Executive Summary

Silviculture is a major land use in Florida, supporting a wood products industry which produces lumber, paper, pulp, fabrics, and various organic chemicals from the harvesting and processing of trees. Tree harvesting, which typically occurs on a 20 to 30 year cycle for pulpwood and a 50 to 80 year cycle for saw timber, often involves clear-cutting. Following a typical clear-cut harvest, mechanical site preparation and tree planting are usually conducted to reforest the area. Herbicides and fertilizers may be applied at certain intervals after the planting process.

As part of the development of the State's Nonpoint Source Management Program, the Florida Department of Agriculture and Consumer Services (FDACS), Division of Forestry, in cooperation with the Florida Department of Environmental Protection (FDEP), universities, and the forestry industries, developed a Silviculture Best Management Practices (BMPs) Manual in 1976. This manual, the *Silviculture BMP Manual* (FDACS 1993), was revised and expanded to address forestry activities in wetland and wildlife habitat protection in 1993. The revision resulted in over 100 specific operational practices, including the establishment of a forested buffer zone next to water bodies, erosion control, and proper use of herbicides and fertilizers.

Although good compliance with silviculture BMPs has been well documented (FDACS 1996), information about BMP effectiveness has been largely qualitative in nature. To address this issue, it was hypothesized that by following BMPs, impacts on aquatic systems associated with silviculture would be minimized or eliminated. To test this hypothesis, and to evaluate the environmental effectiveness of the revised BMPs, five north Florida stream sites (Figure 1) were chosen for an intensive study, using stream bioassessment techniques. Stream sampling parameters included benthic macroinvertebrates, habitat assessment, periphyton (attached algae), and physical/chemical measurements. Silviculture operations evaluated for BMP effectiveness included clear-cut harvesting, intensive mechanical site preparation, machine planting, herbicide application, and fertilizer application.

Based on the Stream Condition Index (SCI), no statistically significant changes were observed between the reference and test conditions after silviculture operations using BMPs. At three of the streams, the reference and test conditions were characterized as "excellent", both before and after the forestry operations. At the remaining stream, the reference and test

conditions were characterized as “good”. Results from habitat assessment showed no major adverse habitat conditions attributable to the forestry operations, and the precision or repeatability of the SCI measurements indicated high reliability of the results. Hence, the study supports the hypothesis that proper application of BMPs during silviculture operations provides adequate protection to adjacent stream systems.

Introduction

Commercial forest land in Florida covers 16 million acres, which represents 47% of the state's total land area. Forestry Best Management Practices (BMPs) were originally developed in the mid-1970's to protect Florida streams and lakes from pollution associated with forestry activities (FDACS 1993). In 1992, a technical advisory committee (TAC) reviewed and significantly revised the BMPs to reflect the scientific and social changes that occurred since the original BMP development (Vowell 1996). The (TAC) continues to meet and revise Florida’s *Silviculture Best Management Practices* Manual as necessary. The most recent revision of the Manual contains all current BMPs for forestry operations (FDACS 2000).

Compliance with BMPs has historically been very good. For example, the most recent BMP Compliance Survey was conducted in 2001 and showed 97% compliance with BMPs statewide (FDACS 2002). In addition, a DEP study was conducted in 1996 and 1997, to determine how effective these practices actually were in protecting the water quality and biological integrity of aquatic systems. FDEP reported that adverse biological effects were not seen when silvicultural BMPs were followed (FDEP 1997, and Vowell 2001). However, this study focused primarily on erosion and sedimentation and did not consider forest chemical treatments. For that reason the study was extended an additional year to determine if other practices, such as herbicide use or fertilization, could be associated with negative biological effects.

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Methods

Traditional methods (water chemistry sampling of storm events, etc.) have proven largely inadequate to detect impairment caused by nonpoint source runoff. Therefore, a biological assessment approach was emphasized in this study. Assessment of biological communities is well suited for evaluating

nonpoint sources for the following reasons: 1) such communities are sensitive to human induced stress; 2) they integrate adverse effects over time, both chronic and episodic, and; 3) they respond to habitat, hydrological, water quality and food web disturbances. The experimental design for the initial sampling in this study is detailed in Figure 2. In February and March of 1996, three replicate stations upstream from the area proposed for clear-cutting (reference site) were sampled, as well as three stations downstream from the area to be logged (test site). After pre-disturbance sampling at the four different streams was completed, the upland areas adjacent to the test sites were harvested, and all subsequent site preparation and replanting activities were conducted. BMPs were strictly adhered to during all aspects of the forestry operations. In February 1997[1], the first post-disturbance sampling was conducted at the identical stations. In February 1998, a second post-disturbance sampling was conducted, along with additional sampling associated with herbicide treatments at two of the sites and a fertilizer application at a fifth site. Habitat quality was determined for each station during an *in situ* assessment. Supplemental physical/chemical data were also collected on all the study sites. Nutrients, total suspended solids, and color were analyzed on water from the "B" stations of the reference and test sites. Methods used for all chemical analyses are on file at the Tallahassee FDEP Chemistry Laboratory.

