RESEARCH AND MANAGEMENT APPLICATION OF GRASS CARP IN IOWA[1/]

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This presentation will cover three aspects of grass carp introductions in Iowa. These are: (1) research, (2) its application to management of aquatic weeds, and (3) the distribution of grass carp in the river systems of Iowa.

The research study objective was to evaluate the effectiveness of grass carp to biologically controlled dense beds of nuisance aquatic vegetation in a 29 ha man-made impoundment in order to improve angler success along the shorelines. This was accomplished by measuring the standing crop of aquatic macrophytes before grass carp were stocked, stocking grass carp and then continuing to measure the biomass and species composition of the macrophyte community. The vital statistics of grass carp including growth, body condition, food consumption, mortality and behavioral activity were described.

The third phase of the investigation was to measure the indirect impact of vegetation control on the water quality, primary production of phytoplankton and the sport fish harvest.

Red Haw Lake, the study area, is a 29 ha man-made impoundment located in south-central Iowa. In July, 1973, 18 grass carp per ha were stocked followed by nine grass carp per ha in July, 1974. Red Haw is a recreational lake surrounded by a state park where public fishing is a major activity. Many areas of the lake are accessible to shore fishermen, yet during the summer months anglers find it nearly impossible to fish from shore because of massive beds of aquatic weeds. This problem exists in many Iowa lakes, resulting in poor use of the fishery resource.

Macrophyte biomass and species composition were measured in 1973 before grass carp were stocked and then monthly during May-September each year thereafter. Divers equipped with SCUBA sampled ten permanently located stations by placing a square frame 0.5 m on each side (0.25 m^2) over the vegetation and extracting all the plants from within the frame. The material was brought to the surface where wet weights were recorded. Samples were preserved for later sorting, identification and measurement of weights for individual plant taxa.

Maximum vegetation biomass occurred prior to grass carp introduction with

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an average estimate of 2,438 g/m^2. Within four years the overall vegetation biomass was reduced to 211 g/m^2 (Figure 1). The greatest reduction in a single season occurred in 1973 when test plot weights were reduced by 73%. Mean sample weight in 1974 was 1,142 g/m^2 decreasing to 445 g/m^2 in 1975 and then to 211 g/m^2 in 1976. Aquatic macrophyte biomass increased greatly in 1977 when the density of grass carp was reduced to an estimated 7 fish per ha.

At first, Potamogeton and Najas dominated the plant community. After three years both groups were nearly eliminated. Potamogeton remained below 100 g/m^2, while Najas increased greatly in 1976 and 1977 when average plot weight in August was greater than 2,000 g/m^2 (Figure 2).

Elodea was nearly nonexistent when grass carp were stocked, but became increasingly important in 1974 and 1975 when test plot values in August were about 1,000 g/m^2 and 500 g/m^2, respectively. In 1976 and 1977 mean biomass was < 500 g/m^2. Ceratophyllum never became a problem and by 1976 and 1977 field weights were reduced to values < 100 g/m^2 (Figure 2).

Vital statistics measured in this investigation were growth, body condition, food consumption, mortality, and behavioral activity. Grass carp were captured with 76-127 mm bar mesh gill nets in shallow embayments in the summer and midwater sets under ice in winter. Lengths, weights and reproductive condition were recorded at the time of capture.

Grass carp grew rapidly from an average length of 320 mm at stocking to 824 mm four years later. Mean weight at introduction was 380 g, while average weight at the end of the 1976 growing season was 6,847 g (Figure 3). Maximum size in the 1976 sample was 890 mm and 10,600 g. Body condition factor, K, ranged from 1.05 - 2.02, while mean K-factor ranged from 1.13 for the sample in October, 1975, to 1.49 in October, 1973. Mean condition when grass carp were stocked was 1.28, but increased to 1.37 or greater by October. By January and February, mean condition factor again decreased to values in the 1.25 - 1.30 range.

Grass carp consumed aquatic vegetation almost entirely. Food volume from 28 grass carp in 1973-1975 was measured and items identified along the entire length of the alimentary tract. The plant material in the gut was identified by comparing it to reference material from plants in Red Haw Lake. First, plant leaves and stems were crushed and mounted on slides where the material was cleared and fixed with chloral hydrate and gum arabic solutions. Material from the gut was treated identically and plant fragments were compated with reference material and identified by cell size and morphometry. Vegetation was the main food source, however, < 0.1% of the food content by volume were invertebrates. Traces of filamentous algae, particularly Oedogonium and Spirogyra were found in most of the alimentary tracts.

Aquatic macrophyte fragments in the gut were composed of Potamogeton, Elodea, Ceratophyllum and Najas. In 1973, Potamogeton was most important contributing 65.7% to the diet followed by Elodea, 24%; Najas, 7.1%; and Ceratophyllum, 3.1%. Thereafter, Potamogeton became less important contributing 22.6% to the ration by 1975, while Ceratophyllum increased greatly to 34.5% of the diet. Elodea remained about the same at 20%, while Najas increased to 22.8% in 1974, but decreased to 11.9% of the diet in 1975 (Table 1).

Electivity indexes ranged from total avoidance (-1.00) in some samples to +0.98 for Najas in April and June, 1974. In all samples, except one, the electivity indexes for Najas were positive. Potamogeton was also positive in five of seven periods sampled. There was less selection for Elodea and Ceratophyllum where indexes were less than +0.52 and +0.61, respectively (Table 2).

Biomass of the grass carp population in Red Haw Lake was estimated annually as the product of numerical abundance and mean weight in the population. Mortality was estimated at 33%. Maximum population biomass was attained in 1975 at 1,767 kg. Initial biomass in July, 1973 was about 200 kg which nearly quadrupled by the end of the growing season. The following year 250 additional grass carp were stocked and by October, 1974 the biomass of both introductions was about 1,600 kg. By 1976 growth slowed and mortality became an important factor causing a decrease in biomass to 1,485 kg (Figure 4).

Exact mortality estimates were not determined, but three sources of mortality were identified. Mortality of fish stocked in 1974 was caused mainly due to a weakened condition from parasitism of Gryodactylus and Lernaea. Grass carp were stocked in 28 July and within 15 days, 38 dead fish were found. Three carp were also found by divers on the lake bottom. Aquarium fish from the same stock were also heavily parasitized. Fish from the 1973 introduction were not affected.

