Investigation of a Shoreline Enhancement Technique for Wetlands Impact Mitigation

FRED K. PARRISH

An attempt was made to mitigate the impact of highway construction on a wetland (beaver pond) margin by enhancing the shoreline of the roadfill. One hundred 20-ft-long fingerlike extensions 10 ft wide were constructed 10 ft apart along the roadfill. The extensions increased the pond-roadfill margin by a factor of three. Willows were planted on the southeastern edge of the fingers. Despite repeated draining of the pond by county surveyors and two successive drought years, the procedure appeared successful. Transects were compared in three areas: an improved section with fingers; an unimproved section of roadfill; and a "control" across the pond from the roadfill. Sampling of the pond margin communities over a 3-year period revealed up to 89 percent the number of benthic invertebrates in the improved area as in the control and only 44 percent of the benthos in the unimproved area as in the control area. Trees occurred on the fingers at a rate 2.3 times greater per unit of shoreline than in the unimproved area, and over half were volunteers. Fish used the improved area about four times as much as the unimproved area. A community comparison index showed the shoreline tree community in the improved area to have about six times the habitat value of the unimproved area. Recommended modifications of the shoreline include making the fingers longer and wider and the sloughs wider and deeper, and providing erosion control and less slope to prevent excessive sedimentation.

The economic importance of wetlands is now generally known and appreciated (*1*). In the construction of the West Austell Bypass (the C.H. James Parkway) located in southwest Cobb County, Georgia, it was necessary to pass through the northeast side of the Powder Springs Creek floodplain (Figure 1), which was inundated as a result of beaver dam construction. Because of roadway fill placement in this wetland habitat, wetland mitigation was provided in accordance with U.S. Army Corps of Engineers' Section 404 regulations and Executive Order 11990, which require the "consideration" of wetland mitigation when such lands are affected by federal-aid highway projects.

Enhancement of the highway fill shoreline was considered an innovative approach to ameliorating the impact on this wetland. Al Tate, at the time in the Georgia Department of Transportation (GDOT) Environmental Section, suggested the procedure. The enhancement technique consisted of incorporating a series of 20-ft-long fingerlike serrations, 10 ft wide, spaced about 10 ft apart, projecting into the wetland. The object was to increase the shoreline area, a border between two ecological systems (an ecotone), that is important as wildlife habitat, and as a source of nutrients (*2–4*).

The objective of this study was to determine whether the shoreline enhancement technique was an effective way of enhancing fish and wildlife habitats and increasing diversity over the habitat values that normally result from a standard fill slope. Additional benefits would be to refine the design of shoreline enhancement methods to (a) reduce construction costs, (b) increase habitat and wildlife productivity benefits, and (c) reduce impacts on the existing wetland.

After completion of construction, the author was asked to evaluate the results. Evaluation of the technique was to be part of the mitigation at this particular site.

METHODOLOGY

Site Description

The wetland chosen for this study was a beaver pond lying along Powder Springs Creek in the southern part of Cobb County, Georgia (Figures 2 and 3). The pond was separated from the creek by a low island, approximately 25 to 100 ft wide, which extended upstream about 2,200 ft (Figure 4). The island was covered with a mature stand of bottomland trees (red maple, *Acer rubrum*, predominated), shrubs, and vines. Privet (*Ligustrum* sp.) was abundant and provided food for the beavers.

The small stream draining the area cut across a bend in Powder Springs Creek. Its size varied from only 2 ft across and about 6 in. deep in places (as in October 1987) to the full extent of 25 acres. It was dammed by beavers in a channel 3 ft deep, about 25 ft from Powder Springs Creek. As the water level in the impoundment rose, the beavers heightened the dam to the top of the stream channel, then built extensions out along the island. Where water overflowed the island upstream, the beavers built ancillary dams.

The pond varied from about 400 to 500 ft wide, covering 25 acres when the beaver dam was at its highest and after rainfall. The maximum depth was about 8 ft. Because of the number and condition of dead trees that were observed standing in the water, the pond was estimated to be about 20 years old. Figure 1 is an aerial view of the pond and fingers taken in 1985 immediately after construction of the roadbed and mitigation fill fingers. Figures 2 and 3 are views of the pond from the roadfill taken in 1987.

The area apparently has been used extensively for outdoor recreation for years. During hunting season, gunfire was frequently heard. The remains of deer that had been field dressed were observed twice. Well-worn trails and an improvised boat launching facility were present (Figure 4). Fishermen were

Georgia State University, University Plaza, Atlanta, Ga. 30303.

