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IMPACTS OF BRAILING ON MUSSEL COMMUNITIES AND HABITAT IN KENTUCKY LAKE

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Abstract

The present mussel law which restricts brailing to the main lake, excluding embayments, has excluded from brailing 30% of the Kentucky portion of Kentucky Lake and 67% of the 277 miles of shoreline at summer pool elevation of 359 ft.

Underwater video provides a useful method for examining and documenting benthic habitats but is restricted to close-up work and small areas of about 1-2 square ft. because of the low visibility. No areas were located in the main lake which appeared to be suitable habitat for crappie nesting.

Twelve species of mussels were found in quadrat sampling. The overall density of mussels has increased since 1980-81 but the mean length, weight and age of the commercial mussels has declined, probably as a combined result of brailing and the increased number of juvenile mussels. The large number of young mussels indicates healthy populations which should sustain the resource into the near future. These populations should be monitored periodically to determine their status and trends.

For the three important commercial species, *Quadrula quadrula*, *Amblema plicata*, and *Megalonaias gigantea*, the length-weight relationships have not changed since 1980-81. This indicates that the growth characteristics which depend on food and water quality are unchanged.

The percent of undersize shells in typical brail harvests ranges from 20% to 60% with a mean of 50%. This reflects the high number of young mussels indicative of a healthy community.

The percentage mortality of undersize shells which are returned to the lake ranges from 30% to 64% with an average of 51%. This high mortality might be reduced if care is taken removing young mussels and if they are returned to the lake immediately into a habitat similar to where they were caught. For the three main commercial species, _A. plicata_ had the highest mortality and _M. gigantea_ had the lowest. In general the smaller shells had higher mortality.

As the number of commercial size mussels declines in an area because of harvest, the brailers move to new areas. With a harvest efficiency of 1.5% it is unlikely that brailers could destroy the mussel resource before being forced to move to another area by economic reasons. This should leave a sufficient number of mussels in the area to reproduce and replenish the resource.

The questionnaire documents that sport fishermen feel that mussel brailing is the most important problem in Kentucky Lake and that brailing is damaging fish habitat and contributing to the decline in fish, especially crappie. Removal of underwater structure is the main problem. The mussel brailer feels that brailing is not damaging the fish resource and that weeds are the most serious problem in the lake with illegal diving being second. Sixty-six percent of all respondents said they would favor allowing brailing to continue if it did not damage fish habitat. Seventy-seven percent of all respondents strongly oppose allowing diving for mussels.

Perhaps if brailers could work to reduce the destruction of underwater structure by avoiding areas known to have structure and limit brailing in heavily used fishing areas especially on weekends and holidays, some of the conflict might be abated. The Department of Fish and Wildlife Resources could work with sport fishermen's organizations and the shell harvester associations to mark areas where structure should be avoided or place fish attractor buoys in areas where structure pulled up by brailers could be dumped to improve fishing if this did not impede navigation.

Overall the mussel resource seems healthy, and under present regulations the resource should sustain a continued harvest. Harvest pressure is declining in the most heavily worked areas as fewer large shells are caught and musselers move to new areas. Some are moving to Lake Barkley where shell quality is excellent, even better than in many areas of Kentucky Lake, and densities are increasing as the reservoir ages. If conflicts with other water resource users can be resolved, and the second segment of this study indicates insignificant damage by brailing to other benthic organisms and fish, then musseling should have a good future in western Kentucky.

Acknowledgments

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IMPACTS OF BRAILING ON MUSSEL COMMUNITIES AND HABITAT IN KENTUCKY LAKE

INTRODUCTION

The value of freshwater mussel shells used in the cultured pearl industry continues to rise as the supply dwindles. Prices paid to the commercial musseler for "green" shells (fresh from the water with mussel body intact) exceeded $1.50 per pound while the highest quality dry shells brought over $2.00 per pound in 1989. The legal harvest from the 40 mile section of Kentucky Lake in Kentucky is estimated to exceed $3,000,000 this year with the illegal harvest probably approaching that figure. Over the past 5 years the shellfishing pressure in the Kentucky portion of Kentucky Lake has increased many fold stimulated by high prices and the development of techniques for brailing outside of the old river channel on the shallow submerged fields or overbank, levees, and old flood plain. For 40 years after the construction of Kentucky Dam in 1944, shallow areas were not brailed because of low densities of shells and the many stumps that hang brails. As mussels colonized the areas outside of the old river channel, illegal diving became the primary method of harvest, and by 1980 reports of individual divers each collecting over 1,000 pounds of mussels in a single night were common. As mussel densities increased, commercial brailers learned methods for brailing in the shallow waters, and by 1985 it was economically profitable to brail for mussels in areas that were once corn fields and pastures 45 years ago. By 1986 about 100 brail boats cold be seen plowing the waters throughout the Kentucky portion of Kentucky Lake, and in 1987 over 400 mussel fishing licenses were purchased.

The typical brail boat is a flat-decked boat 18-28 feet in length with a small aft cabin which facilitates work under most weather conditions. Each boat is equipped with two 16 ft. brails consisting of the brail bar along which 3 ft. lengths of chain or rope are suspended every 3 in. with 6 to 8 wire hooks attached at the ends. The hooks are made of heavy gauge wire with usually 4 or sometimes 6 prongs. The tips of the hooks are often heated with an acetylene torch to form a small bead which helps hold the mussel. This method of construction was developed around 1900 with several styles of hooks actually being patented at that time (Coker, 1919). Figure 1 shows a computer graphics image of a brail hook. The brail is lowered to the lake bottom and pulled at a slow velocity of about 20 ft./min. The hooks scrape the surface of the sediment. Mussels lie partially buried in the sediment with their shell opened slightly while feeding. If a hook prong enters the shell, the mussel closes on the hook and may be lifted from the sediment.

Mussel brails have a tendency to catch on any submerged object with the result being that brailers often pull up debris, brush, small stumps or broken roots, old trotlines, and a variety of junk. Some of this material may have been used by fish which often congregate around submerged structures. Therefore, a controversy has developed between various groups, particularly

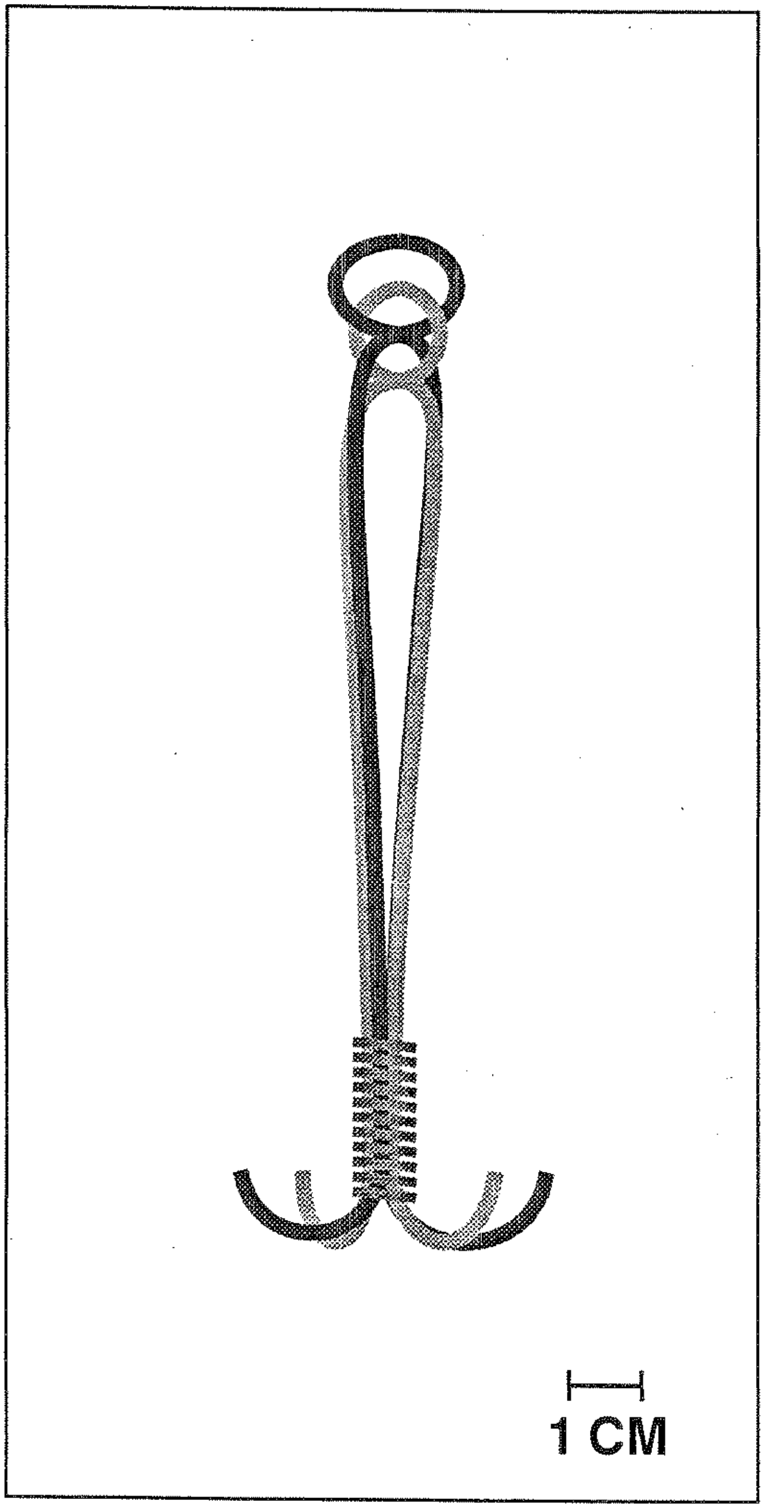


Figure 1. Computer graphics image of a crowfoot brail hook.

sport fishermen, and the mussel brailers regarding the impact of brailing on lake resources.

This project which is the first part of a 2 year study is designed to examine some aspects of the impact of brailing on the benthic habitat and the mussel community and to gather opinions by a questionnaire from individuals who make direct use of the Kentucky Lake resources. The second segment of this study will examine the impacts of mussel brailing on other benthic organisms, a major source of food for the fish community, and attempt to locate crappie nests in the spring of 1990 and examine the impact of brailing these nests.

Materials and Methods

Study Area

Kentucky Lake is one of the most prominent and economically important physiographic features in western Kentucky. It was formed in 1944 as a result of the construction of Kentucky Dam by the Tennessee Valley Authority at a location 22.4 miles up the Tennessee River from where that river flows into the Ohio River. Since its construction, the reservoir has served the multiple purposes for which it was designed -- power generation, flood control and navigation. In addition, valuable recreation, tourism, and sport and commercial fisheries activities have developed on the reservoir.

Kentucky Lake extends from Kentucky Dam at Tennessee River mile (TRM) 22.4 to Pickwick Landing Dam at TRM 206.7. The portion of Kentucky Lake included in this study is that part within the Commonwealth of Kentucky. This section extends from the Kentucky-Tennessee line at TRM 62.4 on the west shore and TRM 49.2 on east shore north to Kentucky Dam. Between TRM 49.2 and TRM 62.4 the state line follows the old river channel (Figure 2).

The surface area of Kentucky Lake is 160,300 acres (6.48×10^8 m^2) at the summer pool elevation of 359 ft. above mean sea level (109.4 m) (Carriker and Cox, 1984) with 49,660 acres (2.01×10^8 m^2) or 31% occurring in Kentucky (MARC, 1989). The major embayment (those with creek names) surface area in Kentucky is 14,620 acres, (5.91×10^7 m^2) or 29.4% of the total lake area in Kentucky. The shoreline of the entire reservoir at summer pool

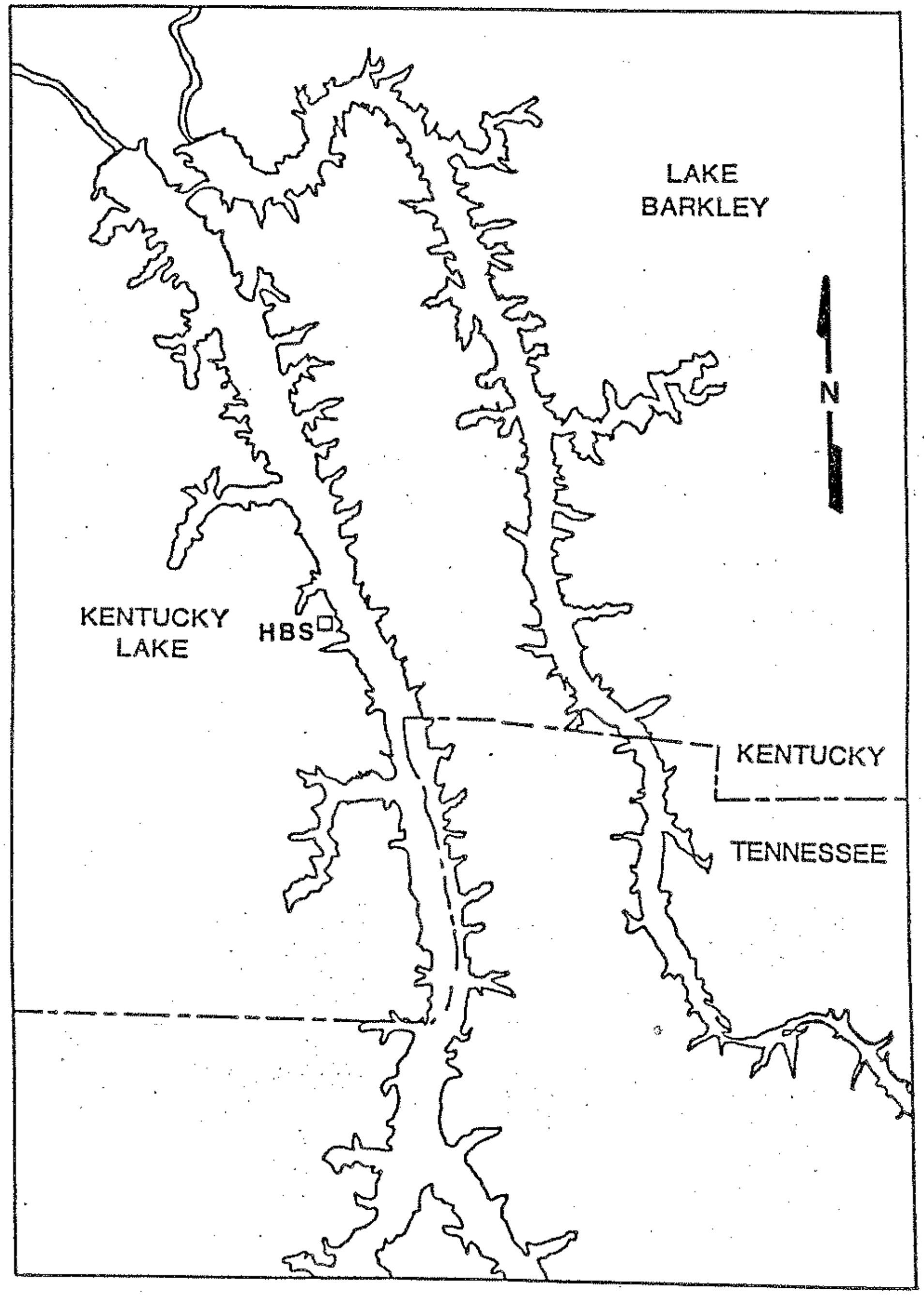


Figure 2. Outline of Kentucky Lake and Lake Barkley within the Commonwealth of Kentucky. HBS is Hancock Biological Station of Murray State University.

elevation is 2,025 miles (3259 km) (Carriker and Cox, 1984). Within Kentucky, the shoreline length including embayments is 277 miles (445.8 km) (MARC, 1989). The embayment shoreline length is 186 miles (299.3 km) or 67% of the total shoreline within Kentucky. Table 1 summarizes these data for the section of the lake in Kentucky.

Table 1. Comparison of surface area and shoreline length of Kentucky Lake embayments and main lake within the Commonwealth of Kentucky at summer pool elevation of 359 ft. (109.4 m). (MARC, 1989)

	Surface Area acres (hectares)	Shoreline Length miles (km)
Kentucky Lake in Kentucky	49,660 (20,100)	277 (446)
Embayments in Kentucky	14,620 (5,910)	186 (299)
Lake excluding embayments	35,040 (14,180)	91 (146)

The mean depth of Kentucky Lake at summer pool is 17.7 ft. (5.4 m) (Carriker and Cox, 1984) with the maximum depth in the main lake being about 70 ft. (21.3 m). One embayment, an old quarry at TRM 34, has a depth of 115 ft. (35 m).

Methods

For the purpose of evaluating the impact of brailing on benthic habitat and mussels, five habitat classifications were used: embayment, shoreline, overbank, levee, and channel. Most brailing activity is confined to the levee and overbank areas, so the emphasis was placed on these habitats. Brailing is not allowed in embayments, but embayment sites were included in the study because historical data exists on mussels in embayments (Sickel and Chandler, 1982). Little brailing occurs in the channel or immediately adjacent to the shore because mussels living in the deep water grow slower and many are under the legal size limit and shorelines are generally rocky and steep which makes brailing difficult.

