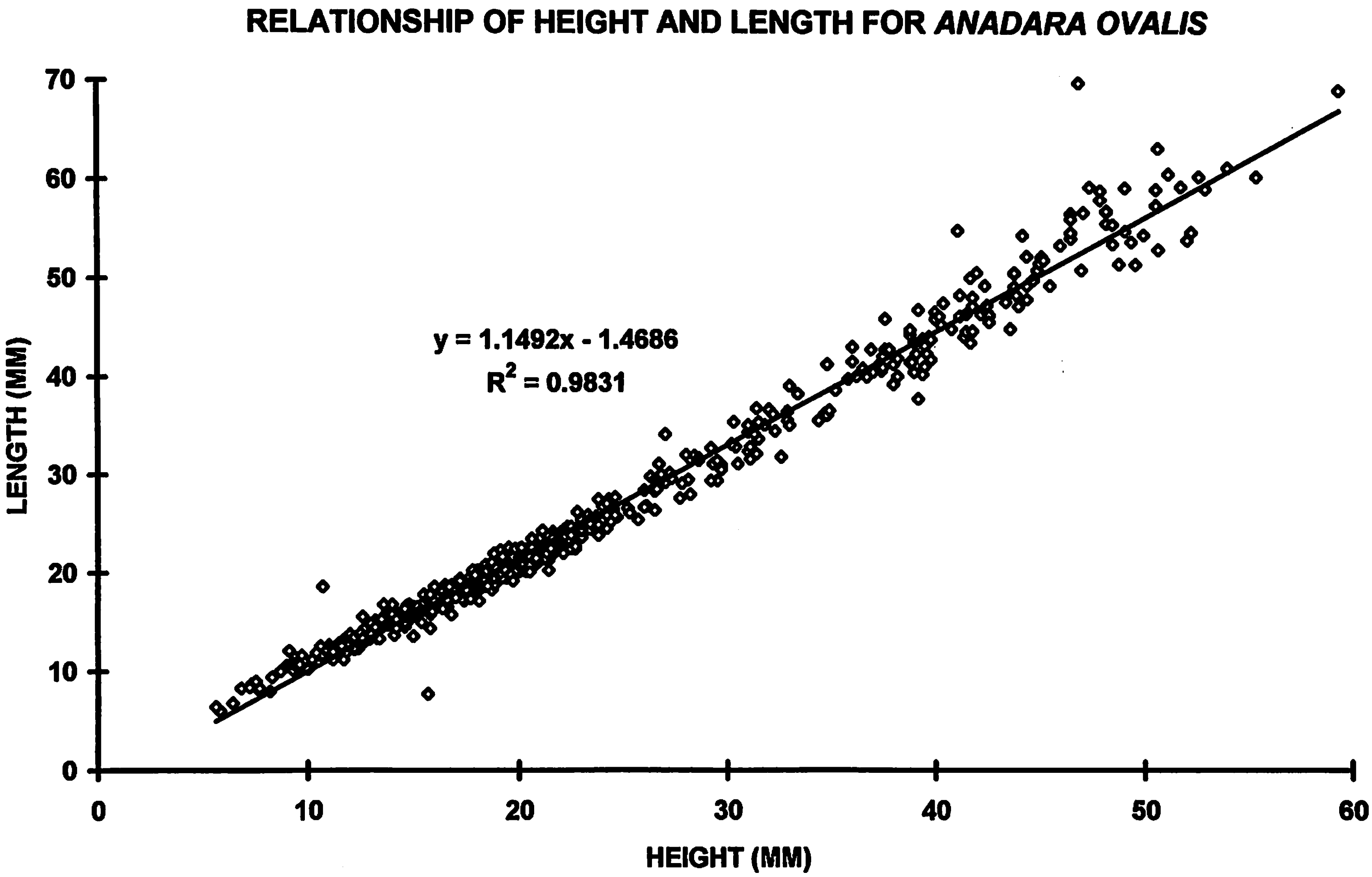


Figure 16. Regression of height vs. length for *Anadara ovalis*. Data are from several sources, including 1994 field survey, commercial catches, and growth studies (n=778).