Benthic macroinvertebrate communities were evaluated at all receiving water sites. Invertebrates were collected from multiple substrates (*e.g.*, snags, leaf packs, root mats) using 20 discrete dip net sweeps. Bacterial populations were analyzed for total and fecal coliforms and *Escherichia coli* following the methods of APHA (1989).

Explanation of Measurements of Community Health

Several different measurements of macroinvertebrate and algal community health have been employed to determine the effects of a discharge. These are briefly discussed here.

Habitat: Seven attributes known to have potential effects on the stream biota were evaluated and scored, with 20 possible points for each factor. Based on the sum of these individual scores, overall habitat quality is assigned to one of four categories: Optimal (105-140 points); Suboptimal (70-104 points); Marginal (35-69 points); and Poor (0-34 points) (see example habitat assessment field sheets in Appendix).

Taxa richness: Stress tends to reduce the number of different types of organisms present in a system.

Percent Dominance: Excessive numerical dominance of a single type of organism (a high % contribution of the dominant taxon) is generally associated with disturbance.

Numbers of pollution sensitive taxa: Some organisms become rare or absent as the intensity or duration of disturbance increases. For example, the Florida Index assigns points to stream-dwelling macroinvertebrates based on their sensitivity to pollution (Ross 1990). A site with a high Florida Index score is considered healthy.

Ephemeroptera/Plecoptera/Trichoptera (EPT) Index: This index is

[1]Note that the Econfina site was inaccessible in February, 1997 due to high water levels.

Community structure: Substantial shifts in the proportions of major groups of organisms, compared to reference conditions, may indicate degradation.

Trophic composition/feeding guilds: Disturbance can shift the feeding strategies of invertebrates. In Florida, for example, pollution may be responsible for reducing the numbers of filter-feeders (Barbour et al. 1996).

The **Stream Condition Index** (SCI) for Florida is a composite macroinvertebrate metric (Barbour et al. 1996). The SCI assigns points to a variety of parameters, depending on how closely each parameter approaches an expected reference condition.

The following personnel were involved in this investigation: Jeff Vowell and Tom Gilpin (FDACS, Division of Forestry) and Tom Frick, Russel Frydenborg, Joy Jackson, Elizabeth Miller, (Tallahassee Bi ology Laboratory).

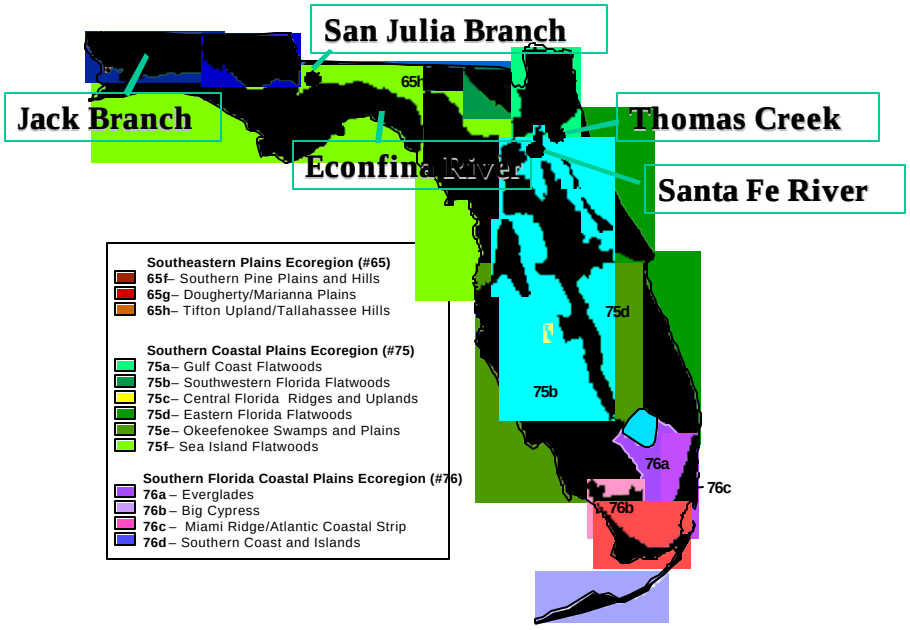
Site Descriptions

This section provides detailed background information for each of the four streams studied, including soil characteristics, stream morphology, surrounding land use, and specific forestry practices employed (Jeff Vowell, Division of Forestry, personal communication). Watershed information and silviculture treatments for each site are summarized in Tables 1 and 2.

San Julia Branch

San Julia Branch is located in the northeast quadrant of Section 14, Township 3N, Range 4W, in Gadsden County, Florida. The watershed associated with the portion of the stream within the project area is approximately 400 acres, most of which is forested and owned by St. Joseph Paper Company.

Soils in the study area consist of loamy fine sand, with some gravel near the surface. Soil types include Carnegie, Tifton, Lakeland and Orangeburg. Slopes throughout the study area are generally steep, with grades of 6% to 14%. The channel has a site sensitivity class (SSC) of C4 ((Rosgen 1996), which includes highly erodible soil and steep topography (FDACS 1993). According to the BMP Manual, this site requires a 35-foot Primary zone and a 265-foot Secondary zone, which provides a total Special Management Zone (SMZ) of 300 feet.