Underwater video photography was accomplished using a Sony CCD-V9 Video 8 camera in an Amphibian V9N housing (Amphibico Inc., 9563 Cote de Liesse, Dorval, Quebec, Canada H9P 1A3). The camera was fitted with two 35 watt halogen flood lights attached by a 100 ft. cable to a 12 volt battery in the boat. The lights were attached to the housing on jointed arms made of aluminum bar and adjusted to illuminate the subject from approximately 45 degree angles 1 ft. from the housing lens. This gave a uniformly lighted area out to 1 ft. in front of the lens. Because of high turbidity during the 1989 period, photography was not effective beyond about 1 ft., therefore a 120 degree wide angle lens was used.

To determine the size and age distribution of mussels for comparison with data collected in 1980-81, sites were selected from those studied in 1980-81 for which quadrat samples had been taken and mussel density had been determined (Sickel and Chandler, 1982). This allowed a direct comparison for each habitat type that was sampled in 1980-81. The sample sites used in the 1980-81 study from which the present study sites were selected are shown on the lake maps in Figure 3.

Mussels were collected by divers from 10 or 20 1 m^2 quadrats

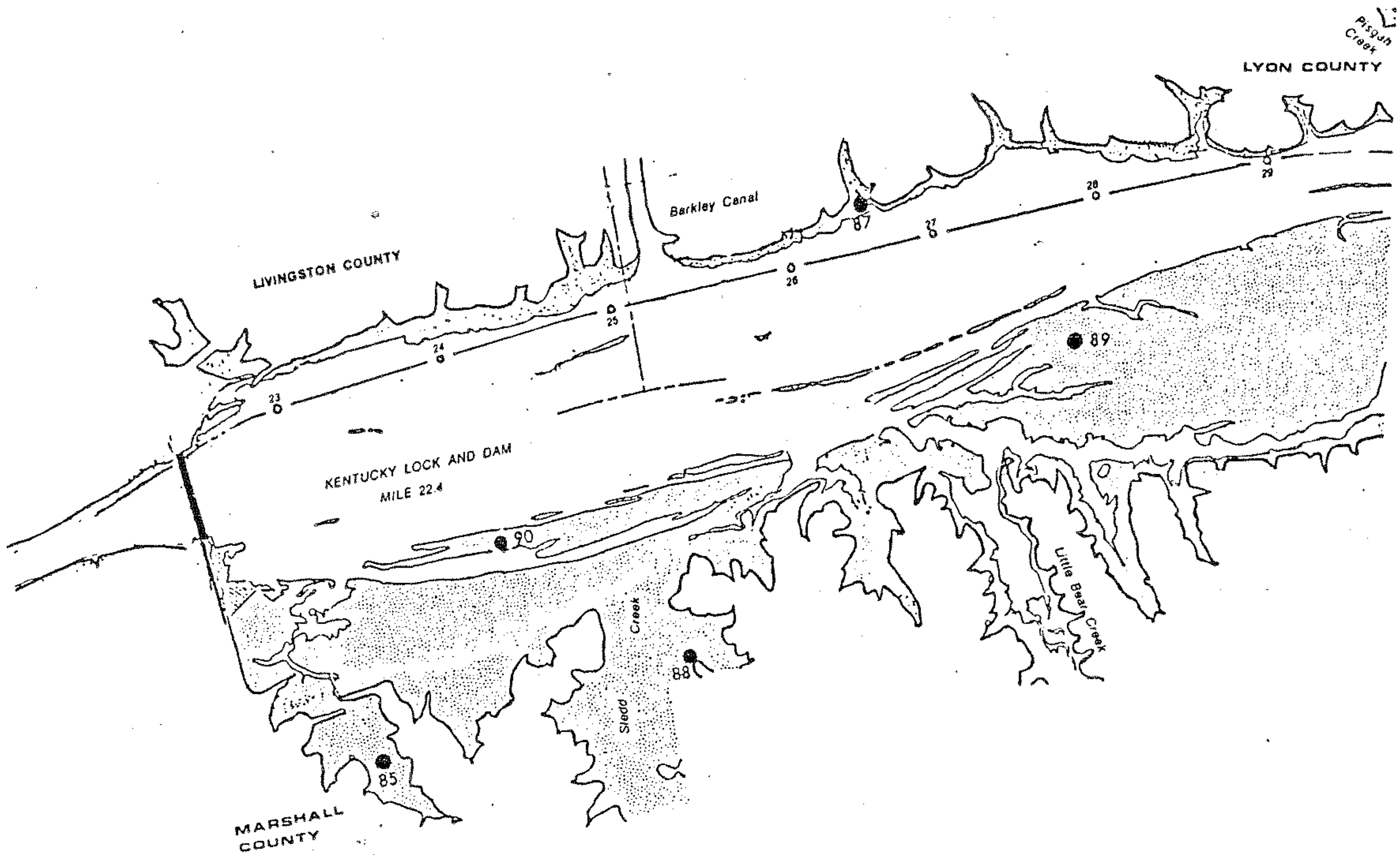
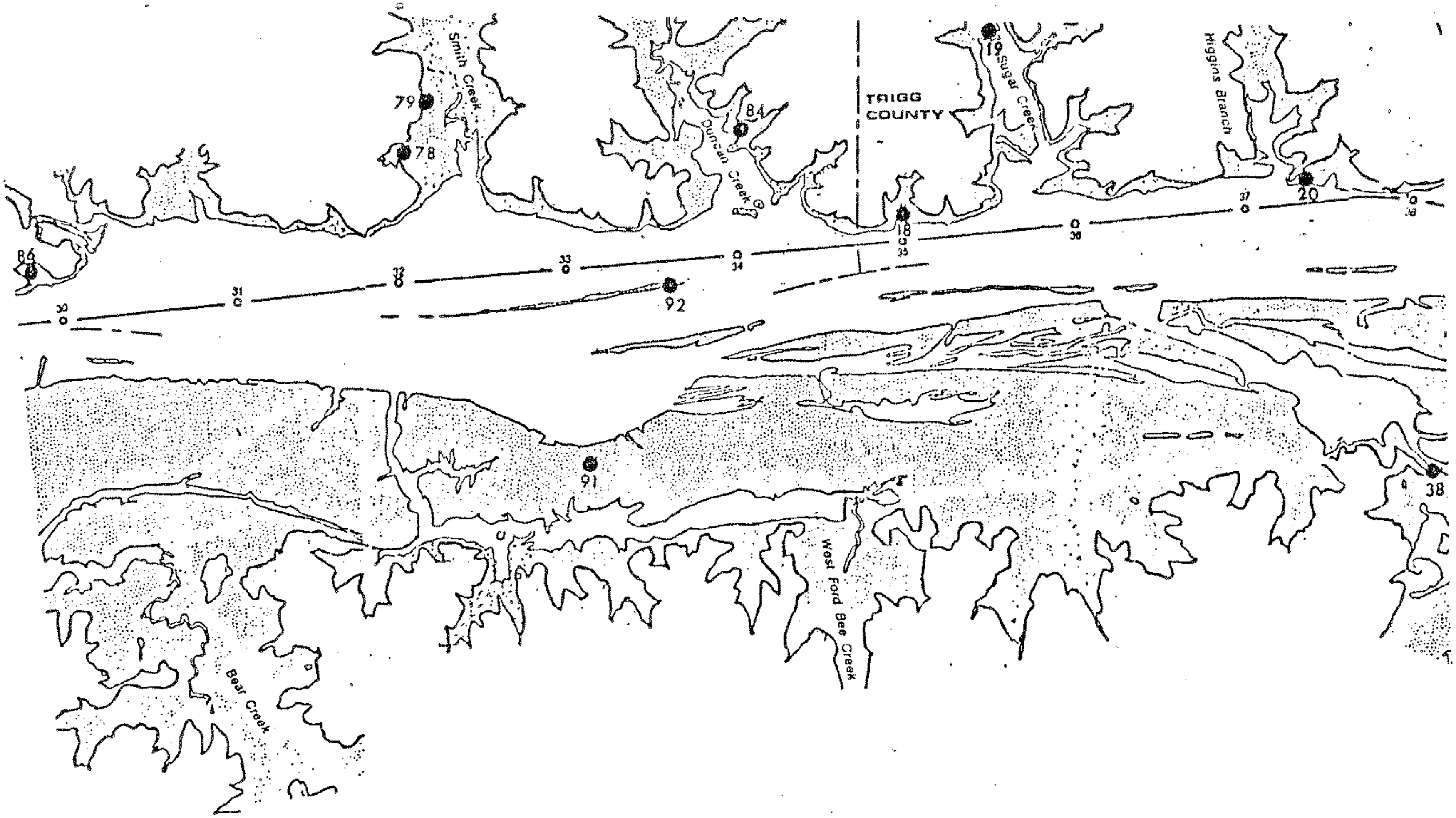


Figure 3. Map of Kentucky Lake showing the 1980-81 sample sites as solid dots.



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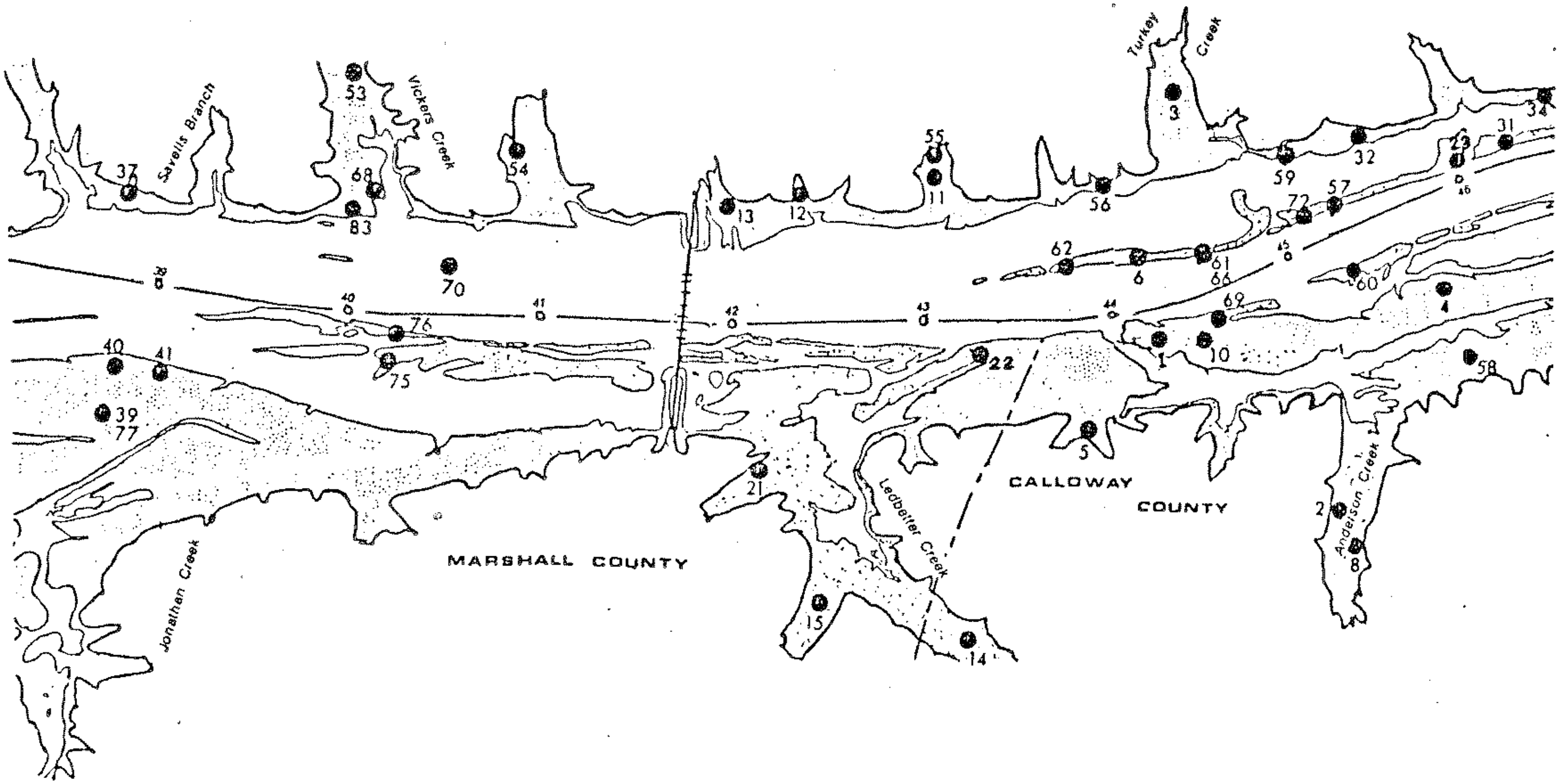

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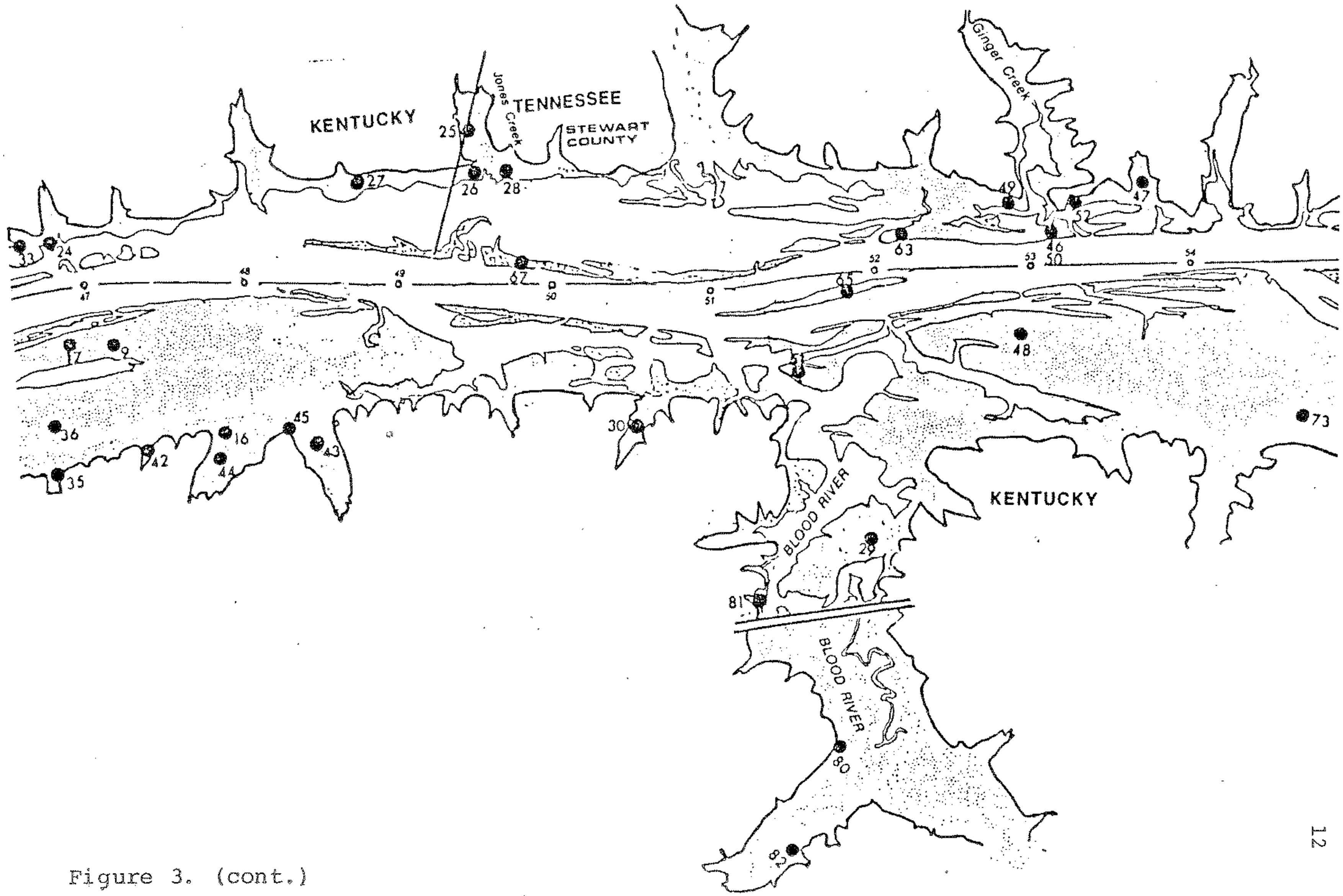

Figure 3. (cont.)

Figure 3. (cont.)

at each site. All mussels were identified, weighed, and length measurements for each annual growth increment and total length were recorded.

For the study of mortality of undersize mussels, commercial brailers cooperated by allowing project personnel to count the number of undersize shells which are caught on brails and returned to the lake. Several hundred of these shells were collected, labeled, and placed in enclosures in the lake for observation. An equal number of mussels were collected from similar areas by divers, labeled in the same manner and placed with brailed shells to compare the mortality of brailed with non-brailed shells.

Mussel tags consisted of numbered, laminated plastic ovals measuring 3 X 7 mm (Floy Tag and Manufacturing, Inc. 4616 Union Bay Place N.E., Seattle, WA 98105). Shells were brushed and rinsed to remove all mud and to expose a clean area of smooth periostracum. The spot where the tag was to be attached was air dried. To speed drying a jet of compressed air was often used. A number of adhesives available locally were tried, but only one proved to be waterproof, quick drying and permanent. This was the Surehold brand of cyanoacrylate 108 with trichloroethane surface prep solution (Surehold, Inc. 600 N. McClurg Ct., Chicago, IL 60611). A tiny spot of the glue was placed on the tag which was conveniently held by placing a needle probe through the hole which is in one end of the tag. A dab of surface prep was applied to the clean, dry shell using the applicator brush, and the tag was pressed into position and allowed to dry for 15 minutes.