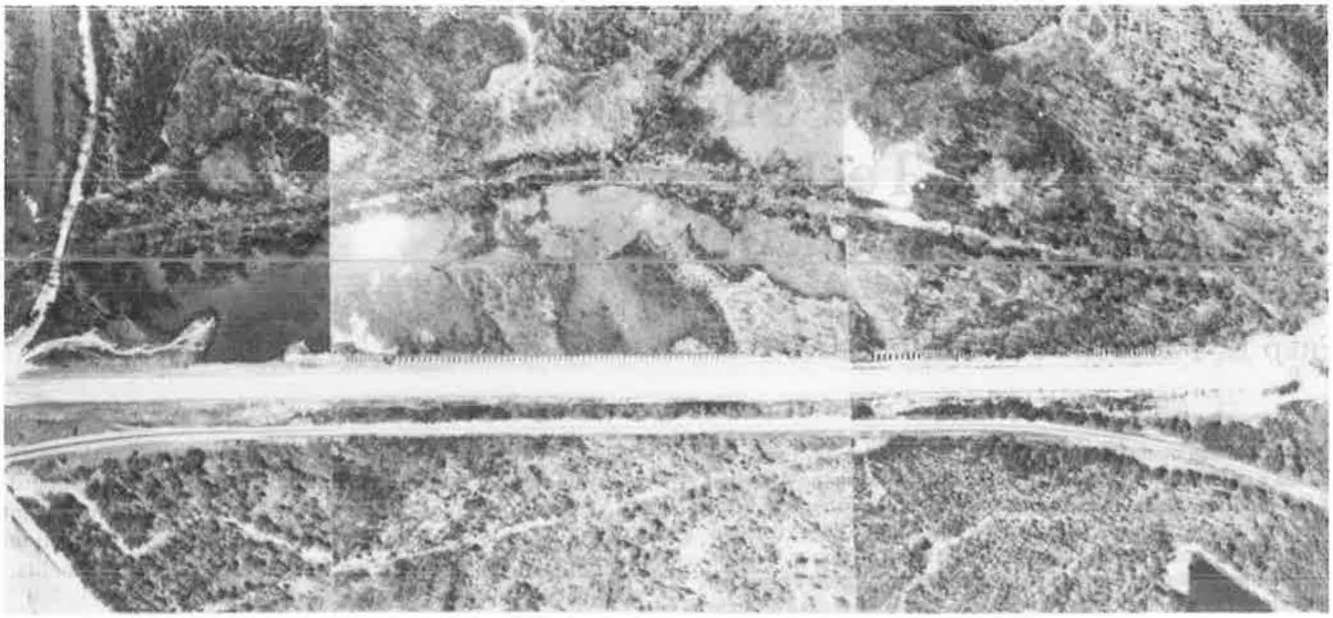

FIGURE 1 Aerial photograph of the site taken April 4, 1985.

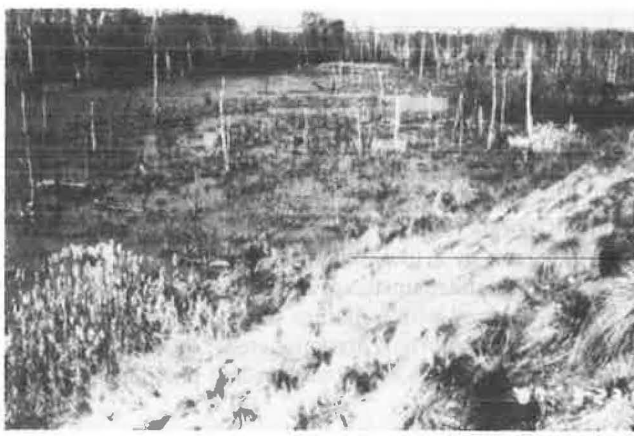

FIGURE 2 View of pond from roadfill taken March 1987. U 1, U 2, and U 3 are between the clumps of cattails. Note absence of trees after 2 years. Compare with Figure 6 taken September 16, 1986, 6 months earlier and after only 18 months. C 4 is across the pond, upper left in photograph.

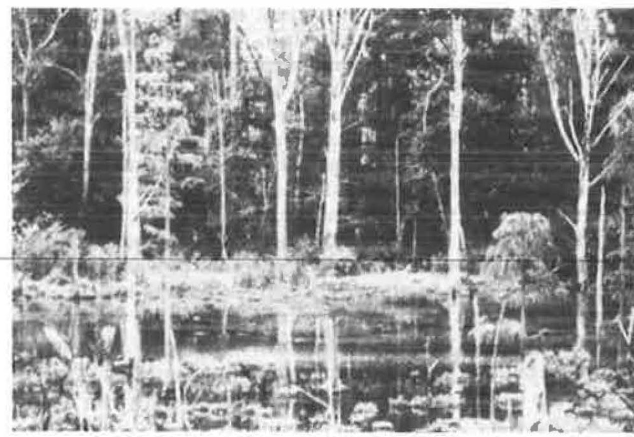

FIGURE 3 Telephoto view across pond. C 3 is visible. Note the four baldcypress trees. The specimen on the left is about 30 ft high, suggesting that the pond has a history of wet and dry periods, and that the pond is several years old.

seen on nearly all collecting trips. Local fishermen told us that trophy largemouth bass were occasionally caught.

