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Off-Road Vehicles and Their Impacts in the Big Cypress National Preserve

l Park, South Florida Research Center, P.O. Box 279, Homestead, Florida 33030

OFF-ROAD VEHICLES AND THEIR IMPACTS IN THE BIG CYPRESS NATIONAL PRESERVE

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Michael J. Duever, John E. Carlson and Lawrence A. Riopelle

Ecosystem Research Unit
National Audubon Society
Box 1877, Route 6
Naples, Florida 33999

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ABSTRACT

We conducted detailed field studies in the Big Cypress National Preserve (BICY) of (1) experimental impacts produced by all commonly used types of off-road vehicles (ORVs) in all habitats regularly used by ORVs and one annual cycle of recovery from these treatments, (2) recovery over one growing season in abandoned major trails in all habitats, (3) water flows in major trails, and (4) temporal-spatial patterns of use by each type of ORV. Our objective was to document significant aspects of ORV use in BICY so that the National Park Service would have a sound basis upon which to develop appropriate management practices and regulations for incorporation into their master plan. These should then make it possible to realistically minimize impacts and maximize compatibility of ORV use with other activities, while at the same time taking into consideration the needs of ORV users.

Vehicles tested in the impact study included five types of swamp buggies, a three-wheel all-terrain cycle (ATC), an airboat, and a track vehicle. Habitats included small scattered cypress forests, pinelands, and marl, sand, and peat substrate marshes. Each vehicle attempted to produce three levels of impact (one-pass, a significant vegetation impact, and a significant soil impact) ineach of three replicate plots in each habitat. Tests were conducted in fall 1978 and the resulting impacts were evaluated through fall 1979. While measurements of some impacts were made immediately following the treatments, most parameters were measured in late winter 1979 before the growing season began and in early fall 1979, shortly after it ended. Parameters measured were (1) noise produced by each vehicle in each habitat during the tests, (2) visual impacts, (3) soil impacts including rut depth, adjacent ridge height, and soil compaction, (4) understory vegetation impacts, including biomass, percent cover, height, standing litter, and taxonomic composition, and (5) shrub and tree impacts.

Noise levels were dependent primarily on engine type and rpm. Swamp buggies had similar relatively low noise levels except when an automatic transmission resulted in higher rpms. The airboat produced the highest overall noise levels, while the ATC and track vehicle produced intermediate noise levels. Habitat type did not generally influence noise levels.

Water level was the single most important environmental factor influencing severity of initial vehicle impacts, and was inversely related to the number of passes required to reach a specific level of impact. When water is above ground or near the soil surface at the time ORV impacts occur, the degree of impact and time required for recovery are greatly increased. Water levels also indirectly influence ORV impacts by controlling vegetation and soil characteristics.

Small cypress and airboat-track vehicle marl and peat marshes were most sensitive to ORV impacts. Wheeled-vehicle marl marshes were only slightly less sensitive. Pineland was the least sensitive, and sand marshes were

just slightly more sensitive than pineland.

Pine plots showed the greatest recovery, which was complete after one year for most parameters measured, and sand marsh showed only slightly less recovery. In all other habitats recovery was incomplete for most parameters measured at all impact levels. There was a general trend of decreasing recovery with increasing impact level.

The most severe visual impacts were associated with the track vehicle and the least with the airboat. Of the parameters we measured, this showed the least recovery during the first year.

Among the types of soil impacts, soil compressibility was least affected. Soil compaction never occurred, and soils in some lanes were still a loose slurry one year after the tests. Rutting was the most severe soil impact. However, rut depths tended to decrease rapidly following the tests, and were generally quite shallow, if detectable, one year later. The height of ridges along the test lanes were minor initially and generally undetectable one year after the treatments.

Of the quantitative measures of ORV impact on live vegetation, initially average height of understory vegetation was most affected by ORVs, while percent cover was least affected and biomass was intermediate. Of the three parameters, recovery was greater for height and biomass than percent cover during the first growing season. Standing litter was still severely reduced in the vehicle lanes one year after the tests. This was accentuated by the fact that the current year's production had not yet died. Taxonomic composition was altered with the gain or loss of one or more dominant species in at least the medium and heavy impact lanes in virtually all plots. Small cypress plots had both missing taxa and reduced numbers of other taxa compared to the controls, while wheeled-vehicle marl marsh plots had only reduced numbers. New taxa had appeared and/or the frequency of others had increased to levels greater than were present in the controls in all of the wheeled-vehicle plots by the end of the first growing season. Plant diversity was decreased only in track vehicle treatments, which also consistently eliminated, or at least reduced, the number of taxa in test lanes. Only the airboat treatments exhibited essentially no change in taxonomic composition during the vehicle impact study. However, few differences between test lane and control samples were consistent enough to allow us to predict the long-term direction or duration of these changes.

The degree of overall impact generally depended on the amount of soil disturbance, and thus measurement of soil parameters would provide the most sensitive means of quantifying initial impacts. However, the soil recovered much more quickly than did the vegetation, and thus measurement of vegetation parameters would be the most sensitive means of quantifying recovery from impacts.

Degree of impact on shrubs and small trees increased with plant size and impact level. Recovery of cypress and wax myrtle was facilitated by resprouting during the growing season, while willow tended to show increased mortality.

Swamp buggies and the track vehicle generally produced the most severe impacts and showed least recovery after one year. Variations in swamp buggy characteristics (weight per unit area and tread type) had a minor effect on their ability to impact study sites compared to water levels, and most were not important in terms of recovery rates after one year. In marl substrate habitats, the tractor buggy produced heavy impacts in slightly fewer passes than the chain and heavy buggies. The light buggy required two to four times as many passes to reach the same level of impact, and the resulting relatively severe ruts, which still existed one year later, were a function of the increased number of passes. The ATC had the least impact of the wheeled-vehicles, but had only slightly better recovery rates. The airboat had the least impact of all vehicles and showed complete recovery after one year for most parameters.

In general, once significant damage has been done to a habitat by a particular vehicle type, it will continue to be a significant impact for at least one year. Thus, unless a long-term increase in significant impacts is acceptable on portions, or all of BICY, it will be necessary to implement management practices that will minimize the creation of significant impacts wherever they are deemed inappropriate.

Old trail recovery was monitored before and after the first growing season following abandonment in all major BICY habitats regularly penetrated by ORVs. The parameters monitored and methods employed were essentially identical to those used in the vehicle impact study.

Initially, the old trail sites were 2-6 m wide, and all exhibited severe visual impacts. Most were deeply rutted across their whole width and/or worn to bedrock. All but one of the wetter sites had little or no vegetation in the lanes, while the drier sites generally had some. Soil ridges were rarely seen along the trails. Taxonomic composition in old trails was consistently less diverse than in adjacent control areas at all sites.

Airboat trails through marl marshes were the only sites exhibiting relatively little or no impact, except in terms of taxonomic composition, which was greatly reduced in diversity in the trails. Percent recovery of virtually all parameters in old trail study plots was less than 30 percent and frequently less than 15 percent after one growing season. Vegetation height was the only parameter that consistently showed considerably more recovery.

We measured water flows over the range of normal wet and dry season water levels in trails and adjacent habitats at six trail - natural flowway and six trail - canal intersections, which are the types of sites where we expected flows to be most pronounced. While surface water flow velocities in trails perpendicular to direction of natural flow were generally not affected, flow velocities in trails oriented with the flow were increased by a factor of two to four times over those in adjacent habitats. Flows in some trails continued after they had ceased in the surrounding habitat due to water table decline. Once flows began, their velocity tended to remain more or less constant. The small increase in cross-sectional flowway area associated with rutted trails suggests that ORV trails have a very minor impact on the total water budget of BICY. The most significant impacts might be associated with a shortened hydroperiod in localized areas where a slightly more rapid decline in the water table may occur as it approaches and then declines below the general ground surface.

We conducted an initial inventory of all ORVs parked in the preserve at the beginning of our study, and then a periodic census of numbers, kinds, and locations of ORVs or ORV transport vehicles parked along roads in BICY over the next eighteen months. Censuses were most frequent in the peak use period during the late fall - early winter hunting season, when the vast majority of ORV activity occurred. On the opening day of hunting season, we counted twice as many ORVs as compared to any other day of the year, and almost ten times as many as on all eight of the 1979 non-hunting season days combined. Vehicle use was consistently greater on weekends than on weekdays.

Of the ORVs permanently parked in or near the preserve, the majority were swamp buggies, with much smaller numbers of track vehicles and airboats. Of the ORVs transported to the preserve, again the majority were swamp buggies. ATCs and airboats each totaled about one third the number of buggy observations, while track vehicles were much less frequently encountered. Access points for ORVs were located along the Loop Road, Tamiami Trail, and Turner River Road. There were no major access points along Alligator Alley within BICY. Airboat and track vehicle use was concentrated south of the Loop Road and south of Tamiami Trail west of Monroe Station, where buggies and ATCs were less common.

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A number of individuals contributed significantly to our being able to accomplish what we did. Bill Robertson, with the National Park Service (NPS) South Florida Research Center, facilitated administrative aspects and worked with us to make sure that NPS data needs were adequately met in the design, implementation, and write-up phases of the study.

Big Cypress National Preserve staff were particularly helpful throughout the study. Irv Mortenson worked with us on the study design, and in his capacity as park manager, facilitated execution of all aspects of our field work. Carroll Schell participated in design of the study, site selection, development of field techniques, and review of the draft final report. Howard DeMont provided NPS vehicles for the vehicle treatment tests and on several occasions, to facilitate access to some of the more remote sites. Fred Dayhoff advised us on site and vehicle selection.

Melvin "Smitty" Smith, Al Bravaldo, and Louis Murray supplied off-road vehicles for the vehicle treatment tests. The Everglades Conservation and Sportsman Club provided a trailer space and hookup for a travel trailer that was our base of operations while doing field work in the eastern part of the preserve.

Calvin Stone and Ruth Wallace, who are actively involved with two of the major Big Cypress National Preserve ORV-user groups, coordinated contacts with their respective organizations, which resulted in valuable input to the study design.

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INTRODUCTION

During the past two decades vehicular travel through roadless country has increased tremendously. While off-road vehicles (ORVs) provide recreational access to many areas that otherwise would be enjoyed by few, they are causing marked impacts on natural ecosystems, and since many of the most severely affected areas are, like the Big Cypress, quasi-wilderness regions which have been set aside as natural preserves, any such damage is of great concern. With certain constraints on times, places, types, methods of operation, and purposes, reasonable numbers of ORVs can undoubtedly be used without disrupting the integrity of most ecosystems. However, there is little data available upon which to base appropriate regulations. This has led to several recent studies (Harrison 1974a, Leatherman and Godfrey 1979), symposia (Committee on Environment and Public Policy 1977), and reports (U.S. Department of the Interior 1972, Baldwin and Stoddard 1973, Sheridan 1979) on the ORV problem.

Unfortunately, since most of the work done to date has involved types of vehicles and terrain not normally encountered in South Florida, its application to the Big Cypress National Preserve (BICY) is limited. Schemnitz and Schortemeyer (1974) did study the effects of airboats and track vehicles on marsh vegetation in the Everglades, but the soil types and plant communities they investigated are relatively uncommon in the Big Cypress and the vehicles they studied are not types widely used in the BICY. As part of the resource inventory and analysis for BICY, Duever et al. (1979) summarized off-road vehicle use patterns in the Big Cypress. This report included data on the types and numbers of ORVs, when and why they are used, an analysis of the historical development of ORV trails, and a qualitative assessment of impacts. Stubbs (1979) detailed the social aspects of ORV use in BICY by surveying the major ORV user groups. While this information provides a perspective on past and present ORV use in BICY, it does not adequately answer many questions pertinent to their proper role in the future, particularly in the context of their rapidly expanding numbers.

In order to develop a data base for decisions on the future role of ORVs in the BICY, the National Park Service (NPS) contracted with the National Audubon Society Ecosystem Research Unit to evaluate ORV impacts and their subsequent recovery rates in the preserve's major habitats. During fall 1978 we tested vehicles representative of the spectrum of types commonly used in the preserve in pine forests, open cypress forests, and several types of marshes. Initial impacts were evaluated, and during the following winter and fall we made quantitative measurements of soil and vegetation impacts. Other aspects of the study included monitoring recovery of abandoned trails that had been in use for many years, evaluating the effects of trails on natural surface water flows, and determining when and where different types of ORVs are used.

PART I.

VEHICLE IMPACT STUDY

METHODS

Vehicle Selection

Eight vehicles representing the four major types of ORVs used in the preserve were tested (Table 1). The less variable ORV types, three-wheel all-terrain cycles (ATCs) (Figure 1), airboats (Figure 2), and track vehicles (Figure 3) were each represented by a single vehicle, while five vehicles were chosen to represent the highly variable swamp buggy type (Figures 4-7). The swamp buggies chosen represent the wide range of total weights, weight per unit area, and major tread types used in the Big Cypress. The sample included one light and one heavy weight per unit area buggy and three intermediate examples with the most common tire tread types used in the Big Cypress: smooth, smooth with chains, and tractor. The heavy buggy needed to attach "cleats" or short pieces of angle iron to its tires to operate in the small cypress plots. All buggies were two-axle, four tire, four-wheel drive vehicles except the heavy buggy which had rear-wheel drive with dual wheels on the rear drive axle, giving it a total of six tires.

We measured empty vehicle weights on a hard flat surface with an Enerpac hydraulic jack. Front and rear axles were weighed separately by raising the tires just off the ground. We then placed a piece of cardboard under one tire on each axle and after the vehicle had been let down, made a "print" or outline of the tire area on the cardboard with aerosol spray paint. We used these prints to measure tire width in contact with the ground and also to determine the total contact area with a 2.5 cm grid pattern. We calculated weight per unit area by dividing the weight recorded for each axle by the square centimeters of tire contact area on that axle.

Availability influenced the vehicles chosen for the study. Major problems involved scheduling the operator, transportation of the vehicle, and reluctance of operators to be responsible for damage to their vehicles when used in unfamiliar territory. However, even though we were not in a position of choosing any vehicle we desired, we feel those selected represent a reasonable cross-section of the types normally used in the preserve.

Study Site Selection

Three replicate plots were established in each of the major habitats used by ORVs in the Big Cypress. These include marshes with sand, marl, and peat substrates, pine sites with variable rock and sand substrate, and sites occupied by small scattered cypress growing on a marl substrate.

Table 1. Characteristics of wheeled and track off-road vehicles tested in Big Cypress National Preserve.

	Light Buggy	Chain and Smooth Buggy	Tractor Buggy	Heavy Buggy*	ATC	Track Vehicle
Frame Type	steel channel	jeep truck	jeep truck	military truck	3-wheel honda	steel channel
Engine Cylinders	6	6	4	6	1	6
Drive Type	4-wheel drive	4-wheel drive	4-wheel drive	rear dual wheels	rear 2-wheel drive	full track weasel rear end**
Transmission	automatic	standard	standard	standard	standard	standard
Tires Width x Height (cm)	46x106	25x91	25x119	30x117 front 30x106 rear	23x56	46x213
Tread Type	diamond	smooth aircraft with/without .78 cm chain	tractor	smooth aircraft with .78 cm chain	knobby	otter track
Tread Depth (cm)	2.5	1.9	2.5	1.9	1.0	-
Weight (kg)						
Front Axle	840	635	750	1400	57***	910
Rear Axle	635	545	635	1400	120***	1000
Weight Per Unit Area (kg/cm^2)						
Front Axle	0.39	0.44	0.48	0.59	0.16***	0.14
Rear Axle	0.28	0.38	0.40	0.46	0.14***	

* Kg/cm^2 exerted by vehicle tires or tracks on ground surface.
** Power delivered to tracks independently.
*** Calculated with one 77 kg operator.

Figure 1. All-terrain cycle (ATC)

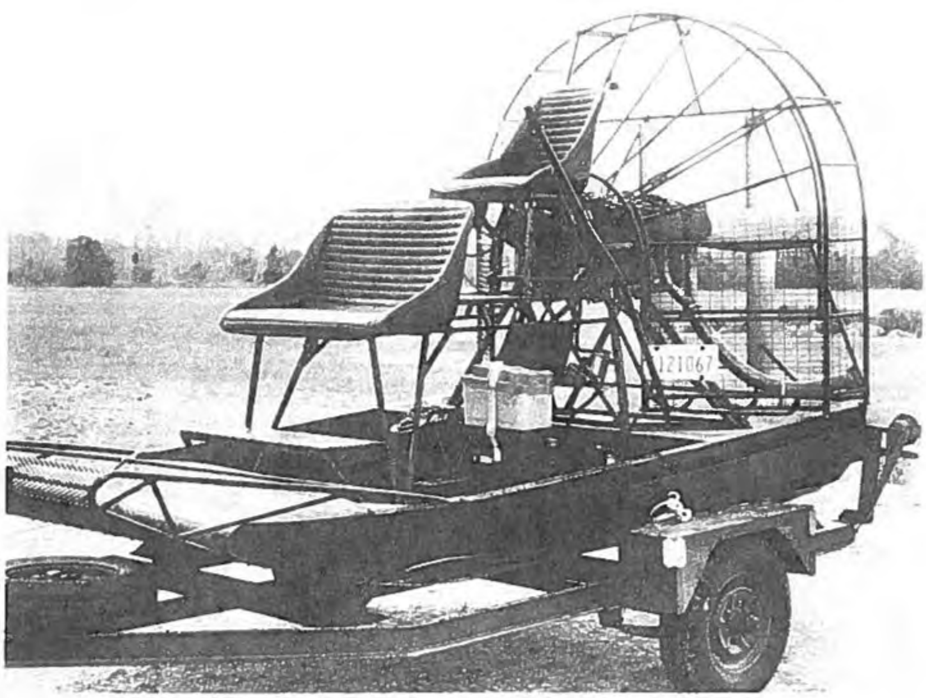


Figure 2. A typical airboat on its trailer

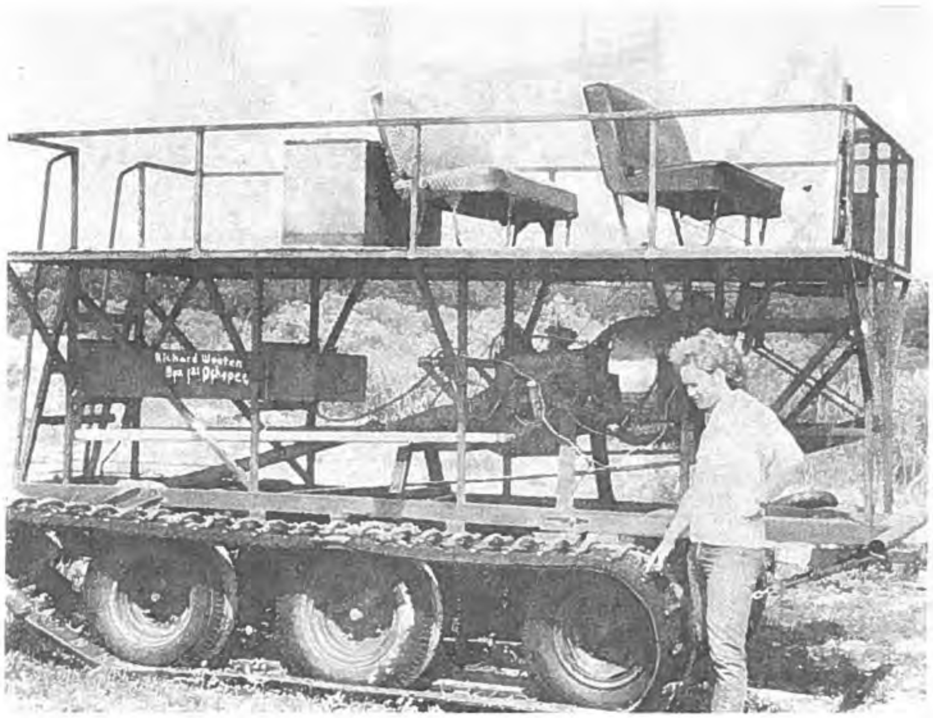


Figure 3. A typical full-track vehicle

Figure 4. Our "light" swamp buggy on a trailer in foreground

Figure 5. Our "heavy" swamp buggy

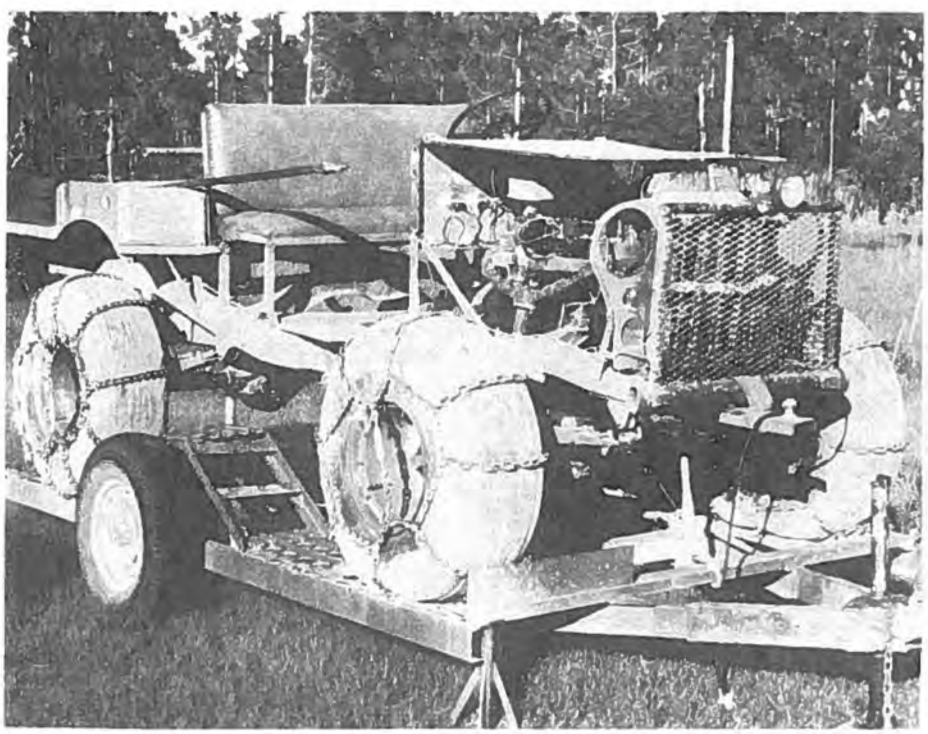


Figure 6. One of our "intermediate" swamp buggies. It was the "smooth" buggy without chains and the "chain" buggy with chains.

