J. Aquat. Plant Manage. 24: 46-56

Mapping Aquatic Weeds with Aerial Color Infrared Photography and Evaluating Their Control by Grass Carp[1]

R. D. MARTYN, R. L. NOBLE, P. W. BETTOLI AND R. C. MAGGIO[2]

ABSTRACT

Lake Conroe is an 8,100 ha reservoir located 75 kilometers north of Houston, Texas. Hydrilla, (*Hydrilla verticillata* Royle) was first observed in the lake in 1975, and by 1978 had become a serious pest. In 1979, a study was begun to document the increase and spread of hydrilla and other submersed aquatic weeds, and to introduce and evaluate the grass carp (*Ctenopharyngodon idella* Val.) as a biological control agent. Aerial color infrared photography was used to monitor changes in vegetation. Submersed species increased from 2,350 ha in 1979 to 3,645 ha in July 1981, prior to the first stocking. From September 1981 to September 1982, 270,000 grass carp, mostly 20.3 cm or longer, were stocked into Lake Conroe. Significant decline in area of surfaced weed mats was evident throughout the lake during the year following stocking and by October 1983, all 3,645 ha of submersed weeds were gone from the lake. Feeding patterns typical of grass carp behavior, coupled with growth, abundance, and distribution data of captured fish, indicated virtually all of the decline in vegetation was directly attributable to grass carp.

Key words: Remote sensing, biological control, white amur, aerial photography, hydrilla, Eurasian watermilfoil, coontail.

INTRODUCTION

Unchecked growth of aquatic vegetation is generally undesirable and reduces over-all value of a water impoundment. Excessive amounts of aquatic weeds directly reduce the recreational value of the water by restricting boating, fishing, and swimming activities. Additionally, weeds may indirectly affect economic value of surrounding property because of the loss of such activities.

Lake Conroe is an 8,100 ha, man-made reservoir located in Montgomery County, Texas approximately 75 kilometers north of Houston. Construction began in 1970 and the lake was filled by 1973. The primary function of

[1]Approved for publication as Texas Agricultural Experiment Sta Journal Series No. TA 20428.

[2]Associate Professor, Dept. of Plant Sciences; Professor, Dept Wildlife & Fisheries Sciences; Research Associate, Dept. of Wildlif Fisheries Sciences; and Assistant Professor, Dept. of Forestry, resj tively, all of the Texas Agricultural Experiment Station, College Stat TX 77843. Current address of second author: Departments of Zool and Forestry, North Carolina State University, Raleigh, NC.

the reservoir is to supply water for the immediate vicinity and the city of Houston. Aquatic weeds, especially hydrilla, became a major concern in Lake Conroe soon after impoundment. Hydrilla was first observed in Lake Conroe during the summer of 1975, 2 years after the lake was filled. During the next 6 years it spread rapidly throughout the lake.

Aquatic weeds often grow in areas not easily accessible by conventional boat travel and, therefore, accurate determinations of the extent and spread of such weed infestations are extremely difficult. In many instances results do not accurately estimate the biomss of weeds present.

Several techniques have been employed for estimating the extent of submersed aquatic weed infestations. These include methods such as self-contained underwater breathing apparatus (SCUBA) observations (17), recording fathometer soundings (9, 10), croppings (4), optical densities (16), low altitude photography from balloons (5) and airplanes (18), and Landsat satellite photography (8). Each of these methods has its advantages; however, none is well suited for large scale use such as in Lake Conroe.

In 1979, a study was begun in anticipation of stocking grass carp as a biocontrol agent of the submersed weeds present in Lake Conroe. The project involved preparation of baseline aquatic vegetation maps of the lake for comparison of baseline and post-treatment vegetation infestations. Data were to be obtained utilizing aerial color infrared photographic techniques.

The advantages of color infrared remote sensing over conventional means for monitoring aquatic weeds include: (1) ability to survey large areas quickly; (2) potential identification of species based on reflectance patterns; (3) accessibility to remote areas; (4) accurate delineations of plant communities; and, (5) ability to detect changes in plant communities over time with successive flights.

Several studies have evaluated remote sensing techniques for monitoring aquatic weeds (1, 2, 3, 5, 8, 18). The effectiveness and efficacy of remote sensing photography depends largely upon the film type, altitude and scale used (2, 3, 8). A previous study in Texas (2, 3,) determined that color infrared film, and an altitude of 3,700 meters and scale of 1:24,000 was the most cost-effective and informative for photo-interpretation of aquatic weeds. Similar procedures have been used in the Lake Conroe study.

The purpose of this study was to map the aquatic weeds in Lake Conroe and determine the amount of infested area. Successive surveys depicted increases or decreases in the infestations and accurately evaluated the efficacy of the grass carp control program. A series of progress reports of this project have been published (11, 12, 13, 14). This report summarizes the 5-year period beginning nearly 2 years prior to grass carp introduction in 1979 and extending through 1984.

MATERIALS AND METHODS

Aerial Survey. A total of nine photographic flights were made over Lake Conroe from 1979 to 1983, in a Cessna TU-206 aircraft at an altitude of 3,714 meters and a ground speed of 87 knots. Photographic images were recorded with a Wild RC-8 large format mapping camera with a 15 cm Aviogon lens and 500 nm filter. Kodak Infrared Aerochrome Film Type 2443 was used throughout the study. Exposure was 1.5X and allowed for optimal recording of submersed species. Photographs were made every 2,926 meters which resulted in a 60% forward overlap in each frame and provided standard stereo coverage.

Photographic analysis was done on a Richards/Bausch and Lomb photoanalytical light table. Variations in color tone, texture, context, and growth pattern were indicative of different species as confirmed by ground surveys. These variations, recorded on transparent overlays, permitted subsequent map compilation. A baseline map of the lake was compiled at a 1:24,000 scale and the areas of hydrilla, coontail (*Ceratophyllum demersum* L.) and Eurasian watermilfoil (*Myriophyllum spicatum* L.) determined planimetrically. Photographic flights were made on 6 October 1979, 11 June 1980, 3 October 1980, 21 July 1981, 20 October 1981, 7 June 1982, 20 October 1982, 20 July 1983, and 13 October 1983. Ground verification surveys were conducted on 40 to 75 sites within 2 weeks after each flight.

Because clear, deep water is a good filter of infrared light, totally submersed species are represented simply as dark shadows and are not distinguishable as to species. Additionally, depending on water clarity, plants growing at depths greater than 3 to 4 meters may not be detected at all. Consequently, during ground verification surveys, estimates of vegetation not detectable in the photographs were made by drag-line samples and recording fathometer soundings (9, 10). Transects from the edge of surfaced weed mats to open water were made at selected sample sites, and bottom samples and fathometer soundings were taken along the transect line until weeds were no longer detected. The extension of any weed mat was subsequently entered onto the mylar tracing of the actual mat dimensions detected on film. Figures reported for weed infestations include both actual areas depicted on the photographs plus any extension detected by ground surveys. Detailed aquatic vegetation maps were prepared for each October flight as described for the October 1979 flight and the area calculated for the submersed species.