As an added precaution in case of tag loss, the tag number was written on the shell with white drawing ink and allowed to dry while the tag was being applied. These numbers were harder to read and not as permanent as the tag.

A four page questionnaire was prepared to elicit opinions and comments about the impacts of mussel brailing in Kentucky Lake. The questionnaires were mailed with postage paid return envelopes to all licensed musselers in Kentucky and a selection of sport fishermen, commercial fishermen, marina and resort owners, and recreational boaters. A total of 500 questionnaires were mailed.

Results and Discussion

Benthic Habitats

Because Kentucky Lake is a large reservoir formed by a dam on the Tennessee River, the benthic habitats are diverse, and the bottom contours are complex, following old terrain features such as creek beds, flood plain, ridges, and the old river levees. The east and west shores of the lake differ greatly also, many east shore features being Mississippian and Cretaceous formations while much of the west shore consists of Tertiary gravel. A complete description of the benthic environment of Kentucky Lake is beyond the scope of this study. However, a general description of the five habitat classifications will be useful since these rather distinct habitats tend to support mussel communities of varying densities, growth rates, and species composition.

The five habitat classifications are embayments, shoreline, overbank, levee, and channel (Sickel and Chandler, 1982). The embayments differ widely depending on size, depth, tributary size and volume of flow, orientation to main lake, size of mouth and surrounding terrain features and soil type. The embayments include some features in common with several other habitat classifications such as shoreline and channel if the embayment is deep. The embayment shoreline, however, differs from the main lake shoreline in the size of the sediment particles. Shorelines of the main lake consist of large gravel and sand while embayment shorelines are generally smaller gravel and sands near the mouth of the embayments grading to finer gravel and sand and finally silt at the backs of embayments.

The sediment distribution along the shoreline is obviously related to the degree of wave action received by the shore and the characteristics of the parent material being eroded by the waves. Where waves interact with shoreline materials, the finer particles are washed offshore leaving larger particles at the shoreline.

One method of describing sediments in terms of particle size is the phi-scale where phi is the negative base 2 logarithm of the particle diameter in mm. The classification according to Folk (1974) and Hynes (1970) is given in Table 2. These sediment particles are of great importance to the distribution and abundance of benthic organisms and have a major function in spawning success of a number of fish which depend on the attachment of their eggs to larger particles on a stable bottom.

Along wave swept shores one finds larger rocks, pebbles, and gravel with small amounts of sand and silt between or under the rocks. Moving away from shore the sediments grade to finer particles with smaller gravel and sand abundant to a depth of 1-2 m and finer sand and silt beyond a depth of 3 m. In deeper parts of the lake such as deep embayments and the secondary and main channel at depths from 8-20 m the sediment is predominantly silt and clay of recent origin, i.e., it has accumulated since the construction of the dam. This material is soft and easily suspended by divers. It may be somewhat flocculent if deposited under anaerobic conditions such as is often found in the main

Table 2. Phi scale of particle size and classification modified from Folk (1974) and Hynes (1970).

Name of Particle	Size Range (mm)	Phi Scale
Boulder	> 256	-8
Large Cobble	128-256	-7
Small Cobble	64-128	-6
Large Pebble	32-64	-5
Small Pebble	16-32	-4
Large Gravel	8-16	-3
Medium Gravel	4-8	-2
Small Gravel	2-4	-1
Very Coarse Sand	1-2	0
Coarse Sand	0.5-1	1
Medium Sand	0.25-0.5	2
Fine Sand	0.125-0.25	3
Very Fine Sand	0.0625-0.125	4
Coarse Silt	0.0312-0.0625	5
Medium Silt	0.0156-0.0312	6
Fine Silt	0.0078-0.0156	7
Very Fine Silt	0.0039-0.0078	8
Clay	< 0.0039	≥ 9

channel. In other areas such as the overbanks and embayments it is soft yet compact enough to support burrows of the mayfly nymph Hexagenia bilineata which may achieve high densities of several hundred per m^2.

The shallower overbanks make up a large part of the offshore region of the lake not included in the channel and secondary channels. This region was once flood plain forests, fields, or inhabited towns and small communities before Kentucky Dam was built. For lack of a better term it has been called overbank to indicate it is beyond the channel margins. Because the old river levees at the channel margin often have a distinct fauna, I have called them a separate habitat different from the overbank which includes the region from the levee to the nearshore area excluding the secondary channels which I include with channel habitat. Within the overbank will be found two subhabitats. The shallow overbank areas ranging in depth of 1-4 m typically do not accumulate more than a thin layer of silt less than 1 cm thick. Deposition is balanced by erosion of the fine silt during storms on high flow. The material immediately below this silt is original soil of preimpoundment origin. In deeper areas of the overbank, 5-10 m deep, very fine sands, silt and clays are accumulating much like in the channel.

The levee sites occur at the margin of the main channel. Their depths range from 4-7 m (summer pool). Because of the channel current during high discharge from the dam, little silt ever accumulates on these sites.

Most brailing occurs at levee and shallow overbank sites.

The deeper overbank sites consisting of soft silt like the channel have fewer mussels, and mussels grow larger and faster in the shallower water. Higher densities of mussels usually occur near terrain features such as drop-offs associated with creek channels or the main channel. This is because fish carry the parasitic larval stage of the freshwater mussel known as the glochidium, and many species of fish either feed or migrate in close proximity to terrain features. Areas where fish spend the most time are most likely to receive young juvenile mussels as they drop free from the fish.

Video photography documented the types of sediment found in embayments and overbanks. Only in embayments near shore in approximately 1 m of water was clean gravel seen. At other locations gravel was not present or it was covered by a thick later of silt. Centrarchids including the white crappie, Pomoxis annularis, and the black crappie, Pomoxis nigromaculatus, are known to nest in clean gravel usually in coves protected from large wave activity. Males fan an area clean of silt and females deposit the adhesive eggs. Males fertilize and guard the eggs which hatch in about three days. The fry remain attached to the substrate by an adhesive substance for a few more days before vigorously freeing themselves (Pflieger, 1975). Males guard the nest most vigorously during the time from hatching until fry free themselves (Colgan and Brown, 1988).

White crappie generally spawn at depths of less than 2 m with vegetation often associated with the spawning substrate of gravel (Hansen, 1951). However, Vasey indicates that white crappie may spawn at depths to 6 m in Table Rock Reservoir, Missouri (Pflieger, 1975). He also indicates that finely divided plant roots in addition to gravel may serve as the nest substrate but invariably in coves protected from wave action. In Kentucky Lake these substrates were seen only in embayments and near shore where gravel and plant roots are exposed.

For the past few years (1986-1988) fishermen in Kentucky Lake have complained about a decline in the number of crappie. Records of KDFWR support the claim of declining crappie populations. These same years, brailing has been most intensive, with numerous cases of brailers hauling up stumps and brush and dumping it in other locations as they clear an area for brailing. The correlation of increased brailing and decreased crappie is evident. However, correlations do not prove cause.

It is true that crappie use submerged structure for nest sites. Males select sites near a log or large object and construct nests by fanning away loose material on a silt-free substrate of fine gravel or finely divided plant roots onto which adhesive eggs attach (Pflieger, 1975). This is "invariably" in coves protected from wave action (Pflieger, 1975). The stumps in Kentucky Lake being removed by brailers are in the main lake and are generally in areas of fine silt with little or no gravel. So, it is unlikely that crappie spawn at these sites.

Other factors could account for the decline in crappie. Drawdown of the lake during spawning season has been reported by fishermen. This would have exposed nests and eggs laid in the shallow water in gravel around the roots of brush. Paxton et al.

(1981) indicated that water level fluctuations during centrarchid spawning and nursery periods was a major determinant of reproductive success. Young crappie are planktivorous, feeding primarily on zooplankton (Bozeman, 1975; O'Brien et al., 1986). During the past three summers of the drought, Kentucky Lake water has been unusually clear indicating a low density of plankton and suspended solids. Zooplankton densities were low during the summer of 1988 and may have been low throughout the drought. This may have resulted in insufficient food for young crappie. Also, the clear water may have reduced the nesting area by forcing fish into deeper water where the substrate is less suitable for successful nesting. A fourth factor may be the increase in bass. Boxrucker (1987) has demonstrated that, at least in several impoundments in Oklahoma, the presence of more larger largemouth bass is correlated with a reduction of crappie. Since the weeds have invaded Kentucky Lake, bass fishing is said to be better than ever. Bass are one of the major predators of young crappie. Also the weeds may have affected the crappie. The millfoil grows in dense clumps which tend to accumulate silt in areas where gravel sediments once dominated the shallow shores of coves. The weeds may have covered much of the favored nest sites of the crappie. These potential factors are mentioned here merely to suggest that a number of factors other than brailing may have contributed to the decline in the crappie population.

Mussel Size Distribution

A total of 56 sites that had been surveyed in 1980-81 were re-surveyed by divers in 1988-89. Twenty embayment sites were surveyed (Numbers 2, 3, 5, 8, 11, 12, 13, 14, 15, 16, 18, 25, 29, 30, 35, 43, 44, 55, 80, and 82), 15 overbank sites (4, 6, 9, 10, 17, 20, 22, 24, 27, 40, 51, 73, 75, 89, and 90), 7 shoreline sites (32, 34, 37, 59, 78, 79, and 81), and 14 levee sites (23, 28, 46, 60, 61, 62, 63, 64, 65, 67, 69, 70, 76, and 93).

In the 1988-89 quadrat samples, twelve species were found while in 1980-81 seventeen species were found in quadrat samples. The scientific and common names of these species are given in Table 3. The smaller number of species found in 1988-89 is probably a reflection of the smaller area surveyed rather than the actual loss of species from the lake.

The three most abundant mussel species found in this study were *Quadrula quadrula*, *Amblema plicata* and *Megalonaias gigantea*. These are also the three most valuable commercial species.

A comparison of growth characteristics, length and total wet weight, was made between the three abundant species for 1980-81 and 88-89. A power relationship was used for the regression model $y = ax^b$, where y = total weight in grams and x = length in mm. The constants "a" and "b" are regression coefficients. A straight line results when plotted on a log x log scale, log Y = log a + b log x, where b is the slope. The length-weight relationships for each of the three species in each of four habitat types (embayment, overbank, shoreline, and levee) are

Table 3. Species and common names of mussels in the Kentucky portion of Kentucky Lake found in quadrat samples in 1980-81 and 1988-89 study. (* not found in 1988-89 quadrat samples)

Species	Common Name
Amblema plicata (Say, 1817)	Three-ridge
Anodonta grandis Say, 1829	Giant floater
Anodonta suborbiculata Say, 1831	Flat floater
Arcidens confragosus (Say, 1829)	Rock pocketbook
Carunculina parva* (Barnes, 1823)	Lilliput
Leptodea fragilis* (Rafinesque, 1820)	Fragile papershell
Fusconaia ebena (Lea, 1831)	Ebony shell
Fusconaia undata (Barnes, 1823)	Pig-toe
Megalonaias gigantea (Barnes, 1823)	Washboard
Obliquaria reflexa Rafinesque, 1820	Three-horned wartyback
Plectomerus dombeyanus (Valenciennes,1827)	Bank-climber
Proptera alata (Say, 1817)	Pink heelsplitter
Proptera laevissima* (Lea, 1830)	Pink papershell
Quadrula nodulata (Rafinesque, 1820)	Wartyback
Quadrula pustulosa* (Lea, 1831)	Pimpleback
Quadrula quadrula (Rafinesque, 1820)	Mapleleaf
Tritogonia verrucosa* (Rafinesque, 1820)	Pistol-grip; buckhorn

plotted in Figures 4-15 which include the equations for the regression lines and the values of r^2, the coefficient of determination.

To determine if the slopes of the regression lines differed between the 1980-81 and 1988-89 samples, a t-test was used (Zar, 1984). Table 4 shows that none of the t values were significant ($P<.05$) and, therefore, it is concluded that the growth characteristics of the 3 species, Quadrula quadrula, Amblema plicata, and Megalonaias gigantea, have not changed between 1981 and 1989 in the 4 habitats studied. A significant change might have indicated some stress such as pollution.

One of the primary goals of this study was to survey mussels from the same areas that were studied in 1980-81 to determine if mussel populations had changed significantly in the presence of intense brail harvest and illegal diver harvest. This information will be useful in any management plan for the mussel resource. Two measurements of population parameters were used, density and mean shell size. It is assumed that the exact same sample sites were not sampled by divers so that mussels removed from sample area in 1980-81 study would have no effect on 1988-89 samples. However, this assumption was not tested.

Mussel densities varied for each habitat and for species. Some species seem to be better adapted to life on the levees where more current occurs from the main channel flow while some species are more abundant in embayments where there is little current and soft, fine sediments. As an example Fusconaia ebena is generally found only on the levees in the northern part of

Table 4. Values of t-test comparing slopes of regression lines of log (length) vs. log (weight) for 1981 and 1989 data for three species of mussels from four habitats of Kentucky Lake.

Species	Habitat	t	d.f.	Prob.
Quadrula quadrula	Embayment	1.58	224	0.112
	Overbank	1.53	92	0.125
	Shoreline	1.89	132	0.058
	Levee	1.39	174	0.161
Amblema plicata	Embayment	0.63	32	0.541
	Overbank	0.54	23	0.598
	Shoreline	1.80	61	0.073
	Levee	0.43	65	0.653
Megalonaias gigantea	Embayment	0.76	4	0.491
	Overbank	1.89	22	0.069
	Shoreline	0.51	14	0.615
	Levee	0.65	47	0.527

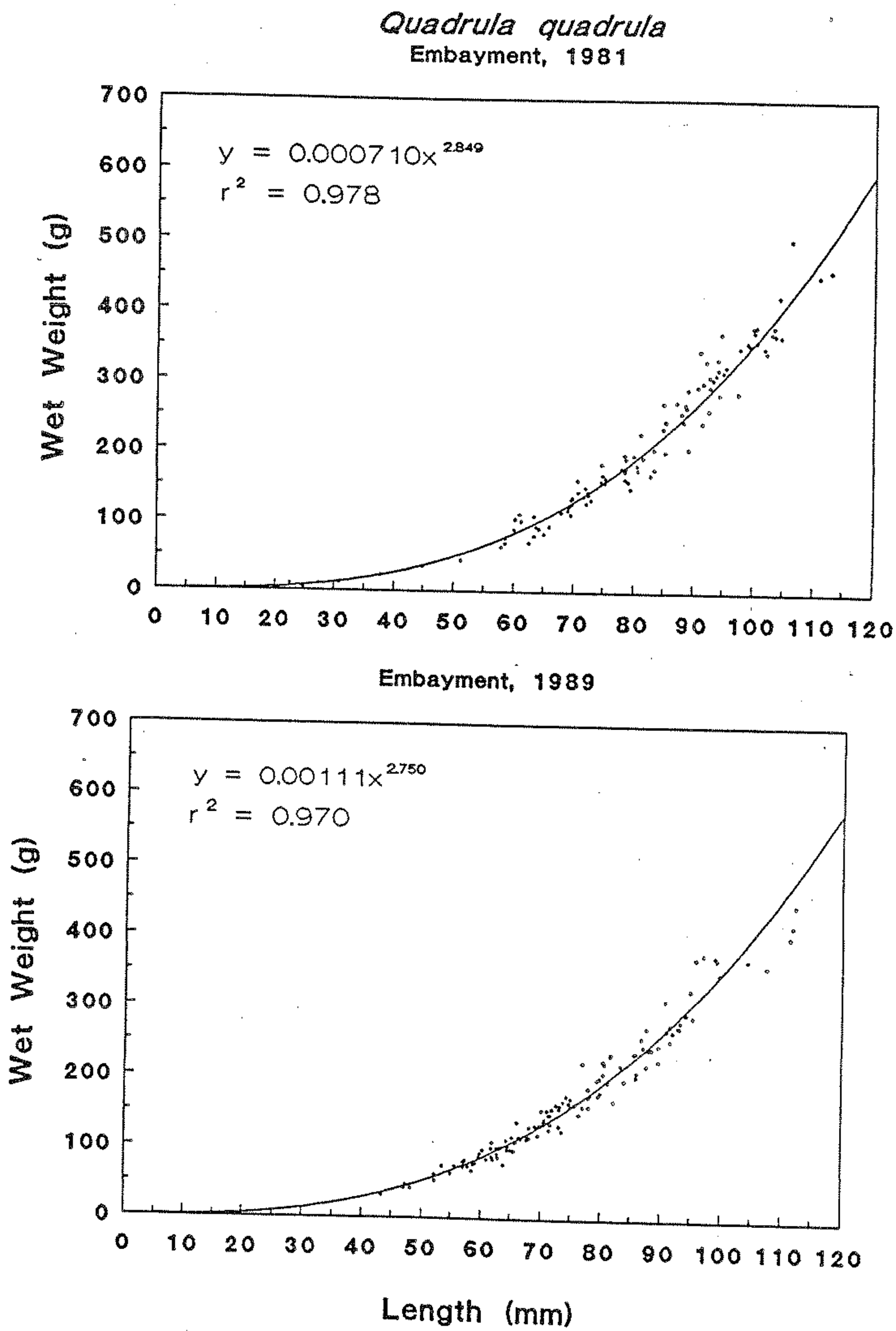

Figure 4. Length-weight relationship of Quadrula quadrula from embayment sites collected in 1980-81 and 1988-89.