Figure 7. Our other "intermediate" swamp buggy which had tractor-tread tires and was referred to as the "tractor" buggy.

A total of twelve plots (three each in sand marsh, marl marsh , small cypress and pine habitats) were established for wheeled-vehicle treatments, and six plots (three each in peat and marl marshes) for the airboat and track-vehicle treatments (Figure 8).

Appropriate habitats representative of those used by ORVs was the major objective of test site selection, but several other factors influenced their ultimate distribution. Accessibility was a primary consideration. In an area as large as Big Cypress, where travel is often slow and difficult due to characteristics of the terrain, travel time to and from remote interior study plots would have added significantly to the time and expense involved. The NPS also wanted to use the study sites as relatively accessible demonstration plots. Locating most of the plots near roads helped to alleviate these problems. Security was also a consideration, since vandalism or even unintentional disturbance of the study plots by even a small percentage of the large number of ORVs operating in Big Cypress could have significantly diminished the value of the study. Locating study plots near roads enabled both NPS and Florida Game and Freshwater Fish Commission personnel to watch for unauthorized use while making their regular rounds. Patchy federal ownership both reduced the potential area available for sites, and added substantially to the time required for site selection. Final plot selection was based on substrate and vegetation characteristics. Twenty soil samples were taken in each plot to determine soil type and where possible, depth to bedrock. At the same time, major plant species were identified and their relative abundance noted.

Vehicle Tests

All plots were marked by a single permanent corner, usually a nail and small aluminum tag on a tree or shrub. Test runs were made perpendicular to a base line extending along a fixed compass bearing from this corner (Table 2). Treatments were made at 4 m intervals along the baseline in marsh habitats, and at 6 m intervals in pine and cypress habitats (Table 3). The extra distance between treatments in wooded habitats allowed vehicles to avoid large trees without overlapping adjacent treatments. Plots varied in width from 216 m (36 wheeled-vehicle treatments in pine and cypress) and 144 m (36 wheeled-vehicle treatments in marshes) to 60 m (15 airboat and track vehicle treatments). Each vehicle treatment was at least 70 m long through undisturbed habitat. This was several times the distance needed for monitoring recovery and allowed for a certain amount of unplanned disturbance. Wherever possible, treatments were oriented perpendicular to the general flow of ORV traffic so that any unauthorized vehicles driving through a plot would be likely to cross test tracks, rather than follow them.

Each vehicle was required to make three levels of impact in each plot along three separate lanes. The lowest level was a single pass, which in most cases did no significant damage to vegetation or soils. Continuous running back and forth was then done in another lane until

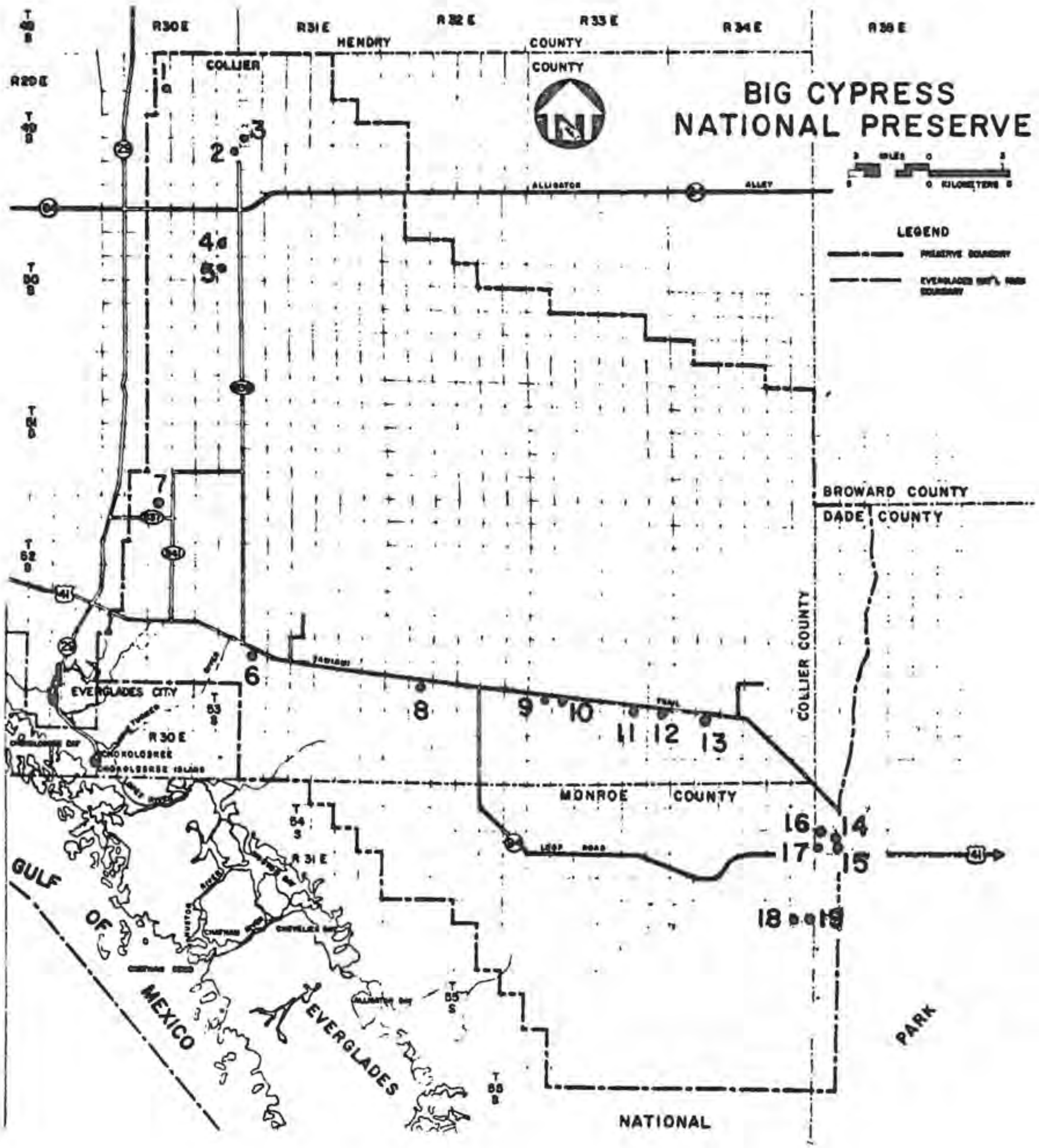


Figure 8. Locations of vehicle impact study plots.

1 Sand Marsh 1
2 Sand Marsh 2
3 Sand Marsh 3
4 Pine 1
5 Pine 2
6 Pine 3
7 Wheeled Vehicle Marl Marsh 1
8 Wheeled Vehicle Marl Marsh 2
9 Wheeled Vehicle Marl Marsh 3
10 Small Cypress 1
11 Small Cypress 2a
12 Small Cypress 2b
13 Small Cypress 3
14 Airboat and Track Marl Marsh 1
15 Airboat and Track Peat Marsh 2
16 Airboat and Track Peat Marsh 1
17 Airboat and Track Marl Marsh 2
18 Airboat and Track Marl Marsh 3
19 Airboat and Track Peat Marsh 3

Table 2. Orientation of test plot baselines and vehicle test lanes.

	Baseline Compass Direction (^{o})	Test Lane Compass Direction (^{o})
Wheeled-Vehicle Test Plots		
Small Cypress 1	270	360
Small Cypress 2	100	190
Small Cypress 3	100	190
Marl Marsh 1	270	360
Marl Marsh 2	180	270
Marl Marsh 3	180	85
Sand Marsh 1	220	310
Sand Marsh 2	180	270
Sand Marsh 3	230	140
Pine 1	0	90
Pine 2	180	270
Pine 3	180	90
Airboat-Track Vehicle Plots		
Marl Marsh 1	216	126
Marl Marsh 2	186	96
Marl Marsh 3	230	320
Peat Marsh 1	216	306
Peat Marsh 2	186	96
Peat Marsh 3	230	140

Table 3. Locations of wet season vehicle treatment lanes in test plots. Baseline position represents the distance from the marked corner of the plot.

Small Cypress 1

Vehicle Type[a]	Impact Intensity[b]	Baseline Position (m)
Chain	l	21
ATC	M	51
ATC	H	57
ATC	l	69
Light	l	87
Heavy	l	93
Heavy	H	99
Chain	H	111
Tractor	l	141
Light	H	153
Heavy	M	171
Tractor	H	177
Light	M	183

Small Cypress 2

Vehicle Type	Impact Intensity	Baseline Position (m)
	Plot 2a	
Tractor	l	39
Tractor	H	75
ATC	l	81
ATC	M	105
ATC	H	117
	Plot 2b	
Light	l	15
Light	M	33
Chain	l	39
Light	H	45
Chain	H	63
Heavy	H	81
Heavy	l	87
Heavy	M	93

Small Cypress 3

Vehicle Type	Impact Intensity	Baseline Position (m)
Tractor	H	9
Tractor	l	15
ATC	l	21
Chain	l	39
ATC	H	45
ATC	M	51
Light	H	117
Light	l	123
Chain	H	129
Heavy	H	135
Heavy	l	141

Table 3. Continued.

Marl Marsh 1			Marl Marsh 2			Marl Marsh 3		
Vehicle Type[a]	Impact Intensity[b]	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)
Chain	H	2	Chain	1	6	Light	H	2
ATC	M	18	Light	1	22	Tractor	H	6
Heavy	H	38	Chain	H	26	Heavy	1	14
Chain	M	46	Tractor	1	34	Heavy	H	22
Tractor	1	66	ATC	M	50	ATC	1	34
Heavy	1	74	Light	M	54	Heavy	M	38
ATC	H	78	Light	H	58	Tractor	1	42
Tractor	H	86	ATC	1	70	Chain	H	50
Light	1	98	ATC	H	90	Light	M	58
ATC	1	102	Tractor	H	98	Light	1	62
Heavy	M	106	Chain	M	106	Chain	1	82
Tractor	M	110				ATC	M	86
Light	M	114				ATC	H	122
Light	H	119				Chain	M	134
Chain	1	134						

Table 3. Continued.

Sand Marsh 1			Sand Marsh 2			Sand Marsh 3		
Vehicle Type[a]	Impact Intensity[b]	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)
Tractor	M	10	Tractor	l	2	ATC	l	2
Light	M	18	Tractor	H	6	Chain	H	6
Heavy	M	30	Light	l	18	Smooth	l	34
ATC	l	34	Tractor	M	22	Tractor	M	42
Heavy	H	38	Heavy	l	34	ATC	M	46
Chain	l	50	Light	M	50	Heavy	H	50
Light	H	54	Heavy	H	54	Chain	M	54
Tractor	H	62	ATC	M	58	Heavy	l	58
Smooth	l	66	Smooth	M	74	Heavy	M	62
Heavy	l	74	Chain	M	90	Smooth	M	66
ATC	M	86	ATC	H	98	Light	M	74
Light	l	90	Heavy	M	102	ATC	H	78
Chain	H	98	Chain	l	114	Light	H	82
Smooth	M	106	Smooth	l	126	Light	l	114
ATC	H	122	ATC	l	130	Chain	l	122
Chain	M	126	Chain	H	134	Tractor	l	126
Smooth	H	134	Light	H	138	Tractor	H	134
Tractor	l	142	Smooth	H	142	Smooth	H	142

Table 3. Continued.

Pine 1			Pine 2			Pine 3		
Vehicle Type[a]	Impact Intensity[b]	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)
Chain	M	3[c]	Chain	l	3	Tractor	l	1
Chain	H	3	ATC	l	15	Light	l	9
Chain	l	9	Chain	H	21	Heavy	l	15
ATC	M	15	ATC	M	27	Chain	l	33
Tractor	l	21	ATC	H	33	Smooth	M	51
Light	l	27	Tractor	l	39	ATC	M	57
Heavy	l	45	Light	l	51	ATC	l	65
ATC	l	64	Chain	M	63	ATC	H	77
ATC	H	75	Smooth	H	81	Smooth	H	87
Smooth	l	111	Heavy	l	87	Smooth	l	99
Smooth	H	129	Smooth	M	171	Chain	M	147
Smooth	M	141	Smooth	l	177	Chain	H	165

Table 3. Continued.

Marl and Peat Marsh 1			Marl and Peat Marsh 2			Marl and Peat Marsh 3		
Vehicle Type[a]	Impact Intensity[b]	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)	Vehicle Type	Impact Intensity	Baseline Position (m)
Airboat	1 slow	2	Airboat	M slow	14	Track	1 slow	6
Airboat	M slow	6	Track	1 slow	18	Airboat	M fast	10
Track	1 slow	22	Track	H slow	22	Track	H slow	14
Airboat	M fast	26	Track	M slow	26[d]	Airboat	M slow	18
Airboat	H slow	30	Airboat	H fast	34-42[e]	Track	M slow	22[d]
Track	H slow	38	Airboat	H slow	42-54[e]	Airboat	1 slow	30
Airboat	H fast	42	Airboat	1 slow	46	Airboat	H slow	42
Track	M slow	46[d]	Airboat	M fast	54-34[e]	Airboat	H fast	54

a Vehicle types described in Table 1 , except airboat
b 1 = one pass, M = medium impact, H = heavy impact
c Chain M located 3 m south of plot corner, all other lanes north of corner
d Peat Marsh only
e First number is position in peat marsh plot, second number is position in marl marsh plot

a "heavy impact" was achieved. We defined a heavy impact as severe or total destruction of vegetation and severe soil disturbance. This level was usually reached when severe rutting of the soil occurred; in some plots ruts were to bedrock. Once the heavy impact had been observed, a third series of passes was made in another lane to produce a "medium impact". This level usually involved a severe impact on the vegetation without significant effects on the soil. There were 36 possible treatments in each wheeled-vehicle test plot: 6 vehicles x 3 impact intensities x 2 seasons (wet and dry). Track vehicle and airboat plots had 18 possible treatments: 2 vehicles x 2 speeds x 3 impact intensities x 1.5 seasons (track wet and dry, airboat wet only). Each treatment was allocated a randomly-selected position along the baseline by separate drawings of all possible treatments at each test plot.

As treatments were performed, some theoretically possible ones had to be eliminated. The smooth-tired swamp buggy would not operate in marl marshes or small cypress. The same vehicle with chains, however, completed all runs in both habitats. During the wet season, marl soils of these habitats were simply too slippery for a smooth-tired vehicle of this weight and tire size. Initial treatments of pine plots with this same vehicle, both with and without chains, resulted in substantial damage to the vehicle. Driving a straight line through a rocky pineland with a saw palmetto (Serenoa repens) and pine stump understory resulted in multiple breakdowns and delays. Steering mechanisms in particular are subject to damage in this habitat. We feel that it is unrealistic to expect large vehicles to make repeated runs through unimpacted pinelands, and that under normal circumstances these vehicles stay on previously established trails. We failed to make a heavy impact in pinelands with our intermediate-weight vehicle, with or without chains, even after 60 passes in the same lane. Therefore, medium and heavy impact tests were eliminated in pinelands for the other swamp buggies. ATCs, however, being much lighter and more maneuverable, were operated at all three impact intensities in pinelands. One-pass at a fast speed for airboats in marl and peat marshes was also eliminated. Airboat operators stated that this treatment is also unrealistic and potentially hazardous to vehicle and operator, simply because of the danger of striking a rock or stump hidden in unimpacted vegetation. Therefore, an initial slow run was made prior to "fast" airboat treatments to determine if subsequent fast runs were possible. Our track test vehicle could not vary its speed enough under wet season conditions to make a meaningful comparison of slow and fast speeds, so all of its runs were done at slow speed only. Under some conditions very few vehicle passes (four or less) were required to create a heavy impact. When this occurred three separate impact intensities were not possible, and only two intensities, one-pass and heavy, were performed.

Airboat test runs were made during a two-day period late in September. Wet season wheeled-vehicle test runs were begun in late September and completed November 10. Difficulty in scheduling a track vehicle delayed testing of this vehicle until December 12. Dry season treatments were not conducted as planned in 1979 because it was an unusually wet year and a valid comparison of wet and dry season conditions would not have been possible.

In general, the way we operated vehicles during the treatments was representative of how they are normally operated in BICY. Vehicle speeds were largely determined by water levels and substrate conditions and would have been essentially the same for normal recreational vehicle use. Although examples of our three impact levels can be found in all BICY habitats in which we tested vehicles, the representativeness of repeated use of the same lane or track by any ORV has been questioned for at least one habitat. ORVs generally do tend to use the same trails continuously unless rutting and loss of traction slow vehicle progress or even make it questionable. In most pine and sand marsh habitats these factors are not a problem, and normal vehicle use would be expected to regularly occur in the same trails. In small cypress habitats, vehicles are generally forced by tree density to use the same trails. In marl and peat marshes, however, vehicles are able to avoid deteriorating trails by simply pulling over to unimpacted,or less impacted, areas parallel to the existing trail. Thus, a single set of heavily impacted vehicle ruts in an otherwise undisturbed marl marsh is not likely. However, in areas where particularly intensive vehicle use occurs, previously impacted ruts are unavoidable, and impacts comparable to those created in our heavy impact test lanes do occur.

Vehicle Noise Measurements

A Quest Model 215 sound meter was used to measure decibels of sound produced by each test vehicle in each habitat type. Measurements were made during regular test runs in at least two study plots of each habitat type. Noise levels were recorded at the beginning (within 3 m of vehicle) and end (approximately 100 m away from vehicle) of five replicate test runs in each plot.

Impact Assessment

Initial Measurements

Immediately after all treatments, rut depths were estimated and visual impacts rated on a numerical scale. The rating system initially considered both soil and vegetation impacts. A test lane with no discernable impact was rated zero. A slight visual impact such as vegetation bent over, but not really damaged or removed, and no soil disturbance, received a one. Lanes with some vegetation removed or killed, and slight to moderate soil disturbance, received a two. Destruction of most of the vegetation in the trail, and moderate to heavy disturbance of the soil was rated three.

Total destruction of vegetation, and severe soil disturbance was rated four.

These methods allowed an initial qualitative assessment of impacts which was all that was possible due to time constraints during the vehicle testing period. Actually, little more than this could have been done anyway, since ruts in some looser soils began to fill in immediately after treatment, and mortality of vegetation that had been pushed over, coated with soil, and/or partially submerged was impossible to determine.

Pre- Growing Season Measurements

The first detailed measurements of impacts in wheeled-vehicle treatment plots were done during February 1979, approximately four months after the impacts were made. Airboat and track-vehicle impacts were not measured until the middle of March, five-and-one-half months after airboat treatments and three months after track-vehicle treatments. The effect of these delays on initial sampling results was minimal due to the slow growth of vegetation during the winter months, and many of the heavy impact lanes still supported no vegetation. Postponement of sampling enabled us to make the distinction between vegetation that was damaged, but not killed, and that which was killed as a result of the treatments.

Evaluation of soil impacts involved measurements of rut depth and height of the adjacent ridge of displaced soil at 30 random 0.5 m segments along the test lane. Vegetation impacts were evaluated in three 10 x 100 cm plots (shaped to fit vehicle tracks) located randomly along one track of each vehicle treatment and in nine similarly-shaped control plots adjacent to the vehicle tracks at each study site. In each plot, percent cover of vegetation was estimated, its height measured, dominant taxa and their relative abundance noted, and living vegetation clipped, dried at 105^{o}, and weighed.

Impacts on shrubs and small trees struck by vehicles during test treatments were evaluated by a numerical rating system: zero for no observable impact; one for low impact (plant disturbed, but only a small portion removed or killed); two for heavy damage (a majority of the plant removed or killed); and three for mortality. A representative sample of test lanes was inspected for impacted woody vegetation in February 1979, when each tree and shrub present in a vehicle lane was recorded by genus and size class, and evaluated according to the rating system.