Construction

The original construction plans (Figure 5) for the mitigation area required the following but were later modified. The original plans included the following:

1. About 100 fingerlike projections 20 ft long and 10 ft wide.
2. Ten-ft-wide sloughs between the fingers (making a distance of 20 ft from one finger centerline to the next).
3. Slopes of 2:1 on the sides of the fingers (the same as the roadfill).
4. Where the toe of the finger extended into saturated wetland soil, connection of the sloughs to the pond by a 5-ft-wide canal.
5. A water depth in the sloughs of 4 ft.

Deviations from the original plans included the following:

1. The 10 fingers southeast of the culvert (shown in Figure 4) measured about 12 ft wide center to center, whereas the remainder measured 17 ft center to center.
2. The width of water between fingers was 1 to 4 ft.
3. The depth of water in the sloughs was from 8 in. at the inner end of the slough to about 18 in. at the pond or canal.

Shortly after construction in 1984 and before this study began in March 1985, the beaver dam was apparently breached,

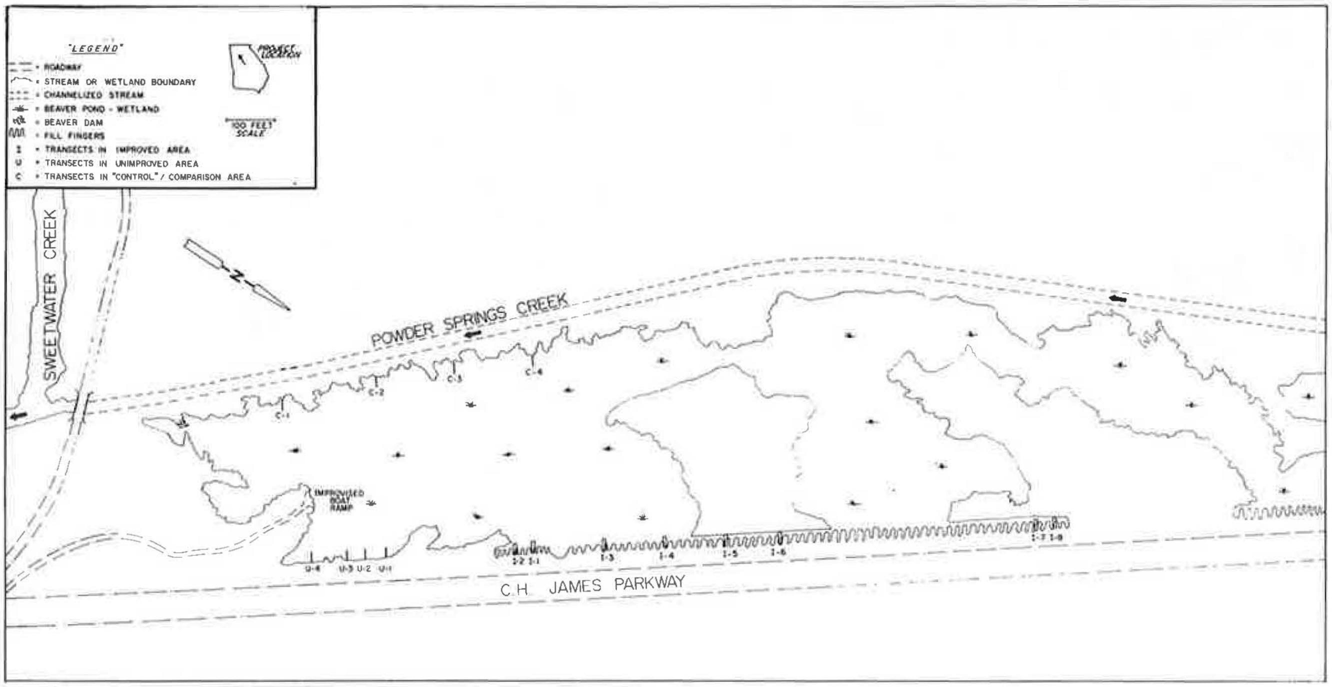

FIGURE 4 Outline of wetland showing location of fingers, transects, beaver dam, and improvised boat ramp.