Grass Carp Stocking and Sampling. In 1980, a permit was issued to the Texas Agricultural Experiment Station by the Texas Department of Parks and Wildlife to import and release grass carp into Lake Conroe. In 1981, the Lake Conroe Association purchased 270,000 grass carp and stocking rate was set at 74 fish/vegetated ha. Grass carp were stocked during September to October 1981 (167,835 fish) and June to September 1982 (103,165 fish) at 29 sites in amounts proportionate to the vegetation present in the release areas (Figure 1). Age of fish stocked ranged from I to III, with most being age I and II. Mean total length and weight of the 1981 stock were 28.9 cm and 309 g, respectively. Mean values for the 1982 stock were 24.7 cm and 179 g. Pelvic fin clips were given to 12,225 fish, which were released at two sites to monitor fish dispersal within the lake. Scale samples were collected from a subsample of grass carp when stocked each year, and from subsamples of fish subsequently collected during fish surveys in the lake. Scales were removed from the area above the lateral line and below the dorsal fin. Scale impressions were made on acetate strips using a roller press and microscopically examined. Scales of fish caught after stocking were analyzed to back-calculate lengths at time of stocking and determine year stocked. Lengths were back-calculated using the Lee method (6).

Post-stocking data on length, weight and age of the grass carp were obtained from cove rotenone (3 ppm emulsified 5% rotenone) samples taken during May 1982 and 1983. Block nets were set at the mouth of six coves and dead fish were collected for 3 days. Individual coves sampled ranged in size from 0.4 to 2.4 ha.

RESULTS AND DISCUSSION

Eighteen species of aquatic plants were identified in Lake Conroe in October 1979 (12). No attempt was made to identify the numerous emergent shore-line plant species. Because submersed species were the most serious weed problem, efforts were made to distinguish among hydrilla, Eurasian watermilfoil, and coontail on the basis of the relative infrared reflectance (color), apparent texture, context, and growth patterns. Pure stands of hydrilla and Eurasian watermilfoil could be distinguished from each other when their mats had broken the surface of the water or were very near to the surface. Surfaced hydrilla had a distinctive cinnamon-brown color return (Figure 9); the color return of Eurasian watermilfoil was a mottled pattern of gray-brown. It was not possible to distinguish with certainty among the submersed species more than 0.5 meters below the water surface. In these instances, ground verification was necessary.

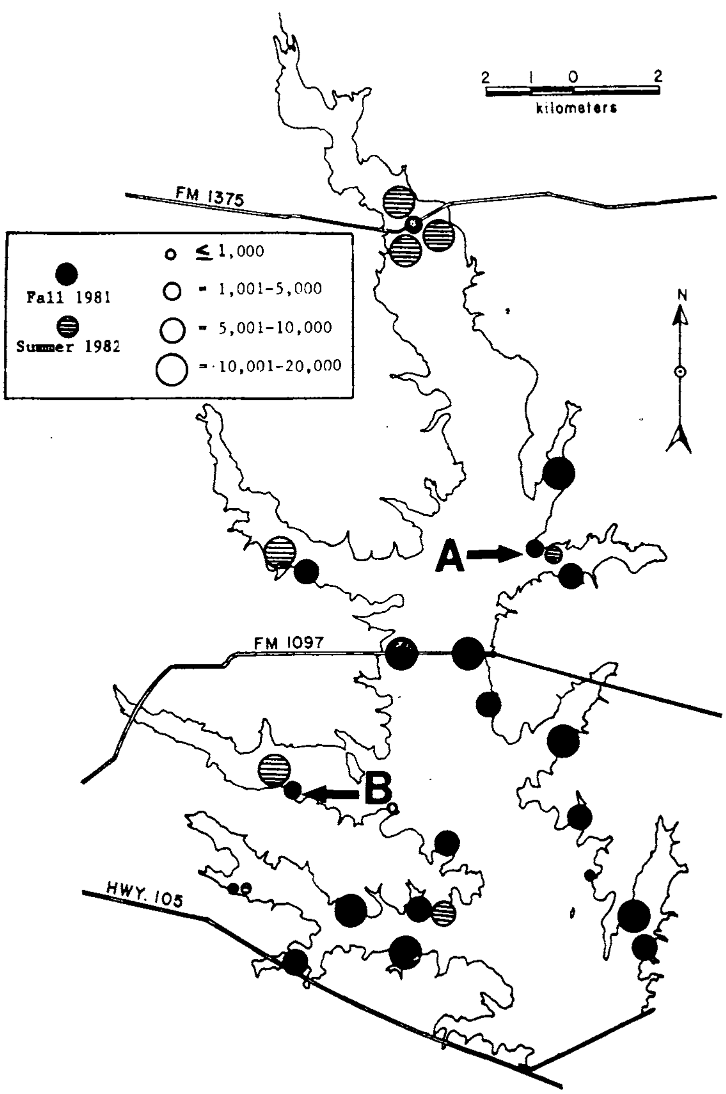

Figure 1. Grass carp stocking sites in Lake Conroe. Stocking occurred during September to October, 1981 and June to September, 1982 in amounts proportionate to the vegetation present in each area of lake. Arrows A and B indicate release sites of marked fish.

In many areas there were mixed populations of hydrilla, Eurasian watermilfoil and coontail. Generally, Eurasian watermilfoil grew most abundantly within the top meter of water, while hydrilla and coontail were most abundant beneath the Eurasian watermilfoil at a depth of 2 to 4 m. Frequently, hydrilla or coontail would grow up through the Eurasian watermilfoil and entwine with it. In these instances, it was not possible to separate the species by photointerpretations and ground verification was required. Initially, area figures for "mixed species" was reported (12); however in subsequent reports (13, 14) these were separated into their respective species based on the approximate percentages of each within the mat. In most cases, hydrilla was the dominant species in a mixed population, generally comprising approximately 40 to 50% of the biomass. Eurasian watermilfoil generally ranked second and coontail third.

In 1979, 1,540 ha of hydrilla occured as pure stands and were detected throughout the lake (Figures 2 & 7). Eurasian watermilfoil and coontail accounted for an additional 304 and 196 ha, respectively. Of the three major species studied, hydrilla represented 79% of the infestation, Eurasian watermilfoil 13% percent, and coontail 8%.

The June 1980 survey indicated an increase of 340 ha of all submersed species, bringing the total infestation of the lake to 2,694 ha or 34% of the total lake's surface area (Figure 7). This represented over a 14% increase in the number of infested hectares and a 4% increase in the total percentage of the lake infested. Hydrilla accounted for the greatest increase with 238 new hectares or almost a 13% increase from October 1979.

By October 1980, the total amount of hectares infested with submersed weeds was 3,261 (Figures 3 & 7). This was an increase of 39% in 1 year. The percent of the lake's surface area infested increased 11% from 29% in October 1979 to 41% in October 1980.

During October 1979 to October 1980, hydrilla accounted for all of the increases. The area infested by coontail did not change significantly, and the amount of Eurasian watermilfoil decreased slightly. These changes can be correlated with the extremely high temperatures and drought experienced during June to September 1980. We believe that water temperatures as high as 42 C near the surface coupled with a decrease of over 1 m in water elevation (Barrett, personal communication, San Jacinto River Authority) placed serious stress on the Eurasian watermilfoil and allowed for greater hydrilla expansion. These decreases in Eurasian watermilfoil were most noticeable in the shallow areas, which were predominantly mixed beds.

