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SINK BRANCH: STREAM RELOCATION AND RECLAMATION BY THE FLORIDA PHOSPHATE INDUSTRY

Prepared under the In-house Research Program of the

Florida Institute of Phosphate Research

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FLORIDA INSTITUTE OF PHOSPHATE RESEARCH

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FINAL REPORT

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Prepared for

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NOTE

There is an inherent shortcoming to this research, one which the investigator recognizes but which could not be overcome. The difficulty is the lack of replication of treatments (i.e. mining), a problem with experimental design labeled "pseudoreplication" by Hurlbert (1984). Pseudoreplication limits the value of the results of the project because significant differences observed between the Mined and Unmined channels cannot be attributed to the effect of mining or channel relocation. In order to state definitively, for example, that mining leads to increased species diversity, several independent mined stream sections would have to be compared to several unmined sections. To develop a causal relationship, then, the diversities of the mined segments would have to be statistically indistinguishable, the diversities of the unmined segments would have to be similarly identical, and the diversity of the mined group would have to be greater than the unmined. At the time this investigation was undertaken, Mobil's Sink Branch project was the only reclaimed stream channel available, so it would have been impossible to replicate the Mined treatment. Conclusions about the effects of surface mining on stream ecosystems should be drawn carefully from these data, fully recognizing that differences detected in the channels may not stem from mining-related changes.

David J. Robertson, Ph.D.
Principal Investigator

DISCLAIMER

PERSPECTIVE

David J. Robertson

Florida Institute of Phosphate Research

Stream relocation to allow mining and the subsequent rehabilitation of the system in terms of water quality, aquatic biota and riparian habitat are particularly controversial because of the increasing recognition of the value of wetlands and because little data have been collected to demonstrate or refute that a stream and its environs can be reclaimed. Stream reclamation is a multifaceted problem involving channel relocation and topographic alignment, water quality maintenance and downstream monitoring to document perturbations.

Industry-wide, there are only a handful of stream relocation and reclamation projects that have been completed. The first of these, Mobil's 1979 Sink Branch project, is the subject of this report.

Since the completion of the Sink Branch research, Mobil has undertaken a series of stream reclamation projects. Between October 1981 and September 1982, Mobil graded and revegetated a small tributary of Guy Branch of the North Prong Alafia River named George Allen Creek. The project incorporated 1.2 ha of strand habitat and 2 ha of deep water lake over a distance of approximately 1.8 km of stream. The site was heavily planted with a variety of tree species and herbaceous vegetation. Unfortunately, severe erosion problems that developed almost immediately after contouring was completed dictated that the site be entirely regraded and flow attenuation structures such as rocky riffles installed in the streambed. This rehabilitation has been completed and the channel has begun to undergo succession.

The headwaters of McCullough Creek lie partially within the boundary of Mobil's Ft. Meade Mine. The watershed consists of a series of mining cuts filled with sand tailings and graded to appropriate slopes. The total wetland area in the project, completed in 1986, is 9.2 ha consisting of 0.8 ha of marsh and 7.7 ha of floodplain hardwood swamp. The reclaimed floodplain is approximately 1.1 km in length, 60 m in width, and the depth is variable.

Myers Branch, a tributary of the Peace River parallel to Sink Branch has also been reclaimed. The project involved the reforestation of 3 ha of hardwood swamp along 0.4 km of stream channel. The company mulched the streambed with peat material borrowed from similar habitats slated for mining.

Mobil is in the process of restoring the watershed of Rocky Branch with money from the state's Non-mandatory Reclamation Trust. Rocky Branch, formerly a direct tributary of the Peace River northeast of Ft. Meade, was diverted into Sink Branch to allow mining in its watershed. With the resource depleted, Rocky Branch is being returned to approximately its original location. The stream currently rises in settling areas, which will be revegetated as bayheads. The channel will be routed between retired settling areas until it reenters the Peace River floodplain.

Mobil's newest and most ambitious stream project is at the company's Nichols Mine. A portion of the eastern part of the mine is drained by Bird Branch, a tributary of the North Prong Alafia River. Bird Branch enters the reclamation area and flows through a shallow swale planted with a variety of wetland tree species. The bottom and sides of the swale were mulched with peat to encourage wetland redevelopment. Erosion at the head of the reclamation site led to initial difficulties, but streamflow has been controlled and the stream has excavated a shallow channel in the swale supporting dense vegetation that should help to retard further soil loss.

Brewster Phosphates relocated three small tributaries of the South Prong Alafia River at the Fort Lonesome Mine: Lizard, Dogleg and Hall Branches. Brewster has been monitoring the success of the projects for several years, concentrating on water quality, aquatic macroinvertebrate recolonization and wetland vegetation survival and growth.

IMC's Lake Branch stream channel and headwater restoration project in Hillsborough County was completed in 1985. The wetland consists of approximately 4 ha of cypress swamp and bayhead, including a 100 m of the stream channel, a tributary of the South Prong Alafia River. The watershed, encompassing over 40 ha, was reestablished on sand tailings capped with overburden.

In May 1982, the Institute began working with the U.S. Bureau of Mines, the U.S. Geological Survey and the U.S. Fish and Wildlife Service on a stream reclamation project at AMAX Chemicals' Big Four Mine. The "Wetlands Reclamation Research Project" (FIPR #82-03-027) is unique in that the stream, its associated riparian forest and the area's hydrology were all evaluated before the 6.5 ha tributary of Lake Branch of the South Prong Alafia River was mined in 1984. This pre-disturbance data will provide a basis for comparison once reclamation is complete.

In addition to directly altering stream channels through diversion or construction of settling areas, the Florida phosphate industry has also exerted more subtle effects on streams. Alterations in hydrology produced by mining, draining of wetlands, deposition of phosphatic clays, and changes in stream and groundwater chemistry have all influenced riparian forest ecosystems. Recognizing the potential significance of these perturbations, the Florida Institute of Phosphate Research funded two projects with the Center for Wetlands at the University of Florida. The results from the first of these projects, "Interactions Between the Phosphate Industry and Wetlands" (FIPR Pub. #03-007-025), indicated that changes in growth rates of floodplain trees might be correlated with the phosphate industry's activities, although direct cause-and-effect relationships could not be established. A follow-up study, "Interactions of Wetlands with Phosphate Mining" (FIPR #83-03-041R) is nearing completion and will contain additional information on floodplain forests.

RESEARCH RECOMMENDATIONS

(1) Stream channel restoration. Research is needed to determine the best configuration for the stream channel and the floodplain. Recent reclamation projects have incorporated broad, shallow swales into channel design, with the intention that the stream will find its own course. Although this approach is probably better than trying to force the water to flow through a designated channel, it will be necessary to devise techniques to control erosion and to create a natural, meandering course.

(2) Revegetation. Nearly all streams to be reclaimed will be bordered by swamp forest. Very little herbaceous aquatic vegetation grows naturally in central Florida streams, although it may be necessary to introduce a few common species such as *Sagittaria*. Most revegetation efforts will be concentrated on the floodplain, where information is needed on the appropriate species of trees and herbaceous cover to be introduced as well as the best techniques for introducing them. As in all reclamation, weedy invader species are a persistent problem, and methods for controlling terrestrial and aquatic weeds need to be explored.

(3) Hydrology. There is a serious lack of information concerning the hydrologic characteristics of watersheds. Questions frequently posed include: How large a watershed is necessary to provide perennial flow? What effect does the type of reclamation in the watershed have on stream water quality? Does the type of reclaimed land in the drainage basin (e.g. clay settling area vs. sand tailings fill) have an effect on stream discharge and the nature of flow?

(4) Impacts on Unmined Wetlands. Additional study of the effects of phosphate mining through accidental waste discharge, alteration of groundwater hydrology, or changes in the chemical composition of stream water might be valuable, but only if the perturbations can be carefully defined in time and other potential alterations in the stream, groundwater or watershed that could also affect tree growth can be excluded.

(5) Reference Sites. Nearly all reclaimed forested wetland sites are compared to existing, mature riparian swamps. Newly planted tracts beginning to undergo primary succession are radically different from climax ecosystems. An evaluation of the merits of using a mature forest as a model for development of a reclaimed wetland warrants additional attention.

(6) Success Criteria. The rules of the Department of Natural Resources specify minimum survival rates for trees planted in forested wetland projects. Swamps, however, are characterized by other

biological parameters in addition to trees. Would assessment of other aspects of reclaimed stream systems (e.g. macroinvertebrates, wildlife, fish) enhance the measure of success of these systems, or would such measures simply lead to expensive monitoring with no better indication of success?

(7) Inoculation and Colonization Dynamics. Many of the small, first-order, intermittent stream systems that drain into large perennial rivers are candidates for mining. The aquatic ecosystems in these two types of streams are radically different. Organisms inhabiting the rivers may not be adapted to conditions in streams, and reclamation of small creeks will leave them isolated from similar habitat that could serve as a faunal recolonization source. Is success enhanced by inoculating newly reclaimed stream systems with appropriate macroinvertebrate, reptile, amphibian, and fish species, or will these organisms find their way to the sites without assistance within a reasonable length of time?

ACKNOWLEDGMENTS

The special efforts of a number of people helped to ensure the success of this project. Ms. Susan Service and Ms. Kathyrn Piwowar each endured sleepless nights collecting diel drift net samples, and each devoted long, tedious hours in the laboratory to sorting and identifying macroinvertebrates. Laboratory technicians Gail Hall, Lucinda Sammons and Janice Wireman assisted with sample preparation. Mr. William Hawkins of Mobil Mining and Minerals Company encouraged this investigation and provided access to the research sites. Mr. Rick Stout of the Florida Game and Fresh Water Fish Commission helped with site selection, offered valuable suggestions, and located one of the artificial multiplate samplers concealed by an impenetrable growth of primrose willow. Mr. Richard Cantrell of the Florida Department of Environmental Regulation and Dr. Leonard Ferrington, Jr. of the Kansas Biological Survey identified difficult mayfly, caddisfly, and midge specimens. Ms. Janice Crowder, Ms. Renee Cohee and Ms. Rosemarie Garcia of the Institute's staff assisted in the preparation of this report. The extraordinary commitment of Dr. Mary Robertson is especially acknowledged for allowing the project to be completed on schedule and within budget.

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EXECUTIVE SUMMARY

Interest in stream reclamation has increased considerably since Mobil Chemical Company (now Mobil Mining and Minerals) established the first experimental stream reclamation research project at Sink Branch. The project began in December 1979 when 0.3 km of Sink Branch, a tributary of the Peace River in Polk County, was diverted from its original unmined channel into a parallel channel excavated on mined land. Excavation was completed in January 1980, but the new channel was not immediately connected with the original in order to establish vegetation to retard erosion. A 1.0 ha tract of reclaimed land north of the new channel was used to test reforestation techniques. The forest experiment area was divided into four treatments: 30 cm layer of topdressed organic soil, 15 cm layer of topdressed soil, fertilization of transplanted trees , and no treatment (control).

Tree-spading began in February 1980 and was completed by March. Potted and bare-root seedlings were planted in the reforestation area in February and March, and again in September to compensate for earlier mortality. On September 15, 1980, the earthen dams at the upper and lower ends of the excavated channel were removed and Sink Branch was diverted into the reclaimed streambed.

Mobil made provisions for monitoring the growth of the forest, but largely ignored the aquatic ecosystem when initial sampling revealed acceptable water quality. This project complements the terrestrial investigation by emphasizing the development of the aquatic invertebrate community, the substrate, and water quality in the stream three years after the diversion was completed. Two locations were selected for study and comparison: the "Mined" channel excavated on reclaimed land, and an "Unmined" section of the stream with an intact riparian forest approximately 1 km upstream from the Mined channel.

AQUATIC MACROINVERTEBRATE COMMUNITY

One hundred-eleven species of invertebrates (exclusive of the oligochaetes) and five species of fish were collected from Sink Branch from May 1983 to March 1984. One hundred-one invertebrate species were collected from the Unmined channel, 29% of which were found only in that channel; 81 species were collected in the Mined channel, 11% of which were restricted to that channel. The presence of a smaller number of species (species richness) in the Mined channel was probably due to a lack of habitat diversity.

The similarity of the communities inhabiting each of the channels based on presence/absence data was compared using Czekanowski's index. The collections from the Mined channel tended to be most similar, followed by the collections from the Unmined channel. When the Mined collections were compared to the Unmined, the similarity values were much lower, indicating considerable dissimilarity between the two areas.

The uniformity of the Mined channel, the diversity of microhabitats in the Unmined channel, and the differences in habitat characteristics between the two channels combined to limit the similarity between locations.

In addition to presence/absence data, the abundance of the macroinvertebrates was also taken into consideration (Shannon-Wiener species diversity). The Mined channel, in general, supported a more diverse benthic community than the Unmined channel. Despite the lower species richness of the Mined channel, the organisms which were present were distributed among the species more evenly than they were in the Unmined channel, where many species were represented by few individuals and a few species were represented by many individuals.

Organism density measurements indicated no statistically significant differences between areas within channels or between channels. Both channels were populated with approximately the same number of organisms per square meter.

WATER QUALITY

Based on a single series of samples spanning 24 hours in August 1983, physical and biological water quality in the two channels did not differ. Chemically, the Mined channel had significantly higher concentrations of nitrogen species, but lower levels of phosphorus. The chemical disparity may have been the result of water quality in Rocky Branch, a tributary which enters the stream between the two channels.

Samples collected immediately above and below the Mined channel for nearly a year revealed that all measured parameters were present in lower concentrations after the water had flowed through the Mined channel, but the reduction in ammonia was the only characteristic that was reduced significantly. Routing Sink Branch through the Mined channel had a slight ameliorating effect on water quality.

SUBSTRATE

Replicate sediment samples separated into surface and subsurface layers were subjected to particle size distribution and organic content analyses. Sediment composition was uniform throughout the length of the channels and between the upper and lower layers. Likewise, no measurable differences were present between channels despite the presence of phosphatic clay in the Mined substrate.

REFORESTATION

Of the 1794 trees planted in the reclaimed area in 1980, 531 were alive three years later. The overall survival rate was 29%, and was sufficient to establish the minimum number and variety of trees per acre to meet the state's criteria for successful wooded wetland reclamation. Tree survival varied depending on species, planting stock, and planting location. Because the soil treatments were not replicated, it was impossible to statistically correlate survival with soil treatments. Growth rates of transplanted trees were not significantly different among locations, with the exception of slash pines, which grew best in the areas of the mulch topdressing.

INTRODUCTION

BACKGROUND TO MOBIL'S SINK BRANCH RECLAMATION PROJECT

The potential for successful reclamation of forested wetland ecosystems following phosphate mining in Florida has not been well established. Projects undertaken by Agrico, AMAX Chemicals (Sandrick and Crabill 1983, Uebelhoer 1981), Brewster Phosphate (Clewell 1981), and W.R. Grace and Co. (Shuey and Swanson 1979, Swanson and Shuey 1980, Conservation Consultants 1979, 1980, 1981, Clewell 1981, Ford 1983) have demonstrated considerable promise for recreating herbaceous marshes. Experiments in hardwood swamp and riparian forest reclamation, however, have been restricted to "Parcel B," a nine year old site at International Minerals and Chemicals Corporation (Gilbert, et al. 1979, 1980, 1981, Barkuloo 1980, Clewell 1981, Dunn and Best 1983), several ambitious projects at Agrico adjacent to Payne Creek (Carson 1982, 1983 a,b), the Hall and Dogleg Branches restoration projects at Brewster Phosphate begun in 1983, and Gardinier's watershed rehabilitation project tributary to Whidden Creek.