Post- Growing Season Measurements

A second set of quantitative measurements was made during the post- growing season in October 1979, using most of the same techniques described above. In addition, standing litter was collected in the 10 x 100 cm plots and dried and weighed separately. The visual rating system was changed slightly for this sampling period. When we attempted to apply the original rating system developed in fall 1978 to the test lanes, the relatively greater recovery of soils compared to vegetation tended to skew winter 1979 data to the low impact end of the scale. Many slight-to-moderate soil disturbances had recovered completely by February 1979, while vegetation recovery was minimal. Thus, we decided to eliminate the February data and base our visual ratings in October 1979 on vegetation impacts only. The system was the same, except categories two and three were better defined: some-to-half of the vegetation removed was rated two, and more than half, but not all, vegetation removed was rated three.

Relative soil compaction was determined with a Soil Test Inc. Model CL 700 penetrometer, which measures the resistance of soil to penetration by a rod with a 0.64 or 2.5 cm diameter base, in terms of its "unconfined compressive strength". An initial survey was performed during October 1979 in all test plots by taking five measurements in two heavy-impact lanes, and ten measurements in an adjacent control site. In most plots we pushed the 0.64 cm rod at least several centimeters into the substrate to assess soil compressibility, but in sand marsh sites added a 2.5 cm diameter adaptor foot, which was pushed only 0.5 cm into these relatively firmer substrates. The lower compressive strength values shown for the sand marsh plots resulted from the difference in penetration depth and the use of the adaptor foot. A more detailed study was done during March 1980 in the small cypress and wheeled-vehicle marl marsh plots. It involved pushing the penetrometer through the soil until bedrock was just barely reached, thus measuring the resistance of the soil above bedrock to penetration by the rod. Seven measurements were taken in each lane that was still visible, and nine were taken in an adjacent control area at each plot.

Statistical Analyses

Our statistical analyses of the vehicle test plot data utilized Duncan's new multiple range tests of each set of vehicle-type - impact-level data for each plot-sampling period. Probability levels were always .05.

When one reads the Duncan's new multiple range test tables, treatments with the same letter within a column are not significantly different from one another. No statistical tests were made comparing a treatment in different plots or on different sampling dates, so results along a row in these tables are not statistically comparable.

RESULTS

Vehicle Noise Levels

Noise level measurements for each vehicle type were essentially the same in most habitat types, and there were only small differences between the different types of wheeled vehicles (Table 4). All "far" readings for buggies were similar, probably because all were powered by basically the same types of muffled automotive engines. The light buggy, however, had slightly higher "near" values. It was the only one with an automatic transmission, and its engine rpm was consistently greater than the other buggies which probably accounted for the higher sound levels.

Table 4. Range of average sound levels (dB) produced by vehicles during test runs.

Vehicle	Proximity to Sound Meter Near*	Far**
ATC	78-81	53-56
Light Buggy	82-84	41
Chain (Smooth) Buggy	68-74	39-44
Tractor Buggy	73-79	37-40
Heavy Buggy	68-70	37-43
Airboat		
Fast	91-92	74-75
Slow	86	63-69
Track Vehicle		
Marl Marsh	92	43
Peat Marsh	91	60

* Approximately 3 m away
** Approximately 100 m away

The two buggies with the largest and most powerful engines produced the least noise. These vehicles, with excess power and a manual transmission, were able to simply idle quietly through most test runs. The "far" readings for all swamp buggies were comparable to background noise levels. The ATC had "far" readings that were about 15 dB higher than the swamp buggies. This vehicle had a much smaller muffled engine, but in order to provide enough power, it was run at a very high rpm. This resulted in a high-pitched "whining" sound, which carried farther.

"Near" readings for the track vehicle and airboat in marl and peat marshes were similar. This was surprising since the airboat seemed much louder during the test runs, which would agree with the fact that airboat operators normally wear earplugs to protect against excessive noise while track-vehicle operators do not. Our measurements were greatly influenced by vehicle performance and position of the sound meter. While airboats are capable of producing noise in excess of 120 dB when accelerating, we measured the lower sound levels of a steadily cruising boat. Also, since all measurements were taken by an observer standing on the ground, this placed the sound meter in close proximity to the engine and moving tracks of the track vehicle. The combination of the clattering and splashing of tracks moving through water and the high engine rpm needed to power the tracks probably accounts for the high "near" track vehicle readings. Airboat noise reached much greater sound levels at the far end of the test plots than did any other vehicle. Location of the unshrouded engine and propeller, both of which are significant sound producers, high above the water surface and most vegetation allowed the sound to travel much farther. Track vehicle "far" readings were similar to the range of wheeled-vehicle "far" values. However, for unknown reasons, they were significantly higher in the peat marshes than in the marl marshes.

A comparison of our measured vehicle noise levels with Florida's legal limits for street vehicles provides a useful perspective from which to evaluate the significance of these data. Under the Vehicle Noise Prevention and Control Act of 1974, section 316.293, sound level limits for motorcycles (over 5 hp), passenger cars, and large trucks (gross vehicle weight rating of 4525 kg or more), traveling under 56 km/hr and 15 m from the measuring device, are 78, 72, and 86 dB, respectively. Since our "near" readings were made within 3 m of the test vehicles, we would expect 15 m readings to be somewhat lower, and all of our wheeled vehicles to fall within the range of allowable noise levels for cars and motorcycles. Tracks and airboats, however, would probably be above this level, but would probably be within the limit allowed for large trucks. Harrison (1974a, 1974b) proposes that where ORVs themselves are not considered objectionable, a limit of 85 dB at 15 m for all vehicles is generally acceptable to human observers, but where a wilderness experience is desired, any detectable ORV noise can be unacceptable.

Site Characteristics

Depth and physical characteristics of soils were similar in small cypress and wheeled-vehicle marl marsh plots, with the exception of marl marsh plot 1, which had a more variable soil type and depth (Table 5).

Table 5. Characteristics of vehicle impact study plots.

Study Plots	Depth to Rock (cm) $\bar{X}$	Range	Water Depth (cm)*	Substrate Description	Vegetation
Small Cypress 1	18.3	5-35	3-10	3-5 cm periphyton over gray-brown to gray sandy marl with interspersed freshwater shell.	Grass and sedge understory, *Panicum*, *Muhlenbergia*, *Cladium* *Dichromena*. Scattered dwarf *Taxodium* overstory up to 7 m.
Small Cypress 2a	15.7	5-30	5-10	See Small Cypress 1	See Small Cypress 1
Small Cypress 2b	17.3	0-35	5-10	0-3 cm periphyton over 5-10 cm dark organic stained sandy marl over heavy gray clay-like marl with interspersed fresh-water shell.	Grass and sedge understory as above but with *Muhlenbergia* dominant. *Taxodium* slightly smaller, up to 5 m.
Small Cypress 3	21.0	10-45	8-13	3-5 cm periphyton over gray sandy marl with interspersed freshwater shell.	See Small Cypress 2b
Wheeled-Vehicle Marl Marsh 1	25.1	0-76	0	Soil variable, some areas marl from surface to bed-rock while other areas mostly sand, generally 3-10 cm gray marl over gray brown sandy marl.	Treeless grassland, *Muhlenbergia* and *Panicum* dominant grasses, *Centella* dominant forb, *Cladium* common sedge.
Wheeled-Vehicle Marl Marsh 2	14.5	5-45	0	Dark gray sandy marl over dense light gray marl.	See Marl Marsh 1
Wheeled-Vehicle Marl Marsh 3	18.0	5-50	0	3 cm periphyton over slightly sandy gray brown marl.	See Marl Marsh 1

Table 5. Continued.

Study Plots	Depth to Rock (cm) X	Range	Water Depth (cm)*	Substrate Description	Vegetation
Sand Marsh 1	30+	-	20-25	5-10 cm dark organic stained sand over brown sand.	Forbs Ludwigia, Bacopa, Centella dominant, Panicum present. Scattered Cephalanthus.
Sand Marsh 2	30+	-	0	3-5 cm dark organic sand over brown sand.	Spartina and Cladium dominant, Centella common forb, Panicum, Proserpinaca present
Sand Marsh 3	30+	-	**	Uniform medium brown sand with trace of marl mixed in.	Muhlenbergia and Panicum dominant, Centella common
Pine 1	13.5	0-25	**	3-5 cm salt and pepper sand over 5-10 cm brown sand (slight marl content) over brown sand with rusty mottling.	Grasses Aristida, Panicum dominant understory. Scattered Serenoa estimated 20% of total cover. Overstory 7-15 m Pinus.
Pine 2	10.9	0-30	**	3-7 cm dark organic sand over light brown sand; some marl in last 3 cm before rock; 5-10% of plot has rock at surface.	See Pine 1
Pine 3	19.0	5-50	0	5-10 cm dark organic sand over light brown sand. No rock at surface.	See Pine 1

Table 5. Continued.

Study Plots	Depth to Rock (cm) X	Range	Water Depth (cm)*	Substrate Description	Vegetation
Airboat-Track Vehicle Marl Marsh 1	18.5	5-50	10-15	3-5 cm periphyton over dark gray marl with interspersed freshwater shell.	Cladium, 1 m or less dominant, some Eleocharis. Few scattered Taxodium, 1-3 m.
Airboat-Track Vehicle Marl Marsh 2	17.3	10-30	10-15	See Marl Marsh 1	See Marl Marsh 1
Airboat-Track Vehicle Marl Marsh 3	19.3	10-35	8-13	5-10 cm crumbly light gray marl interspersed with freshwater shell.	Cladium, 1 m or less dominant.
Peat Marsh 1	27.9	5-50	20-35	Peat soil occasionally with 3-5 cm of marl over bedrock.	Cladium and Typha, 2-3 m dominant. Occasional small Taxodium and Salix
Peat Marsh 2	24.4	10-50	20-35	Sandy peat.	Cladium, 2-3 m. Scattered Salix and Taxodium.
Peat Marsh 3	25.1	10-45	20-30	Peat; deeper soil has 3-5 cm marl over bedrock.	See Peat Marsh 2

* Water depth during treatments; 0 = water table at ground surface
** Water table well below ground surface

Taxonomic composition of understory vegetation in these habitats was also very similar. However, water level measurements made during the vehicle treatments showed that the cypress habitats were deeper and had a longer hydroperiod than the marl marsh habitats.

Sand marsh plots had highly variable plant communities. Sand marsh 1, located in the Okaloacoochee Slough, was inundated with 20-25 cm of water throughout the vehicle treatment period and was dominated by plant taxa relatively tolerant of inundation. Sand marsh plots 2 and 3 had no surface water throughout the treatment period, however visual examination of soil samples showed organic matter and soil moisture were greater in plot 2 than in plot 3. This indicates that plot 2, which is dominated by sand cordgrass (Spartina bakeri), and sawgrass (Cladium jamaicensis), is lower and has a longer hydroperiod than sand marsh plot 3, which is dominated by low panicums (Panicum sp.), and Muhlygrass (Muhlenbergia capillaris).

Although the pine plots generally had similar characteristics, plots 1 and 2 were located near the north end of the preserve in an area bounded by three major canals, while plot 3 was located near the coast and a major canal outfall (Turner River Canal). Soils of the northern plots were dry during the treatments and surface water was never observed in these plots or in adjacent lower cypress habitats. While there was never any surface water in pine plot 3, surrounding cypress and marsh habitats did have surface water and the sandy soils of this plot were saturated. The water table was within a few centimeters of the ground surface and vehicle ruts quickly filled with water.

Marl marsh plots used for airboat and track vehicle treatments differed primarily in that plot 3 was a very uniform stand of sawgrass, while plots 1 and 2 contained some spike rush (Eleocharis cellulosa), and scattered small cypress. Water levels were similar to those in the wheeled-vehicle small cypress sites.

The only differences in the peat marsh plots were that plots 2 and 3 were nearly pure stands of sawgrass, while plot 1 contained sawgrass and substantial amounts of cattail (Typha sp.). This was the deepest habitat tested.

Numbers of Passes to Produce Impacts

The number of passes required to produce a significant impact on vegetation and soils proved to be a useful, if subjective, measure of their susceptibility to damage by different types of vehicles (Figure 9).

Small Cypress

The smallest number of passes necessary to create significant impacts occurred in small cypress habitats, where heavy, tractor, and chain buggies quickly impacted the sites. The light buggy took only slightly longer to produce equivalent impacts. The smooth buggy could not operate on these sites. All four of the swamp buggies tested cut through the marl soils to bedrock in only a few passes after the initial runs broke up the surface

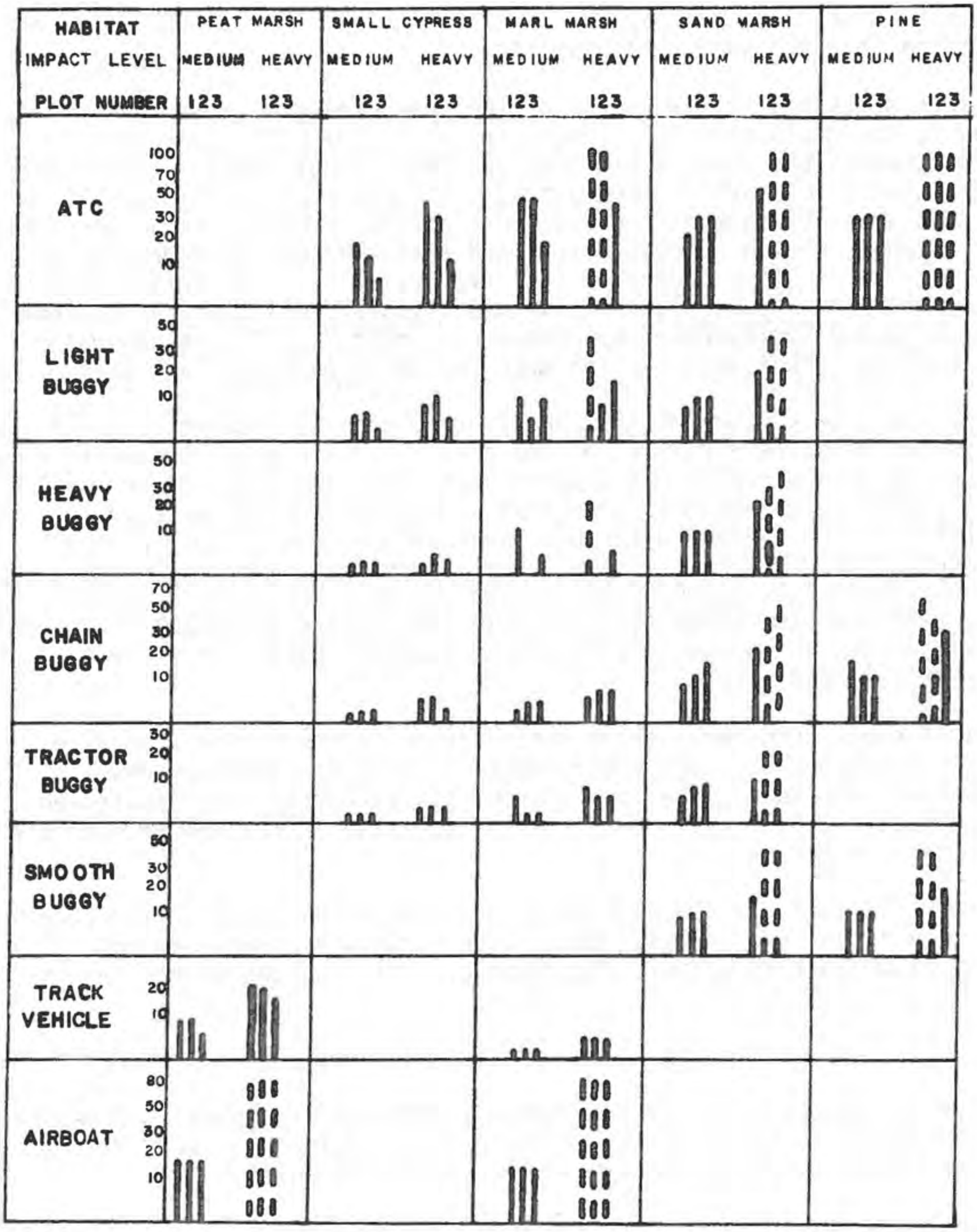


Figure 9. Relative numbers of passes required to produce medium and heavy impacts in three test plots in each habitat. A dashed line indicates the vehicle could not produce a heavy impact in that number of passes.

root mat. The very light-weight ATC, however, did not displace soils as quickly as the other wheeled vehicles. Since its impacts were more gradual, relatively fine differences in the resistance of cypress study plots to impacts can be seen in the ATC data. Cypress plots 1,2, and 3 showed progressively less resistance to impacts, and had progressively deeper water (Table 5) and longer hydroperiods. Thus, not only were cypress plots in general more susceptible to impact than the other relatively drier habitats, but within this habitat the wetter sites were more susceptible.

Marl Marsh (Wheeled-Vehicle)

In marl marsh study plots, the tractor and chain buggies again produced significant impacts more quickly than the other vehicles, and reached medium and heavy impacts in approximately the same number of passes as in cypress plots. The heavy buggy performed similarly to the tractor and chain buggies in marl marsh plot 3, but took many more runs to reach medium impacts in marl marsh plot 1, and did not achieve heavy impacts in plot 1 after 20 passes. After getting stuck several times in an attempt to make test runs, this vehicle was not operated in plot 2. The light buggy again required somewhat higher numbers of runs to reach the desired levels of impact in comparison to the other buggies in this habitat, and also when compared to the same vehicle in the cypress plots. Also, compared to other wheeled vehicles in marl marshes, and itself in cypress plots, the number of ATC passes required to produce impacts were considerably higher, and at two of the marl marsh sites they did not achieve heavy impacts after even 100 passes. However, few ATC passes were required for medium and heavy impacts in plot 3 compared to plots 1 and 2, and we feel these results were significantyl influenced by water levels when the tests were made. Tractor and chain buggies were the first vehicles tested in marl marsh plots when they were wettest. This influenced the numbers of passes required for medium and heavy impacts and resulted in their being similar to the cypress habitat results. As the dry season progressed water levels in plot 1 decreased faster than in plots 2 and 3 due to its proximity to several major canals. Marl plots 2 and 3 continued to be impacted similarly to the cypress sites by the light and heavy vehicles, but the drier soils at plot 1 became more resistant to impacts. Due to problems in scheduling vehicles, the ATC was tested in marl marsh plot 3 three weeks before tests in plots 1 and 2. If plots 1 and 2 had been tested at the same time as plot 3, the results for all three would have more closely resembled those of the cypress plots.

Sand Marsh

All swamp buggies made comparable numbers of runs to achieve medium impacts in sand marsh plots, and in general, these averaged somewhat higher than runs to achieve medium impacts in marl marsh plots. The ATC, however, averaged slightly fewer runs for a medium impact compared to marl marsh plots. No wheeled vehicle produced heavy impacts in sand marsh plots 2 and 3, which were dry throughout the test period. All vehicles, however, produced heavy impacts in the inundated sand marsh plot 1.

Pine

Only three vehicles were used to make medium and heavy impacts in pinelands. Chain and smooth swamp buggies made essentially the same number of runs to achieve medium impacts in all pine plots and averaged only one run higher than in sand marshes. The ATC made the same number of runs to achieve medium impacts in all pine plots, also averaging slightly higher than in sand marsh plots. Neither of the buggies tested were able to produce heavy impacts in the drier pine plots 1 and 2, and the ATC did not make heavy impacts in any of the pine plots. We were able to heavily impact the wetter pine plot 3 by both buggy types, although the numbers of runs required were higher than in any other habitat.

Marl Marsh (Airboat-Track Vehicle)

Medium impacts in marl marsh plots were reached in 14 passes by airboats, but they were never able to produce heavy impacts.

The track vehicle required only one pass to produce medium impacts and three for heavy impacts. These marl marsh sites were inundated during the tests and the rates of impact are comparable to those made by the three most quickly impacting buggies in the small cypress plots.

Peat Marsh

The airboat again produced medium impacts after 14 passes, and was unable to create heavy impacts even after 80 passes.

The track vehicle took considerably longer to produce impacts in this habitat, which also was inundated, than in the airboat-track vehicle marl marsh site. The number of runs required for it to reach specific impact levels was approximately intermediate between numbers of runs required by buggies in the wheeled-vehicle marl marsh and sand marsh habitats.

Visual Impacts

While the visual rating system provided us with a method for evaluating aesthetic impacts of ORVs, its design tended to distort the spectrum of possible visual conditions, particularly in terms of measuring recovery. Crossing the threshold from a rating of 4 to 3, or from 1 to 0 required a relatively small degree of change in condition, while a change from 3 to 2, or 2 to 1 could require a very much larger improvement in condition. This is relevant to the discussion of some of our results,in that while recovery actually occurred in many of the medium impact plots, it was frequently not detected by this method, and tended to be minimized in the heavy impact lanes.

Small Cypress

Visual impacts in all test lanes were significantly different from controls immediately after the treatments (Table 6). This was still the situation one year later, except for the ATC one-pass and most plot 1 one-pass treatments. Both initially and one year later, there was little difference in condition of the lanes created by one-pass and medium impact treatments (Table 7), but heavy impact lanes were significantly more visually damaged. After one year the most severe damage in heavy impact lanes had been caused by the light buggy, and the chain buggy lanes were still almost as bad. The ATC lanes exhibited somewhat less damage compared to the swamp buggies. Percent recovery of visual damage over the one-year period following treatments was equal to, or less than, 50 percent in the one-pass and medium impact lanes, except for the more rapidly recovering ATC and plot 1 lanes (Table 8). Recovery in the heavy impact lanes was never more than 25 percent.