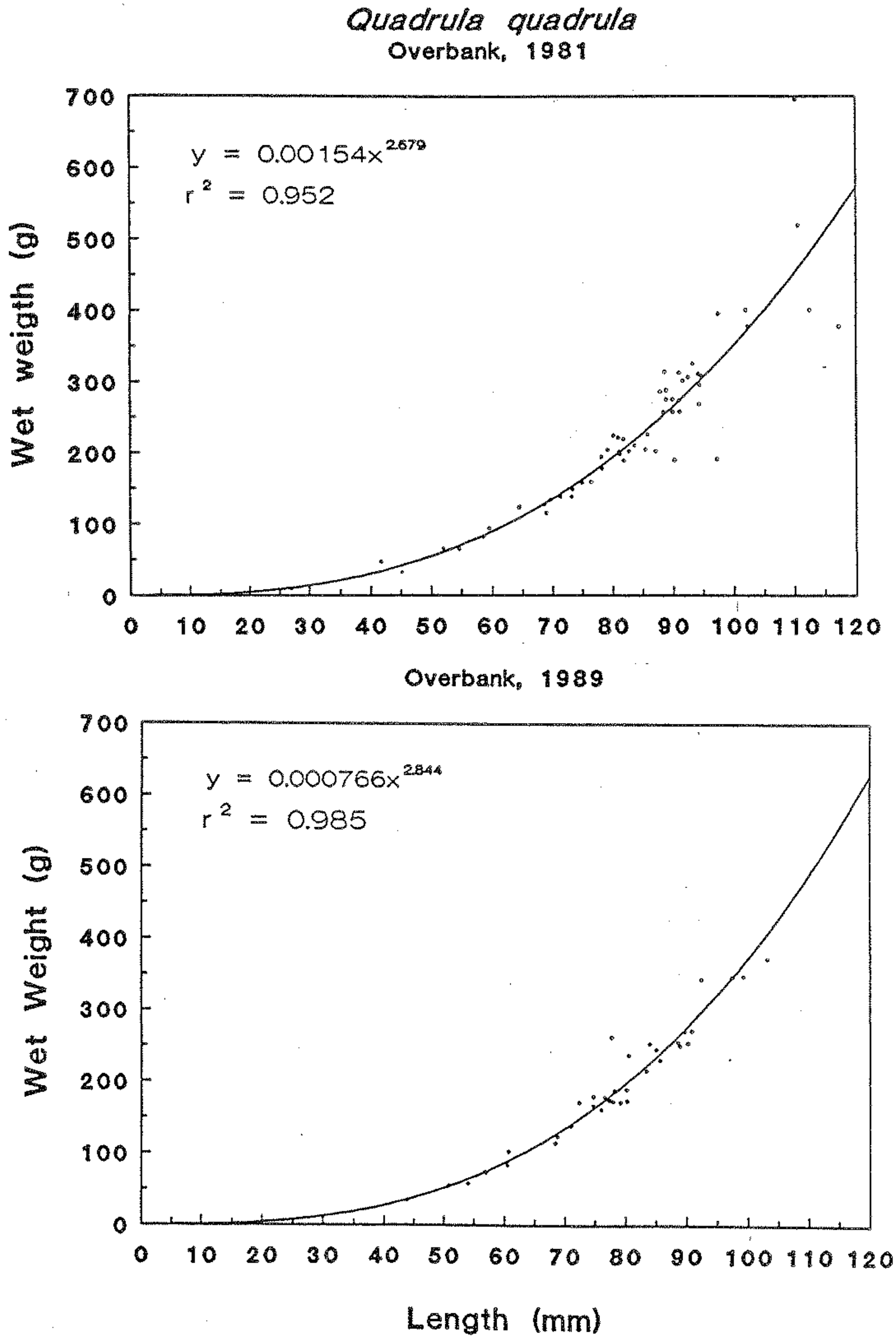

Figure 5. Length-weight relationship of Quadrula quadrula from overbank sites collected in 1980-81 and 1988-89.

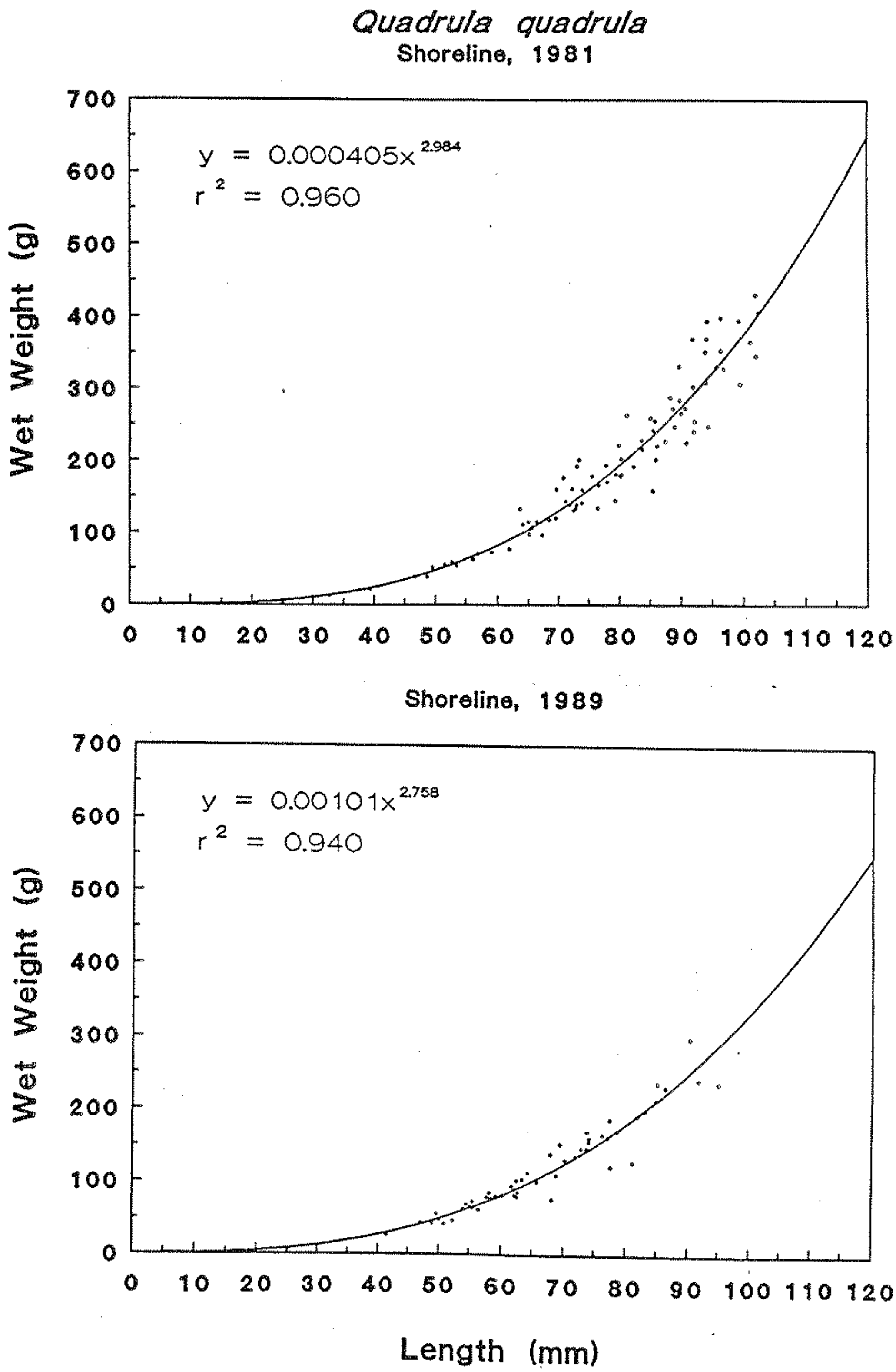

Figure 6. Length-weight relationship of Quadrula quadrula from shoreline sites collected in 1980-81 and 1988-89.

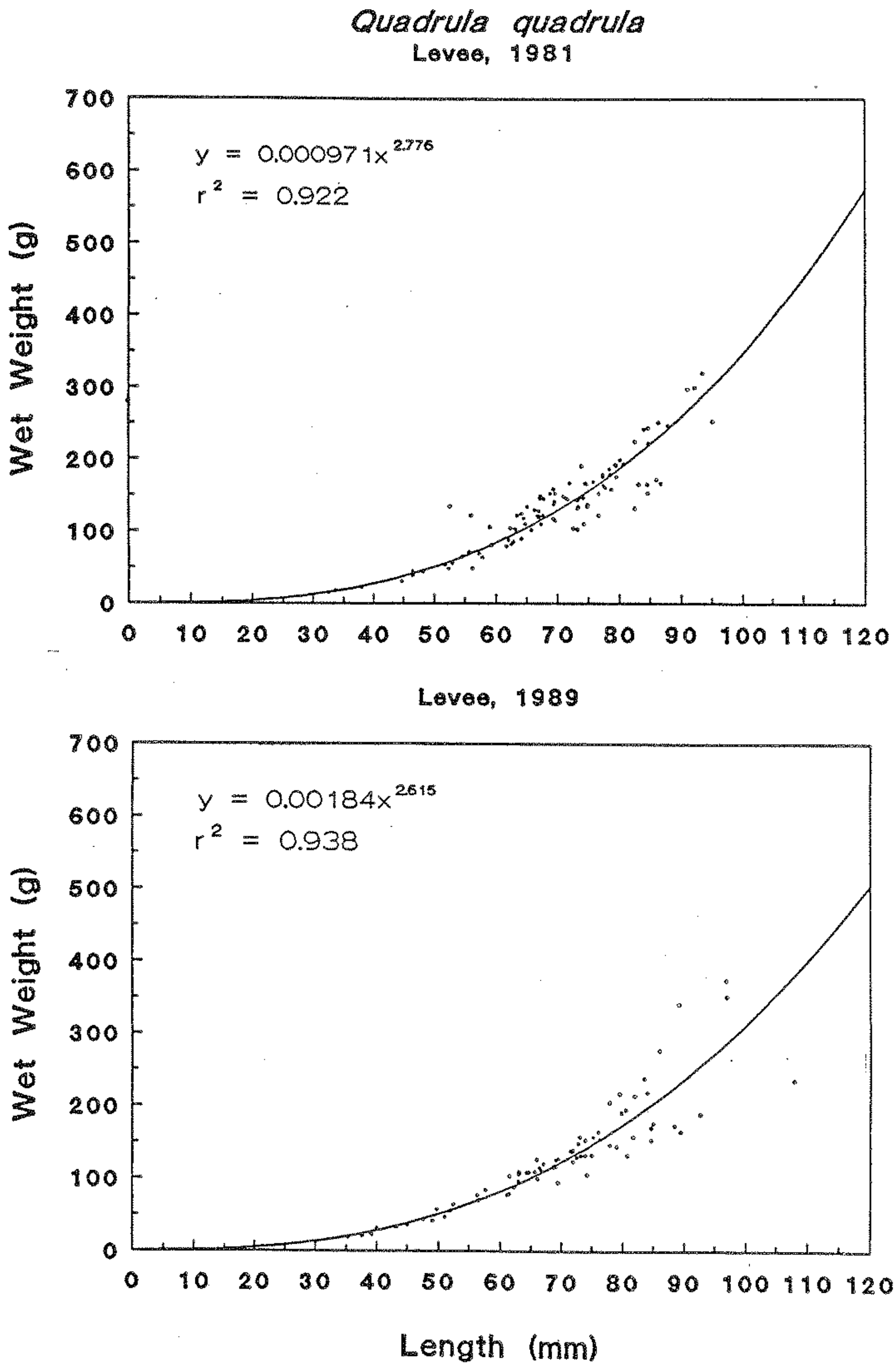

Figure 7. Length-weight relationship of Quadrula quadrula from levee sites collected in 1980-81 and 1988-89.

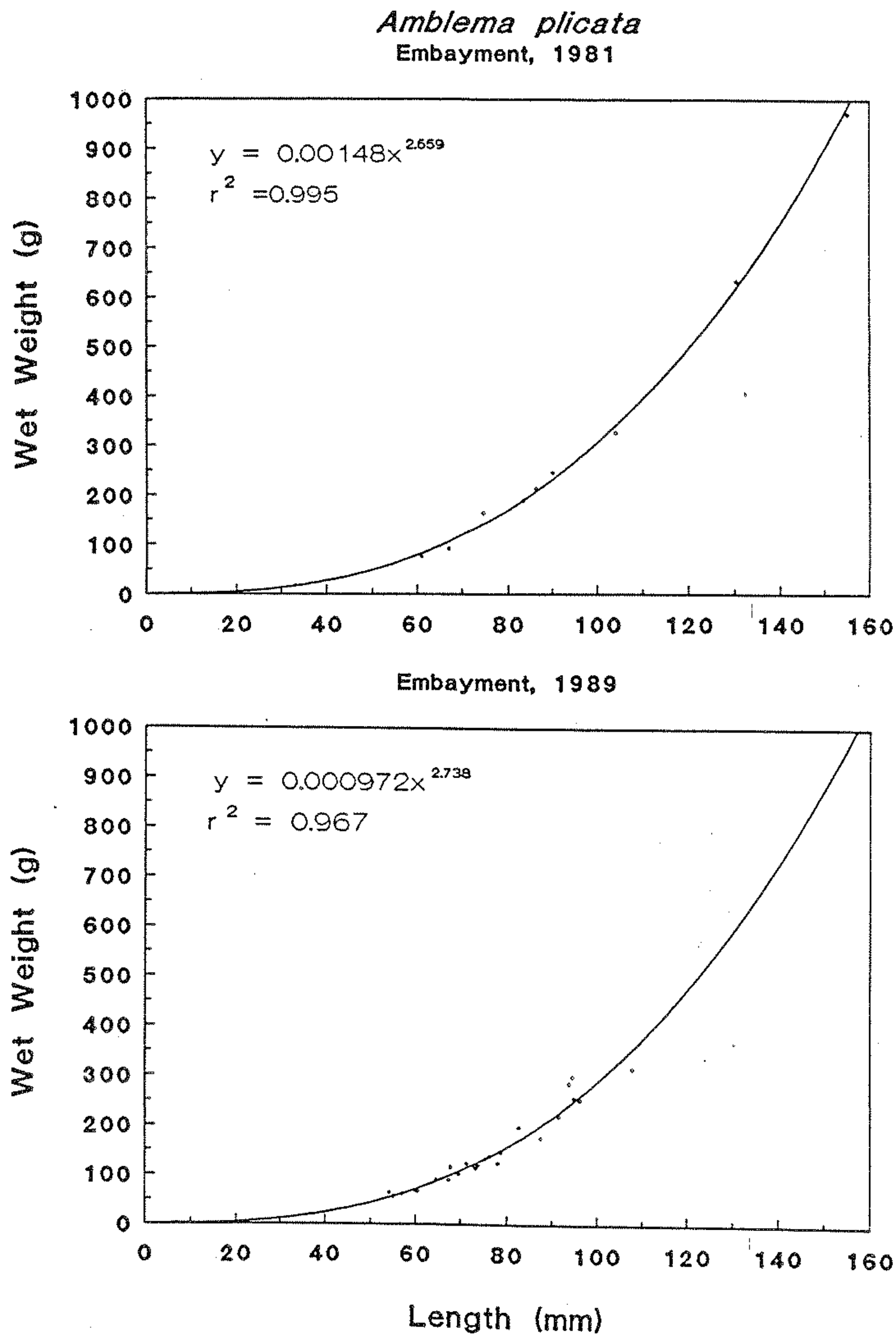

Figure 8. Length-weight relationship of Amblema plicata from embayment sites collected in 1980-81 and 1988-89.