Stream relocation to allow mining and the subsequent restoration of water quality and biological integrity is a particularly controversial aspect of wetland reclamation. In large measure, the Florida Department of Environmental Regulation is reluctant to issue Dredge and Fill permits for stream relocation and reclamation projects because no data exist to support or refute the claim that a stream in central Florida can be returned to an equivalent condition following mining.

Interest in stream reclamation has increased steadily since 1979 when Mobil Chemical Company established an experimental reclamation research project at Sink Branch. Mobil undertook the project to demonstrate the feasibility of re-routing and reforesting small streams. The project began in December 1979 when 0.3 km of Sink Branch, a tributary of the Peace River, was diverted from its original unmined channel into a parallel channel excavated on mined land lying to the north. Excavation of the portion of the new channel that was not subject to Dredge and Fill permitting began on December 26, 1979 and was completed on January 10, 1980. The new channel, which was not immediately connected with the original channel, rapidly filled with water and was colonized by wetland vegetation.

The 1.0 ha ribbon of reclaimed land north of the new channel was used to test techniques to establish a riparian forest along the stream. The area was divided into four treatments:

Treatment 1 - 30 cm layer of topdressed organic soil
Treatment 2 - 15 cm layer of topdressed organic soil
Treatment 3 - fertilization of transplanted trees
Treatment 4 - control (no treatment)

After the completion of all earthmoving, the area was immediately planted in a mixture of bahia grass (*Paspalpum* notatum var. *saurae* Parodi) bermuda grass (*Cynodon dactylon* [L.] Pers.) rye (*Lolium* sp. L.) and mulched with hay to stabilize the new channel against erosion. At the same time, 560 kg of 16-4-8 fertilizer were applied per hectare over the entire area to stimulate the growth of the forage cover crop.

Tree spading of 5-10 cm diameter trees obtained from nearby Mobil property began on February 5 and was completed on March 13, 1980. On February 16 and 17, 150 potted and 250 bare-root seedlings were transplanted along the northern margin of the new channel. An additional 700 bare-root seedlings were transplanted into the rest of the area on March 14. All tree plants were completed on March 15 with the transplanting of 300 potted seedlings.

One hectare-centimeter of irrigation water was applied over the entire area during the last week in March. Prior to the irrigation, potassium nitrate (15-0-14) was applied by hand around the base of all transplanted trees in Treatment 3 area. A total of 23 kg of fertilizer was used. Only nitrogen and potassium were included in the fertilization since soil testing indicated that phosphate levels were well above adequate in the reclaimed soil. Growth and survival were monitored for one year by Zellars-Williams, Inc., Mobil's consultant on the project (Zellars-Williams 1980, 1981).

On September 15, 1980, the earthen dams at the upper and lower ends of the excavated channel were removed and Sink Branch was diverted into the reclaimed streambed. Four months later, additional bare root and potted seedlings were transplanted into the reclamation are to compensate for mortality in the previous year's plantings and to establish trees in the areas disturbed by the removal of the dams.

Zellars-Williams also monitored seven water quality parameters for eight months prior to and six months following diversion. Water samples were collected monthly from the downstream end of the existing channel prior to the diversion and from the downstream end of the reclaimed channel after the diversion. At that time, the only change detected by the monthly "grab bag" samples was an increase in pH from an average of 6.7 prior to the diversion to an average of 7.7 after the diversion. The increase was modest and was based on relatively few samples. There were no significant changes in the average concentrations of total phosphorus, ortho-phosphate, Kjeldahl nitrogen, biochemical oxygen demand, suspended solids or dissolved oxygen. Zellars-Williams concluded that the diversion did not lead to a degradation in water quality. No other aspects of the aquatic ecosystem were monitored.

Mobil initially made provisions for monitoring the growth of the riparian forest, but ignored the aquatic ecosystem. This research was designed to complement the terrestrial investigation by emphasizing the substrate in the excavated channel and the complex aquatic invertebrate community that colonized the stream when reclamation was complete.

SINK BRANCH WATERSHED

Sink Branch is typical of the perennial streams tributary to the Peace River draining the Winter Haven Ridge in Polk County (Stewart 1966). The stream rises from a series of marshes and wetlands at an elevation of 42.7 m on the Ridge approximately 6 km east of the Peace River (Figure 2). The area is poorly drained and also serves as the headwaters for Bowlegs Creek, a Peace tributary which enters the river south of Fort Meade. The elevation at the mouth of Sink Branch is 22.9 m, giving the stream an average gradient of 3.3 m/km.

Most of the Sink Branch watershed has been cleared of the natural scrub vegetation that previously occupied the well-drained, sandy uplands and has been planted to citrus groves. The riparian woodlands have largely been eliminated by grazing, relic water control structures, and direct channelization to improve drainage. Large portions of the drainage basin on either side of the lower stream channel were mined, then reclaimed as pasture.

Most of the water in Sink Branch is derived from lateral movement of groundwater from the surficial aquifer. The only significant tributary is the artificial diversion of Rocky Branch, which enters Sink Branch from the north at a point approximately 2 km above the mouth. Rocky Branch was formerly a direct tributary of the Peace River, but mining plans required its flow to be diverted southward through an excavated channel leading to Sink Branch. Mobil is recreating the original Rocky Branch drainage with funds from the state's Non-mandatory Reclamation Trust, thereby reestablishing the original characteristics of the two streams.

Although much of the watershed and stream channel have been altered, sections of the stream on Mobil's property between Brooke Road and Lake Hendry Road retain considerable natural values. The bay swamp remains largely intact and the braided channel has not been dredged or channelized. One of these relatively undisturbed sections was chosen as representative of the "original" condition of the stream.

RESEARCH SITES

Mined (T31S, R26E, Sec. 30, 1.2 km west of Brooke Road).

The Mined research site encompasses the entire 302 m excavated channel and the adjoining uplands (Figure 3). The area totals 1.01 ha

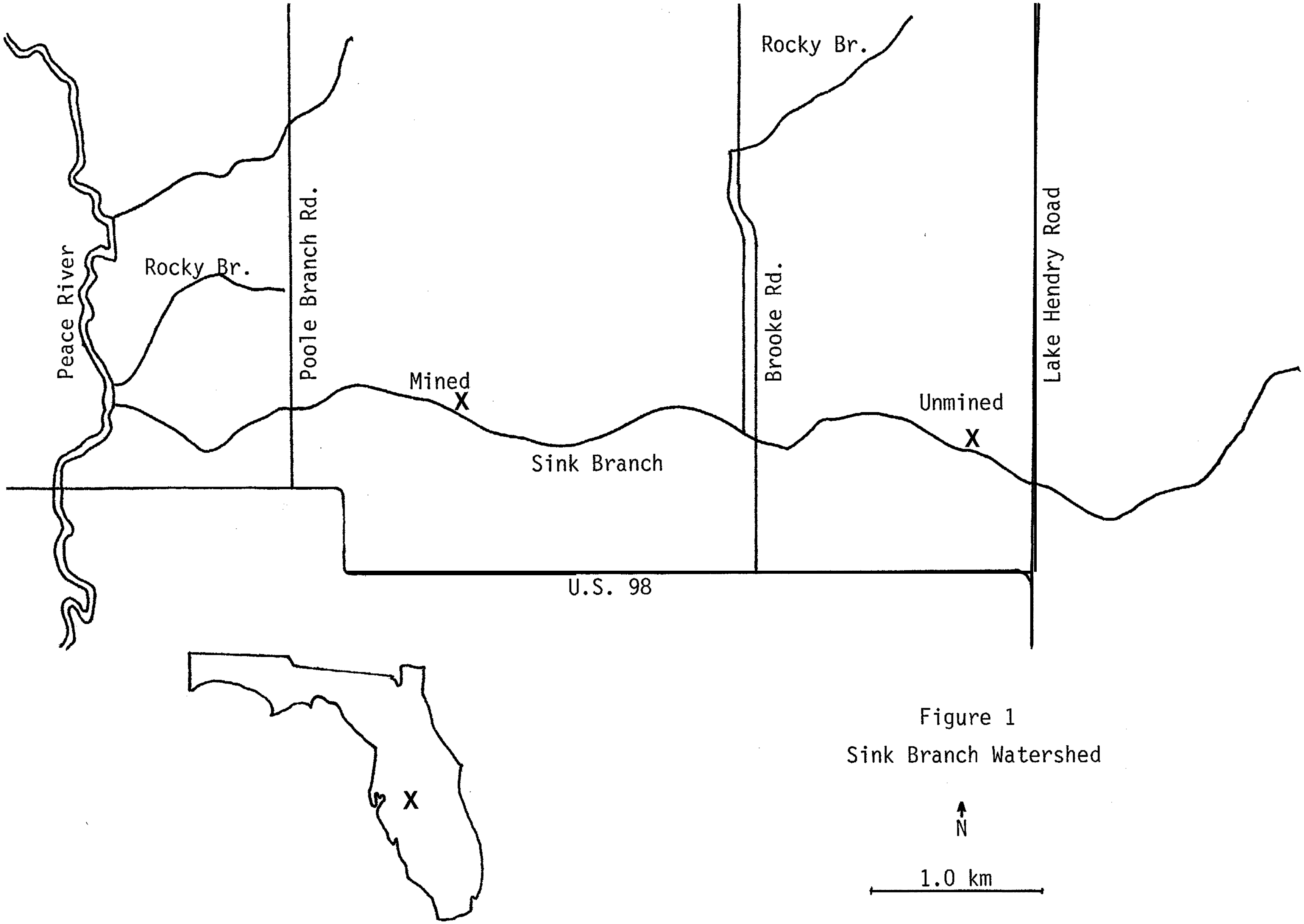

Figure 1
Sink Branch Watershed

and is completely enclosed within a barbed wire fence to prevent cattle grazing on the reclaimed settling area to the north from browsing on the planted trees. Primrose willow (*Ludwigia peruviana* [L.] Hara) forms a dense stand throughout the entire length of the excavated channel. At varying intervals, cypress trees (*Taxodium distichum* Rich.) planted by Mobil at the edge of the stream are beginning to overtop the luxuriant primrose willow growth. Upslope of the hydric zone, scattered wax myrtle (*Myrica* *cerifera* L.) and saltbush (Baccharis *glomeruliflora* Pers.) intermingle with planted sweetgum (*Liquidambar styraciflua* L.).

Three access points to the stream were originally cleared with a machete and were maintained as necessary throughout the growing season:

The "Mined Upper" site is located 91 m from the eastern (upstream) end of the excavated channel. The stream at this point is wide ($\bar{w}$ = 8.2 m), deep and slow moving (Table 1). The southern bank is very low, allowing the stream to broaden in response to heavy rainfall. The substrate consists of a mixture of sand, flocculated phosphatic clay and finely dissected organic material.

The "Mined Middle" site is 190 m from the eastern end of the channel. The channel averages 4.3 m wide and is confined between distinct banks that allow for less variability than occurs at the upper site. The substrate is identical to that found at the Upper site.

The "Mined Lower" site is located immediately upstream of the mouth of the excavated channel. Like the Middle site, the stream flows in a well-defined channel exhibiting little variability. However, since the channel is considerably narrower than at either of the two upstream sites, the current is more swift.

Cross-sectional stream profiles are shown in Appendix Figures 1-7.

Unmined (T31S, R26E, Sec. 29, 0.13 km west of Lake Hendry Rd.)

The Unmined research site retains essentially all of the natural structural integrity that is present elsewhere only in isolated reaches of the stream. The site includes approximately 120 m of stream channel and associated riparian bay swamp along both banks (Figure 3). The hydric areas are dominated by a canopy of sweetbay (*Magnolia* virginiana L.) and swamp tupelo (*Nyssa* *sylvatica* var. *biflora* Walt.). Virtually no understory is present in the wet areas although some redbay (*Persea palustris* Sarg.) and red maple (*Acer rubrum* L.) occur at the site. As the bay swamp grades into uplands, live oak (Quercus *virginiana* Mill.) and a thick growth of palmetto (*Serenoa* *repens* [Bartr.] Small) replace the hydric vegetation. At midpoint in the site, the trees have been cleared and the stream expands into a broad pool used by cattle as a wallow and watering hole.

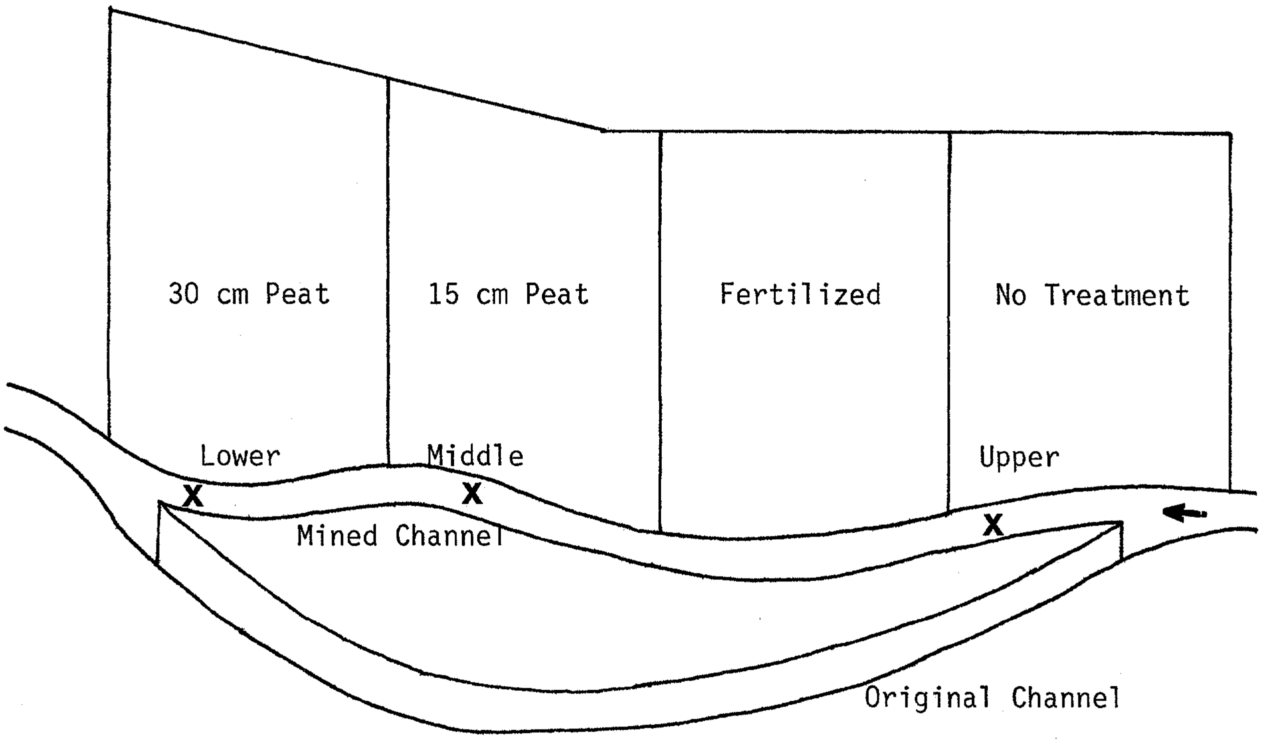

Figure 2
Mined Sites

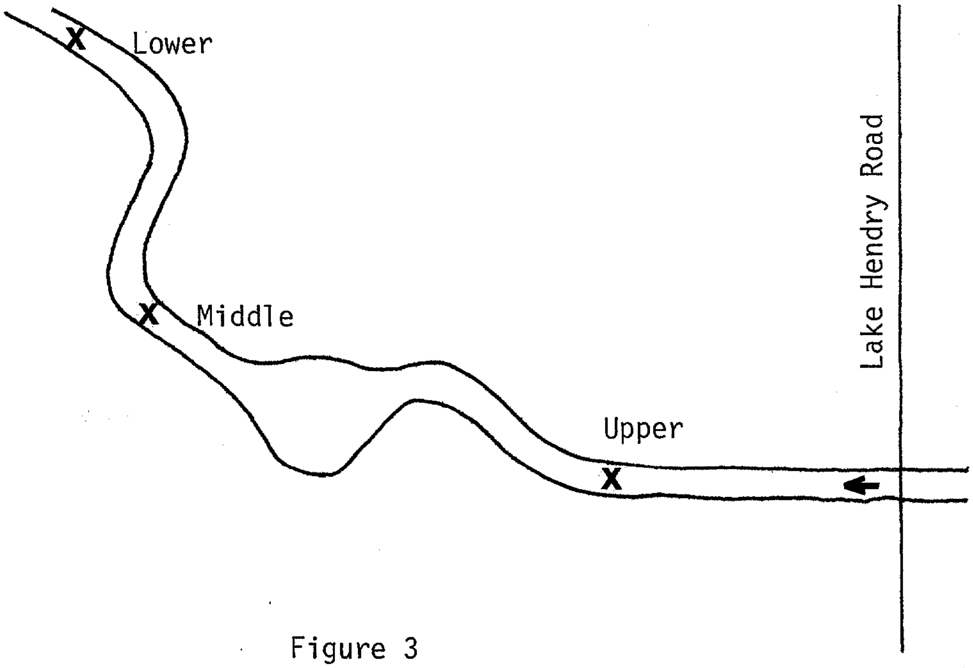

Figure 3
Unmined Sites

N ↑

200 m

The "Unmined Upper" sampling site is located 129 m west of the bridge on Lake Hendry Road. This site marks the upstream boundary of the Unmined channel. The stream profile at this site is variable (Table 1), consisting of a series of rapid, sandy runs alternating with deeper pools that act as organic sediment traps. The channel is well-defined and averages 3.1 m wide. As at all of the sites, Mined and Unmined, the stream is stained with tannins derived from decomposition of wetland vegetation in the headwaters.