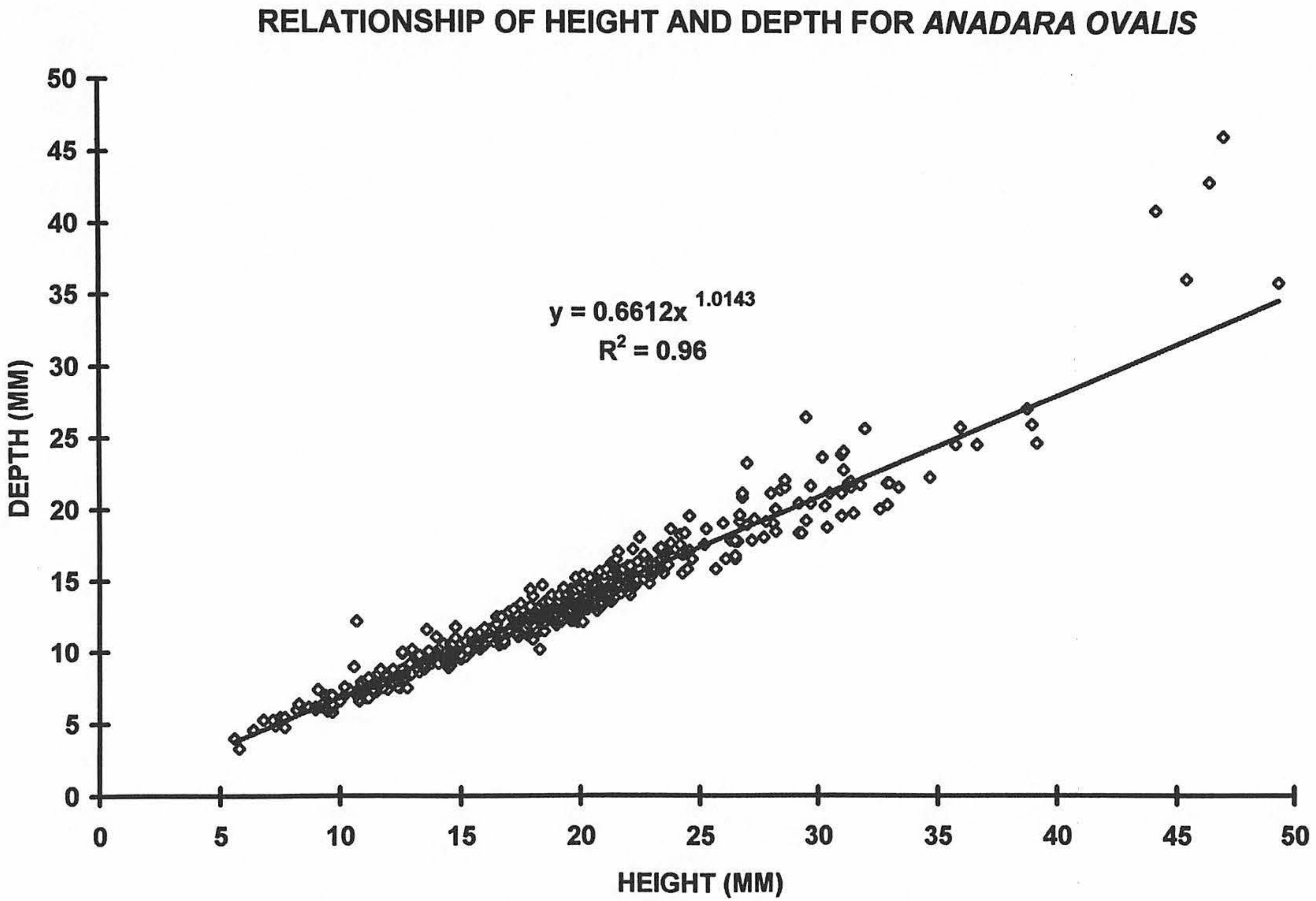


Figure 17. Regression of height and depth for *Anadara ovalis*. Data are from several sources, including 1994 field survey, commercial catch samples, and growth studies (n=641).

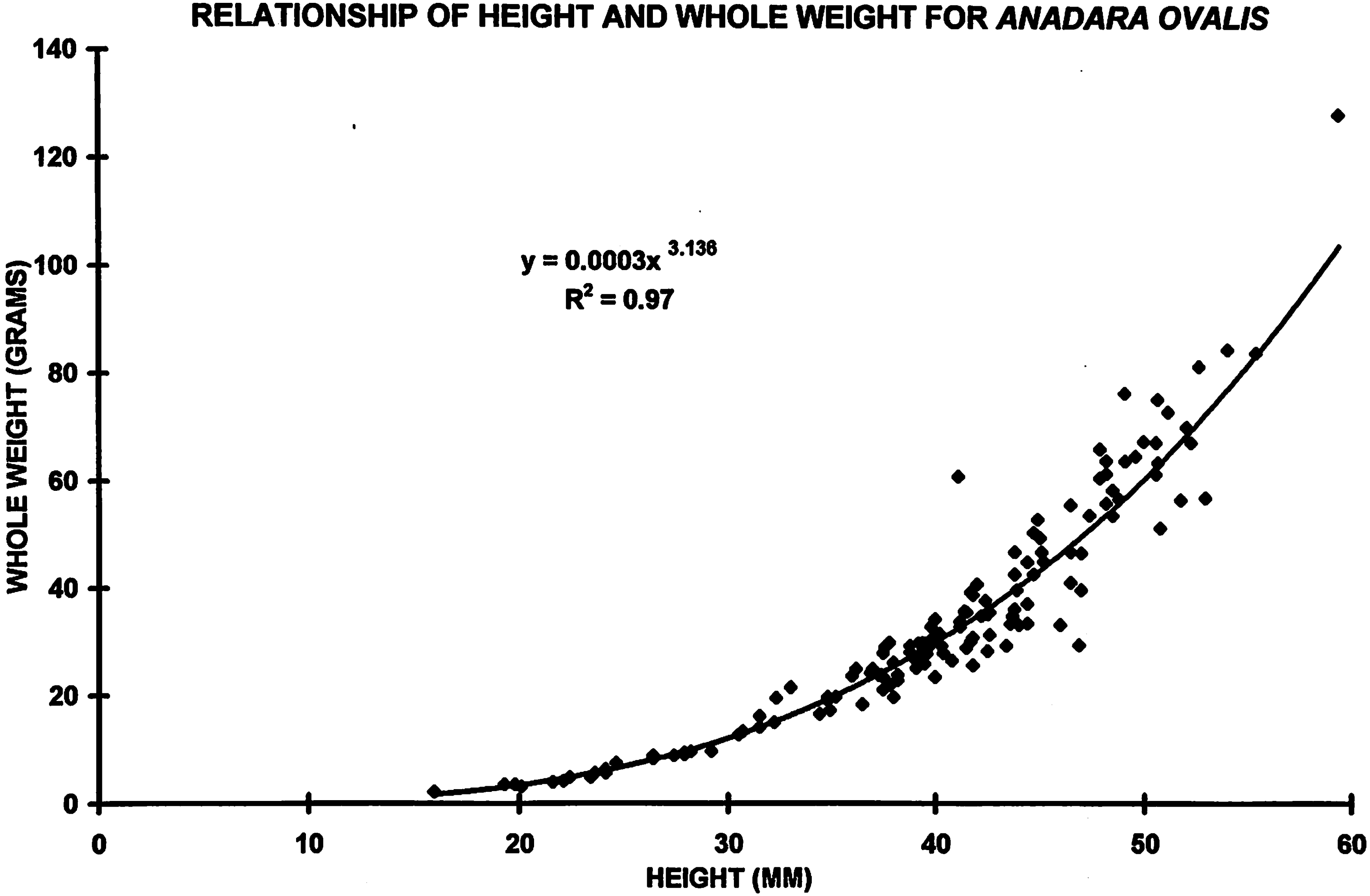


Figure 18. Relationship of height and whole weight for *Anadara ovalis*. Data are from several sources, including 1994 field survey, commercial catch samples, and growth studies (n=139).

