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QUANTITATIVE MUSSEL SURVEY IN POOLS 22 AND 24 OF THE UPPER MISSISSIPPI RIVER AT MRM 300 AND 309 DURING SUMMER, 1988

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EXECUTIVE SUMMARY

Quantitative mussel surveys were conducted at two locations in the Mississippi River during 1988, one in Pool 24 Mississippi River Mile (MRM) 300 below Lock and Dam 22 in Ralls County and another in Pool 22 (MRM 309) near Hannibal in Marion County. Both sites were in the main channel border, with substrate consisting primarily of sand, gravel and rock with some finer sediment along the shore. These surveys provided us with valuable insight into the density and size/age structure of several common mussel species, although much remains to be learned.

Total numbers of mussel species recorded at MRM 300 and MRM 309 were 19 and 20 respectively. Previous qualitative surveys recorded 32 species from Pools 22 and 24. Mussel density was remarkably similar at both sites with 24 mussels per square meter at MRM 300 and 22 per square meter at MRM 309. These densities were low compared with densities averaging 125 mussels per square meter in other pools. Standing crop estimates for the 48,000 square-meter areas sampled at MRM 300 and 309 were 1,166,400 and 1,060,800 respectively. The mean age of selected living mussels ranged from 2.7 years for the fawnsfoot to 22.4 years for the washboard. Length and age distributions for selected species were similar at the two sites; however, not enough is known of mussel population dynamics to state confidently that these samples reflect river-wide conditions.

Recruitment of juvenile mussels seems low in some species, especially the commercially valuable washboard and threeridge. Recruitment may occur sporadically or at regular lengthy intervals in certain species. We have evidence which suggests that the washboard may be recruiting at 4-5 year intervals.

The management of this resource may best be approached on a long term monitoring basis. Additional surveys should include detailed substrate analyses, more accurate ageing techniques and sampling of different habitats. However, the immediate concern with potential overharvest of commercial species, considering their low and sporadic recruitment, provides the justification to obtain additional baseline data.

INTRODUCTION

Few quantitative data exist regarding the mollusk fauna in the upper Mississippi River, especially in that portion bordering Missouri. Basic information must be acquired before we can begin managing this unique and valuable resource. This report provides quantitative and qualitative information on two mussel communities in Pools 22 and 24. Mussel communities may exist in various portions of the Mississippi River depending upon available habitat. The two areas discussed herein exist along a suitable portion of the main channel border.

Background

Little interest was shown in the mussel resource in the Mississippi River prior to the discovery that the shell could be used in the manufacture of buttons. Beginning in the late 1800's, the mussel resource in the Upper Mississippi experienced extensive harvest and depletion due to this demand. The concern about over-harvest caused considerable interest in the early 1900's and resulted in the establishment of a research station by the U.S. Bureau of Fisheries at Fairport, Iowa. Efforts were conducted there to prevent depletion of the mussel resource but were suspended, in part due to pollution in the river preventing establishment of new mussel "beds". The harvest of mussels diminished in the 1920's-30's and eventually ceased during the 1940's-50's due in part to depletion of the resource and the manufacture of plastic buttons. Harvest resumed during the 1960's as mussels were utilized in the production of cultured pearls. Harvest of this resource has continued to the present. Recent harvest in Missouri was first observed in 1982 (Gordon Farabee, pers. comm.) and has continued and increased in recent years.

In addition to the economic value of this resource, mussels are valuable as biological indicators of environmental quality. Juvenile mussels are being used in toxicity tests (TVA, Don Wade, personal communication) and mussel communities are being evaluated as to their role in attracting sport fish (ILDOC, personal communication). Although there has been recent renewed interest and attention given to the mussel resource, much remains to be learned about the mussel fauna of the Mississippi River.

METHODS

Preliminary site selection was done by brailing to ascertain if mussels were present and to determine the extent of the mussel community. Two sites were selected for sampling, one in Pool 24 at Mississippi River Mile (MRM) 300.0, located approximately one mile downstream of Lock and Dam 22 on the Missouri side of the navigation channel (Figure 1). The second site was located in Pool 22 at MRM 309.0 near Hannibal (Figure 2) on the Missouri side of the channel. Both sites were situated between the navigation channel and shoreline along the open river, with substrate consisting primarily of sand, gravel and rock with some finer sediment along the shore. At each site, the total area in which samples were collected was 48,000 square meters, delineated by an area 800 meters in length and 60 meters wide. At MRM 300.0 this area was contiguous; but at MRM 309.0 was separated by about 70 meters due to boat traffic which created unsafe sampling conditions.

Areas were subdivided into 100 meter by 60 meter sections and each section further subdivided into 20 meter by 10 meter sampling units. A total of 47 and 50 units were randomly selected from the 240 sampling units at MRM 300.0 and 309.0, respectively. Each unit selected for sampling was marked near its center with an anchored five gallon plastic jug. Measurements were made with a Ranging 1200 Rangematic-MK5 distance finder. A floating line was used to aid in marking off portions of the sample area.

Sampling was done by divers using a three-inch modified gold mining suction dredge. The tip of the suction dredge tubing was narrowed to 2 3/4 inches to prevent clogging by large objects. The sampling process began with the dive boat anchoring near the plastic jug to ensure collection would be within the selected unit. A metal 1/4 meter square quadrat frame was lowered to the river bottom. A diver holding the end of the suction tubing, followed the cord connecting the boat to the sampling frame. The diver first collected large mussels (>2 inches) by hand from within the sampling frame and placed the mussels in a fine mesh bag which was raised to the surface by the boat tender. The suction dredge was then activated and the diver moved the end of the suction tube over the substrate within the sampling frame, removing material to a depth of 4 to 6 inches. Material brought to the surface by the dredge exited onto a series of sieves. Sieves were constructed of a 2 by 4 inch redwood frame with an inside square measurement of 54.6 centimeters with openings of the following sizes, 11.1, 3.4 and 2.0 millimeters. Sieves were stacked on a frame under which a chute directed water and fine sediment over the boat's edge. When the diver signaled that sampling was completed, he then randomly moved the sampling frame from 2 to 5 feet and the sampling process was repeated.

Two samples were collected in each selected unit. Large, coarse material was discarded, but other material retained by the sieves was placed into plastic Ziploc bags and labeled, and later placed in a freezer for storage. Processing of material was accomplished by thawing and emptying the contents of the bag onto a metal tray. Mussels, snails and clams were then separated from the substrate, bagged, labeled and stored in a freezer. Organisms were later identified and height and length measurements to the nearest millimeter recorded on mussels and the Asian clam, Corbicula fluminea (Muller, 1774). Mussels were aged by determining and counting external growth rests. Some young mussels were designated as "age-plus" if it seemed that there was growth beyond the most recent annual growth rest. Old mussels sometimes received an "age-plus" designation when age was uncertain, but was greater than or equal to the number given. Mollusk names used in this report follow that of Turgeon et. al. (1988) except for the pocketbook mussel, which is referred to as Lampsilis ventricosa (Barnes, 1823) instead of L. cardium (Rafinesque, 1820), pending resolution of correct nomenclature.

RESULTS AND DISCUSSION

Mussel species recorded

The total number of species recorded during this survey at MRM 300.0 and MRM 309.0 were 19 and 20, respectively (Table 1). This compares to a record of 32 species (fresh dead or alive) from these two pools from various qualitative surveys or collections conducted since 1986. The species represented were typical of those which are likely to occur in habitat near the main channel border or open portion of the river experiencing substantial flow. Most species not recorded during quantitative sampling were either extremely rare and/or were not likely to occur in this particular habitat.

Snails and clams recorded

Three species of snails were recorded at both sites including the silty hornsnail, Pleurocera canaliculata (Say 1821), the olive mystery snail, Viviparus subpurpureus (Say, 1829), and the pointed campeloma, Campeloma decisum (Say, 1817). The Asian clam and an unidentified species of Sphaeriidae were present at both sites. Little is know about the snail fauna occurring in this portion of the Mississippi River; however, the sampling method used in this study possibly selected for the larger species. Smaller snails such as the hydrobiids and Physa spp. are present in the river. They either did not occur in our sampling locations or were not retained by our large-mesh sieve.

Mussel species density

For most species, densities were remarkably similar at both sites (Table 2). The deertoe, Truncilla truncata (Rafinesque, 1820) and the butterfly, Ellipsaria lineolata (Rafinesque, 1820) were approximately twice as dense at MRM 300.0 as at MRM 309.0. The mapleleaf, Quadrula quadrula (Rafinesque, 1820) was over three times as dense at MRM 309.0 than MRM 300.0 and was the dominant species numerically. The overall densities recorded at both of these locations was low compared to certain sites in other pools of the Mississippi River where an average of 125 (31 to 333) mussels per square meter have been observed (Miller, 1990).

Densities of the two primary commercial species, the washboard, Megalonaias nervosa (Rafinesque, 1820) and the threeridge, Amblema plicata (Conrad, 1841), were similar between sites with the threeridge being more dense at MRM 309.0. Both sites experienced harvest pressure up to and beyond the time of this survey; however, the MRM 300.0 site is an area designated as a mussel sanctuary in 1989. A quantitative mussel survey conducted in Wisconsin during 1986 in Pools 9 and 10 found that mean densities of washboards ranged from .28 to 1.47 per square meter in five communities sampled (Heath et. al., 1988), lower than the average 1.6 per square meter in our survey.

Size distribution of commercially exploited washboards and threeridges was similar at both sites (Table 3). The majority of individuals of each of these species were of "legal size". Continued harvest of legal sized mussels, if sufficient to remove most of the available adults, could result in an extensive period to replenish these stocks. Future surveys on other "beds" within these pools may provide different results. The densities we found may seem too low for commercial fishing to be profitable; however, a fisherman, by stretching and sweeping his hands and arms out to feel for the large mussels, is able to cover a large area in a short period of time.

Standing crop estimates were similar for the two 48,000 square meter areas sampled (Table 4). These particular areas probably contained more mussels than other nearby portions of the Mississippi River. The actual availability of suitable habitat for each species is unknown. Concentrations or clumps of mussels often occur sporadically, even within suitable habitats.

Snail and clam densities

Density and standing crop estimates for snails and clams were much lower than for mussels (Table 4). The vast majority of clams at both sites were sphaeriids (Figure 3), while Pleurocera canaliculata and Viviparus subpurpureus dominated the snail community (Figure 4). Most snail shells contained living snails, but 42 percent of V. subpurpureus shells were fresh dead at MRM 300 (Table 5).

Mussel position

An attempt was made to determine if there was a pattern in regard to mussel position within the sample area. Mussel position might be influenced by changes in substrate and/or navigation effects from propeller wash or other factors. At each site mussels were recorded as occurring in the inner, center or outer portion of the sampling area. These portions were each 20 meters in width and extended the entire length of the study area. At MRM 300.0 species such as the deertoe, the fawnsfoot, T. donaciformis (I. Lea, 1828), and the washboard were somewhat evenly distributed (Figure 5). The butterfly, the fragile papershell, Leptodea fragilis (Rafinesque, 1820), the threehorn wartyback, Obliquaria reflexa (Rafinesque, 1820), the hickorynut, Obovaria olivaria (Rafinesque, 1820), the pink heelsplitter, Potamilus alatus (Say, 1817), the pimpleback, Quadrula pustulosa (I. Lea, 1831) and the mapleleaf were collected in greater number away from the river's edge. At MRM 309.0, the mapleleaf, the threehorn wartyback and the deertoe were more abundant in the center portion (Figure 6). Habitat conditions within these areas were generally similar enough to expect only slight variations. More detailed sampling of the substrate in relation to existing mussels is necessary to adequately address mussel position or habitat preferences within the areas studied.

Age and length of mussels

Most mussels observed were living (Tables 6 and 7). Fresh dead valves were most evident among the shorter-lived species, which in most instances are thin-shelled, weigh less and might be expected to be swept from the site earlier than the longer-lived species. If fresh dead valves are not being removed from the site at which death occurred, then natural mortality may be low at these locations. Age structure of live mussels of most species was similar at the two locations; however, the deertoe and the fragile papershell were younger at MRM 300.0 and the mapleleaf were younger at MRM 309.0 (Table 8). The reasons behind these apparent age differences are not clear and may not be explained until more sites and/or habitats are examined.

Age structure varied among eight selected species, but was often similar between sites for a particular species (Figures 7-14). Four of eight species, the deertoe, the fawnsfoot, the fragile papershell and the threehorn wartyback were represented primarily by young individuals. The deertoe, the fawnsfoot and the fragile papershell are all relatively short-lived species. This age structure might be expected in a "normal" population of mussels; however, the butterfly, mapleleaf, washboard and threeridge are much different. The butterfly (Figure 11) had a relatively high number of young individuals present (1-2 years old). It is possible this relatively high number of young could be an extraordinary year class; however, little is known about this species' recruitment success and it will take further studies to determine if this is atypical for the butterfly. The mapleleaf (Figure 12) had lower numbers and scattered age groups at MRM 300.0, indicating it is doing poorly there as compared to MRM 309.0. At MRM 309.0 mapleleaf recruitment has been more successful; however, at both sites recent reproduction was low.

The commercially valuable washboard and threeridge were represented mostly by very young (ages 1-2) and old, mature individuals (Figures 13 and 14). These data suggest that if the large mussels are harvested extensively it may require up to 20 years before exploitable stocks are replenished. Also, depletion of current adult stocks may weaken recruitment, which seems unpredictable and low. Unfortunately, little is actually known of stock-recruitment relationships in mussel populations. Judging from Figure 13, it seems that washboards may undergo at least some recruitment every four or five years. In Wisconsin, washboards recruited successfully at approximately seven-year intervals (Heath et. al. 1988).

Length-frequency data lead to similar interpretations as the age-frequency histograms. Deertoe and fawnsfoot exhibited similar size structure, and both were most numerous at MRM 300.0 (Figures 15 and 16). There were far more large fragile papershell at MRM 309.0 than at MRM 300.0 (Figure 17). Threehorn wartyback and butterfly had similar population structures, with few mid-size individuals (Figures 18 and 19). Mapleleaf were more numerous at MRM 309.0 than at MRM 300.0, but populations at both sites were characterized by increasing numbers at larger sizes (Figure 20). Very few mid-sized washboard or threeridge were sampled at either site (Figures 21 and 22).

Age and length curves (Figures 23-30) were derived by using a simple linear regression formula for those which seemed to best fit a straight line, and a quadratic regression formula was used for the remaining species (Appendix A). Curves derived from these formulae may be especially useful in determining the approximate age of a mussel at a particular length (Figures 23-30). Although there are great variations evident, the species represented are

generally more ageable using the external growth rest method than some other species. Less variation in age was evident in the smaller or younger individuals. Minimum size regulations are usually based on height measurements. The curves for washboard and threeridge may be helpful in determining expected age at harvestable size (Figures 31 and 32).

CONCLUSIONS AND RECOMMENDATIONS

It is difficult to draw conclusions about the health and stability of the mussel communities in Pools 22 and 24 from these initial quantitative surveys. Comparisons between the two sites are also limited even though habitat conditions appear similar to some degree. Continued surveys are necessary to determine trends in density and recruitment. Additional surveys should include detailed substrate analysis, more accurate ageing techniques, and the sampling of different habitats.

An important concern noted in this report is recruitment of juveniles into the population. It is apparent that recruitment may be low in commercially valuable species and also in certain species not utilized in the shell industry. Although commercial harvest may or may not influence recruitment, other reasons for low recruitment must also be examined for these and other species. The life span of most mussel species indicates the need for a long term monitoring approach. If recruitment occurs sporadically, or at regular lengthy intervals, dive surveys of the kind reported herein may not be required annually for each community initially examined; however, other quantitative sampling (eg. peterson and ponar dredge, snorkeling) may be appropriate on an annual basis.

The overall management of this resource may best be approached on a long term basis; however, the immediate concern with overharvest of commercial species, apparent low recruitment and the status of rare species, provides the justification to obtain additional baseline data.

REFERENCES CITED

Heath, D. J., M. P. Engel and J. A. Holzer. 1988. An assessment of the 1986 Commercial Harvest of Freshwater Mussels in the Mississippi River bordering Wisconsin. Wisconsin Department of Natural Resources, La Crosse Area Office, La Crosse, Wisconsin, (Draft Report), 33p.

Miller, A. C., B. S. Payne, D. J. Hornbach and D. V. Ragland. 1990. "Physical effects of increased commercial navigation traffic on Freshwater Mussels in the Upper Mississippi River: Phase I Studies, " Technical Report EL-90-3, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 27 p.

Table 1. Mussel species recorded live or fresh-dead since 1986 from qualitative surveys in pools 22 and 24 and species recorded during the MAY-JUNE 1988 quantitative survey at MRM 300.0 and 309.0.

Scientific Name		Vernacular Name	Pool 22 and 24	MRM 300	MRM 309
Cumberlandia monodonta	*	spectaclecase	x	-	-
Anodonta imbecillis		paper pondshell	x	x	x
Anodonta grandis		giant floater	x	-	-
Strophitus undulatus		squawfoot	x	-	-
Arcidens confragosus	*	rock-pocketbook	x	-	x
Lasmigona complanata		white heelsplitter	x	-	-
Megalonaias nervosa		washboard	x	x	x
Tritogonia verrucosa		pistolgrip	x	-	-
Quadrula quadrula		mapleleaf	x	x	x
Quadrula metanevra		monkeyface	x	x	x
Quadrula nodulata	*	wartyback	x	x	x
Quadrula pustulosa		pimpleback	x	x	x
Amblema plicata		threeridge	x	x	x
Fusconaia ebena	*	ebonyshell	x	-	-
Fusconaia flava		Wabash pigtoe	x	x	x
Plethobasus cyphyus	*	sheepnose	x	-	x
Elliptio crassidens	*	elephant-ear	x	-	-
Obliquaria reflexa		threehorn wartyback	x	x	x
Actinonaias ligamentina		mucket	x	-	-
Ellipsaria lineolata		butterfly	x	x	x
Obovaria olivaria		hickorynut	x	x	x
Truncilla truncata		deertoe	x	x	x
Truncilla donaciformis		fawnsfoot	x	x	x
Leptodea fragilis		fragile papershell	x	x	x
Potamilus alatus		pink heelsplitter	x	x	x
Potamilus ohiensis		pink papershell	x	x	-
Potamilus capax	*	fat pocketbook	x	-	-
Toxolasma parvus		lilliput	x	-	-
Ligumia recta		black sandshell	x	x	x
Lampsilis higginsi	*	Higgins eye	x	-	-
Lampsilis teres		yellow sandshell	x	x	x
Lampsilis ventricosa		plain pocketbook	x	x	x
		TOTAL	32	19	20

Table 2. Density of mussels per square meter at MRM 300.0 and MRM 309.0 during May-June 1988.