The second most numerous cause of mortality was from netting and holding. Grass carp were captured and held in tanks in order to develop surgical techniques for implantation of sonic tags. This activity accounted for the loss of eight fish. Another source of mortality was from electrofishing. Two shocked fish did not recover equilibrium and later six dead fish were found in the same area where electrofishing gear was used.

Behavioral activity was determined by locating and following grass carp with ultrasonic tags surgically implanted in the body cavity. Transmitters were sealed in polypropylene tubes which measured 16 x 60 mm and weighed 8 g in water. Each transmitter emitted a different frequency and impulse rate ranging from 74-76.56 kHz with impulse rates ranging from 46 to 120 per minute.

The recipient fish was anesthetized for 5-8 minutes and placed ventral side up on a V-shaped holding table. A 20-25 mm incision was made 10 mm laterally and parallel to the mid-ventral line. Transmitters were inserted posteriorly between the viscera and body wall followed by closure of the incision with 3-4 sutures of No. 000 braided surgical silk. Battery lift provided a minimum of 120 days of observation.

The nine tagged fish were located by slowly following the lake perimeter approximately 50 m from shore with the hydrophone pointed towards shore. Occasionally the hydrophone was slowly rotated 360° so fish could be located in midwater. The overall distribution of grass carp was summarized by adjusting the number of observations from the fish which were released earlier. Thus, each tagged fish was equally represented in the distribution regardless of the number of times it was contacted.

Contact locations were further grouped into four hydrographic components including shallow water (depth < 3 m), midwater (depth $\geq$ 3 m), embayments and the main lake (Figure 5). Fish in the midwater area were confined to the upper lake strata during June-August by a well defined thermocline < 4 m from the surface. Shallow water areas contained 10 ha and were dominated by vegetation, while midwater contained 19 ha. Four embayments comprised 9.3 ha of which 5.7 ha were shallow and 3.6 ha were midwater.

Tagged fish were contacted 412 times which accounted for 62 hours of monitoring. Contact time averaged 9 minutes per fish, but ranged from brief receptions of two minutes to continuous monitoring of 24 hours.

Tagged fish were located in all areas of the lake except near the dam where vegetation was extremely sparse. Shallow water depth (depth $\leq$ 3 m) was by far the most frequently inhabited area where 251 of 412 contacts were made. In the shallow water segment, 75 contacts were within embayments, while 176 were in the main lake. Locations in deep water comprised the remaining 161 observations of which 63 were in embayments and 98 in the main lake (Table 3).

Chi-square analysis was used to compare observed values with the expected distribution given the assumption there was equiprobability of contacting sonic tagged grass carp in all habitat components. Frequency of contact within each component was adjusted for the size of each component so the observed values were on the basis of contacts per hectare, thereby component size had no influence on the analysis.

Additional analysis showed the significant χ^2 values were due to either a paucity or dominance of observed contacts compared with the expected (Table 4). Large χ^2 values caused by a greater than expected contact frequency showed a significant affinity for a particular area, and conversely, significantly large χ^2 values caused by lower than expected contacts with tagged fish in an area indicated avoidance of that area. Chi-square values which were nonsignificant showed neither avoidance nor affinity for the area.

Overall, the greatest selection was for shallow water of the main lake as seven of the nine fish had an affinity for that particular habitat. Conversely, seven of nine fish avoided deep water within the main lake. Six fish had no particular affinity for midwater within embayments and only two of nine fish had an affinity toward shallow water within embayments.

Usually grass carp were sedentary and moved very little. Movement was in and near weed beds and was slow and erratic, while movement in midwater was rapid and extended over longer distances. Average swimming speed in midwater was 0.12 - 1.16 m/sec, while maximum speed was 1.46 m/sec.

Two fish showed definite homing tendency toward established activity centers. Both fish were monitored many times leaving and/or returning to an area which they occupied nearly constantly. An example occurred on 10 July when Alice left her activity center twice and was observed returning three times within several hours. Nocturnal activity was not greatly different from diurnal movement.

Phosphates, nitrates, turbidity, alkalinity, pH, and biochemical oxygen demand (BOD) were measured each month commencing in March, 1974 with the samples taken at the surface, 4 m and 8 m at a single location.

Organic phosphates at the surface ranged from 0.21 mg/l in 1977 to 0.46 mg/l the previous year. Values in 1974 and 1975 were 0.24 and 0.32 mg/l, respectively. Surface inorganic phosphates showed a similar trend with the highest concentrations in 1976 at 0.41 mg/l. The lowest value occurred in 1974 at 0.28 mg/l followed by consecutive increases in 1975 and 1976 when average inorganic phosphate concentrations were 0.32 and 0.41 mg/l.

Nitrate nitrogen concentration at the surface was greatest in 1974 at 1.11 mg/l and lowest the following year at 0.29 mg/l. Thereafter there was a gradual increase to 0.34 and 0.50 mg/l in 1976 and 1977. Nitrite nitrogen showed a similar trend with the greatest average concentration in 1974 at 0.021 mg/l followed by two consecutive decreases to 0.009 mg/l and 0.004 mg/l in 1975 and 1976. In 1977 nitrite nitrogen increased to levels near 1974 where the average concentration was 0.017 mg/l.

Turbidity increased during 1974-1976, but then decreased to the lowest level in 1977. Average water clarity in 1974 was 7.24 FTU followed by 10.01 and 10.90 FTU in 1975 and 1976. Average turbidity at the surface in 1977 was 6.30 FTU.

Alkalinity increased each year during the investigation from 109 mg/l in 1974 to 127 mg/l in 1977.

Average pH in 1974 was 7.74 which increased to 7.91 in 1975 and then was followed by a decrease in 1976 to 6.38. Average pH in 1977 was 6.70.

Biochemical oxygen demand decreased from 4.44 mg/l in 1974 to 2.80 in 1976 when it increased to an average of 3.33 in 1977.