This first order stream appears to have undergone significant episodes of erosion in the past, based on observations of historic aerial photographs (Jeff Vowell, personal communication). There is evidence of previous rill and small gully erosion on the steep slopes, which appears to have been associated with past poor farming practices. However, no recent or active erosion or sedimentation was observed on the site, and the present watershed appears stable.

An intermittent tributary flows through the silviculture treatment area, and enters San Julia Branch just upstream of the test site. It was expected that this intermittent tributary would be the major potential contributor of sediment from the silviculture operations to San Julia Branch. Erosion from this intermittent tributary, again appearing to have been related to past

farming practices, has been temporarily stabilized by tree roots. However, this area is a major potential source of sedimentation to San Julia Branch, should headcutting reactivate upstream beyond the root-mat.

Moderate sediment loads are prevalent within San Julia Branch, as it continues to shift bedload sands downstream. Some channel scouring is occurring, but the stream banks appear relatively stable. Numerous point bars and center bar development were observed within the stream. Flow in San Julia Branch does not appear to exceed its banks, except during extreme storm events. Stream bed entrenchment appears to be the result of down-cutting through sediment inputs, much of which was likely deposited in the past via the intermittent tributary.

Historically (pre-1900), this study site was used for agricultural purposes (cotton and tobacco). Forestry resources in the study area consist of loblolly pine planted in 1983, with little understory vegetation, and a heavy layer of pine straw for ground cover. Pines were planted to within 20 feet of the intermittent tributary in some places, and within 60 feet of San Julia Branch. A small bottom-land hardwood forest is associated with San Julia Branch, although there is little merchantable timber.

In March/April 1996, 80 acres were clear-cut, then chopped, burned, wind-rowed, and bedded during the summer of 1996. The site was machine planted with slash pine (*Pinus eliottii*) in January, 1997.

Jack Branch

Jack Branch is located in the northwest quadrant of Section 7, Township 4 N, Range 23 W in Okaloosa County, Florida. It is a tributary of Poverty Creek, and is contained entirely within Champion International Corporation's Choctawhatchee Forest. The watershed associated with the portion of the stream within the project area is approximately 500 acres.

The site consists of Escambia fine sandy loam and Pansey sandy loam soils, characterized by low to moderate slopes. For BMP purposes, the site is classified as a “C2” site (FDACS 1993), reflecting a moderate risk of soil erosion. By the BMP guidelines, such a stream requires a 25-foot Secondary Zone in addition to the 35-foot Primary Zone. The total SMZ at this site was 60 feet.

Jack Branch appears to be a moderately stable second order stream with a C6 channel. The main channel is well defined, averaging roughly 0.5 m deep and 1.5 m wide throughout most of its run within the project area. It

meanders through a fairly broad flood plain littered with natural vegetative debris and sand which are deposited regularly at high water levels. This was the only site that included a stream crossing at the monitoring station. The original crossing, armored with rock, had been installed a number of years ago and was replaced with a new culvert and rock in 1996.

From a forestry standpoint, the site was fairly productive, with a site index of 66 sq. ft. (25-year base) and supported a stand density of approximately 414 stems per acre at the time of harvest.

Historically the Hart property, adjacent to the Jack Branch monitoring station, has been used for agriculture, cattle grazing, turpentine, and timber production. For the last 30 years, the property has been used extensively for timber production, primarily for pulp and paper products. Additionally, Champion currently manages the land for wildlife, leasing areas for hunting game species. The land adjacent to Jack Branch was planted with slash pine (Pinus elliotti) in 1970. During the summer of 1996, 120 acres were clear-cut, yielding approximately 2,600 cords of wood. The site was chopped with tandem drums in November 1996, bedded in December 1996, and machine-planted with loblolly pine (*Pinus taeda*) in January, 1997. On May 18, 1998 20 oz/acre of Arsenol/Garlon was applied to the entire site.

Thomas Creek

The land at this site is part of the "Weeks Tract" within Gilman Timberland Company's "Trailridge Forest" in Clay County. The site consists of a 700 acre tract of upland pine and hardwood-pine creek bottomland. It is located in Section 2 of Township 7 S and Range 24 E.

The upland portion of the site consists of flat to gently sloping topography, with well-drained soils of fine sands. Soils types found in the upland areas of this tract are Hurricane, Mandarin and Leon fine sands. The slopes become steeper near Thomas Creek, approaching a 12% grade in some areas adjacent to the waterbody. The SSC for this site was B3, requiring a 35-foot Primary Zone and a 40-foot Secondary Zone, for a total SMZ of 75 feet.

The site is well suited for pine production. The Site Index was 55 sq. ft (25-year base), supporting roughly 290 stems of slash pine per acre at the time of the most recent harvest. The soils immediately adjacent to Thomas Creek are of the Rutledge-Osier complex, supporting a diverse vascular plant community. Thomas Creek, a tributary of Ates Creek, is a stable, second order stream originating on this tract, and has a SSC of C6.