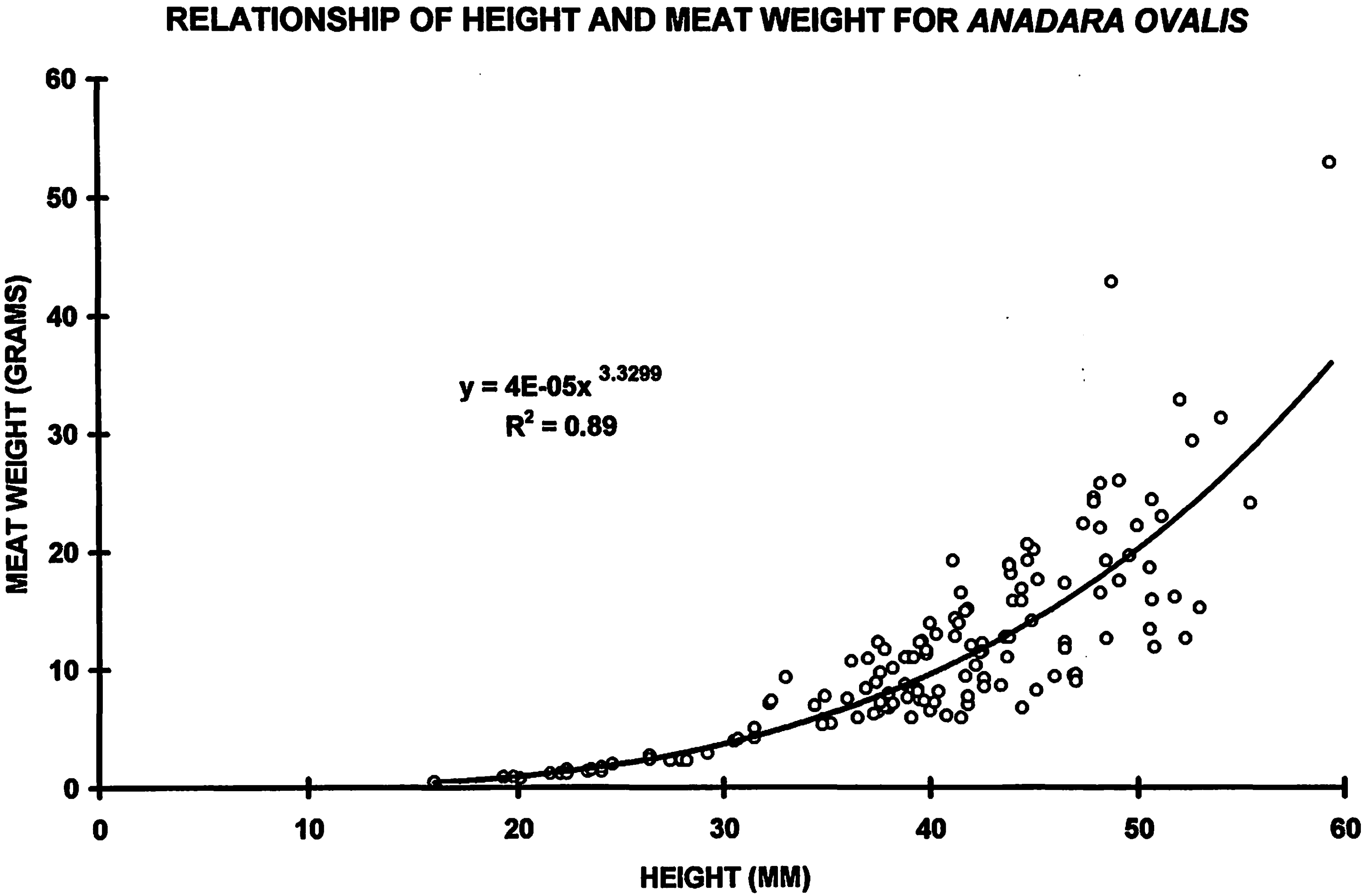


Figure 19. Relationship of height and wet meat weight for *Anadara ovalis*. Data are from several sources, including 1994 field survey, commercial catch samples, and growth studies (n=139).

than whole weight, and the coefficient of determination was slightly lower ($r^2 = 0.89$) than for the regression of height and whole weight ($M = 4E^{-05} H^{3.3299}$). Mean whole weight for the *Anadara* sample was 34.2 g (± 21.2, n = 139), mean shell weight was 22.7 g (± 14.2, n = 139), and mean meat weight was 11.5 g (± 8.2, n=139). Shell weight constituted about 66% of total weight, and meat weight 34%, or about 10% more than *Noetia*.

6. Age-size relationships

Acetate peels were prepared from clams taken in the field survey and augmented by clams purchased from fishermen. Some data from recent growth studies (1992- 1994) were incorporated as baseline data points for one and two year old *Anadara* and *Noetia*, as well as some data from a previous study. Age- height data for *Noetia* are summarized in Table 8 and Fig. 20. The equation which best fits the shell height and age data for *Noetia* is a second degree polynomial, $H = -0.3023A^2 + 7.9582A + 2.9112$, where H = height in mm and A = age in years ($r^2 = 0.94$, $p \leq .001$) . Growth increments are very small for *Noetia* after the first 4-5 years, and growth lines are sometimes difficult to determine within a 2 year period for older clams. However, after very careful examination of the acetate peels, we are confident that the data presented are reasonably accurate. Growth data (Fig. 20) show that larger clams (i.e., ≥ 50 mm) will probably be about 8 years old or older. Mean height of clams from a fishery sample in 1992 was 56 mm. Using the polynomial equation derived from the shell aging study, 56 mm clams would be approximately 10+ years old. More recent fisheries data (1994) in catches from the same vicinity showed that the average size (height) of *Noetia* was about 45 mm (a decrease in mean height of about 10 mm), or clams of about age 6+. In addition, mean height for *Noetia* in field survey samples was about 43 mm, which may indicate that the older clams are being depleted and smaller, younger clams are now being harvested.

Table 8. Age and mean height for *Noetia ponderosa* on the Eastern Shore of Virginia. Data are from several sources, including 1994 field survey, growth studies, and clams purchased from local watermen.

AGE	MEAN HEIGHT (MM)	ST. DEV. (MM)	RANGE (MM)	N
0+ - 1	8.99	1.5	5.2 - 12.5	101
1+ - 2	16.3	2.7	10.0 -28.7	181
2+ - 3	28.7	3	23.8 - 34	8
3+ - 4	35.5	3.6	31.2 - 41.9	12
4+ - 5	37.6	5.4	31.8 - 47.2	12
5+ - 6	41.2	5.2	33.5 - 50.3	13
6+ - 7	44.9	3.8	38.2 - 51.8	8
7+ - 8	46.1	3.2	41.5 - 50.8	6
8+ - 9	48.6	4.3	42.0 - 54.6	8
9+ - 10	50.6	7.2	43.2 - 61.5	6
10+ - 11	52.7	5.4	42.4 - 58.7	6
11+ - 12	52.6	4.9	47.5 - 57.4	3
12+ - 13	53.9	5.5	47.8 - 60.0	5
13+ - 14	54.5	3.3	51.7 - 58.4	4
14+ - 15	56.5	5	50.4 - 65	6