The "Unmined Middle" site is 228 steam-meters west of Lake Hendry Road and 50 m below the cattle crossing. The stream is broader and the channel contains several sand bars, but the basic characteristics observed at the Upper site of clean, sandy runs alternating with mucky pools hold constant at the Middle site. The sand bars are fringed and stabilized by mats of southern watergrass (*Hydrochloa caroliniensis* Beauv.), and the roots of the bays that extend into the water from the margin of the stream provide a sheltered habitat for arrowhead (*Sagittaria latifolia* Willd.)

At the "Unmined Lower" site, the stream assumes a braided configuration flowing through numerous small channels around islands created by the roots of large bays. This braided form is typical of much of the remainder of the stream between the Unmined site and Brooke Road. At low water levels, a single main channel is evident and this area was used routinely as the sampling location. It is 250 stream meters west of Lake Hendry Road. The stream is bordered by a heavy growth of southern watergrass, smartweed (*Polygonum hydropiperoides* Michx.) and lizard's-tail (*Saururus cernuus* L.) rooted in the deep organic muck, although the stream itself flows over clean sand. Because of the inability to distinguish the limits of the stream during the summer months, the channel was measured only during low water ($\overline{W}$ = 1.25 m), but water undoubtedly flows through the saturated organic soils as well as through the channel even at low discharge.

Cross-sectional stream profiles are shown in Appendix Figures 8-14.

Table 1

Sampling Site Characteristics

		Unmined			Mined		
Date		Upper	Middle	Lower	Upper	Middle	Lower
05-03-83	Temperature	20.0			22.0		
	pH	5.1			5.4		
06-17-83	Width (cm)	300.0	350.0	130.0	700.0	380.0	330.0
	Flow (cm/sec)	4.0	3.5	5.0	4.0	9.0	6.5
	Volume (1/sec)	23.6	23.2	7.4	36.3	95.7	44.8
	Temperature	25.0			23.5		
	pH	4.6			5.1		
08-01-83	Width	290.0	370.0	120.0	880.0	450.0	370.0
	Flow	3.5	4.5	19.0	6.0	12.0	16.0
	Volume	25.1	33.4	31.1	144.7	150.1	137.4
	Temperature	25.5			26.0		
	pH	4.5			5.0		
09-14-83	Width	340.0	420.0		1100.0	450.0	450.0
	Flow	23.5	17.0	18.0	4.0	11.0	11.0
	Volume	216.3	129.3		116.9	158.9	113.3
	Temperature	25.0			24.0		
	pH	4.4			-		
11-03-83	Width	310.0	330.0		670.0	350.0	310.0
	Flow	19.0	13.0	11.0	9.0	11.5	16.0
	Volume	77.0	58.9		183.8	112.8	127.0
	Temperature	22.0			18.0		
	pH	5.5			5.0		

Table 1 (Continued)

Sampling Site Characteristics

		Unmined			Mined		
Date		Upper	Middle	Lower	Upper	Middle	Lower
12-21-83	Width	310.0	440.0		765.0	500.0	360.0
	Flow	14.0	19.0		11.0	14.0	21.5
	Volume	79.3	153.6		249.8	183.8	161.9
	Temperature	17.0			17.0		
	pH	-			6.4		
02-01-84	Width	320.0	370.0		700.0	380.0	310.0
	Flow	19.1	11.1	9.0	5.3	10.1	15.7
	Volume	71.5	55.8		121.4	110.2	109.7
	Temperature	11.0			14.0		
	pH	4.6			5.3		
03-14-87	Width	280.0	360.0		700.0	380.0	280.0
	Flow	15.8	9.4		6.8	11.8	18.9
	Volume	47.7	45.4		160.2	110.8	107.9
	Temperature	21.5			18.0		
	pH	4.8			5.4		

OBJECTIVES

The overall goal of this program was to determine the degree of similarity between the undisturbed section of the stream that served as a reference and the excavated channel of Sink Branch. In order to accomplish this goal, the program included research to accumulate qualitative and statistically testable quantitative data about four important stream characteristics. These characteristics were embodied in specific project objectives:

Objective 1: Compare the aquatic macroinvertebrate communities inhabiting the undisturbed and excavated channels in terms of species diversity, species richness and organism density.

Objective 2: Determine what effect, if any, diverting the stream had on water quality.

Objective 3: Compare the substrate particle size distribution occurring in the excavated channel with that in the undisturbed streambed.

Objective 4: Update survival and growth data on transplanted trees.

METHODOLOGY

OBJECTIVE 1

Aquatic macroinvertebrate sampling began on May 3, 1983 and ended on March 14, 1984. Samples were collected either at 1-1/2 or 3 month intervals as described below in greater detail. The dynamic nature of invertebrate populations, especially in sub-tropical Florida, required frequent sampling to characterize the community on an annual basis. Most of the species comprising aquatic communities are present year-long except for the characteristically brief period following emergence into the terrestrial environment typical of aquatic insects. Yet, despite their continuous presence, invertebrates progress through a series of complex stages which requires constant reorganization of the trophic and hierarchical structure of the community based on the changing availability of food resources. Frequent sampling is the only way to document the shifts in population interactions.

Four techniques were used to sample the aquatic macroinvertebrate communities inhabiting the Unmined and Mined channels of Sink Branch. Three of the techniques were designed to provide quantitative data: Hester-Dendy multiple plate samplers, substrate cores and diel drift net samples. The remaining technique, dip net collections, provided qualitative information about the communities. All four sampling techniques are standard assays used routinely for aquatic macrobenthic research in central Florida and throughout the nation.

Hester-Dendy samples

The Hester-Dendy multiple plate sampler is constructed of 7.5 cm-diameter tempered hardboard plates stacked one on top of another with spacers between along a threaded rod to provide a variety of microhabitats for invertebrate colonization. The effective surface area of the sampler is $0.13m^2$. When incubated in the stream, the sampler is colonized by an assemblage of motile organisms such as insect larvae. It is, however, not the sampling technique of choice for borrowing or sedentary organisms.

Hester-Dendy samples were collected at 1-1/2 month intervals. One sampler was located at each of the three sampling sites per channel (i.e. Mined and Unmined). At the start of each collection trip, the sampler which had been in place for the previous six weeks was replaced with a new sampler. The colonized device removed from the stream was rapidly disassembled and transferred to a plastic container with 70% ethanol as a preservative. Samples received further processing in the laboratory.

Substrate cores

"Stovepipe" coring devices represent the only quantitative device suitable for sampling shallow-water habitats containing stands of vegetation as are found in portions of Sink Branch. The device used for sampling Sink Branch was a 60 cm section of 25 cm-diameter aluminum irrigation pipe fitted with handles specially fabricated by Race and Race, Inc. of Winter Haven, Florida. In use, the pipe was manually forced into the substrate with a twisting action to a depth of approximately 0.5 m. The vegetation and substrate were removed to a sieve with 125μ mesh, which retained all macroinvertebrates while allowing the water and fine sediment to pass through. The coring device sampled an area of 0.05 m^2.

Core samples were collected at 1-1/2 month intervals. Five cores were collected along the length of each treatment in a variety of locations in an attempt to sample as many microhabitats as possible. The collected organisms, detritus and substrate were preserved in the field and returned to the laboratory for processing.

Drift net samples

The drift of aquatic organisms from upstream sources is probably the most important mechanism responsible for colonizing denuded and newly-created stream habitats. Consequently, a qualitative estimate of the number and kind of drifting organisms is an essential component of the sampling regime.

Drift was sampled with commercial drift net assemblies consisting of a rectangular 0.3 x 0.4 m steel frame to which was attached a 1.0 m nylon net with No. 54 mesh (363μ openings). The nets were anchored in the stream with the open end facing upstream and the net trailing in the current. The top of the open net was positioned just below the water surface to permit calculation of the volume of water filtered through the net and to lessen the chance for collecting floating terrestrial insects.

Because of the large number of insects collected in the drift nets, they were used at 3 month (cf. 1-1/2 month) intervals. Two nets placed side-by-side were used in each channel (i.e. two each at the Unmined Upper and Mined Middle sites). Samples were collected at 3-hour intervals for 24 hours. At the end of each 3-hour period, the sample nets were removed from the stream and immediately replaced with two new nets. The sample nets' contents were preserved and the nets thoroughly inspected to ensure that all macroscopic organisms had been removed. Retrieving the nets at 3-hour intervals ensured that they would not clog with detritus, and frequent sampling helped to reduce predation pressure on prey organisms by carnivores trapped in the net.

Dip net collection

The samples collected with the Hester-Dendy, coring and drift net devices were augmented by qualitative dip net collections. The dip net is a long-handled nylon net with a muslin skirt to prevent the net material from snagging in vegetation. By shaking or dragging the net in the habitat to be sampled, organisms are dislodged and collected in the net.

Dip nets have limited utility for quantitative research because the net integrates samples from a variety of microhabitats and it is impossible to determine the amount of substrate that has been sampled. In addition, the nylon mesh supplied with the net is large, allowing small larvae to elude capture. However, as a qualitative device, the dip net typically collects many more and different types of organisms than are usually collected by quantitative techniques because it represents a cross-section of the fauna from a large number and diversity of habitats.

Dip net samples were collected at 1-1/2 month intervals over the 12-month period. In an effort to make the dip net collections semi-quantitative, sampling was restricted to exactly five minutes for each treatment. The material collected in the net was transferred to a plastic container, preserved with 70% ethanol and returned to the laboratory for additional processing.

Laboratory processing and analyses

The field-preserved samples were further processed and sorted in the laboratory. After washing twigs, leaves and phosphate pebbles with a water spray over a sieve (125 mesh) to remove lodged organisms, these inclusions were discarded. Small portions of the preserved sample were then decanted into white plastic trays and sorted under strong light. Large pieces of detritus were agitated in water in the pan, examined for clinging invertebrates, then discarded. Detritus and sand grains too small to remove from the tray by hand were transferred to a Syracuse watch glass and examined at 12X magnification. All invertebrates then were preserved and identified in 70% ethanol. Invertebrate count data were transformed for statistical analysis using the square root transformation (Sokal and Rohlf 1969).

OBJECTIVE 2

In order to determine if the excavated channel had any effect on the quality of water in the stream, water samples were collected at 6-hour intervals during each of the eight sampling trips. Each of the samples consisted of two 1 litre "grabs," one collected just upstream of the beginning of the excavated channel to determine water quality before the stream entered the channel, the other collected at the Mined Lower site. At the suggestion of the Florida Department of Environmental Regulation, each sample was analyzed for 8 parameters:

I. Total suspended solids
Total dissolved solids
Turbidity

II. Chlorophyll a and phaeophytin
Ortho-phosphate
Ammonia nitrogen
Nitrate nitrogen
Kjeldahl nitrogen

The characteristics in Group I give an indication of physical changes in the channel. For example, an increase in suspended solids or turbidity would indicate that the excavated channel is an erosional environment that could be attributed to increased water velocity, unstable substrate or bank subsidence. The parameters in Group II are primarily indicators of the biological integrity of the system. Chlorophyll a/phaeophytin is an indirect measure of the phytoplankton biomass in the water column that could, if necessary, be related to the total number of phytoplankters by time-consuming direct cell counts. The chemicals in Group II are all plant nutrients that could conceivably be removed or augmented by chemical or biological processes occurring in the excavated channel.

OBJECTIVE 3

Three substrate samples were taken at each of the sampling sites in both the Mined and Unmined portions of the stream. The samples were obtained by carefully pressing the open end of a 3 x 15 cm polycarbonate centrifuge tube into the substrate. A hole previously drilled in the end of the tube allowed water to escape from the tube as it was being forced into the bottom. This hole was covered with the thumb to create a vacuum as the substrate-filled tube was lifted. The tubes were capped, packed in ice, returned to the laboratory and analyzed for sand, silt, clay and organic carbon.

Each sample was dried to constant weight, then mixed to ensure homogeneity. Approximately half the sample was used for Walkley-Black organic carbon analysis (Allison 1965). The remainder of the sample was used for particle size determinations (Jackson 1950).

OBJECTIVE 4

Zellars-Williams, Inc. (1981) last recorded tree survival and growth at Sink Branch on January 20-21, 1981. This survey concentrated exclusively on trees planted during late winter of the previous year because seedlings planted in 1981 had been in the ground for less than a week. Tree survival and growth monitoring was suspended after the January 1981 census, so data were not available on the revegetation effort after that date.

The Institute’s project personnel identified, numbered, tagged and measured all trees on the reclamation site between March and May 1984. Tree identities and locations were plotted on maps of the site to provide a baseline for future study. The height of trees that were less than 2 m tall was recorded from ground level to meristem. Bole diameter at breast height (dbh) was measured on trees greater than 2 m tall.

RESULTS

OBJECTIVE 1

The goal of the first objective of this project was to compare the aquatic macroinvertebrate communities inhabiting the Unmined and Mined channels. The communities were evaluated in terms of species richness (number of species inhabiting the area of interest), community similarity, species diversity and density of organisms collected in standardized samplers. The results of each of these community measures will be presented individually.

Species richness

Changes in diversity are frequently cited throughout the applied literature as evidence that community structure has been altered by external stresses. An obvious measure of diversity is the number of species comprising the community, or species richness. All four sampling techniques discussed in the Methodology section yielded information on species richness.