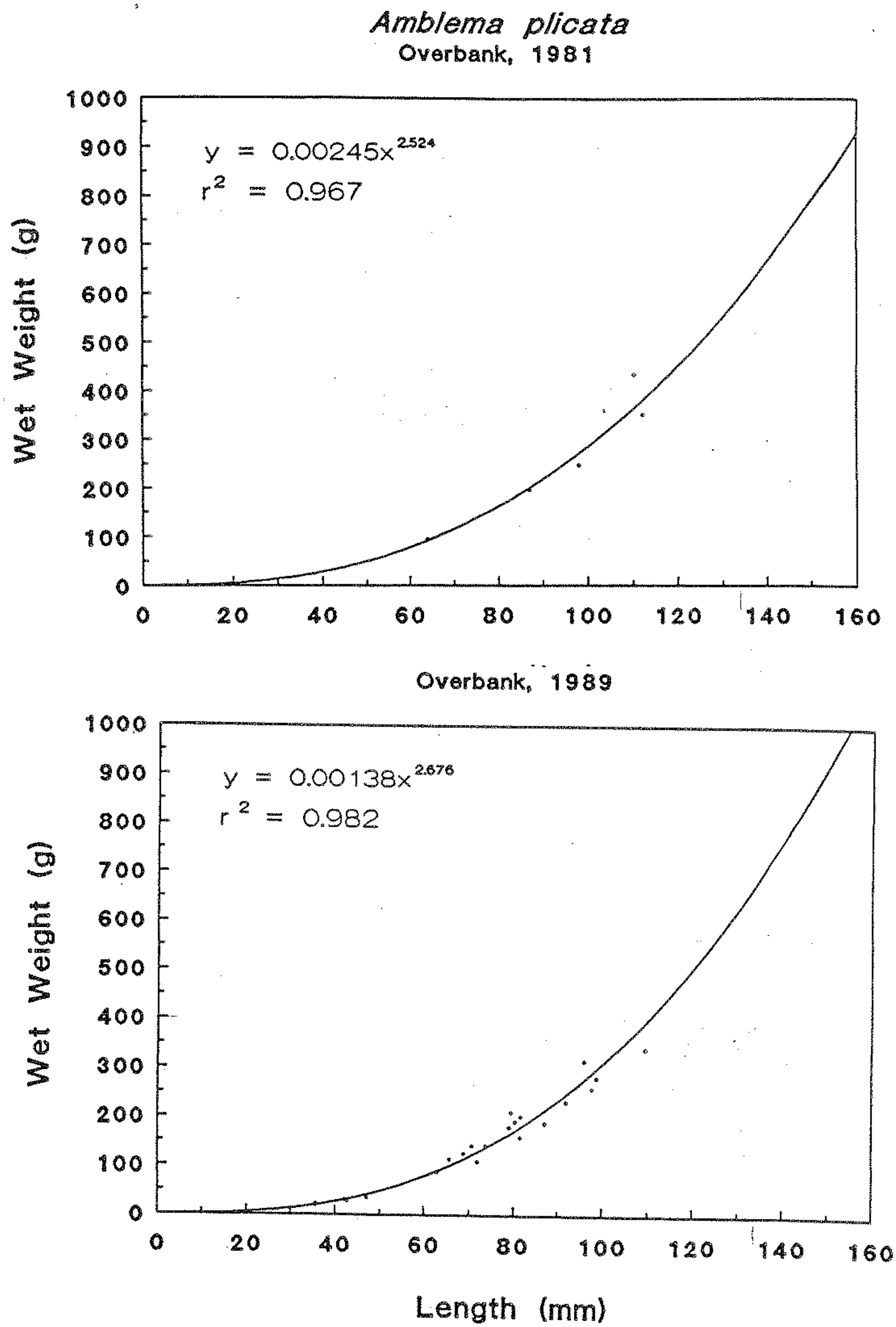

Figure 9. Length-weight relationship of Amblema plicata from overbank sites collected in 1980-81 and 1988-89.

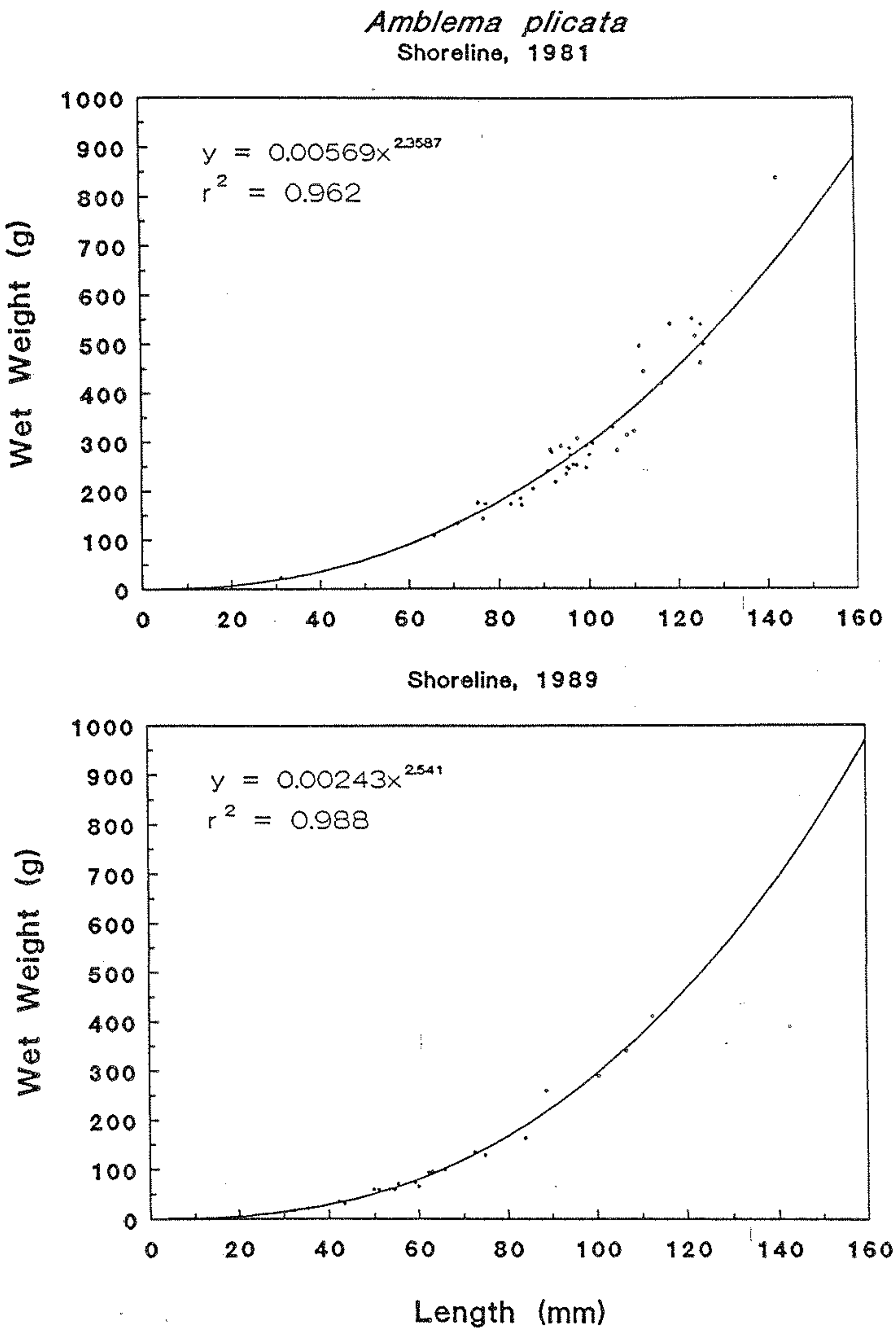

Figure 10. Length-weight relationship of <u>Amblema</u> <u>plicata</u> from shoreline sites collected in 1980-81 and 1988-89.

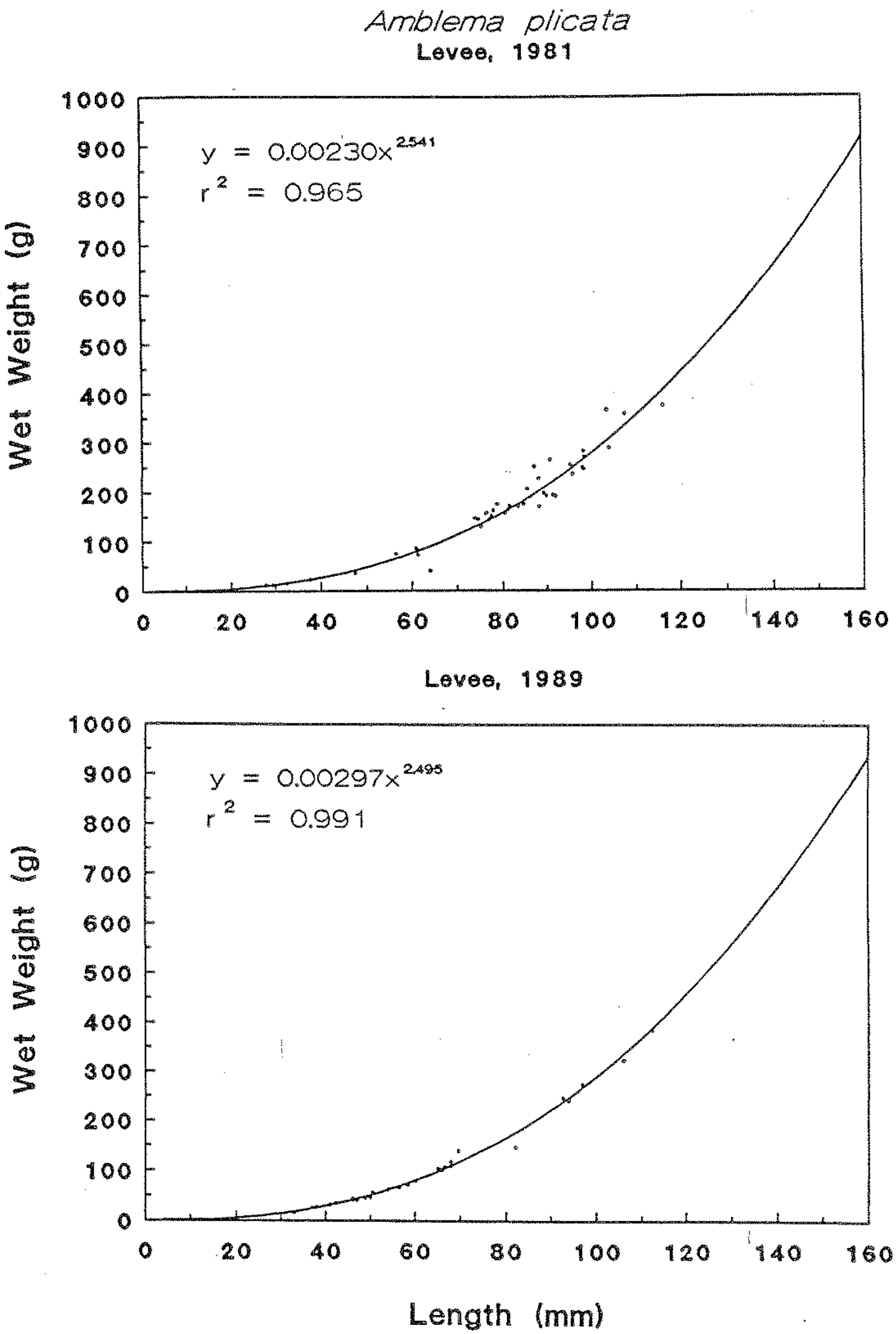

Figure 11. Length-weight relationship of Amblema plicata from levee sites collected in 1980-81 and 1988-89.

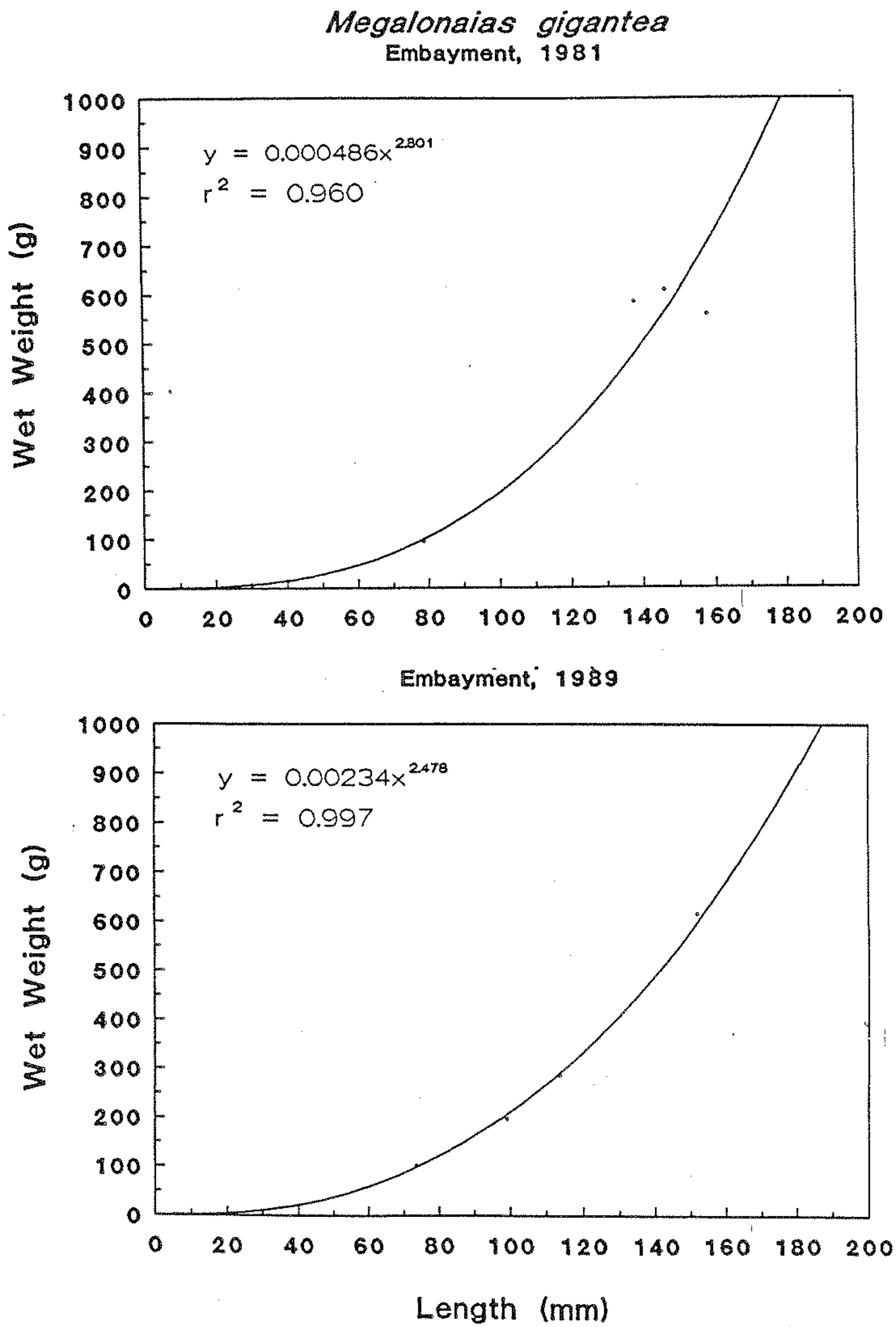

Figure 12. Length-weight relationship of Megalonaias gigantea from embayment sites collected in 1980-81 and 1988-89.

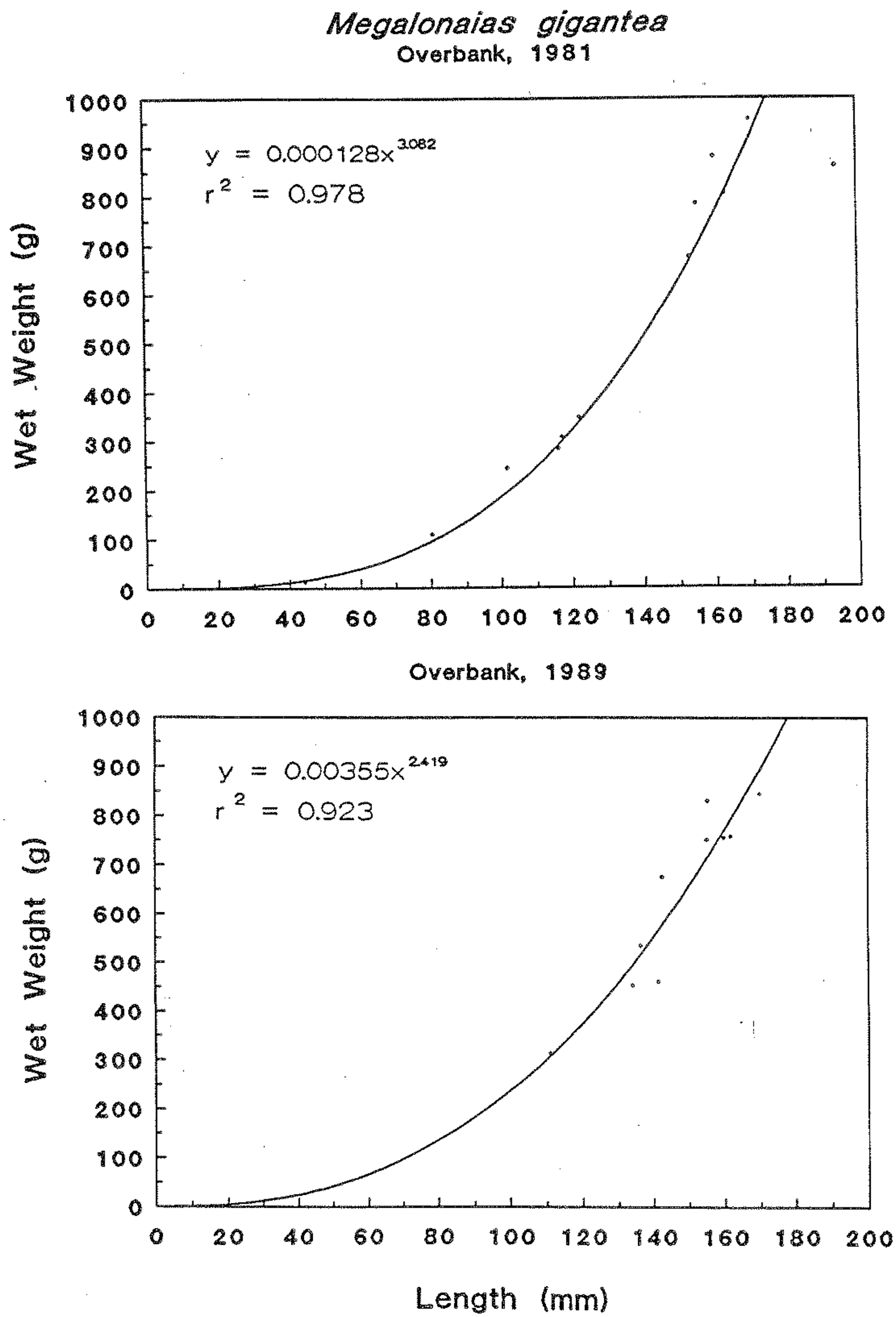

Figure 13. Length-weight relationship of Megalonaias gigantea from overbank sites collected in 1980-81 and 1988-89.