Marl Marsh (Wheeled-Vehicle)

As in the small cypress plots, visual damage in all test lanes was significantly different from controls immediately after treatment (Table 9). One year later, the ATC one-pass and plot 1 one-pass treatments had recovered completely, while all others were still significantly different from the controls. Both immediately following treatments and one year later, there was a trend of increasing visual damage as impact level increased (Table 10), but within each impact level there were generally few differences among the different types of vehicles. What differences did exist were more prominent during the post- growing season sampling period when, within an impact level, ATCs were frequently significantly less damaging than buggies, and tractor buggy lanes tended to show the most severe impacts. Except for the few lanes that recovered completely, recovery of visual damage over the year following treatments was almost always less than 35 percent (Table 8).

Sand Marsh

Visual damage immediately following treatments were similar for all vehicles within each impact level, but increased as level of impact increased (Table 11). After the first year, recovery was complete for all one-pass treatments, all but one ATC lane, and all but one of the medium impact lanes in plot 1. All other lanes were still significantly more visually damaged than the controls (Table 12), but exhibited the same general degree of damage. Percent recovery in these lanes was always 50 percent or less after one year (Table 13).

Pine

As in the sand marsh sites, visual damage immediately following treatments was similar for all vehicles within each impact level, but increased as level of impact increased (Table 14). After the first year, recovery was

Table 6. Duncan's new multiple range tests of visual ratings in individual and combined ($\bar{X}$) small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Postgrowing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a
ONE PASS								
ATC	#	#	#	b	R	R	R	R
Light	#	#	#	c	R	b	b	b
Smooth	-	-	-	-	-	-	-	-
Chain	#	#	#	c	R	b	b	b
Tractor	#	#	#	e	c	b	b	c
Heavy	#	#	#	c	R	b	bc	bc
MEDIUM IMPACT								
ATC	#	#	#	c	R	c	b	b
Light	#	#	#	cd	b	c	-	b
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	#	#	#	de	c	c	cd	d
Light	#	#	#	e	e	d	e	g
Smooth	-	-	-	-	-	-	-	-
Chain	#	#	#	e	de	c	e	fg
Tractor	#	#	#	e	d	c	cd	ef
Heavy	#	#	#	e	d	c	d	e
n				35	224	163	152	539

R Vehicle treatment recovered and no longer visible.
\- Treatment was not performed.
\# No replication for statistical analysis

Table 7. Average visual ratings in small cypress test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	X
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	1.0	1.0	1.0	1.0	R	R	R	R
Light	1.0	2.0	3.0	2.0	R	2.0	2.0	1.3
Smooth	-	-	-	-	-	-	-	-
Chain	2.0	2.0	3.0	2.3	R	2.0	2.0	1.3
Tractor	3.0	4.0	4.0	3.7	2.6	2.0	2.0	2.2
Heavy	2.0	2.0	3.0	2.3	R	2.0	2.4	1.5
MEDIUM IMPACT								
ATC	2.0	2.0	3.0	2.3	R	3.0	2.0	1.7
Light	2.0	3.0	-	2.5	2.0	3.0		2.5
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	3.0	3.0	4.0	3.3	2.5	3.4	3.0	3.0
Light	4.0	4.0	4.0	4.0	3.7	3.8	3.5	3.7
Smooth	-	-	-	-	-	-	-	-
Chain	4.0	4.0	4.0	4.0	3.5	3.0	3.5	3.3
Tractor	4.0	4.0	4.0	4.0	3.3	3.3	3.0	3.2
Heavy	4.0	4.0	4.0	4.0	3.3	3.1	3.1	3.2

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 8. Percent recovery from initial fall 1978 visual ratings after one annual cycle in small cypress and wheeled-vehicle marl marsh test plots. Actual control ratings are indicated.

Sampling Period	Small Cypress Post- Growing Season Fall 1979				Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	100	100	100	100	100	100	100	100
Light	100	0	33	35	100	0	0	30
Smooth	-	-	-	-	-	-	-	-
Chain	100	0	33	43	100	0	0	30
Tractor	13	50	50	41	100	0	0	24
Heavy	100	0	20	35	100	-	0	50
MEDIUM IMPACT								
ATC	100	-50	50	26	0	0	0	0
Light	0	0	-	0	0	0	-10	-5
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	0	0	33	13
Tractor	-	-	-	-	0	-	-	0
Heavy	-	-	-	-	0	-	33	20
HEAVY IMPACT								
ATC	17	-13	25	9	0	0	33	13
Light	7	5	12	7	0	32	15	19
Smooth	-	-	-	-	-	-	-	-
Chain	12	25	12	17	50	17	15	27
Tractor	17	17	25	20	33	10	15	19
Heavy	17	22	22	20	0	-	25	17

\- Treatment was not performed

Table 9. Duncan's new multiple range tests of visual ratings in individual and combined ($\overline{X}$) wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\overline{X}$	1	2	3	$\overline{X}$
CONTROL	#	#	#	a	a	a	a	a
ONE PASS								
ATC	#	#	#	b	R	R	R	R
Light	#	#	#	b	R	b	b	b
Smooth	-	-	-	-	-	-	-	-
Chain	#	#	#	b	R	b	b	b
Tractor	#	#	#	bc	R	c	c	c
Heavy	#	-	#	b	R	-	b	b
MEDIUM IMPACT								
ATC	#	#	#	bcd	b	c	c	c
Light	#	#	#	bcd	b	c	c	c
Smooth	-	-	-	-	-	-	-	-
Chain	#	#	#	cde	b	c	c	c
Tractor	#	-	-	bcd	b	-	-	c
Heavy	#	-	#	cde	b	-	c	c
HEAVY IMPACT								
ATC	#	#	#	cde	b	c	c	c
Light	#	#	#	ef	b	d	e	d
Smooth	-	-	-	-	-	-	-	-
Chain	#	#	#	f	b	e	e	d
Tractor	#	#	#	f	b	f	e	d
Heavy	#	-	#	def	b	-	d	d
n				40	168	183	196	547

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
No replication for statistical analysis

Table 10. Average visual ratings in wheeled-vehicle marl marsh test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	1.0	1.0	1.0	1.0	R	R	R	R
Light	1.0	1.0	1.0	1.0	R	1.0	1.0	0.7
Smooth	-	-	-	-	-	-	-	-
Chain	1.0	1.0	1.0	1.0	R	1.0	1.0	0.7
Tractor	1.0	2.0	2.0	1.7	R	2.0	2.0	1.3
Heavy	1.0	-	1.0	1.0	R	-	1.0	0.5
MEDIUM IMPACT								
ATC	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1
Light	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.0
Smooth	-	-	-	-	-	-	-	-
Chain	2.0	2.0	3.0	2.3	2.0	2.0	2.0	2.0
Tractor	2.0	-	-	2.0	2.0	-	-	2.0
Heavy	2.0	-	3.0	2.5	2.0	-	2.0	2.0
HEAVY IMPACT								
ATC	2.0	2.0	3.0	2.3	2.0	2.0	2.0	2.0
Light	2.0	4.0	4.0	3.3	2.0	2.7	3.4	2.7
Smooth	-	-	-	-	-	-	-	-
Chain	4.0	4.0	4.0	4.0	2.0	3.3	3.4	2.9
Tractor	3.0	4.0	4.0	3.7	2.0	3.6	3.4	3.0
Heavy	2.0	-	4.0	3.0	2.0	-	3.0	2.5

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 11 . Average visual rating in sand marsh test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	X̄	1	2	3	X̄
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	1.0	R	R	0.3	R	R	R	R
Light	1.0	1.0	1.0	1.0	R	R	R	R
Smooth	1.0	1.0	1.0	1.0	R	R	R	R
Chain	1.0	1.0	1.0	1.0	R	R	R	R
Tractor	1.0	1.0	1.0	1.0	R	R	R	R
Heavy	1.0	1.0	1.0	1.0	R	R	R	R
MEDIUM IMPACT								
ATC	2.0	2.0	2.0	2.0	R	R	R	R
Light	2.0	2.0	2.0	2.0	R	R	2.0	0.7
Smooth	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
Chain	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
Tractor	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
Heavy	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
HEAVY IMPACT								
ATC	4.0	2.0	2.0	2.7	R	2.0	R	0.7
Light	4.0	3.0	2.0	3.0	2.0	2.0	2.0	2.0
Smooth	4.0	3.0	3.0	3.3	2.4	2.0	2.0	2.1
Chain	4.0	3.0	3.0	3.3	2.6	2.0	2.0	2.2
Tractor	4.0	3.0	3.0	3.3	2.0	2.0	2.0	2.0
Heavy	4.0	3.0	2.0	3.0	2.5	2.0	2.0	2.2

R Vehicle treatment recovered and no longer visible

Table 12. Duncan's new multiple range tests of visual ratings in individual and combined ($\bar{X}$) sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a
ONE PASS								
ATC	#	#	#	b	R	R	R	R
Light	#	#	#	b	R	R	R	R
Smooth	#	#	#	b	R	R	R	R
Chain	#	#	#	b	R	R	R	R
Tractor	#	#	#	b	R	R	R	R
Heavy	#	#	#	b	R	R	R	R
MEDIUM IMPACT								
ATC	#	#	#	c	R	R	R	R
Light	#	#	#	c	R	R	b	b
Smooth	#	#	#	c	R	b	b	c
Chain	#	#	#	c	R	b	b	c
Tractor	#	#	#	c	R	b	b	c
Heavy	#	#	#	c	bc	b	b	ed
HEAVY IMPACT								
ATC	#	#	#	cd	R	b	R	b
Light	#	#	#	d	b	b	b	c
Smooth	#	#	#	d	cd	b	b	d
Chain	#	#	#	d	e	b	b	de
Tractor	#	#	#	d	b	b	b	c
Heavy	#	#	#	d	de	b	b	e
n				54	174	128	47	349

R Vehicle treatment recovered and no longer visible
No replication for statistical analysis

Table 13. Percent recovery from initial fall 1978 visual ratings after one annual cycle in sand marsh and pine test plots. Actual control ratings are indicated.

Sampling Period	Sand Marsh Post- Growing Season Fall 1979				Pine Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	***	0	0
ONE PASS								
ATC	100	100	100	100	100	100	100	100
Light	100	100	100	100	100	100	100	100
Smooth	100	100	100	100	100	100	100	100
Chain	100	100	100	100	100	100	100	100
Tractor	100	100	100	100	100	100	100	100
Heavy	100	100	100	100	100	100	100	100
MEDIUM IMPACT								
ATC	100	100	100	100	100	100	100	100
Light	100	100	0	65	-	-	-	-
Smooth	100	0	0	35	0	100	0	35
Chain	100	0	0	35	0	100	100	65
Tractor	100	0	0	35	-	-	-	-
Heavy	0	0	0	0	-	-	-	-
HEAVY IMPACT								
ATC	100	0	100	74	100	100	100	100
Light	50	33	0	33	-	-	-	-
Smooth	40	33	33	36	33	100	33	57
Chain	35	33	33	33	33	100	33	57
Tractor	50	33	33	39	-	-	-	-
Heavy	37	33	0	27	-	-	-	-

\- Treatment was not performed

*** No treatments visible after fire

Table 14. Average visual ratings in pine test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	***	0
ONE PASS								
ATC	1.0	1.0	1.0	1.0	R	R	R	R
Light	1.0	1.0	1.0	1.0	R	R	R	R
Smooth	1.0	1.0	1.0	1.0	R	R	R	R
Chain	1.0	1.0	1.0	1.0	R	R	R	R
Tractor	1.0	1.0	1.0	1.0	R	R	R	R
Heavy	1.0	1.0	1.0	1.0	R	R	R	R
MEDIUM IMPACT								
ATC	2.0	2.0	2.0	2.0	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	2.0	2.0	2.0	2.0	2.0	R	2.0	1.3
Chain	2.0	2.0	2.0	2.0	2.0	R	R	0.7
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	2.0	2.0	2.0	2.0	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	3.0	3.0	3.0	3.0	2.0	R	2.0	1.3
Chain	3.0	3.0	3.0	3.0	2.0	R	2.0	1.3
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible

\- Treatment was not performed

*** No treatments visible after fire

complete for all one-pass, ATC, and plot 2 lanes. The few remaining lanes were still significantly more visually damaged than the controls (Table 15), although all exhibited the same degree of damage. Percent recovery in these few remaining lanes in fall 1979 was less than 35 percent (Table 13).

Marl Marsh (Airboat-Track Vehicle)

Initial airboat visual damage was the same at all impact levels and at both slow and fast speeds (Table 16). At that time, the lanes were significantly different from the controls (Table 17), but all completely recovered during the first year following treatment (Table 18). This was due to the short sparse vegetation on these sites, which the airboat merely bent over as it passed.

Initial track-vehicle damage increased rapidly with impact level (Table 16 and 17), and exhibited little or no recovery during the first year following the treatments (Table 18). All of the one-pass lanes actually appeared more severely damaged one year later than they had initially.

Peat Marsh

Initial airboat visual damage increased significantly only between the one-pass and medium impact levels (Table 19). Speed was not a factor in the degree of damage (Table 20). After one year, all of the plot 1 lanes had recovered, as had the one-pass and medium impact-fast speed lanes in the other plots (Table 18). The remaining medium impact-slow speed and both heavy impact lanes were still significantly more damaged than the controls, but were not significantly different from each other (Table 19).

Initial track-vehicle damage increased significantly with impact level (Table 19). The one-pass lanes had completely recovered one year later, while the medium and heavy impact lanes showed little or no recovery (Table 18). Again, some of the medium impact lanes actually appeared more severely damaged one year later than they had initially (Table 20).

Soil Impacts

Rut Depth

Small Cypress

Most estimates of rut depths immediately following the treatments were not significantly different from the controls at one-pass and medium impact levels (Table 21). However, at the one-pass level, the ATC was the only vehicle that did not cause some rutting in any of the three plots, while the chain and tractor buggies produced ruts in all three plots. (Table 22). The tractor buggy ruts were significantly deeper than those produced by any other vehicle in one-pass lanes (Table 21). All vehicles produced significant impacts that were not significantly different from one another at the heavy impact level.

Table 15. Duncan's new multiple range tests of visual ratings in individual and combined ($\bar{X}$) pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	***	a	a
ONE PASS								
ATC	#	#	#	b	R	R	R	R
Light	#	#	#	b	R	R	R	R
Smooth	#	#	#	b	R	R	R	R
Chain	#	#	#	b	R	R	R	R
Tractor	#	#	#	b	R	R	R	R
Heavy	#	#	#	b	R	R	R	R
MEDIUM IMPACT								
ATC	#	#	#	c	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	#	#	#	c	b	R	b	c
Chain	#	#	#	c	b	R	R	b
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	#	#	#	c	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	#	#	#	d	b	R	b	c
Chain	#	#	#	d	b	R	b	c
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
n				36	21	0	99	120

R Vehicle treatment recovered and no longer visible.
\- Treatment was not performed.

\# No replication for statistical analysis
*** No treatments visible after fire

Table 16. Average visual ratings in airboat-track vehicle marl marsh test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
AIRBOAT								
One pass	1.0	1.0	1.0	1.0	R	R	R	R
Medium Impact								
Slow	1.0	1.0	1.0	1.0	R	R	R	R
Fast	1.0	1.0	1.0	1.0	R	R	R	R
Heavy Impact								
Slow	1.0	1.0	1.0	1.0	R	R	R	R
Fast	1.0	1.0	1.0	1.0	R	R	R	R
TRACK VEHICLE								
One pass	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0
Medium Impact								
Slow	-	-	-	-	-	-	-	-
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	4.0	4.0	4.0	4.0	3.6	3.3	3.6	3.5
Fast	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible

\- Treatment was not performed

Table 17. Duncan's new multiple range tests of visual ratings in individual and combined ($\bar{X}$) airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a
AIRBOAT								
One pass	#	#	#	b	R	R	R	R
Medium Impact								
Slow	#	#	#	b	R	R	R	R
Fast	#	#	#	b	R	R	R	R
Heavy Impact								
Slow	#	#	#	b	R	R	R	R
Fast	#	#	#	b	R	R	R	R
TRACK VEHICLE								
One pass	#	#	#	c	b	b	b	b
Medium Impact								
Slow	-	-	-	-	-	-	-	-
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	#	#	#	d	c	c	c	c
Fast	-	-	-	-	-	-	-	-
n				21	74	74	74	222

R Vehicle treatment recovered and no longer visible.
- Treatment was not performed.
No replication for statistical analysis

Table 18. Percent recovery from initial fall 1978 visual ratings after one annual cycle in airboat-track vehicle marl marsh and peat marsh test plots. Actual control ratings are indicated.

Sampling Period	Airboat-Track Vehicle Marl Marsh Post- Growing Season Fall 1979				Peat Marsh Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
AIRBOAT								
One pass	100	100	100	100	100	100	100	100
Medium Impact								
Slow	100	100	100	100	100	0	0	35
Fast	100	100	100	100	100	100	100	100
Heavy Impact								
Slow	100	100	100	100	100	0	0	35
Fast	100	100	100	100	R	0	0	35
TRACK VEHICLE								
One pass	-50	-50	-50	-50	100	100	100	100
Medium Impact								
Slow	-	-	-	-	0	-65	-75	-45
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	10	17	10	12	22	17	12	17
Fast								

\- Treatment was not performed

Table 19. Duncan's new multiple range test of visual ratings in individual and combined ($\bar{X}$) peat marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a
AIRBOAT								
One pass	#	#	#	b	R	R	R	R
Medium Impact								
Slow	#	#	#	c	R	b	b	b
Fast	#	#	#	c	R	R	R	R
Heavy Impact								
Slow	#	#	#	c	R	b	b	b
Fast	#	#	#	c	R	b	b	b
TRACK VEHICLE								
One pass	#	#	#	b	R	R	R	R
Medium Impact								
Slow	#	#	#	c	b	c	c	c
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	#	#	#	d	c	c	c	d
Fast	-	-	-	-	-	-	-	-
n				24	75	81	81	237

R Vehicle treatment recovered and no longer visible.
- Treatment was not performed.
No replication for statistical analysis

Table 20 . Average visual ratings in peat marsh test plots.

Sampling Period	Initial Fall 1978				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
AIRBOAT								
One pass	1.0	1.0	1.0	1.0	R	R	R	R
Medium Impact								
Slow	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
Fast	2.0	2.0	2.0	2.0	R	R	R	R
Heavy Impact								
Slow	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
Fast	2.0	2.0	2.0	2.0	R	2.0	2.0	1.3
TRACK VEHICLE								
One pass	1.0	1.0	1.0	1.0	R	R	R	R
Medium Impact								
Slow	2.0	2.0	2.0	2.0	2.0	3.3	3.5	2.9
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	4.0	4.0	4.0	4.0	3.1	3.3	3.5	3.3
Fast	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed

Table 21. Duncan's new multiple range tests of soil rut depths in individual and combined (X̄) small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	X̄	1	2	3	X̄	1	2	3	X̄
CONTROL	#	#	#	a	a	a	a	a	a	a	a	a
ONE PASS												
ATC	#	#	#	a	a	a	a	a	R	R	R	R
Light	#	#	#	a	a	a	a	a	R	a	a	a
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	#	#	#	ab	a	a	a	a	R	a	a	a
Tractor	#	#	#	c	bc	a	a	bc	c	a	a	bc
Heavy	#	#	#	a	a	a	b	d	a	a	b	c
MEDIUM IMPACT												
ATC	#	#	#	a	a	a	a	a	R	a	a	a
Light	#	#	#	a	a	a	-	a	a	a	-	a
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-
HEAVY IMPACT												
ATC	#	#	#	bc	ab	b	a	b	b	b	a	b
Light	#	#	#	c	d	d	c	f	e	d	c	e
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	#	#	#	c	d	a	b	e	e	a	c	d
Tractor	#	#	#	c	c	b	a	c	d	a	a	c
Heavy	#	#	#	c	c	c	bc	d	c	c	c	d
n				35	225	144	141	510	212	153	142	507

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
No replication for statistical analysis

Table 22. Average soil rut depths (cm) in small cypress test plots.

Sampling Period	Initial Fall 1978				Pre-Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0	0	0	0	0
ONE PASS												
ATC	0	0	0	0	0	0	0	0	R	R	R	R
Light	0	0	6	2	0	0	0	0	R	0	0	0
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	4	4	10	6	0	0	0	0	R	0	0	0
Tractor	10	17	21	16	3	0	0	1	3	0	0	1
Heavy	0	3	5	3	0	0	7	2	R	0	4	1
MEDIUM IMPACT												
ATC	0	0	3	1	0	0	0	0	R	0	0	0
Light	0	5	-	3	1	0	-	<1	1	0	-	<1
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-
HEAVY IMPACT												
ATC	5	10	21	12	2	3	0	2	2	2	0	1
Light	18	17	21	19	9	9	9	9	7	7	6	7
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	18	17	21	19	8	0	7	5	7	0	5	4
Tractor	18	17	21	19	4	3	0	2	5	1	0	2
Heavy	18	17	21	19	4	6	8	6	3	4	6	4

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

During the pre- growing season sampling period, no ruts were visible in most one-pass and medium impact lanes (Table 22), while ruts in most of the heavy impact lanes were still significantly different from controls (Table 21). At this time ruts produced by the light buggy in the heavy impact lanes were consistently the most, or among the most, severe, while the ATC produced the least severe ruts (Table 22). Except for slight decreases in depth, the ruts changed little during the first growing season (Table 23). Thus, the majority of the recovery took place shortly after the treatments were made. Most one-pass and medium impact lanes had recovered by the pre- growing season sampling period, and recovery was generally more than 50 percent complete in the heavy impact lanes, where it increased by only about 10 percent during the growing season.