Prior to Gilman acquiring the land in the early 1950's, the land was owned by the J. C. Penny Foundation and the Reinhold Corporation. Both owners used the land for cattle grazing and timber production. In 1962, three hundred and sixty acres of previously cut timberland were mechanically prepared and planted with slash pine. In the spring of 1996, 80 acres of the pine plantation adjacent to Thomas Creek were clear-cut by Gilman. During the summer of 1996, the site was chopped, spot-raked into windrows, burned, and bedded. The clear-cut acreage was planted with slash pine in January 1997 and sprayed with 6 oz/acre of Velpar/Oust on May 15, 1997. In addition to timber production, the tract is being used for apiary, cattle, and hunting activities.

Econfina River

This site consists of 65 acres of planted pine in the Cabbage Grove area of Taylor County. It is located east of the Econfina River in the Southeastern quarter of Section 5, Township 4 S, Range 5 E. The treatment area was formerly owned by Foley Land and Timber Company but is currently owned by the Suwannee Water Management District. Foley Land and Timber conducted the forestry operations during the treatment period.

The conditions and characteristics at this site are typical of “pine flatwoods” in the coastal region of the state. Slopes average less than 2%. Soils consist of poorly to moderately drained sandy soils of the Chaires-Sapelo Series. The site is fairly well suited for pine production. Foley Land and Timber gave it a Site Index of 62.4 sq. ft. (25-year base). At the time of the most recent harvest, it supported roughly 299 stems per acre. Given the soil type and slope of the site, it would be classified as an "A1" site, meaning it has very low potential for soil erosion, and therefore, would not have any restrictions on forest operations outside of the Primary Zone.

The Econfina River is an Outstanding Florida Water, monitored regularly by FDEP as a reference stream for their bioassessment program. It is deep in places (greater than 5 feet) and averages more than 25 feet wide during normal flow. The stream has a channel classification of C4. The stream is separated from the surrounding area by an "alluvial berm" throughout much of the study area, connected by occasional drains. The river floodplain supports cypress, gum, blue beech, and other wetland species.

Because this waterbody is one of Florida's "Special Waters", the BMP Manual requires a 200-foot Primary Zone during forestry operations. However, the landowner implemented the "Managed Pine Exception" to the Primary Zone requirement, which allows clear-cutting of pine timber which

had been previously planted within the 200-foot zone. Under the BMPs, however, unrestricted timber harvest could not be conducted within 50 feet of the water channel. Not more than two hundred linear feet along the river qualified for this exception.

The land at this site has historically been used for timber production, primarily for pulp and paper products. The site was planted with slash pine in 1974 by Buckeye Cellulose Company, which later became Foley Land and Timber Company. The stand was fertilized twice during rotation: once with diammonium phosphate (DAP) in the summer of 1990, and a second time, with urea, in May of 1992. The 65-acre stand was clear-cut in April 1996. Approximately 3,400 tons of wood were removed during the harvest. The site was chopped with a single-drum chopper in August 1996, burned in September, 1996, and raked in November, 1996. It was machine planted with longleaf pine (*Pinus palustris*) in December, 1996.

Santa Fe River

The portion of the Santa Fe River studied was located near its headwaters along the Bradford and Alachua County line. At this point along the river the upstream watershed is approximately 25, 000 acres. This site consists of 192 acres of planted pine in the southeastern quarter of Section 5, Township 4 S, Range 5 E. The treatment area is owned by the Rayonier Corporation, which was responsible for conducting the forestry operations during the treatment period.

Conditions at this site are characteristic of pine flatwoods with slopes averaging 3 - 5%. Soils consist of moderately drained sandy soils and is well suited for pine production. Foley Land and Timber gave it a Site Index of 62.4 sq. ft. (25-year base). Based on the soil type and slope of the site, it would be classified as an "A2" site, meaning it has low potential for soil erosion, and would only minor if any restrictions on forest operations outside of the Primary Zone.

The Santa Fe River is an Outstanding Florida Water and averages more than 20 feet wide during normal flow. The stream has a channel classification of C4 with an active river floodplain that supports cypress, gum, blue beech, and other wetland species. Because the OFW designation, the BMP Manual requires a 200-foot Primary Zone along the river during forestry operations such as harvesting and site preparation and forest chemical application.

The land at this site has historically been used for timber production, primarily for pulp and paper products. The site was planted with loblolly pine

in 1994 and fertilized with 200 lbs/acre of diammonium phosphate (DAP) in 1996. For the study the site was fertilized a second time, again with 200 lbs/acre of DAP, applied by helicopter in September of 1998.

Results and Discussion

Habitat quality was in the "optimal" category at all sites, both before and after silviculture activities (Table 5, Figure 3). The degree of artificial channelization and the riparian zone vegetation quality did not change between sites or between years. Some components of the habitat assessment, such as water velocity, varied temporally due to factors other than BMP application (*i.e.*, hydrological regime). Habitat smothering and bank stability are two factors which would be affected by inadequate erosion control during silviculture operations. Scores for habitat smothering and bank stability were virtually unchanged at the post-disturbance test sites (Table 5), indicating that BMPs successfully protected the streams.