One hundred-eleven distinct taxa of invertebrates were collected from Sink Branch, exclusive of the oligochaetes. These species were distributed among four phyla, seven classes, 18 orders and 61 families of organisms. In addition, five species of fish were collected from the stream. Table 2 presents a complete taxonomic classification and species list. Collection records by date and sampling device are presented in Appendix Tables 1-34.

The species were not uniformly distributed between the Mined and Unmined channels. One hundred-one species were collected from the Unmined channel, while only 81 species were collected from the Mined channel. Table 3 shows the distribution of species between the sampling locations.

Of the 101 species collected in the Unmined channel, 29 (29%) were restricted to that location. A smaller proportion (11%, or 9 out of 81) were restricted to the Mined location. Table 4 is a list of those species restricted to one or the other of the two channels.

Analysis of variance of the sampling data (excluding chironomid midges counts , which were assessed only from the drift nets) indicated that the four sampling devices did not census the number of species comprising the communities equally well (ANOVA $P<0.001$). Additional analysis revealed that the numbers of species collected by each of the devices were different, and that the order of effectiveness was: dip nets drift nets multiplates substrate cores (SNK $P<0.05$).

Table 2

Taxonomic Classification and Species List

- Phylum Arthropoda
  - Class Crustacea
    - Subclass Ostracoda
      - Order Podocopa
    - Subclass Copepoda
      - Order Eucopepoda
    - Subclass Malacostraca
      - Order Isopoda
        - Family Asellidae
      - Order Amphipoda
        - Suborder Gammaridae
          - Family Talitridae
            - *Hyallela azteca* (Saussure)
      - Order Decapoda
        - Family Astacidae
    - Subclass Branchiopoda
      - Order Diplostraca
        - Suborder Cladocera

  - Class Arachnoidea
    - Order Hydracarina

  - Class Insecta
    - Subclass Pterygota
      - Order Ephemeroptera
        - Family Baetidae
          - *Baetis propinquis* (Walsh)
        - Family Heptageniidae
          - *Stenonema exiguum* Traver
          - *Stenacron interpunctatum* (Say)
        - Family Caenidae
          - *Caenis diminuta* Walker
      - Order Odonata
        - Suborder Zygoptera
          - Family Coenagrionidae
            - *Anomalagrion* sp.
            - *Argia sedula* (Hagen)
            - *Ischnura* sp.
            - *Enallagma cardenium*
        - Suborder Anisoptera
          - Family Libellulidae
            - *Perithemis* sp.
            - *Brachymesia gravida* (Calvert)
            - *Erythemis* (*simplicicollis?*) (Say)

- Family Aeshnidae
  - *Epiaeschna* sp.
- Family Macromiidae
  - *Macromia* (*taeniolata* or *georgina*) Rambur or (Selys)
- Family Gomphidae
  - *Gomphus* (*cavillaris*?) (Needham)
- Order Diptera
  - Family Empididae
  - Family Culicidae
    - *Mansonia perturbans* (Walker)
    - *Uranotaenia sapphirina* (Osten Sacken)
  - Family Chaoboridae
    - *Chaborus albatus* Johnson
  - Family Tipulidae
    - *Dolichopeza* sp.
    - *Tipula* sp.
  - Family Limoniinae
    - *Antocha* sp.
  - Family Simuliidae
    - *Simulium* sp.
  - Family Tabanidae
    - *Chrysops* sp.
  - Family Stratiomyiidae
    - *Stratiomys* sp.
  - Family Ceratopogonidae
    - *Palpomyia* cplx. sp. 1
    - *Palpomyia* cplx. sp. 2
    - Dasyheleinae
    - *Atrichopogon* sp.
  - Family Chironomidae
    - Subfamily Tanypodinae
      - Tribe Macropelopiini
        - *Procladius* sp.
      - Tribe Pentaneurini
        - *Ablabesmyia* sp.
    - Subfamily Orthocladiinae
      - Tribe Orthocladiini
        - *Brillia* sp.
        - *Cricotopus* sp. 1
        - *Cricotopus* sp. 2
        - *Psectrocladius* sp.
        - *Rheocricotopus* sp.
    - Subfamily Chironominae
      - Tribe Chironomini
        - *Chironomus* sp.
        - nr. *Harnischia* sp.
        - *Kiefferulus* sp.
        - *Phaenopsectra* sp.
        - *Polypedilum* sp.
        - *Polypedilum ophiodes* (Townes)
        - *Stenochironomus* sp.
      - Tribe Tanytarsini
        - *Rheotanytarsus* sp.

- Order Hemiptera
    - Family Naucoridae
        - *Pelocoris* *carolinensis* Torre-Bueno
    - Family Gelastocoridae
        - *Gelastocoris* *oculatus* *oculatus* (Fabricius)
    - Family Gerridae
        - *Gerris* sp.
    - Family Hydrometridae
        - *Hydrometra* sp.
    - Family Pleidae
        - *Neoplea* *striola* (Fieber)
    - Family Mesoveliidae
        - *Mesovelia* *mulsanti* White
    - Family Veliidae
        - *Microvelia* *borealis* Bueno
    - Family Belostomatidae
        - *Belostoma* sp.
    - Family Nepidae
        - *Ranatra* *kirkaldyi* Torre-Bueno
        - *Ranatra* *nigra* Herrich-Schaeffer
    - Family Notonectidae
        - *Bueona* sp.
        - *Notonecta* sp.
    - Family Hebridae
        - *Hebrus* sp.
- Order Lepidoptera
    - Family Pyralidae
        - Subfamily Nymphulinae
            - *Petrophilia* *fulicalis* (Clemens)
            - *Munroessa* *icciusalis* (Walker)
            - *Vogtia* sp.
    - Family Noctuidae
        - *Lithacodia* *carneola* (Guenee)
- Order Coleoptera
    - Family Haliplidae
        - *Peltodytes* *sexmaculatus* Roberts
    - Family Simidae
        - *Stenelmis* *crenata* (Say)
        - *Stenelmis* *fuscata* Blatchley
        - *Dubiraphia* sp.
    - Family Noteridae
        - *Suphisellus* (*gibbulus*?) (Aube)
        - *Hydrocanthus* sp.
    - Family Dytiscidae
        - *Hydaticus* sp.
        - *Hydroporus* sp.
        - *Hydrovatus* sp.
        - *Laccophilus* *maculosa* *maculosa* Say
    - Family Gyrinidae
        - *Dineutes* sp.
        - *Gyrinus* (*elevatus*?) LeConte

Family Hydrophilidae
Tropisternus lateralis nimbatus (Say)
Hydrobiomorpha casta (Say)
Berosus sp.
Family Ptilodactylidae
Anchytarsus sp.
Family Heteroceridae
Family Helodidae
Cyphon sp.
Family Chrysomelidae
Hydrothassa obliquata (LeConte)
Order Trichoptera
Family Hydropsychidae
Cheumatopsyche sp. 1
Cheumatopsyche sp. 2
Hydropsyche (*rossi*?) Flint, Voshell, and Parker
Symphitopsyche sparna (Ross)
Family Hydroptilidae
Hydroptila sp.
Orthotrichia sp.
Oxyethira sp.
Family Leptoceridae
Oecetis sp.
Nectopsyche exquisita (Walker)
Leptocella sp.
Triaenodes sp.
Family Philopotamidae
Chimarra sp.
Dolophilodes sp.
Family Polycentropodidae
Cyrnellus fraternus (Banks)
Polycentropus sp.
Family Odontoceridae
Order Neuroptera
Family Sisyridae
Order Collembola
Family Sminthuridae

Phylum Platyhelminthes
Class Turbellaria

Phylum Annelid
Class Hirudinea

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Order Basommatophora

Family Ancylidae
    Ferressia rivularis (Say)
Family Physidae
    Physa sp.
Family Lymnaeidae
  Subfamily Lymnaeinae
Family Planorbidae
Class Pelecypoda
    Family Unionidae

Phylum Vertebrata
  Class Osteichthyes
    Order Teleostei
      Family Centrarchidae
        Lepomis gulosus (Cuvier)
      Family Peociliidae
        Peocila latipinnia (Lesueur)
        Gambusia affinis (Baird & Girard)
        Heterandria formosa Agassiz
      Family Percidae
        Etheostoma fusiforme (Girard)

Table 3
Distribution of Taxa

Taxa	Unmined	Mined
Crustaceans		
Ostracods	+	+
Copepods	+	+
Asellid isopods	-	+
Hyallela *azteca*	+	+
Crayfish	+	+
Cladocera	+	+
Arachnids		
Hydracarina	+	+
Insects		
Baetis *propinquis*	+	+
Stenacron *interpunctatum*	-	+
Stenonema *exiguum*	-	+
Caenis *diminuta*	+	+
Anomalagrion sp.	+	+
Argia *sedula*	+	+
Enallagma *cardenium*	+	+
Perithemis sp.	+	+
Gomphus (*cavillaris*?)	+	+
Brachymesia *gravida*	+	+
Erythemis (*simplicicollis*?)	+	+
Epiaeshna sp.	+	-
Macromia (*taeniolata* or *georgina*)	+	-
Empidids	+	+
Tipula sp.	+	+
Antocha sp.	+	-
Palpomyia *cplx*. sp 1	+	+
Palpomyia *cplx*. sp 2	+	+
Dashelein no-see-ums	+	+
Atrichopogon sp.	-	+
Stratiomys sp.	+	-
Dolichopeza sp.	+	-
Simulium sp.	+	-
Chaoborus *albatus*	+	-
Uranotaenia *sapphirina*	+	-
Mansonia *perturbans*	+	-
Procladius sp.	+	-
Ablabesmyia sp.	+	+
Brillia sp.	+	+
Cricotopus sp. 1	+	+
Cricotopus sp. 2	+	+
Psectrocladius sp.	+	+
Rheocricotopus sp.	+	+

Chironomus sp.	+	-
nr. *Harnischia* sp.	+	-
Parachironomus sp.	+	-
Phaenopsectra sp.	+	+
Polypedilum sp.	+	+
Polypedilum ophiodes	+	+
Stenochironomus sp.	+	+
Rheotanytarsus sp.	+	+
Pelocoris carolinensis	+	+
Hydrometra sp.	+	+
Neoplea striola	+	+
Mesovelia mulsanti	+	+
Gerris sp.	+	+
Gelastocoris oculatus	+	-
Ranatra kirkaldyi	+	-
Ranatra nigra	+	-
Belostoma sp.	+	+
Microvelia borealis	+	-
Notonecta sp.	+	+
Buenoa sp.	+	-
Hebrus sp.	+	-
Petrophila fulicalis	+	+
Lithacodia carneola	+	+
Munroessa icciusalis	+	+
Vogtia sp.	+	-
Peltodytes sexmaculatus	+	+
Stenelmis crenata	+	+
S. fuscata	+	+
Hydrocanthus sp.	+	+
Suphisellus (*gibbulus*?)	+	+
Hydaticus sp.	+	-
Hydroporus sp.	+	-
Hydrovatus sp.	+	-
Berosus sp.	+	+
Dubiraphia sp.	+	+
Hydrothassa obliquata	-	+
Cyphon sp.	+	-
Hydrobiomorpha casta	+	+
Laccophilus maculosa	+	-
Dineutes sp.	+	+
Gyrinus (*elevatus*?)	+	+
Tropisternus lateralis	+	-
Anchytarsus sp.	+	-
Cheumatopsyche sp 1	+	+
Cheumatopsyche sp 2	+	+
Symphitopsyche sparna	+	+
Odontocerid caddisflies	-	+
Hydropsyche (*rossi*?)	+	+
Hydroptila sp.	+	+

Ochrotrichia sp.	+	+
Orthotrichia sp.	+	+
Oxyethira sp.	+	+
Oecetis sp.	+	+
Nectopsyche exquisita	+	+
Chimarra sp.	+	+
Dolophilodes sp.	+	-
Cyrnellus fraternus	+	+
Polycentropus sp.	+	+
Triaenodes sp.	-	+
Leptocella sp.	-	+
Sminthurid springtails	-	+
Sisyrid spongillaflies	+	-
Turbellaria	+	+
Hirudinea	+	+
Gastropods		
Ferressia rivularis	+	+
Physa sp.	+	+
Limnaein snails	+	+
Planorbid snails	+	+
Prosobranch snails	-	+
Pelecypods		
Unionids	+	+

Table 4

Ranges of Restricted Taxa

Unmined	Mined
Epiaeshna sp.	Asellid isopods
Macromia taeniolata	*Stenacron interpunctatum*
Stratiomys sp.	*Stenonema exiguum*
Dolichopeza sp.	*Atrichopogan* sp.
Antocha sp.	*Hydrothassa obliquata*
Simulium sp.	*Odontocerid* caddisflies
Chaoborus albatus	*Triaenodes* sp.
Uranotaenia sapphira	*Leptocella* sp.
Mansonia perturbans	*Sminthurid* springtails
Procladius sp.	
Chironomus sp.	
nr. *Harnischia* sp.	
Parachironomus sp.	
Gelastocoris oculatus	
Ranatra kirkaldyi	
Ranatra nigra	
Microvelia borealis	
Buenoa sp.	
Hebrus sp.	
Vogtia sp.	
Hydaticus sp.	
Hydroporus sp.	
Hydrovatus sp.	
Laccophilus maculosa	
Cyphon sp.	
Tropisternus lateralis	
Anchytarsus sp.	
Dolophilodes sp.	
Sisyrid spongillaflies	

Comparison of the two channels revealed that the sampling devices tended to collect a greater number of species per sample in the Mined channel (ANOVA $P<0.001$), despite the lower overall richness in the channel. The individual Mined samples were richer because the organisms present in the Mined channel are more evenly distributed among the species present than is the case in the Unmined channel.

Although the sampling devices collected more species per sample in the Mined channel than the Unmined, the individual sampling devices did not consistently distinguish between channels. The substrate cores and multiplates collected larger numbers of species in the Mined channel (ANOVA $P<0.001$). The drift net and dip net samples revealed no differences whatsoever in the number of species collected (ANOVA $P>0.05$).

<u>Community similarity</u>

To quantify community similarity, ecologists for decades have used coefficients of community. Similarity measured by a coefficient of community value does not take into account the relative abundances of the various species present in the samples, only whether the species is present or absent from the sample or the community. Community similarity indices bridge the gap between simple comparisons of taxonomic lists and the more complex diversity indices that attach importance values to abundance.

One of the most widely used coefficients of community is the Czekanowski coefficient (Grieg-Smith 1964, Wolda 1981), also known as the Sorensen coefficient (Sorensen 1948) and the "quotient of similarity:"

$$CC_C = \frac{2a}{2a + b + c}$$

where a is the number of taxa common to both communities, b is the number of taxa unique to community 1, and c is the number of taxa unique to community 2. Values for Czeknowski's index range between 0.0 (for two communities with no taxa in common) to 1.0 (for communities with identical taxon lists).

Each invertebrate collection on a given date was compared to all other collections made with the same sampling device on that date. For example, the Mined Upper multiplate sample on May 3, 1983 was compared with each of the other multiplate samples collected on May 3, 1983 using Czeknowski's index. The results were subsequently grouped according to the type of treatment being compared, i.e. Mined samples compared to other Mined samples, Unmined vs. Unmined, and Mined vs. Unmined. These data are presented in Appendix Tables 35 - 38.