	MRM 300.0			MRM 309.0		
	Species	Density/sq. meter	Standard Error	Species	Density/sq. meter	Standard Error
1.	Truncilla truncata	7.22	2.01	Quadrula quadrula	3.50	1.17
2.	Ellipsaria lineolata	3.71	0.87	Truncilla truncata	3.46	0.74
3.	Obliquaria reflexa	3.68	0.79	Obliquaria reflexa	3.30	0.76
4.	Truncilla donaciformis	2.75	0.23	Amblema plicata	2.55	0.60
5.	Megalonaias nervosa	1.52	0.72	Ellipsaria lineolata	2.05	0.65
6.	Amblema plicata	1.54	0.57	Truncilla donaciformis	1.86	0.47
7.	Leptodea fragilis	0.99	0.50	Megalonaias nervosa	1.79	0.52
8.	Quadrula pustulosa	0.75	0.30	Obovaria olivaria	1.09	0.46
9.	Quadrula quadrula	0.75	0.28	Leptodea fragilis	1.08	0.51
10.	Obovaria olivaria	0.54	0.25	Quadrula pustulosa	0.99	0.37
11.	Potamilus alatus	0.42	0.22	Anodonta imbecillis	0.51	0.27
12.	Fusconaia flava	0.21	0.15	Potamilus alatus	0.29	0.17
13.	Lampsilis vertrcosa	0.21	0.17	Quadrula nodulata	0.25	0.13
14.	Quadrula metanevra	0.12	0.06	Arcidens confragosus	0.16	0.16
15.	Anodonta imbecillis	0.09	0.06	Lampsilis ventricosus	0.13	0.07
16.	Potamilus ohiensis	0.05	0.05	Quadrula metanevra	0.08	0.08
17.	Lampsilis teres	0.05	0.05	Plethobasus cyphyus	0.08	0.08
18.	Quadrula nodulata	0.04	0.04	Lampsilis teres	0.08	0.06
19.	Ligumia recta	0.04	0.04	Fusconaia flava	0.04	0.04
20.				Ligumia recta	0.04	0.04
	Total (all species) / sq. meter = 24.68			Total (all species) / sq. meter = 23.33		

Table 3. Number and percent of the two primary commercially valuable mussel species by size grouping from MRM 300.0 and MRM 309.0.

Location	Washboard (Megalonaias nervosa)*			Threeridge (Amblema plicata)**		
	Height	No.	(%)	Height	No.	(%)
MRM 300.0	(3.5"	5	(10.4)	(2.5"	10	(19.2)
	3.5" - (3.75"	0	(0)	2.5" - (2.75"	0	(0)
	3.75" - (4.0"	1	(2.1)	2.75" and)	42	(80.8)
	4.0" and)	42	(87.5)			
MRM 309.0	(3.5"	9	(17.3)	(2.5"	22	(26.8)
	3.5" - (3.75"	0	(0)	2.5" - (2.75"	0	(0)
	3.75" - (4.0"	0	(0)	2.75" and)	60	(73.2)
	4.0" and)	43	(82.7)			
Combined MRM 300.0 and 309.0	(3.5"	14	(14.0)	(2.5"	32	(23.9)
	3.5" - (3.75"	0	(0)	2.5" - (2.75"	0	(0)
	3.75" - (4.0"	1	(1.0)	2.75" and)	102	(76.1)
	4.0" and)	85	(85.0)			

* minimum legal size for the washboard is 3.75 inches.
** minimum legal size for the threeridge is 2.75 inches.

Table 4. Mean number per square meter and standing crop estimates for mussels, snails and clams from MRM 300.0 and MRM 309.0 during May-June, 1988.

Location	Mean No./sq. meter	Standing Crop est. *
	Mussels	
MRM 300.0	24.7	1,185,600
MRM 309.0	23.3	1,118,400
	Snails	
MRM 300.0	5.5	264,000
MRM 309.0	3.1	148,800
	Clams	
MRM 300.0	3.7	177,600
MRM 309.0	3.5	168,000

* Standing crop estimate is for the area sampled, which was 800 meters by 60 meters.

Table 5. Number and percent of live and fresh dead snails found at MRM 300.0 and MRM 309.0 during May-June 1988.

Location	Species	Live		Fresh Dead	
		No.	(%)	No.	(%)
MRM 300.0	Pleurocera canaliculata	91	(81)	21	(19)
	Viviparus subpurpureus	30	(58)	22	(42)
	Campeloma decisum	3	(100)	--	--
MRM 309.0	Pleurocera canaliculata	44	(71)	18	(29)
	Viviparus subpurpureus	31	(70)	13	(30)
	Campeloma decisum	2	(100)	--	--

Table 6. Number and percent of live and fresh dead mussels by species and age group at MRM 300.0 during May-June 1988.

Species	Age	Live		Fresh Dead	
		No.	(%)	No.	(%)
Megalonaias nervosa	<1-5	4	(100)	--	--
	>5-10	2	(100)	--	--
	>10-15	--	--	--	--
	>15-20	3	(100)	--	--
	>20-25	7	(100)	--	--
	>25-30	13	(100)	--	--
	>30-35	5	(100)	--	--
Quadrula quadrula	<1-5	2	(100)	--	--
	>5-10	--	--	--	--
	>10-15	2	(100)	--	--
	>15-20	5	(100)	--	--
	>20-25	6	(100)	--	--
	>25-30	1	(100)	--	--
Amblema plicata	<1-5	8	(100)	--	--
	>5-10	1	(100)	--	--
	>10-15	1	(100)	--	--
	>15-20	3	(100)	--	--
	>20-25	13	(100)	--	--
	>25-30	7	(100)	--	--
	>30-35	2	(100)	--	--
Obliquaria reflexa	<1-5	45	(98)	1	(2)
	>5-10	10	(100)	--	--
	>10-15	2	(100)	--	--
	>15-20	11	(100)	--	--
	>20-25	7	(100)	--	--
	>25-30	3	(100)	--	--
Ellipsaria lineolata	<1-5	34	(100)	--	--
	>5-10	6	(100)	--	--
	>10-15	22	(100)	--	--
	>15-20	8	(100)	--	--
	>20-25	7	(100)	--	--
	>25-30	3	(100)	--	--

Table 6: cont.

Truncilla truncata	<1-1	2	(50)	2	(50)
	>1-2	75	(100)	--	--
	>2-3	16	(89)	2	(11)
	>3-4	46	(94)	3	(6)
	>4-5	20	(100)	--	--
	>5-6	6	(100)	--	--
	>6-7	1	(100)	--	--
	>7-8	5	(100)	--	--
	>8-9	3	(100)	--	--
Truncilla donaciformis	<1-1	--	--	1	(100)
	>1-2	18	(95)	1	(5)
	>2-3	18	(95)	1	(5)
	>3-4	8	(89)	1	(11)
	>4-5	5	(100)	--	--
	>5-6	2	(100)	--	--
Leptodea fragilis	<1-1	--	--	1	(100)
	>1-2	8	(100)	--	--
	>2-3	8	(100)	--	--
	>3-4	2	(50)	2	(50)
	>4-5	3	(100)	--	--
	>5-6	1	(100)	--	--

Table 7. Number and percent of live and fresh dead mussels by species and age group at MRM 309.0 during May-June 1988.

Species	Age	Live		Fresh Dead	
		No.	(%)	No.	(%)
Megalonaias nervosa	<1-5	6	(100)	--	--
	>5-10	3	(100)	--	--
	>10-15	3	(100)	--	--
	>15-20	3	(100)	--	--
	>20-25	7	(100)	--	--
	>25-30	9	(100)	--	--
	>30-35	10	(100)	--	--
	>35-40	2	(100)	--	--
Quadrula quadrula	<1-5	6	(86)	1	(14)
	>5-10	34	(100)	--	--
	>10-15	9	(100)	--	--
	>15-20	15	(100)	--	--
	>20-25	15	(100)	--	--
	>25-30	3	(100)	--	--
Amblema plicata	<1-5	11	(85)	2	(15)
	>5-10	8	(100)	--	--
	>10-15	4	(100)	--	--
	>15-20	4	(100)	--	--
	>20-25	18	(100)	--	--
	>25-30	13	(100)	--	--
	>30-35	4	(100)	--	--
Obliquaria reflexa	<1-5	35	(97)	1	(3)
	>5-10	28	(96)	1	(4)
	>10-15	8	(100)	--	--
	>15-20	3	(100)	--	--
	>20-25	3	(100)	--	--
Ellipsaria lineolata	<1-5	8	(100)	--	--
	>5-10	11	(100)	--	--
	>10-15	15	(100)	--	--
	>15-20	8	(100)	--	--
	>20-25	2	(100)	--	--

Table 7: cont.

Truncilla truncata	<1-1	1	(100)	--	--
	>1-2	17	(100)	--	--
	>2-3	12	(100)	--	--
	>3-4	17	(100)	--	--
	>4-5	15	(100)	--	--
	>5-6	6	(100)	--	--
	>6-7	5	(100)	--	--
	>7-8	3	(100)	--	--
	>8-9	3	(100)	--	--
	>9-13	3	(100)	--	--
Truncilla donaciformis	<1-1	3	(60)	2	(40)
	>1-2	14	(78)	4	(22)
	>2-3	9	(90)	1	(10)
	>3-4	5	(63)	3	(37)
	>4-5	6	(100)	--	--
	>5-6	5	(100)	--	--
	>6-7	1	(100)	--	--
	>7-8	1	(50)	--	--
	>8-9	1	(100)	--	--
Leptodea fragilis	<1-1	--	--	--	--
	>1-2	--	--	--	--
	>2-3	1	(50)	1	(50)
	>3-4	3	(100)	--	--
	>4-5	4	(100)	--	--
	>5-6	6	(100)	--	--
	>6-7	4	(100)	--	--
	>7-8	2	(100)	--	--
	>8-9	1	(100)	--	--
	>9-13	3	(100)	--	--

Table 8. Mean age of selected living mussels from MRM 300.0 and MRM 309.0, May and June 1988.

Species	Location					
	MRM 300.0			MRM 309.0		
	Mean age	N*	(SD)**	Mean age	N*	(SD)**
Megalonaias nervosa	22.4	34	(9.8)	21.5	43	(11.3)
Amblema plicata	17.8	32	(10.0)	18.1	62	(10.6)
Quadrula quadrula	17.7	16	(6.9)	13.4	83	(7.4)
Ellipsaria lineolata	9.9	80	(8.3)	10.6	44	(5.7)
Obliquaria reflexa	8.7	78	(8.0)	7.5	77	(5.0)
Leptodea fragilis	2.8	22	(1.3)	6.2	24	(2.1)
Truncilla truncata	3.0	174	(1.8)	4.2	82	(2.4)
Truncilla donaciformis	2.7	51	(1.2)	3.2	45	(1.9)

* N = number of mussels
** SD = standard deviation

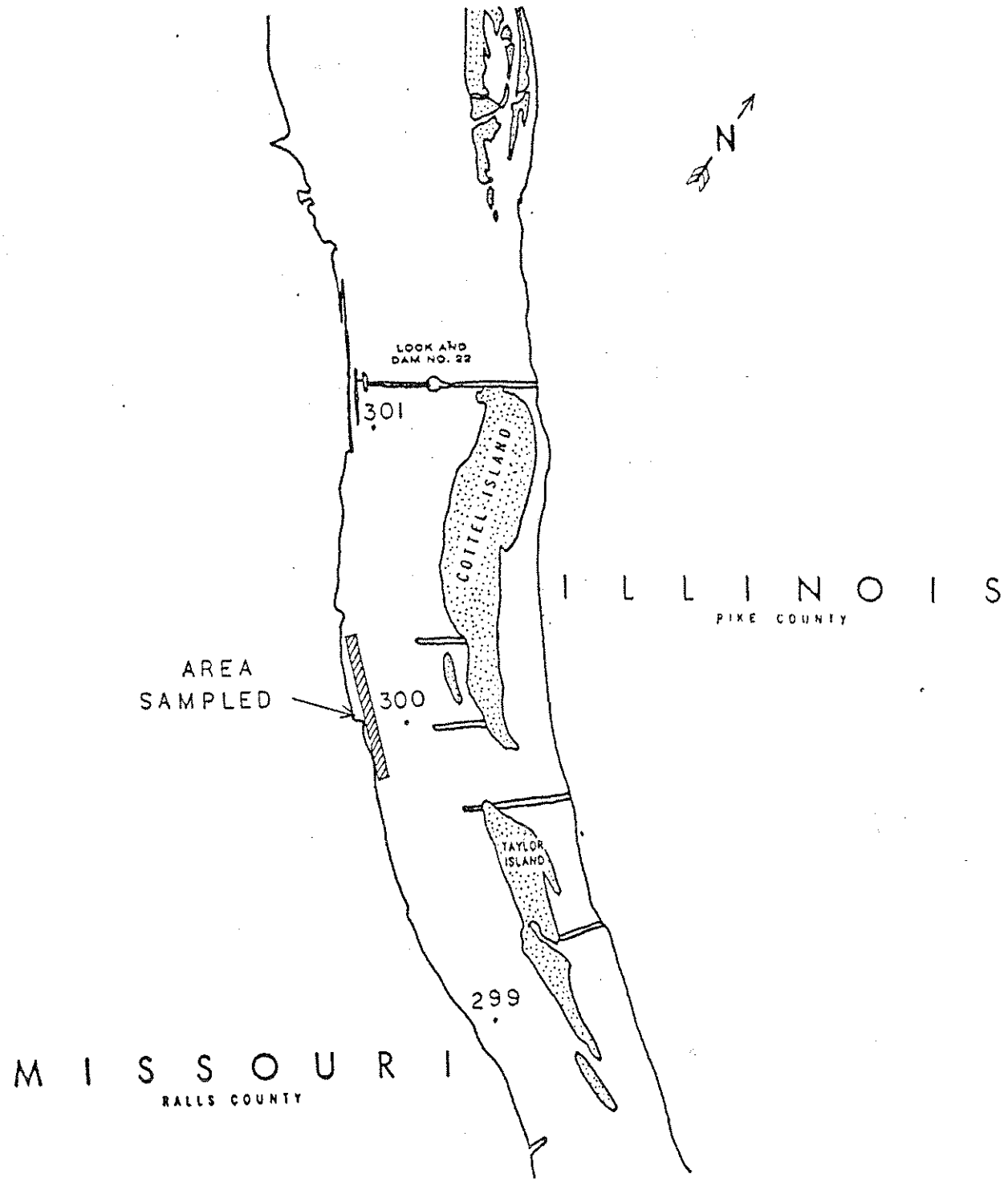

Figure 1: Area sampled at Mississippi River Mile (MRM) 300.0 during May and June, 1988.

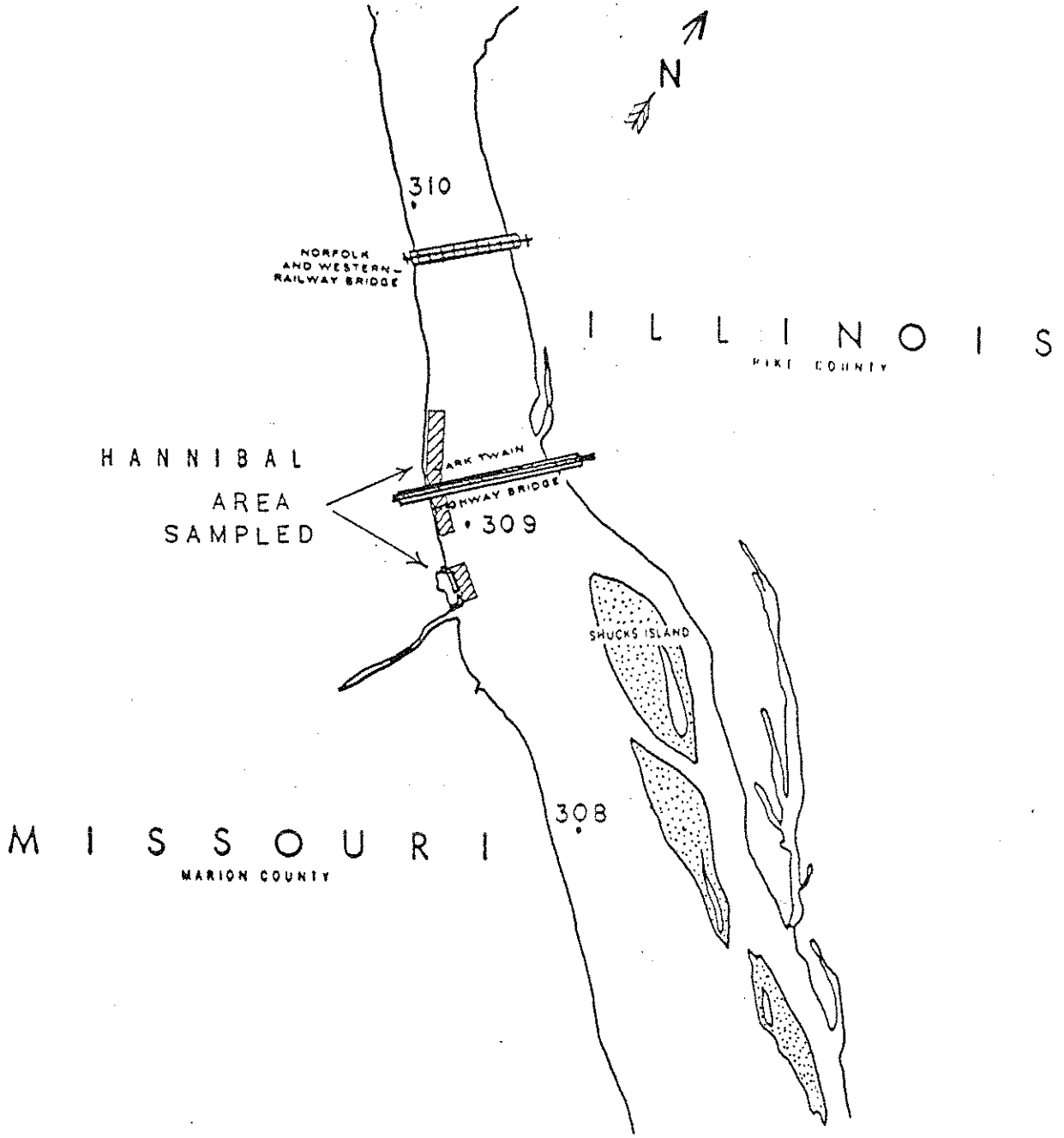

Figure 2: Area sampled at Mississippi River Mile (MRM) 309.0 during May and June, 1988.