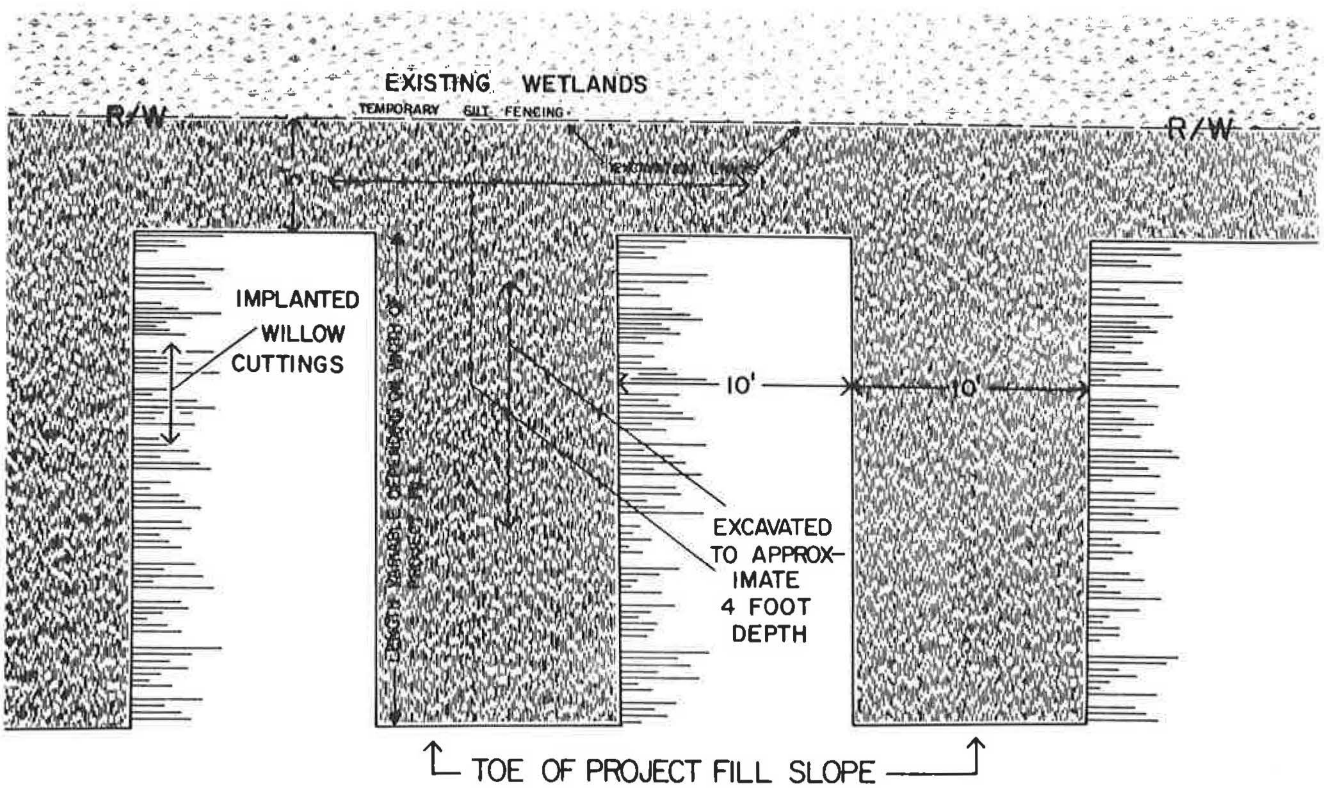

FIGURE 5 Diagram of fingers as originally designed for Powder Springs Creek Wetland.

FIGURE 6 Fingers in early March 1985. Weeping love grass is just coming up. B. Pruitt is standing on finger to the left of I 7. Note low water in slough, only about one-fourth of which is submerged. By end of March, when this study began, water was about 18 in. deep.

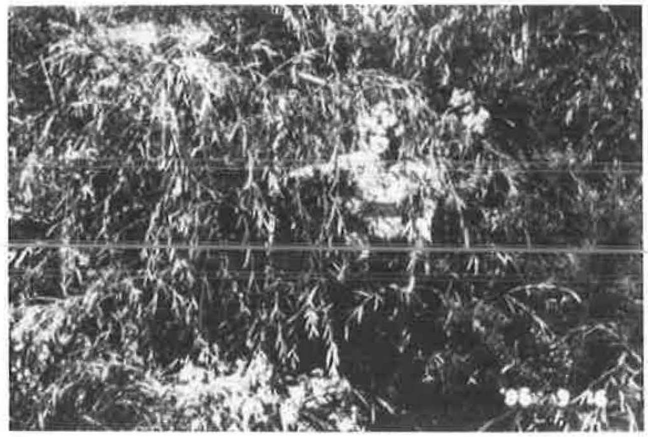

FIGURE 7 I 7 in September of 1986—18 months after Figure 5. Assistant B. J. Soteres is holding a surveyor's rod 6.6 ft (2 m) long at the base of a weeping willow tree.

making the water shallower and the width of the water narrower in the sloughs, and extending the length and width of the fingers (Figure 6). Sediment from the roadfill and finger edges was up to 32 in. deep in the sloughs. Thus, when the water level in the pond was down by 14 in., many sloughs were dry and most had only a few inches of water for less than one-fourth of their length.

Silt fencing was placed along the GDOT right-of-way in the wetland area before construction to protect the pond. It was designed to extend to the bottom in areas abutting directly on the pond and at least 2 ft above the water level. Fallen trees, however, knocked the silt fencing down in a number of places, allowing access by fish into the finger sloughs and entrance of suspended solids into the pond. Beaver, muskrats, and otters crossed the fencing at will. A den was found dug into one of the fingers before the fencing was removed.

A total of 72 fingers were constructed in the study area. The additional cost of constructing the fingers was $8,503.00.