Age and size data for *Anadara* (Table 9 and Fig. 21) are best described by the linear regression equation $H = 6.88A + 14.89$, ($r^2 = 0.83$), where H = height in mm and A = age. A slight, but not significant, improvement in fit ($r^2 = 0.83$) was obtained with a second degree polynomial equation. A curvilinear regression ($H = 8.57 \ln A + 26.11$) yielded an even smaller coefficient of determination, $r^2 = 0.71$, and was not as good a fit for the data as the linear equation. Mean height for *Anadara* taken in the field survey was 25 mm, or about 1+ - 2 year class clams, while mean height for a fisheries sample (1994) was about 40 mm, or 3.5 + years old. Although the linear equation fits the data, a polynomial equation or Von Bertalanffy growth curve would be more realistic, as growth increments clearly decrease (i.e.,

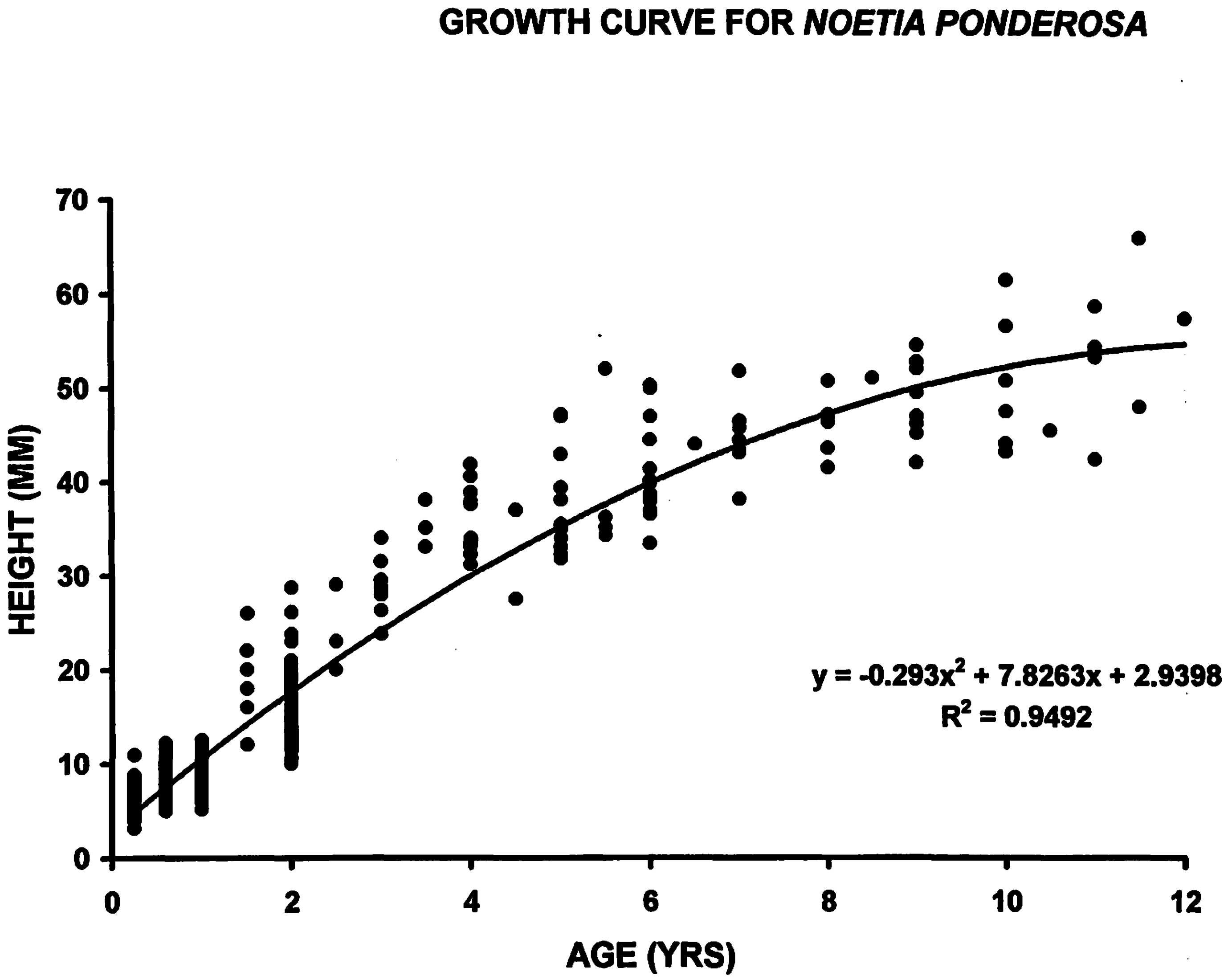


Figure 20. Growth curve for *Noetia ponderosa* from the Eastern Shore of Virginia (includes clams from growth study) (n=609).

become asymptotic) after about age 4 - 4.5 years. We obtained only 5 *Anadara* over 5 years in age, which suggests that this species does not live very long, at least on the Eastern Shore of Virginia. This is also suggested by the mortality data from articulated shells, where mortality rates increase abruptly after the first two years.

Table 9. Age and mean height for *Anadara ovalis* from the Eastern Shore of Virginia. Data are from several sources, including 1994 field survey, growth studies, and clams purchased from local watermen.

AGE	MEAN HEIGHT (MM)	STANDARD DEVIATION (MM)	RANGE (MM)	N
0+ - 1	21.9	1.67	18.4 - 26.3	74
1+ - 2	36.2	3.58	32.2 - 39.1	3
2+ - 3	41.5	4.03	31.5 - 48.2	24
3+ - 4	42.6	5.19	32.3 - 54	40
4+ - 5	48.1	4.20	39.6 - 51.8	12
5+ - 6	49.3	9.20	34.9 - 59.5	5

B. Fisheries Catch Data

We obtained some catch data on blood clams in the study area from Mr. David Bishop, a commercial fisherman on the Eastern Shore. Ratios of blood clams to hard clams and size-frequency data were gathered from some of his daily catches in September, October, and November, 1994. Approximately 20% - 30% of Mr. Bishop's total clam harvest is *Noetia*, about 10% is *Anadara*, and the rest is *Mercenaria*. Actual catch data approximate the species distributions from survey data. Mr. Bishop's daily average catches (Table 10 and Fig. 22) for September, October, and November, 1994 were: 4,373, 3,872, and