Tables 5 - 8 summarize the coefficient of community values for the Sink Branch collections regardless of date. The results for each of the four sampling devices are presented in individual tables. On each table, the community comparisons are grouped according to treatment: Mined vs. Mined, Unmined vs. Unmined, and Mined vs. Unmined. Within each of the three groups, coefficient

Table 5

Summary of Czekanowski's Coefficient of Community (CC_c) Values All Sampling Events

Substrate Core Samples

CC_c	Mined vs. Mined No. Comparisons	Mined vs. Mined Percentages	Unmined vs. Unmined No Comparisons	Unmined vs. Unmined Percentages	Mined vs. Unmined No Comparisons	Mined vs. Unmined Percentages
0.00 - 0.09	4	5.00%	26	32.50%	61	30.50%
0.10 - 0.19	2	2.50	6	7.50	57	28.50
0.20 - 0.29	9	11.25	8	10.00	40	20.00
0.30 - 0.39	14	17.50	13	16.25	28	14.00
0.40 - 0.49	21	26.25	16	20.00	11	5.50
0.40 - 0.59	22	27.50	6	7.50	3	1.50
0.60 - 0.69	7	8.75	4	5.00	-	-
0.70 - 0.79	1	1.25	1	1.25	-	-
	80		80		200	

Table 6

Summary of Czekanowski's Coefficient of Community (CC_c) Values All Sampling Events

Multiplate Samples

CC_c	Mined vs. Mined		Unmined vs. Unmined		Mined vs. Unmined	
	No. Comparisons	Percentages	No Comparisons	Percentages	No Comparisons	Percentages
0.00 - 0.09	2	8.3%	6	25.0%	20	27.8%
0.10 - 0.19	-	-	3	12.5	18	25.0
0.20 - 0.29	1	4.2	3	12.5	16	22.2
0.30 - 0.39	1	4.2	2	8.3	12	16.6
0.40 - 0.49	6	25.0	2	8.3	3	4.2
0.40 - 0.59	10	41.7	1	4.2	3	4.2
0.60 - 0.69	2	8.3	4	16.7	-	-
0.70 - 0.79	2	8.3	1	4.2	-	-
0.80 - 0.89	-	-	2	8.3	-	-
	24		24		72	

Table 7

Summary of Czekanowski's Coefficient of Community (CC_c) Values
All Sampling Events

Drift Net Samples

CC_c	Mined vs. Mined		Unmined vs. Unmined		Mined vs. Unmined	
	No. Comparisons	Percentages	No Comparisons	Percentages	No Comparisons	Percentages
0.00 - 0.09	-	-	-	-	3	2.8%
0.10 - 0.19	-	-	4	4.8%	15	13.9
0.20 - 0.29	1	1.2%	3	3.6	25	23.1
0.30 - 0.39	1	1.2	8	9.5	36	33.3
0.40 - 0.49	16	19.0	11	13.1	25	23.1
0.40 - 0.59	21	25.0	28	33.3	2	1.9
0.60 - 0.69	24	28.6	12	14.3	2	1.9
0.70 - 0.79	14	16.7	10	11.9	-	-
0.80 - 0.89	7	8.3	8	9.5	-	-
	84		84		108	

Table 8

Summary of Czekanowski's Coefficient of Community (CC_c) Values
All Sampling Events

Dip Net Samples

CC_c	Mined vs. Mined		Unmined vs. Unmined		Mined vs. Unmined	
	No. Comparisons	Percentages	No Comparisons	Percentages	No Comparisons	Percentages
0.00 - 0.09	-	-	-	-	-	-
0.10 - 0.19	-	-	-	-	-	-
0.20 - 0.29	1	3.6%	2	7.2%	9	25.0%
0.30 - 0.39	4	14.3	4	14.5	21	58.3
0.40 - 0.49	6	21.4	12	42.5	6	16.7
0.40 - 0.59	9	32.1	7	25.0	-	-
0.60 - 0.69	7	25.0	3	10.8	-	-
0.70 - 0.79	1	3.6	-	-	-	-
	28		28		36	

Table 9
Mean Organism Density

DATE	CORES organisms/m		MULTIPLATES organisms/m		DRIFT organisms/m	
	Unmined	Mined	Unmined	Mined	Unmined	Mined
05-03-83	11,992 ± 25,945	2,096 ± 3,066	320 ± 408	638 ± 468	-	-
06-17-83	2,188 ± 3,214	2,420 ± 514	323 ± 247	200 ± 173	-	-
08-01-83	452 ± 487	936 ± 538	603 ± 661	549 ± 462	0.828 ± 0.423	* 0.450 ± 0.182
09-14-83	556 ± 428	512 ± 212	262 ± 217	1,084 ± 651	-	-
11-03-83	180 ± 84	* 1,144 ± 652	1,526 ± 898	2,710 ± 1,018	1.224 ± 1.380	0.318 ± 0.160
12-21-83	1,236 ± 2,120	2,068 ± 1,257	862 ± 98	1,443 ± 1,492	-	-
02-01-84	992 ± 840	1,032 ± 990	672 ± 343	602 ± 432	0.354 ± 0.349	0.276 ± 0.121
03-14-84	512 ± 580	3,168 ± 5,389	790 ± 188	1,708 ± 1,306	-	-
All Dates	2,264 ± 4,212	1,672 ± 1,577	670 ± 383	1,117 ± 750	0.802 ± 0.717	0.348 ± 0.154

* Significant difference between treatments

of community values are tabulated in ten-unit intervals. In addition, the proportion of comparisons falling within each ten-unit interval is presented.

A consistent pattern of community similarity is apparent for the samples collected with all sampling devices: the collections within the Mined treatment tend to be most similar, followed by the collections within the Unmined treatment. When the two treatments are compared, the Czeknowski index values are much lower, indicating considerable dissimilarity between the two treatments. If an arbitrary cutoff point is selected (e.g. CC_C= 0.50), and the proportions below (dissimilar collections) and above (similar collections) the limits are calculated, the pattern becomes even more apparent (Tables 5 - 8).

Species diversity

All species contribute equally to measurements of diversity based on richness. In an attempt to reduce the significance of the occasional rare species included in a collection (i.e. to differentiate between communities of equal size and richness in which all species are represented by the same number of individuals in contrast to those in which several species are represented by many individuals and many species by few individuals), the abundance of each species can be taken into consideration when calculating diversity. A community with all species present in about equal numbers will, therefore, be more diverse than a second community comprised of the same number of species but with some species common and some rare.

Several measurements of species diversity have been developed based on the study of information theory. All measure the uncertainty of predicting the identity of an individual drawn at random from the entire community. For example, in a community consisting of "n" species all of which are about equally common, it is very difficult to predict the specific identity of any individual drawn at random. In a second community, though, also with "n" species in which species$_1$ (S_1) is very common and S through S are rare, the probability of predicting the identity of a randomly selected individual is much higher. Therefore, the uncertainty, or diversity, of a community can be increased by increasing "n", the species richness, or by evening-out the distribution of the individuals among species.

Among the most commonly used diversity estimates is the Shannon-Wiener Index. In its simplest form, it is expressed by:

$$H' = - \sum_{i=1}^{n} p_i \ln p_i$$

(MacArthur and MacArthur 1961) where n is the number of species and p_i is the proportion of the total number of individuals belonging to the i-th species.

Species diversity values for each channel are reported in Appendix Tables 39-42. The sample diversities are organized by date and sampling device.

None of the sampling devices revealed significant differences in the species diversity of samples collected within channels (ANOVA P>0.05). In terms of diversity, the benthic communities were uniform over the length of each of the channels.

While all of the sampling devices verified the homogeneity of the aquatic communities within the two channels, the consensus among sampling techniques broke down when the diversities of samples collected from the two channels were compared. Diversities of the dip net and drift net samples were not significantly different between the two channels (ANOVA P>0.05). However, samples collected from the Mined channel by the stovepipe cores and the multiplates were more diverse than those collected from the Unmined channel (ANOVA 0.01>P> 0.001 and 0.05>P>0.01, respectively). Therefore, two of the sampling devices indicated that there were differences in diversity between channels, while two others indicated no differences between the two communities. These results mirror the data on taxonomic richness provided by the individual sampling devices.

Additional analyses of variance were performed to examine changes in community diversity by date. Like the richness data, the results of the multiplate and dip net samples revealed no changes in diversity over the 12-month sampling period (P>0.05). The drift net and substrate core samples, on the other hand, were most diverse during late spring and summer. Richness estimated with the drift nets and substrate cores did not change seasonally. Diversity declined in the autumn then began to increase again in late winter (ANOVA 0.05>P>0.001 and P<0.001, respectively).

Density

The density of organisms inhabiting a given area may be an indication of the trophic quality of the habitat, the number of microhabitats that are available, or both. Density was estimated using the three quantitative sampling techniques employed in this study: multiplates, substrate cores and drift nets.

Table 9 presents average organism density by date, sampling device and channel. The values reported in the table are the means of all replicate samples collected on that date with standard deviations indicated. Densities for the substrate cores and the multiplates are shown in numbers of organisms per square meter of surface, whereas drift density is reported as number of organisms per cubic meter of water filtered.

Analysis of variance of the core data revealed no significant differences in density between sites within each of the channels, regardless of date (ANOVA P>0.25). The same held true for the multiplate data.

The densities of the substrate core samples were compared between channels by evaluating all samples in each channel regardless of date. Analysis of variance confirmed ($0.25<P<0.50$) that the number of macroinvertebrates inhabiting a given unit of area on the substrate in both channels was nearly identical. The Hester-Dendy multiplate samples corroborate the results of the cores (ANOVA $0.10<P<0.25$).

In an effort to determine whether organism density differed between sampling devices, the substrate core sample data were compared to the multiplate sample results by analysis of variance. The test revealed that organism density based on core samples was not significantly different from density estimates based on the Hester-Dendy multiplate samples. Even though the components of the entire community that are sampled by these two techniques may differ somewhat (refer to results of the species richness collections), our results indicate that density of organisms is not substantially different between sampling devices.

The coefficient of variation was calculated to compare the variability inherent in the density samples. The coefficient relates the standard deviation to the sample mean values. Higher values are indicative of higher variability (Elliott 1977). Analysis of variance indicated that there were no significant differences in the coefficients of variation of the density data between channels. This held true, regardless of whether the samples were collected with the substrate core ($0.10<P<0.25$) or the multiplates ($P>0.75$). In order to determine if either of the sampling devices produced less variability than the other, the coefficients of variation for the core samples were compared with those for the multiplates. Although the multiplate density estimates generally exhibited lower variability than those reported from the cores, there was such disparity between samples that significant differences between sample types were not apparent ($0.1<P<0.25$).

Drift density data were available for three out of four dates; current velocity and discharge data were unavailable for the first sampling event (May 3, 1983), so it was impossible to calculate flow volume or the quantity of water filtered on that date. The density of organisms in the Mined channel was lower than that drifting in the Unmined channel, but the differences in density were not significant (ANOVA $P>0.05$). Coefficients of variation were calculated for the Mined and Unmined drift density data for each date independently. Analysis of variance revealed that there were no significant differences in variability between samples collected in the Mined channel and those collected in the Unmined channel ($0.5<P<0.75$).

OBJECTIVE 2

Comparison of water quality between treatments (Unmined vs. Mined) on August 1-2, 1983 is reported in Table IO. Data for water collected above the excavated channel ("above") are compared with data

Table 10

Water Quality in Control and Reclaimed Channels
1-2 August 1983

Time	Suspended Solids (mg/1)		Dissolved Solids (mg/1)		Turbidity (J/F/NTU)		Nitrogen NO_3 (mg/1)		Nitrogen TKN (mg/1)		Nitrogen NH_3 (mg/1)		O-Phosphate Total (mg/1)		Chl-A (μg/1)		Phaeopytin (μg/1)	
	Control	Mined	Control	Mined	Control	Mined	Control	Mined	Control	Mined	Control	Mined	Control	Mined	Control	Mined	Control	Mined
2400	< 5	< 5	109	107	2.2	1.8	0.856	4.68	0.45	1.1	0.01	0.14	0.296	0.267	1.52	3.46	< 0.2	< 0.20
0600	< 5	< 5	115	124	2.3	1.8	0.865	4.91	0.46	1.2	0.01	0.13	0.310	0.254	1.63	3.94	< 0.2	0.55
1200	< 5	12	116	120	3.0	4.3	0.823	4.63	0.46	1.6	0.02	0.14	0.284	0.259	2.02	5.78	< 0.2	10.80
1800	< 5	< 5	110	99	2.7	1.3	0.817	4.49	0.45	1.1	0.01	0.13	0.332	0.244	2.92	4.69	< 0.2	< 2.09

Table 11

Water Quality Above and Below Reclaimed Channel

Date	Time	Suspended Solids (mg/l)		Dissolved Solids (mg/l)		Turbidity (J/F/NTU)		Nitrogen NO_3 (mg/l)		Nitrogen TKN (mg/l)		Nitrogen NH_3 (mg/l)		O-Phosphate Total (mg/l)		Chl-A (µg/l)		Phaeophytin (µg/l)	
		above	below	above	below	above	below	above	below	above	below	above	below	above	below	above	below	above	below
9-14-83	2400	<5	<5	110	104	3.9	4.4	0.755	0.715	0.93	0.90	0.03	0.01	0.377	0.379	0.70	0.70	1.06	3.75
	0600	<5	<5	109	112	2.5	2.8	0.855	0.807	0.72	0.72	0.02	0.01	0.315	0.308	0.70	0.70	1.07	0.20
	1200	<5	5	109	108	4.6	3.6	0.811	0.785	0.77	0.72	0.03	0.01	0.314	0.308	2.17	1.05	2.21	0.53
	1800	<5	<5	103	107	5.2	5.9	0.765	0.685	0.85	0.76	0.03	0.01	0.371	0.418	0.70	1.66	1.12	2.46
11-3-83	2400	<5	8	91	90	3.3	4.7	2.130	2.100	0.74	0.65	0.02	0.01	0.254	0.247	1.35	0.39	7.56	14.30
	0600	<5	<5	91	91	2.8	3.4	2.170	2.140	0.78	0.60	0.02	0.01	0.246	0.242	5.35	3.85	9.00	12.40
	1200	<5	7	90	138	2.4	7.7	2.060	2.040	0.67	0.62	0.02	0.02	0.242	0.240	4.97	1.48	8.65	15.10
	1800	<5	<5	91	92	2.8	3.2	2.060	2.020	0.67	0.64	0.01	0.01	0.255	0.246	1.73	0.48	6.36	5.85
12-21-83	2400	6	5	102	109	3.0	3.1	2.150	2.130	0.71	0.65	0.04	0.02	0.326	0.325	0.32	0.40	0.75	<0.20
	0600	10	8	110	109	8.8	3.0	2.150	2.100	0.78	0.76	0.04	0.02	0.499	0.338	2.65	2.49	<0.20	0.32
	1200	13	30	110	104	6.4	2.8	2.110	2.160	0.76	0.67	0.03	0.03	0.353	0.325	1.20	1.04	<0.20	0.47
	1800	9	16	110	113	3.1	4.6	2.170	2.100	0.71	0.66	0.03	0.02	0.323	0.325	1.12	0.32	<0.20	0.46
2-1-84	2400	<5	5	86	78	2.5	2.2	3.490	3.490	0.74	0.78	0.03	0.02	0.228	0.219	1.25	2.31	0.77	<0.20
	0600	<5	14	89	81	2.2	3.8	3.590	3.540	0.75	0.70	0.03	0.01	0.214	0.214	0.87	5.39	<0.20	2.09
	1200	<5	<5	90	77	2.0	2.0	3.480	3.450	0.81	0.59	0.02	0.01	0.211	0.209	1.54	5.58	0.62	1.09
	1800	<5	<5	83	85	2.4	2.5	3.470	3.440	0.84	0.75	0.02	0.01	0.223	0.217	2.69	1.73	0.25	1.70
3-14-84	2400	6	<5	98	102	2.9	2.2	2.870	2.820	0.63	0.62	0.02	<0.01	0.250	0.230	0.70	<0.70	1.88	1.30
	0600	<5	6	84	80	2.5	3.1	2.860	2.840	0.63	0.53	0.02	<0.01	0.261	0.239	2.65	4.41	2.24	2.61
	1200	<5	14	84	98	3.0	5.6	2.830	2.800	0.55	0.73	0.02	<0.01	0.258	0.286	1.44	10.80	1.87	2.60
	1800	6	6	100	100	2.9	3.2	2.800	2.740	0.64	0.66	0.03	<0.01	0.248	0.233	0.96	<0.70	1.17	1.68
5-3-84	2400	<5	<5	82	79	2.4	2.0	1.480	1.320	0.51	0.63	0.01	<0.01	0.162	0.113	<0.70	1.60	0.95	0.42
	0600	<5	<5	82	82	2.1	1.5	1.690	1.520	0.40	0.58	0.01	<0.01	0.150	0.142	1.92	1.76	<0.20	0.31
	1200	<5	<5	88	84	1.7	1.2	1.560	1.430	0.48	0.61	0.01	<0.01	0.152	0.145	4.25	1.36	0.97	0.60
	1800	<5	<5	82	81	3.1	2.1	1.470	1.300	0.64	0.39	0.01	<0.01	0.166	0.153	<0.70	0.96	0.78	<0.20
6-14-84	2400	<5	<5	84	82	3.7	1.4	1.170	0.957	0.25	0.13	0.01	<0.01	0.203	0.177	<0.70	<0.70	1.57	<0.20
	0600	<5	<5	76	80	3.5	1.8	1.230	1.060	0.23	0.15	0.01	<0.01	0.203	0.200	0.72	<0.70	1.58	1.15
	1200	6	<5	92	84	9.5	2.0	1.190	0.971	0.26	0.17	0.03	<0.01	0.426	0.209	1.76	0.72	2.05	0.62
	1800	5	<5	90	88	3.7	1.7	1.050	0.758	0.19	0.14	0.01	<0.01	0.209	0.182	<0.70	1.52	1.54	<0.20