Changes in hydrilla, Eurasian watermilfoil, and coontail again occurred in Lake Conroe from 1980 to 1981

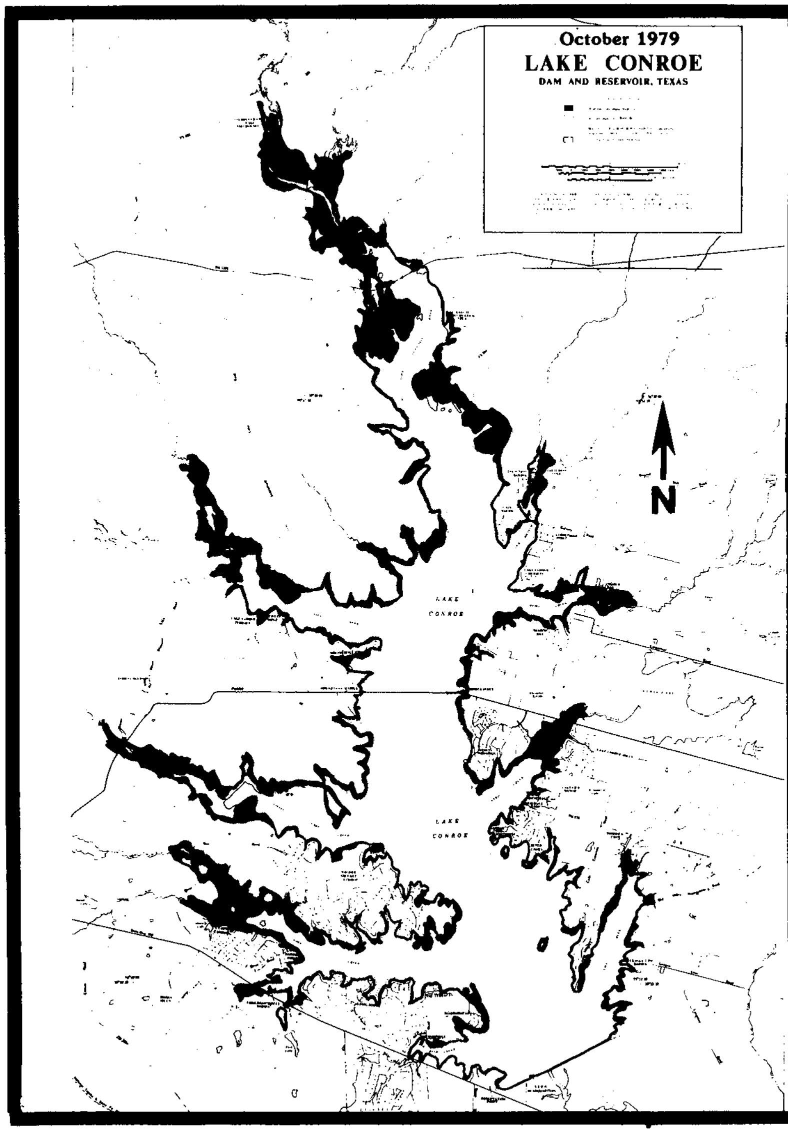

Figure 2. 1979 base-line aquatic vegetation map of Lake Conroe. Vegetation delineations based on color infrared remote sensing survey conducted on 6 October 1979 and ground verification survey on 1 November 1979. Black areas denote infestation of submersed aquatic weeds. Total area of weed infestation represented is 2,353 ha or 29% of the lake's surface area.

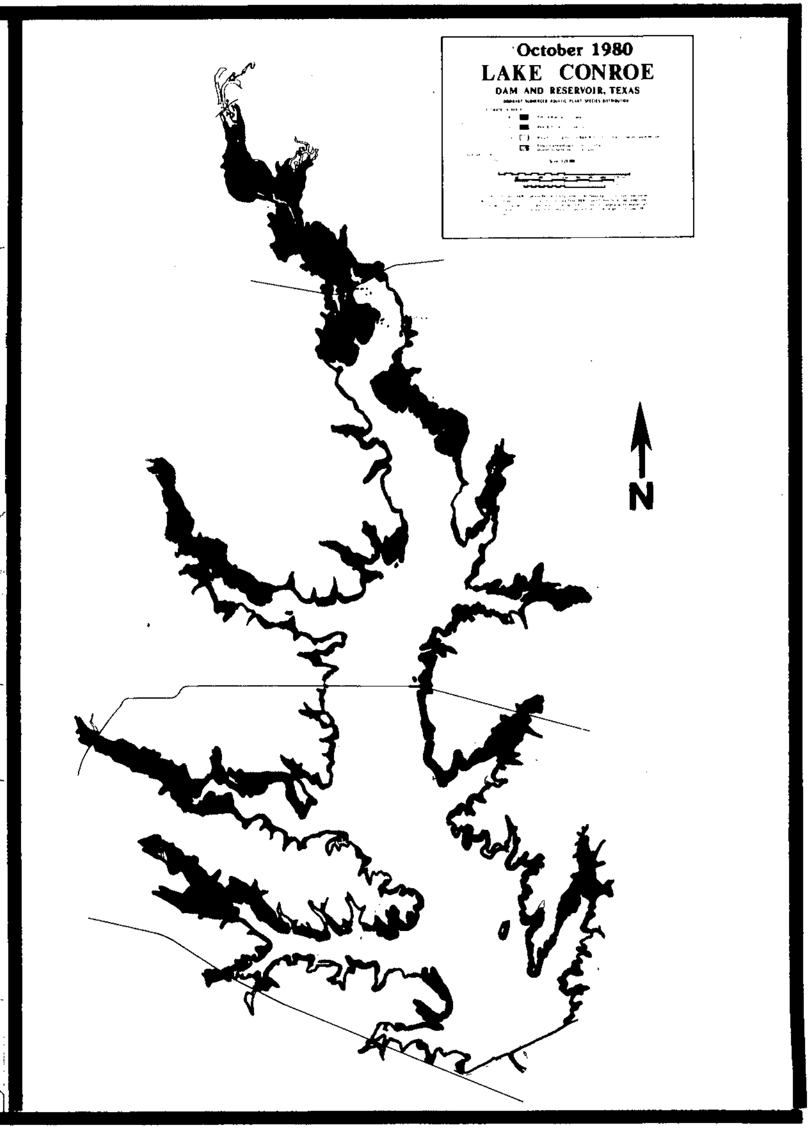

Figure 3. 1980 aquatic vegetation map of Lake Conore. Based on color infrared remote sensing survey conducted on 3 October 1980 and ground verification survey on 13 October 1980. Total area of weed infestation represented is 3,261 ha or 41% of the lake's surface area.