Primary production of phytoplankton was measured biweekly by the light and dark bottle technique where a replicate set of bottles were suspended at 1 m intervals from 1 - 5 m.

Primary production was quite variable during the season (Figure 6) ranging from 0.05 grams of carbon per m^2 per day ($gC/m^2/day$) to 3.92 $gC/m^2/day$ in 1976. Average production in 1974 was 1.91 $gC/m^2/day$ nearly identical to the production in 1975 when mean production was 1.90 $gC/m^2/day$. In 1976 average primary production decreased to 1.59 $gC/m^2/day$. A further decline in production occurred in 1977 when the average was 1.29 $gC/m^2/day$.

Primary production was greatest near the surface with an overall average of 0.62 $gC/m^3/day$. Thereafter production values decreased to 0.33, 0.19 and 0.14 $gC/m^3/day$ at 2, 3 and 4 m, respectively. Production at 5 m increased slightly to 0.18 $gC/m^3/day$.

The ultimate objective of introducing grass carp in Red Haw Lake was to increase the angler success along the shoreline. The sport fishery was monitored during April through 15 September by an expandable census in 1974, 1975 and 1976.

Bluegill, by far, dominated the fishery followed by crappie and largemouth bass. Catch in 1974 was 12,781 followed by 22,372 and 14,638 in 1975 and 1976.

Catch and angler effort were separated by boat and shore anglers. Boat anglers caught far more fish and were more successful than shore anglers. For example, in 1975 shore anglers caught 4,340 fish compared to 18,031 fish for boat anglers and during the same year catch-effort of shore anglers was 0.90 fish/hour compared to 1.97 fish/hour for boat anglers.

Effort for boat anglers remained nearly constant, while effort from shore increased from 2,974 hours in 1974 to 7,181 hours in 1976. While vegetation biomass decreased from about 1,700 g/m^2 in 1974 to < 100 g/m^2 in 1975 fishing pressure increased nearly 2.5-fold (Figure 7).

Findings of this investigation showed water quality changed with intensive biological vegetation control. Phosphate concentrations and turbidity increased, but nitrates, nitrites and BOD decreased with higher levels of vegetation control. Alkalinity increased throughout the study and pH showed no particular trend with intensity of vegetation control. Regardless of the changes in water quality average primary production of phytoplankton decreased during the investigation.

The use of grass carp has been expanded to 25 lakes in Iowa where nuisance vegetation has become a problem in the harvest of sport fish. Most of the introductions were made in 1976 and 1977 so results of these stockings are not available. Within a few years the results of introducing 12 to 88 grass carp/ha in these lakes should be known.

The distribution of grass carp of unknown origin in Iowa rivers are shown in Figure 8. One fish was taken in the Mississippi River and verified by Illinois biologists. One carp was taken in a fish renovation project in a backwater of the Des Moines River by Iowa biologists, but most of the reports come from the Missouri River where four fish were captured by commercial fishermen.

Table 1. Percent occurrence of food items in the alimentary tract of 20 grass carp at Red Haw Lake.

	Potamogeton	Elodea	Ceratophyllum	Najas	Unidentified
1973	65.7	24.0	3.1	7.1	0.1
1974	43.3	21.8	13.8	22.8	0
1975	22.6	19.0	34.5	11.9	12.1

Table 2. Electivity indexes of four major food groups consumed by grass carp at Red Haw Lake.

	Potamogeton	Elodea	Ceratophyllum	Najas
1973				
September	+0.27	+0.52	+0.15	-0.79
1974				
April	-0.08	+0.07	+0.09	+0.98
June	+0.13	-1.00	-1.00	+0.98
August	-0.45	-0.55	+0.61	+0.92
1975				
June	+0.59	-0.72	-0.88	+0.67
August	+0.84	-0.39	-0.23	+0.22
September	+0.81	+0.51	-0.30	+0.91

Table 3. Frequency of ultrasonic contacts with nine grass carp in four hydrographic areas at Red Haw Lake.

	Embayments		Main lake	
	Shallow	Deep	Shallow	Deep
Alice	5	2	28	11
Bertha	21	3	19	3
Carla	2	5	9	30
Debra	9	8	16	13
Ethel	12	6	18	10
Fay	19	6	15	5
Gertrude	7	3	25	10
Helen	0	0	46	0
Ida	0	30	0	16
Total	75	63	176	98

Table 4. Affinity (+), avoidance (-) or nonselection (0) of grass carp in four hydrographic components at Red Haw Lake based on χ^2 analysis of contact frequency.

	Embayments		Main lake	
	Shallow	Deep	Shallow	Deep
Alice	-	-	+	-
Bertha	+	0	+	-
Carla	-	0	0	0
Debra	0	0	+	-
Ethel	0	0	+	-
Fay	+	0	+	-
Gertrude	0	0	+	-
Helen	-	-	+	-
Ida	-	+	-	0