The only post-disturbance habitat assessment component to consistently change at three of the initial four sites was riparian zone buffer width. To receive maximum points for the riparian zone buffer width, the FDEP habitat assessment procedure, as a general condition, calls for a minimum of 18 m (approximately 60 feet) of undisturbed area adjacent to the stream. The forestry BMP document has a more specific procedure for determination of the width of the Primary SMZ, based on slope and soil type. Depending on the situation, the BMPs allow disturbance up to 35 feet from the stream channel. This was the case at San Julia Branch, Jack Branch, and Thomas Creek. Consequently, the FDEP habitat assessment score for riparian zone buffer width at the test site areas decreased from 20 points (the pre-disturbance value) to 10 points at San Julia Branch, and 9 points at Jack Branch and Thomas Creek alike. This minor decrease did not shift the overall habitat category at any site, as all sites remained in the "optimal" category after silviculture activities took place.

There appeared to be no major changes in physical-chemical measurements due to silviculture activities (Table 4). Dissolved oxygen ranged from 6.2 mg/L at the Econfina reference site in 1996 to 9.0 mg/L at Jack Branch reference site in 1997. All sites complied with the 5.0 mg/L minimum Class III dissolved oxygen standard. Water was close to neutral in pH at the Econfina River (between 7.2 SU and 7.6 SU), but somewhat acidic at the remaining sites (ranging from 4.8 SU at Jack Branch in 1996 to 6.1 SU at Thomas Creek in 1997. Conductivity at all sites was low (ranging from 10

µmhos/cm to 30 µmhos/cm) except for the Econfina River (where conductivity ranged from 175 µmhos/cm to 322 µmhos/cm). The higher pH and conductivity at the Econfina River is probably due to the contact the water has with extensive limestone outcrops throughout the stream.

Stream water temperature ranged between 13.1° C to 20.0° C at the study sites. No shade trees were removed from the banks of any of the streams, so no additional (above background) summertime increases in temperature would be expected at any of the test sites. Water at these streams was moderately to highly colored, ranging from 20 PCUs to 500 PCUs. Many streams in north Florida have colored water due to the leaching of tannins and lignins from the abundant leaf litter in their watersheds. Turbidity was low at all sites. The highest turbidity (3.3 NTU), which occurred at the Thomas Creek test site in 1997, is relatively average for a Florida stream (see Table of Typical Water Quality Values in Appendix). The low turbidities suggest that, at least during the time of sampling, erosion was not a problem at the test sites. During an intense rain in February, 1997, direct observation during the bioassessment at Jack Branch indicated that no turbid water from the disturbed site was reaching the stream.

Fecal coliforms exceeded the Class III water quality standard of 800 organisms/100 mL (maximum) at three sites (Table 4). Fecal coliforms present in water from Thomas Creek in 1997 (4,800 organisms/100 mL at the reference site and 2,000 organisms/100 mL at the test site) and San Julia Branch in 1997 (900 organisms/100 mL at the test site) exceeded the water quality standard (Rule 62-302.530(6) FAC). Total coliform bacteria exceeded the Class III water quality standard (maximum of 2,400 organisms/100 mL) at Thomas Creek in 1997 (28,000 organisms/100 mL at the reference site) and at San Julia Branch (5,200 organisms/100 mL at the test site). The Thomas Creek watershed is used for cattle grazing, which is probably contributing to the coliforms found in the stream. Extensive wildlife activity (beavers, deer) has been observed in the San Julia watershed, which may possibly be the source of the bacteria there.

Nutrients were relatively low at all sites, both before and after the forestry operations (Table 4). The highest values of total phosphorus (0.097 mg/L), ammonia (0.24 mg/L), and nitrate-nitrite (0.045 mg/L) found at any site were average or less than average for a Florida stream (see Table of Typical Water Quality Values in Appendix). It did not appear that forestry operations were causing nutrient enrichment at the systems studied.

Invertebrate Results

Macroinvertebrate sampling at all 30 stations in this study consisted of the 20 dipnet sweep method for calculation of the Stream Condition Index (SCI). The Stream Condition Index assigns points to seven metrics, depending on how closely each parameter approaches an expected reference condition (Barbour et al. 1996). These metrics include taxa richness, the Ephemeroptera/Trichoptera/Plecoptera (EPT) Index, the Florida Index, % contribution of the dominant taxon, % Diptera, number of chironomidae, and % filter-feeders. Streams with SCI scores of 27 or above are ranked as "excellent", while those with scores between 21 and 26 are in the "good" category. Scores less than 21 are ranked either "poor" or "very degraded", depending on how low the score is.

The SCI data for each site were log10-transformed prior to running analysis of variance (ANOVA) using SPlus 2000 Professional Release 2. A separate ANOVA was run for each site since they were sampled on different days. The ANOVA tables have terms for "treatment" (reference versus test), "time" (each sample date), "treatment by time" interaction, and error. A summary of the results follows (the detailed tables are provided in Appendix 1).