for water collected at the downstream end of the Mined channel ("below") on seven dates between September 14, 1983 to June 14, 1984 in Table 11.

Water Quality Between Treatments

In terms of physical parameters (suspended and dissolved solids and turbidity), water quality was very similar between treatments. The only anomalous values appeared in the Mined channel at noon on August 1, 1983 when suspended solids, dissolved solids and turbidity showed a sharp increase. This rise can be attributed to the fact that invertebrate sampling had recently been completed 112 m upstream of the water collection point.

Chemically, the two sections of the stream were more disparate. The concentrations of all forms of nitrogen (nitrite/nitrate, ammonia and Kjeldahl), chlorophyll a and phaeophytin were much higher in the excavated channel than in the Unmined portion upstream. Conversely, orthophosphate levels in the Mined channel were always lower over the 24 hour sampling period than those reported in the Unmined area.

Water Quality Above and Below the Mined Treatment

Samples collected immediately above and below the excavated channel revealed that, for a large majority of the dates, parameters and times, the water exiting the Mined channel was of better quality than water entering the channel from upstream. This trend is demonstrated especially well by the chemical parameters (i.e., nitrogen species and orthophosphate). However, statistical evaluation of the data revealed that the only characteristic that was significantly different was ammonia-nitrogen, (ANOVA $P<0.001$).

OBJECTIVE 3

Eighteen substrate samples were collected from the Sink Branch streambed. Three replicate samples were collected at each of the three sites in both channels. Table 12 reports the results of the particle size and organic carbon composition analyses.

Analysis of variance indicated a uniformity of particle size distribution and organic carbon content among all samples collected within the same channel. Similarly, a comparison of the particle size distributions and organic carbon content revealed no significant differences (ANOVA $p>0.05$) between the Mined and Unmined channels.

OBJECTIVE 4

Tree counts conducted between, March and May 1984 disclosed 531 trees growing on the 1.01 ha reclamation site (Appendix Table 43). The locations of the trees on the site corresponding with the data in Appendix Table 43 are included on Appendix Figures 15 A-F. Ten species were represented: sweetgum (*Liquidambar styraciflua* L.), live

Table 12

Substrate Composition

Percentages by Weight

	Unmined				Mined			
	Upper	Middle	Lower	Mean	Upper	Middle	Lower	Mean
Clay	3.2	1.3	1.9		44.0	31.7	5.2	
	1.1	2.0	0.0	1.1	32.2	10.1	5.3	19.6
	0.3	0.1	0.1		4.1	39.1	4.6	
$\bar{x}$	1.5	1.1	0.7		26.7	27.0	5.0	
Silt	0.4	1.0	4.1		7.3	2.0	0.0	
	0.7	3.3	0.2	1.3	6.5	2.2	2.2	2.8
	1.0	0.2	0.9		2.1	2.7	0.0	
$\bar{x}$	0.7	1.5	1.7		5.3	2.3	0.7	
Sand	96.4	97.7	94.4		48.7	66.3	94.8	
	98.2	94.7	99.8	97.6	61.3	87.7	92.5	77.6
	98.7	99.7	99.0		93.8	58.2	95.4	
$\bar{x}$	97.8	97.4	97.7		67.9	70.7	94.2	
Organic	1.8	3.4	23.7		41.5	6.5	5.2	
Carbon	1.0	4.1	0.2	4.4	6.5	4.4	7.5	9.9
	4.1	0.2	0.9		2.1	11.8	3.7	
$\bar{x}$	2.3	2.6	8.3		16.7	7.6	5.5	

oak (Quercus virginiana Mill.), Florida elm (Ulmus floridana Chapm.), slash pine (Pinus elliotti Engelm.), sweetbay (Magnolia virginiana L.), red maple (Acer rubrum L.), bald cypress (Taxodium distichum Rich.), green ash (Fraxinus pennsylvanica Marsh.), dogwood (Cornus florida L.), and black cherry (Prunus serotina Ehrh.). All of the trees with the exception of the black cherries had been planted on the site; the cherries (represented by five individuals) volunteered from seeds.

Survival

Tables 13-17 are a synopsis of the tree plantings, 12-month survival data, and longer term (3-4 year) survival data (where available) by species, planting stock and planting location. Because Mobil did not tag all of the trees planted on the site, and because the majority of the labeled trees had lost their tags in the intervening three years, it was possible to develop longer term survival data by planting stock for only a limited number of species and stocks. Table 18 presents a summary of the plantings and longer-term survival for all species by planting location regardless of planting stock.

Tree survival varied considerably between species, planting stocks and planting location. The results of each of the planting varieties will be discussed separately.

Tree Spade. Survival data are available for four of six species tree spaded onto the reclaimed site: sweetgum and live oak (short-term survival only), and elm and sweetbay (short- and long-term survival). The remaining two species (slash pine and red maple) were planted in numbers too low to be evaluated statistically. The sweetgum and oak transplants showed no significant differences (G-test $P>0.05$) in survival between planting sites after one growing season. Elm and sweetbay (tree spaded transplants) both exhibited significant differences (G-test elm $P<0.001$, sweetbay $0.001<P<0.01$) in survival between sites. The differences were evident after one growing season and persisted for the following three years. For elm, the order of survival by site was: 2/4>3>1, for sweetbay: 4>2/3.

Potted Seedlings. Potted seedlings are available in several forms ranging from trees rooted in plastic nursery pots to "tubelings" grown in a variety of tubelike containers. All are alike in that soil surrounding the root mass is transferred to the planting hole with the tree, minimizing damage to the root system.

Five species were planted as potted seedlings, and survival data are available for all five: sweetgum and pine (short-term only), and maple, ash and cypress (short- and long-term). Potted sweetgum and pine both showed highly significant short-term responses to planting location (G-test $P<0.001$). The order of survival after one growing season was 2>1>3>4 for sweetgum and 1>2>4>3 for pine. Maple showed significant differences after 12 months (G-test $0.001<P<0.01$) and 4 years (G-test $P<0.001$) with order of survival by site: 2>1>3>4. Cypress showed significant differences in survival after 12 months (G-test $0.01<P<0.05$) (order of survival: 1/2>3>4), but the differences disappeared after three additional growing seasons (G-test $P>0.05$).

Table 13
Planting and Survival Data
Treatment 1 - Topdressed with 30 cm Topsoil

Planting Stock and Species	Planted 1980	Surviving 1981		Planted 1981	Surviving 1984	
		Number	Percentage		Number	Percentage
Tree Spade						
Sweetgum	11	10	91%	-	-	-
Oak	8	6	75%	-	6	75%
Elm	4	0	0%	-	-	0%
Pine	-	-	-	-	-	-
Sweetbay	-	-	-	-	-	-
Maple	-	-	-	-	-	-
Potted Seedling						
Cypress	11	11	100%	10	10	48%
Ash	13	13	100%	12	11	44%
Sweetgum	29	26	90%	18	-	-
Maple	28	15	71%	14	5	12%
Pine	26	22	85%	20	37	80%
Bare Root						
Sweetgum	90	33	36%	-	-	-
Oak	13	3	23%	-	1	7%
Dogwood	25	0	0%	-	0	0%
Pine	-	-	-	3	3	100%

Table 14
Planting and Survival Data
Treatment 2 - Topdressed with 15 cm Topsoil

		Surviving 1981			Surviving 1984	
Planting Stock and Species	Planted 1980	Number	Percentage	Planted 1981	Number	Percentage
Tree Spade						
Sweetgum	7	6	86%	-	-	-
Oak	10	7	70%	-	-	-
Elm	3	3	100%	-	3	100%
Pine	-	-	-	-	-	-
Sweetbay	7	4	57%	-	0	0%
Maple	-	-	-	-	-	-
Potted Seedling						
Cypress	13	13	100%	-	4	31%
Ash	16	16	100%	-	4	25%
Sweetgum	29	28	97%	-	-	-
Maple	28	25	89%	-	12	43%
Pine	31	25	81%	-	11	35%
Bare Root						
Sweetgum	110	30	27%	-	-	-
Oak	14	8	57%	-	-	-
Dogwood	31	7	23%	-	3	1%
Pine	-	-	-	2	1	50%

Table 15
Planting and Survival Data
Treatment 3 - Fertilized Transplants

Planting Stock and Species	Planted 1980	Surviving 1981		Planted 1981	Surviving 1984	
		Number	Percentage		Number	Percentage
Tree Spade						
Sweetgum	10	6	60%	-	-	-
Oak	29	21	72%	-	-	-
Elm	5	5	100%	-	4	80%
Pine	1	0	0%	-	0	0%
Sweetbay	8	0	0%	-	0	0%
Maple	1	1	100%	-	-	-
Potted Seedling						
Cypress	13	10	76%	-	3	23%
Ash	16	13	81%	-	2	13%
Sweetgum	25	18	72%	1	-	-
Maple	29	17	59%	-	-	-
Pine	50	19	38%	2	-	-
Bare Root						
Sweetgum	110	20	18%	-	-	-
Oak	63	5	8%	-	-	-
Dogwood	24	2	9%	-	0	0%
Pine	-	-	-	49	-	-

Table 16
Planting and Survival Data
Treatment 4 - Control (No Treatment)

		Surviving 1981			Surviving 1984	
Planting Stock and Species	Planted 1980	Number	Percentage	Planted 1981	Number	Percentage
Tree Spade						
Sweetgum	1	1	100%	-	-	-
Oak	16	12	75%	-	-	-
Elm	4	3	75%	-	4	100%
Pine	1	0	0%	-	0	0%
Sweetbay	1	1	100%	-	1	100%
Maple	2	2	100%	-	0	0%
Potted Seedling						
Cypress	8	6	75%	10	3	17%
Ash	5	5	100%	10	1	7%
Sweetgum	17	12	71%	19	-	-
Maple	15	8	53%	10	0	0%
Pine	43	17	40%	38	-	-
Bare Root						
Sweetgum	90	16	18%	-	-	-
Oak	60	1	2%	-	-	-
Dogwood	20	2	10%	-	0	0%
Pine	300	2	1%	55	-	-

Table 17
Planting and Long-Term Survival

	Treatment 1 Planted	Treatment 1 Surviving	Treatment 1 % Surv.	Treatment 2 Planted	Treatment 2 Surviving	Treatment 2 % Surv.
Sweetgum	148	54	36%	146	29	20%
Oak	21	7	33%	24	9	38%
Elm	4	0	0%	3	3	100%
Pine	49	40	82%	33	12	39%
Sweetbay	-	-	-	7	0	0%
Maple	42	5	12%	28	12	43%
Cypress	21	10	48%	13	4	31%
Ash	25	11	44%	16	4	25%
Dogwood	25	0	0%	31	3	10%

	Treatment 3 Planted	Treatment 3 Surviving	Treatment 3 % Surv.	Treatment 4 Planted	Treatment 4 Surviving	Treatment 4 % Surv.
Sweetgum	146	20	14%	127	20	16%
Oak	92	27	29%	76	13	17%
Elm	5	4	80%	4	4	100%
Pine	102	6	6%	437	20	5%
Sweetbay	8	0	0%	1	1	100%
Maple	30	7	23%	27	0	0%
Cypress	13	3	23%	18	3	17%
Ash	16	2	13%	15	1	7%
Dogwood	24	0	0%	20	0	0%

Table 18

Long-Term Survival Regardless of Planting Stock

Species	Significance	Survival Order
sweetgum	$P<0.001$	1 > 2 > 4 > 3
pine	$P<0.001$	1 > 2 > 3 > 4
maple	$P<0.001$	2 > 3 > 1 > 4
sweetbay	$0.001<P<0.01$	4 > 2/3
ash	$0.001<P<0.01$	1 > 2 > 3 > 4
elm	$P<0.001$	2/4 > 3 > 1

Green ash exhibited survival that is difficult to interpret. Survival after 12 months was not influenced by planting location (G-test $P > 0.05$), but an evaluation of survival data three years later revealed significant differences (G-test $0.001 < p < 0.01$), with best survival in Site 1 and declining survival in each consecutive location.

Bare-Root Seedlings. Three species were planted in sufficient numbers to evaluate bare root stock as a planting type: sweetgum and live oak (short-term survival only), and dogwood (short- and long-term survival). Bare root slash pine were also planted, but only in large numbers in sites 3 and 4. Unfortunately, few of the tags remained on the trees, making an evaluation of planting stock impossible.

All three species for which planting stock data are complete showed significant differences in survival between locations after one growing season (G-test sweetgum $0.001 < P < 0.01$, oak $P < 0.001$, dogwood $0.01 < P < 0.05$). The order of survival by location for each species was sweetgum and live oak: 1>2>3>4; dogwood: 2>4>3. The differences between locations for dogwood, however, disappeared after four years (G-test, $p > 0.05$).

The impact of the planting sites on long-term survival regardless of planting stock varied between species. The survival of only three of the planted species was not influenced by planting site (G-test, $P > 0.05$): live oak, dogwood and cypress. The remaining six species exhibited differences in survival that depended on the location (Table 19).

Growth

The effects of the various planting locations on long-term tree growth were evaluated for all species except sweetbay and dogwood, which were present in numbers too low to evaluate statistically. Growth responses were measured by comparing the diameters (dbh) of trees of the same species between locations regardless of planting stock. In order to ignore the effect of planting stock, however, it was necessary to assume that, for each species considered individually, similar numbers of trees of each stocking type were planted in the four locations. An examination of the planting data in Tables 10-13 reveals that the assumption is generally valid. If the assumption were not applicable, disproportionately large numbers of bare-root seedlings or tree-spaded trees could lead to a built-in bias.