Planting

The roadfill and fingers were seeded with weeping love grass (*Eragrostis* sp.) and interstate lespedeza (*Lespedeza stipulacea*) shortly after construction. These plants were just in evidence (Figure 6) when this study began in March 1985. The roadfill and finger banks had not yet completely stabilized.

Willow seedlings were planted in March 1985, two per linear foot, in a ditch at least 12 in. deep and 4 in. wide on the southeast side of each finger. After planting, soil was tamped and watered to saturation. A total of 2,612 willows were transplanted. Survival and compliance with specifications were checked in April 1985 by a GDOT engineer. The cost of planting the willow seedlings was $3,000.00.

Physical-Chemical Determinations

Critical environmental parameters were measured to determine if any extraordinary factor precluded normal habitat colonization.

During the quarterly sampling periods, samples from the water column were taken from selected transects, immediately placed on ice, and transported to the GDOT laboratory for determination of biochemical oxygen demand (BOD), turbidity, pH, suspended solids, alkalinity, nitrates, nitrites, and oil and grease. Determinations of air and water temperatures, dissolved oxygen, and illumination were made in the field. Temperature and oxygen were determined by using a Yellow Springs Instrument Co. (YSI) model 51A meter that was checked for accuracy against a laboratory calibrated GDOT YSI model 51A meter. Illumination was determined at waist height and arm's length with a General Electric type 214 light meter. Water samples were taken to the Extension Pesticide Laboratory at the University of Georgia at Athens in June 1985 and January 1986 for pesticide analysis.

Biological Sampling

Biological evaluation was divided into two major parts. The first part was an intensive descriptive survey of the Powder Springs Creek wetland at the project site. This part of the study compared the benthic, fish, and plant communities in the shoreline enhancement segment of the fill with the same communities in a segment of project fill without enhancement and those in a control area of wetland not affected by highway construction. The second part of the study was to pursue those aspects of community composition found to be the most informative in the first phase.

The first phase of the study began in March 1985. Four 2-m-wide by 10-m-long transects were laid out in each area: the control (C 1-4), the unimproved (U 1-4), the improved area facing the water (I 1-4), and the improved area constructed in the previous upland (I 5-8) (Figure 4).

In each transect, macrophytes and vertebrates were inventoried and four replicate ponar samples were taken to determine macroinvertebrate community composition. Macrophytes were field identified, and representative specimens were pressed for later reference; pictograms were made illustrating distribution. Fish were collected by using an electric shocker, identified, and then released. Invertebrates were preserved in ethanol and carried to the laboratory for identification and analysis.

Data Analysis

The original plan was to inventory and then compare the biotic communities, using representative transects, in the shoreline and pond margin communities in the improved, unimproved, and comparison (control) sites. Biologists have developed several methods of evaluating and quantifying ecological resources (*4–9*) that meet the criteria of being both mathematically acceptable as well as biologically sound to avoid what Slobodkin (*6*) characterized as taking biological nonsense to mathematical certainty. Of these, habitat assessment using biological communities is commonly used.

The widely used procedure developed by the U.S. Fish and Wildlife Service (USFWS) called Habitat Evaluation Procedure [HEP (*10–13*)] is also widely criticized for several reasons, one of which is its subjective nature (what makes one species "better" than another). HEP assumes that habitat quantity and quality for a species or guild can be numerically described. In use, values (on a scale of 0 to 1) are assigned to the environmental factors (for example, vegetation cover) responsible for the presence or absence of selected species or guilds. A summation or comparison, or both, of these values for a habitat results in the Habitat Suitability Index (HSI). The HSI is then multiplied by the habitat space available to give Habitat Units (HU). Habitat Units between different locales can then be compared.

A technique used more and more frequently in recent years is the comparison of one community's composition in species and numbers with another's (*9*). Biological communities are composed of numerous species, each with its own environmental requirements, containing numerous individuals, with varying tolerances to deviations in those requirements. If these requirements are not met, the species probably will not endure long in that habitat. On the other hand, if a species can get into a habitat and survive, it will usually endure. As a result, community analysis can be used to determine ambient environmental conditions. In some cases, and this study was one, community composition appeared more sensitive than human testing.

Of the numerous community comparison procedures, Pontasch and Brusven (*14*) found the average chi-square test of Parrish and Wagner (*15*) most reliable in tracking benthic community recovery after an oil spill. The average chi-square procedure averages the similarity of frequency distribution (chi-square) of each species in an experimental ("observed") as compared with a comparison community ("expected"). One form of the equation is

$$\overline{\chi}^2 = 2[\sum_{i=1}^{n} (O_i - E_i)^2/E_i]/N$$

where E_i is the mean of the individuals in a taxon in the two communities being compared; O_i is the number of individuals in one community; and N is the total number of individuals in both communities.

The result is a number on a linear scale of 0 (identical) to 1 (totally different). Replicate samples from the same community usually give an average chi-square value of 0.1 ± 0.05.