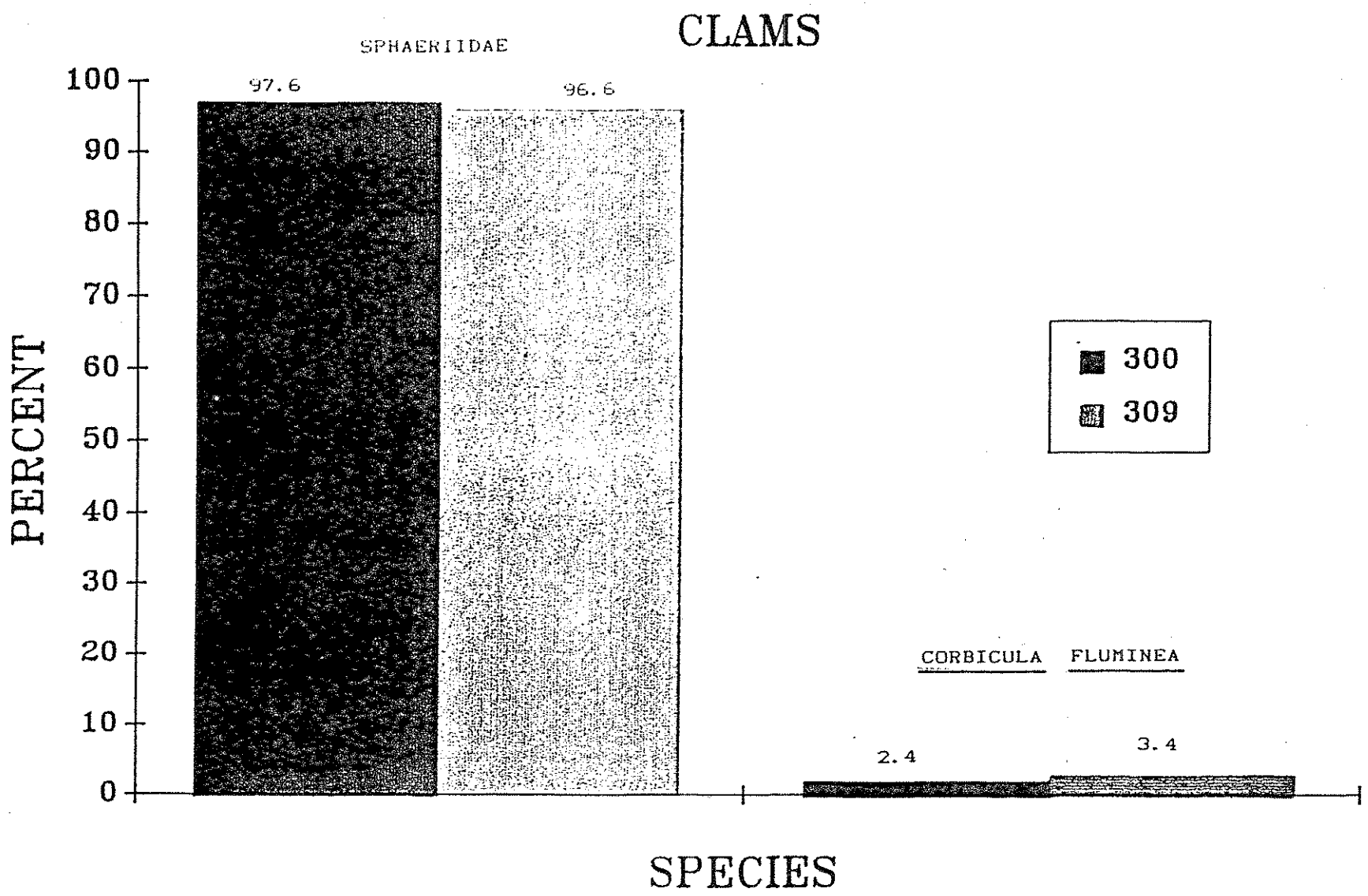

Figure 3. The percentage of the two species of clams from MRM 300.0 and 309.0 recorded during May-June 1988.

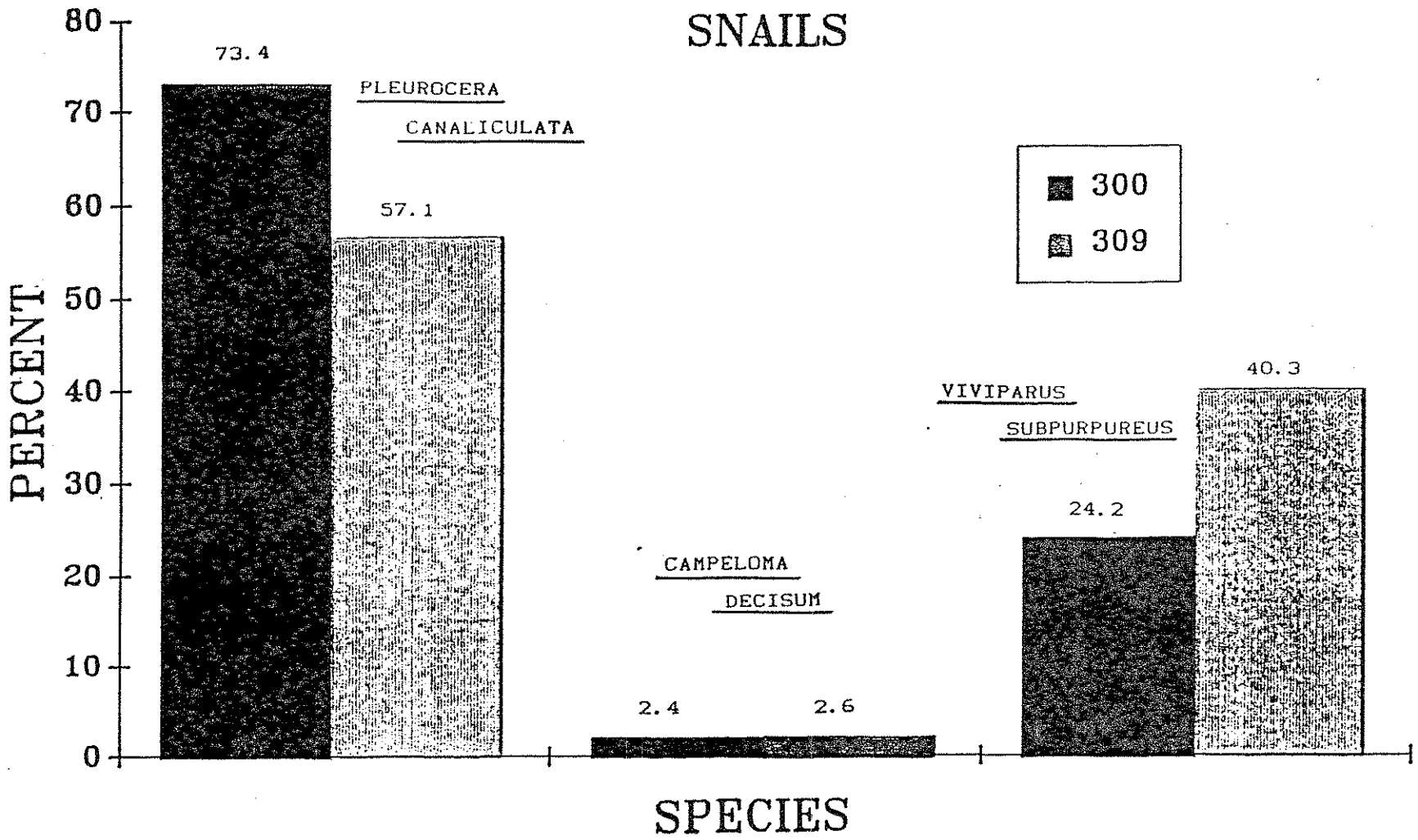

Figure 4. The percentage of the three species of snails fron MRM 300.0 and 309.0 recorded during May-June 1988.

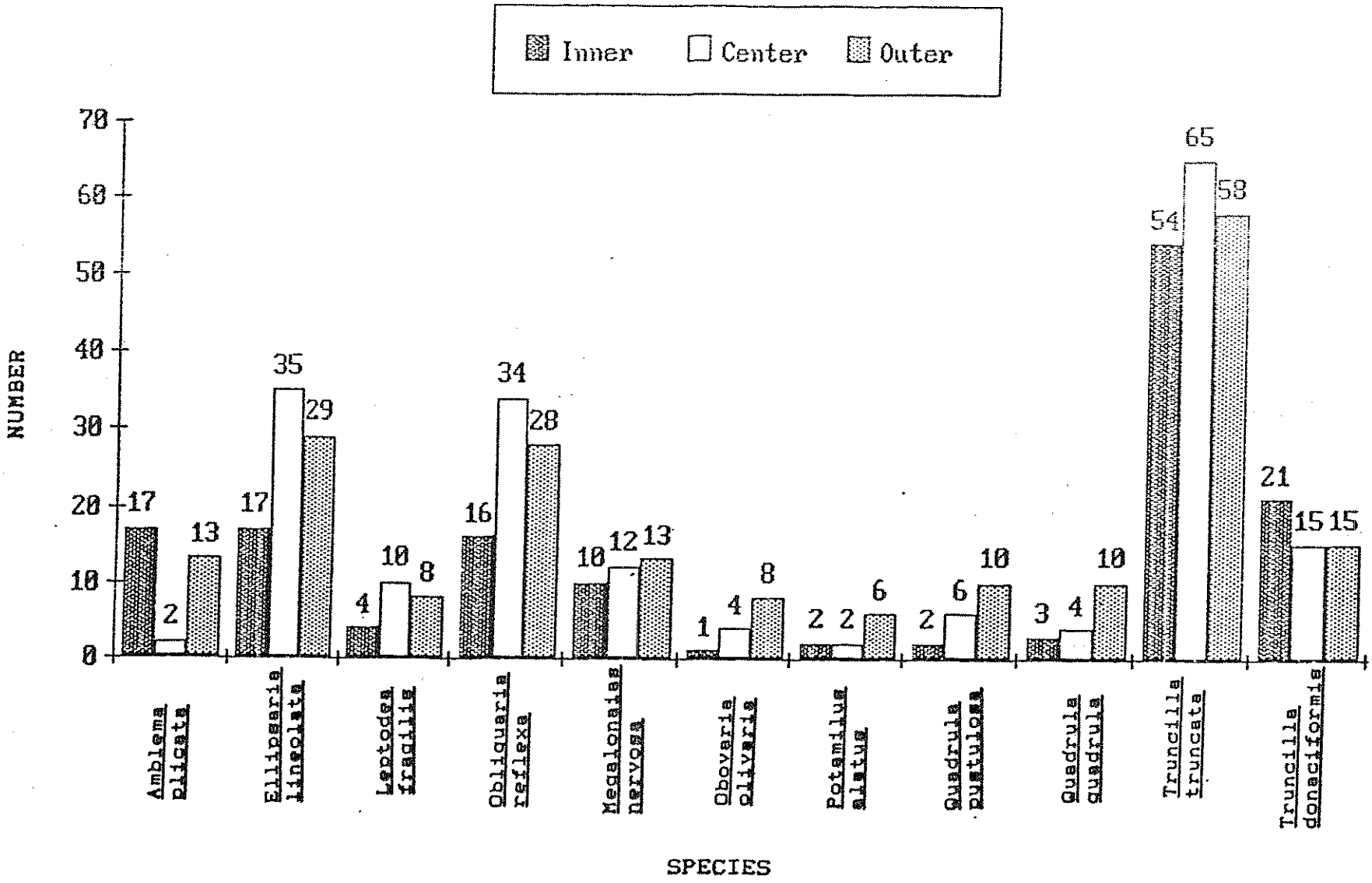

Figure 5. Number of selected mussel species recorded in the inner, center and outer portions of the study area at MRM 300.0 during May-June 1988.

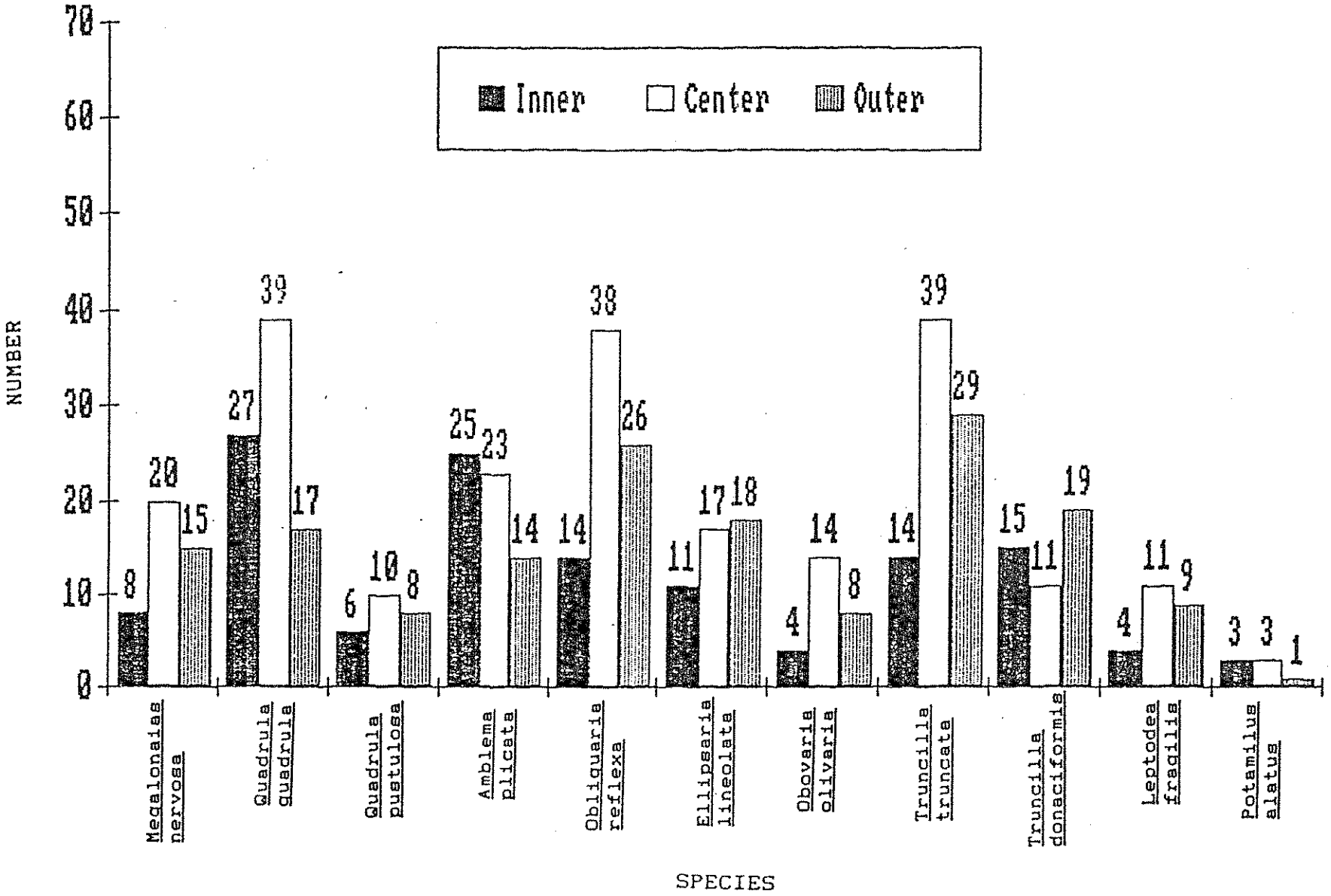

Figure 6. Number of selected mussel species recorded in the inner, center and outer portions of the study area at MRM 309.0 during May-June 1988.

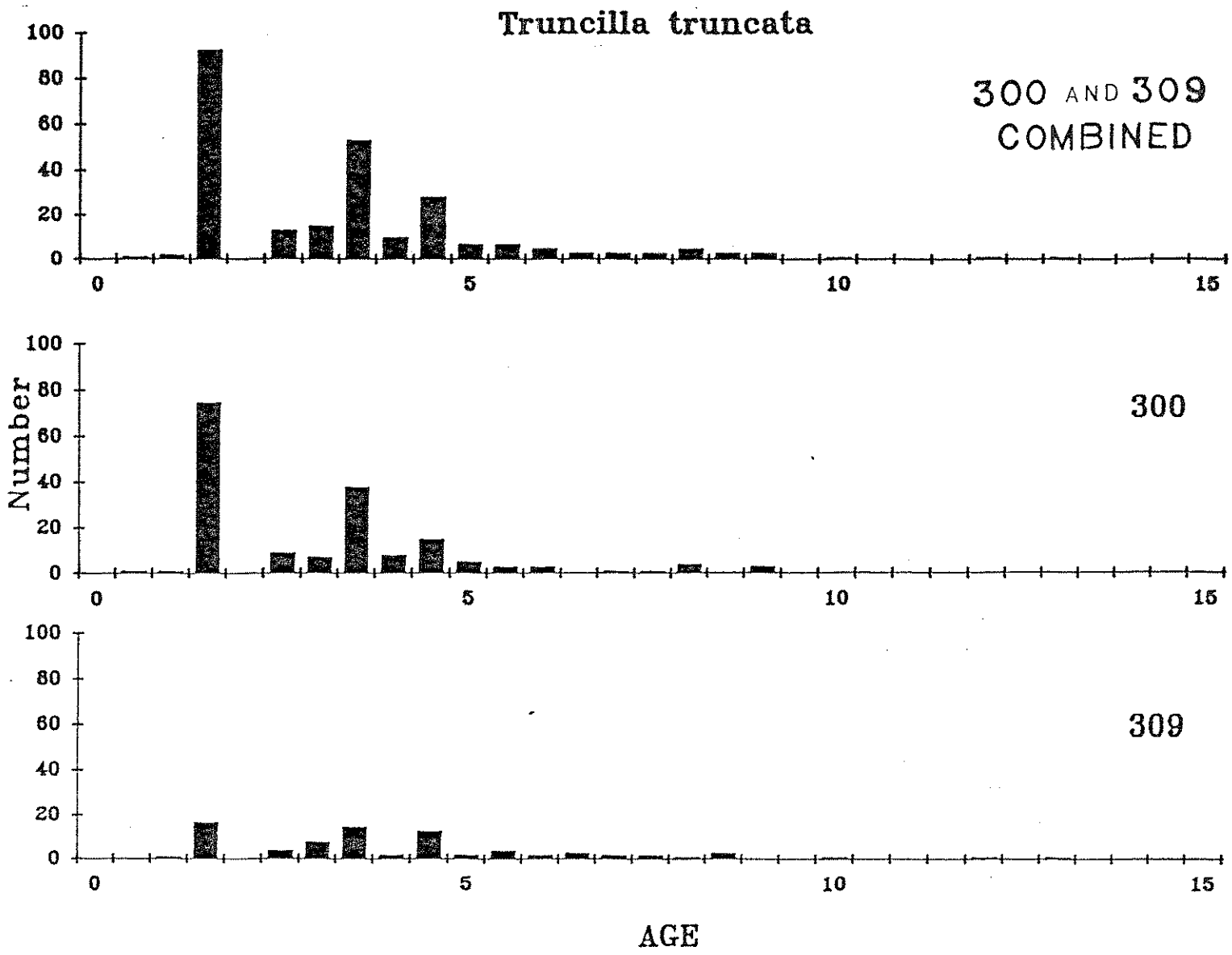

Figure 7. The number and age of Truncilla truncata recorded at MRM 300.0 and 309.0 during May-June 1988.