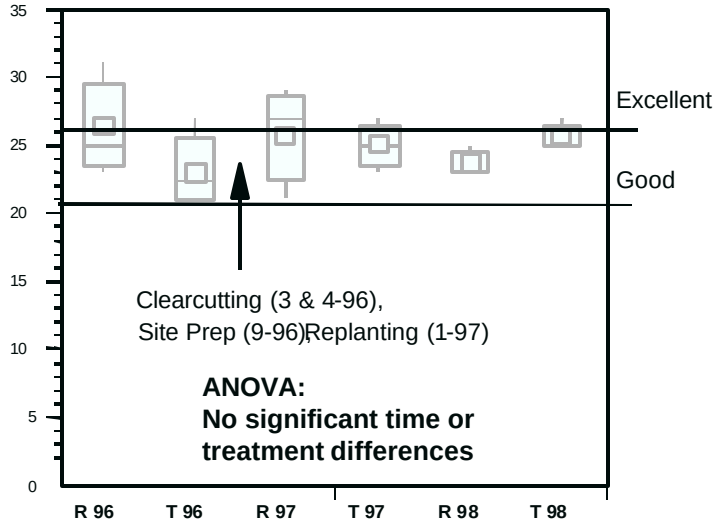
Site	Time Effect	Treatment Effect	Time by Treatment Interaction
San Julia	NS*	NS	NS
Santa Fe	p=.01**	p=.005**	NS
Jacks Branch	NS	NS	NS
Thomas Creek	NS	NS	NS
Econfina Creek	p=.03***	NS	NS

*NS = not statistically significant

** SCI in 8/98 was lower than in 11/98 and was lower at the Reference than the Test site

***There was a difference in the average SCI for each time period (33 in 2/96, 32 in 4/97, 31 in 5/98).

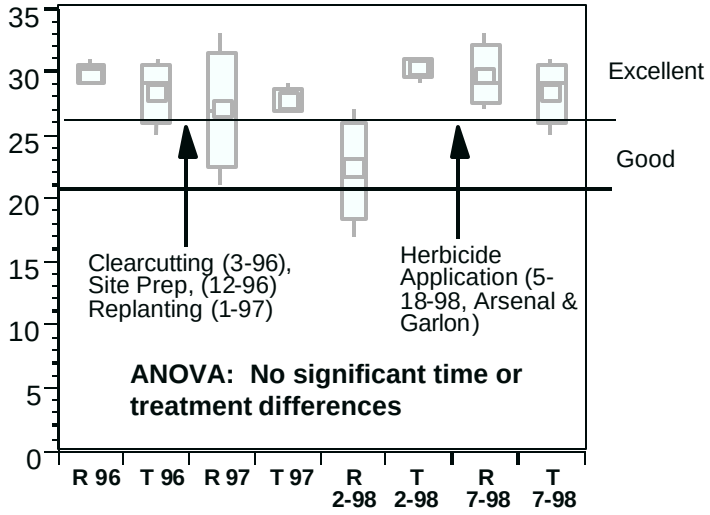
San Julia SCI Results



There were no significant time or treatment differences in the SCI at San Julia Branch throughout the entire study. The mean SCI at the test site was generally in the "good" range, both prior to and after silvilcultural activities. Similarly, the mean SCI at the reference site was consistently in the good range.

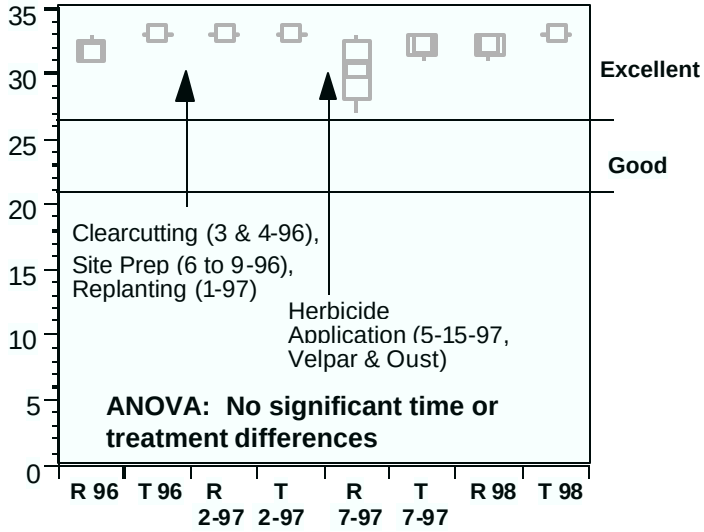
As San Julia was the smallest stream in the study and the site was located at its headwaters, it is possible that reduced macroinvertebrate recruitment potential from upstream areas would be a limiting factor, keeping SCI scores in the good rather than excellent range. After replanting, no further silvicultural activities took place at this site, but it was studied to evaluate possible effects not seen during the first year of study.