The relatively rapid recovery of the tractor buggy heavy impacts as compared to those of the light buggy (Table 23) was associated with the tread and weight per unit area characteristics of these vehicles. In the soft marl soils of the cypress plots, the tractor buggy cut down to bedrock after only two passes. The deep, widely-spaced treads of this vehicle chopped up the surface layer of soil and vegetation on the first pass, and on the second churned through the soft marl to bedrock. However, after only two passes the edge of the rut was very ragged and began sloughing back into the rut immediately. The light buggy, however, normally took more than seven passes to reach bedrock in this habitat. Because of its lower weight per unit area and smoother tire surfaces, it took longer to wear through the surface layer and underlying soil. With each pass the wide tires pushed some soil and water laterally out of the vehicle tracks, and by the time bedrock was reached, a wide cleaned out and thus more stable rut had been produced.

Marl Marsh (Wheeled-Vehicle)

The ATCs produced no ruts at any impact level, and in the one-pass lanes, only the tractor buggy produced ruts (Table 24). At the medium and heavy impact levels, all buggies tested produced ruts in at least half of the plots. However, none of the medium impact lanes had ruts that were significantly different from the controls, while at the heavy impact level three of the four buggies tested had ruts that were significantly different from the controls (Table 25).

During the pre- growing season sampling period, only one lane in each of the one-pass and medium impact treatments was significantly different from the controls, while most of the heavy impact treatments were still different (Table 25). Rut depth generally increased with increasing impact level (Table 24). There was a slight further decrease in rut depths by the end of the growing season (Table 24), but few changes in statistical differences (Table 25).

Table 23. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in small cypress test plots. Actual control values (cm) are indicated.

Sampling Period	Pre-Growing Season Winter 1979				Post-Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	100	100	N	N	100	100
Smooth	-	-	-	-	-	-	-	-
Chain	100	100	100	100	100	100	100	100
Tractor	69	100	100	94	71	100	100	94
Heavy	N	100	-34	16	N	100	19	49
MEDIUM IMPACT								
ATC	N	N	100	100	N	N	100	100
Light	-100	100	-	80	-60	100	-	88
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	60	72	100	87	64	80	100	89
Light	53	45	59	54	61	59	72	65
Smooth	-	-	-	-	-	-	-	-
Chain	57	100	69	74	63	100	75	78
Tractor	76	84	100	87	71	96	100	89
Heavy	80	65	63	69	82	79	72	77

\- Treatment was not performed

N No rut created during treatment

Table 24. Average soil rut depths (cm) in wheeled-vehicle marl marsh test plots.

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0	0	0	0	0
ONE PASS												
ATC	0	0	0	0	R	0	0	0	R	R	R	R
Light	0	0	0	0	0	0	0	0	R	0	0	0
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	0	0	0	0	0	0	0	0	R	0	0	0
Tractor	0	3	3	2	0	2	0	<1	R	2	0	4
Heavy	0	-	0	0	0	-	0	0	R	-	0	0
MEDIUM IMPACT												
ATC	0	0	0	0	0	0	0	0	0	0	0	0
Light	0	3	3	2	0	1	2	1	0	0	2	<1
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	3	5	10	6	1	4	0	2	2	2	0	1
Tractor	3	-	-	3	1	-	-	1	1	-	-	1
Heavy	0	-	8	4	0	-	0	0	0	-	0	0
HEAVY IMPACT												
ATC	0	0	0	0	0	0	0	0	0	0	0	0
Light	0	15	18	11	0	2	7	3	0	1	4	2
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	25	15	18	19	3	7	5	5	2	5	3	3
Tractor	10	15	18	14	4	7	7	6	3	4	5	4
Heavy	0	-	18	9	0	-	5	3	0	-	5	3

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 25. Duncan's new multiple range tests of soil rut depths in individual and combined ($\bar{X}$) wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a	a	a	a	a
ONE PASS												
ATC	#	#	#	a	a	a	a	a	R	R	R	R
Light	#	#	#	a	a	a	a	a	R	a	a	a
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	#	#	#	a	a	a	a	a	R	a	a	a
Tractor	#	#	#	a	a	b	a	ab	R	b	a	bc
Heavy	#	-	#	a	a	-	a	a	R	-	a	a
MEDIUM IMPACT												
ATC	#	#	#	a	a	a	a	a	a	a	a	a
Light	#	#	#	a	a	a	a	ab	a	a	b	bc
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	#	#	#	ab	a	c	a	b	c	b	a	c
Tractor	#	-	-	ab	a	-	-	a	b	-	-	ab
Heavy	#	-	#	ab	a	-	a	a	a	-	a	a
HEAVY IMPACT												
ATC	#	#	#	a	a	a	a	a	a	a	a	a
Light	#	#	#	bc	a	c	c	c	a	ab	d	d
Smooth	-	-	-	-	-	-	-	-	-	-	-	-
Chain	#	#	#	d	b	d	b	c	c	c	c	c
Tractor	#	#	#	cd	c	d	c	d	d	c	e	f
Heavy	#	-	#	abc	a	-	b	c	a	-	d	ef
n				40	151	194	177	522	155	173	186	514

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
No replication for statistical analysis

As in the cypress plots, major recovery in rut depths occurred shortly after the treatments, and most of the one-pass and medium impact plots had recovered by the pre- growing season sampling period (Table 26). In the heavy impact lanes, rut depth recovery was more than 50 percent complete by then, and increased to more than 70 percent by the end of the growing season.

Sand Marsh

Site characteristics influenced rut depth impacts, as plot 1 was most susceptible to rutting and plot 3 least. No ruts were made with one pass by any vehicle, while most vehicles made ruts only in plot 1 at medium impact levels, and most vehicles made ruts only in plots 1 and 2 at heavy impact levels (Table 27). As was seen in cypress and marl marsh habitats, rutting impacts tended to be seen first in the tractor buggy lanes.

With the exception of one medium impact tractor buggy lane, no ruts were visible in the one-pass or medium impact test lanes during the pre- growing season sampling period (Table 27), and the one exception was not significantly different from the controls (Table 28). Most of the initially rutted heavy impact lanes were still significantly different from the controls, both before and after the growing season. Although reductions in rut depths have generally been rapid and continuous in the year since the treatments, most of the originally affected heavy impact lanes in plot 2 have shown little recovery (Table 29).

Pine

The only ruts made in this habitat were in the plot 3 medium and heavy impact lanes by the only two buggies tested there (Table 30). Recovery during the growing season was minor to complete in the medium impact lanes, and about 75-80 percent complete in the heavy impact lanes (Table 31). Only the heavy impact lanes during the pre- growing season sampling period were significantly different from the controls (Table 32).

Marl Marsh (Airboat-Track Vehicle)

Airboats produced no ruts (Table 33), while track vehicles produced ruts that were significantly different from controls in the one-pass and heavy impact lanes, the only two impact levels tested (Table 34). Statistically, the same conditions still existed during the post- growing season sampling period, although some recovery of the track vehicle impacts had occurred, primarily during the growing season (Table 35).

Peat Marsh

The same patterns appeared in the peat marsh rut depth data as were observed for the marl marsh sites. The only differences were that track vehicles were run at all three impact levels, and no effects were observed in the one-pass lanes (Table 36). Again, some recovery of the track

Table 26. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in wheeled-vehicle marl marsh test plots. Actual control values (cm) are indicated.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Smooth	-	-	-	-	-	-	-	-
Chain	N	N	N	N	N	N	N	N
Tractor	N	27	100	64	N	44	100	72
Heavy	N	-	N	N	N	-	N	N
MEDIUM IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	N	77	27	52	N	100	27	64
Smooth	-	-	-	-	-	-	-	-
Chain	73	24	100	74	30	68	100	79
Tractor	70	-	-	70	70	-	-	70
Heavy	N	-	100	100	N	-	100	100
HEAVY IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	N	84	60	71	N	91	78	84
Smooth	-	-	-	-	-	-	-	-
Chain	89	57	72	75	92	69	83	83
Tractor	60	56	43	59	70	71	71	71
Heavy	N	-	72	72	N	-	75	75

- Treatment was not performed

N No rut created during treatment

Table 27. Average soil rut depths (cm) in sand marsh test plots.

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	X	1	2	3	X	1	2	3	X
CONTROL	0	0	0	0	0	0	0	0	0	0	0	0
ONE PASS												
ATC	0	0	0	0	R	R	R	R	R	R	R	R
Light	0	0	0	0	R	0	0	0	R	R	R	R
Smooth	0	0	0	0	R	0	0	0	R	R	R	R
Chain	0	0	0	0	R	0	**	0	R	R	R	R
Tractor	0	0	0	0	R	0	0	0	R	R	R	R
Heavy	0	0	0	0	R	0	0	0	R	R	R	R
MEDIUM IMPACT												
ATC	3	0	0	1	0	0	0	0	R	R	R	R
Light	0	0	0	0	0	0	0	0	R	R	0	0
Smooth	5	0	0	2	0	0	0	0	R	0	0	0
Chain	4	0	0	1	0	0	0	0	R	0	0	0
Tractor	3	3	0	2	0	2	0	1	R	0	0	0
Heavy	0	0	0	0	0	0	0	0	0	0	0	0
HEAVY IMPACT												
ATC	15	0	0	5	9	0	0	3	R	0	R	0
Light	10	0	0	3	7	0	0	2	3	0	0	1
Smooth	20	4	0	8	14	4	0	6	2	5	0	2
Chain	18	3	0	7	13	3	0	5	3	3	0	2
Tractor	15	10	1	9	8	8	0	5	2	6	0	3
Heavy	15	3	0	6	11	0	0	4	3	0	0	1

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Table 28. Duncan's new multiple range tests of soil rut depths in individual and combined ($\bar{X}$) sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a	a	a	a	a
ONE PASS												
ATC	#	#	#	a	R	R	R	R	R	R	R	R
Light	#	#	#	a	R	a	a	a	R	R	R	R
Smooth	#	#	#	a	R	a	a	a	R	R	R	R
Chain	#	#	#	a	R	a	**	a	R	R	R	R
Tractor	#	#	#	a	R	a	a	a	R	R	R	R
Heavy	#	#	#	a	R	a	a	a	R	R	R	R
MEDIUM IMPACT												
ATC	#	#	#	a	a	a	a	a	R	R	R	R
Light	#	#	#	a	a	a	a	a	R	R	a	a
Smooth	#	#	#	a	a	a	a	a	R	a	a	a
Chain	#	#	#	a	a	a	a	a	R	a	a	a
Tractor	#	#	#	a	a	a	a	a	R	a	a	a
Heavy	#	#	#	a	a	a	a	a	R	a	a	a
HEAVY IMPACT												
ATC	#	#	#	a	b	a	a	bc	R	a	R	a
Light	#	#	#	a	b	a	a	b	d	a	a	bc
Smooth	#	#	#	a	d	c	a	c	b	c	a	cd
Chain	#	#	#	a	cd	b	a	bc	d	b	a	bc
Tractor	#	#	#	a	b	d	a	bc	bc	d	a	d
Heavy	#	#	#	a	c	a	a	c	cd	a	a	b
n				54	203	160	50	413	153	111	30	294

R Vehicle treatment recovered and no longer visible

\# No replication for statistical analysis

** Treatment lane destroyed by unauthorized vehicle use

Table 29. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in sand marsh test plots. Actual control values (cm) are indicated.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	X	1	2	3	X
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Smooth	N	N	N	N	N	N	N	N
Chain	N	N	**	N	N	N	N	N
Tractor	N	N	N	N	N	N	N	N
Heavy	N	N	N	N	N	N	N	N
MEDIUM IMPACT								
ATC	100	N	N	100	100	N	N	100
Light	N	N	N	N	N	N	N	N
Smooth	100	N	N	100	100	N	N	100
Chain	100	N	N	100	100	N	N	100
Tractor	100	47	N	74	100	100	N	100
Heavy	N	N	N	N	N	N	N	N
HEAVY IMPACT								
ATC	42	N	N	42	100	N	N	100
Light	26	N	N	26	70	N	N	70
Smooth	28	-5	N	22	90	-18	N	72
Chain	29	0	N	25	84	3	N	73
Tractor	44	20	100	38	85	43	100	70
Heavy	25	100	N	38	83	100	N	83

N No rut created during treatment
** Treatment lane destroyed by unauthorized vehicle use

Table 30. Average soil rut depths (cm) in pine test plots.

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0	0	***	0	0
ONE PASS												
ATC	0	0	0	0	0	0	R	0	R	R	R	R
Light	0	0	0	0	0	0	0	0	R	R	R	R
Smooth	0	0	0	0	0	0	0	0	R	R	R	R
Chain	0	0	0	0	0	0	0	0	R	R	R	R
Tractor	0	0	0	0	0	0	0	0	R	R	R	R
Heavy	0	0	0	0	0	0	0	0	R	R	R	R
MEDIUM IMPACT												
ATC	0	0	0	0	0	0	0	0	R	R	R	R
Light	-	-	-	-	-	-	-	-	-	-	-	-
Smooth	0	0	5	2	0	0	2	<1	0	R	4	1
Chain	0	0	5	2	0	0	1	<1	0	R	R	0
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-
HEAVY IMPACT												
ATC	0	0	0	0	0	0	0	0	R	R	R	R
Light	-	-	-	-	-	-	-	-	-	-	-	-
Smooth	0	0	19	6	0	0	5	2	0	R	5	2
Chain	0	0	19	6	0	0	5	2	0	R	4	1
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 31. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in pine test plots. Actual control values (cm) are indicated.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	X̄	1	2	3	X̄
CONTROL	0	0	0	0	0	***	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Smooth	N	N	N	N	N	N	N	N
Chain	N	N	N	N	N	N	N	N
Tractor	N	N	N	N	N	N	N	N
Heavy	N	N	N	N	N	N	N	N
MEDIUM IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	-	-	-	-	-	-	-	-
Smooth	N	N	64	64	N	N	30	30
Chain	N	N	80	80	N	N	100	100
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	-	-	-	-	-	-	-	-
Smooth	N	N	73	73	N	N	76	76
Chain	N	N	75	75	N	N	78	78
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-

\- Treatment was not performed
N No rut created during treatment

Table 32. Duncan's new multiple range tests of soil rut depths in individual and combined ($\bar{X}$) pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
Replicate Plots	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	#	#	#	a	a	a	a	a	a	***	a	a
ONE PASS												
ATC	#	#	#	a	a	a	R	a	R	R	R	R
Light	#	#	#	a	a	a	a	a	R	R	R	R
Smooth	#	#	#	a	a	a	a	a	R	R	R	R
Chain	#	#	#	a	a	a	a	a	R	R	R	R
Tractor	#	#	#	a	a	a	a	a	R	R	R	R
Heavy	#	#	#	a	a	a	a	a	R	R	R	R
MEDIUM IMPACT												
ATC	#	#	#	a	a	a	a	a	R	R	R	R
Light	-	-	-	-	-	-	-	-	-	-	-	-
Smooth	#	#	#	a	a	a	a	a	a	R	a	b
Chain	#	#	#	a	a	a	a	a	a	R	R	a
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-
HEAVY IMPACT												
ATC	#	#	#	a	a	a	a	a	R	R	R	R
Light	-	-	-	-	-	-	-	-	-	-	-	-
Smooth	#	#	#	a	a	a	b	b	a	R	a	b
Chain	#	#	#	a	a	a	b	b	a	R	a	b
Tractor	-	-	-	-	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-	-	-	-	-
n				36	36	36	142	214	13	0	90	103

R Vehicle treatment recovered and no longer visible

- Treatment was not performed

*** No treatments visible after fire

Table 33. Average soil rut depths (cm) in airboat-track vehicle marl marsh test plots.

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0	0	0	0	0
AIRBOAT												
One Pass	0	0	0	0	R	R	R	R	R	R	R	R
Medium Impact												
Slow	0	0	0	0	R	R	R	R	R	R	R	R
Fast	0	0	0	0	R	R	R	R	R	R	R	R
Heavy Impact												
Slow	0	0	0	0	R	0	R	0	R	R	R	R
Fast	0	0	0	0	R	R	R	R	R	R	R	R
TRACK VEHICLE												
One Pass	5	10	10	8	0	10	10	7	5	5	5	5
Medium Impact												
Slow	-	-	-	-	-	-	-	-	-	-	-	-
Fast	-	-	-	-	-	-	-	-	-	-	-	-
Heavy Impact												
Slow	19	17	19	18	0	17	19	12	12	10	10	11
Fast	-	-	-	-	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 34. Duncan's new multiple range tests of soil rut depths in individual and combined ($\bar{X}$) airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	a	a	a	a	a	a	a
AIRBOAT												
One Pass	#	#	#	a	R	R	R	R	R	R	R	R
Medium Impact												
Slow	#	#	#	a	R	R	R	R	R	R	R	R
Fast	#	#	#	a	R	R	R	R	R	R	R	R
Heavy Impact												
Slow	#	#	#	a	R	a	R	a	R	R	R	R
Fast	#	#	#	a	R	R	R	R	R	R	R	R
TRACK VEHICLE												
One Pass	#	#	#	b	a	b	b	a	b	b	b	b
Medium Impact												
Slow	-	-	-	-	-	-	-	-	-	-	-	-
Fast	-	-	-	-	-	-	-	-	-	-	-	-
Heavy Impact												
Slow	#	#	#	c	a	c	c	b	c	c	c	c
Fast	-	-	-	-	-	-	-	-	-	-	-	-
n				21	11	12	11	34	61	60	60	181

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
\# No replication for statistical analysis

Table 35. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in airboat-track vehicle marl marsh test plots. Actual control values (cm) are indicated.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
AIRBOAT								
One Pass	N	N	N	N	N	N	N	N
Medium Impact								
Slow	N	N	N	N	N	N	N	N
Fast	N	N	N	N	N	N	N	N
Heavy Impact								
Slow	N	N	N	N	N	N	N	N
Fast	N	N	N	N	N	N	N	N
TRACK VEHICLE								
One Pass	100	0	0	18	0	50	50	39
Medium Impact								
Slow	-	-	-	-	-	-	-	-
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	100	0	0	34	39	41	37	43
Fast	-	-	-	-	-	-	-	-

\- Treatment was not performed
N No rut created during treatment

Table 36. Average soil rut depths (cm) in peat marsh test plots.

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0	0	0	0	0
AIRBOAT												
One Pass	0	0	0	0	R	R	R	R	R	R	R	R
Medium Impact												
Slow	0	0	0	0	0	0	0	0	R	0	0	0
Fast	0	0	0	0	0	0	0	0	R	R	R	R
Heavy Impact												
Slow	0	0	0	0	0	0	0	0	R	0	0	0
Fast	0	0	0	0	0	0	0	0	R	0	0	0
TRACK VEHICLE												
One Pass	0	0	0	0	0	0	0	0	R	R	R	R
Medium Impact												
Slow	5	10	10	8	0	10	10	7	4	9	10	7
Fast	-	-	-	-	-	-	-	-	-	-	-	-
Heavy Impact												
Slow	28	24	25	26	20	24	20	21	15	16	17	16
Fast	-	-	-	-	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

vehicle impacts had occurred after one year (Table 37), but it was the least seen for any of the habitats or vehicles tested, and rut depths were still significantly different from the controls (Table 38).

The absence of ruts in some of the plot 1 track vehicle lanes in the marl and peat marsh sites during the pre- growing season (Tables 33 and 36) was due to the difficulty of measuring them in these extremely soft substrates. Observations of track vehicle impacts in marl marsh plot 1 during the pre- growing season sampling period revealed no visible soil rutting, and no measurements were attempted. In plots 2 and 3 shallow ruts were visible, and while attempting to measure them we found that they were filled with a very loose slurry of disturbed soil, which would not support the weight of the meter stick used to measure all other vehicle ruts. Thus, the actual effect of the track vehicle on the soil still extended beyond the visible surface. We felt that the upper layers of this slurry were loose enough to be considered disturbed and rut measurements were thereafter made to the bottom of this unconsolidated material.

Ridge Height

Small Cypress

At one-pass and medium impact levels, only a few vehicle-plot combinations resulted in even small ridges that were still present during our pre- growing season sampling period three to five months after the treatments (Table 39). At heavy impact levels all vehicles produced ridges in at least two of the three plots. ATCs tended to produce the lowest ridges, although they were not consistently significantly lower than those produced by buggies (Table 40). Recovery during the growing season was generally less than 55 percent (Table 41).

Marl Marsh (Wheeled-Vehicle)

ATCs never produced ridges at any impact level (Table 42). More types of buggies produced increasingly higher ridges in more plots as impact level increased. When ridges existed, they were significantly higher in chain and tractor buggy lanes (Table 43), probably because the high tractor tread or chains tended to lift soil out of the ruts and drop at least some of it along the sides of the tires. Recovery during the growing season was least in plot 1 where it was less than 26 percent, while in the other two plots it generally varied from 40-80 percent (Table 41).