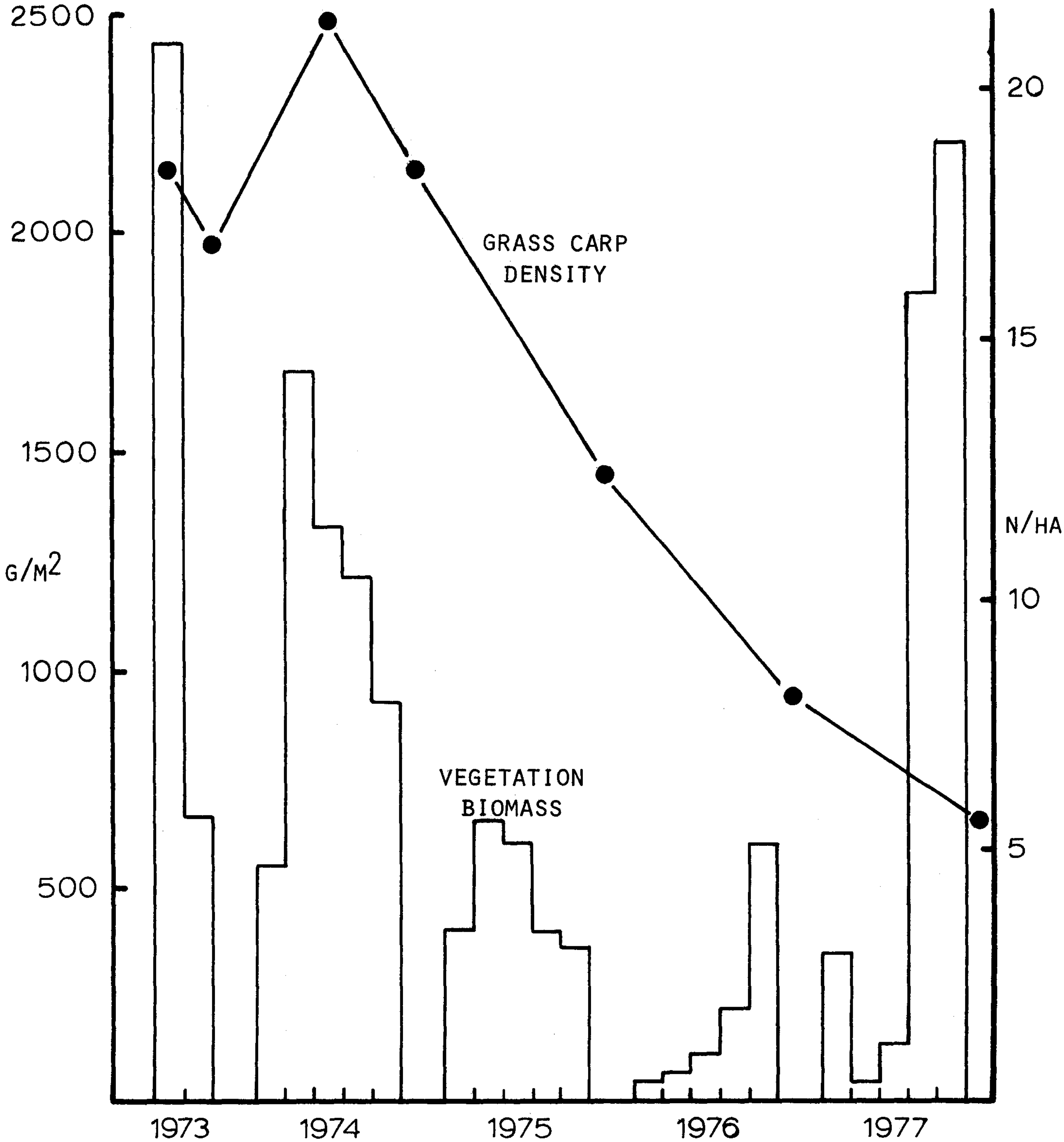

Figure 1. Grass carp density and vegetation biomass 1973 - 1977 in Red Haw Lake, Iowa.

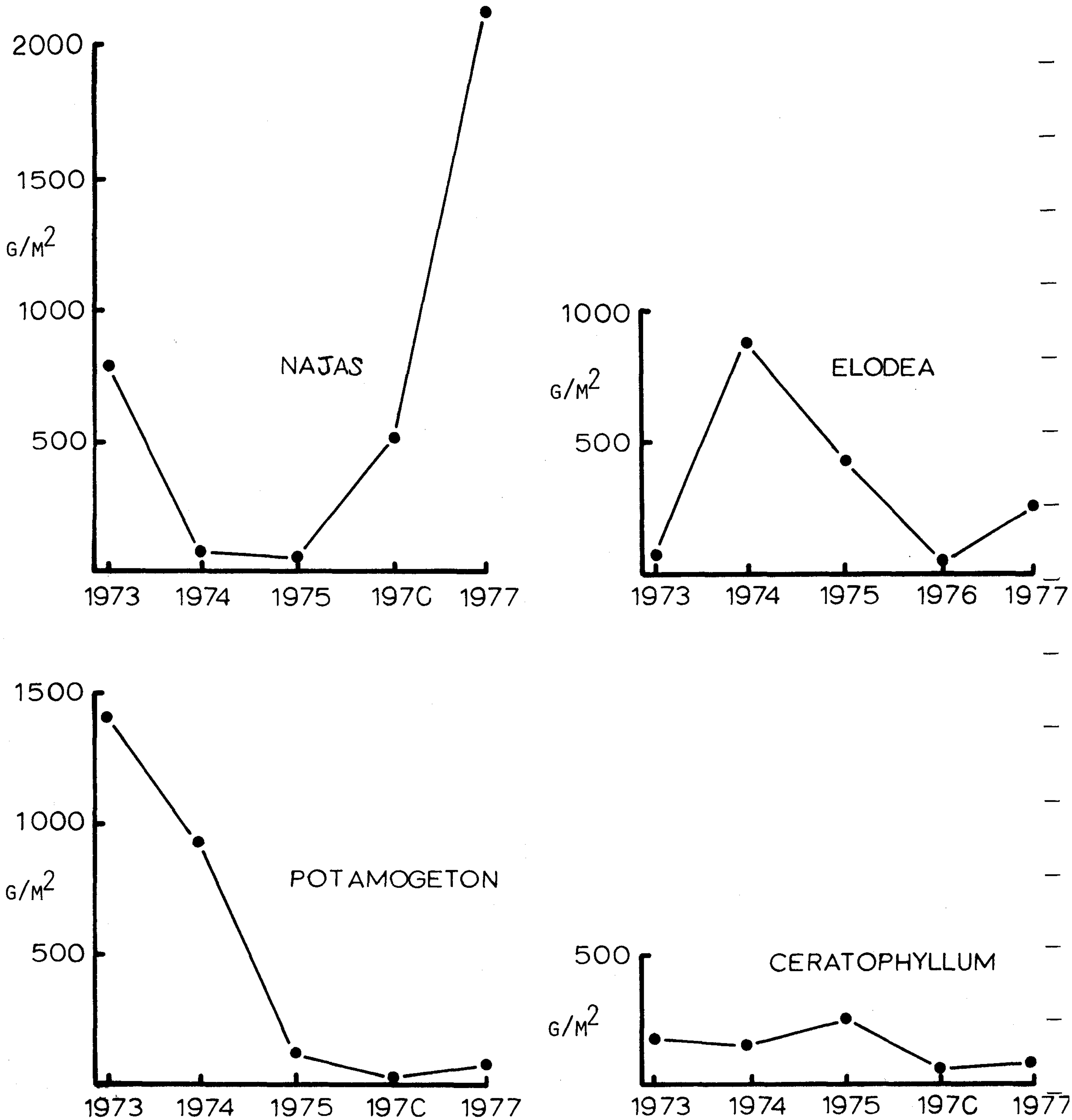

Figure 2. Biomass of Najas, Elodea, Potamogeton and Ceratophyllum in Red Haw Lake, 1973 - 1977.