Jack Branch SCI Results



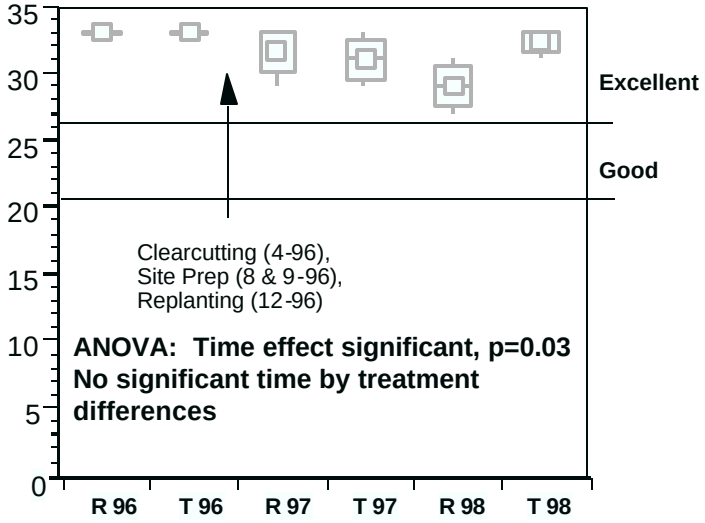
There were no significant time or treatment differences in the SCI at Jack Branch throughout the entire study. With one exception, the mean SCI at the test and reference sites was in the "excellent" range, both prior to and after silvilcultural activities. The slightly lower score in February, 1998 (at the reference site) probably reflect somewhat less efficient sampling effort due to the high water conditions that were prevalent. Note that the SCI score (sampled in July, 1998) at the test site was in the excellent range following application of the herbicides Arsenal and Garlon on May 18, 1998. These compounds were not detected in water samples taken during the biological sampling. This suggests that either the compounds did not migrate to the stream or that the concentrations that did reach the stream were below the detection limit.

Thomas Creek SCI Results



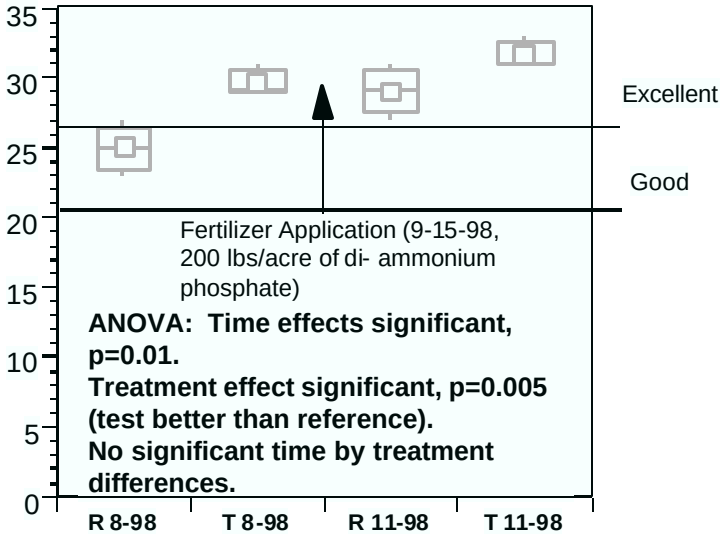
There were no significant time or treatment differences in the SCI at Thomas Creek throughout the entire study. The mean SCI values at the test and reference sites were consistently in the "excellent" range. The herbicides Oust and Velpar were applied on 5-15-97 and the site was sampled for biological and chemical parameters in July, 1997. The herbicides were not detected in the water column and no negative effects were noted at the test site after chemical application. Again, this suggests either that the herbicides did not migrate to the stream or that the concentrations were below the detection limit and below chronically toxic levels.

Econfina River SCI Results



The SCI was in the excellent range at the test and reference sites in the Econfina River during every sampling. There was a significant (although minor) decrease in the SCI over time in this system, but not due to silvicultural activities, as the reference site followed the same trend. This was probably due the extreme low water that occurred during the first sampling event in 1996, making sampling for invertebrates very effective. Somewhat higher water levels in succeeding years made sampling more difficult, although the scores clearly remained in the excellent category. Note that no additional disturbance occurred after the 1996 harvesting and replanting activities.

Santa Fe River SCI Results

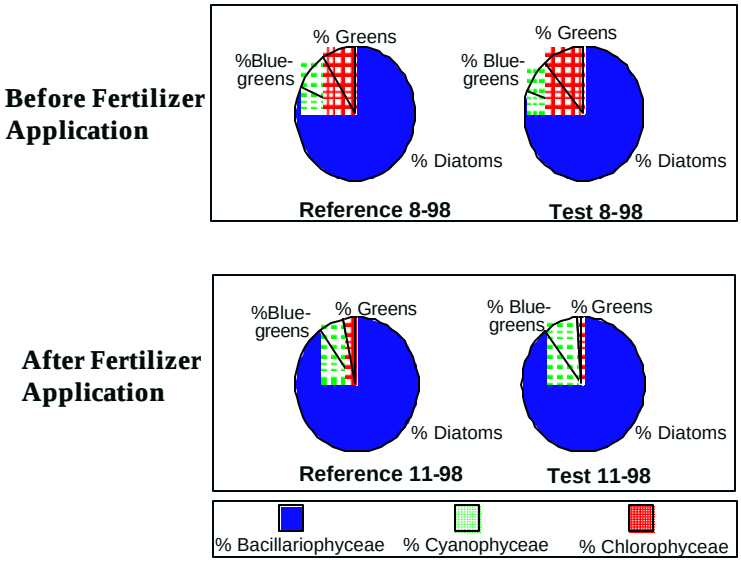


In the Santa Fe River, there were statistically significant improvements in the SCI score during the second sampling event, compared with the initial sampling event ($p = 0.01$). Additionally, the test site score was significantly higher than the reference site score during both sampling events ($p = 0.005$). Between sampling events, 200 pounds/acre of di-ammonium phosphate was applied on 5 year old pines in the vicinity of the test site.