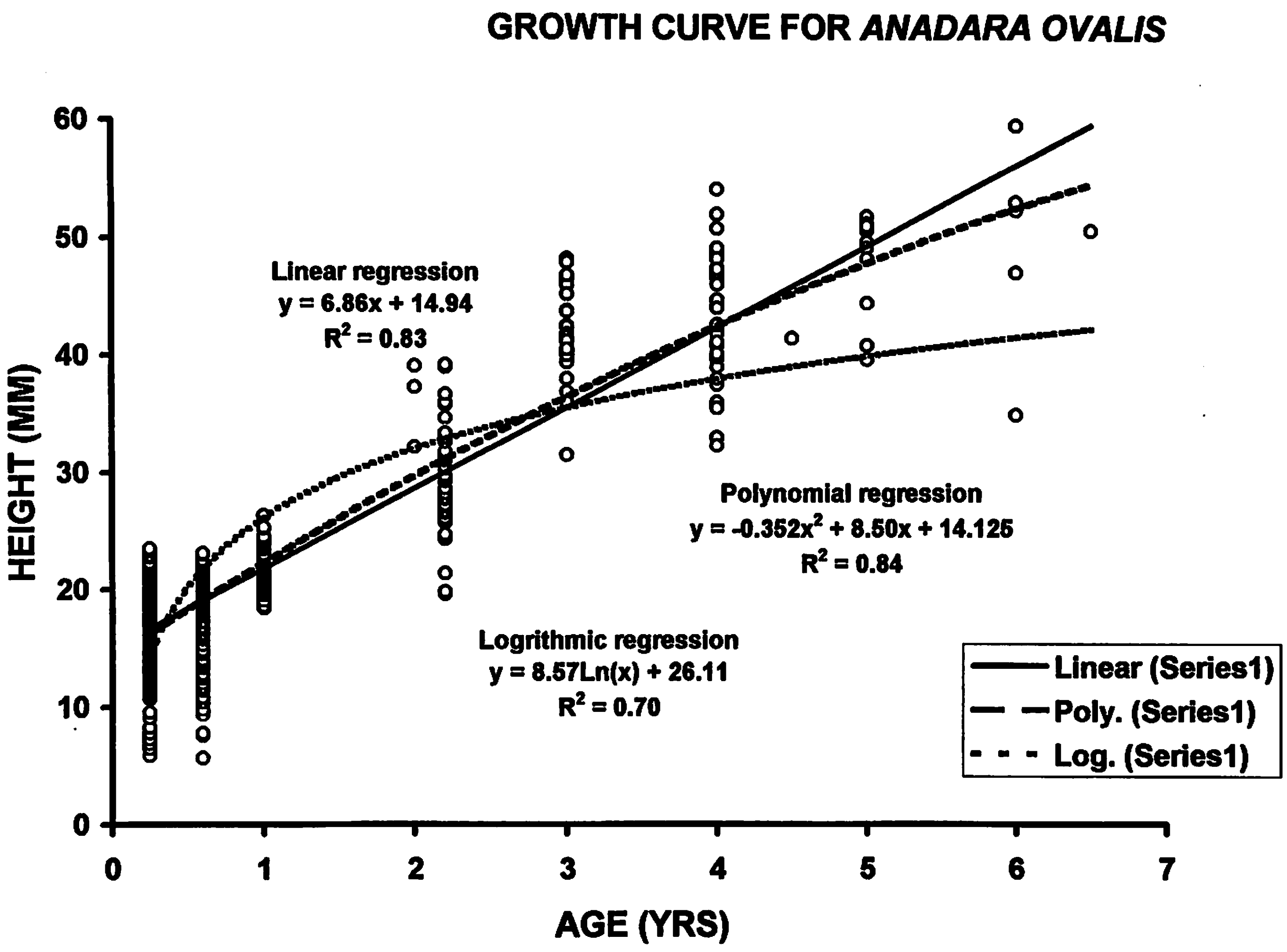


Figure 21. Growth curves for *Anadara ovalis* from the Eastern Shore of Virginia (includes clams from 1994 field survey, commercial catches, and growth study; n = 560).

3,642 clams per day, respectively. The percentages of blood clams in catches for those three months were about 18% for September, 21% for October, and 26% for November.

Table 10. Average daily catches on the Eastern Shore of Virginia for September, October, and November, 1994 (data provided by Mr. David Bishop of Oak Hall, VA.).

AVERAGE DAILY CATCHES			
MONTH	*MERCENARIA*	BLOOD CLAMS	TOTAL
SEPT 94	3575 (±516.6, N=4)	798 (±72.7, N=4)	4373 (± 568.8, N=4)
OCT 94	3079 (±759.9, N=19)	793.7 (± 277.1, N=19)	3872.6 (± 783.5, N=10)
NOV 94	2710 (± 1.85.8, N=10)	931.6 (± 629, N=10)	364.6 (± 1081, N=10)

On November 11, 1994, and January 12, 1995, we collected some additional catch data from Mr. Bishop's commercial catches in the area. On November 11, 540 "tries" or grabs with tongs yielded 4400 *Mercenaria*, 774 *Noetia*, and 75 *Anadara*, for a total of 5,249 clams, or a catch per unit effort of 9.72 clams. The corresponding percentages of the catch were as follows: *Noetia*, 14.7%; *Mercenaria*, 83.8%; and *Anadara*, 1.4%. The average heights of *Noetia* and *Anadara* were 44.7 mm and 34 mm, respectively (Figs 23 and 24). The November samples were taken in Little Gap Channel and Sandy Island Channel, just south of Quinby. However, during December Mr. Bishop worked in an area just north of