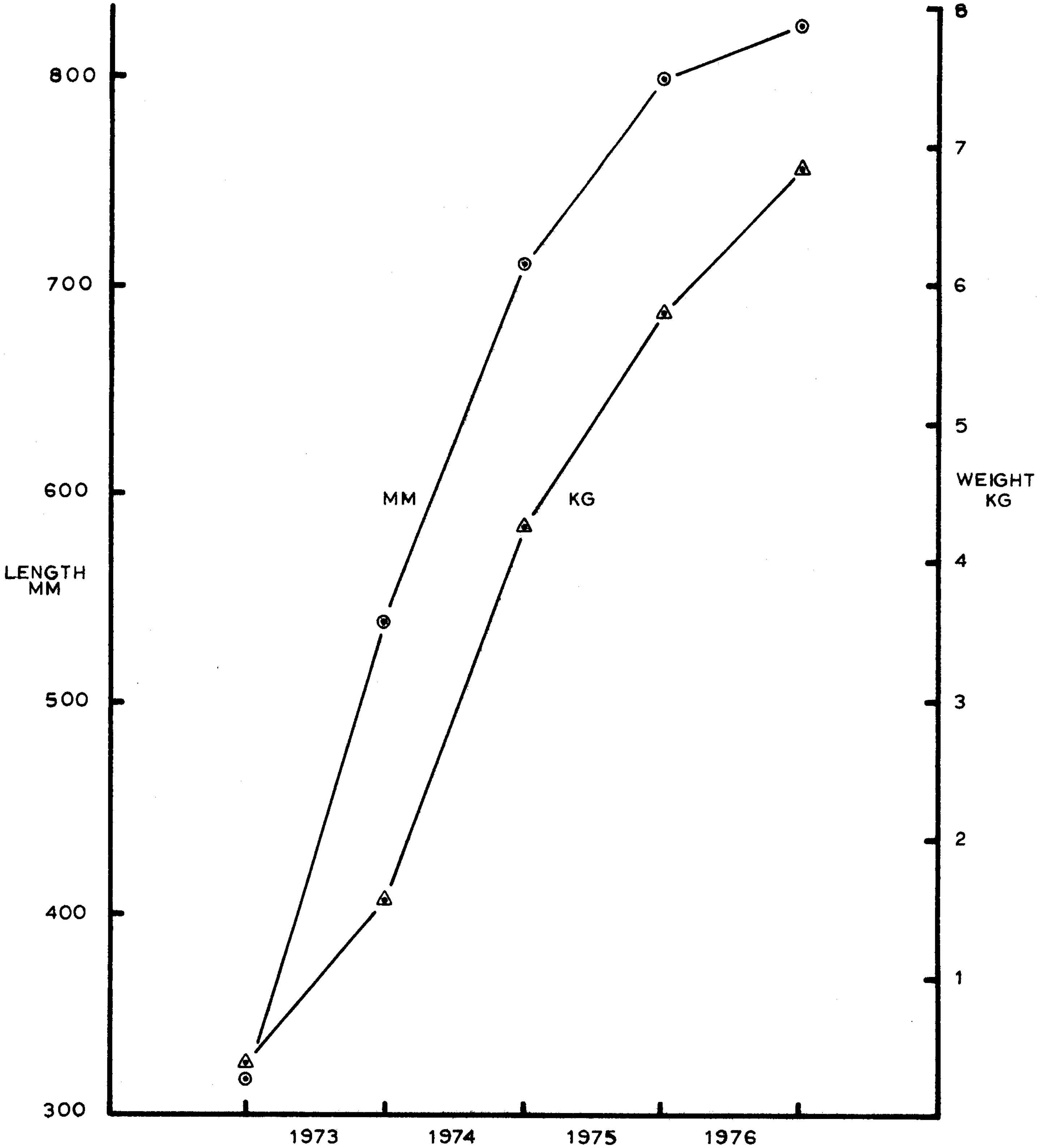

Figure 3. Growth in length and weight of grass carp at Red Haw Lake.