Odum (*3*) lists the trends to be expected in the development of mature ecosystems. Some of these trends include weblike foodchains (adding complexity and stability to the system), high species diversity (a variety of species present), large organisms, long life cycles, and well-organized stratification (in conjunction with the others, adding different ecological niches). In most areas, a climax community will have a higher general HSI than a prior successional stage. Given these trends, the average chi-square "distance" between dominant community components can become a measure of relative habitat suitability the closer an experimental or stressed community matches with a natural climax community.

FINDINGS

Summary

The success of enhancing the pond margin was demonstrated, although from the beginning sampling in the pond margin ran into difficulty. The beaver dam backing up the pond was breached by county surveyors before the study began in 1984. Although the dam was rebuilt, it was breached again on September 3, 1985. The year of 1986 brought a severe drought. The dam was utterly destroyed by dynamiting about March 10, 1987 and was never rebuilt. As a result, the most meaningful information was derived from a habitat evaluation of the tree component of the pond margin community (see the sections on plants and community comparison below). This quantification was supported by the macroinvertebrate and fish data that were collected. Physical-chemical and macroinvertebrate data highlighted sedimentation problems and revealed nothing in the water column that precluded normal colonization by organisms.

Physical-Chemical Parameters

No pesticides were detected that would adversely affect the biotic communities. Ambient physical and chemical parameters were usually within expected ranges.

Air and water temperatures, dissolved oxygen, and illumination were measured in June 1985; December 1985; March 1986; July 1986; September 1986; and January 1987. Most readings were within the tolerance limits of fish and benthos (5–10 mg/L) except during times of extreme low water when compacted vegetation lowered the oxygen (0.5–1 mg/L).

Laboratory determinations of BOD, turbidity, pH, suspended solids, alkalinity, nitrates, nitrites, and oil and grease were determined in March 1985, June 1985, December 1985, July 1986, and September 1986. All readings were within acceptable limits for fish and benthos (e.g., pH about 6.5–7) except during extreme low water, at which time the dying compacted vegetation raised the (5-day) BOD to about 7 mg/L. Temporary high pH values (pH 9.48) and alkalinities (20.6 mg/L) occurred once as a result of hydroseeding of the roadfill slope. Frequent high levels (>80 mg/L) of suspended solids occurred as a result of transport from upstream as well as erosion from the roadfill. During low water it was often impossible to collect samples without stirring up bottom sediments.

During one period of low water, sediments deposited in the sloughs were examined. A terrace approximately 5 ft long and up to 32 in. deep extended outward from the roadfill toe into the slough, filling about one-fourth the slough length.

Several sloughs were filled by collapse of the roadfill bank or by roadbed drainage. The accumulation of sediments meant that one-fourth of the slough was normally shallow and, with low water, dry. The shallow water and dry condition negated the planned methodology.

Fish

Two important trends appeared. The first trend was that gamefish used the sloughs in approximately equal numbers in the areas facing the pond and in the sloughs connected by canals but constructed in former upland areas. The second trend was that, so far as could be determined, bedding fish appeared to favor the improved site (see planting section in methodology).

In March 1985, more gamefish were found in the improved areas (five) than in either the controls (zero) or the unimproved area (three). In May 1985, a special trip was made to the site to count the number of fish beds. None were seen in the unimproved or control areas. Six were seen in the improved area. These six belonged to either largemouth bass (*Micropterus salmoides*) or green sunfish (*Lepomis cyanellus*) since adults of these species were seen in association with the nests. In June 1985, 28 gamefish were collected in the improved area, one was collected in the unimproved area and four were collected in the control area.

More gamefish were found in the improved area (22) in September and December than were found in the unimproved area (6). The control area was inaccessible in September because of rapid water flow through the breached dam. In March 1986, only one gamefish, a chain pickerel (*Esox niger*), was found in the control area, eight bluegills (*Lepomis macrochirus*) and nine warmouth bass (*Lepomis gulosus*) were collected in the improved area, and one each of bluegill, pickerel, and warmouth were collected in the unimproved area.

Fish collected during the June 1986 sampling period included seven gamefish (green sunfish, warmouths, and bluegills) in the improved area; a small large mouth and a green sunfish in the unimproved area; and no gamefish in the control area. Three fish nests were found in the improved area, one in the unimproved, and none in the control. Almost certainly, the low water level added to the negative effect of the slough's siltation to reduce the numbers of fish present.

The fish collected in this study are largely territoral in nature (*16,17*). Most will inhabit shallow open water but prefer nearby shelter and "structure" to hide from predators and to use as a reference for the maintenance of territorial boundaries. The substrate also provides a source of invertebrate food (*18,19*).

Other Vertebrates

Qualitative observations on other vertebrates revealed a steady increase in use of the improved area by birds, small mammals, and humans. No such increase was seen in the unimproved area.

Macroinvertebrates

A total of 3,401 macroinvertebrates in 85 taxa were collected and identified. Of these, there were 1,200 individuals in 58 taxa in the control area, 522 individuals in 45 taxa in the unimproved area, 984 individuals in 38 taxa in the improved area facing the pond, and 695 in 52 taxa in the sloughs connected by canals. The improved area facing the pond had 82 percent of the number found in the control, the improved sloughs connected by canals had 58 percent, whereas the unimproved area had only 44 percent of individuals occurring in the controls.