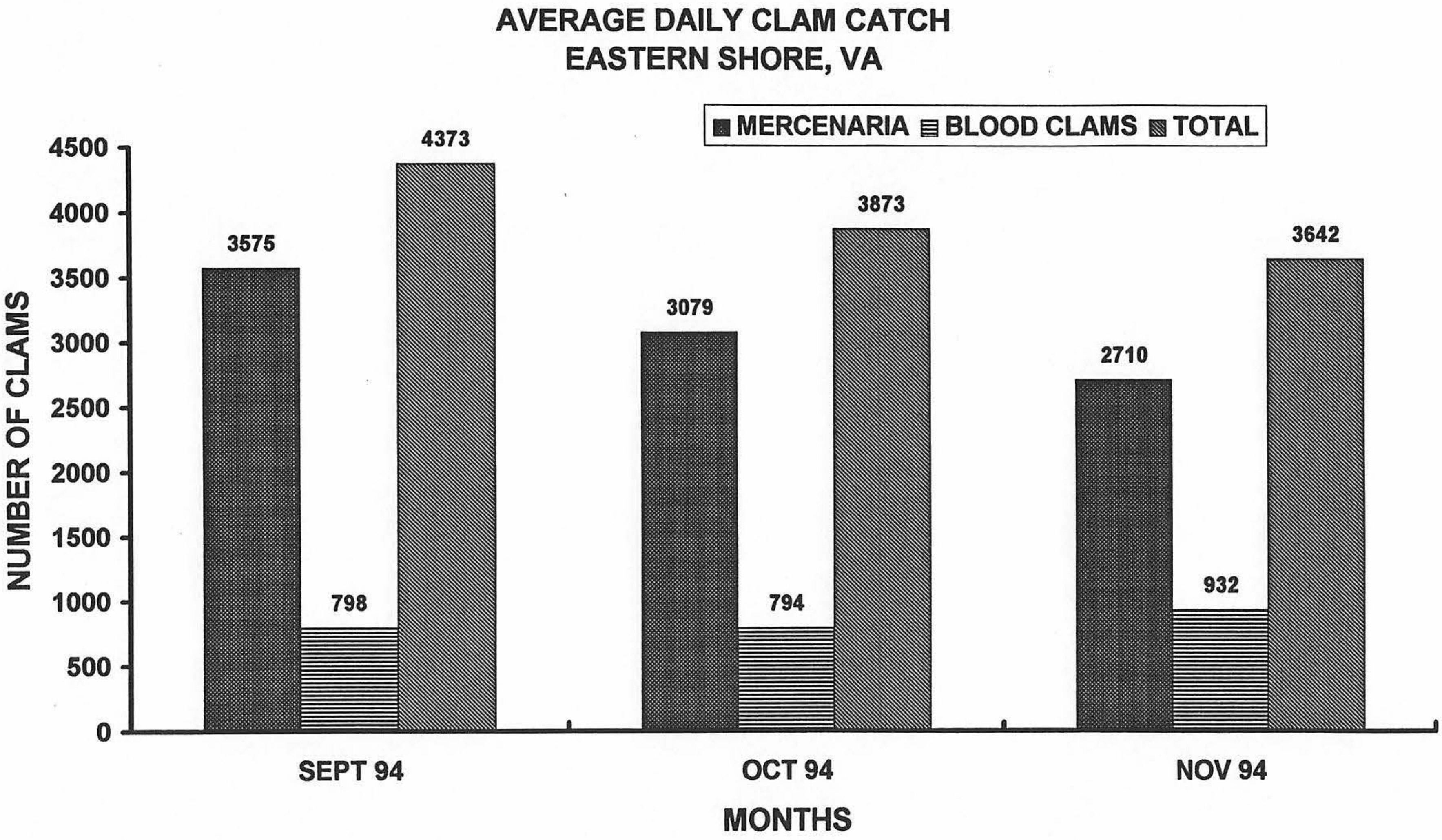


Figure 22. Average daily catch for one waterman, by species, during September, October, and November, 1994, on the Eastern Shore of Virginia.

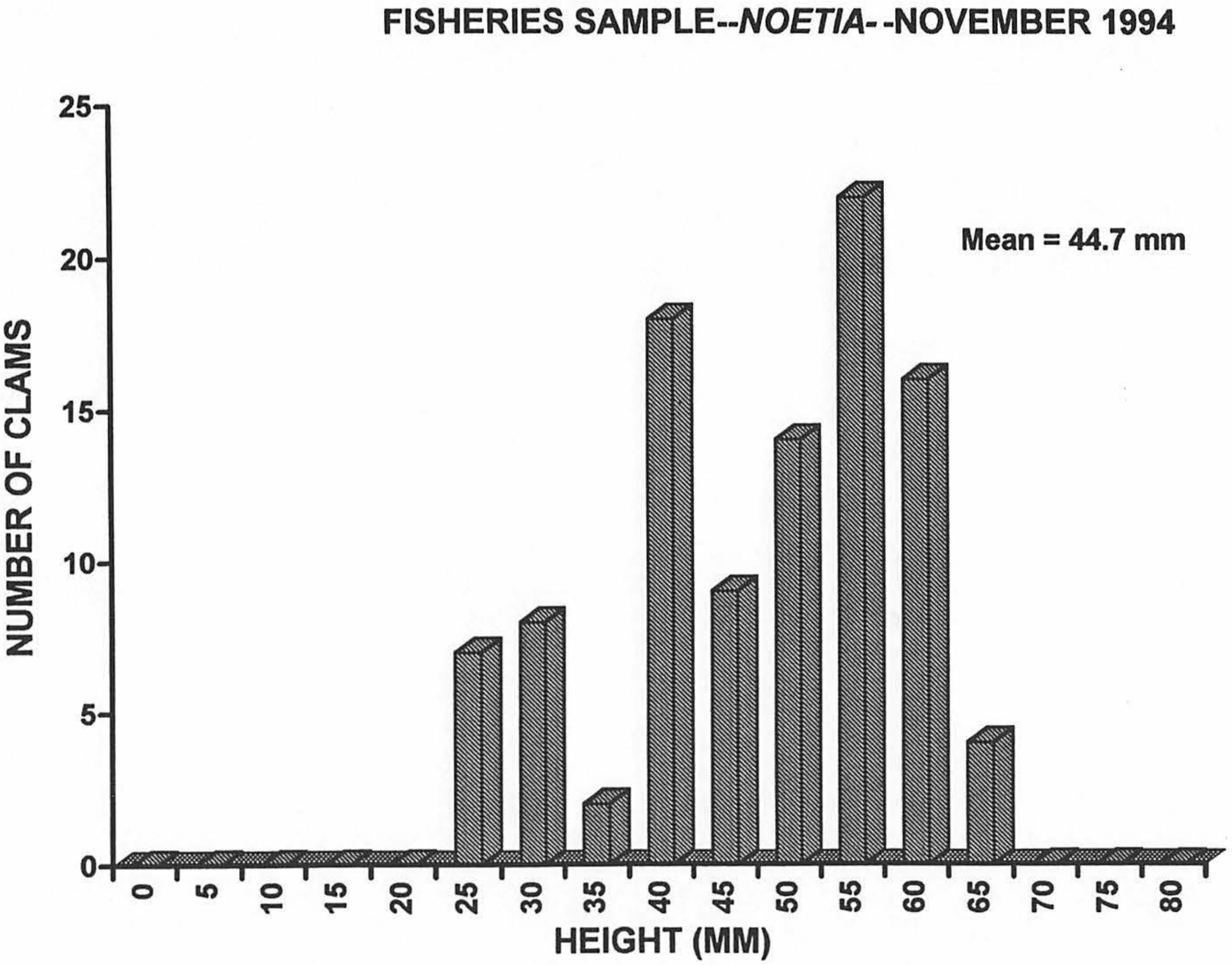


Figure 23. Height-frequency data for *Noetia* subsample from Mr. David Bishop's catch, November 1994 (n=100).