Except for slash pine, there were no differences in growth between planting sites for any of the species of trees (ANOVA $P > 0.05$). Unlike survival, the locations had no long-term influence on growth. Slash pine was the only species that responded to location (ANOVA $P < 0.001$). Additional evaluation of the pine growth data with the Student-Newman-Keuls (SNK) test revealed that the growth response of Site 2 was greatest, followed by Site 1. The effects of Sites 3 and 4 were not separable and were significantly lower than those for Sites 1 and 2.

DISCUSSION

OBJECTIVE 1

Multiplate artificial substrate devices were included in the Sink Branch sampling regime in order to differentiate between the channels without introducing sample variability that could be attributable to differences in microhabitat or sampler efficiency. By presenting identical, standardized colonization sites to the benthic fauna, some investigators have demonstrated a higher level of sampling precision than could be obtained using direct sampling techniques (Beak et al. 1973, Weber 1973, Shaw and Minshall 1980). Other studies, however, have not always corroborated a significant reduction in variability (Mason 1976, Rabeni and Gibbs 1978, Hughes 1975, Chadwick and Canton 1983).

In order to compare variability in sampling methods, a coefficient of variation value was calculated for the organism density and species richness data collected by the substrate core, drift net and multiplate samplers (Elliott 1977). In terms of both total density and number of species, the artificial substrate samples were no more or less variable than either of the direct sampling techniques. The lack of variability was evident for all sampling events and for both treatments. In fact, none of the sampling devices exhibited any significant variability, either between treatments or sampling events, indicating that all three techniques offer precise estimates of richness and diversity for those components of the macroinvertebrate community they are designed to census.

Richness

Few generalizations can be made about the species restricted to either of the channels. Many dipteran and hemipteran species were found only in the Unmined channel, but most of these species were represented by very few, and in some cases, one individual. In addition, the species restricted to the Unmined channel filled a wide and diverse array of trophic and behavioral niches; they could not be classified as exploiting a single resource or set of resources that are more common in the Unmined channel than in the Mined channel.

The comparatively fewer species in the Mined channel may be a result of the failure of reproductive individuals to locate the channel or a lack of habitat suitable for colonization. The Mined channel is separated from the few remaining portions of relatively undisturbed aquatic habitat upstream by intervening stretches of channelized and otherwise severely disturbed streambed. Aquatic invertebrates that might have colonized the Mined channel by drift or migration from upstream could have been excluded by the difficulty of negotiating long distances of poor habitat. Migration upstream from the intact Peace River floodplain is similarly precluded by mining-related disturbances. The difficulties associated with colonization via the aqueous environment notwithstanding, though, the depauperate fauna of the Mined area is probably more a reflection of lack of suitable habitat within the channel rather than isolation from distant sources of colonization. Inhospitable conditions upstream and downstream of the channel may prevent transit by immatures, but the area is within easy dispersal distance of aerial adults. The channel probably does not offer the diversity of habitats that are needed to support all of the organisms found in the Unmined channel.

The Mined streambed, as previously described, consists largely of a relatively featureless channel with a deep, sticky, anoxic substrate in which is rooted a single type of vegetation. In contrast, the channel of the Unmined area features various hydrophyte species rooted in a sandy matrix. Roots of riparian trees extending into the channel deflect, the current and larger roots form miniature dams that create pools on their downstream sides. Numerous studies have demonstrated that the more complex the substratum, the more diverse the invertebrate fauna (Hynes 1970); the richness data from the two Sink Branch channels further confirm this general finding. While muddy substrates such as those that are found in the Mined channel may be very rich in biomass, they tend to harbor few species (Sprules 1947). The Sink Branch data are in agreement on this point as well since richness is lower in the Mined channel but substrate organism density is not significantly different from that found at the Unmined site.

Community Similarity

The results of the Czeknowski coefficient of community comparisons lend further support to the explanation for the discrepancies observed between the two treatments. The comparisons within the Mined collections display the greatest similarity, followed by those within the Unmined treatment. The samples collected between the Mined and Unmined treatments tended to be least similar. The relative homogeneity of the Mined channel and the concomitant paucity of microhabitats appears to limit the number of taxa inhabiting the area. Because the channel is so similar along its entire length, a sample taken in any one spot should be fairly similar to a sample collected at nearly any other location.

The more diverse habitat offered by the Unmined channel, with alternating runs and pools, considerably more stable and well-aereated substrate, submerged snags and tree roots, and several varieties of aquatic macrophytes, increases the probability that collections made within the Unmined area will differ from one another. The similarity of samples depends to a much greater extent on the type of specific microhabitat sampled than it did in the Mined channel. Organisms collected clinging to a snag or buried in clean sand will most likely be different from those collected in a bed of watergrass.

Significant portions of the macroinvertebrate communities in both the Mined and Unmined channels are comprised of different taxa, leading to the low Czeknowski values obtained when the two treatments were compared. The diversity of the microhabitats available in the Unmined treatment, the lack of similar heterogeneity in the Mined channel, plus the differences in habitat characteristics all combine to limit the similarity of the communities inhabiting the two channels.

Diversity

Species diversity measured by the Shannon-Wiener index is only the diversity of the individual sample, not the entire community. How closely sample diversity matches that of the intact community is directly related to how accurately the sample represents the population from which it was collected. The results of the Sink Branch investigation strongly suggest that the individual sampling devices did not all sample the same components of the larger community and, as a consequence, do not lead to identical conclusions about the organization of the benthic communities in the two channels. The dilemma, then, is how to interpret the findings.

The dip net and drift net sample diversities were not significantly different between channels. The dip nets collected organisms indiscriminately from all microhabitats in the stream including the substrate, vegetation rooted in the current, plant roots and stems along the periphery, and sunken, waterlogged limbs. The drift nets were more selective, sampling only those organisms suspended in the current. Except during spates (catastrophic drift), most drifting is a behavioral response to crowding, predation, or lack of food, and some species are more common components of the drift fauna than others.

Unlike the results from the two net samplers, however, the substrate core and multiplate results indicated differences in diversity, with higher diversity in the Mined channel than the Unmined. The cores are restricted to sampling organisms on and within the substrate and on vegetation. Like the drift nets, the multiplates sample only organisms that come into contact with and colonize the device suspended in the current. The multiplates are inherently biased because they will exclude burrowing and some sessile species (e.g. bivalves) while they will disproportionately collect other organisms that require a firm substrate for attachment.

While each of the devices sampled a different portion of the benthic community, and each portion could have a diversity that differed from the others, overall the community inhabiting the Mined channel probably is more diverse than that in the Unmined. The lack of corroboration from the dip net and drift net samples can be attributed to the fact that the drift and dip nets collected many benthic taxa that were not collected by the other samplers. In fact, the dip nets were the most effective device for collecting these "unique" taxa, followed by drift nets. Most of the unique taxa in the drift were present in low numbers and were restricted to the Unmined channel. Because Shannon-Wiener diversity is an expression of the distribution of organisms among species (evenness) as well as the number of species present (richness), lower diversity in terms of evenness is balanced by the greater richness of the individual samples collected from the Mined channel. The even distribution of organisms among species collected by the cores and multiplates in the Mined channel produced a significant difference in species diversity between the two areas.

Measurements of diversity are frequently used throughout the applied literature as evidence that community structure has been altered by external stresses. Almost invariably, an organically enriched ecosystem is less diverse than the unperturbed control. Patrick's (1949) line of reasoning to explain this finding is not atypical: under normal conditions a great many species representing various taxonomic groups should be present in the community but no single species should be represented by a large number of individuals. If the ecosystem has remained fairly stable for a reasonable length of time, it should offer a wide variety of microhabitats suitable for colonization by many different species. Competition would be intense and minor differences in conditions would serve as barriers that precisely limit niche boundaries. An external stress could eliminate many species. The few which manage to survive would be released from competition and have a greater opportunity to multiply. The result would be a reduction in species number and a greater abundance of those that remain.

In most cases, Patrick's explanation is tenable. The majority of the stresses with which applied benthic ecologists are faced are pollutants producing enrichment or toxicological effects. For example, tolerances to low oxygen tension resulting from high biochemical oxygen demand in organically polluted waters are not uniform among all benthic invertebrates, with some species typically able to survive in far more anaerobic conditions than others. The same is true of poisons. In extreme instances, pollutants could result in extirpation of some groups and a decline in species number in others reducing diversity far below the level found before the addition of the pollutant.

Even though they are perhaps the most common, however, pollutants are not the only stresses to which aquatic ecosystems are subject. Streams with severly disturbed watersheds may be influenced by increased turbidity and bed load, elevated water temperatures, direct insolation, and reduced input of allochthonous material. Some of the disturbances mimic the effects produced by pollutants and it is not difficult to understand their role in reducing diversity. For example, sediment fills the intersticies in the substrate and eliminates a variety of microhabitats, and increased turbidity can severely damage organisms with delicate external respiratory structures. But alterations persisting beyond the initial disturbance are far less predictable and the effects on diversity are not as clear.

Michael Huston (1978) put forth the argument that perhaps we actually ought to expect diversity values in samples collected from disturbed ecosystems to be higher, not lower, than those from undisturbed systems. Huston based his hypothesis on differences in the rates at which populations of competing species making up a community approach the competitive equilibrium that exists in a system which has remained stable for ecologically significant periods of time. The hypothesis assumes that most communities exist in a state in which equilibrium is prevented from developing by periodic population reductions and environmental fluctuations. When this equilibrium is disturbed, a dynamic balance may be established between the rate of competitive displacement (the reduction in numbers or exclusion of some species) and the frequency of population reduction which results in a stable level of diversity. Under conditions of infrequent reductions (i.e. as the system approaches relative stability), the differences in the intrinsic growth rates of competitors will generally result in decreased diversity since those species with higher growth rates tend to have the competitive advantage and are able to exclude competitors.

The benthic environment of the relatively undisturbed Unmined channel has a high degree of predictability even if conditions do not remain constant. Spates constitute the only serious potential disturbance of the benthic community and such flooding is rare. Channel disturbance, on the other hand, obviously upsets the dynamic equilibrium that existed in the community, thereby allowing renewed competition by formerly excluded species. In Huston's view, the addition of new immigrant species or the expansion of preexisting older populations that were kept in check by superior competitors would increase the diversity following the disturbance.

Density

Tsui and Breedlove (1978) compared benthic samples collected in lotic environments in Florida by multiplates and by petite Ponar grabs. They concluded that data developed from the two samplers cannot be meaningfully compared because the devices sampled different components of the benthic community. The stovepipe core used in this investigation effectively sampled the same habitat as Tsui and Breedlove's petite Ponar. Like the petite Ponar, the coring device differed significantly from the multiplate in the ability to qualitatively census benthic community composition. However, both the cores and the multiplates were equally effective for measuring organism density. Both methods also revealed that there were no differences in the density of organisms inhabiting the two channels considered overall and on an individual sampling event basis. These results reflect the homogeneity of the channels.

Density of macroinvertebrates in the stream fluctuated over the 12-month sampling period. Densities measured by the cores and multiplates (drift densities were collected too infrequently to develop any patterns) reached a peak during the winter and fell to their lowest levels in late summer. The multiplate density increase tended to begin approximately six weeks prior to that of the cores. In addition, the core sample density tended to be bimodal: the maximum density was reached in early winter, density declined in early spring, then increased again in late spring, but to a lower level than that which occurred in winter. Summer densities were similar (and lowest) for both sampling devices. The differences observed between the results of the two sampling devices and the bimodal fluctuations observed in the substrate samples cannot be reconciled by considerations of life history data. Nor can they be attributed solely to significant population changes in a few species. The organisms which tended to produce the largest fluctuations in density were the caddisflies and the hydracarina. Taxa with more moderate changes were the ostracods, prosobranch snails, and beetles. The contributions of the less common species were unpredictable and important only on a few dates.

OBJECTIVE 2

Prior to the enactment of the Wetlands Protection Act of 1984 (F.S.S. Chapter 403, Part VIII), the Florida Department of Environmental Regulation routinely denied applications to mine stream bottoms and riparian swampland on the basis that the mining activities would degrade water quality downstream. Therefore, one of the principal objectives of this investigation was to document changes in water quality that occurred as a result of routing Sink Branch through the excavated channel. Because the study also included a comparison of the benthic communities inhabiting two portions of the stream, an evaluation of water quality in the two channels was also of interest.

As reported in the Results section, water quality in general did not differ appreciably between channels. The only anomalous values among the physical and biological parameters occurred in one set of Mined samples that were collected too close to a disturbed invertebrate sampling site. The chemical characteristics were more disparate between channels (all nitrogen species were elevated and orthophosphate was depressed in the Mined channel). While these differences in chemical quality were interesting and may have had some effect on benthic algal populations, they were probably not of a magnitude to exert a significant impact on the benthic invertebrate community.

The source of the large differences in the nitrogen species is somewhat enigmatic, especially because the concentrations in the Mined channel during subsequent sampling trips were consistently half or less than those reported when the Mined and Unmined areas were compared in August. Nonetheless, even if the "normal" value in the Mined channel is half that reported in August, it is still substantially greater than the concentration in the Unmined channel. Rocky Branch, the tributary which was diverted into Sink Branch between the two locations may have been responsible for the difference. Although the two Sink Branch sampling sites are separated by only 1.2 km, water draining from the Rocky Branch watershed could have increased the concentration of nitrogen in Sink Branch. Rocky Branch may have drained shallow pools supporting nitrogen-fixing algae. Water was never analyzed from Rocky Branch to refute or support this conjecture.

After August 1, all samples were collected above and below the Mined channel to assess the impact of the excavated channel on water quality. The results of the analyses indicated that, for a large majority of the dates, characteristics, and times, water collected from below the channel was of better quality than water entering from above. For ammonia nitrogen, the difference was statistically significant.

The reduction in nutrient concentrations may have been the result of dense vegetation rooted in the Mined channel or may reflect the high cation exchange capacity of the substrate. Hynes (1970) has remarked on the lack of knowledge concerning the influence of higher plants on nutrients in rivers. However, it has been shown that some aquatic plants can extract ammonia (Schwervel and Tillimans 1964a and b), phosphate (Caines 1965), and nitrate (Walter 1961) from water passing around them, thereby reducing the nutrient concentration. The concept has practical applications for wastewater management and is finding increasing acceptance (Stephenson, et al. 1980). Nutrient uptake by the dominant macrophyte in the Mined channel, the noxious aquatic weed Ludwigia peruviana, has not been investigated, but could have led to the observed improvements in water quality.

The phosphatic clay in the substrate may also have contributed to the lower nutrient content of the water. The clay, with its substantial ability to adsorb charged materials on a surficial exchange complex, may have removed some nutrients and sequestered them in the bottom. However, although the role of the clay may have been important, changes in nutrient concentrations over the course of the year suggest that biological or meteorological influences may have been of greater significance.

The concentrations of nitrogen and phosphate fluctuated throughout the year (Table 11). Concentrations tended to be highest during the winter months, declined as spring approached, and reached their lowest levels in late summer. The trend coincided with the growing season; uptake by photosythetically-active primrose during the spring and summer may have been responsible for the lower levels observed. Another factor that may have contributed to the lower concentrations was precipitation. At the onset of the rainy season in June, the increased volume of water in the stream may have simply diluted the nutrients that were present. As the rainfall declined, water levels fell and the nutrient concentration increased.