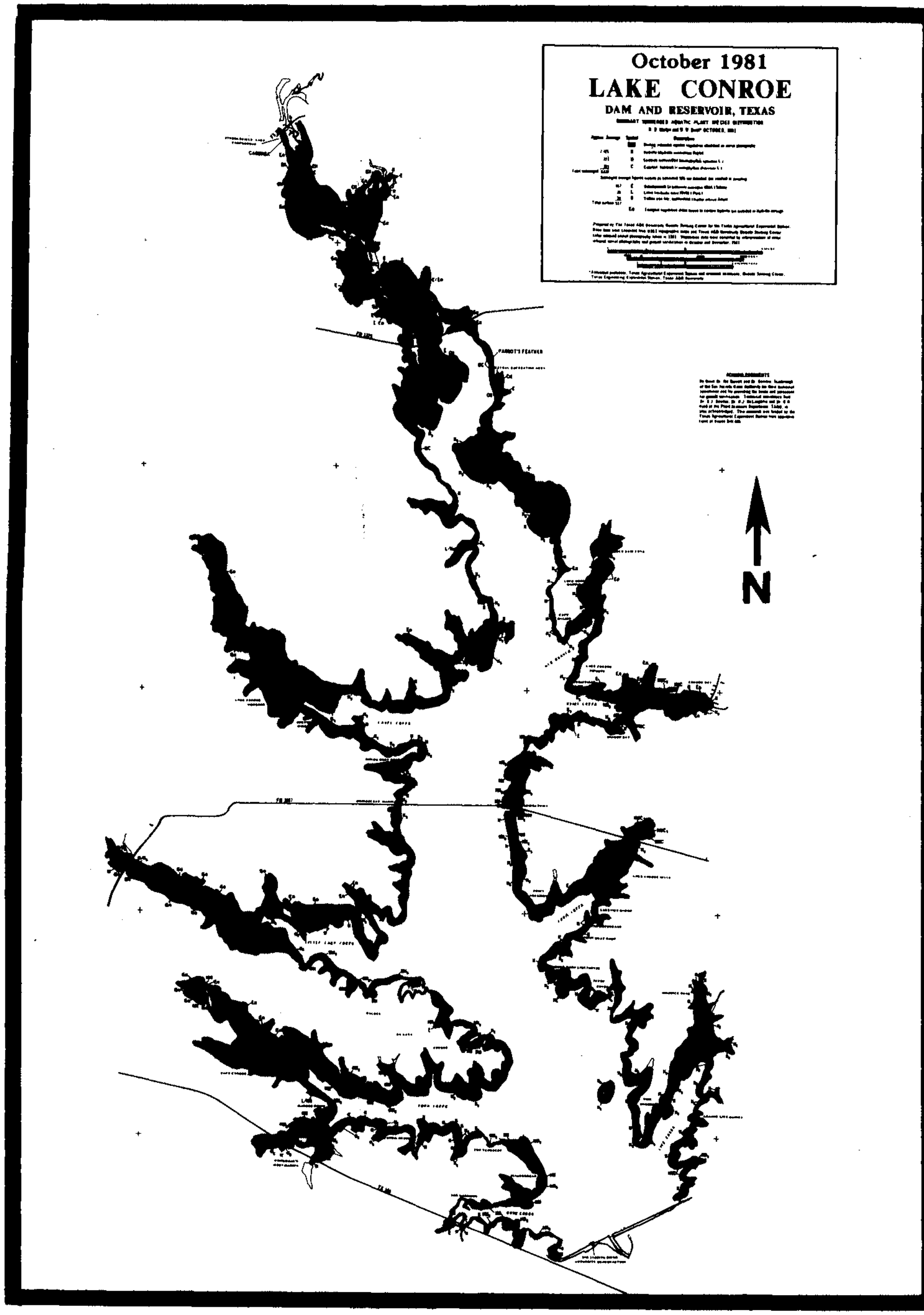

Figure 4. 1981 aquatic vegetation map of Lake Conroe. Based on color infrared remote sensing survey conducted on 20 October 1981 and ground verification survey on 2 November 1981. Total area of weed infestation represented is 3,497 ha or 44% of the lake's area.

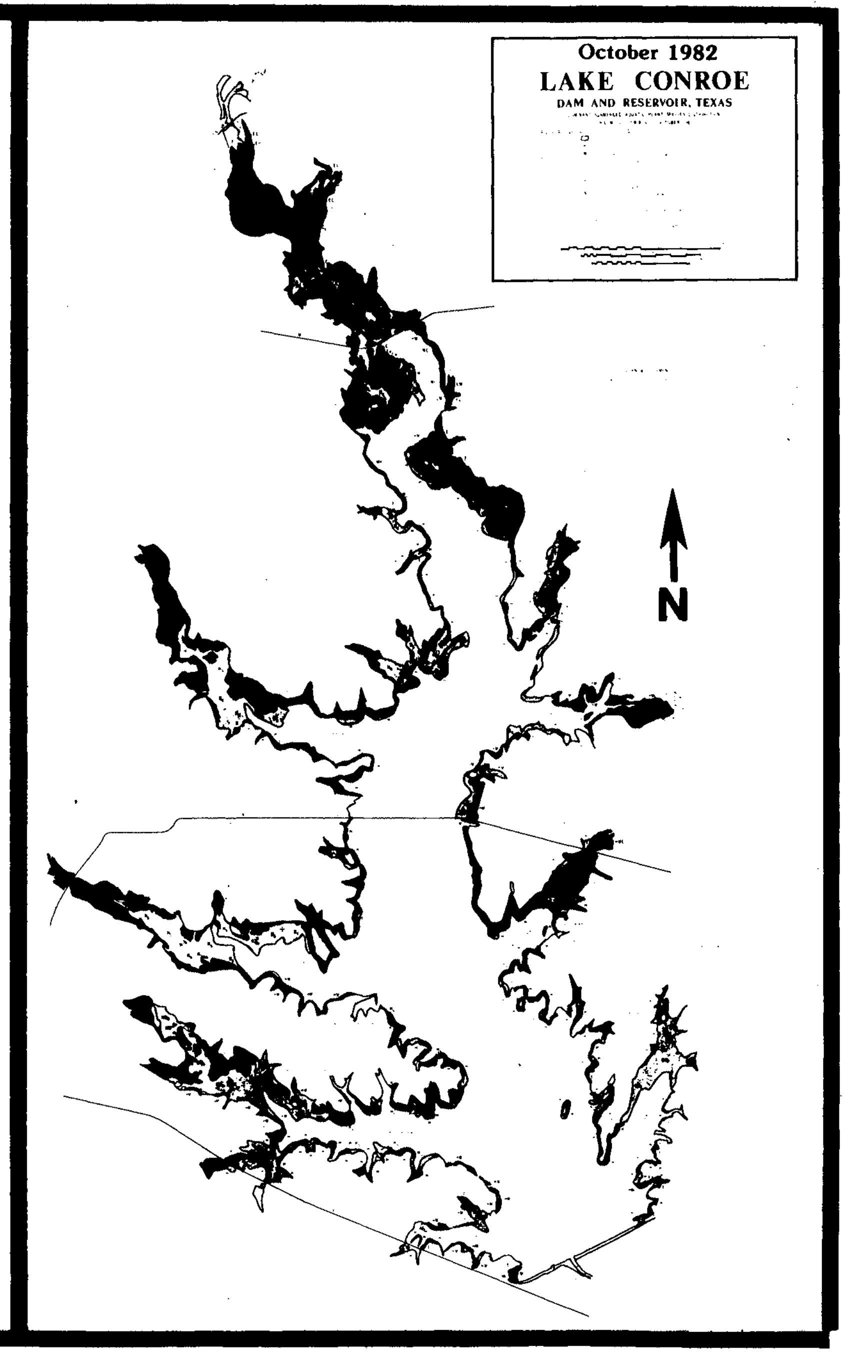

Figure 5. 1982 aquatic vegetation map of Lake Conroe. Based on color infrared remote sensing survey conducted on 20 October 1982 and ground verification survey on 11 November 1982. Total area of weed infestation represented is 3,131 ha or 39% of the lake's surface area. Black areas denote surfaced vegetation. Light gray areas represent the "holes""where grass carp have grazed. See text for explanation. Area represented by these holes is 891 ha.