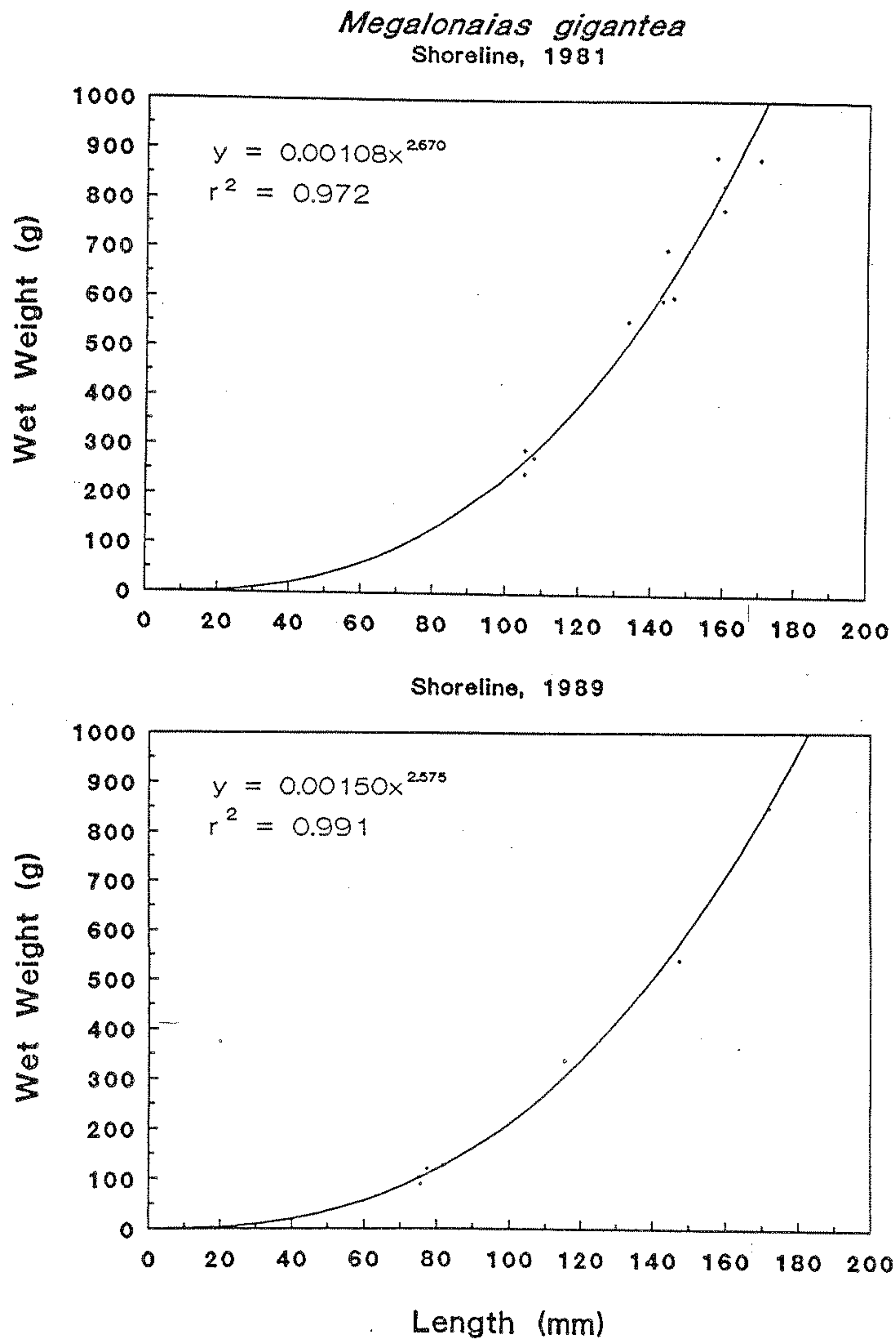

Figure 14. Length-weight relationship of Megalonaias gigantea from shoreline sites collected in 1980-81 and 1988-89.

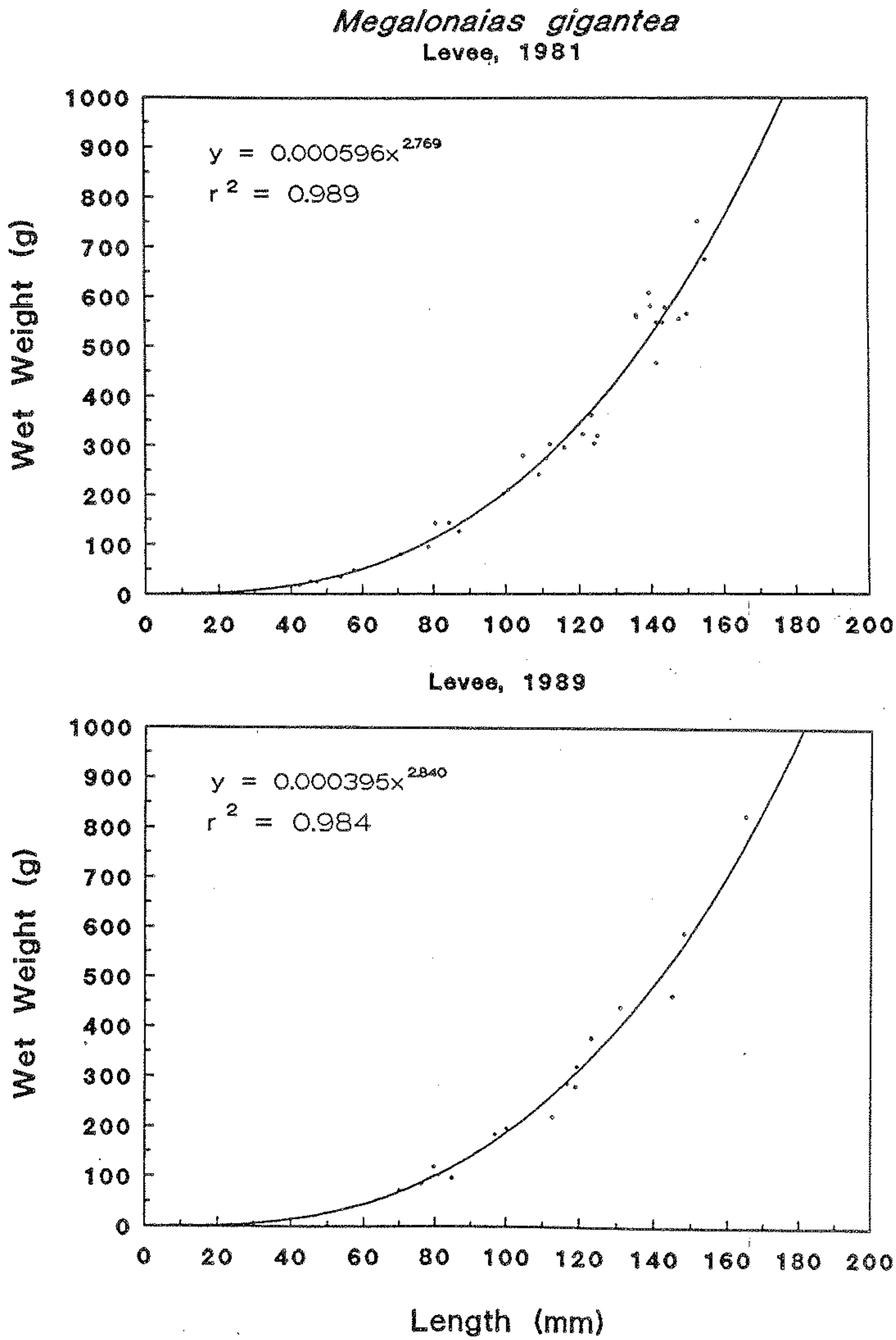

Figure 15. Length-weight relationship of Megalonaias gigantea from levee sites collected in 1980-81 and 1988-89.

Kentucky Lake while Anodonta suborbiculata is most abundant in embayments. Because of this difference in species distribution, densities were calculated for the 4 different habitats, embayment, shoreline, overbank and levee. Table 5 compares the live mussel density of each species in the 4 habitats for 1980-81 and 1988-89.

During the 8 years between 1980-81 and 1988-89 the total number of mussels increased in each habitat in Kentucky Lake even with the increased brail harvest beginning in 1986 and the illegal diver harvest which occurred throughout the period. For the 3 commercially most important species, Amblema plicata more than doubled in numbers at embayment, overbank and shoreline sites while increasing by 45% at the levee sites, and Quadrula quadrula increased substantially at embayment and shoreline sites but decreased at overbank sites and only slightly increased at levee sites, while Megalonaias gigantea decreased at all but shoreline sites where the numbers were more than double the 1980-81 numbers. This indicates good reproductive and recruitment success for most of the mussels.

To determine if the size distribution of mussels had changed since 1980-81 the mean lengths and weights of the three most abundant species were compared. Again, each habitat was compared separately because of the known differences in growth rates between habitats. An IBM PC statistics package was used to analyze the data (Doane, 1988). The means were compared using a t-test with an F test for equality of variances being performed to determine if Welch's Behrens-Fisher correction for t should be

Table 5. Density of mussels (number/10 m^2) in the Kentucky portion of Kentucky Lake comparing 1980-81 with 1988-89 for 4 different habitats.

SPECIES	Embayment		Overbank		Shoreline		Levee	
	1981	1989	1981	1989	1981	1989	1981	1989
Area Surveyed(m^2):	426	220	260	150	95	70	235	150
Amblema plicata	0.42	1.18	0.81	1.47	1.26	3.14	2.26	3.27
Anodonta grandis	0.04	0.00	0.08	0.00	0.32	0.14	0.08	0.00
Anodonta suborbiculata	0.02	0.50	0.00	0.07	0.21	0.28	0.00	0.00
Arcidens confragosus	0.00	0.00	0.12	0.00	0.00	0.71	0.13	0.71
Carunculina parva	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fusconaia ebena	0.00	0.00	0.00	0.07	0.00	0.28	0.13	0.47
Fusconaia undata	0.05	0.04	0.04	0.07	0.11	0.43	0.72	0.33
Leptodea fragilis	0.00	0.00	0.12	0.00	0.00	0.00	0.13	0.00
Megalonaias gigantea	0.28	0.18	0.81	0.80	0.42	1.00	2.00	1.60
Obliquaria reflexa	0.02	0.04	0.23	0.20	0.10	0.43	0.89	1.13
Plectomerus dombeyanus	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.47
Proptera alata	0.02	0.00	0.00	0.00	0.00	0.57	0.00	0.00
Proptera laevissima	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
Quadrula nodulata	0.09	0.18	0.23	0.47	0.53	1.00	1.53	1.33
Quadrula pustulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quadrula quadrula	2.96	5.64	3.04	2.60	4.10	7.57	5.19	5.40
Tritogonia verrucosa	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Total Density	3.94	7.77	5.46	5.73	7.16	15.57	13.23	14.67

used (Welch, 1937; Brownlee, 1960). The comparison for mean length is presented in Table 6 which includes mean lengths, standard error, F test values and the two-tailed probabilities of exceeding them, and the t-test values with their single-tailed probabilities. In 10 of the 12 cases the mean length of the mussels is lower in 1989 than in 1981. Seven of those 10 cases had statistically significant reductions in mean length while 2 more were marginal. <u>Quadrula quadrula</u> at levee sites was the only case in which there was no clear cut decline in mean length. At two sites, overbank and levee, <u>Megalonaias gigantea</u> appeared to experience an increase in mean length but these increases were not significant. Identical relationships occurred for mean weight as for mean length as would be expected from the high correlation of length and weight.

The data support the contention that since 1980-81 the number of mussels in the Kentucky portion of Kentucky Lake has increased while the mean length of the commercially valuable species has declined. This is probably the result of the harvesting of legal size individuals by brail or diving. In a separate study it was shown that brailing is about 1.5% efficient at catching mussels on any single haul. For the four years brailing has been intense, this harvest rate does not appear to have damaged the mussel resource, but this should be monitored periodically since very little data of this type is available. The present study along with one by Sickel and Chandler (1982) provides the baseline data for monitoring and managing the Kentucky Lake mussel resource.

Table 6. Comparison of mean lengths for 3 species of mussels collected from 4 habitats in Kentucky Lake in 1980-81 and 1988-89. (F test and its probability for equality of variances to determine if Behren-Fisher correction will be used. T-test compares means with * indicating significant differences.)

Species	Habitat	Year	N	Mean Length (mm)	S.E.	F	P(F)	t	P(t)
Q. quadrula	Embayment	1981	194	79.0	1.36				
		1989	124	75.2	1.31	1.70	0.003	2.01*	0.024
	Shoreline	1981	131	73.6	1.72				
		1989	53	67.1	1.73	2.43	0.001	2.65*	0.004
	Overbank	1981	140	79.1	1.51				
		1989	39	75.3	2.57	1.24	0.20	1.19	0.14
	Levee	1981	145	70.1	1.26				
		1989	81	69.0	1.67	1.02	>.50	0.56	>.25
A. plicata	Embayment	1981	26	94.2	4.77				
		1989	26	75.5	2.83	2.84	0.006	3.38*	<.001
	Shoreline	1981	50	97.6	3.35				
		1989	22	65.1	4.68	1.16	>.50	5.50*	<.001
	Overbank	1981	42	98.1	2.91				
		1989	22	72.7	4.53	1.27	0.50	4.90*	<.001
	Levee	1981	109	82.9	1.73				
		1989	49	54.0	2.75	1.13	>.50	9.10*	<.001
M. gigantea	Embayment	1981	16	133.9	8.50				
		1989	4	109.5	16.40	1.07	>.50	1.29	0.12
	Shoreline	1981	12	142.7	7.34				
		1989	7	106.4	15.00	2.44	0.19	2.45*	0.017
	Overbank	1981	41	140.7	5.19				
		1989	12	152.9	6.12	2.45	0.13	1.20	0.13
	Levee	1981	55	111.4	4.68				
		1989	24	117.0	6.63	1.14	>.50	0.67	0.25

Percent Undersize Shells in Catch

The size limits for the commercial shells in Kentucky are such that a legal *Megalonaias gigantea* will not pass through a 3.75 in. diameter ring, an *Amblema plicata* will not pass through a 2.75 in. diameter ring, and a *Quadrula quadrula* will not pass through a 2.50 in. diameter ring. The average length of shells this size is 120 mm for *M. gigantea*, 95 mm for *A. plicata* and 78 mm for *Q. quadrula*. For lake shells this size corresponds to an age between 6 and 8 years at which time the mussels begin to reproduce. For mussels growing in the deep channel or in rivers such as downstream from Kentucky Dam or the Ohio River, growth is slower and the mussels reach maturity several years before reaching legal size.

On four different days the brail harvest was evaluated from 3 different brailers. All brailers were brailing in overbank sites. Three of the sites had a similar distribution of shell sizes with 40% of *Q. quadrula* undersize, 41% of *A. plicata* and 23% of *M. gigantea* being undersize. At a site near the Eggners Ferry Bridge there was a high percentage of young shells. In seven brail hauls 56% of *Q. quadrula*, 62% of *A. plicata*, and 50% of *M. gigantea* were undersize. Overall the percentage of undersize shells in 22 brail hauls was 50% for *Q. quadrula*. 48% for *A. plicata*, 39% for *M. gigantea*, 67% for *Fusconaia ebena*, 54% for *Fusconaia undata*, and 71% for *Quadrula nodulata*. All *Obliquaria reflexa* are under the 2.5 in. size limit. It is a small species which is fairly common but never gets large enough for legal harvest even though it has a thick shell valuable to the commercial trade.

The abundance of undersize shells is another indication that harvest has changed the size distribution to more but smaller shells. This may be a healthy situation for brailers if they will refrain from brailing in areas with a high percentage of young shells for a few years to let those shells mature.

Mortality of Undersize Shells

One major concern with the high percentage of undersize mussels in brail harvests is the mortality of those caught on brails and returned to the lake as required by law. No information on the percentage mortality was available.

In this study 238 undersize mussels were collected from brailers as the mussels were pulled from the hooks and placed in buckets of water. These mussels were returned to the Hancock Biological Station, tagged, and placed in cages in the lake. Another group of 178 mussels was handled in a similar manner except that they were collected by divers. These served as controls. The mussels in the cages were examined at various times over the next six months. Of the 238 brailed shells, 122 died or 51.3% while only 2 of the 178 control group died or 1.1%. Of the three brailers from whom the mussels were obtained, there was a large difference in mortality of the juvenile mussels. The mussels from the three brailers had mortalities of 29.5%, 47.2% and 63.7%. This large difference was not explained but might be worth investigating to see if some aspect of brailing gear, technique, or handling of the mussels might reduce mortality significantly.