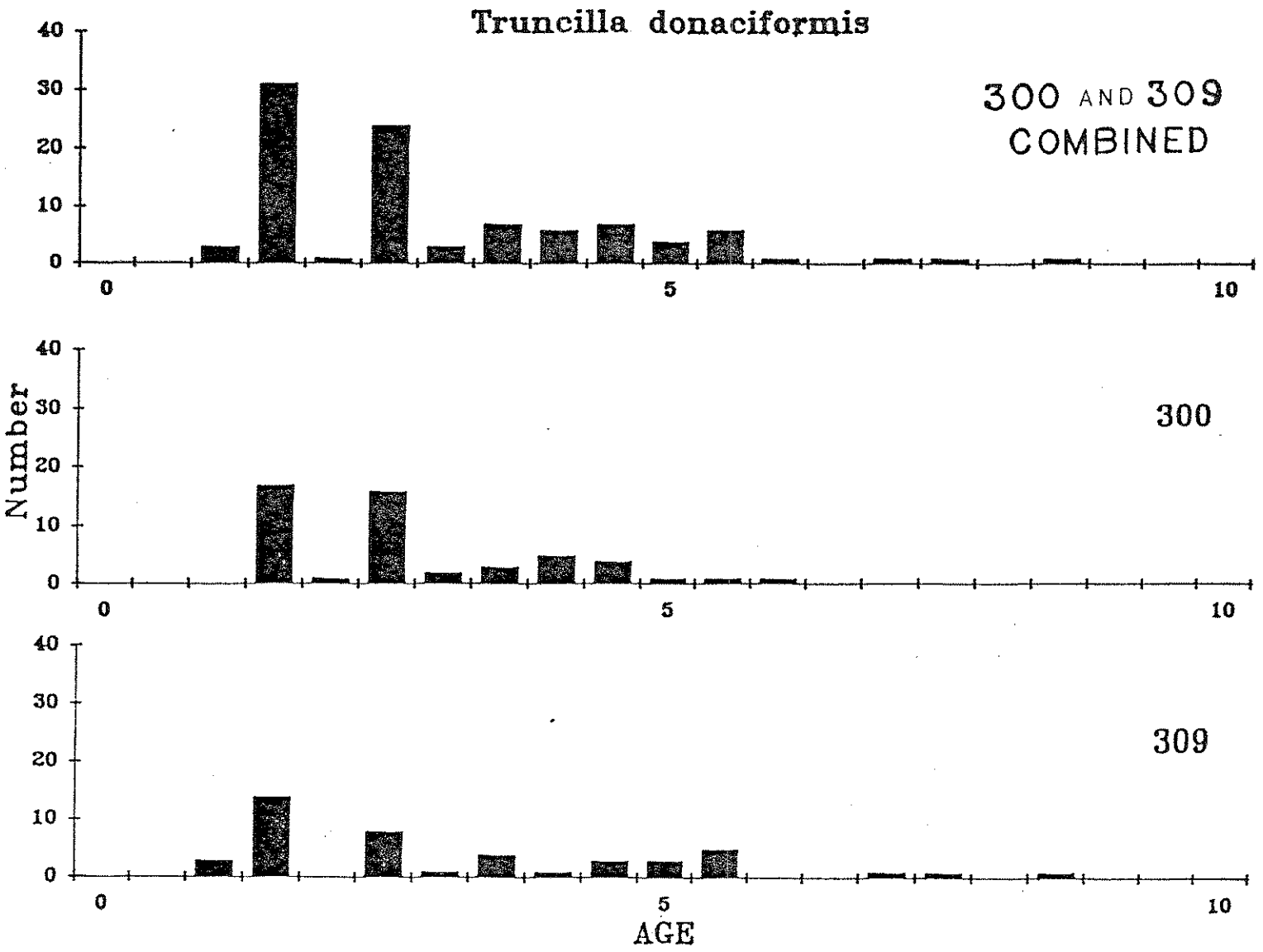

Figure 8. The number and age of Truncilla donaciformis recorded at MRM 300.0 and 309.0 during May-June 1988.

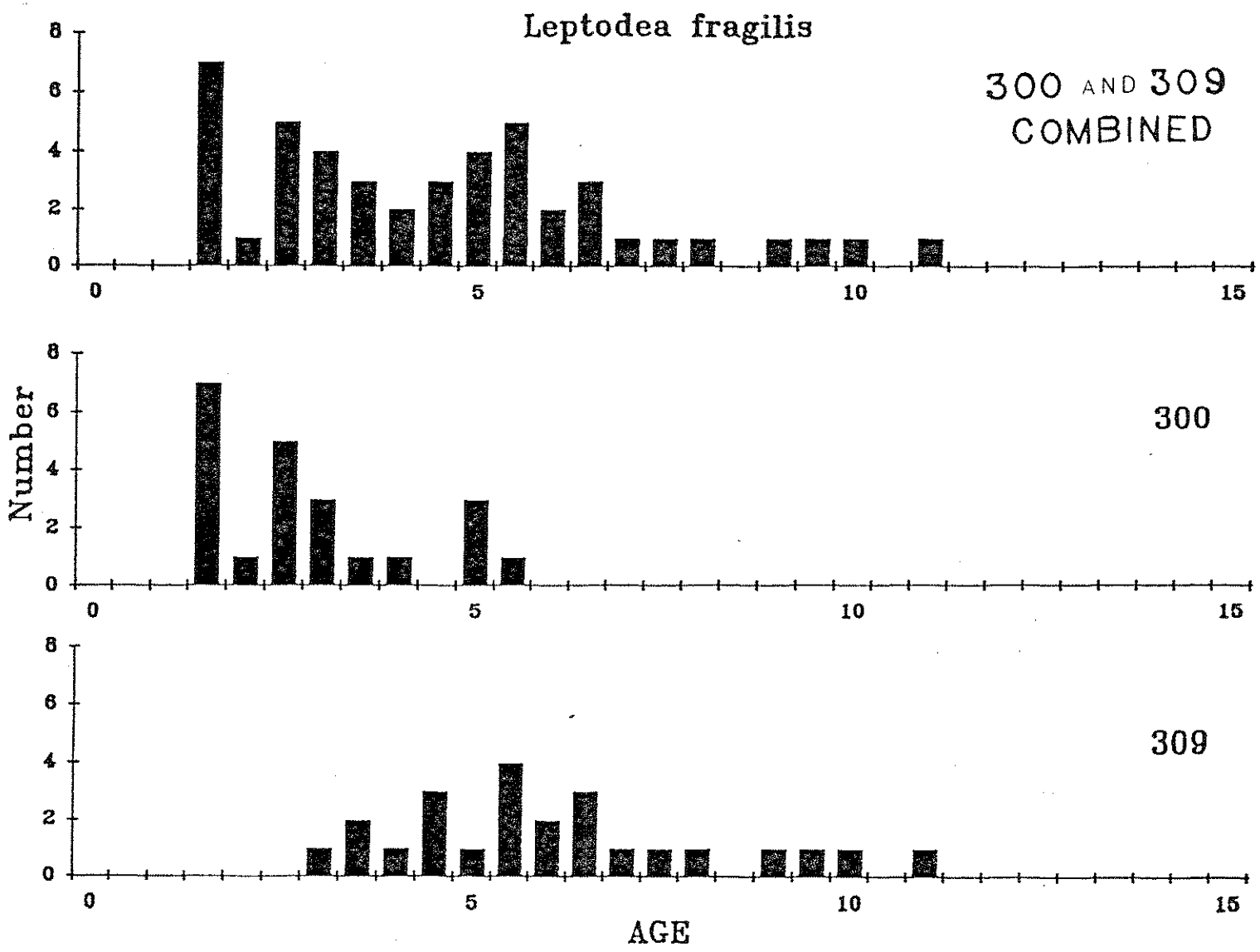

Figure 9. The number and age of Leptodea fragilis recorded at MRM 300.0 and 309.0 during May-June 1988.

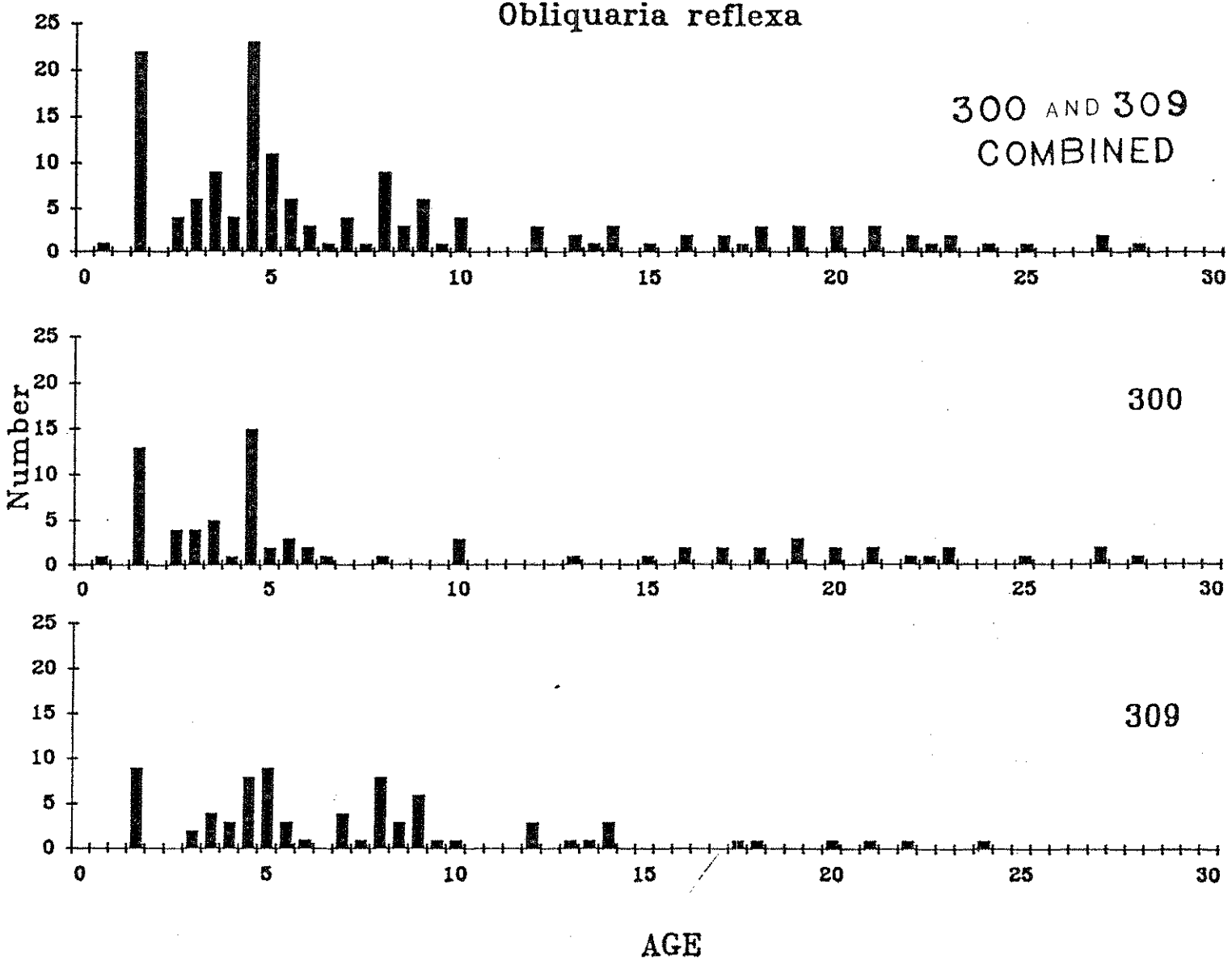

Figure 10. The number and age of Obliquaria reflexa recorded at MRM 300.0 and 309.0 during May-June 1988.

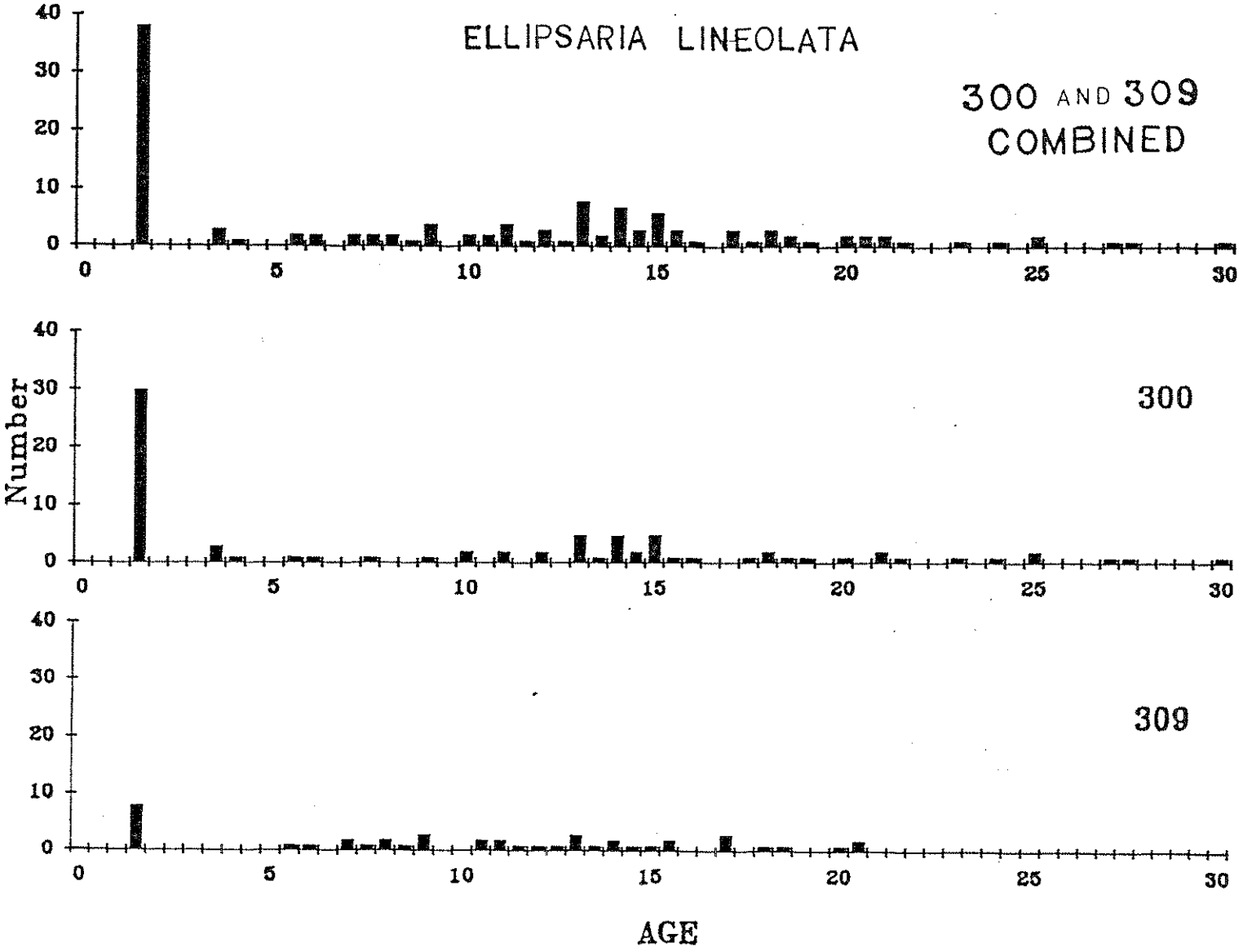

Figure 11. The number and age of Ellipsaria lineolata recorded at MRM 300.0 and 309.0 during May-June 1988.

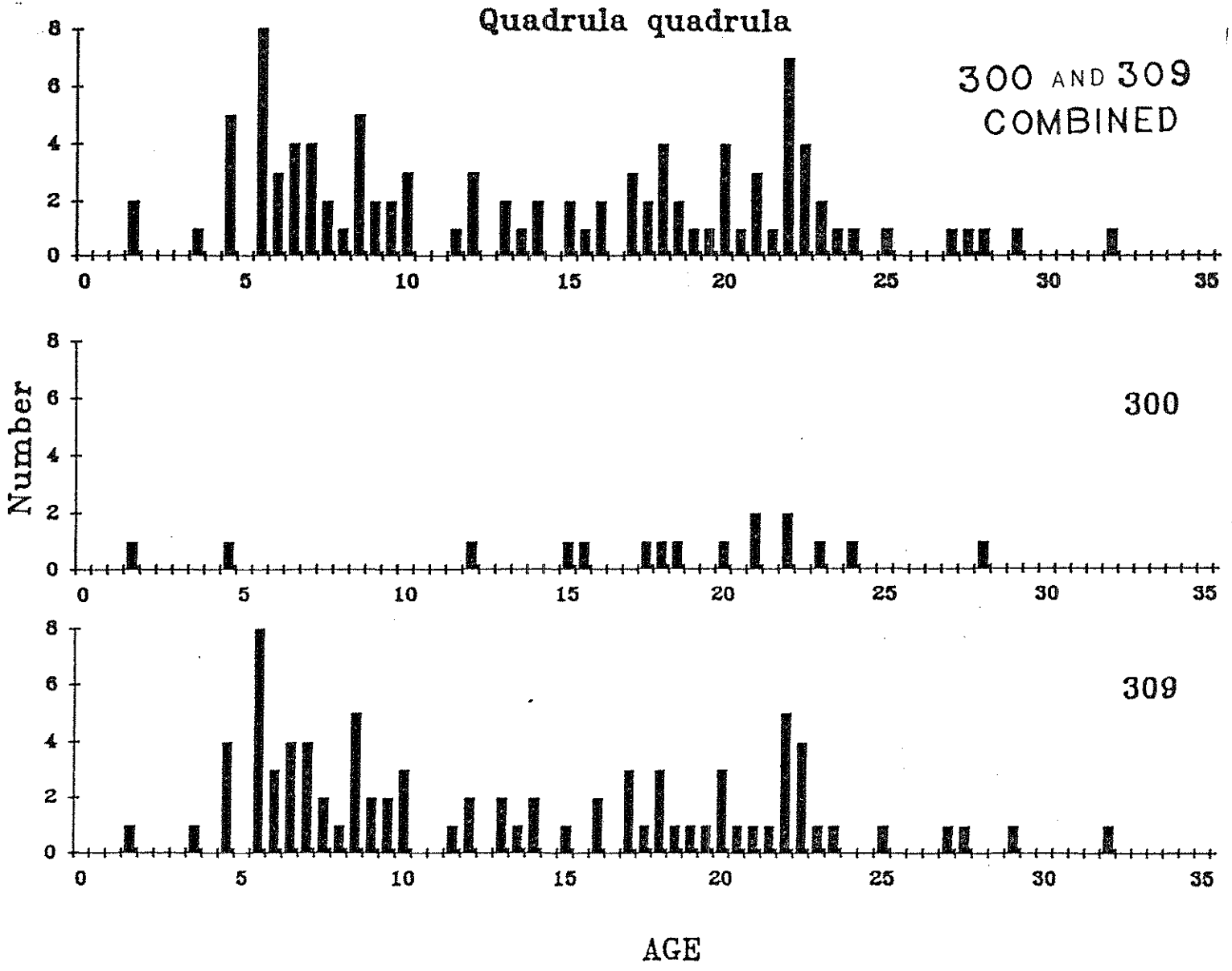

Figure 12. The number and age of Quadrula quadrula recorded at MRM 300.0 and 309.0 during May-June 1988.