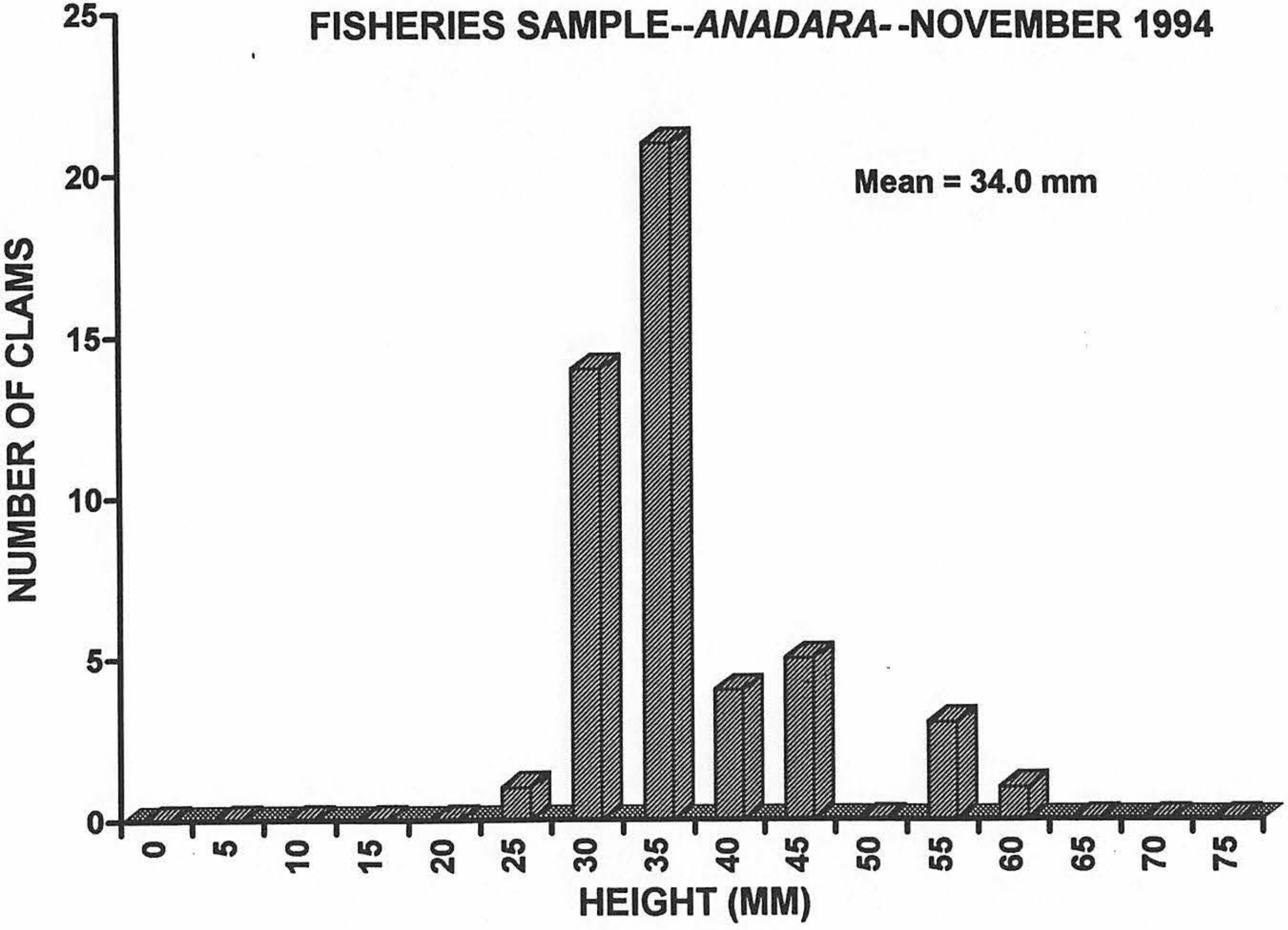


Figure 24. Height-frequency data for *Anadara* subsample from Mr. David Bishop's catch, November, 1994, from Little Gap channel, southeast of Quinby (n=49).

Wachapreague (Gargatha Creek) and caught almost all *Anadara ovalis*, the highest percentage catch of that species of which we are aware.

The average height for *Anadara* from the January sample in Gargatha Creek was 40.2 mm (Fig. 25). Most of the clams were in the 35 - 40 mm size range, or about 2.5 - 3 years old. The absence of 0+ year class *Anadara* in commercial fisheries samples may simply reflect the difficulty in seeing and collecting very small clams in the mud and debris which accompany catches; however, it may also indicate low recruitment and/or high mortality rates. Also, during field surveys we used a 1 cm^2 plastic mesh, which retained smaller clams.

C. Description of Additional Work:

The potential for expanding the market for blood clams seems good if sufficient quantities can be produced and harvested. A few clam growers on the seaside of the Eastern Shore have expressed some interest in trying to grow *Anadara ovalis* in addition to *Mercenaria mercenaria* on their leases to try and meet market demands. It would be advantageous to follow some hatchery-produced cohorts of *Anadara* planted on leases in order to ascertain mortality rates and growth rates at given densities so that growers can maximize their production of *Anadara*. Studies of natural recruitment may also provide ways to augment hatchery production and planting with natural production.

In addition, there is at least one other species of blood clam, (e.g., *Anadara transversa*), in some of the drainage systems of the Chesapeake Bay (i.e., the James River) which might be harvested to fill market demands. To our knowledge blood clams in the Chesapeake Bay have not been harvested to any extent, if at all, and, as is the case with *Anadara ovalis* and *Noetia ponderosa*, little is known regarding abundance, distribution,