The state's Class III water quality criteria (FDER 17-3.121) do not set a limit on the concentrations of nutrients in water. The standards state only that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." While the Mined channel does remove nutrients from the water flowing through it, the quantities removed were insignificant in terms of the composition and functioning of the aquatic ecosystem in Sink Branch or the Peace River. Nonetheless, the Mined channel did appear to be an effective filter of nutrient materials that could contribute to eutrophication of surface waters downstream.

OBJECTIVE 3

Despite initial impressions to the contrary, physical analysis of the sediments revealed that the streambeds in both channels were remarkably similar. There were no significant differences in particle size distribution at any depth, either among sites or between channels. When evaluated by weight-percentage, the sand, silt, clay and organic fractions did not vary throughout the two locations.

These results are contrary to empirical observations at the Mined Upper and Mined Middle sites. The channel at these sites was excavated at the toe of a phosphatic clay settling area and the substrate appeared to contain significant quantities of clay. The streambed had low weight-bearing capacity compared to other sites with sandy beds. The sediment formed a sticky, airtight seal around boots, anchoring the wader in place. A sample of the sediment placed into a 125 sieve instantly clogged the mesh, unlike the sandy sediments which drained freely. All these observations led us to expect a significant clay component at these two sites.

Clay did comprise a larger proportion of the sediment in some of the samples extracted from the two upstream Mined sites (Table 12) than it did in the remaining sites. However, the variability between samples was so great that differences in the quantities of the various size fractions were insignificant in comparison. An analysis of variance was performed comparing the Upper and Middle Mined sites (only) with all three of the Unmined sites to determine if the Mined Lower site (which appeared to be very similar to the Unmined sites) was responsible for the lack of differences between treatments. This analysis, too, failed to demonstrate differences between channels indicating that the samples collected from the two channels were very similar.

The implications of these results are important for future mining and reclamation programs:

(1) Even small quantities of phosphatic clay can have a major impact on the character of the substrate. The clay is responsible for the sticky nature of the sediments. It fills intersticies in the sand and blankets the substrate with loosely flocculated curds. It also limits oxygenation of deeper sediments making them anoxic.

(2) Major differences between the benthic communities inhabiting the sandy and clay-enriched channels were not observed. The Unmined channel has a richer invertebrate fauna, but the community in the Mined channel is more diverse and is composed of many of the same species. In addition, the differences that *were* documented cannot be readily correlated with specific substrate characteristics.

(3) Relocation of the channel, even onto a site with considerable clay, had minimal impact on the particle size distribution of the streambed sediments. On sites not so closely associated with settled clays, the fines content should be even lower.

Although the clay particles are extremely small, they show little tendency to move downstream. The Mined channel has supported the diverted current of Sink Branch for nearly six years, yet the flocculated clay has not washed out of the sediment. The persistence is probably a result of few turbulent flood events, attenuation of current velocity by the dense stands of primrose willow stems, and stabilization of the sediments by the mesh-like willow root systems.

OBJECTIVE 4

Mobil planted a total of 1794 trees at the Sink Branch site. The trees were planted in February during two consecutive years and included tree-spaded, potted, and bare-rooted trees. After a period ranging from 3 to 4 years depending on planting date, 531 trees remained alive on the 1.01 ha site. The living trees represent 29% of the trees that were planted. While the proportion of surviving trees is low, there are sufficient numbers to satisfy the wooded wetland reclamation requirements of the rules of the Department of Natural Resources Chapter 16C-16.051(9)(d). The Rules call for a minimum of 200 indigenous hardwood and coniferous trees per acre; the Sink Branch site contains 213 trees/acre, including nine hardwood and one coniferous species. Therefore, the Sink Branch project meets the letter as well as the intent of the law in creating a diverse woodland.

Survival

While overall tree survival was 29% there was a wide disparity among species and planting stocks (Tables 13-18). Some performed far better than general, and others performed substantially more poorly. Three plantings gave especially disappointing results. The survival rates of bare-rooted dogwood and slash pine seedlings and tree-spaded sweetbay were so low that similar applications in the future are pointless since they seem doomed to failure. More encouragingly, the potted slash pine and tree-spaded elms had very high survival rates in most locations, suggesting that these planting stocks will perform well on reclaimed sites. The remaining species ranged between 30 - 70% survival, with survival of each species dependent on planting stock (e.g. bare-root, potted, or spaded) and location.

Survival of the various planting stocks differed among locations. Four species planted with tree spades were introduced in numbers sufficient for interpretation. Of these four, two (sweetgum and oak) showed no significant differences in survival among locations. The other two species (elm and sweetbay), exhibited differential survival, with Site 4 showing the highest survival followed or matched by Site 2. Site 2, in turn, supported more tree-spaded trees that Site 3. No were planted in Site 1, but this location showed the poorest response for the tree-spaded elms.

Five species were planted as potted seedlings: sweetgum, slash pine, red maple, green ash, and bald cypress. For every species that demonstrated a significant difference in short- or long-term survival, highest survival occurred on one of the two mulched treatments and lowest survival occurred on the fertilized and control treatments.

There were no exceptions. Green ash showed no differences in short-term survival among treatments, but after 3 years survival matched the pattern established by the other potted seedlings. Conversely, the cypress trees, which initially demonstrated differential short-term survival, showed no differences after 3 or 4 years. The cypress, all planted along the edge of the stream, probably had their rooting environment modified by the stream over the intervening period which could account for the lack of persistent differences.

Data were only available for three species planted as bare-rooted seedlings: sweetgum, live oak, and dogwood. The pattern of survival among the bare-rooted seedlings was identical to that of the potted seedlings over the short-term. Similar data after 3-4 years were not available for the sweetgum and oak, and the dogwood did not demonstrate any differences after 3 years.

Interpretations based on these findings must be made with caution because only two of the species were introduced as more than one planting stock. In those cases in which the species were planted using only one stock, survival differences may be species-specific rather than site related. Sweetgum was planted in all three forms; spaded trees showed no differences among locations, while potted and bare-rooted trees demonstrated differential survival. Oak was planted as spaded trees and bare-rooted seedlings. Survival followed the same pattern as for sweetgum. All of the rest of the trees for which data are available were planted as only one stock.

A second point to be considered in evaluating the tree survival and growth data is that the soil treatments were not replicated. Because there is only one plot for each of the four soil treatments, it is impossible to attribute differences in survival and growth to differences in the soil brought about by the various amendments. For example, while tree spaded elms survived best in the untreated area (Site 4) and performed most poorly with fertilization (Site 3), this observed disparity may be due as much to differences in slope or soil moisture between sites as to the soil treatment. Without replicated plots, all that can be said with any degree of certainty is that the location had a significant impact on survival; the specific aspect or aspects of the location that produced the difference are unknown.

In general, however, if differences in survival between sites can be attributed to soil treatments, trees that are introduced with their roots in fairly immediate and direct contact with the reclaimed soil (potted and bare-rooted seedlings) may benefit substantially from soil topdressing. This soil provides good edaphic structure, readily available nutrient sources, and a relatively intact microbial community that includes beneficial mycorrhizal fungi. The tree-spaded trees, transplanted with a large , native soil ball, would not be expected to respond as dramatically since the amount of topsoil applied to the channel sites is insignificant in comparison to the volume of transferred soil in the root ball. In addition, the spaded trees are already colonized by a viable microbial assemblage, and the roots, shocked by transplanting, are slow to penetrate into the reclaimed soil. This conjecture is plausible for the tree-spaded species that showed no response to the treatments (sweetgum and oak), but it fails to explain why the elm and sweetbay survived better in some locations than others. These responses remain enigmatic and may warrant additional investigation, especially for elm, which had among the highest survival rates of any of the species.

Growth

With the exception of slash pine, none of the species exhibited significant differences in growth among the various locations. The pines responded best in the mulched plots, and grew less rapidly in the fertilized and control plots. This pattern of growth mirrors that of the survival of the potted pine seedlings. However, without additional corroborating evidence from other species or planting stocks, it is virtually impossible to draw any conclusion about the effects of planting location on growth.

On several counts, the Sink Branch plantings have been extremely successful. In purely practical terms, the plantings were successful at establishing the minimum number of trees per acre to meet the regulations for acceptable reclamation. The experiment introduced a diverse array of species to the site, especially near the stream; stretches of the streambank just upstream of the Mined channel are completely dominated by willow, so the introduction of a more diversified group of desirable species will lead to more attractive riparian habitat when the trees have matured.

On the other hand, the species that have been planted on the site are all climax swamp forest trees that will mature, tend to persist, and resist invasion by other species. Unfortunately, this assemblage of arboreal species bears little resemblance to the vegetational community at the Unmined site, an area that was specifically selected to represent a relatively undisturbed portion of the stream. The Unmined site is largely dominated by sweetbay, with minor understory components of redbay and red maple. When mature, the Mined site will be dominated by cypress, sweetgum, ash and elm, with a few red maples and sweetbays occupying the understory. The Mined forest will become a bona fide swamp forest over time , and may even eventually come to closely resemble the Unmined site if propagules of sweetbay and redbay are able to colonize and reproduce on the bank. However, the presence of an established stand will certainly slow the successional process. A comparison of the benthic community similar to the one performed as a part of this project would be interesting once the Mined forest is mature in order to correlate canopy composition with the aquatic community.

CONCLUSIONS

OBJECTIVE 1

Species Richness

One hundred-eleven species of invertebrates (exclusive of the oligochaetes) and five species of fish were collected from Sink Branch over a one-year sampling period. One hundred-one invertebrate species were collected from the Unmined channel, 29% of which were found only in that channel; 81 species were collected in the Mined channel, 11% of which were restricted to that channel. The species restricted to one or the other of the channels were widely distributed among trophic and behavioral niches and did not appear to be exploiting unique resource bases that could be readily associated with conditions in either of the channels. The lower overall richness of the Mined channel was probably due to a lack of habitat diversity.

The four sampling devices used in this investigation were not equally effective for measuring richness. The order of effectiveness was: dip net > drift net > multiplate artificial substrate core. While overall richness was greater in the Unmined channel, the individual Mined core and multiplate samples tended to be richer than the Unmined because of the more even distribution of individuals among species in the Mined channel. The individual dip and drift net richness values were not different between channels.

Variability estimated by calculating coefficients of variation did not differ among sampling devices. Variability of samples collected with the same device did not differ when the results were evaluated among dates or between channels.

Community Similarity

Coefficient of community estimated by Czekanowski's similarity index revealed that the invertebrate collections from the Mined treatment tended to be most similar, followed by the collections from the Unmined treatment. When the Mined collections were compared with the Unmined, the Czekanowski values were much lower, indicating considerable dissimilarity between the two treatments.

Because the Mined channel is so homogeneous along its entire length, a sample taken in any one spot will be similar to a sample collected at nearly any other location. The more diverse habitat offered by the Unmined treatment, on the other hand, increases the probability that collections will differ from one another. The uniformity of the Mined channel, the diversity of the microhabitats in the Unmined channel, and the differences in habitat characteristics between the two channels combine to limit the community similarity between treatments.

Species Diversity

Replicate diversity estimates within each of the two channels indicated no differences in species diversity. Similarly, the dip and drift net samples revealed no differences between the channels. The core and multiplate samples, however, were more diverse in the Mined channel. The Mined channel in general supported a more diverse benthic community as measured by the Shannon-Wiener index; the failure of the two net samplers to corroborate the core and multiplate findings was probably an artifact of the collection techniques.

Two of the samplers, the drift nets and substrate cores, revealed annual fluctuations in diversity. These samples were most diverse in late spring and summer, experienced a decline in the autumn, then gradually became more diverse throughout the winter and spring.

Density

Population densities were measured with the substrate core and multiplate samplers. Both devices indicated no differences in density either between samples collected within a channel or between channels. Additional analysis revealed that density estimates produced by both samplers were statistically indistinguishable. The density of organisms in the drift was also calculated, with higher values recorded from the Unmined channel. Sample variability did not differ significantly within or between channels, regardless of the sampling device.

Sampling Recommendations

Future aquatic macroinvertebrate sampling in reclaimed streams can be tailored to the specific objectives of the study. For strictly qualitative investigations, dip and drift net samples are the most effective devices. For quantitative assessments, substrate cores and multiplate artificial substrates make the sharpest distinctions between treatments. The substrate cores were no more effective than the multiplates for assessing any of the three community parameters measured; however, because core samples are so much more difficult and time-consuming to process, they could be eliminated from a sampling program without compromising the integrity of the investigation.

OBJECTIVE 2

Based on a single series of samples spanning 24-hours in. August 1983, physical and biological water quality in the two channels did not differ significantly. Chemically, the Mined channel had significantly higher concentrations of all forms of nitrogen (NH_3, NO_2^-, NO_3^-), but lower levels of orthophosphate. The chemical disparity may have resulted from the contribution of Rocky Branch, a heavily-disturbed tributary to Sink Branch located between the two channel locations.

After August, samples were collected immediately above and below the Mined channel to assess the impact of the channel on water quality. All measured parameters were present in lower concentrations after the water had flowed through the channel, but the reduction in ammonia-nitrogen was the only characteristic that was reduced significantly. Routing Sink Branch through the Mined channel improved overall water quality.

OBJECTIVE 3

Replicate sediment samples were collected at all sampling sites. Samples were separated into surface (0-2 cm) and subsurface (below 2 cm) layers and subjected to particle size distribution and organic content analyses. Sediment composition was uniform throughout the length of each of the channels. No differences were observed between the upper and lower sediment layers in either of the channels. Likewise, no measurable differences were present between the channels, despite the presence of phosphatic clay in the Mined substrate. Relatively small quantities of clay had a noticeable impact on the nature of the substrate, but the effect of the clay could not be correlated with any changes in the invertebrate community. The substrate in the Mined channel was stable, with no indication that the extremely fine clay particles were migrating downstream.

OBJECTIVE 4

Of the 1794 trees Mobil planted along the reclaimed channel in 1980 and 1981, 531 were alive three years later. The overall survival rate was 29%, and was adequate to establish the minimum number and variety of trees per acre to meet the state's criteria for successful wooded wetland reclamation.

Trees were introduced using three planting stocks: mature specimens tree-spaded on site, potted seedlings and bare-rooted seedlings. The trees were planted in four plots that had received soil amendments during site reclamation: 30 cm of wetland peat, 15 cm of peat, fertilizer in planting holes, and no amendments (control). Because the treatments were not replicated, though, it was possible to correlate survival with planting location only, and not with soil treatment.

Four species were tree-spaded in numbers sufficient for statistical evaluation of survival. Sweetgum and live oak showed no significant short-term (one year) responses to planting location. Elm and sweetbay responded to location on both a short- and long-term (three-year) basis.

Potted seedlings of five species were planted on the site. All survived best on one of the two mulched sites, performed less well with fertilization, and survived most poorly in the untreated area. Sweetgum, pine, red maple and cypress all exhibited planting location-related differences in survival on the short-term; green ash did not. Longer term survival data, available only for maple, cypress and ash, indicated differential survival for the maple and ash seedlings only; there were no significant differences among locations for the three-year old cypress.

Bare-rooted sweetgum, live oak and dogwood seedlings exhibited short-term survival patterns identical to those observed for the potted stock. Long-term data were not available for sweetgum and oak, but dogwood survival after three years was not significantly different between locations.

Growth rates of transplanted trees were not significantly different among locations , with the exception of the slash pines. The pines grew best in the areas of mulched peat, the 15 cm treatment giving better response than the 30 cm treatment. Growth was slower, and statistically identical, in the fertilized and untreated areas.

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