Many benthic species show marked habitat preference, and much can be learned from the taxa present in a given ecosystem. A qualitative discussion of the benthos is included in the full report but is not included here because the frequent drying of the pond precluded usable benthic data.

Plants

As can be seen in the aerial photograph (Figure 1), the fingers in the winter of 1984–1985 were bare clay. When this study began in March 1985, newly seeded weeping love grass and interstate lespedeza were just coming up (Figure 5). A survey for other plant species revealed only a few scattered dandelions (*Taraxacum officinale*).

By early 1987, because of the obvious low survival of the planted willows and continued difficulties obtaining adequate aquatic invertebrate samples, it was decided, in conjunction with the GDOT, that a survey of the species and size of colonizing trees would be most useful. In October 1987, trees on alternate fingers (36 of 72) and on the 200-ft margin of unimproved roadfill were field identified, the number in each species was counted, and their heights were determined to the nearest foot. All willows that occurred were counted together because it was not possible to distinguish between planted and volunteer individuals on the finger ends and the roadfill toe. The data are summarized in Table 1.

One hundred nineteen willows [in two species: weeping willow (*Salix babylonica*) and black willow (*Salix nigra*)] were found on the 36 fingers. Doubling this, to estimate survival for all 72 fingers, gives a total of 238 transplants that survived of the 2,612 individuals originally planted, a 9 percent survival rate. However, the actual survival rate was not this good since about one-fourth of the trees were on the northwest facing slope of the fingers and appeared to be volunteers.

By comparison, 137 individuals in nine species other than willows were found on the 36 fingers counted. Doubling this to estimate recruitment for the 72 fingers gives 274. Considering all individuals of all species, a total of 512 trees in 11 species is estimated to occur on the fingers; an average of 7.1 trees per finger. The mean of means for the willow tree height was 6.7 ft; the mean of means for the other trees was 3.4. The difference probably represents one season's growth for willow seedlings.

In deriving an "average" community of the fingers for community comparison, the following figures can be derived from the data given. More than three species occurred on 21 of the 36 fingers counted. Six species had more than 12 individuals. Therefore, an average of at least six species would be expected on three or more fingers. For 200 linear feet of roadfill (12 fingers) a total of 85 trees in at least six different species could be expected. It is important to note that over half the tree community considered in the habitat evaluation were volunteers.

In the unimproved area, a 6-ft-wide transect along the 200-

TABLE 1 SUMMARY OF NUMBER AND HEIGHT OF TREES IN OCTOBER 1987

IMPROVED SITE; number on 36 alternate fingers of the 72 total.

SPECIES \ HEIGHT (in feet)	1	2	3	4	5	6	7	8	9	10	>10	TOTAL NO'S	AVE HT.
PLANTED?													
Weeping willow	1		5	16	18	7	20	8		3	(18')	79	5.7
Black willow		1	1	2	8	6	10	6	3	1	(15',25')	40	7.7
VOLUNTEERS													
Pines		10	17	10	2							39	3.1
Sweetgum	7	13	16	5	1							42	2.3
Red maple	3	14	1	1								19	2.0
Tulip popular		1										1	2.0
Winged sumac	1	2	2	1		1						7	3.0
Sycamore	1	7	5		8	1	1		1			24	3.8
Alder		1		1	1							3	3.7
Ash						1						1	6.0
Hickory (pecan?)					1							1	5.0
TOTAL VOLUNTEERS												137	
GRAND TOTAL												256	

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UNIMPROVED SITE; 200' along roadfill (12 finger shoreline equivalent).

SPECIES \ HEIGHT (in feet)	1	2	3	4	5	6	7	8	9	10	>10	TOTAL NO'S	AVE HT.
Black willow			1	3		1						5	4.2
Pines				1								1	4.0
Sweet gum		1	1									2	2.5
Alders				1	1							2	4.5

ft shoreline was surveyed for comparison. Ten trees in four species were found. Again, the situation is not simple. The aerial photograph taken after construction and before tree recruitment (Figure 1), shows that the tall black willows already were present; omitting these trees leaves five or six individual trees in the unimproved area. (All ten trees were included in the community comparison calculation so as not to bias the results.)

Community Comparison

The unimproved area was 200 ft long. In a 6-ft-wide transect along the entire 200-ft pond-roadfill toe margin, ten trees in four species were found (Table 1). A 6-ft-wide transect of 200 ft of pond-finger shoreline in the improved area would include 3.3 fingers. On these, one could expect to find 23.43 trees (average 7.1 trees per finger [see the section on plants]) in about six different species. Dividing the 23 trees among the six most numerous species in the proportion found in the survey gives the following "average" community: eight weeping willows, four black willows, four pines (*Pinus* sp.), four sweetgums (*Liquidambar styraciflua*), two sycamores (*Platanus occidentalis*), and one red maple (*Acer rubrum*).