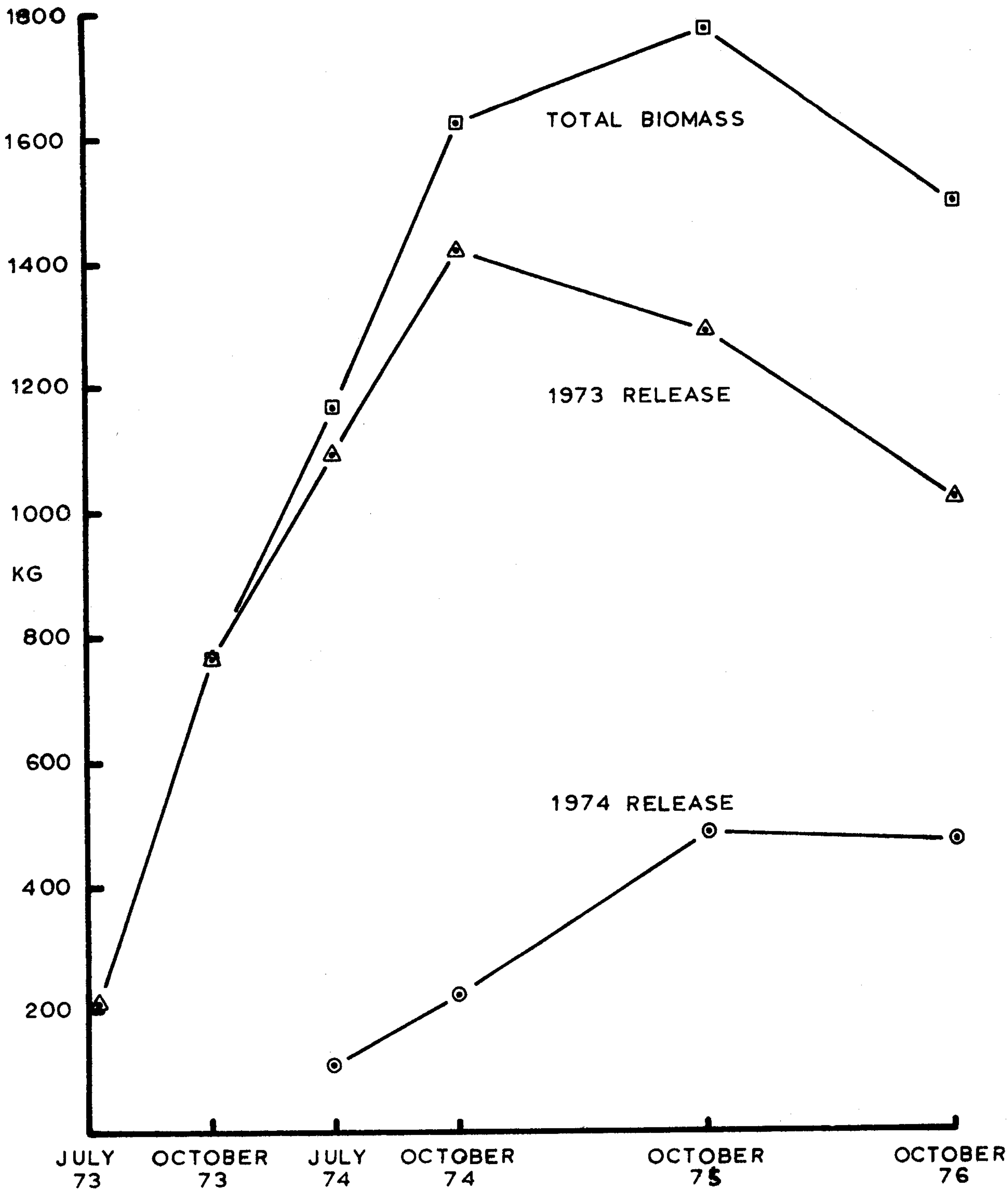

Figure 4. Biomass estimates of grass carp at Red Haw Lake from populations released in 1973 and 1974.

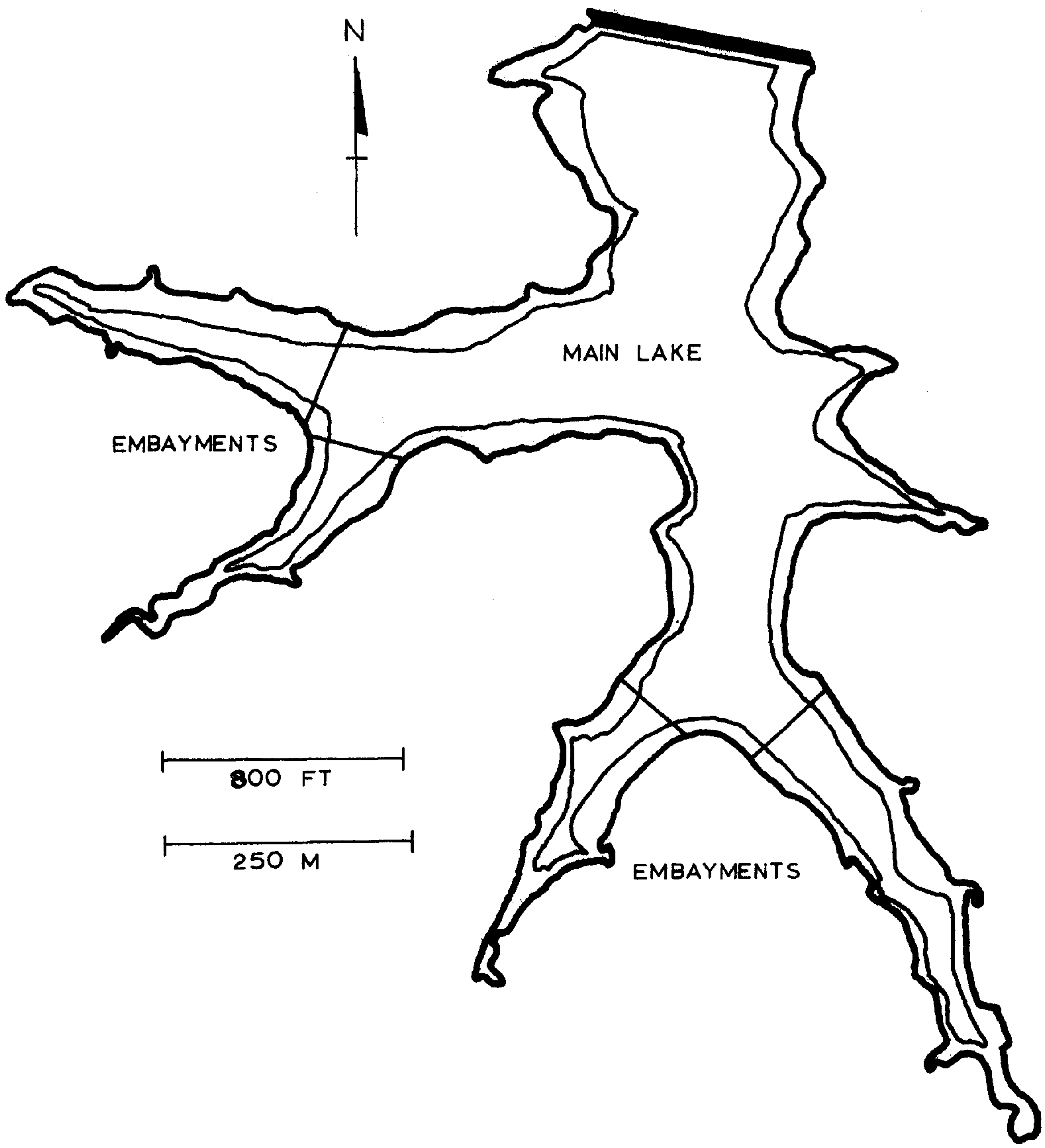

Figure 5. Hydrographic components of Red Haw Lake used to describe the distribution of contact locations for sonically tagged grass carp where deep and shallow water components were separated by the 10 ft contour.