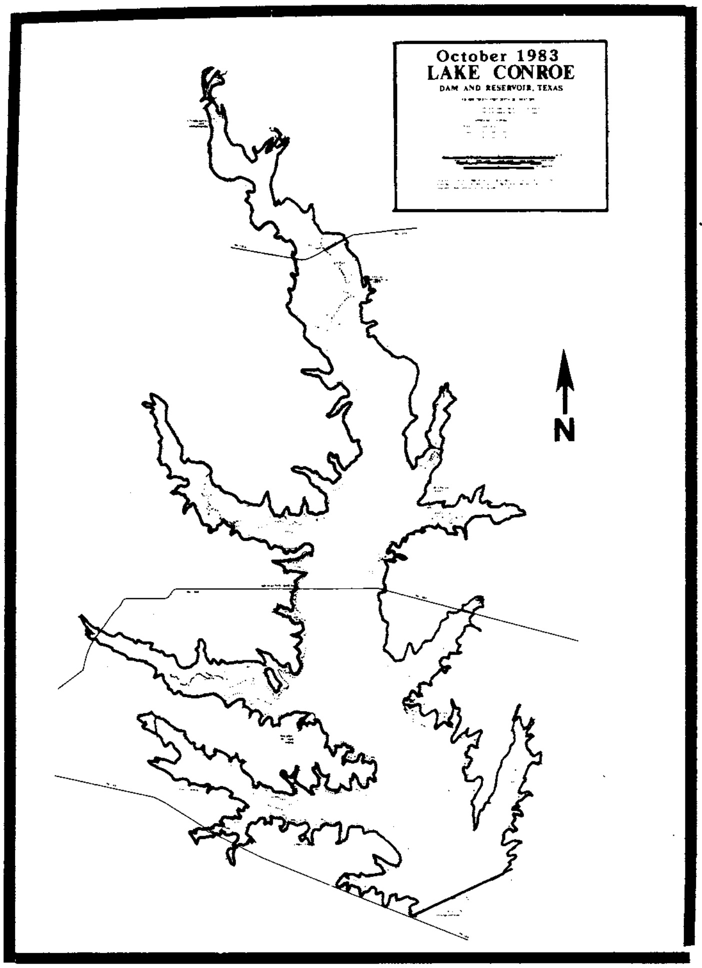

Figure 6. 1983 aquatic vegetation map of Lake Conroe. Based on color infrared remote sensing survey conducted on 13 October 1983 and ground verification surveys on 3 November 1983. No submersed weeds were detected by any of the methods employed.

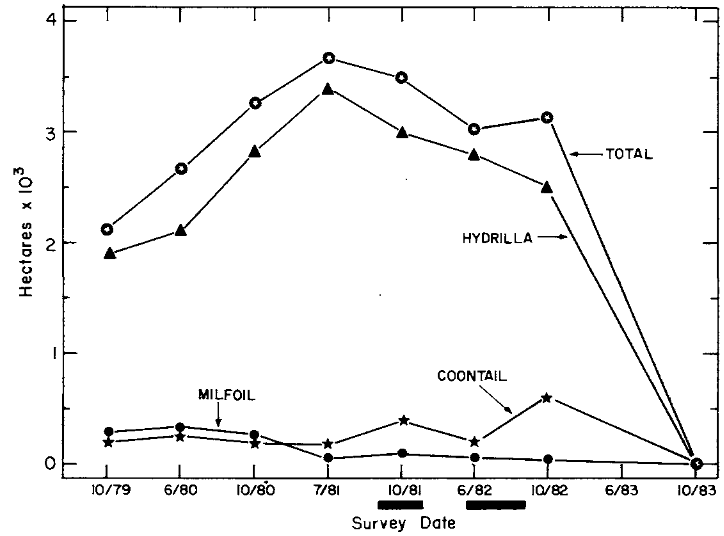

Figure 7. Change in areas of submersed aquatic weeds in Lake Conroe from October 1979 to October 1983. Total curve is the sum of the other three. Bars indicate periods during which grass carp were released into the lake.

although somewhat less than from the previous year (Figure 4). The increase in all three species was 236 ha, bringing the total hectares of submersed aquatic weeds in Lake Conroe to 3,497 ha by October 1981 (Figure 7). In July 1981, the infestation reached a maximum of 3,647 ha. In October 1981, submersed weeds occupied 44% of Lake Conroe, up almost 4% from October 1980. Hydrilla accounted for 86 percent of the total weed infestation. At their peak abundance, submersed weeds occupied virtually all of the lake less than 7 meters in depth. Maximum depth at which hydrilla was found growing was 8 meters.

During the fall 1981 and summer 1982, 270,000 grass carp were released into Lake Conroe. Feeding activity by the grass carp was observed almost immediately after stocking. Large schools were seen grazing hydrilla beds throughout the lake and by October 1982, declines in vegetation were detectable in the aerial photographs (Figure 8). Surface mats of hydrilla were conspicuously reduced in the middle resulting in an atoll effect characterized by a ring of surfaced weeds surrounding open water. This pattern was typical and consistent throughout the lake. This pattern resulted from the relationship of grass carp feeding behavior and the growth habitat of hydrilla. Although hydrilla may grow as free-floating fragments, it generally roots on the bottom and grows toward the surface. In deep water, hydrilla produces sparse strands with long internode spaces; however, as the quality and quantity of light improves near the surface, the strands begin to branch and internode lengths shorten, forming a dense, entwined mat on the surface. This is also where the newest, most tender vegetation occurs. Consequently, grass carp feeding was concentrated in these areas. As the fish grazed the mats, they ate out depressions in the middle resulting in "holes". These holes are depicted on the 1982 vegetation map as lightly shaded areas and occurred uniformly throughout the lake (Figure 5). The total area represented by these holes was 891 ha. Based on reported weight figures for hydrilla (9), the calculated net biomass reduction by the fish in these areas was 37,000 tons fresh weight. Modelling of grass carp energetics indicated that nearly twice that biomass of vegetation was consumed, part of which was probably new production (Nobel, unpublished data).

From July 1981 through October 1982, the total area infested with coontail increased 3-fold (Figure 7). The first increase, from July 1981 to October 1981, can be attributed to reduced areas of Eurasian watermilfoil, which occurred earlier thereby providing less competition for the coontail. The second increase, from June 1982 to October 1982, was attributed to the reduction in hydrilla due to preferential grass carp feeding thus allowing the coontail to grow faster. Ultimately, the coontail was also eliminated by the grass carp.

Grass carp continued feeding aggressively throughout 1982 and 1983. By October 1983, just 2 years from the initial stocking, all the hydrilla, Eurasian watermilfoil and coontail biomass had been eliminated (Figure 7). The 1983 vegetation map is blank (Figure 6). None of these species was detected by aerial photography, fathometer soundings or drag-line samples.