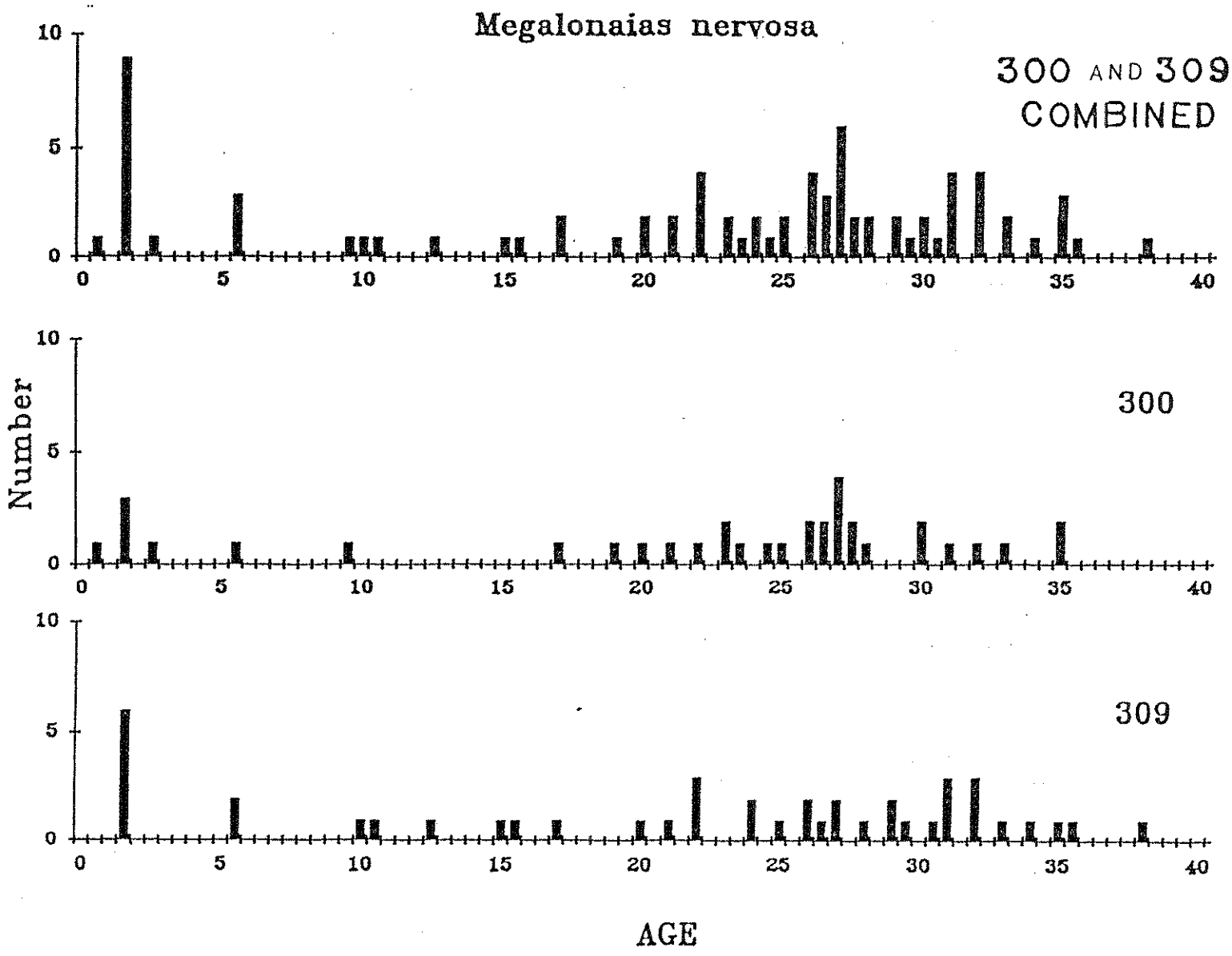

Figure 13. The number and age of Megalonaias nervosa recorded at MRM 300.0 and 309.0 during May-June 1988.

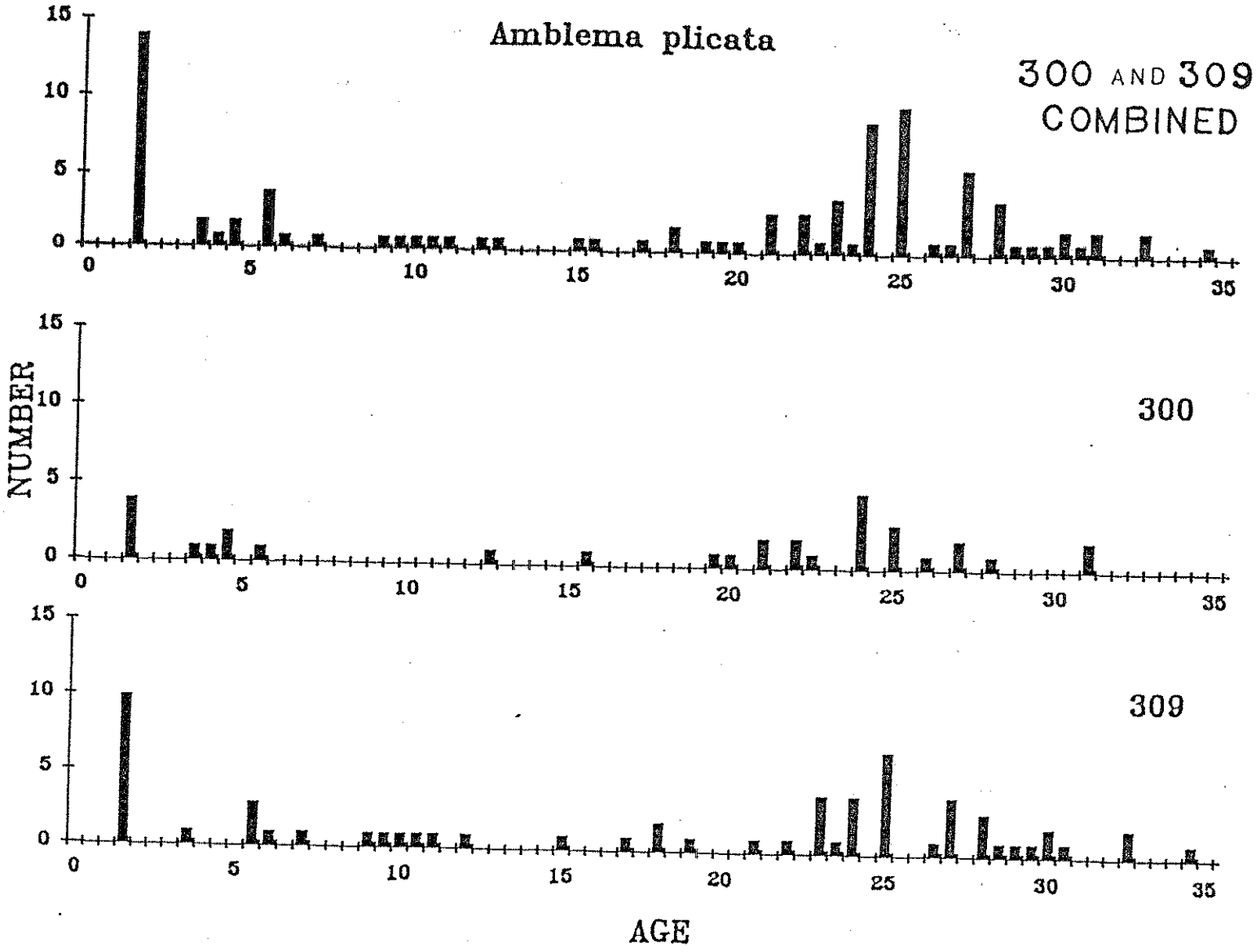

Figure 14. The number and age of Amblema plicata recorded at MRM 300.0 and 309.0 during May-June 1988.

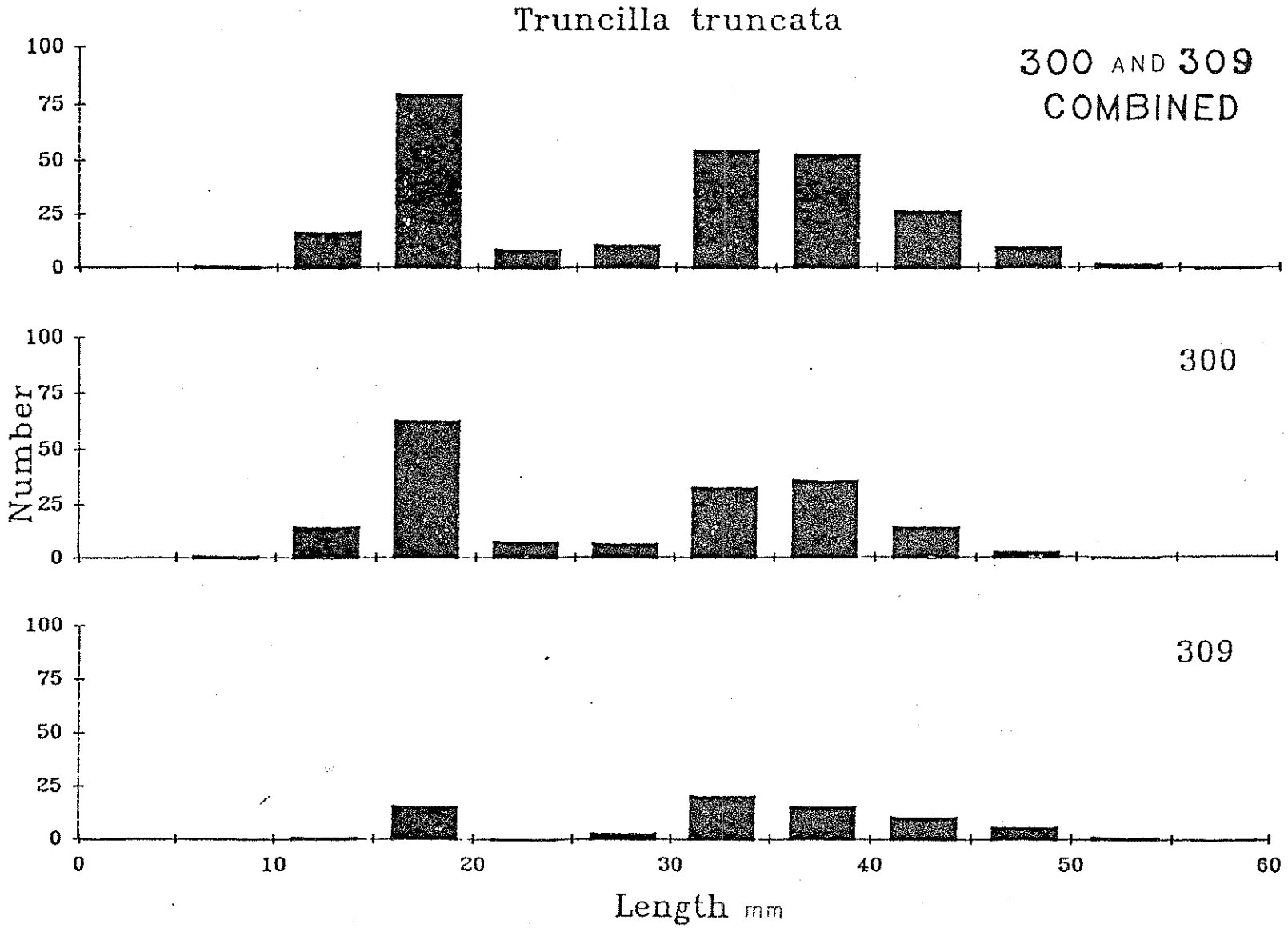

Figure 15. The number and length of Truncilla truncata recorded at MRM 300.0 and 309.0 during May-June 1988.

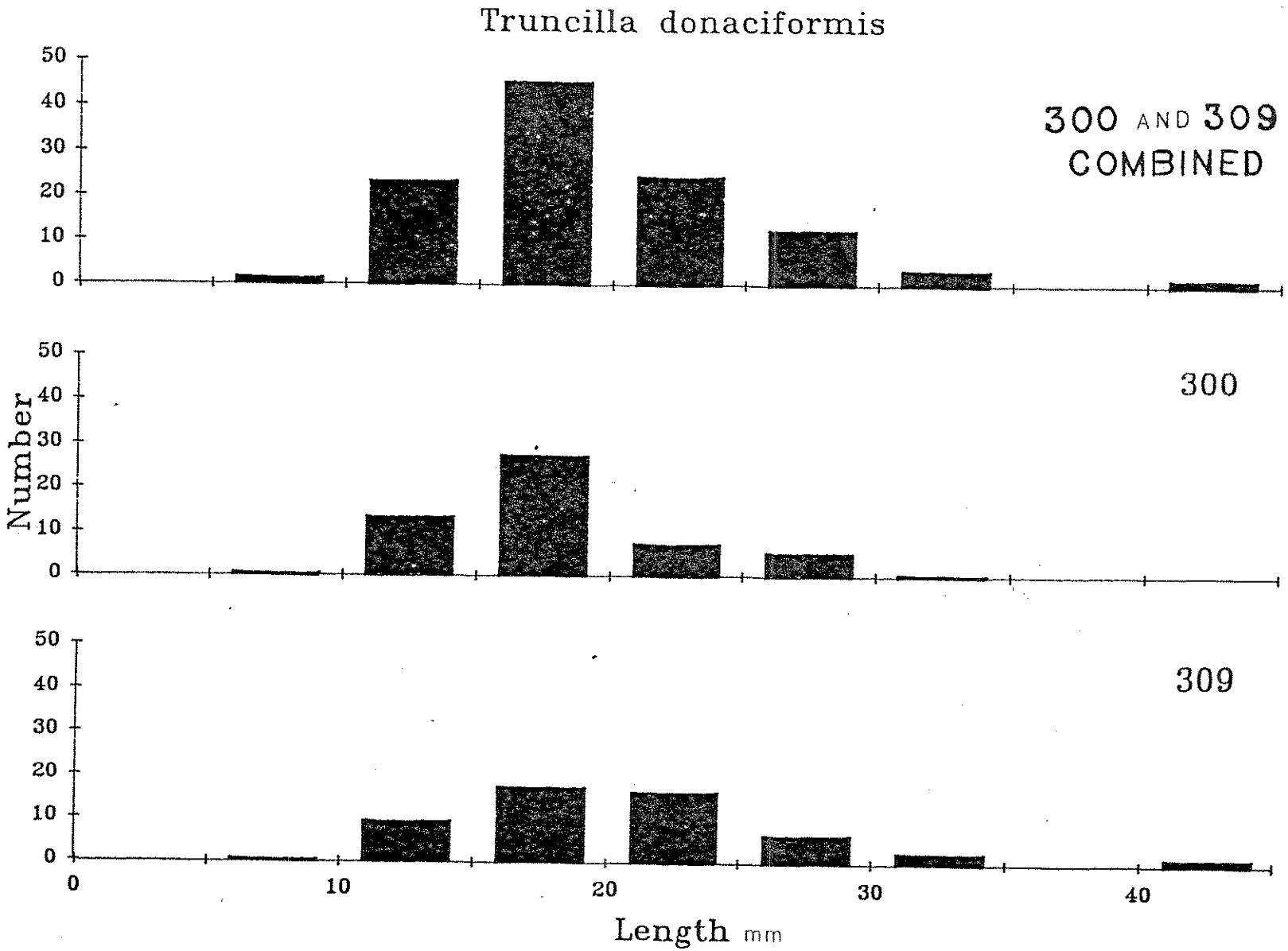

Figure 16. The number and length of Truncilla donaciformis recorded at MRM 300.0 and 309.0 during May-June 1988.

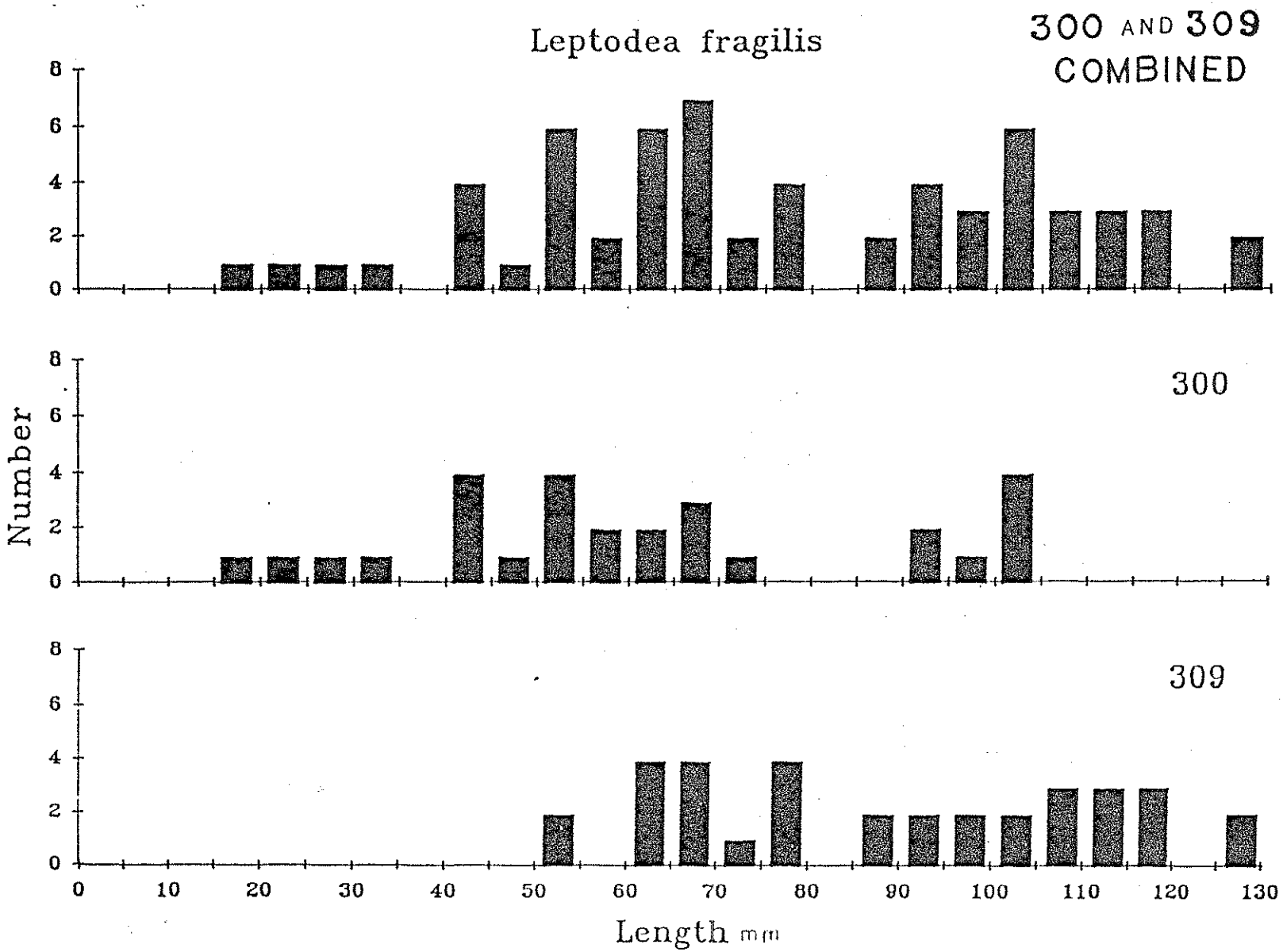

Figure 17. The number and length of Leptodea fragilis recorded at MRM 300.0 and 309.0 during May-June 1988.