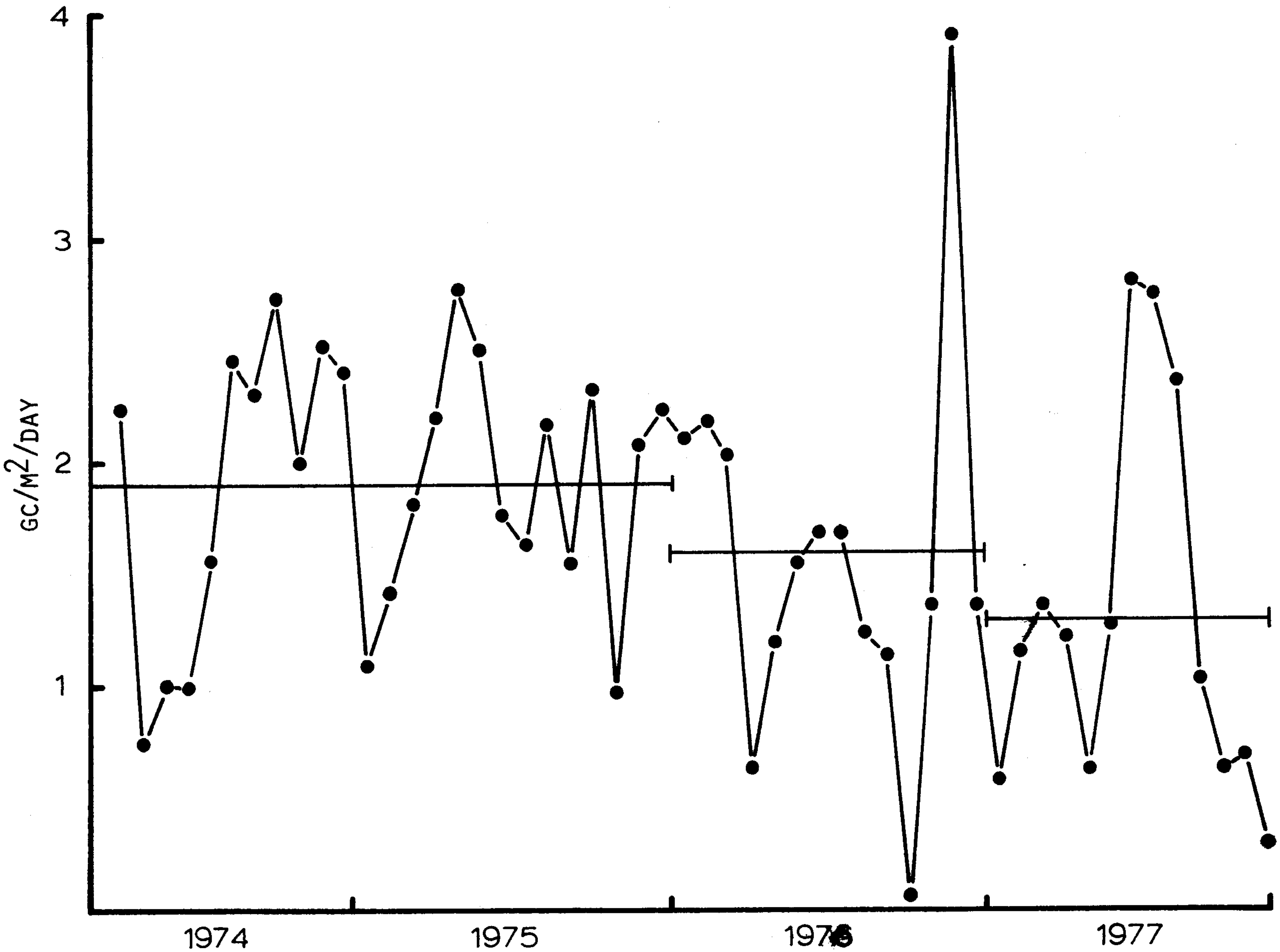

Figure 6. Primary productivity values for Red Haw Lake, 1974 - 1977.