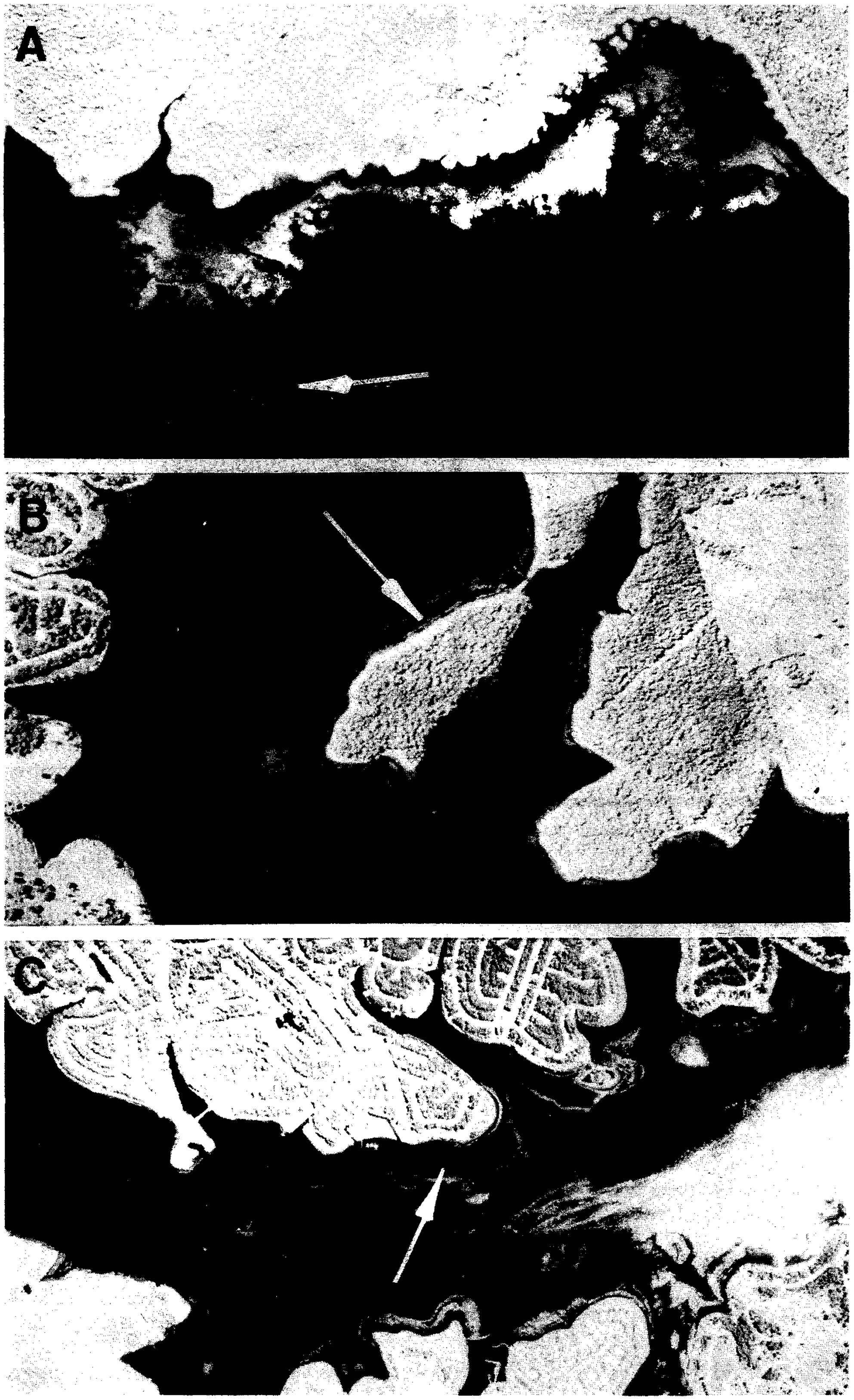

Figure 8 (A-C). Aerial color infrared photographs (reproduced in black and white) of three different areas of lake Conroe depicting the "atoll effect" created by grass carp feeding (arrows). All three photographs were taken on 20 October 1982.

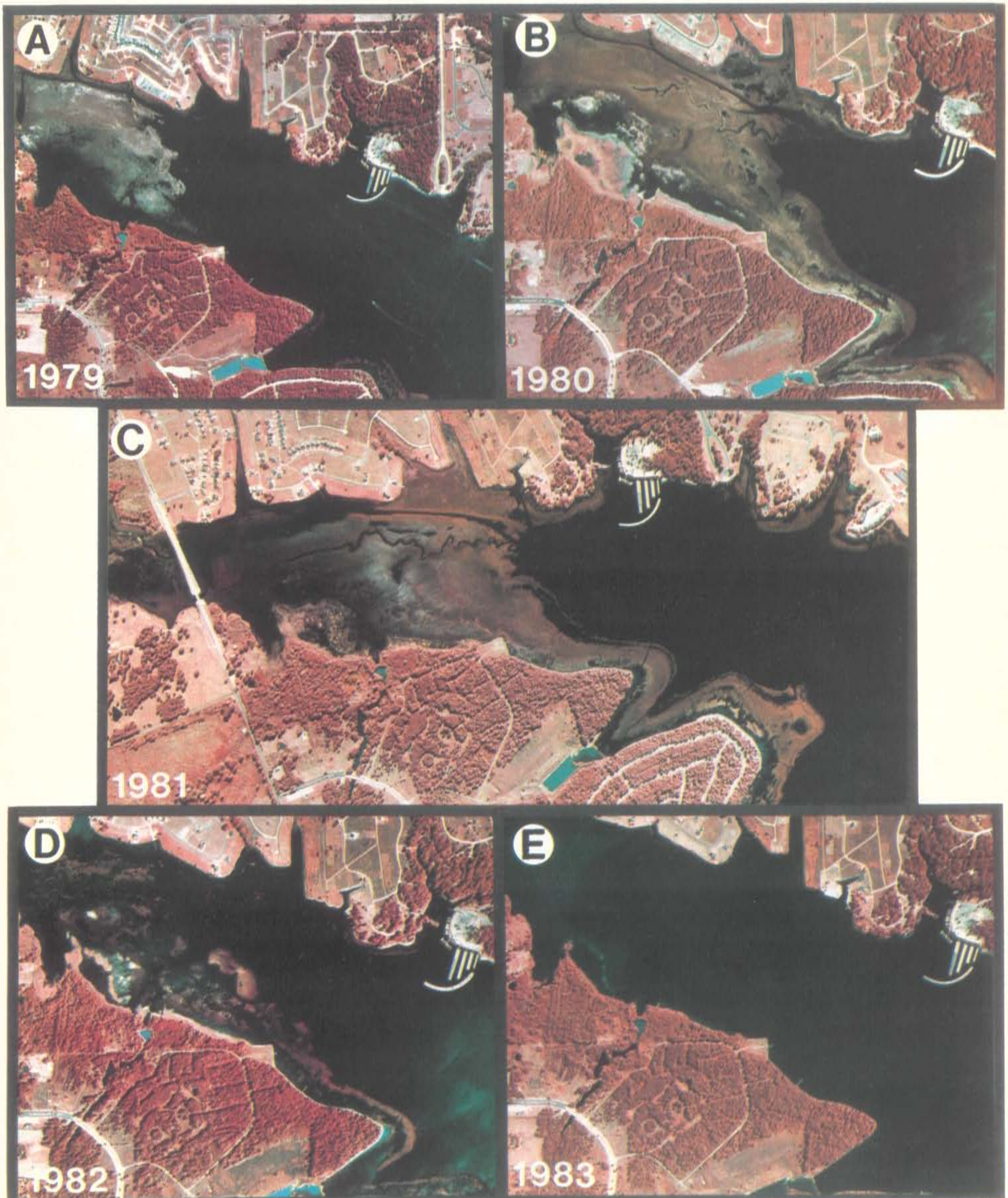

Figure 9 (A-E). Color infrared photographs of an area in Lake Conroe depicting the increase in hydrilla from 1979 to 1981 and subsequent decline from 1981 to 1983 after stocking of grass carp. Hydrilla shows as a cinammon-brown color return, whereas Eurasian watermilfoil is a mottled gray-brown. Surrounding land vegetation (primarily pines and hardwoods) shows as a deep pink color return. A) 6 October 1979; B) 3 October 1980; C) 20 October 1981; D) 20 October 1982; E) 13 October 1983.