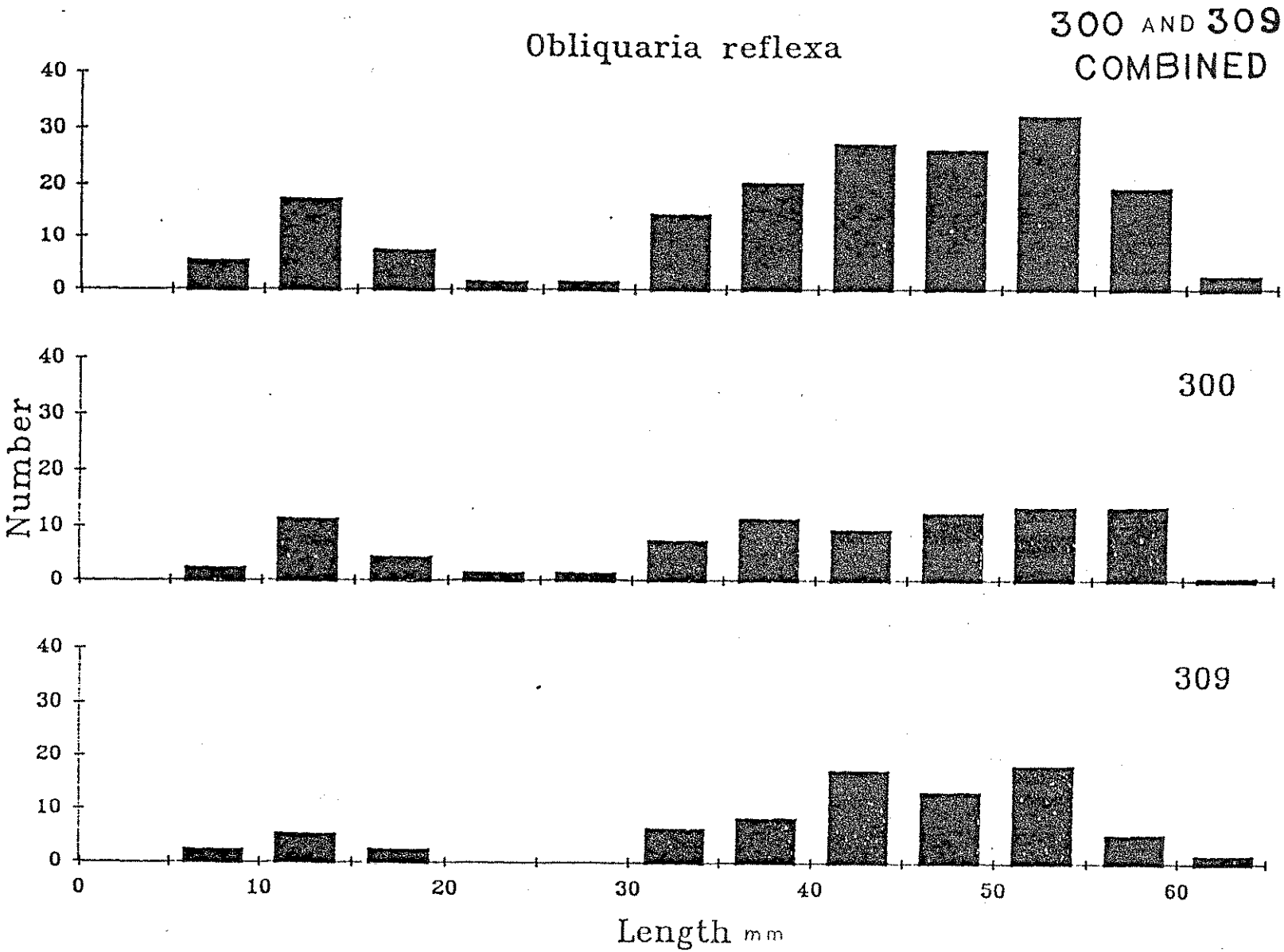

Figure 18. The number and length of Obliquaria reflexa recorded at MRM 300.0 and 309.0 during May-June 1988.

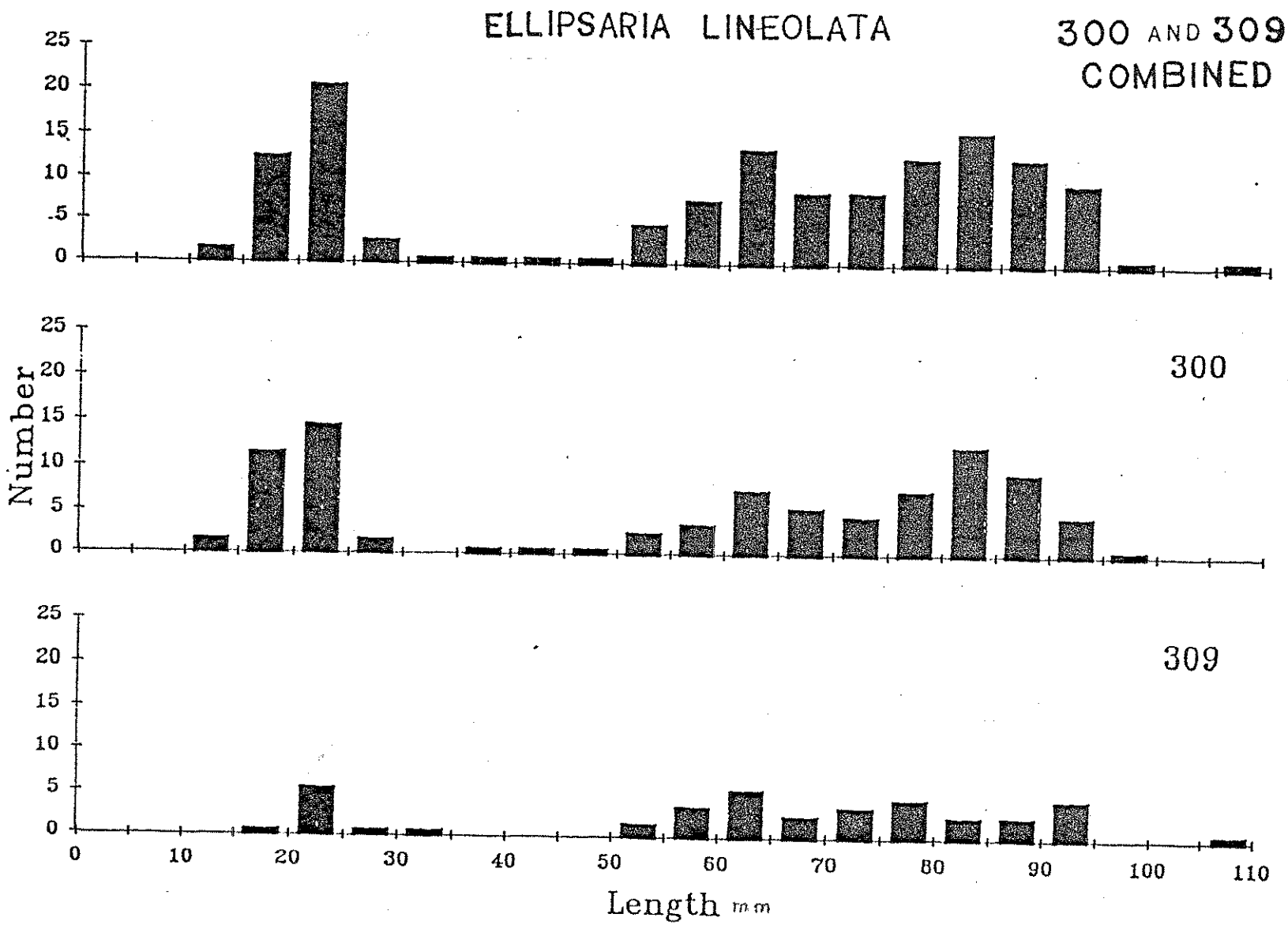

Figure 19. The number and length of Ellipsaria lineolata recorded at MRM 300.0 and 309.0 during May-June 1988.

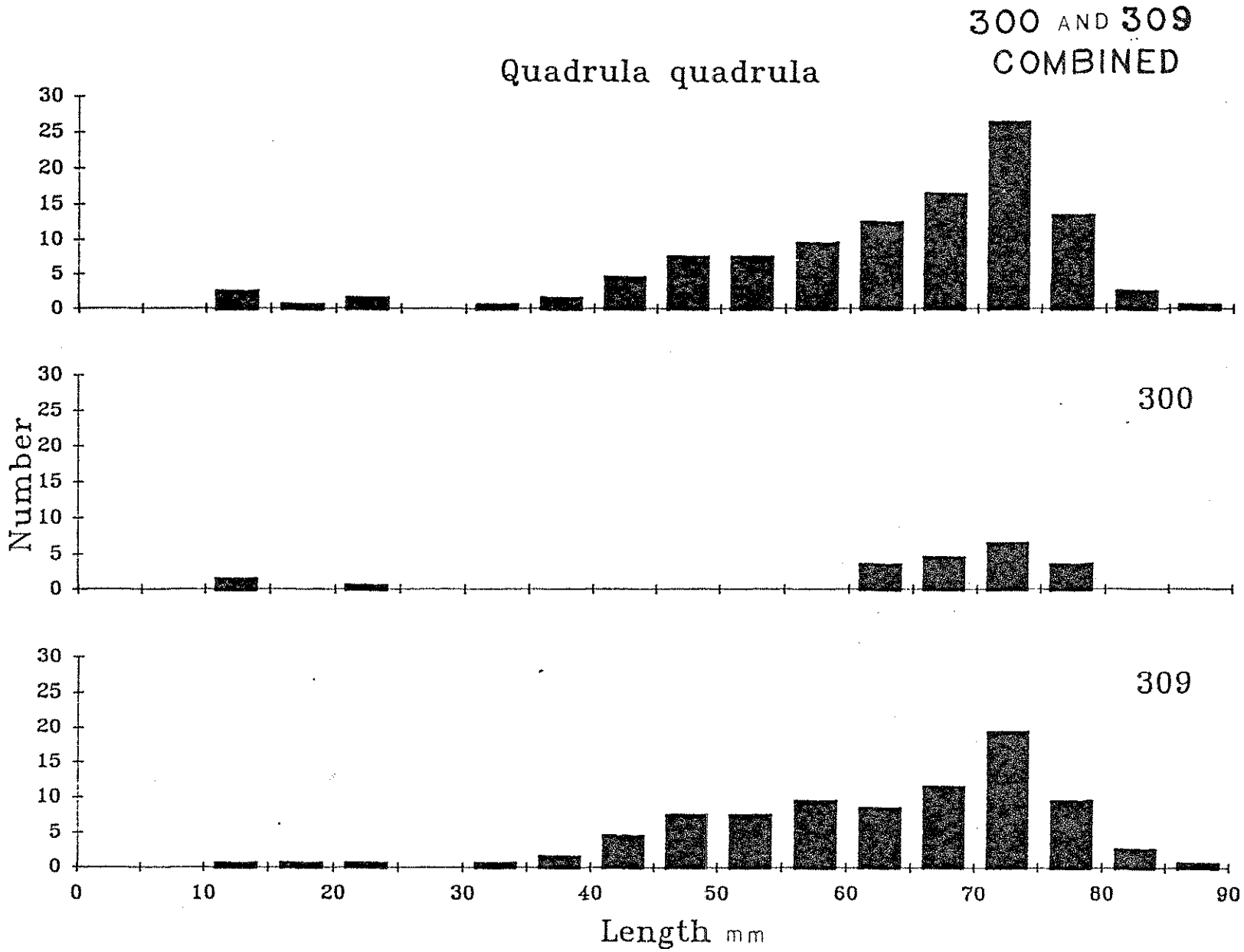

Figure 20. The number and length of Quadrula quadrula recorded at MRM 300.0 and 309.0 during May-June 1988.

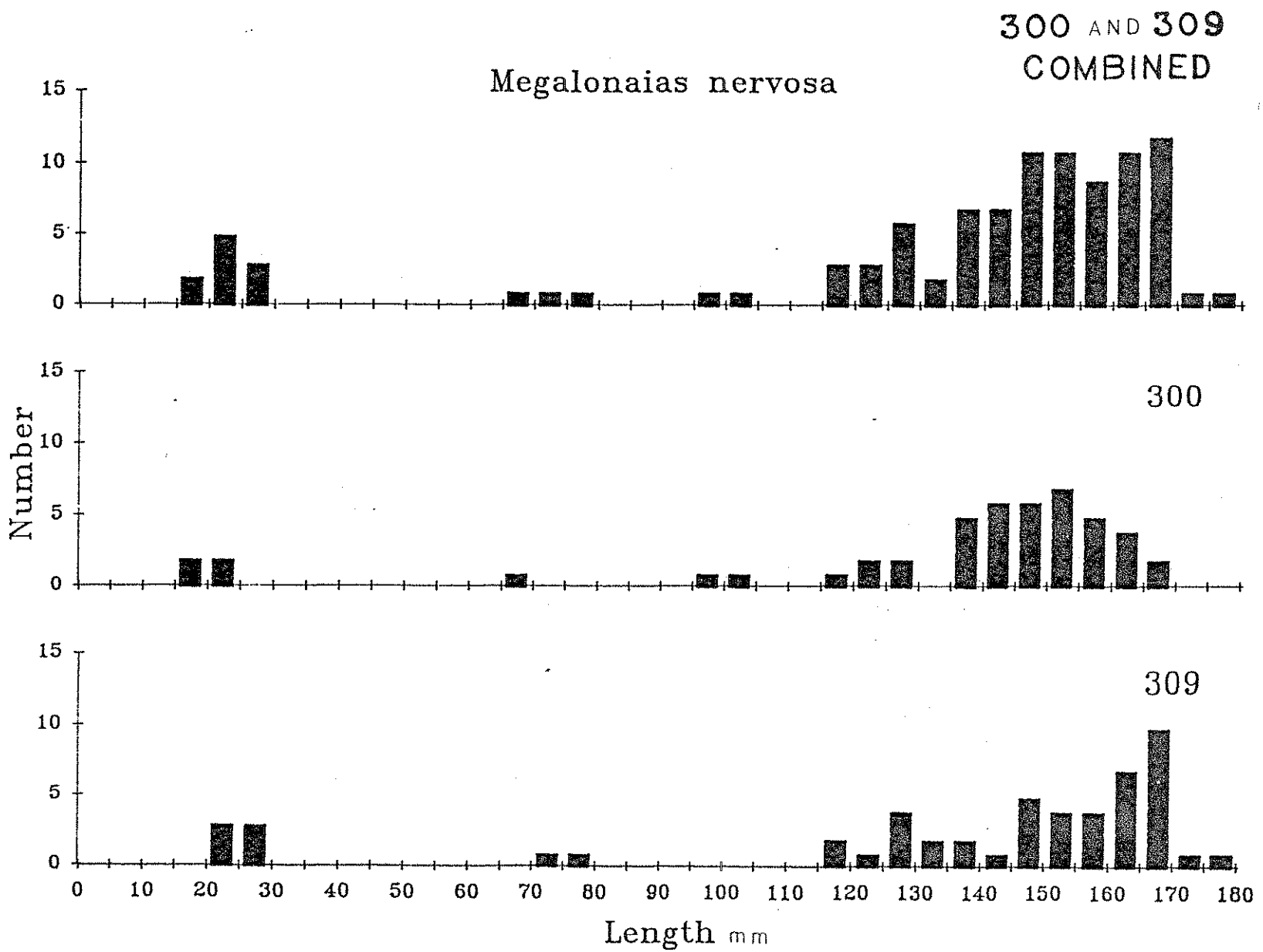

Figure 21. The number and length of Megalonaias nervosa recorded at MRM 300.0 and 309.0 during May-June 1988.

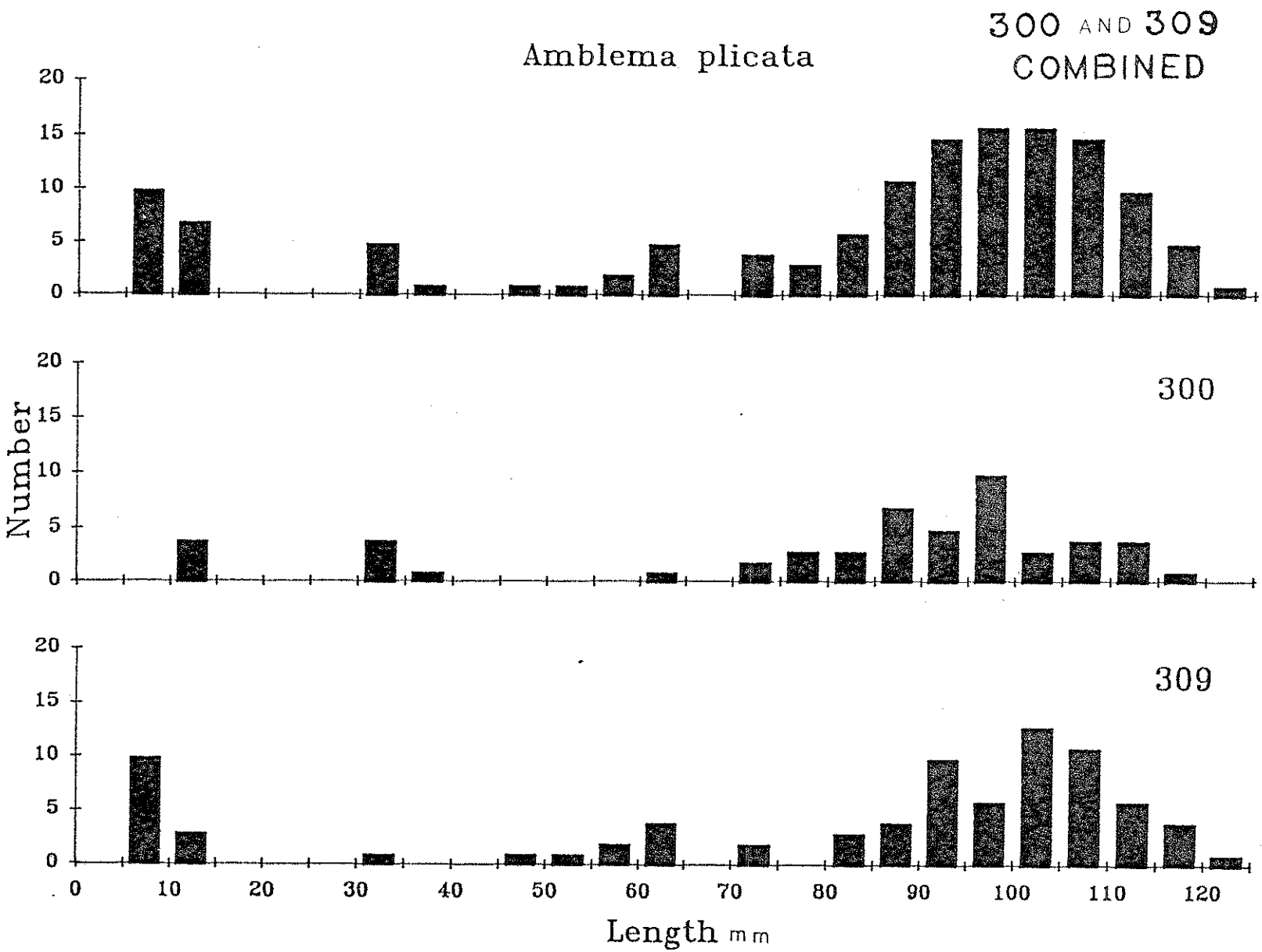

Figure 22. The number and length of Amblema plicata recorded at MRM 300.0 and 309.0 during May-June 1988.