Sand Marsh

Significant ridges were only produced in plot 2, and then only by the smooth, chain, and tractor buggies at the heavy impact level (Table 44

Table 37. Percent decrease of soil rut depths 3-5 months and one year after vehicle treatments in peat marsh test plots. Actual control values (cm) are indicated.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
AIRBOAT								
One Pass	N	N	N	N	N	N	N	N
Medium Impact								
Slow	N	N	N	N	N	N	N	N
Fast	N	N	N	N	N	N	N	N
Heavy Impact								
Slow	N	N	N	N	N	N	N	N
Fast	N	N	N	N	N	N	N	N
TRACK VEHICLE								
One Pass	N	N	N	N	N	N	N	N
Medium Impact								
Slow	100	0	0	19	20	15	2	11
Fast	-	-	-	-	-	-	-	-
Heavy Impact								
Slow	29	0	20	17	46	32	31	37
Fast	-	-	-	-	-	-	-	-

\- Treatment was not performed
N No rut created during treatment

Table 38. Duncan's new multiple range tests of soil rut depths in individual and combined ($\bar{X}$) peat marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Initial Fall 1978				Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	a	a	a	a	a	a	a
AIRBOAT												
One Pass	#	#	#	a	R	R	R	R	R	R	R	R
Medium Impact												
Slow	#	#	#	a	a	a	a	a	R	a	a	a
Fast	#	#	#	a	a	a	a	a	R	R	R	R
Heavy Impact												
Slow	#	#	#	a	a	a	a	a	R	a	a	a
Fast	#	#	#	a	a	a	a	a	R	a	a	a
TRACK VEHICLE												
One Pass	#	#	#	a	a	a	a	a	R	R	R	R
Medium Impact												
Slow	#	#	#	b	a	b	b	b	b	b	b	b
Fast	-	-	-	-	-	-	-	-	-	-	-	-
Heavy Impact												
Slow	#	#	#	c	b	c	c	c	c	c	c	c
Fast	-	-	-	-	-	-	-	-	-	-	-	-
n				24	22	22	22	66	65	71	71	207

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
No replication for statistical analysis

Table 39. Average soil ridge heights (cm) in small cypress test plots.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	0	0	0	0	R	R	R	R
Light	0	0	0	0	R	0	0	0
Smooth	-	-	-	-	-	-	-	-
Chain	0	0	0	0	R	0	0	0
Tractor	3	0	0	1	2	0	0	1
Heavy	0	0	3	1	R	0	2	1
MEDIUM IMPACT								
ATC	0	0	0	0	R	0	0	0
Light	1	0	-	1	1	0	-	1
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	1	3	0	1	1	2	0	1
Light	4	8	4	6	4	7	3	5
Smooth	-	-	-	-	-	-	-	-
Chain	6	0	1	3	2	0	1	1
Tractor	5	4	0	3	4	1	0	2
Heavy	6	4	4	5	4	2	2	3

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 40. Duncan's new multiple range tests of soil ridge heights in individual and combined ($\bar{X}$) small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	a	a	a
ONE PASS								
ATC	a	a	a	a	R	R	R	R
Light	a	a	a	a	R	a	a	a
Smooth	-	-	-	-	-	-	-	-
Chain	a	a	a	a	R	a	a	a
Tractor	b	a	a	bc	b	a	a	bc
Heavy	a	a	b	bc	R	a	bc	bc
MEDIUM IMPACT								
ATC	a	a	a	a	R	a	a	a
Light	a	a	-	a	a	a	-	a
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-	-	-	-
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	a	b	a	b	a	b	a	b
Light	bc	c	b	f	c	c	c	e
Smooth	-	-	-	-	-	-	-	-
Chain	d	a	a	cd	b	a	a	b
Tractor	cd	b	a	de	c	a	a	cd
Heavy	d	b	b	e	c	b	b	d
n	225	144	141	510	212	153	142	507

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 41. Percent decrease of soil ridge heights 3-5 months and one year after vehicle treatments in small cypress and wheeled-vehicle marl marsh test plots. Actual control values (cm) are indicated.

Sampling Period	Small Cypress Pre- Growing Season Fall 1979				Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Smooth	-	-	-	-	-	-	-	-
Chain	N	N	N	N	N	N	N	N
Tractor	24	N	N	24	N	0	N	0
Heavy	N	N	21	24	N	-	N	N
MEDIUM IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	0	N	-	0	N	100	50	65
Smooth	-	-	-	-	-	-	-	-
Chain	-	-	-	-	-262	69	N	22
Tractor	-	-	-	-	14	-	-	14
Heavy	-	-	-	-	N	-	N	N
HEAVY IMPACT								
ATC	54	34	N	38	N	N	N	N
Light	-2	19	33	18	N	37	N	37
Smooth	-	-	-	-	-	-	-	-
Chain	74	N	29	65	19	42	43	38
Tractor	18	87	N	48	26	55	79	55
Heavy	34	51	47	41	N	-	56	56

\- Treatment was not performed
N No soil ridge was ever present in test lane

Table 42. Average soil ridge heights (cm) in wheeled-vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	X̄	1	2	3	X̄
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	R	0	0	0	R	R	R	R
Light	0	0	0	0	R	0	0	0
Smooth	-	-	-	-	-	-	-	-
Chain	0	0	0	0	R	0	0	0
Tractor	0	2	0	1	R	2	0	1
Heavy	0	-	0	0	R	-	0	0
MEDIUM IMPACT								
ATC	0	0	0	0	0	0	0	0
Light	0	1	2	1	0	0	1	<1
Smooth	-	-	-	-	-	-	-	-
Chain	1	3	0	1	2	1	0	1
Tractor	1	-	-	1	1	-	-	1
Heavy	0	-	0	0	0	-	0	0
HEAVY IMPACT								
ATC	0	0	0	0	0	0	0	0
Light	0	3	0	1	0	2	0	1
Smooth	-	-	-	-	-	-	-	-
Chain	3	9	5	6	2	5	3	3
Tractor	4	7	4	5	3	3	1	2
Heavy	0	-	4	2	0	-	2	1

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 43. Duncan's new multiple range tests of soil ridge heights in individual and combined ($\bar{X}$) wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	a	a	a
ONE PASS								
ATC	R	a	a	a	R	R	R	R
Light	a	a	a	a	R	a	ab	a
Smooth	-	-	-	-	-	-	-	-
Chain	a	a	a	a	R	a	ab	a
Tractor	a	ab	a	ab	R	b	ab	cd
Heavy	a	-	a	a	R	-	ab	a
MEDIUM IMPACT								
ATC	a	a	a	a	a	a	ab	a
Light	a	a	b	ab	a	a	bc	a
Smooth	-	-	-	-	-	-	-	-
Chain	a	b	a	b	b	ab	ab	c
Tractor	a	-	-	a	a	-	-	a
Heavy	a	-	a	a	a	-	ab	a
HEAVY IMPACT								
ATC	a	a	a	a	a	a	a	a
Light	a	b	a	ab	a	b	a	ab
Smooth	-	-	-	-	-	-	-	-
Chain	b	d	d	d	b	d	e	e
Tractor	c	c	c	d	c	c	c	d
Heavy	a	-	c	c	a	-	d	bc
n	151	195	177	523	155	173	186	514

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 44. Duncan's new multiple range tests of soil ridge heights in individual and combined ($\bar{X}$) sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	a	a	a
ONE PASS								
ATC	R	R	R	R	R	R	R	R
Light	R	a	a	ab	R	R	R	R
Smooth	R	a	a	ab	R	R	R	R
Chain	R	a	**	ab	R	R	R	R
Tractor	R	a	a	ab	R	R	R	R
Heavy	R	a	a	ab	R	R	R	R
MEDIUM IMPACT								
ATC	a	a	a	ab	R	R	R	R
Light	a	a	a	ab	R	R	a	abc
Smooth	a	a	a	ab	R	a	a	ab
Chain	a	a	a	ab	R	a	a	ab
Tractor	a	a	a	ab	R	a	a	ab
Heavy	a	a	a	ab	a	a	a	ab
HEAVY IMPACT								
ATC	a	a	a	a	R	a	R	a
Light	a	a	a	a	a	a	a	a
Smooth	a	c	a	c	a	c	a	c
Chain	a	b	a	b	a	b	a	bc
Tractor	a	d	a	d	a	d	a	d
Heavy	a	a	a	a	a	a	a	a
n	204	160	49	413	153	111	30	294

R Vehicle treatment recovered and no longer visible

** Treatment lane destroyed by unauthorized vehicle use

and 45). Recovery during the growing season was quite limited (Table 46).

Pine

Ridges were produced only in plot 3 by buggies tested at medium and heavy impact levels (Table 47), but only the heavy impacts resulted in significant ridges (Table 48). Recovery was again quite limited during the growing season (Table 46).

Marl Marsh (Airboat-Track Vehicle) and Peat Marsh

No ridges were produced by either airboats or track vehicles.

Soil Compaction

Soil compaction did not occur as a result of any of our treatments. The churning effect of the wheels tended to break up the soil structure, resulting in a slurry of water, soil, and vegetation.

Our initial survey in October 1979 showed no appreciable difference in compressive strength between heavy impact and control sites in sand marsh and pine habitats, while cypress and wheeled-vehicle marl marsh sites did show appreciable differences (Table 49). It was not possible to measure compressive strength of the top 5-8 cm of soil in the marl marsh track vehicle ruts because of the very loose consistency of the material in them. The penetrometer values for track vehicle impacts in peat marshes were much lower than control values, while those for airboats were similar.

The following describes the results of a more detailed study we conducted in the small cypress and wheeled-vehicle marl marsh test plots during March 1980, 1.5 years after the treatments were made.

Small Cypress

The tractor buggy was the only vehicle that consistently caused a significantly reduced soil compressive strength in the one-pass lanes, while except in one ATC test lane, all heavy impact level treatments had resulted in significant reductions in compressive strength 1.5 years later (Table 50). ATCs consistently caused the least reduction at each impact level, but there were few significant differences between the buggies within each impact level (Table 51). Soil compressive strength 1.5 years after the treatments was typically 50-80 percent of controls at one-pass and medium impact levels, and 30-65 percent of controls at heavy impact levels, except for the ATC, which had values that were over 75 percent of the controls (Table 52).

Marl Marsh (Wheeled-Vehicle)

Significant reductions in soil compressive strength occurred only in the buggy lanes in plot 3 or in the chain buggy lanes at heavy impact levels

Table 45. Average soil ridge heights in sand marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	0	0	0
ONE PASS								
ATC	R	R	R	R	R	R	R	R
Light	R	0	0	0	R	R	R	R
Smooth	R	0	0	0	R	R	R	R
Chain	R	0	**	0	R	R	R	R
Tractor	R	0	0	0	R	R	R	R
Heavy	R	0	0	0	R	R	R	R
MEDIUM IMPACT								
ATC	0	0	0	0	R	R	R	R
Light	0	0	0	0	R	R	0	0
Smooth	0	0	0	0	R	0	0	0
Chain	0	0	0	0	R	0	0	0
Tractor	0	1	0	< 1	R	0	0	0
Heavy	0	0	0	0	0	0	0	0
HEAVY IMPACT								
ATC	0	0	0	0	R	0	R	0
Light	0	0	0	0	0	0	0	0
Smooth	0	5	0	2	0	4	0	1
Chain	0	3	0	1	0	3	0	1
Tractor	0	8	0	3	0	5	0	2
Heavy	0	0	0	0	0	0	0	0

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Table 46 . Percent decrease of soil ridge heights 3-5 months and one year after vehicle treatments in sand marsh and pine test plots. Actual control values (cm) are indicated.

Sampling Period	Sand Marsh Post- Growing Season Fall 1979				Pine Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	***	0	0
ONE PASS								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	N	N	N	N
Smooth	N	N	N	N	N	N	N	N
Chain	N	N	**	N	N	N	N	N
Tractor	N	N	N	N	N	N	N	N
Heavy	N	N	N	N	N	N	N	N
MEDIUM IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	-	-	-	-
Smooth	N	N	N	N	N	N	-63	-63
Chain	N	N	N	N	N	N	100	100
Tractor	N	100	N	100	-	-	-	-
Heavy	N	N	N	N	-	-	-	-
HEAVY IMPACT								
ATC	N	N	N	N	N	N	N	N
Light	N	N	N	N	-	-	-	-
Smooth	N	34	N	34	N	N	26	26
Chain	N	17	N	17	N	N	40	40
Tractor	N	34	N	34	-	-	-	-
Heavy	N	N	N	N	-	-	-	-

\- Treatment was not performed
N No soil ridge was ever present in test lane
** Treatment lane destroyed by unauthorized vehicle use
*** No treatments visible after fire

Table 47. Average soil ridge heights (cm) in pine test plots.

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	0	0	0	0	0	***	0	0
ONE PASS								
ATC	0	0	R	0	R	R	R	R
Light	0	0	0	0	R	R	R	R
Smooth	0	0	0	0	R	R	R	R
Chain	0	0	0	0	R	R	R	R
Tractor	0	0	0	0	R	R	R	R
Heavy	0	0	0	0	R	R	R	R
MEDIUM IMPACT								
ATC	0	0	0	0	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	0	0	2	1	0	R	3	1
Chain	0	0	<1	1	0	R	R	0
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	0	0	0	0	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	0	0	4	1	0	R	3	1
Chain	0	0	4	1	0	R	2	1
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 48. Duncan's new multiple range tests of soil ridge heights in individual and combined ($\bar{X}$) pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979				Post- Growing Season Fall 1979			
REPLICATE PLOTS	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
CONTROL	a	a	a	a	a	***	a	a
ONE PASS								
ATC	a	a	R	a	R	R	R	R
Light	a	a	a	a	R	R	R	R
Smooth	a	a	a	a	R	R	R	R
Chain	a	a	a	a	R	R	R	R
Tractor	a	a	a	a	R	R	R	R
Heavy	a	a	a	a	R	R	R	R
MEDIUM IMPACT								
ATC	a	a	a	a	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	a	a	a	a	a	R	ab	bc
Chain	a	a	a	a	a	R	R	a
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
HEAVY IMPACT								
ATC	a	a	a	a	R	R	R	R
Light	-	-	-	-	-	-	-	-
Smooth	a	a	b	b	a	R	b	c
Chain	a	a	b	b	a	R	a	ab
Tractor	-	-	-	-	-	-	-	-
Heavy	-	-	-	-	-	-	-	-
n	36	36	142	214	13	0	91	104

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
*** No treatments visible after fire

Table 49. Compressive strength of soil (kg/cm^2) in vehicle impact study plots.

	Control		Heavy Impact Lane		Measurement Depth (cm)[a]
Wheeled Vehicle Plots	$\bar{X}$	S.E.	$\bar{X}$	S.E.	
Small Cypress 1	2.48	.15	0.15	.08	6
Small Cypress 2	1.98	.15	0.13	.08	6
Small Cypress 3	2.00	.15	0.10	.22	6
Marl Marsh 1	2.85	.10	1.25	.15	4
Marl Marsh 2	2.43	.09	1.23	.15	4
Marl Marsh 3	2.80	.10	1.60	.15	4
Sand Marsh 1	.05	.01	.03	.01	0.5
Sand Marsh 2	.15	.01	.15	.01	0.5
Sand Marsh 3	.12	.01	.11	.01	0.5
Pine 1	3.95	.18	4.15	.14	6
Pine 3	3.80	.16	3.20	.12	6
Airboat-Track Vehicle Plots					
Marl Marsh 1	1.35	.11	0*	0	6
Marl Marsh 2	1.53	.08	0*	0	6
Peat Marsh 1	2.05	.24	2.15**	.18	6
			.70*	.11	6
Peat Marsh 2	1.90	.25	2.20**	.20	6
			.80*	.13	6

* Track vehicle lane
** Airboat lane
a Depth to which probe was inserted; 2.5 cm diameter adaptor foot used in sand marsh plots, 0.64 cm rod used in all other test plots.

Table 50. Duncan's new multiple range tests of compressive strength of soil in individual small cypress and wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Small Cypress Post- Growing Season Winter 1980			Wheeled-Vehicle Marl Marsh Post- Growing Season Winter 1980		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	ab	a
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	bc	ab	R	a	a
Smooth	-	-	-	-	-	-
Chain	R	ab	c	R	ab	a
Tractor	b	bc	d	R	ab	ab
Heavy	R	ab	d	R	-	a
MEDIUM IMPACT						
ATC	R	bc	a	a	ab	a
Light	b	d	-	a	ab	a
Smooth	-	-	-	-	-	-
Chain	-	-	-	a	ab	ab
Tractor	-	-	-	a	-	-
Heavy	-	-	-	a	-	b
HEAVY IMPACT						
ATC	b	ab	bc	a	ab	a
Light	c	e	d	a	b	e
Smooth	-	-	-	-	-	-
Chain	c	cd	d	b	c	c
Tractor	c	cd	d	a	ab	c
Heavy	c	d	d	a	-	d
n	58	82	79	78	75	100

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 51. Average compressive strength (kg/cm^2) of soils in small cypress and wheeled-vehicle marl marsh test plots.

Sampling Period	Small Cypress Post- Growing Season Winter 1980			Wheeled-Vehicle Marl Marsh Post- Growing Season Winter 1980		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	4.1	3.2	2.7	3.7	3.6	4.6
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	2.5	2.6	R	3.9	4.6
Smooth	-	-	-	-	-	-
Chain	R	2.8	2.1	R	3.5	4.6
Tractor	3.3	2.6	1.4	R	3.6	4.4
Heavy	R	2.8	1.4	R	-	4.6
MEDIUM IMPACT						
ATC	R	2.4	2.8	3.8	3.8	4.6
Light	3.3	1.6	-	3.7	3.9	4.4
Smooth	-	-	-	-	-	-
Chain	-	-	-	3.7	3.5	4.3
Tractor	-	-	-	3.7	-	-
Heavy	-	-	-	3.8	-	4.0
HEAVY IMPACT						
ATC	3.1	2.7	2.3	3.7	3.6	4.5
Light	2.4	1.0	1.0	3.7	3.3	2.5
Smooth	-	-	-	-	-	-
Chain	2.6	1.9	1.3	3.1	2.8	3.6
Tractor	2.6	2.1	1.0	3.6	3.8	3.4
Heavy	2.6	1.7	1.0	3.6	-	3.0

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 52. Compressive strength of soil 1.5 years after treatments in small cypress and wheeled-vehicle marl marsh test plots expressed as a percent of the control values (kg/cm^2).

Sampling Period	Small Cypress Post- Growing Season Winter 1980			Wheeled-Vehicle Marl Marsh Post- Growing Season Winter 1980		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	4.1	3.2	2.7	3.7	3.6	4.6
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	78	*	R	*	*
Smooth	-	-	-	-	-	-
Chain	R	*	77	R	*	*
Tractor	80	81	52	R	*	*
Heavy	R	*	52	R	-	*
MEDIUM IMPACT						
ATC	R	75	*	*	*	*
Light	80	50	-	*	*	*
Smooth	-	-	-	-	-	-
Chain	-	-	-	*	*	*
Tractor	-	-	-	*	-	-
Heavy	-	-	-	*	-	87
HEAVY IMPACT						
ATC	76	*	85	*	*	*
Light	59	31	37	*	*	54
Smooth	-	-	-	-	-	-
Chain	63	59	48	84	78	78
Tractor	63	66	37	*	*	74
Heavy	63	53	37	*	-	65

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from controls (P=.05)

(Table 50). ATCs never affected soil compressive strength (Table 51), and except for one lane, no vehicles caused significant reductions at one-pass and medium impact levels. Soil compressive strength in affected lanes was 55-90 percent of controls 1.5 years after the treatments (Table 52).

Understory Vegetation Impacts

Biomass

Small Cypress

All but two one-pass lanes exhibited significant differences in biomass from the controls at the beginning of the growing season, while there were virtually no significant differences between impact levels or vehicle types (Table 53). However, the small sample sizes and variable distribution of vegetation masked some real differences, particularly between impact levels. Eight of the 15 one-pass lanes supported an average of more than 20 g/m^2 biomass, while the others supported between 1 and 10 g/m^2 (Table 54). Of the five medium impact test lanes, none supported an average of more than 17 g/m^2 biomass, but all had at least 1 g/m^2. Among the 15 heavy impact lanes only two supported an average of 9-11 g/m^2 biomass, and of the remainder four had less than 5 g/m^2, and nine had no live biomass. No vehicle type consistently caused more or less impact on biomass than any other.

At the end of the first growing season, all but two (tractor) of the one-pass lanes had recovered sufficiently that their biomass were not significantly different from controls (Table 53). This was also the case with two of the three medium impact ATC lanes, and all (except ATC) heavy impact lanes in plot 3. In lanes where significant differences from controls still existed, again there were no differences between impact levels or vehicle types. However, five of the 15 heavy impact lanes still did not have any vegetation in our sample plots (Table 54).

While 17 of the 35 lanes created in the small cypress habitat had recovered sufficiently to be statistically similar to control values at the end of the first growing season, in twelve of the remaining plots biomass in the test lanes was still less than 20 percent of controls (Table 55). Ten of the 15 heavy impact, and 2 of the 5 medium impact lanes were in this category, which suggests that at least some small cypress sites receiving these levels of impact can be expected to recover very slowly.