There were also mortality differences noted between species with the highest mortality occurring in the small species Obliquaria reflexa which had 100% mortality of 13 individuals examined. Of the three commercial species, A. plicata had the highest mortality of 58% while Q. quadrula had 52% mortality and M. gigantea had 18% mortality (Figure 16). Within each species younger shells tended to die before larger ones.

As the number of commercial size mussels declines in an area because of harvest, the brailers move to new areas. With a harvest efficiency of 1.5% it is unlikely that brailers could destroy the mussel resource before being forced to move to another area by economic reasons. This should leave a sufficient number of mussels in the area to reproduce and replenish the resource.

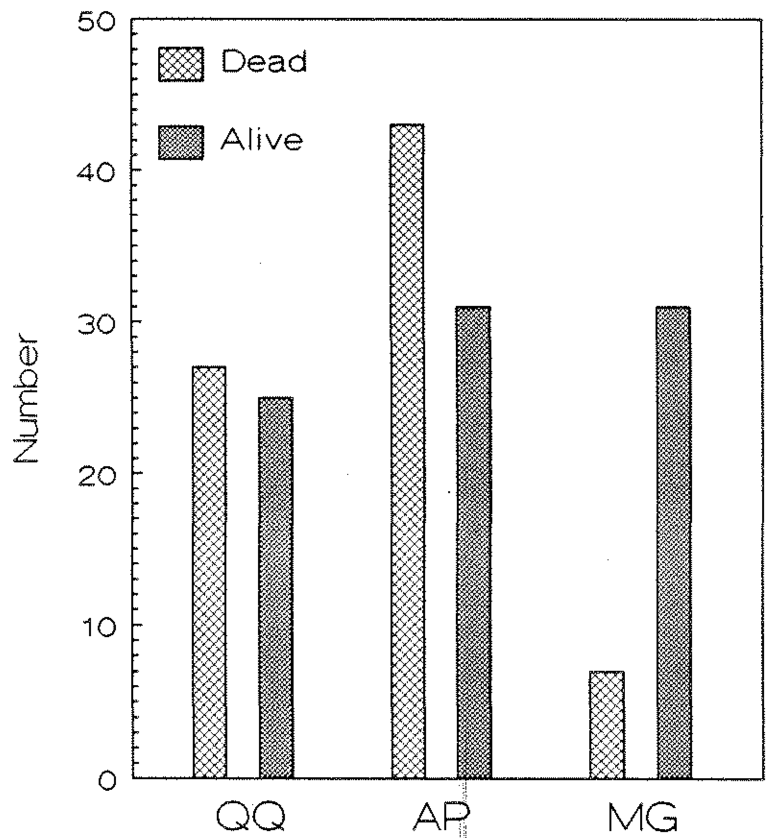

Figure 16. Mortality of commercial mussels caught on brails and returned to lake.

QQ–Q. quadrula, AP–A. plicata, MG–M. gigantea

Questionnaire

A copy of the questionnaire is included in the Appendix A along with a copy with the summarized responses in Appendix B.

Of the 500 questionnaires mailed to 296 resident musselers, 18 marina/resort owners, 106 sport fishermen, 21 fishing guides, 24 commercial fishermen, and 35 classified as recreational boaters, the following numbers from each category were returned: 48 musselers (16.2%), 12 marina owners (66.7%), 88 sport fishermen (83.0%), 20 fishing guides (95.2%), 15 commercial fishermen (62.5%), and 43 recreational boaters (123.9%). The total number of questionnaires returned was 133 or 26.6% of those mailed. A number of individuals responded to several categories, i.e., some musselers were also sport fishermen and recreational boaters.

Only 116 responded to questions 2-4 requesting financial information. Of these the mean annual income was $22,500. Musselers indicated an annual income of $11,600, and 22 of the 48 musselers indicated that over 50% of their income came from musseling while 11 derived 100% of their income from musseling.

Question 5 revealed that 82% of the respondents were familiar with the Kentucky laws governing musseling while 18% were not.

Question 6 indicated that the average time all respondents spent on Kentucky Lake each month was 118 hours.

Question 7 was designed to determine the areas of the lake where various activities occurred most frequently. Area I (river mile 22.4-31) had the most mussel brailing (23 brailers spent 66%

of time in Area I), commercial fishing (8 fishermen spent 51% of time in Area I), sport fishing (59 sport fishermen spent 46% of time in Area I), and recreational boating activities(32 boaters spent 51% of time in Area I). Area III (mile 42-57) had the next highest brailing activity (8 brailers spend 88% of time there), and Area II (mile 31-42) had 9 brailers spending 35% of their time. Area IV (mile 51-62) had none of the respondent musselers. Commercial fishing activity was fairly evenly distributed in the 4 areas. Sport fishing was highest in Area I and showed descending activity in each of Areas II, III, and IV. Recreational boating had the same trend as sport fishing. However, boaters in Area IV tended to spend more of their time within that area (62%). Many of the conflicts between sport fishermen and brailers arise because of the frequency of encounters in high use areas such as Areas I and III. The low number of musselers indicated in Area II in this survey may be biased by the low response (16%) of musselers to the questionnaire.

Question 8 indicated that in the opinion of 122 respondents 24% thought that brailing was most cost effective while 41% said diving was the most cost effective method for harvesting mussels. Thirty-five percent expressed no opinion.

Question 9 asked for opinions regarding the least damaging method of harvest to the mussel resource. Sixty-one percent of the musselers said that brailing was the least damaging while 27% said diving was least damaging. Twelve percent gave no opinion. Of the non-musseling respondents 32% said brailing was least damaging and 50% said diving was least damaging. Eighteen percent had no opinion.

Question 10 gives the response of musselers and non-musselers to the question asking for their opinion regarding the most important problem in Kentucky Lake. The responses are indicated in Table 7. The percentages total over 100% because some individuals checked more than one category. The "Other" responses that were written in the space provided include the following: brailing in bays, old trotlines, lack of enforcement of musseling laws, water level fluctuations (3 respondents), KDFWR, garbage and junk, bass fishermen (2 respondents), crappie decline, toe digging, nets (3 respondents), drunk boaters, Tombigbee Waterway, and bad attitudes. From Table 7 it can be seen that musselers perceive weeds to be the most important problem in Kentucky and illegal diving the second most important. Fishermen on the other hand consider mussel brailing to be the most important problem and weeds the second most.

To investigate whether these opinions held by musselers and fishermen (or non-musselers) were based in fact or were primarily emotional issues, Questions 11 and 12 were inserted.

Question 11 was intended to elicit general impressions about the overall status of Kentucky Lake regarding water quality, mussel resource, commercial fishery, and sport fishery. The results from the two respondent groups, musselers and fishermen, indicate similar responses (Table 8) with both groups reporting good quality for each category. A chi-square test of responses gave a value of 4.94 with 11 degrees of freedom (P=0.934). this

Table 7. Opinions of mussel fishermen and sport fishermen regarding the most important problem in Kentucky Lake. (Number responding to each category/total respondents, with some responding to more than one category.)

Problem	Musselers	Sport Fishermen
Weeds	64% (27/42)	34% (32/94)
Water Quality	19% (8/42)	19% (18/94)
Illegal Diving	45% (19/42)	17% (16/94)
Low Oxygen	14% (6/42)	12% (11/94)
Mussel Brailing	0% (0/42)	55% (52/94)
Commercial Fishing	2% (1/42)	6% (6/94)
Erosion	2% (1/42)	3% (3/94)
Other	26% (11/42)	14% (13/94)

Table 8. Opinions of mussel fishermen and sport fishermen regarding the present conditions of Kentucky Lake. (Number responding to each category/total respondents).

	Musselers	Fishermen
Water Quality		
Excellent	7% (3/42)	10% (9/92)
Good	43% (18/42)	55% (51/92)
Fair	40% (17/42)	33% (30/92)
Poor	10% (4/42)	2% (2/92)
Mussel Resource		
Excellent	19% (8/43)	17% (13/77)
Good	51% (22/43)	56% (43/77)
Fair	28% (12/43)	26% (20/77)
Poor	2% (1/43)	1% (1/77)
Commercial Fishery		
Excellent	24% (9/37)	21% (17/82)
Good	54% (20/37)	61% (50/82)
Fair	22% (8/37)	17% (14/82)
Poor	0% (0/37)	1% (1/82)
Sport Fishery		
Excellent	27% (10/37)	27% (24/90)
Good	51% (19/37)	53% (48/90)
Fair	22% (8/37)	14% (13/90)
Poor	0% (0/37)	6% (5/90)

test shows that the responses of the two groups are statistically similar.

Question 12 asked for responses regarding the effect of brailing on water quality, mussel resource, commercial fishing, sport fishery, and marina income. For comparison with Question 11 the Marina Income category was not considered. Again, the responses were divided into musselers and fishermen (Table 9). This time a chi-square test resulted in a chi-square value of 139.3 with 11 degrees of freedom (P=0.000) indicating a significant difference in responses between the two groups. Whereas Question 11 indicated that both groups believed the quality of Kentucky Lake was good for each category, Question 12 revealed that a majority of fishermen believe mussel brailing is damaging to each category. Only one musseler indicated that brailing was damaging to water quality, commercial fishing, and sport fishing. These responses suggest that the brailing issue is more emotional than based on fact.

Question 13 revealed that 56% of the respondents believe diver harvest of mussels would be harmful to the mussel resource, 16% said it would be beneficial, and 9% said diving would have no effect. Twenty percent were undecided.

The restriction of brailing from embayments mentioned in Question 14 effectively removed 30% of the surface area of the lake from brailing activities (see Table 1). The amount of shoreline in embayments is 67% of the shoreline of the Kentucky portion of Kentucky Lake. Yet, even with these restrictions on brailing, 52% of the respondents said more restrictions were

Table 9. Responses of mussel fishermen and sport fishermen regarding the effect of mussel brailing on Kentucky Lake Resources. (Number responding to each category/total respondents)

	Musselers	Sport Fishermen
Water Quality		
Improves	24% (11/45)	10% (9/92)
Damages	2% (1/45)	48% (44/92)
No Effect	73% (33/45)	42% (39/92)
Mussel Resource		
Improves	37% (16/43)	13% (11/88)
Damages	19% (8/43)	67% (59/88)
No Effect	44% (19/43)	20% (18/88)
Commercial Fishery		
Improves	34% (14/41)	10% (9/91)
Damages	2% (1/41)	59% (54/91)
No Effect	63% (26/41)	31% (28/91)
Sport Fishery		
Improves	29% (12/42)	8% (8/95)
Damages	2% (1/42)	63% (60/95)
No Effect	69% (29/42)	28% (27/95)

needed, 9% said less and 34% said no change was needed. Five percent had no opinion.

Question 15 suggests that a method of harvest of mussels might be found that would not damage fish habitat and not harm the overall mussel resource. If this method could be developed 84% of the respondents said they would be in favor of allowing the harvest of mussels by the method.

Respondents to Question 16 said that legal diver harvest of mussels would be less detrimental or be no different than brailing to water quality. They said diving would be more detrimental to the mussel resource but less detrimental to commercial fishing and sport fishing. Opinions regarding the difference in effect of diving versus brailing to recreational boating were evenly divided with 29% saying more detrimental and 30% saying less detrimental. Several comments indicated a concern by boaters and sport fishermen that if diver harvest of mussels were made legal then dive boats would interfere with surface water activities because boaters are required to stay 100 ft. from a diver flag.

The majority of respondents to Question 17 (66%) said they would be in favor of allowing brailing to continue if it did not damage fish habitat. The premise here is that brailing damages fish habitat. Whether this perceived damage is significant remains to be seen. Certainly, if someone's favorite fish attractor is removed by a brailer, the effect is significant to that fisherman who lost a good fishing spot. But the effect on the overall fish resource may be negligible.

Question 18 asked if all commercial mussel harvest should be prohibited in Kentucky Lake and Lake Barkley. Thirty-three percent said yes and 55% said no with 12% undecided. The majority of people responding to this question believe that some legal harvest of mussels should be continued. This response is from a good cross section of people who use the lakes on a regular basis and probably reflects their vision of the economic importance of musseling to the region. However, it seems odd that in Question 17, only 25% wanted brailing stopped regardless of its impact and in Question 18 33% wanted all musseling stopped.

In Question 19 57% of the respondents said they had seen brailers remove underwater structures such as stumps of brush from Kentucky Lake indicating that this structure removal must be fairly widespread. Much of the material seen pulled up by brailers consists of loose branches washed into the area during high flow in the spring. It is not known whether or not this material serves a useful purpose to fish. Brailers often dump the branches into deep water at the end of their brail run. Perhaps if areas for dumping this material could be marked, such as with fish attractor buoys, and if brailers would voluntarily dump at these sites, then fishing could be improved and brailers could continue to work the cleared areas. This would require a lot of cooperation and a sufficient number of attractor sites where brailers are working so that the brailer would not have to travel a great distance to drop large objects. It may serve no purpose to drop small branches at these sites since they may wash out at the next flood.

Question 20 was answered by brailers only, and 58% indicated they would voluntarily stop brailing if it were demonstrated that their activities were reducing the value of Kentucky Lake resources to a greater extent than the value of the mussels being harvested. This is a good indication that the majority of the musselers have a strong conservation ethic. This has also been expressed through the Western Kentucky Shell Harvesters Association which has voluntarily placed fish attractors in the lake and encouraged members to be aware of ways to reduce the impacts of brailing.

In Question 21 a strong 77% of the respondents were opposed to permitting diving as a method of harvest. Likewise, 76% in Question 22 were opposed to allowing both brailing and diving.

Question 23 asked for a written response of the number one concern about brailing in Kentucky Lake. The overwhelming concern was the destruction of fish habitat--48 of 110 written responses. Five of those believed that brailing interfered with spawning of crappie or sauger and felt that brailing should be prohibited during spawning season. Other written responses included water quality (9), death of small shells (4), erosion (1), illegal shell harvest (5), too many brailers (3), and loss of commercial fish gear (4). Eighteen musselers and one non-musseler wrote in their concern that brailing might be eliminated or further restricted such that they could not earn a living.

A number of written comments were submitted in response to Question 24. These are on file and may be seen through arrangements with the author of this report.

Conclusions

The present mussel law which restricts brailing to the main lake, excluding embayments, has excluded from brailing 30% of the Kentucky portion of Kentucky Lake and 67% of the 277 miles of shoreline at summer pool elevation of 359 ft.

Underwater video provides a useful method for examining and documenting benthic habitats but is restricted to close-up work and small areas of about 1-2 square ft. because of the low visibility.

No areas were located in the main lake which appeared to be suitable habitat for crappie nesting.

Twelve species of mussels were found in quadrat sampling. The overall density of mussels has increased since 1980-81 but the mean length, weight and age of the commercial mussels has declined, probably as a combined result of brailing and the increased number of juvenile mussels. The large number of young mussels indicates healthy populations which should sustain the resource into the near future. These populations should be monitored periodically to determine their status and trends.

For the three important commercial species, _Quadrula quadrula_, _Amblema plicata_, and _Megalonaias gigantea_, the length-weight relationships have not changed since 1980-81. This indicates that the growth characteristics which depend on food and water quality are unchanged.

The percent of undersize shells in typical brail harvests ranges from 20% to 60% with a mean of 50%. This reflects the high number of young mussels indicative of a healthy community.

The percentage mortality of undersize shells which are returned to the lake ranges from 30% to 64% with an average of 51%. This high mortality might be reduced if care is taken removing young mussels and if they are returned to the lake immediately into a habitat similar to where they were caught. For the three main commercial species, A. plicata had the highest mortality and M. gigantea had the lowest. In general the smaller shells had higher mortality.

As the number of commercial size mussels declines in an area because of harvest, the brailers move to new areas. With a harvest efficiency of 1.5% it is unlikely that brailers could destroy the mussel resource before being forced to move to another area by economic reasons. This should leave a sufficient number of mussels in the area to reproduce and replenish the resource.

The questionnaire documents that sport fishermen feel that mussel brailing is the most important problem in Kentucky Lake and that brailing is damaging fish habitat and contributing to the decline in fish, especially crappie. Removal of underwater structure is the main problem. The mussel brailer feels that brailing is not damaging the fish resource and that weeds are the most serious problem in the lake with illegal diving being second. Sixty-six percent of all respondents said they would favor allowing brailing to continue if it did not damage fish habitat. Seventy-seven percent of all respondents strongly oppose allowing diving for mussels.

Perhaps if brailers could work to reduce the destruction of underwater structure by avoiding areas known to have structure and limit brailing in heavily used fishing areas especially on weekends and holidays, some of the conflict might be abated. The Department of Fish and Wildlife Resources could work with sport fishermen's organizations and the shell harvester associations to mark areas where structure should be avoided or place fish attractor buoys in areas where structure pulled up by brailers could be dumped to improve fishing if this did not impede navigation.

Overall the mussel resource seems healthy, and under present regulations the resource should sustain a continued harvest. Harvest pressure is declining in the most heavily worked areas as fewer large shells are caught and musselers move to new areas. Some are moving to Lake Barkley where shell quality is excellent, even better than in many areas of Kentucky Lake, and densities are increasing as the reservoir ages. If conflicts with other water resource users can be resolved, and the second segment of this study indicates insignificant damage by brailing to other benthic organisms and fish, then musseling should have a good future in western Kentucky.