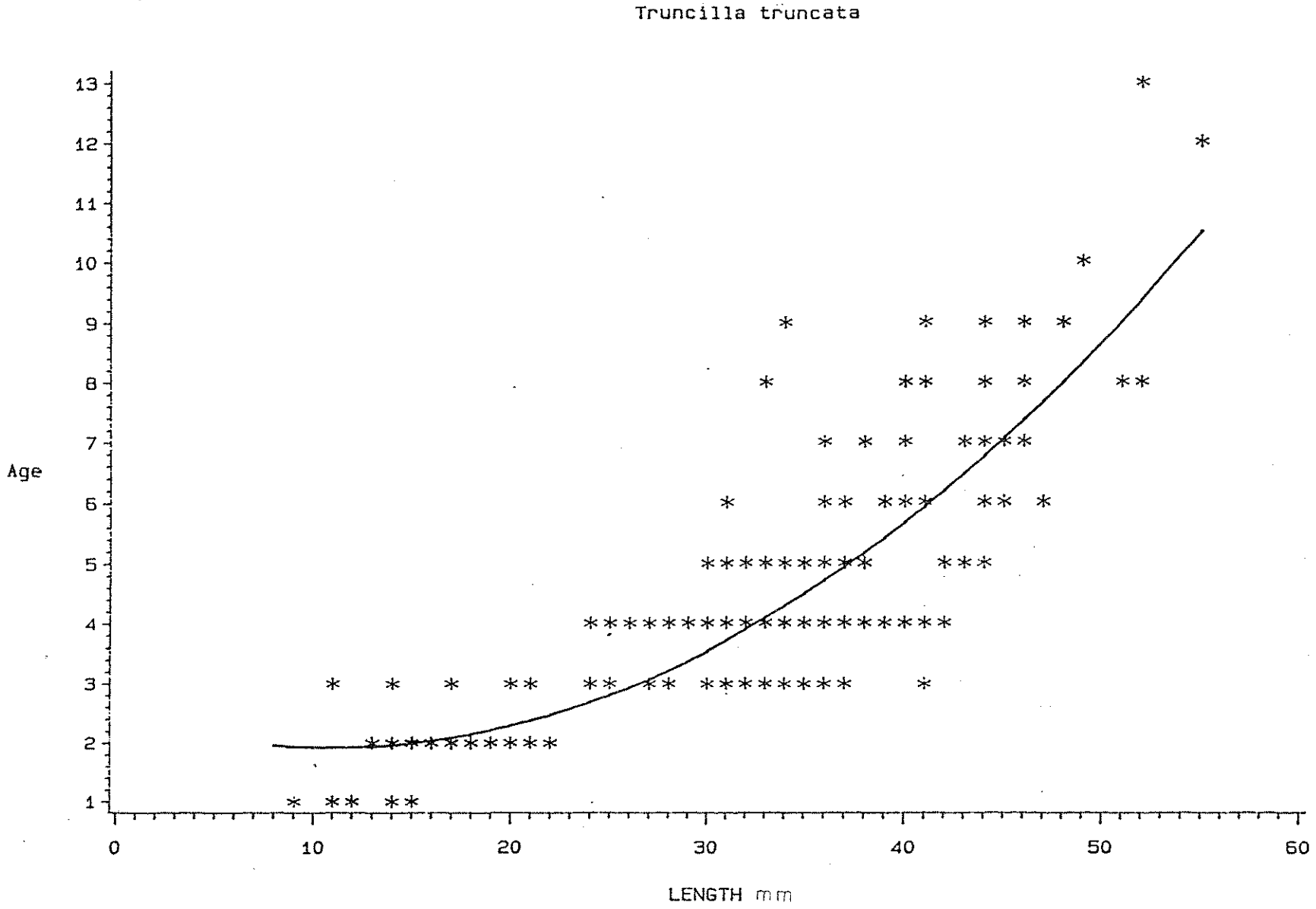

Figure 23. Combined age-length of Truncilla truncata from MRM 300.0 and 309.0 during May-June 1988.

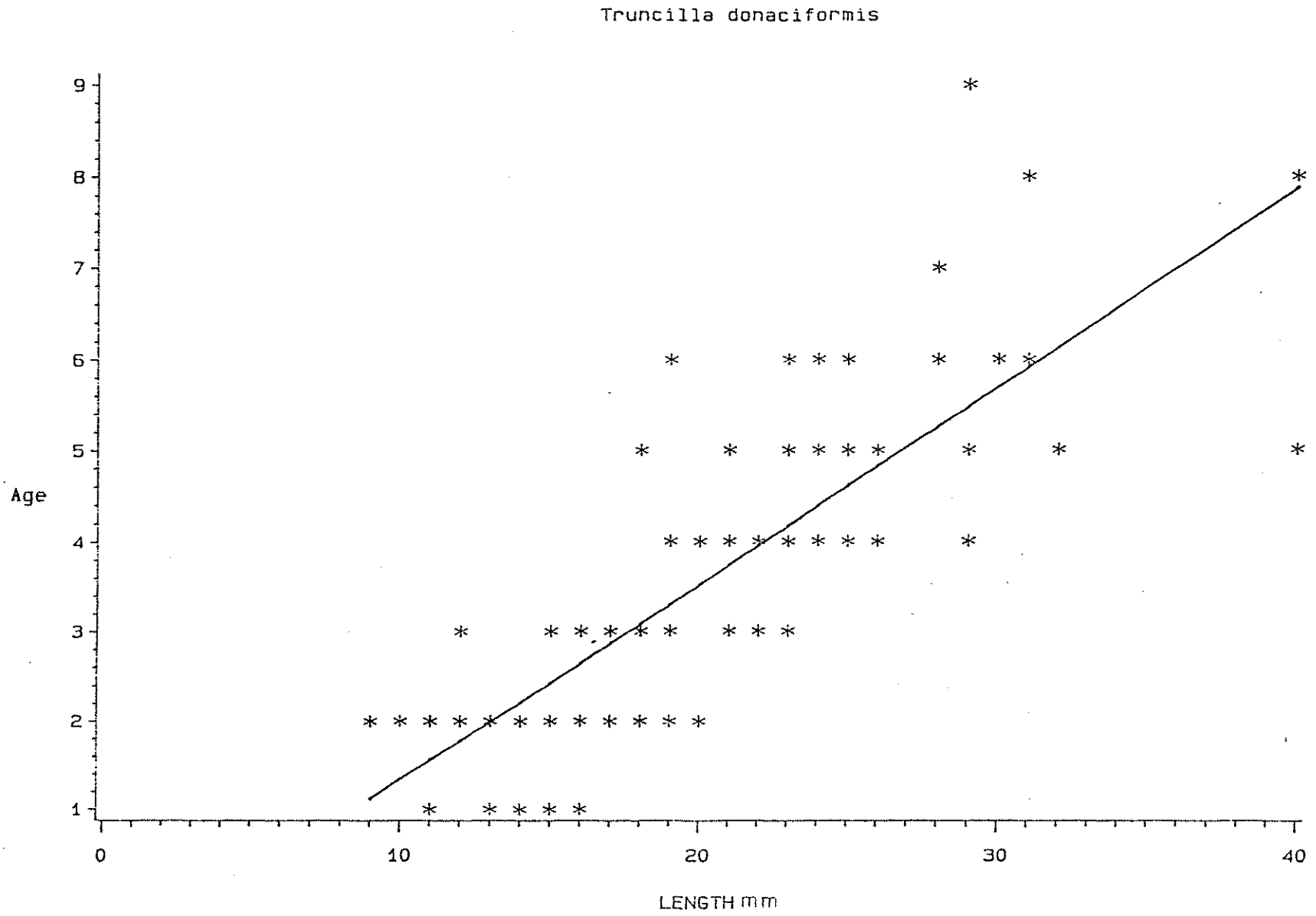

Figure 24. Combined age-length of Truncilla donaciformis from MRM 300.0 and 309.0 during May-June 1988.

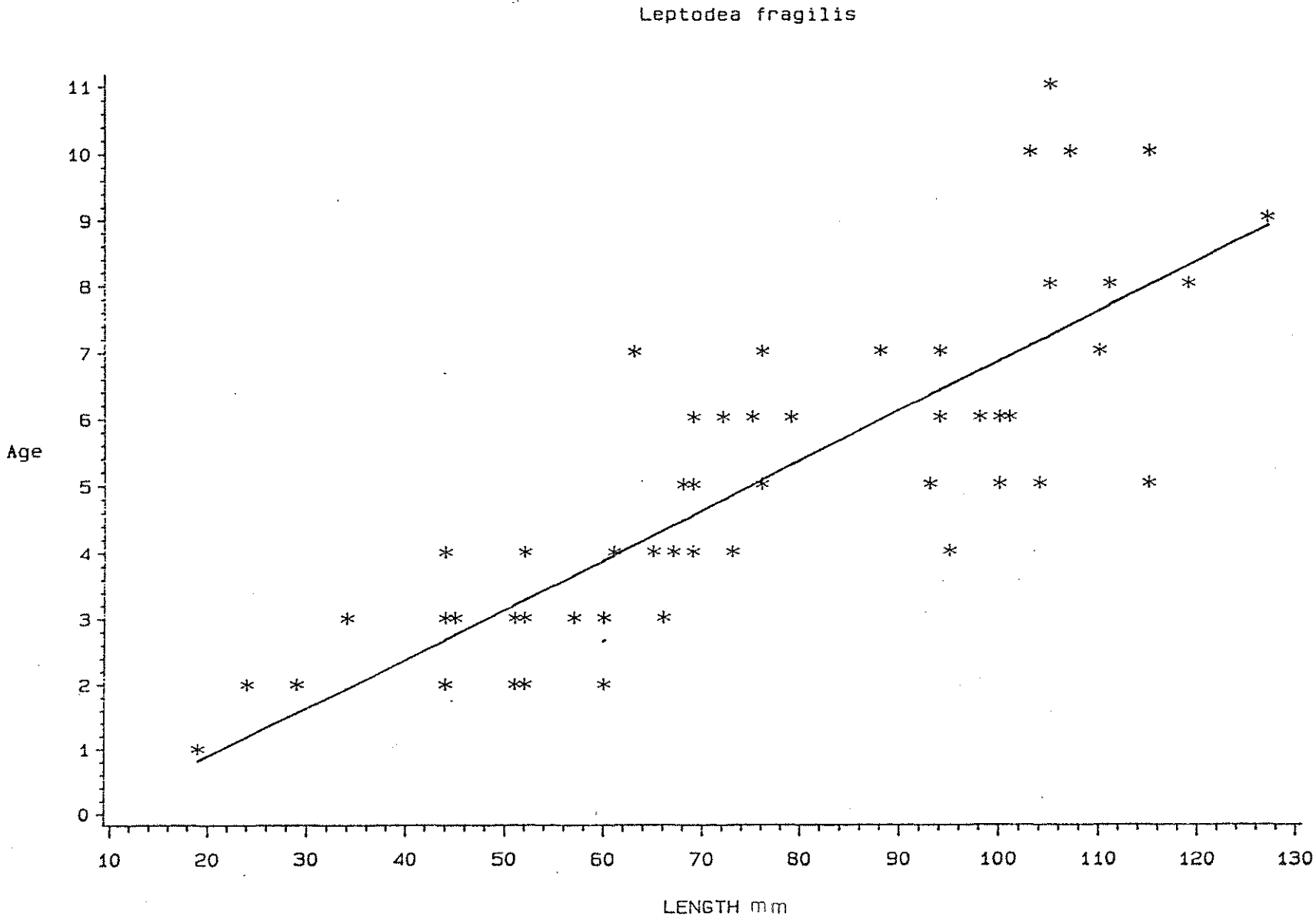

Figure 25. Combined age-length of Leptodea fragilis from MRM 300.0 and 309.0 during May-June 1988.

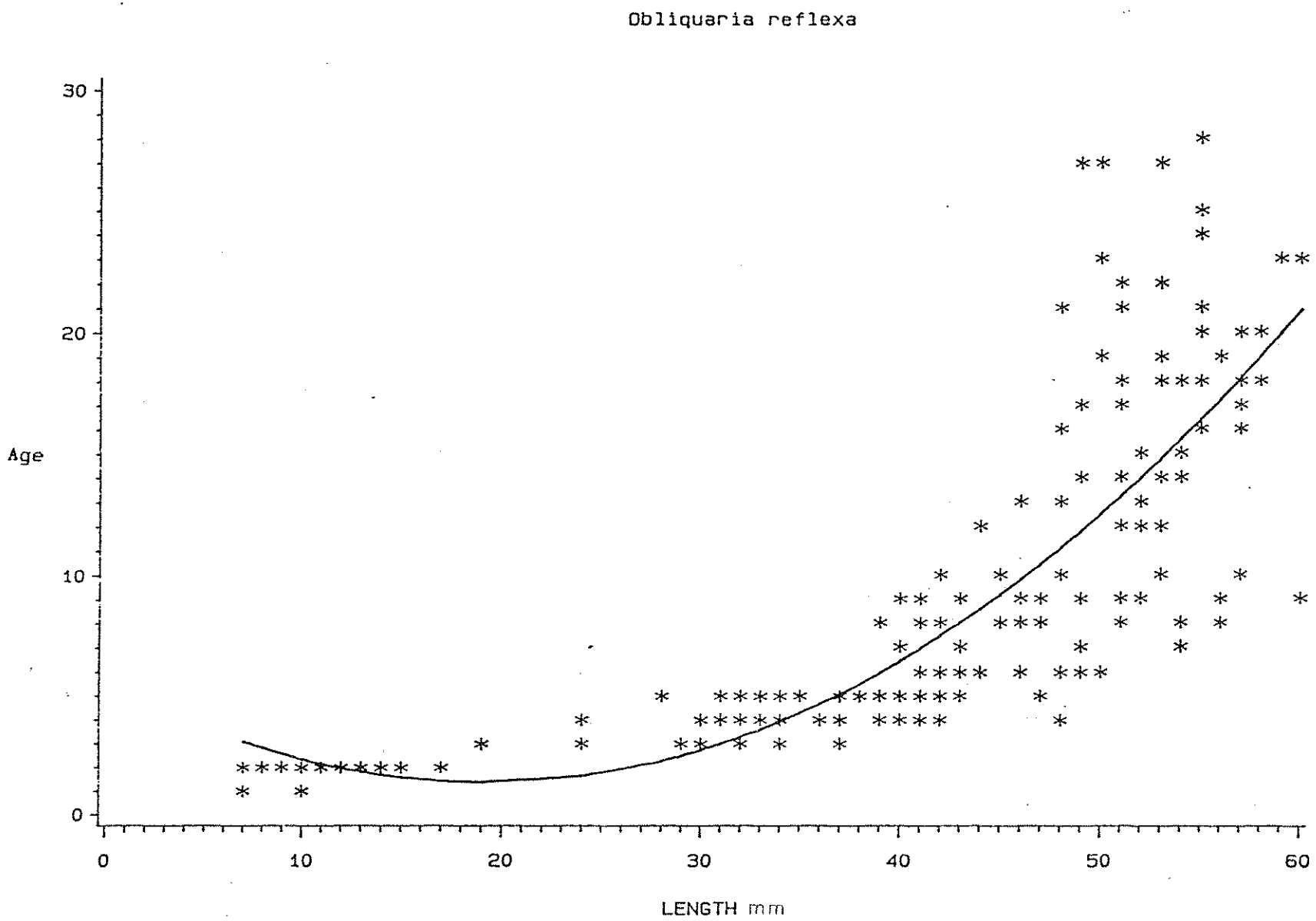

Figure 26. Combined age-length of Obliquaria reflexa from MRM 300.0 and 309.0 during May-June 1988.

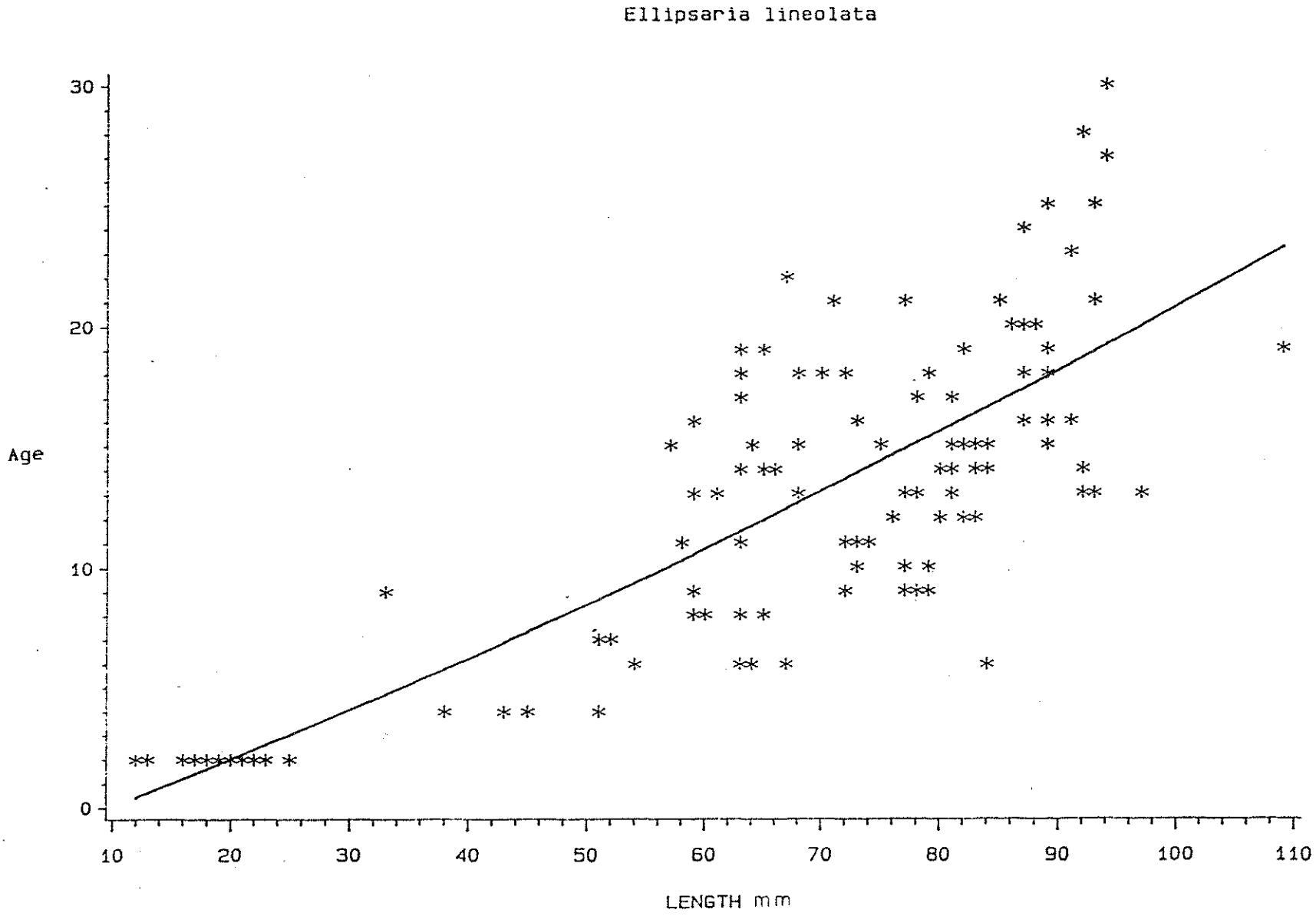

Figure 27. Combined age-length of Ellipsaria lineolata from MRM 300.0 and 309.0 during May-June 1988.