Marl Marsh (Wheeled-Vehicle)

During the pre- growing season sampling period, biomass in the control plots was significantly different from the treatments in 43 percent of the one-pass lanes, 75 percent of the medium impact lanes, and 86 percent of the heavy impact lanes (Table 56). Lanes in plot 1 had fewer significant differences than the other plots, and ATC and light buggy values were more

Table 53. Duncan's new multiple range tests of biomass in individual small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	b	a	a	a	a	ab
ONE PASS						
ATC	a	bc	b	R	R	R
Light	a	bc	b	R	abc	abc
Smooth	-	-	-	-	-	-
Chain	c	b	b	R	ab	abc
Tractor	c	bc	b	bc	bc	ab
Heavy	c	c	b	R	a	a
MEDIUM IMPACT						
ATC	c	bc	b	R	bc	abc
Light	c	c	-	b	c	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	c	bc	b	bc	c	c
Light	c	c	b	c	c	bc
Smooth	-	-	-	-	-	-
Chain	c	bc	b	c	bc	bc
Tractor	c	bc	b	c	bc	abc
Heavy	c	c	b	bc	c	abc
n	45	45	42	29	42	39

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 54. Average biomass (g/m^2) in small cypress test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	58	62	72	99	110	92
ONE PASS						
ATC	96	30	25	R	R	R
Light	88	3	23	R	55	74
Smooth	-	-	-	-	-	-
Chain	21	36	5	R	84	67
Tractor	6	4	10	36	44	95
Heavy	21	1	2	R	124	121
MEDIUM IMPACT						
ATC	10	4	17	R	16	50
Light	3	1	-	52	7	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	< 1	4	9	12	7	9
Light	0	0	0	0	0	26
Smooth	-	-	-	-	-	-
Chain	0	11	0	0	20	31
Tractor	0	2	0	0	48	73
Heavy	4	0	0	16	0	54

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 55 . Biomass in small cypress, wheeled-vehicle marl marsh and sand marsh test plots expressed as a percent of actual control values (g/m^2).

Sampling Period	Small Cypress Post- Growing Season Fall 1979			Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979			Sand Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3	1	2	3
CONTROL	99	110	92	254	251	181	282	380	355
ONE PASS									
ATC	R	R	R	R	R	R	R	R	R
Light	R	*	*	R	*	*	R	R	R
Smooth	-	-	-	-	-	-	R	R	R
Chain	R	*	*	R	*	*	R	R	R
Tractor	36	40	*	R	*	*	R	R	R
Heavy	R	*	*	R	-	*	R	R	R
MEDIUM IMPACT									
ATC	R	15	*	68	*	*	R	R	R
Light	52	6	-	35	*	15	R	R	*
Smooth	-	-	-	-	-	-	R	39	*
Chain	-	-	-	47	*	30	R	34	*
Tractor	-	-	-	40	-	-	R	*	*
Heavy	-	-	-	65	-	43	*	*	*
HEAVY IMPACT									
ATC	12	6	10	59	*	8	R	*	R
Light	0	0	28	57	4	28	*	*	*
Smooth	-	-	-	-	-	-	26	*	57
Chain	0	18	34	16	0	10	40	*	37
Tractor	0	44	*	14	2	24	46	12	30
Heavy	16	0	*	*	-	19	10	*	*

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from control (P=.05)

Table 56. Duncan's new multiple range tests of biomass in individual wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
ONE PASS						
ATC	R	abc	bc	R	R	R
Light	abc	ab	ab	R	ab	ab
Smooth	-	-	-	-	-	-
Chain	bc	ab	abc	R	ab	abc
Tractor	bc	bc	bc	R	ab	abc
Heavy	ab	-	bc	R	-	abc
MEDIUM IMPACT						
ATC	abc	bc	bc	bc	a	abc
Light	abc	bc	c	cd	ab	c
Smooth	-	-	-	-	-	-
Chain	c	bc	c	bcd	ab	bc
Tractor	c	-	-	cd	-	-
Heavy	abc	-	c	bc	-	bc
HEAVY IMPACT						
ATC	abc	bc	c	bc	a	c
Light	abc	bc	c	bc	b	bc
Smooth	-	-	-	-	-	-
Chain	bc	c	c	d	b	c
Tractor	c	bc	c	d	b	bc
Heavy	c	-	c	ab	-	c
n	51	42	50	40	37	49

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

frequently similar to the control biomass than were the other types of buggies. The tractor buggy was the only vehicle which had consistently different biomass values from the controls at all impact levels. With very few exceptions, no vehicle or impact level had biomass values significantly different from one another in the pre- growing season lanes. However, there was a consistent trend of lower biomass as impact level increased, with one medium impact lane and six heavy impact lanes having essentially no vegetation in our sample plots (Table 57). There was also a tendency for test lanes in plot 3 to have a much lower biomass than the other plots, including six lanes with essentially no living vegetation.

All of the one-pass treatments had recovered by the end of the growing season, while 66 and 86 percent of the medium and heavy impact treatments, respectively, were still significantly different from the controls (Table 56). Among the medium impact lanes, none of those in plot 2 were significantly different from the controls. In contrast to the pre- growing season situation, biomass in plot 1 lanes was normally significantly different from the control values. Biomass in the tractor buggy lanes was still more consistently different from control values than was any other vehicle. As during the pre- growing season, biomass values for few of the impact level or vehicle type lanes were significantly different from one another, although there was a trend for decreasing biomass with increasing impact level (Table 57).

While biomass in the one-pass test lanes and some of the medium and heavy impact lanes had recovered within one year, biomass in most of the medium and heavy impact lanes had attained values that were only 30 to 70 percent, and less than 30 percent, respectively, of control values (Table 55). Thus, at our higher impact levels, recovery can be expected to be a slow process taking at least several years.

<u>Sand Marsh</u>

During the pre- growing season sampling period, only one of 17 one-pass lanes had a significantly different biomass from the control plots, while two-thirds of the medium impact and all of the heavy impact lanes were significantly different (Table 58). There were a few significant differences among the vehicle types in either medium or heavy impact plots, but there was a distinct decrease in biomass with increased level of impact (Table 59).

By the end of the growing season, all of the one-pass lanes, 44 percent of the medium impact, and two of the ATC heavy impact lanes could not even be located due to the high degree of recovery. In addition, of the remaining visible lanes, 80 percent of the medium impact and 50 percent of the heavy impact lanes were not significantly different from the controls (Table 58). Biomass in all of the ATC and light buggy lanes was statistically similar to control values, as were all but one of the heavy buggy lanes. None of the lanes that were significantly different from the controls were different from one another.

Table 57 . Average biomass (g/m^2) in wheeled-vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	164	205	119	254	251	181
ONE PASS						
ATC	R	112	39	R	R	R
Light	111	160	79	R	117	168
Smooth	-	-	-	-	-	-
Chain	72	151	69	R	149	114
Tractor	78	85	23	R	118	101
Heavy	163	-	32	R	-	141
MEDIUM IMPACT						
ATC	82	65	52	172	213	101
Light	81	64	1	90	139	27
Smooth	-	-	-	-	-	-
Chain	34	29	9	119	128	54
Tractor	33	-	-	101	-	-
Heavy	104	-	4	164	-	77
HEAVY IMPACT						
ATC	89	40	0	150	179	14
Light	96	13	0	145	9	51
Smooth	-	-	-	-	-	-
Chain	64	1	0	40	0	19
Tractor	33	14	1	36	6	44
Heavy	40	-	1	228	-	34

R Vehicle treatment recovered and no longer visible
- Treatment was not performed

Table 58. Duncan's new multiple range tests of biomass in individual sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	ab	a	a	ab
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	ab	abcde	R	R	R
Smooth	R	abc	abc	R	R	R
Chain	R	abc	**	R	R	R
Tractor	R	abc	abcd	R	R	R
Heavy	R	bc	a	R	R	R
MEDIUM IMPACT						
ATC	bc	bc	abcd	R	R	R
Light	ab	abc	cdef	R	R	a
Smooth	bc	bc	bcdef	R	bc	abcd
Chain	c	abc	cdef	R	bc	abcde
Tractor	bc	c	def	R	abc	bcde
Heavy	bc	bc	bcdef	ab	ab	abcd
HEAVY IMPACT						
ATC	c	bc	def	R	abc	R
Light	c	c	cdef	abc	abc	abc
Smooth	c	c	ef	bc	abc	cde
Chain	c	bc	def	bc	abc	de
Tractor	c	c	f	bc	c	e
Heavy	c	c	def	c	ab	abcde
n	45	60	57	27	39	39

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Table 59. Average biomass (g/m^2) in sand marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	75	243	152	282	380	355
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	235	98	R	R	R
Smooth	R	127	149	R	R	R
Chain	R	137	**	R	R	R
Tractor	R	168	114	R	R	R
Heavy	R	65	182	R	R	R
MEDIUM IMPACT						
ATC	20	68	116	R	R	R
Light	54	90	61	R	R	396
Smooth	24	56	93	R	150	303
Chain	10	113	66	R	129	246
Tractor	34	10	53	R	175	218
Heavy	18	81	92	246	379	303
HEAVY IMPACT						
ATC	0	44	59	R	200	R
Light	0	28	74	177	242	350
Smooth	0	8	24	72	303	201
Chain	0	55	27	114	248	130
Tractor	2	9	5	131	44	105
Heavy	2	26	35	28	362	222

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Among the lanes with post- growing season biomass values significantly different from the controls, the percentage that lane biomass was of the controls generally ranged from 10 to 50 percent (Table 55). This suggests some lanes can be expected to have a reduced biomass for at least several years following medium to heavy impacts.

Pine

During the pre- growing season sampling period, 83 percent of the one-pass, 44 percent of the medium impact, and 22 percent of the heavy impact lanes were not significantly different from the controls (Table 60). None of the treatment lanes were significantly different from one another, and there was no consistent trend of decreasing biomass with increasing impact (Table 61).

Virtually all of the lanes had disappeared due to recovery during the growing season, and of the few that had not, only one was still significantly different from the controls. Thus, in terms of understory biomass, ORVs can be expected to produce no long-term impacts on Big Cypress pine habitats.

Marl Marsh (Airboat-Track Vehicle)

With only one exception, biomass in the airboat lanes had recovered by the pre- growing season sampling period (Table 62), and the one exception was not significantly different from the controls (Table 63). None of the lanes were even visible on the ground in the post- growing season sampling period.

Most track-vehicle lanes were significantly different from controls during both pre- and post- growing season sampling periods (Table 63). During the first period, there was essentially no vegetation in any lane (Table 62). By the end of the growing season, approximately 50 percent of the control plot biomass had become reestablished in the one-pass lanes, but only 3-17 percent in the heavy impact lanes (Table 64). This suggests that at least two years would be required for recovery from even one pass by a track vehicle, and much longer for multiple passes in the marl marsh habitat.

Peat Marsh

Several factors affected airboat test lane-control biomass relationships during the pre- growing season. The high variability in plot 1 control samples tended to mask differences, and the very high biomass in plot 3 controls resulted in all but one-pass airboat lanes being significantly different (Table 65). The only lanes significantly different from plot 2 controls were fast speed medium and heavy impact treatments. There were no statistical differences between any of the test lanes or consistent trends of biomass related to increased level of impact within any of the plots (Table 66). By the end of the growing season, all plots had recovered or test lane biomass was not significantly different from controls.

Table 60. Duncan's new multiple range tests of biomass in individual pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	***	a
ONE PASS						
ATC	ab	ab	R	R	R	R
Light	ab	ab	ab	R	R	R
Smooth	ab	b	ab	R	R	R
Chain	b	ab	ab	R	R	R
Tractor	ab	ab	ab	R	R	R
Heavy	ab	b	ab	R	R	R
MEDIUM IMPACT						
ATC	ab	ab	ab	R	R	R
Light	-	-	-	-	-	-
Smooth	b	b	b	ab	R	a
Chain	b	ab	b	ab	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	b	b	ab	R	R	R
Light	-	-	-	-	-	-
Smooth	b	b	b	b	R	a
Chain	ab	b	b	ab	R	a
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
n	45	45	42	21	0	17

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
*** No treatments visible after fire

Table 61. Average biomass (g/m^2) in pine test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	118	189	101	136	***	126
ONE PASS						
ATC	43	128	R	R	R	R
Light	88	79	55	R	R	R
Smooth	42	26	39	R	R	R
Chain	34	116	33	R	R	R
Tractor	46	107	65	R	R	R
Heavy	65	59	78	R	R	R
MEDIUM IMPACT						
ATC	52	135	44	R	R	R
Light	-	-	-	-	-	-
Smooth	10	14	13	116	R	66
Chain	8	119	6	109	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	11	37	43	R	R	R
Light	-	-	-	-	-	-
Smooth	15	44	1	46	R	14
Chain	47	46	2	73	R	41
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 62. Average biomass (g/m^2) in airboat-track vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	89	57	73	151	185	176
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	71	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	<1	0	0	68	100	87
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	25	31	6
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed

Table 63. Duncan's new multiple range tests of biomass in individual airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	a	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	a	b	b	b	ab	b
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	a	b	b	b	b	b
Fast	-	-	-	-	-	-
n	15	18	15	13	15	14

R Vehicle treatment recovered and no longer visible
- Treatment was not performed

Table 64. Biomass in airboat-track vehicle marl marsh and peat marsh test plots expressed as a percent of actual control values (g/m^2).

Sampling Period	Airboat-Track Vehicle Marl Marsh Post- Growing Season Fall 1979			Peat Marsh Post-Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	151	185	176	561	427	306
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	*	*
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	R	R	R	*	*
Fast	R	R	R	R	*	*
TRACK VEHICLE						
One Pass	45	*	49	R	R	R
Medium Impact						
Slow	-	-	-	*	18	20
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	17	17	3	31	15	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from controls (P=.05)

Table 65. Duncan's new multiple range tests of biomass in individual peat marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post-Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	ab
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	a	ab	b	R	a	bc
Fast	a	bc	b	R	R	R
Heavy Impact						
Slow	a	abc	b	R	ab	bc
Fast	a	bc	b	R	a	b
TRACK VEHICLE						
One Pass	a	bc	b	R	R	R
Medium Impact						
Slow	a	c	b	ab	b	c
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	a	c	b	b	b	c
Fast	-	-	-	-	-	-
n	30	30	30	15	24	24

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 66 . Average biomass (g/m^2) in peat marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	330	322	898	561	427	306
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	364	223	276	R	473	231
Fast	425	127	341	R	R	R
Heavy Impact						
Slow	110	184	71	R	262	100
Fast	152	134	201	R	411	509
TRACK VEHICLE						
One Pass	119	86	28	R	R	R
Medium Impact						
Slow	3	0	<1	359	78	60
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	175	64	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Track vehicle biomass in all plot 2 and 3 lanes were statistically different from controls during the pre- growing season sampling period (Table 65), when there was essentially no vegetation growing in any of the medium and heavy impact lanes (Table 66). The one-pass lanes recovered during the growing season. However, most of the other lanes were still significantly different from the controls at the end of this period, and had actually shown little recovery (Table 64). Thus, recovery could be expected to require a number of years following even medium impact levels.

Percent Cover

Small Cypress

Nearly all pre- growing season test lane percent cover values were significantly different from the controls (Table 67). While there were few significant differences at this time between the impact levels, there was a definite trend of decreasing percent cover with increasing level of impact (Table 68). In the one-pass treatments, although 53 percent of the lanes had a vegetative cover of 1 percent or less, in the remaining lanes it ranged up to 33 percent. The maximum value in the five medium impact lanes was 5 percent, while in the heavy impact lanes the maximum value was less than one, 60 percent having no vegetation at all.

After the first growing season, all of the one-pass ATC lanes had recovered, as had most of the plot 1 one-pass and medium impact lanes. Otherwise, the lanes were still significantly different from controls, and most were similar to each other (Table 67). There was still a general decrease in cover with increasing level of impact, but it was much less distinct (Table 68).

Except for the few treatments that had recovered completely, percent cover in the test lanes was at most 43 percent of control values (Table 69). This suggests that it will require at least several years for percent cover to approach complete recovery, even in many of the one-pass lanes.

Marl Marsh (Wheeled Vehicle)

There was strong plot to plot variation in the pre- growing season percent cover data. In plot 1 few lanes were significantly different from the controls (Table 70), and there was no consistent relationship between percent cover and impact level or vehicle type (Table 71). Almost all medium and heavy impact lanes in plot 2 were significantly different from the controls, while only one-pass and heavy impact values were significantly different from one another, except for the ATC lanes which were all statistically similar (Table 70). Thus, there was a general trend of reduced percent cover with increased level of impact in plot 2 (Table 71). All plot 3 lanes had significantly lower percent covers than controls (Table 70), although there were few statistical differences among the test lanes.

Table 67. Duncan's new multiple range tests of percent cover in individual small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
ONE PASS						
ATC	a	ab	bc	R	R	R
Light	a	c	b	R	b	b
Smooth	-	-	-	-	-	-
Chain	b	bc	bc	R	b	bc
Tractor	b	c	bc	b	b	c
Heavy	b	c	c	R	b	b
MEDIUM IMPACT						
ATC	b	c	b	R	b	bc
Light	b	c	-	b	b	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	b	c	c	b	b	c
Light	b	c	c	b	b	c
Smooth	-	-	-	-	-	-
Chain	b	c	c	b	b	bc
Tractor	b	c	c	b	b	b
Heavy	b	c	c	b	b	bc
n	45	45	42	30	42	29

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 68. Average percent cover in small cypress test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	33	13	10	15	23	23
ONE PASS						
ATC	33	8	1	R	R	R
Light	27	<1	2	R	5	10
Smooth	-	-	-	-	-	-
Chain	7	4	<1	R	5	4
Tractor	1	<1	<1	2	3	2
Heavy	8	<1	<1	R	5	10
MEDIUM IMPACT						
ATC	5	1	2	R	1	5
Light	1	<1	-	2	2	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	<1	<1	<1	3	1	2
Light	0	0	0	0	0	<1
Smooth	-	-	-	-	-	-
Chain	0	<1	0	0	2	7
Tractor	0	<1	0	0	3	10
Heavy	<1	0	0	2	0	7

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 69. Percent cover in small cypress, wheeled-vehicle marl marsh, and sand marsh test plots expressed as a percent of actual control values (percent cover).

Sampling Period	Small Cypress Post- Growing Season Fall 1979			Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979			Sand Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3	1	2	3
CONTROL	15	23	23	46	43	34	86	52	77
ONE PASS									
ATC	R	R	R	R	R	R	R	R	R
Light	R	21	43	R	69	49	R	R	R
Smooth	-	-	-	-	-	-	R	R	R
Chain	R	21	17	R	62	58	R	R	R
Tractor	15	14	9	R	31	29	R	R	R
Heavy	R	21	43	R	-	68	R	R	R
MEDIUM IMPACT									
ATC	R	6	21	*	69	29	R	R	R
Light	13	7	-	*	62	10	R	R	*
Smooth	-	-	-	-	-	-	R	38	*
Chain	-	-	-	44	69	29	R	19	*
Tractor	-	-	-	73	-	-	R	13	*
Heavy	-	-	-	44	-	26	*	32	*
HEAVY IMPACT									
ATC	18	6	7	*	*	5	R	38	R
Light	0	0	1	66	8	19	70	45	83
Smooth	-	-	-	-	-	-	39	45	*
Chain	0	7	29	39	0	2	39	45	*
Tractor	0	12	43	4	4	17	66	45	83
Heavy	13	0	29	44	-	5	10	38	*

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from control (P=.05)

Table 70. Duncan's new multiple range tests of percent cover in individual wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
ONE PASS						
ATC	R	ab	cd	R	R	R
Light	ab	a	b	R	b	bc
Smooth	-	-	-	-	-	-
Chain	ab	ab	bc	R	b	b
Tractor	abc	ab	cd	R	c	cd
Heavy	a	-	cd	R	-	b
MEDIUM IMPACT						
ATC	abc	ab	bcd	ab	b	cd
Light	abc	bc	d	ab	b	d
Smooth	-	-	-	-	-	-
Chain	c	bc	cd	cd	b	cd
Tractor	bc	-	-	b	-	-
Heavy	abc	-	d	cd	-	cd
HEAVY IMPACT						
ATC	abc	bc	d	ab	a	d
Light	a	c	d	bc	d	cd
Smooth	-	-	-	-	-	-
Chain	abc	c	d	d	d	d
Tractor	bc	c	d	e	d	d
Heavy	abc	-	d	cd	-	d
n	51	42	51	40	37	49

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 71. Average percent cover in wheeled-vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	50	56	34	46	43	34
ONE PASS						
ATC	R	40	8	R	R	R
Light	43	67	22	R	30	17
Smooth	-	-	-	-	-	-
Chain	43	50	17	R	27	20
Tractor	30	40	4	R	13	10
Heavy	50	-	7	R	-	23
MEDIUM IMPACT						
ATC	37	40	10	40	30	10
Light	27	17	<1	37	27	3
Smooth	-	-	-	-	-	-
Chain	10	23	5	20	30	10
Tractor	15	-	-	33	-	-
Heavy	33	-	<1	20	-	9
HEAVY IMPACT						
ATC	27	17	0	40	40	2
Light	50	3	0	30	3	7
Smooth	-	-	-	-	-	-
Chain	33	<1	0	18	0	<1
Tractor	14	3	<1	2	2	6
Heavy	27	-	<1	20	-	2

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Plot to plot variation was still an important factor during the post- growing season sampling period. In plot 1, ATC and one-pass lanes were almost the only treatments that had either recovered or were not significantly different from controls (Table 70). Again, there was no clear relationship between percent cover and either impact level or vehicle type (Table 71). In plot 2, one-pass and heavy impact ATC lanes were the only treatments not significantly different from the controls (Table 70). Most one-pass and medium impact percent cover values were statistically similar, while they were different from heavy impact buggy values. Only the one-pass ATC lane was statistically similar to the controls in plot 3 (Table 70), where there was a clear statistical trend of decreasing percent cover with increasing use.