The water level was approximately 0.5 m deeper during the August sampling than it was in November, making sampling in this marginally wadeable river more difficult. This could account for the improvements in the SCI score during the period that the water level was more conducive to collection activities. The higher SCI values at the test site may be explained by the slight improvements in substrate diversity there, as well as the slight reductions in habitat smothering.

There were no significant time by treatment effects, indicating that the fertilizer addition was not linked to the observed changes. Invertebrates are affected indirectly by nutrient enrichment, responding to changes in habitat conditions (e.g., caused by algal smothering) or food sources (e.g., proliferation of less nutritious or noxious algae).

Santa Fe River Periphyton



Periphyton communities respond more quickly to nutrient enrichment effects, and adverse changes in the periphyton community can indicate excessive nutrient enrichment. The periphyton community in the Santa Fe River was dominated by diatoms, both before and after the nutrient application. Many of the diatom taxa found at both sites were indicative of low nutrient conditions, such as *Eunotia pectinalis*, *Frustulia rhomboids*, *Pinnularia major*, *Achnanthes lanceolata*, which is consistent with the water chemistry results.

Conclusions

Habitat quality was in the "optimal" category at all sites, both before and after silviculture activities. The BMPs appeared successful in controlling erosion, since no additional habitat smothering or stream bank instability was noted after silviculture operations took place. The decreases in riparian buffer zone width that were noted at three of the four sites were allowed by the BMPs, and did not shift the overall habitat category at any site.

There appeared to be no major changes in physical-chemical measurements due to silviculture activities. Turbidity was low at all sites. During an intense rain in February, 1997, direct observation at Jack Branch indicated that no turbid water from the clear-cut site was reaching the stream. Nutrients were relatively low at all sites, both before and after the forestry operations.

Fecal coliforms exceeded the Class III water quality standard of 800 organisms/100 mL (maximum) at three sites, including Thomas Creek in 1997 (at the reference and test sites alike) and at the San Julia Branch test site in 1997. Also in 1997, total coliform bacteria exceeded the Class III water quality standard (maximum of 2,400 organisms/100 mL) at the Thomas Creek reference site and at the San Julia Branch test site. The presence of the bacteria was attributed to cattle grazing in the Thomas Creek watershed and extensive wildlife activity (beavers, deer) at San Julia Branch.

Biological health, reflected by the Stream Condition Index (SCI), was not adversely affected by silviculture activities when BMPs were followed. After forestry operations had occurred, the mean SCI scores were in the upper range of the "good" category at the San Julia Branch test and reference sites alike, and in the "excellent" category at both the reference and test sites of Jack Branch, Thomas Creek, and the Econfina River. There were no statistically significant differences in the mean SCI scores (between the reference and test sites) of any stream after logging, site preparation, and replanting had occurred. Additionally, there were no significant differences between any pre- and post-disturbance test site SCI scores. These data suggest the streams were adequately protected by the BMPs.

The SCI coefficient of variation was 10% or less in 12 out of 16 triplicate measures (75% of the total). In the remaining four data sets (25% of the total), the coefficient of variation ranged from 15% to 22%. These results indicate the reproducibility of the SCI methods in arriving at a consistent, repeatable assessment at a given site.

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Appendix 1.

ANOVA Results

San Julia

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Time	1	0.00003963	0.000039631	0.017167	0.8976222
Trt	1	0.00049433	0.000494326	0.214125	0.6506636
Time:Trt	1	0.00658361	0.006583610	2.851794	0.1134109
Residuals	14	0.03232019	0.002308585		

Santa Fe

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Time	1	27.00000	27.00000	10.125	0.0129588
Trt	1	40.33333	40.33333	15.125	0.0046152
Time:Trt	1	3.00000	3.00000	1.125	0.3198134
Residuals	8	21.33333	2.66667		

Jacks Branch

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Time	1	0.00016382	0.000163816	0.036269	0.8508800
Trt	1	0.00509179	0.005091790	1.127341	0.3009968
Time:Trt	1	0.00120459	0.001204590	0.266701	0.6112169
Residuals	20	0.09033271	0.004516635		

Thomas Creek

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Time	1	0.000029998	0.000029998	0.075030	0.7869575
Trt	1	0.001184512	0.001184512	2.962688	0.1006398
Time:Trt	1	0.000000270	0.000000270	0.000676	0.9795205
Residuals	20	0.007996200	0.000399810		

Econfina Creek

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Time	1	0.003252845	0.003252845	6.295347	0.0250250
Trt	1	0.000749024	0.000749024	1.449613	0.2485524
Time:Trt	1	0.001710432	0.001710432	3.310259	0.0902955
Residuals	14	0.007233888	0.000516706		