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APPENDIXES

APPENDIX A: Questionnaire

QUESTIONNAIRE

Impacts of Brailing on the Mussel Communities And Habitat in Kentucky Lake

NOTICE

The attached questionnaire is part of a study being conducted by Murray State University for the Kentucky Department of Fish and Wildlife Resources and the National Marine Fisheries Service. This questionnaire is being distributed to commercial musselers, commercial fishermen, sports fishermen, recreational boaters, fishing guides and marina owners and operators.

Respondents will remain anonymous. Information about the questionnaire can be obtained from Dr. James B. Sickel, Department of Biology, Murray State University, Murray, KY 42071. Phone (502) 762-6326.

Mussel harvesting is a valuable industry in Kentucky. As with any valuable natural resource, the mussel resource must be managed wisely, and established regulations must insure the continued survival and health of the resource while being consistent with management requirements for the overall resource of which the mussels are a part.

This questionnaire is designed to gather information about the mussel industry from those of you most aware of the benefits and the problems of brailing for mussels. Your responses, opinions, and other information are important to the success of this project.

Please complete and return this questionnaire in the self-addressed, postage paid envelope before July 28, 1989. Your assistance is appreciated.

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Impacts of Brailing on the Mussel Communities and Habitat in Kentucky Lake

GENERAL INFORMATION

Prior to the construction of dams on the Tennessee River, the river supported one of the most diverse and densest mussel faunas found anywhere in the world. During the first half of this century, the mussels were a valuable source of shells for the pearl button industry. With the construction of Kentucky Dam in 1944, mussels declined in the old river channel partly because of sediment accumulation. Soon, however, mussels began to populate the old fields and banks flooded by Kentucky Lake. Mussel growth is slow. A mussel requires 6-8 years to reach maturity when it can reproduce, and 8-10 years to reach legal harvestable size. It may live 50 years. The number of mussels living in the shallow regions outside of the old channel has continued to increase and now provides a valuable source of shells for the international cultured pearl industry. The shells are cut and ground into beads which are then placed inside pearl oysters or other mollusks and serve as nuclei for cultured pearls. Musseling has provided a major source of income for some families in western Kentucky for three generations.

Mussels filter silt and organic matter from the overlying water. Some of this material is consumed as food by the mussel, and some is deposited on the surface of the sediment in which the mussels burrow. This material is used as food by other bottom dwelling animals such as mayfly nymphs, midge larvae, and annelid worms which in turn are an important source of food for many fish. While the filtering activities of the mussels may increase sedimentation, burrowing may suspend materials from the sediment and influence chemical processes occurring at the sediment surface. Female mussels produce larvae called glochidia which are released into the water and must attach to a fish for a brief parasitic period during which the glochidium transforms into a juvenile mussel. When this transformation is complete, usually after a few weeks, the juvenile mussel drops from the fish and takes up residence in the sediment. Thus, mussels are an important part of the aquatic environment. The overall significance of mussels to this environment is unknown.

In recent years, mussel fishermen have begun harvesting mussels by brail in the shallow waters of Kentucky Lake. A brail consists of a bar with many wire hooks attached by chains. The brail is pulled by boat such that the hooks scrape the surface of the sediment where mussels live. As a hook enters the open shell of a mussel, the mussel closes and is thus caught. These hooks dig into the sediment and tend to catch on anything they encounter, e.g., old fishing lines, discarded trash, sunken logs, and stumps. Old trees and stumps which attract fish may be removed by brailers as they prepare an area for brailing. The impact of brailing on the lake environment is unknown. This is the reason for the study.

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QUESTIONNAIRE

1. Check only categories which apply to you.
Indicate the approximate percent of time you spend engaged in each activity while on Kentucky Lake.

- ☐ Mussel brailer ____%
- ☐ Fishing guide ____%
- ☐ Mussel diver ____%
- ☐ Sports fisherman____%
- ☐ Marina/Resort manager____%
- ☐ Commercial fisherman____%
- ☐ Recreational boater ____%
- ☐ Other______________ ____%

2. Indicate your annual gross income and portion derived from lake activities.

Annual gross income: ☐ 0-$10,000; ☐ $10,000-$20,000; ☐ $20,000-$30,000; ☐ $30,000-$40,000; ☐ $40,000-$50,000; ☐ $50,000-$75,000; ☐ over $75,000.

Percent of income from lake activities: ☐ 0%; ☐ 0-10%; ☐ 10-25%; ☐ 25-50%; ☐ 50-75%; ☐ 75-95%; ☐ 100%.

3. Indicate your annual gross income derived from the following activities on Kentucky Lake.

- Mussel brailing $____________
- Sport fishing $__________
- Commercial fishing $____________
- Fishing guide $__________
- Marina/Resort operation $________
- Other__________ $________

4. Indicate your annual expenses for the following activities on Kentucky Lake.

- Mussel brailing $____________
- Sport fishing $__________
- Commercial fishing $________
- Fishing guide $__________
- Marina/Resort operation $__________
- Recreational boating $__________
- Other__________ $________

5. Are you familiar with the Kentucky laws governing musseling?

☐ Yes; ☐ No.

6. Approximately how many hours each month (April-October) do you spend on Kentucky Lake? _____

7. For analysis I have divided Kentucky Lake into the 4 areas.

Area 1 - Kentucky Dam to Bear Creek (mile 23 - 31)
Area 2 - Bear Creek to Eggner Ferry Bridge (mile 31 - 42)
Area 3 - Eggner Ferry Bridge to Blood River (mile 42 - 51)
Area 4 - Blood River to Cypress Creek (mile 51 - 62)

Tell the approximate percent of time on the lake that you spend in each area while engaged in each activity appropriate to you.

ACTIVITY	AREA	PERCENT TIME
Brailing	Area 1 (mile 23 - 31)	______
	Area 2 (mile 31 - 42)	______
	Area 3 (mile 42 - 51)	______
	Area 4 (mile 51 - 62)	______
Commercial Fishing	Area 1 (mile 23 - 31)	______
	Area 2 (mile 31 - 42)	______
	Area 3 (mile 42 - 51)	______
	Area 4 (mile 51 - 62)	______
Sport Fishing	Area 1 (mile 23 - 31)	______
	Area 2 (mile 31 - 42)	______
	Area 3 (mile 42 - 51)	______
	Area 4 (mile 51 - 62)	______
Recreational Boating	Area 1 (mile 23 - 31)	______
	Area 2 (mile 31 - 42)	______
	Area 3 (mile 42 - 51)	______
	Area 4 (mile 51 - 62)	______
Other ______	Area 1 (mile 23 - 31)	______
	Area 2 (mile 31 - 42)	______
	Area 3 (mile 42 - 51)	______
	Area 4 (mile 51 - 62)	______

8. Which method of harvest is most cost effective for harvesting mussels?
   - [ ] brailing; - [ ] diving; - [ ] no opinion.

9. Which method of harvest is least damaging to the mussel resource? ☐ brailing; ☐ diving; ☐ no opinion.

10. What is the most important problem in Kentucky Lake?

☐ weeds	☐ mussel brailing
☐ water quality	☐ commercial fishing
☐ illegal diving	☐ erosion
☐ low oxygen	☐ other ________________

11. What is your rating of the current overall status of Kentucky Lake with regard to the following:

Water quality:	☐ Excellent;	☐ good;	☐ fair;	☐ poor.
Mussel resource:	☐ Excellent;	☐ good;	☐ fair;	☐ poor.
Commercial fishery:	☐ Excellent;	☐ good;	☐ fair;	☐ poor.
Sport fishing:	☐ Excellent;	☐ good;	☐ fair;	☐ poor.

12. What is the effect of mussel brailing on:

Water quality:	☐ Improves;	☐ damages;	☐ no effect.
Mussel resource;	☐ Improves;	☐ damages;	☐ no effect.
Commercial fish;	☐ Improves;	☐ damages;	☐ no effect.
Sport fishing;	☐ Improves;	☐ damages;	☐ no effect.
Marina income;	☐ Improves;	☐ damages;	☐ no effect.

13. What effect do you believe diver harvest of mussels would have on the overall mussel resource?

    ☐ harmful; ☐ beneficial; ☐ none; ☐ undecided.

14. Recent brailing regulations have restricted brailing from embayments in Kentucky Lake and limited brailing time to from 8 a.m. to 6 p.m. Do you believe that brailing should have: ☐ more restrictions; ☐ less restrictions; ☐ no change in restrictions; ☐ no opinion.

    Elaborate: ____

15. If mussels could be harvested by some method which would not damage fish habitat and not harm the overall health of the mussel resource, would you be in favor of allowing the harvest of mussels by this method? ☐ Yes; ☐ No.

16. Would allowing the legal harvest of mussels by diving be <u>more</u> or <u>less</u> detrimental than brailing to the following:

Water quality:	☐ more;	☐ less;	☐ no difference.
Mussel resource:	☐ more;	☐ less;	☐ no difference.
Commercial fish:	☐ more;	☐ less;	☐ no difference.
Sport fishing:	☐ more;	☐ less;	☐ no difference.
Recreational boating:	☐ more;	☐ less;	☐ no difference.

17. If brailing could be restricted in such a manner to prevent damage to fish habitat, would you be in favor of allowing brailing to continue? ☐ Yes; ☐ No; ☐ Undecided.

18. Would you prefer that the taking of mussels from Kentucky and Barkley Lakes be prohibited? ☐ Yes; ☐ No; ☐ Undecided.

19. Underwater structure such as old stumps, brush and trees provide habitat or structure which attracts fish and may be important for the survival of some fish species. Have you ever seen mussel brailers remove fish habitat such as stumps or brush from Kentucky Lake? ☐ Yes; ☐ No; ☐ undecided.

20. (Brailers only)
If it were demonstrated that brailing was significantly damaging the Kentucky Lake habitat and reducing the value of resources to a greater extent than the value of mussels being harvested, would you voluntarily stop brailing? ☐ Yes; ☐ No.

21. Are you in favor of permitting diving for mussels in Kentucky and Barkley Lakes? ☐ Yes; ☐ No.

22. Do you believe that both brailing and diving should be allowed? ☐ Yes; ☐ No; ☐ No opinion.

23. Indicate your number one concern about brailing in Kentucky Lake.

____

24. COMMENTS: Please comment or further elaborate on any of the questions. Attach a page if necessary.

<u>Question</u> ____________ Comment ____________

QUESTIONNAIRE SUMMARY

1. Number of respondents in each category.

   Mussel brailer 44 — Fishing guide 20

   Mussel diver 4 — Sports fisherman 88

   Marina/Resort manager 12 — Commercial fishermen 15

   Recreational boater 43 — Other ________ 9

2. Indicate your annual gross income and portion derived from lake activities. (Number of respondents in parenthesis).

   Annual gross income: 0-$10,000 (46); $10,000-$20,000 (24); $20,000-$30,000 (17); $30,000-$40,000 (11); $40,000-$50,000 (4); $50,000-$75,000 (5); over $75,000 (9)

   Percent of income from lake activities: 0% (31); 1-10% (16) 10-25% (11); 25-50% (8); 50-75% (5); 75-95% (10); 100% (33).

3. Indicate your annual gross income derived from the following activities on Kentucky Lake. (Average income)

   Mussel brailing ($9,862.50) — Sport fishing ($4,761.54)

   Commercial fishing ($16,516.67) — Fishing guide ($9,390.63)

   Marina/Resort ($220,535.43) — Other_____ ($41,750.00)

4. Indicate your annual expenses for the following activities on Kentucky Lake. (Averages)

   Mussel brailing ($3,340.47) — Sport fishing ($2,792.38)

   Commercial fishing ($6,545.83) — Fishing guide ($7,058.82)

   Marina/Resort operation ($92,663.50)

   Recreational boating ($683.79) — Other____($5,000.00)

5. Are you familiar with the Kentucky laws governing musseling?

   Yes (82%); No (18%).

6. Approximately how many hours each month (April-October) do you spend on Kentucky Lake? (Average hours per month--118.)

7. For analysis I have divided Kentucky Lake into 4 areas.

Area 1 - Kentucky Dam to Bear Creek (mile 23 - 31)
Area 2 - Bear Creek to Eggner Ferry Bridge (mile 31 - 42)
Area 3 - Eggner Ferry Bridge to Blood River (mile 42 - 51)
Area 4 - Blood River to Cypress Creek (mile 51 - 62)

Tell the approximate percent of time on the lake that you spend in each area while engaged in each activity appropriate to you.

ACTIVITY	AREA	NO. OF RESPONDENTS	PERCENT TIME
Brailing	Area 1 (mile 23 - 31)	(23)	66.26%
	Area 2 (mile 31 - 42)	(9)	35.22%
	Area 3 (mile 42 - 51)	(8)	87.50%
	Area 4 (mile 51 - 62)	(0)	0%
Commercial Fishing	Area 1 (mile 23 - 31)	(8)	51%
	Area 2 (mile 31 - 42)	(7)	36.86%
	Area 3 (mile 42 - 51)	(7)	40.43%
	Area 4 (mile 51 - 62)	(3)	50%
Sport Fishing	Area 1 (mile 23 - 31)	(59)	45.93%
	Area 2 (mile 31 - 42)	(59)	37.34%
	Area 3 (mile 42 - 51)	(47)	34.64%
	Area 4 (mile 51 - 62)	(29)	27.45%
Recreational Boating	Area 1 (mile 23 - 31)	(32)	51.16%
	Area 2 (mile 31 - 42)	(21)	40.76%
	Area 3 (mile 42 - 51)	(10)	49.80%
	Area 4 (mile 51 - 62)	(7)	62.14%
Other	Area 1 (mile 23 - 31)	(11)	48.18%
	Area 2 (mile 31 - 42)	(10)	29.50%
	Area 3 (mile 42 - 51)	(8)	53.75%
	Area 4 (mile 51 - 62)	(4)	28.75%

8. Which method of harvest is most cost effective for harvesting mussels? (Percent of 122 respondents)

brailing (24%); diving (41%); no opinion (35%).

9. Which method of harvest is least damaging to the mussel resource? brailing (41%); diving (43%); no opinion (16%).

10. What is the most important problem in Kentucky Lake?

weeds (23%)	mussel brailing (24%)
water quality (12%)	commercial fishing (3%)
illegal diving (17%)	erosion (2%)
low oxygen (8%)	other___ (11%)

11. What is your rating of the current overall status of Kentucky Lake with regard to the following: (% respondents)

Water quality: Excellent (9); good (51); fair (35); poor (5).

Mussel resource: Excellent (18); good (54); fair (27); poor (1).

Commercial fish: Excellent (22); good (59); fair (18); poor (1).

Sport fishing: Excellent (27); good (53); fair (16); poor (4).

12. What is the effect of mussel brailing on: (% respondents)

Water quality:	Improves (15); damages (33); no effect (52).
Mussel resource;	Improves (21); damages (51); no effect (28).
Commercial fish;	Improves (17); damages (42); no effect (41).
Sport fishing;	Improves (15); damages (44); no effect (41).
Marina income;	Improves (35); damages (30); no effect (35).

13. What effect do you believe diver harvest of mussels would have on the overall mussel resource? (% respondents)

harmful (56%); beneficial (16%); none (9%); undecided (20%).

14. Recent brailing regulations have restricted brailing from embayments in Kentucky Lake and limited brailing time to from 8 a.m. to 6 p.m. Do you believe that brailing should have:

more restrictions (52%); less restrictions (9%);

no change in restrictions (34%); no opinion (5%).

15. If mussels could be harvested by some method which would not damage fish habitat and not harm the overall health of the mussel resource, would you be in favor of allowing the harvest of mussels by this method? Yes (84%); No (16%).

16. Would allowing the legal harvest of mussels by diving be <u>more</u> or <u>less</u> detrimental than brailing to the following: (% respondents)

Water quality:	more (7); less (47); no difference (46).
Mussel resource:	more (61); less (25); no difference (14).
Commercial fish:	more (15); less (57); no difference (28).
Sport fishing:	more (18); less (56); no difference (26).
Recreational boating:	more (29); less (30); no difference (41).

17. If brailing could be restricted in such a manner to prevent damage to fish habitat, would you be in favor of allowing brailing to continue? Yes (66%); No (25%); Undecided (9%).

18. Would you prefer that the taking of mussels from Kentucky and Barkley Lakes be prohibited? Yes (33%); No (55%); Undecided (12%)

19. Underwater structure such as old stumps, brush and trees provide habitat or structure which attracts fish and may be important for the survival of some fish species. Have you ever seen mussel brailers remove fish habitat such as stumps or brush from Kentucky Lake? Yes (57%); No (39%); Undecided (4%)

20. (Brailers only)
If it were demonstrated that brailing was significantly damaging the Kentucky Lake habitat and reducing the value of resources to a greater extent than the value of mussels being harvested, would you voluntarily stop brailing? Yes (58%); No (42%).

21. Are you in favor of permitting diving for mussels in Kentucky and Barkley Lakes? Yes (23%); No (77%).

22. Do you believe that both brailing and diving should be allowed? Yes (18%); No (76%); No opinion (6%).

23. Indicate your number one concern about brailing in Kentucky Lake.

____

24. COMMENTS: Please comment or further elaborate on any of the questions. Attach a page if necessary.