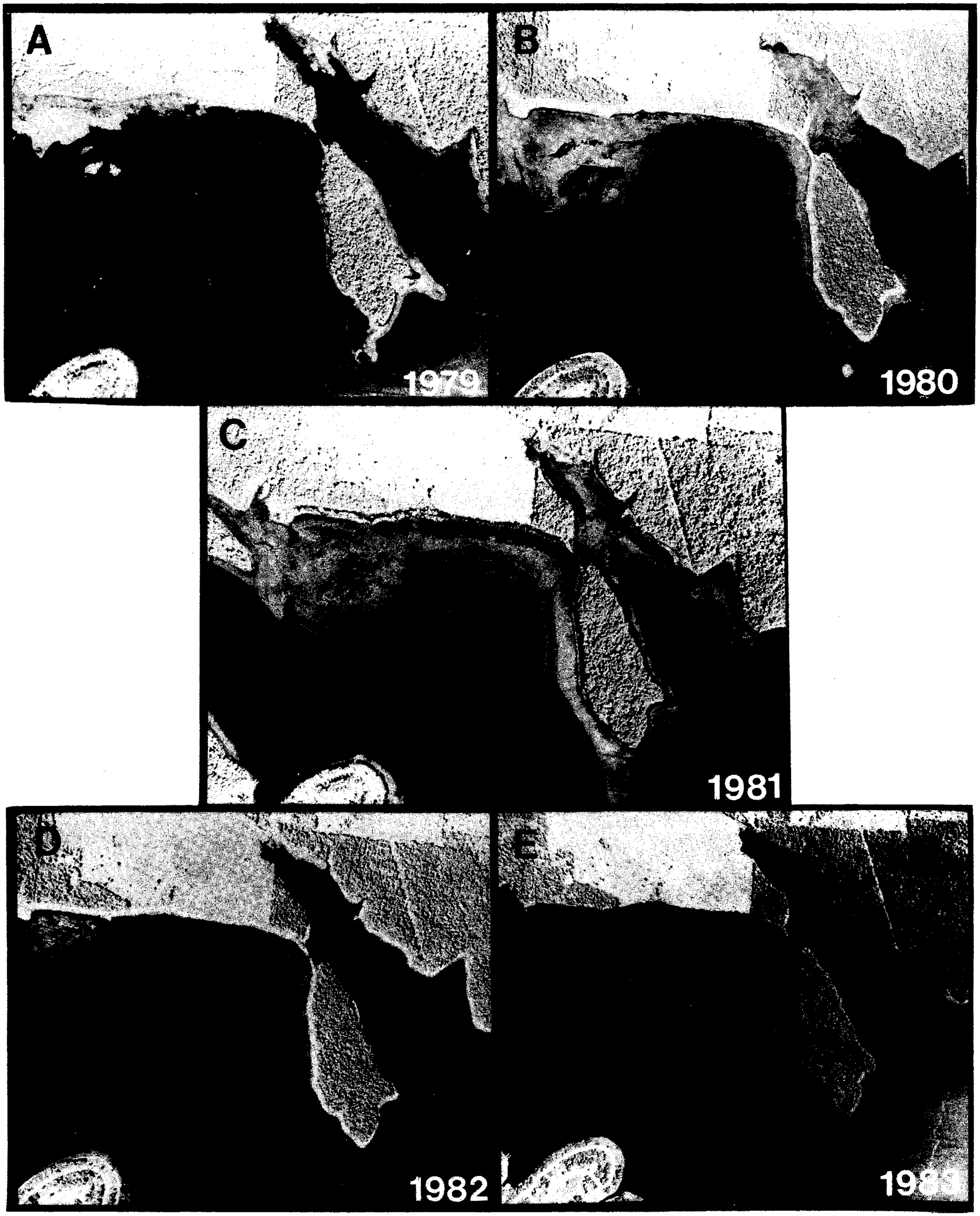

Figure 10 (A-E). Color infrared photographs (reproduced in black and white) of an area of Lake Conroe depicting the increase in aquatic weeds from 1979 to 1981 and subsequent decline from 1981 to 1983 after stocking of grass carp. With black and white reproduction, speciation of weeds is not possible; however, delineations of the weeds are readily visable. A) 6 October 1979; B) 3 October 1980; C) 20 October 1981; D) 20 October 1982; E) 13 October 1983.

The increase in weed infestation in Lake Conroe from 1979 through 1981 and subsequent decrease after the introduction of the grass carp can be seen in Figures 9 and 10. Each figure plate consists of a series of five photographs one taken in October of each year from 1979 to 1983. Figure 9 is reproduced in color to show the reflectance patterns typical of color infrared film. The hydrilla shows as a rich, cinnamon-brown color return. The surrounding land vegetation, primarily pine and deciduous hardwoods, gives a pink color return. Figure 10 is a black and white reproduction of a color plate. In this case, hydrilla cannot be distinguished from other submersed species such as Eurasian watermilfoil; however, infestation patterns are equally discernable.

Growth of 1981-stocked grass carp through May 1982 was rapid. Mean total length increased from 289 mm when stocked during fall 1981 to 457 mm in May 1982. During this same interval, average weight of the fish increased 309 g to 1510 g.

Comparison of number of fish stocked per vegetated hectare in fall 1981 with number collected in the May 1982 cove samples indicated high overwinter survival for the 1981 stock. Analysis of back-calculated lengths at stocking for the fish captured in the 1982 rotenone survey revealed no differential mortality between the small and larger sizes of fish stocked.

The length-frequency distribution of grass carp collected in May 1983, showed broad overlap between fish stocked in 1981 and 1982 (Figure 11). Fish stocked during 1982 with a mean length of 247 mm grew to 520 mm mean length by May 1983. Mean weight of these fish increased by over 1900 g during this time. This growth exceeded growth during the fall 1981 to spring 1982 interval, but the time span was 2 months longer for these fish. The presence of enough small fish (< 450 mm) to skew the length-frequency distribution suggested that by May 1983, food resources had become scarce enough to limit growth, reflected particularly by those grass carp stocked last in late 1982. Conversely, those fish stocked early in 1982 grew very fast and contributed to the observed overlap in length distributions. Fish stocked in 1981 continued to grow rapidly during 1982. Mean length and weight increased to 705 mm and 5.62 kg by May 1983.

Between 1 September 1981 and 1 September 1983, 19 fin-clipped grass carp were recaptured. Fourteen of these fish were collected within 1.6 km of the nearest release site. The minimum distance travelled by the remaining marked fish ranged from 7.2 to 9.1 km. The collection of grass carp in cove rotenone samples away from the immediate release areas, coupled with the recapture locations of marked fish, were considered indicative of adequate distribution of the stocked fish throughout the lake. The distribution of grass carp did not appear to be uniform, however, as the catch of grass carp in individual cove samples indicated a schooling tendency. The number of grass carp captured in the six coves ranged from 7 to 813 per hectare in 1982 and 0 to 200 in 1983. In 1983, no grass carp were collected in coves totally devoid of vegetation, while most were collected from the two coves with the most vegetation still present. Further evidence of schooling behavior is indicated in the catch of grass carp in gillnets set at eight fixed stations. Between September 1981 and September 1983, 27 grass carp were collected in gillnets, of which 17 were collected in a single overnight set at one station.