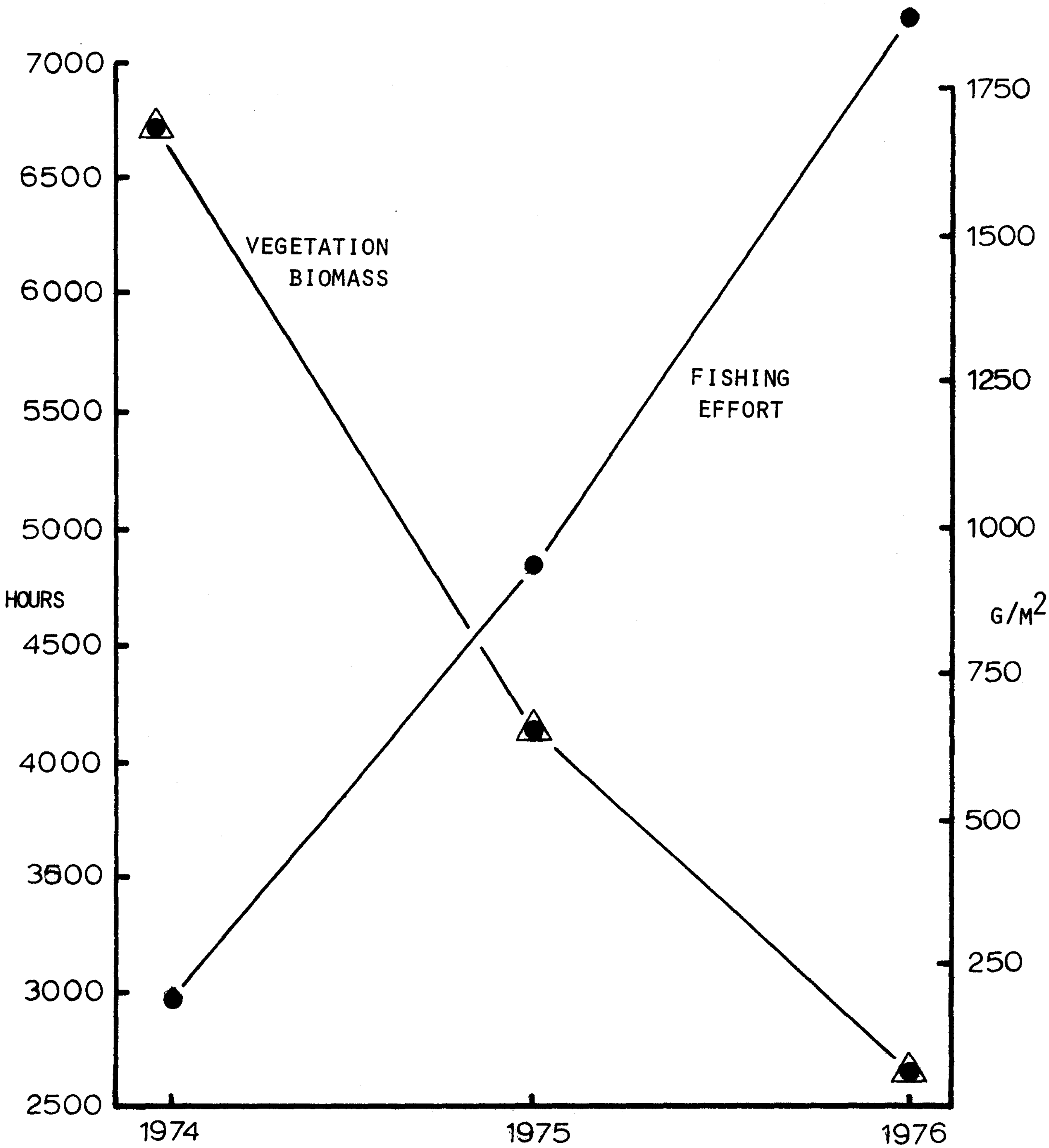

Figure 7. Vegetation biomass and fishing effort data collected from Red Haw Lake, 1974 - 1977.

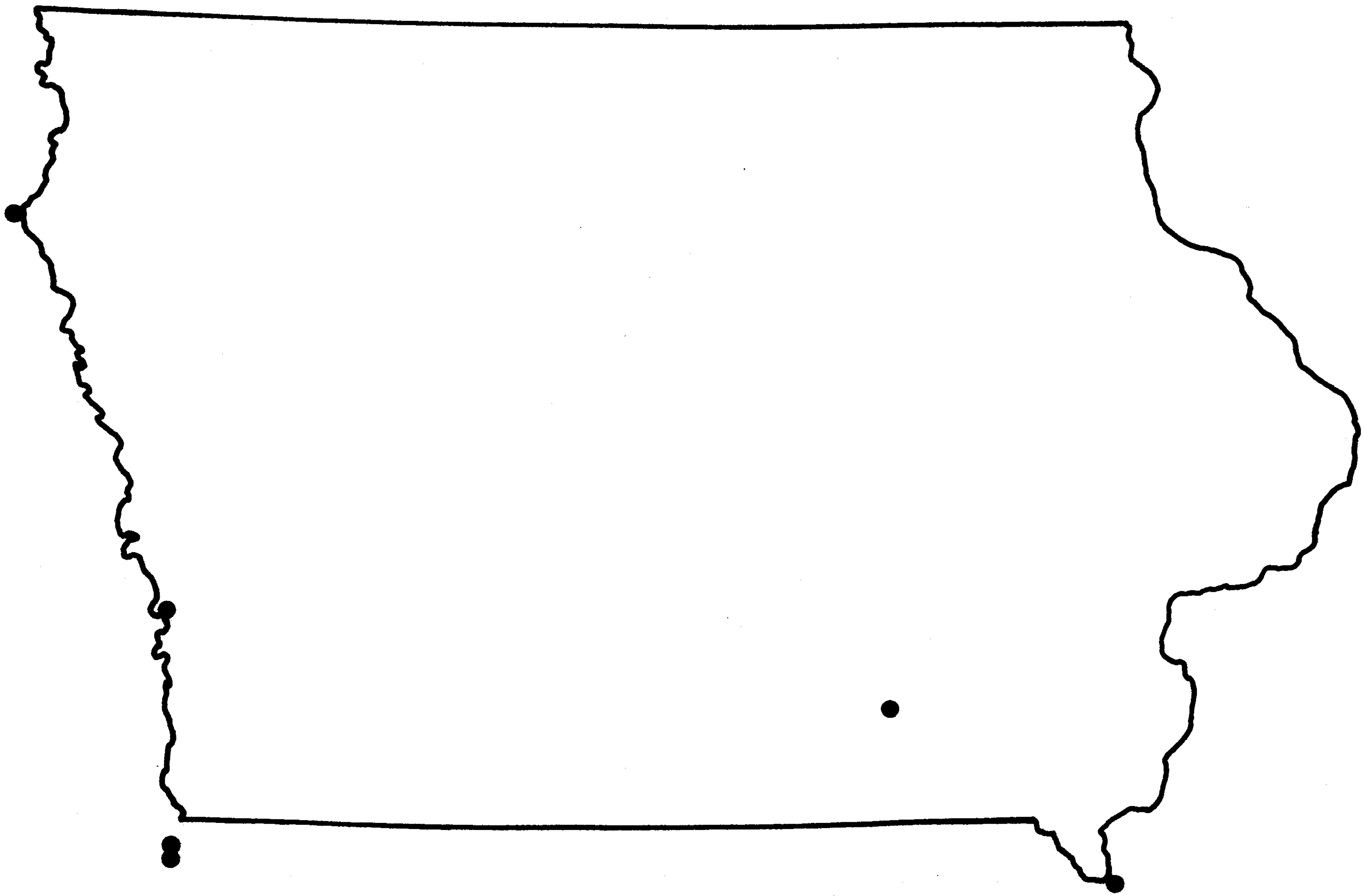

Figure 8. Distribution of grass carp in Iowa rivers.