There are two components of this habitat assessment to be considered. First, did the tree planting or the making of space for trees enhance unit lengths of shoreline? Second, was the construction of fingers, by increasing enhanced shoreline, an effective means of increasing habitat values?

It is important to recognize the difference between shoreline length and roadbed length. In the unimproved area, the straight roadbed and shoreline are of equal lengths—200 ft. In the improved area, because of the finger extensions, the shoreline is approximately three times the roadbed length, e.g., along 200 ft of roadbed there occur 12 fingers with a shoreline distance of about 600 ft. Two hundred feet of shoreline in the improved area includes 3.3 fingers, a roadbed length of about 65 ft.

A comparison of the average community found in the improved area with the community actually found in the unimproved area gives an average chi-square "distance" of 0.48. That the improved area contains more individuals and a variety of species approaching the climax community, indicates, according to Odum (*3*), that the habitat value of the improved area is about two times greater per linear foot of shoreline than that of the unimproved area. Furthermore, the finger complex makes the shoreline three times greater than the linear distance of roadbed in the improved area. This finding means that each linear foot of roadbed in the improved area has six times the habitat value of a linear foot of roadbed in the unimproved area.

Intuitively, this number seems about right: there are over twice as many trees and half again as many species along the improved roadbed. The numerically derived relative habitat values generally agree with those of other field observations, such as the increased occurrence of fish and fish nests and the increased numbers of benthos. Undoubtedly, as the area matures, these figures will change, but at present they demonstrate the increase in habitat value of the enhanced shoreline.

CONCLUSIONS AND RECOMMENDATIONS

The study of the wetland in Cobb County, Georgia, yielded the following conclusions and recommendations:

- The finger concept worked well in improving the pond margin habitat, resulting in a relative habitat value about six times greater than that for the unimproved area (compare Figures 2 and 7). With modifications, even greater enhancement may be possible.
- Nearly all the sloughs between the fingers are filled or partially filled with sediment derived from erosion of the roadfill or as a result of being (in two places) channeled from the roadbed. Recommendations are that fill be anchored as soon as possible and that the angle of the slopes be less (*20*). The water depth in the sloughs needs to be 3 ft after anticipated sedimentation to prevent rapid vegetation build up. Lewis (*21*) recommends at least 3 ft.
- If water depth in the sloughs had been deeper and wider, the addition of shelter, snags, or old Christmas trees would have been appropriate and would have added to invertebrate and fish production (*18,19*). The foodweb through fish, birds, and mammals (including humans) is dependent on the organisms beneath them. Increasing herbivorous invertebrate and fish production makes additional energy and nutrients available to the organisms above.
- The fingers and sloughs should be about 20 ft wide and 25 to 30 ft long. These dimensions would help prevent rapid filling, probably would lower construction costs, and would be as attractive or more attractive to aquatic organisms. Trees colonizing fingers of these dimensions would still spread enough to shade sloughs and fingers, yet be close enough to be influenced by the proximity of water.
- Natural seeding of hardwoods in a locale surrounded by hardwoods appears to occur rapidly enough that planting may not be necessary. Only one season's growth was gained by planting, and the survival rate was low (<9 percent). If planting is done, however, it is recommended that black willow seedlings be specified in the future and that they be planted 4 ft apart. A survival of one or two per finger along with natural colonization is all that the fingers will ultimately support; after a few years, the tree crowns will spread and provide the desired shade.
- Fish appeared to use the sloughs and connecting canals preferentially over the unimproved and control areas. Wider sloughs as recommended would more closely match the larger fishes' territorial requirements.
- An alternative to planting trees that would colonize naturally would be to plant wildlife food-producing trees that would add diversity (*22,23*). A planting schedule of one or two trees for every five fingers would be less expensive and still be habitat enhancing.
- Some government or private agency that will guarantee the integrity of the site needs to have control of all land on which publicly funded mitigation is practiced (The Austell site is privately owned, although it is in the floodplain.) Mitigation is too important and too expensive to waste.
- As demonstrated here, mitigation procedures are more effective if they are tailored to the particular site. Several other practices would have been appropriate at the Austell site, such as:

(1) cleaning out the pond—which is rapidly filling with vegetation—during low water to extend its life;
(2) paving or adding gravel to the boat launching site;
(3) obtaining the land and turning it over to the Department of Natural Resources or Georgia Conservancy to help prevent frequent drainage; and
(4) terracing the slopes of the roadfill and fingers to make the area more attractive to waterfowl (*24*) and not necessarily encroaching on additional wetland acreage.

- Biologically oriented mitigation procedures such as this one, the project at Augusta, Ga., and the Torras Causeway in Brunswick, Ga., need to be monitored over a period of at least 5 years to build an adequate data base for future practices. This need not be more expensive. An intensive 1- or 2-year study followed by an annual survey over a period of years would not cost more but would provide better, longer term data.

ACKNOWLEDGMENTS

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