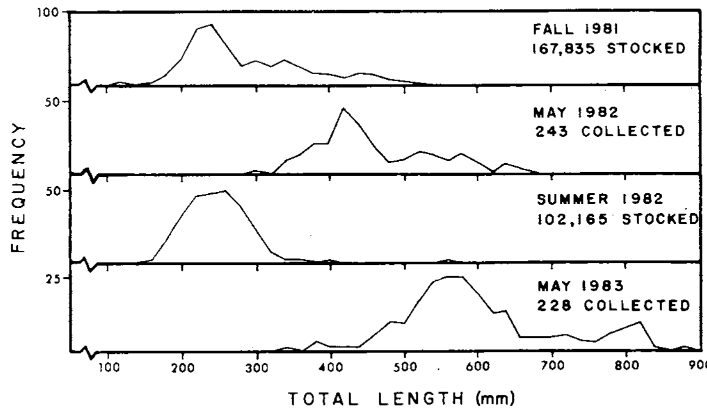

Figure 11. Length frequencies of grass carp released into Lake Conroe based on subsamples of fish at time of stocking and all grass carp collected by cove rotenone samples in May 1982 and May 1983.

The results of this study have demonstrated the grass carp to be an aggressive herbivore and highly effective as a biocontrol agent of submersed aquatic weeds. Similar results were obtained by Van Dyke et al. (7,19) and Miller and King (15) in several small lakes in Florida. Testimonial to this has been presented in the form of vegetation maps and time-sequence photographs depicting actual infestations.

This study has also shown aerial color infrared photography, when accompanied by limited ground verification, to be an effective and efficient method of monitoring and documenting changes in aquatic weed populations. Although reproduced in this publication in small size, the original vegetation maps prepared are of sufficient size (74 cm x 114 cm) to detect small changes in weed infestations. Likewise, the original maps contain data on other weed species which have not been included in thgis report. Since the weeds are now absent from Lake Conroe, the maps represent a permanent history of the weed infestations and could serve additional purposes in the study of plant successions.

The Lake Conroe project is, to date, the largest single grass carp vegetation control study. In 1981, almost 50% of the lake was infested with aquatic weeds. Recreational use of the lake had been seriously curtailed and real estate values were depressed. In just 2 years after the introduction of grass carp, the lake was free of pestiferous aquatic plants. Although no aerial photographic survey was conducted during 1984, ground-based visual surveys, as well as drag-line samples indicated Lake Conroe remained weed-free. It is not known how long the lake will remain clean. Hydrilla has remained absent for 6 years in a central Florida lake after it was initially eradicated by the grass carp (7, 19). It is, however, likely that hydrilla, as well as several other weed species, will be reintroduced into Lake Conroe due to the high boat traffic and migratory waterfowl activity on the lake.

ACKNOWLEDGEMENTS

The following persons have also been directly involved with this project and their technical assistance is gratefully acknowledged: Mr. Robert Betsill, Department of Wildlife and Fisheries Sciences, Texas Agricultural Experiment Station, Mr. W. W. Snell, Remote Sensing Center, Texas Engineering Experiment Station, and Mr. Ike Barret and Mr. Remmie Scarbrough of the San Jacinto River Authority, Conroe, Texas. This research was supported, in part, by the Texas Agricultural Experiment Station from appropriations of House Bill #556.

LITERATURE CITED

1. Benton, A. R., Jr., C. A. Clark, and W. W. Snell. 1980. Monitoring aquatic plants in reservoirs. Trans. Engrg. J. 106:453-470.
2. Benton, A. R., Jr., and R. M. Newman. 1976. Color aerial photography for aquatic plant monitoring. J. Aquat. Plant Manage. 14:14-16.
3. Dardeau, E. A., Jr., 1983. Aerial survey techniques to map and monitor aquatic plant populations—Four case studies. Tech. Rept. A-83-1. USAE-WES. Vicksburg, MS. 49 pp.
4. Edwards, R. W. and M. Owens. 1960. The effects of plants on river conditions. I. Summer crops and estimates of net productivity of macrophytes in a chalk stream. J. Ecol. 48:151-160.
5. Edwards, R. W., and M. W. Brown. 1960. An aerial photographic method for studying the distribution of aquatic macrophytes in shallow waters. J. Ecol. 48:161-163.
6. Lagler, K. C. 1956. Freshwater Fishery Biology. 2nd ed. W. C. Brown Co. Dubuque, IA. 421 pp.
7. Leslie, A. J., L. E. Nall, and J. M. VanDyke. 1983. Effects of vegetation control by grass carp on selected water-quality variables in four Florida lakes. Trans. Am. Fish. Soc. 112:777-787.
8. Long, K. S. 1979. Remote sensing of aquatic plants. Tech. Rept. A-79-2. USAE-WES. Vicksburg, MS. 82 pp and appendices.
9. Maceina, M. J., and J. V. Shireman. 1980. Recording fathometer techniques for determining distribution and biomass of *Hydrilla verticillata* Royle. Misc. Paper A-80-5. USAE-WES. Vicksburg, MS. 46 pp and appendices.
10. Maceina, M. J., J. V. Shireman, K. A. Langeland, and D. E. Canfield, Jr. 1984. Prediction of submersed plant biomass by use of a recording fathometer. J. Aquat. Plant Manage. 22:25-34.
11. Martyn, R. D. 1985. Color infrared photography for determining the efficacy of grass carp in aquatic weed control. Proc. South. Weed Sci. Soc. 38:381-390.
12. Martyn, R. D., and W. W. Snell. 1982. Lake Conroe aquatic vegetation survey. 1. Aerial color infrared photography—base-line map, 1979. Tex. Agric. Exp. Stn. MP-1502. College Station, TX 77843. 9 pp.
13. Martyn, R. D., and W. W. Snell. 1982. Lake Conroe aquatic vegetation survey. II. Aerial color infrared photography—1980 map. Tex. Agric. Exp. Stn. MP-1503. College Station, TX 77843 6 pp.
14. Martyn, R. D., and W. W. Snell. 1982. Lake Conroe aquatic vegetation survey. III. 1981 map and two-year summary (1979-1981). Tex. Agric. Exp. Stn. MP-1519. College Station, TX 77843. 7 pp.
15. Miller, A. C., and R. H. King. 1984. Large-scale operations managment test of use of the white amur for control of problem aquatic plants: Report #5. Tech. Rept. A-78-2. USAE-WES, Vicksburg MS. 77 pp and appendices.
16. Owens, M., M. A. Learner, and P. J. Maris. 1967. Determination of the biomass of aquatic plants using an optical method. J. Ecol. 55:671-676.
17. Sheldon, R. B. and C. W. Boylen. 1978. An underwater survey method for estimating submerged macrophyte populations density and biomass. Aquat. Bot. 4:65-72.
18. Shima, L. J., R. R. Anderson, and V. P. Carter. 1976. The use of aerial color infrared photography in mapping the vegetation of a freshwater marsh. Chesapeake Sci. 17:74-85.
19. VanDyke, J. M., A. J. Leslie, Jr., and L. E. Nall. 1984. The effects of the grass carp on the aquatic macrophytes of four Florida lakes. J. Aquat. Plant Manage. 22:87-95.