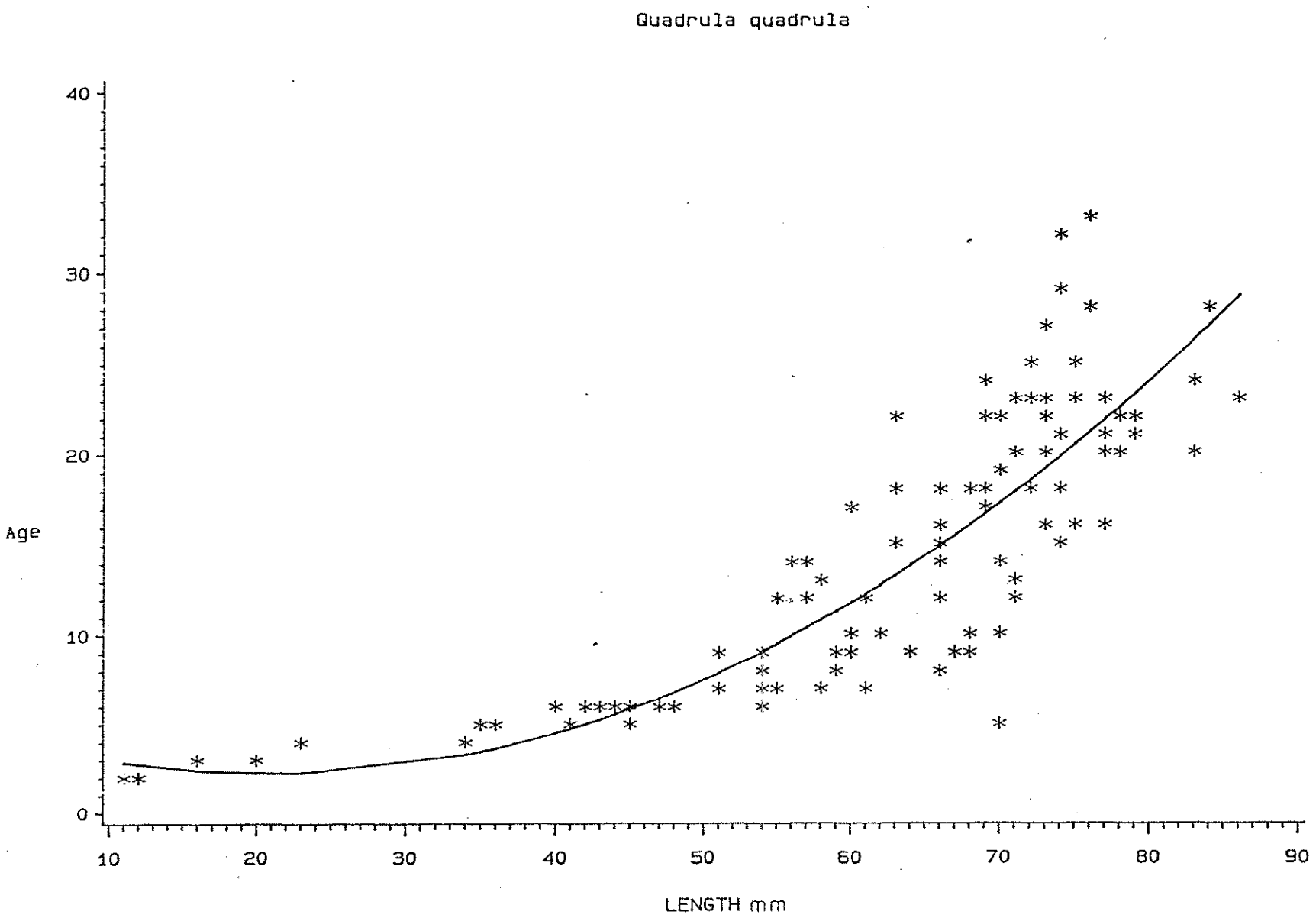

Figure 28. Combined age-length of Quadrula quadrula from MRM 300.0 and 309.0 during May-June 1988.

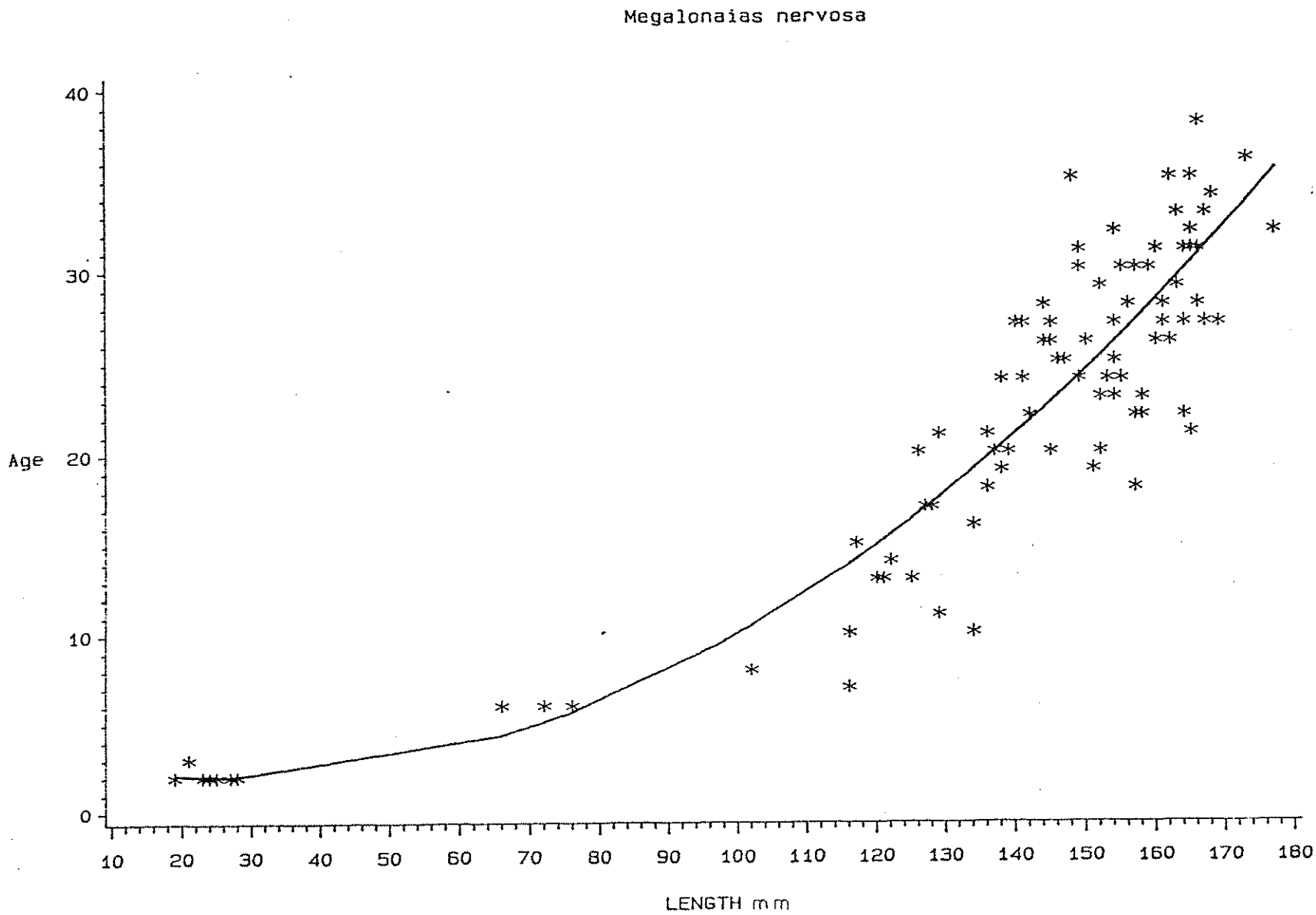

Figure 29. Combined age-length of Megalonaias nervosa from MRM 300.0 and 309.0 during May-June 1988.

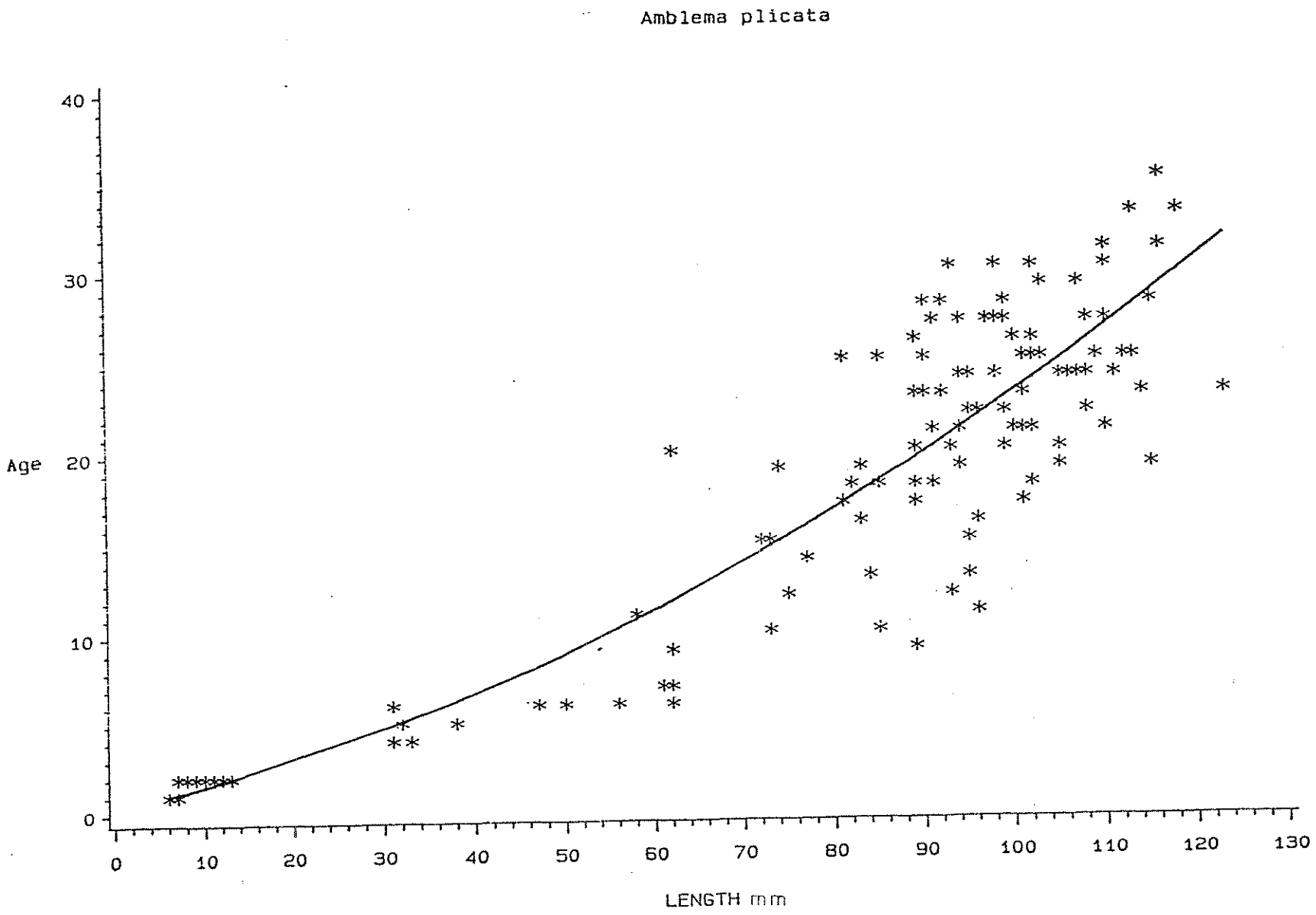

Figure 30. Combined age-length of Amblema plicata from MRM 300.0 and 309.0 during May-June 1988.

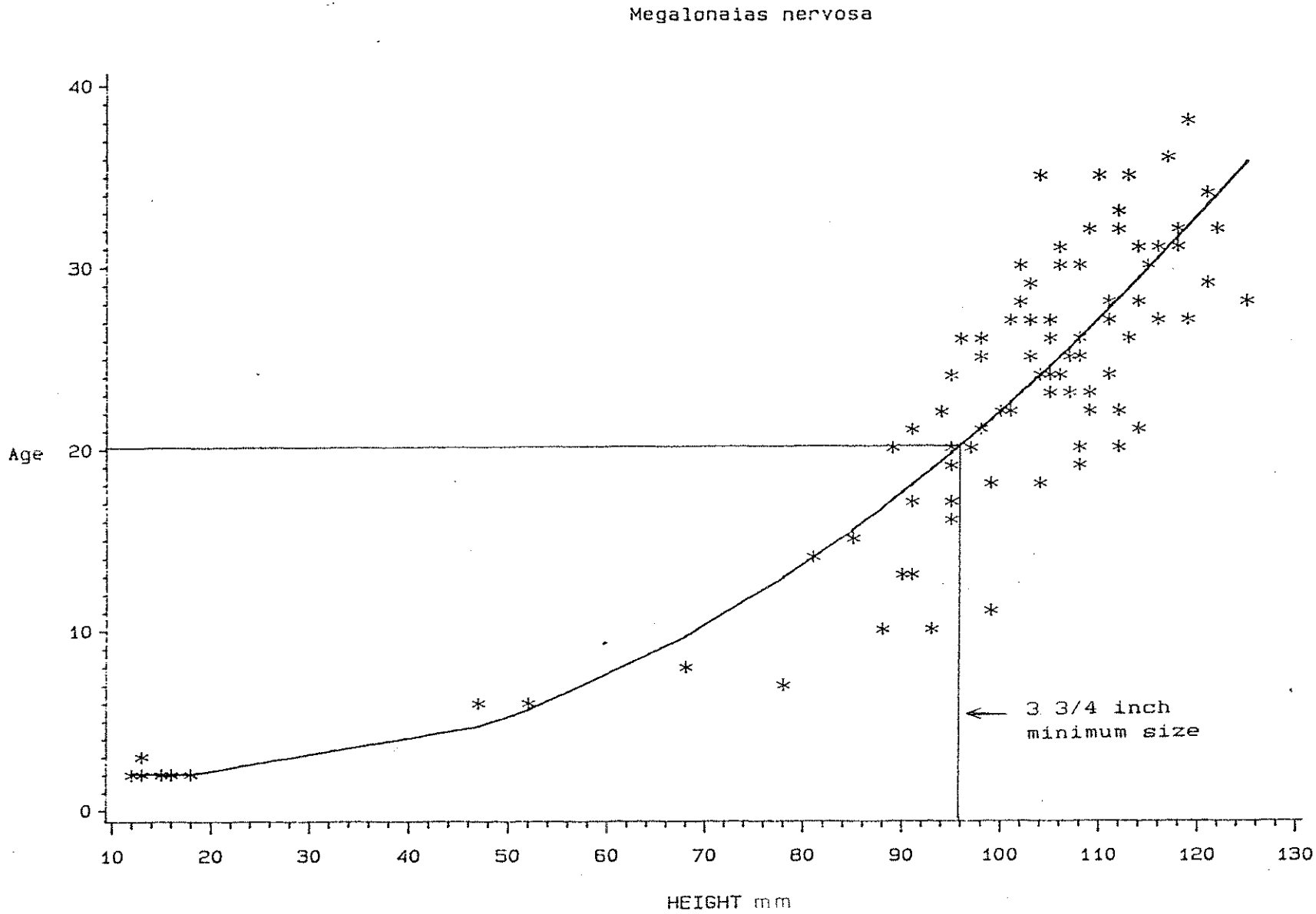

Figure 31. Combined age-height of Megalonaias nervosa from MRM 300.0 and 309.0 during May-June 1988.

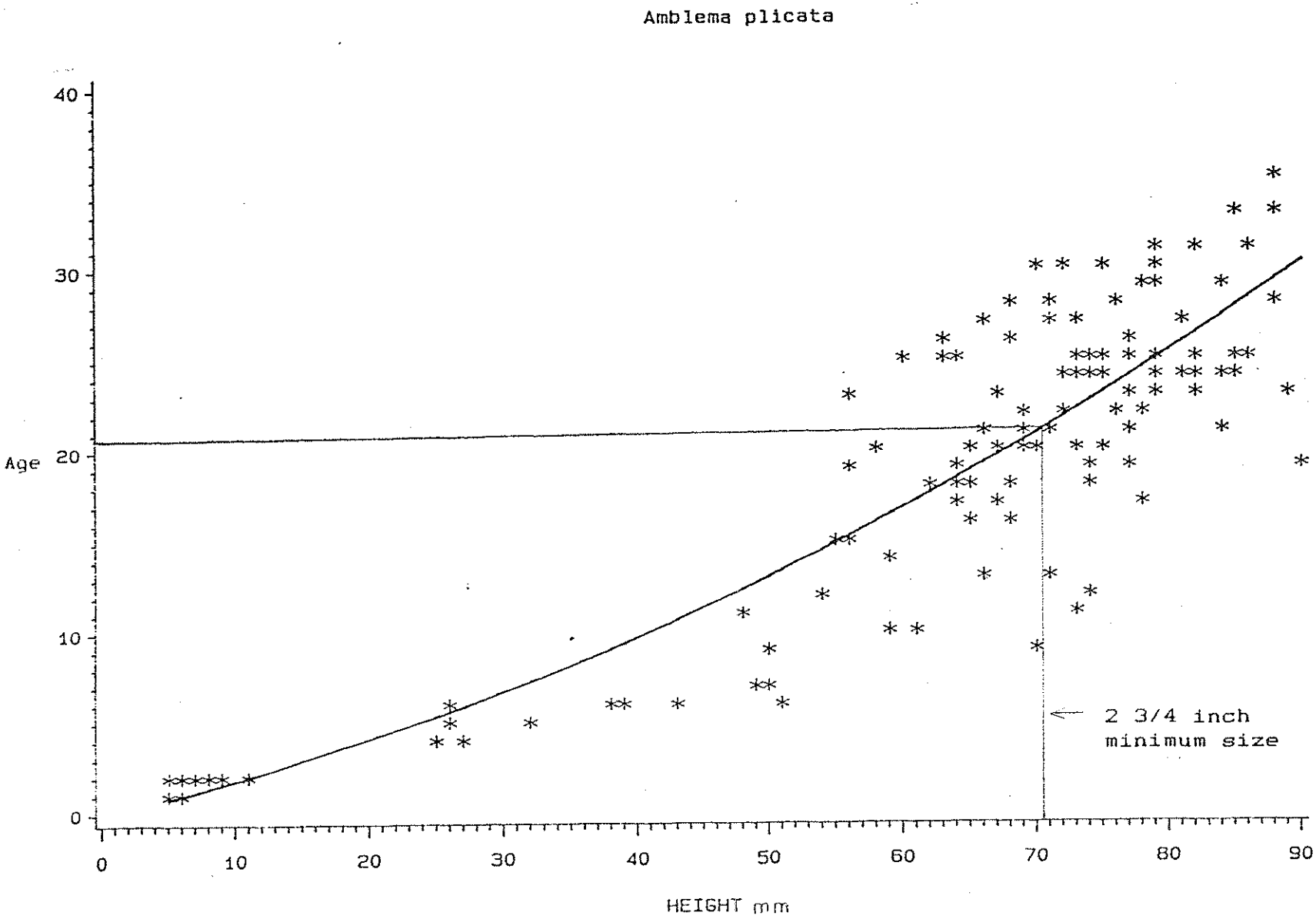

Figure 32. Combined age-height of Amblema plicata from MRM 300.0 and 309.0 during May-June 1988.

APPENDIX A

Simple linear regression formula

$$Y = A + BX$$

Quadratic regression formula

$$Y = A + B_1X^2 + B_2X$$

y = age

x = length