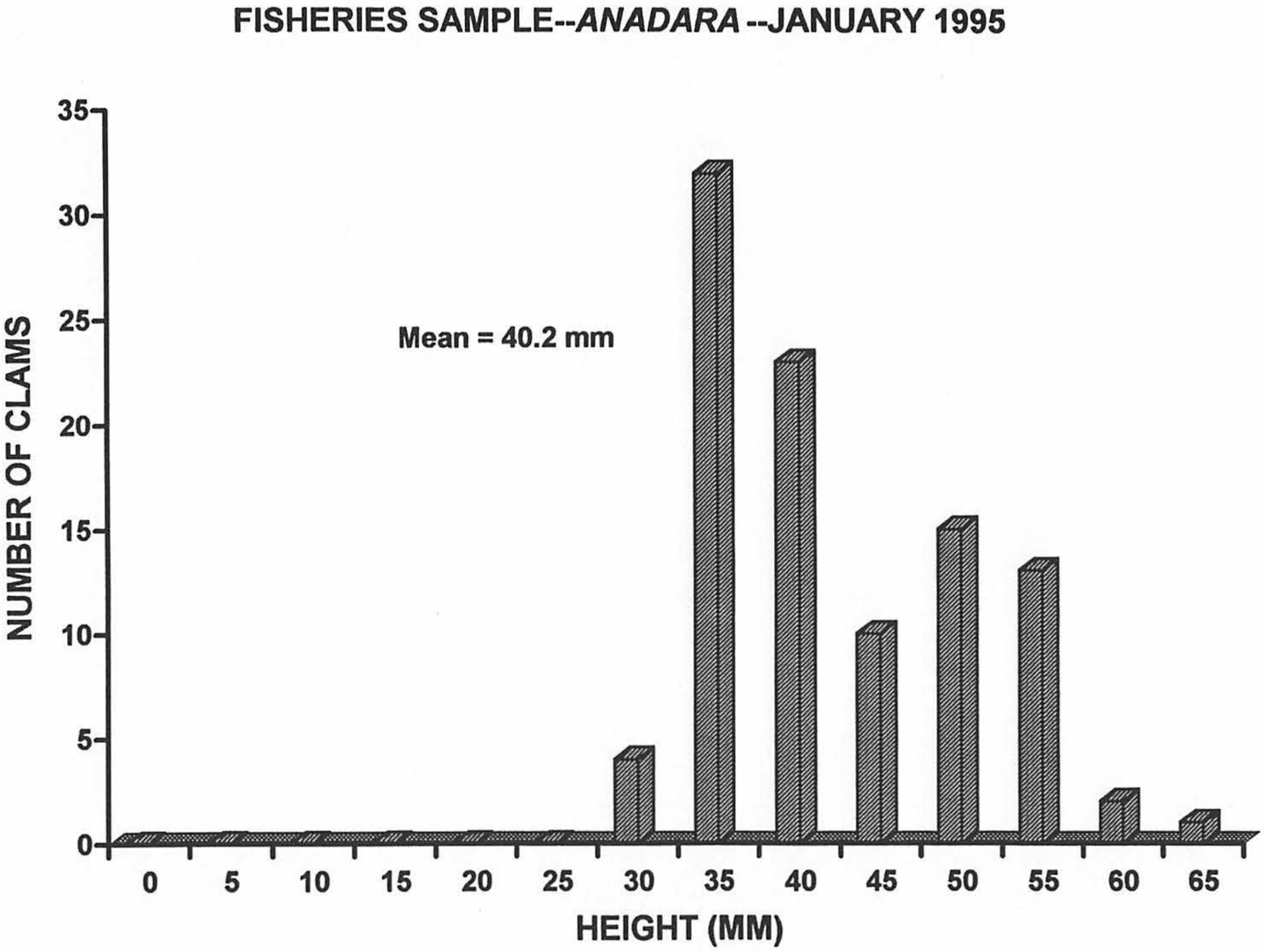


Figure 25. Height-frequecy data for *Anadara* subsample from Mr. David Bishop's catch, January, 1995, from Gargatha Creek (n=100).

growth and mortality rates, and other aspects of life history. A study of blood clam species in parts of the Chesapeake Bay in the near future may provide information which would allow some limited harvesting of blood clams there and possibly avert a situation of overharvesting as has occurred recently with blood clams on the oceanside of the Eastern Shore.

VI. SUMMARY AND CONCLUSIONS:

Survey data substantiate anecdotal information with regard to the species composition of the clam fisheries on the Eastern Shore of Virginia. That is, *Mercenaria* constitutes the majority of the catch, with *Noetia ponderosa* accounting for about 20% and *Anadara ovalis* 10%. However, age-height relationships clearly show that *Noetia*, even though it is more abundant than *Anadara*, is a relatively slow-growing species, and may not be suitable for a fisheries with high exploitation rates. *Anadara*, with a faster growth rate, appears to have a very high mortality rate in most areas, as indicated by the few, small ones that were taken in survey samples. We estimated abundance for *Noetia* and *Anadara* at about 15.2 million and 9.6 million clams, respectively, in the general area surveyed. Some harvest estimates for blood clams were as high as 10,000 clams per day at times during the last two years. If we assume this is correct and also assume this yield for 6 months out of the year, the yearly harvest would be 1.8 million blood clams (mostly *Noetia*), and could be sustained by the present population for about 8 years, without considering recruitment and natural mortality. However, data from Parting Creek and other commercial catch data show a decrease in average size of *Noetia*, indicating that *Noetia* is currently being overfished and that the Virginia Marine Resources Council may need to re-evaluate the current policies governing clam fisheries on the Eastern Shore. Some fishermen have also indicated that they are looking for other work because the population of clams is too low for them to continue fishing.

Given the slow growth rate of *Noetia*, it may be more advantageous to do one of the following: 1) allow clam harvesting only with mechanical tongs; 2) set a limit on the number of *Noetia* that can be harvested per year; 3) set aside certain areas with high densities of *Noetia* (e.g., Machipongo Channel), as spawning areas where *Noetia* may not be harvested; 4) rotate areas which may be harvested and close harvesting in others to allow numbers to increase; 5) produce *Noetia* seed clams in hatcheries or nurseries and use these to establish clam beds in different areas which are opened only on a rotating basis; 6) provide additional substrate (i.e., shells) for recruitment for both *Noetia* and *Anadara*; 7) consider harvesting other species of blood clams from drainage systems in the Chesapeake Bay. In any case, it would be helpful to accumulate more accurate catch data for both hard clams and blood clams on the Eastern Shore.

Because of its fast growth rate, *Anadara ovalis* may be a good candidate for aquaculture ventures on the Eastern Shore. There are already a few clam growers in the area who have expressed interest in culturing *Anadara* in conjunction with *Mercenaria* on their leases. In addition, researchers in Georgia may soon begin some experiments to study the feasibility of growing *Anadara* on the Georgia coast. If *Anadara* can be cultured and marketed profitably, this may augment or supplant the harvest of *Noetia* and, possibly, remove some of the fishing pressure from that species. Otherwise, the population of *Noetia* on the Eastern Shore may decline rapidly over the next several years.

VII. EVALUATION

The major goals and objectives of the project were attained. In addition, we were able to gather some useful fisheries data from local watermen, which provided further insight into the blood clam fishery on the oceanside of the Eastern Shore of Virginia. We believe that the data and information collected during the project and presented in this report will be useful in managing the blood clam fishery.

VIII. ACKNOWLEDGMENTS

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