Except in lanes that had recovered, percent covers in one-pass, medium, and plot 1 heavy impact lanes were about a third to two thirds of control values one year after treatment (Table 69). Heavy impact lanes in plots 2 and 3 generally had percent covers of less than 20 percent. This indicates that at least several years will be required for complete recovery of percent cover on most sites, and substantially longer following heavy levels of impact.

Sand Marsh

Percent cover in most one-pass and plot 3 medium impact lanes had recovered or was not significantly different from controls during the pre- growing season sampling period (Table 72). There was a general trend of decreasing percent cover with increasing level of impact (Table 73), which was also statistically apparent (Table 72). Percent cover in plot 1 was by far most reduced, particularly at heavy impact levels, and plot 3 the least (Table 73). No vehicle was consistently more or less damaging than any other.

By the post- growing season sampling period, all one-pass and plot 1 medium impact, and most ATC and plot 3 lanes had recovered or were not significantly different from controls (Table 72). Few of the remaining lanes were significantly different from one another, and there were no clear trends of decreasing percent cover with increasing impact (Table 73). Plot 2 now had the lowest percent cover values, having recovered more slowly than plot 1.

Most one-pass and medium impact lanes, and even some heavy impact lanes, had recovered within one year of treatment. Most of the remaining lanes had shown much recovery (Table 69), but at least a few can be expected to support a reduced percent cover for several years.

Pine

Virtually all one-pass percent cover values were not significantly different from controls during the pre- growing season sampling period (Table 74). In addition, medium impact ATC and a few other medium and heavy impact values were not significantly different. All other percent cover values were not significantly different from one another, and while there was a tendency for percent cover to decrease with increased use, it was not a clear trend (Table 75).

Table 72. Duncan's new multiple range tests of percent cover in individual sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	b	b	a	a	a
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	c	b	R	R	R
Smooth	R	a	b	R	R	R
Chain	R	ab	**	R	R	R
Tractor	R	ab	a	R	R	R
Heavy	R	ab	ab	R	R	R
MEDIUM IMPACT						
ATC	bc	d	b	R	R	R
Light	b	cd	ab	R	R	ab
Smooth	bc	ef	b	R	b	a
Chain	bc	e	cd	R	b	ab
Tractor	b	ef	cd	R	b	ab
Heavy	b	c	bc	a	b	ab
HEAVY IMPACT						
ATC	c	ef	b	R	b	R
Light	c	ef	cd	b	b	b
Smooth	c	ef	de	c	b	ab
Chain	c	f	de	c	b	ab
Tractor	c	ef	e	b	b	b
Heavy	c	ef	de	d	b	ab
n	45	60	57	27	39	39

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Table 73. Average percent cover in sand marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	52	44	60	86	52	77
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	37	60	R	R	R
Smooth	R	53	57	R	R	R
Chain	R	50	**	R	R	R
Tractor	R	50	80	R	R	R
Heavy	R	50	63	R	R	R
MEDIUM IMPACT						
ATC	5	23	57	R	R	R
Light	23	30	63	R	R	73
Smooth	13	10	57	R	20	77
Chain	17	13	30	R	10	73
Tractor	23	10	27	R	7	73
Heavy	23	33	43	83	17	73
HEAVY IMPACT						
ATC	0	8	53	R	20	R
Light	0	7	30	60	23	63
Smooth	0	4	10	33	23	73
Chain	0	1	13	33	23	73
Tractor	1	10	1	57	23	63
Heavy	1	8	17	8	20	67

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Table 74. Duncan's new multiple range tests of percent cover in individual pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	ab	abc	a	a	***	a
ONE PASS						
ATC	abc	abc	R	R	R	R
Light	abc	ab	abc	R	R	R
Smooth	abc	cd	ab	R	R	R
Chain	abc	a	a	R	R	R
Tractor	bc	abc	a	R	R	R
Heavy	a	d	a	R	R	R
MEDIUM IMPACT						
ATC	abc	bcd	a	R	R	R
Light	-	-	-	-	-	-
Smooth	c	d	bc	a	R	a
Chain	c	abcd	c	a	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	c	d	abc	R	R	R
Light	-	-	-	-	-	-
Smooth	bc	d	c	a	R	a
Chain	c	d	c	a	R	a
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
n	45	45	42	21	0	18

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 75 · Average percent cover in pine test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	36	57	29	28	***	27
ONE PASS						
ATC	30	60	R	R	R	R
Light	27	67	20	R	R	R
Smooth	21	27	23	R	R	R
Chain	18	70	30	R	R	R
Tractor	15	60	27	R	R	R
Heavy	47	15	27	R	R	R
MEDIUM IMPACT						
ATC	17	30	33	R	R	R
Light	-	-	-	-	-	-
Smooth	5	7	5	40	R	11
Chain	5	40	2	30	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	5	17	17	R	R	R
Light	-	-	-	-	-	-
Smooth	12	10	<1	27	R	2
Chain	8	12	<1	27	R	4
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

All lanes had either recovered or were not significantly different from controls after the growing season (Table 74).

Marl Marsh (Airboat-Track Vehicle)

All airboat lanes had recovered in terms of percent cover by the pre-growing season sampling period (Tables 76 and 77).

The track-vehicle lanes had little or no vegetation during the pre-growing season sampling period (Table 76). During the growing season, the one-pass lane values had recovered to within about 30-50 percent of the controls (Table 78), but in five of the six lanes percent cover was still significantly different from the controls (Table 77). Recovery in the heavy impact lanes was only 2-30 percent of controls, and these will require some time yet before they can be expected to fully recover (Table 78).

Peat Marsh

During the pre- growing season sampling period, percent cover in the airboat treatments was statistically similar to the controls in the one-pass and plot 1 medium impact lanes (Table 79). There was no consistent trend of decreasing percent cover with increasing impact (Table 80), and no significant differences or consistent trends related to slow or fast speeds. All of the plot 1 and medium impact-fast lanes recovered during the growing season, while percent cover in the other lanes was still significantly different from the controls (Table 79). These remaining lanes were not significantly different from one another, and there were no trends of decreased percent cover with increased impact (Table 80). Although these lanes had recovered to some extent during the growing season (Table 78), the amount of recovery was small enough that it will probably take several years yet to complete.

All but one of the percent cover values for the pre- growing season track-vehicle lanes were significantly different from the controls (Table 79). Two of the three one-pass percent cover values were significantly different from the medium and heavy impact values, but otherwise all track vehicle values within a plot were statistically similar. Actually, percent cover in all but one of the medium and heavy impact lanes was essentially zero at this time (Table 80). All of the one-pass lanes recovered during the growing season, but recovery in the higher impact lanes was quite variable, ranging from 0-59 percent (Table 78). This suggests that at least some of these lanes will have a reduced percent cover for some time yet.

Vegetation Height

Small Cypress

During the pre- growing season sampling period, vegetation height was significantly different from controls in all treatments except a few

Table 76. Average percent cover in airboat-track vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	9	5	10	19	17	16
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	5	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	<1	0	0	10	5	5
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	3	5	<1
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 77 . Duncan's new multiple range tests of percent cover in individual airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	a	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	a	b	b	ab	b	b
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	a	b	b	b	b	b
Fast	-	-	-	-	-	-
n	15	18	15	15	15	15

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 78. Percent cover in airboat-track vehicle marl marsh and peat marsh test plots expressed as a percent of actual control values (percent cover).

Sampling Period	Airboat-Track Vehicle Marl Marsh Post- Growing Season Fall 1979			Peat Marsh Post-Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	19	17	16	91	88	71
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	68	56
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	R	R	R	68	42
Fast	R	R	R	R	68	56
TRACK VEHICLE						
One Pass	*	30	32	R	R	R
Medium Impact						
Slow	-	-	-	*	8	19
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	14	30	2	59	45	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from control (P=.05)

Table 79. Duncan's new multiple range tests of percent cover in individual peat marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post-Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	a	b	b	R	b	b
Fast	a	bcd	b	R	R	R
Heavy Impact						
Slow	b	d	b	R	b	b
Fast	b	cd	b	R	b	b
TRACK VEHICLE						
One Pass	a	bc	b	R	R	R
Medium Impact						
Slow	b	e	b	ab	d	b
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	b	e	b	b	c	b
Fast	-	-	-	-	-	-
n	30	30	30	15	24	24

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 80. Average percent cover in peat marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	69	79	63	91	88	71
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	77	60	30	R	60	40
Fast	87	40	20	R	R	R
Heavy Impact						
Slow	10	23	7	R	60	30
Fast	30	37	27	R	60	40
TRACK VEHICLE						
One Pass	73	50	5	R	R	R
Medium Impact						
Slow	7	0	1	63	7	13
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	53	40	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

of the one-pass lanes (Table 81). There was a general, but not consistent, tendency for height to decrease with increased level of impact, which was emphasized by 9 of the 15 heavy impact lanes not having any vegetation (Table 82).

In contrast to the pre- growing season results, height of vegetation during the post- growing season period showed plot to plot variation. In plots 1 and 2, height in most of the one-pass and medium impact lanes was not significantly different from the controls, while only the one-pass ATC lane was not in plot 3 (Table 81). In addition, three of the five heavy impact lanes in plot 2 were not different. There was a clear decrease in vegetation height with an increased level of impact at this time(Table 82).

Among the lanes that had not completely recovered by the end of the growing season, vegetation height had reached more than 30 percent of control values in the one-pass lanes, but only 50 percent or less in the heavy impact lanes (Table 83). This indicates that some lanes can be expected to have a reduced vegetation height for several years following even one-pass level impacts.

Marl Marsh (Wheeled-Vehicle)

Vegetation height in half of the one-pass lanes was not significantly different from the controls, but all other lanes were different during the pre- growing season sampling period (Table 84). Only a weak trend of decreasing height with increasing impact level was evident at this time (Table 85).

During the post- growing season sampling period, there was some plot to plot variation. Controls were not significantly different from any of the one-pass and medium impact lanes in plots 1 and 2, most plot 3 one-pass, and most plot 1 heavy impact lanes (Table 84). There was a general trend of decreasing height with increasing use (Table 85).

While vegetation height in most lanes had recovered after one growing season, a number of heavy impact lanes had shown little recovery (Table 83), and height of the vegetation will probably be reduced in these lanes for some time.

Sand Marsh

During the pre- growing season sampling period, vegetation height was not significantly different from controls in the plot 1 and 3 one-pass lanes and in the plot 2 ATC one-pass lanes (Table 86). Although different from the controls, heights in few of the other lanes were significantly different from one another. There was a general trend of decreasing height with increasing level of impact (Table 87).

Table 81. Duncan's new multiple range tests of vegetation height in individual small cypress test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	ab	a
ONE PASS						
ATC	ab	bc	ab	R	R	R
Light	bc	d	ab	R	abc	bc
Smooth	-	-	-	-	-	-
Chain	bcd	ab	cde	R	ab	cd
Tractor	cd	d	bc	b	abcd	de
Heavy	de	d	de	R	a	b
MEDIUM IMPACT						
ATC	de	bc	bcd	R	bcd	bc
Light	ef	d	-	a	cd	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	f	d	cde	b	bcd	f
Light	f	d	e	b	d	ef
Smooth	-	-	-	-	-	-
Chain	f	cd	e	b	bcd	f
Tractor	f	d	e	b	abcd	ef
Heavy	ef	d	e	b	d	f
n	45	45	42	30	42	39

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 82. Average vegetation height (cm) in small cypress test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	56	60	57	60	60	88
ONE PASS						
ATC	47	40	43	R	R	R
Light	40	7	43	R	53	67
Smooth	-	-	-	-	-	-
Chain	33	53	17	R	63	47
Tractor	27	7	33	20	33	37
Heavy	23	13	10	R	70	70
MEDIUM IMPACT						
ATC	23	40	30	R	23	60
Light	10	7	-	73	13	-
Smooth	-	-	-	-	-	-
Chain	-	-	-	-	-	-
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	7	7	13	30	20	3
Light	0	0	0	0	0	17
Smooth	-	-	-	-	-	-
Chain	0	20	0	0	23	7
Tractor	0	7	0	0	28	20
Heavy	10	0	0	23	0	13

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 83. Vegetation height in small cypress and wheeled-vehicle marl marsh test plots expressed as a percent of actual control values (cm).

Sampling Period	Small Cypress Post- Growing Season Fall 1979			Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	60	60	88	108	94	71
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	*	76	R	*	*
Smooth	-	-	-	-	-	-
Chain	R	*	53	R	*	*
Tractor	33	*	42	R	*	61
Heavy	R	*	80	R	-	*
MEDIUM IMPACT						
ATC	R	*	68	*	*	*
Light	*	22	-	*	*	38
Smooth	-	-	-	-	-	-
Chain	-	-	-	*	*	52
Tractor	-	-	-	*	-	-
Heavy	-	-	-	*	-	61
HEAVY IMPACT						
ATC	50	*	4	*	*	19
Light	0	0	19	*	7	9
Smooth	-	-	-	-	-	-
Chain	0	*	8	41	0	19
Tractor	0	*	23	22	7	38
Heavy	39	0	15	*	-	28

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from control (P=.05)

Table 84. Duncan's new multiple range tests of vegetation height in individual wheeled-vehicle marl, marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
ONE PASS						
ATC	R	ab	bc	R	R	R
Light	cd	bc	ab	R	a	abc
Smooth	-	-	-	-	-	-
Chain	bcd	bc	ab	R	a	abcd
Tractor	bc	ab	ab	R	a	bcde
Heavy	ab	-	bc	R	-	abc
MEDIUM IMPACT						
ATC	bcd	bcd	bc	a	a	ab
Light	cd	bcd	cd	a	a	defg
Smooth	-	-	-	-	-	-
Chain	cd	bcd	cd	ab	a	cdef
Tractor	d	-	-	ab	-	-
Heavy	bc	-	d	ab	-	cde
HEAVY IMPACT						
ATC	bcd	bcd	d	ab	a	fg
Light	cd	cd	d	ab	b	g
Smooth	-	-	-	-	-	-
Chain	cd	cd	d	bc	b	fg
Tractor	cd	d	cd	c	b	defg
Heavy	cd	-	cd	ab	-	efg
n	51	42	51	40	37	49

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 85. Average vegetation height (cm) in wheeled-vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	84	86	60	108	94	71
ONE PASS						
ATC	R	60	33	R	R	R
Light	43	50	47	R	90	57
Smooth	-	-	-	-	-	-
Chain	50	48	43	R	83	50
Tractor	60	63	50	R	87	43
Heavy	73	-	33	R	-	63
MEDIUM IMPACT						
ATC	50	47	33	93	100	70
Light	40	47	10	90	100	27
Smooth	-	-	-	-	-	-
Chain	43	27	17	87	70	37
Tractor	30	-	-	73	-	-
Heavy	63	-	3	87	-	44
HEAVY IMPACT						
ATC	53	40	0	83	100	13
Light	40	13	0	83	7	7
Smooth	-	-	-	-	-	-
Chain	40	13	0	44	0	13
Tractor	40	10	10	23	7	27
Heavy	40	-	13	80	-	20

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 86. Duncan's new multiple range tests of vegetation height in individual sand marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	ab	a	a	a
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	bcdef	ab	R	R	R
Smooth	R	b	abc	R	R	R
Chain	R	bc	**	R	R	R
Tractor	R	bcdef	a	R	R	R
Heavy	R	cdef	ab	R	R	R
MEDIUM IMPACT						
ATC	bc	bcdef	abc	R	R	R
Light	b	bcde	abcd	R	R	a
Smooth	c	bcdef	abcd	R	ab	a
Chain	c	bcd	f	R	bc	a
Tractor	b	cdef	def	R	ab	a
Heavy	bc	bcdef	cde	a	abc	a
HEAVY IMPACT						
ATC	c	cdef	abcd	R	ab	R
Light	c	cdef	bcde	a	ab	a
Smooth	c	def	def	a	a	a
Chain	c	f	def	a	abc	a
Tractor	c	cdef	ef	a	c	a
Heavy	c	ef	ef	a	a	a
n	45	60	57	27	39	39

R Vehicle treatment recovered and no longer visible

** Treatment lane destroyed by unauthorized vehicle use

Table 87. Average vegetation height (cm) in sand marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	44	140	53	76	134	63
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	57	57	R	R	R
Smooth	R	87	50	R	R	R
Chain	R	77	**	R	R	R
Tractor	R	47	60	R	R	R
Heavy	R	37	57	R	R	R
MEDIUM IMPACT						
ATC	13	52	50	R	R	R
Light	23	63	43	R	R	63
Smooth	7	50	43	R	127	57
Chain	7	70	13	R	87	63
Tractor	23	33	27	R	127	60
Heavy	13	50	33	77	17	47
HEAVY IMPACT						
ATC	0	38	40	R	123	R
Light	0	33	37	60	120	67
Smooth	0	27	30	57	137	70
Chain	0	13	30	70	117	87
Tractor	7	37	20	67	73	57
Heavy	3	23	20	53	147	50

R Vehicle treatment recovered and no longer visible
** Treatment lane destroyed by unauthorized vehicle use

Only two lanes were significantly different from controls during the post- growing season sampling period (Table 86). Many of the treatments, particularly the one-pass and ATC lanes, had recovered completely (Table 87).

Pine

In more than half of the one-pass treatments, pre- growing season vegetation heights were not significantly different from controls, while in most of the medium and heavy impact lanes they were different (Table 88). All lanes that were significantly different from the controls were not different from one another. Only plot 3 showed a trend of decreasing vegetation height with increasing impact level (Table 89).

At the end of the growing season, vegetation height in all one-pass, ATC, and plot 2 lanes had recovered, and only two of the plot 3 heavy impact lanes were still significantly different from controls (Table 88). Thus, on the basis of our data, virtually all ORV impacts on understory vegetation height in pine habitats could be expected to recover within one annual cycle.

Marl Marsh (Airboat-Track Vehicle)

In all airboat treatments, except the slow heavy impact lane which was significantly different from the controls (Table 90), recovery of vegetation height was complete by the pre- growing season sampling period, and all had recovered by the end of the first growing season (Table 91).

All of the track vehicle lanes had little or no vegetation during the pre- growing season, but vegetation height had recovered substanially by the end of the growing season (Table 91). Two of the post- growing season one-pass lanes were not significantly different from the controls (Table 90), and the remaining lanes had recovered to within about 30-40 percent of the control vegetation height (Table 92). This indicated that it may take at least two to three years for the vegetation in these lanes to attain heights similar to the controls.

Peat Marsh

During the pre- growing season sampling period, the airboat one-pass and most of the medium impact lanes were not significantly different from the controls (Table 93). After the growing season, all of the treatments were statistically similar to the controls, and the one-pass, plot 1, and medium impact-fast lanes had completely recovered (Table 94). Speed of the runs did not appear to affect vegetation height.

Two of the three pre- growing season one-pass track-vehicle lanes were not significantly different from the controls (Table 93), while the medium and heavy impact lanes were not only different from the controls, but were close to, or actually zero (Table 94). By the end of the growing season,

Table 88. Duncan's new multiple range tests of vegetation height in individual pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	***	a
ONE PASS						
ATC	bcd	abc	R	R	R	R
Light	abcd	abc	bc	R	R	R
Smooth	bcd	ab	ab	R	R	R
Chain	abc	bc	bc	R	R	R
Tractor	ab	abc	abc	R	R	R
Heavy	cd	c	bc	R	R	R
MEDIUM IMPACT						
ATC	bcd	bc	abc	R	R	R
Light	-	-	-	-	-	-
Smooth	bcd	c	bc	a	R	ab
Chain	cd	bc	bc	a	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	cd	c	bc	R	R	R
Light	-	-	-	-	-	-
Smooth	d	c	c	a	R	b
Chain	abcd	bc	bc	a	R	b
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
n	45	45	42	21	0	18

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 89. Average vegetation height (cm) in pine test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	70	70	86	69	***	70
ONE PASS						
ATC	37	50	R	R	R	R
Light	50	50	40	R	R	R
Smooth	33	60	63	R	R	R
Chain	57	33	43	R	R	R
Tractor	63	47	57	R	R	R
Heavy	23	23	47	R	R	R
MEDIUM IMPACT						
ATC	37	37	50	R	R	R
Light	-	-	-	-	-	-
Smooth	33	17	23	70	R	37
Chain	24	43	37	77	R	R
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-
HEAVY IMPACT						
ATC	27	27	33	R	R	R
Light	-	-	-	-	-	-
Smooth	17	27	13	50	R	23
Chain	50	30	15	70	R	27
Tractor	-	-	-	-	-	-
Heavy	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 90. Duncan's new multiple range tests of vegetation height in individual airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post-Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	b	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	b	c	b	ab	b	a
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	b	c	b	b	b	b
Fast	-	-	-	-	-	-
n	15	18	15	15	15	15

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 91. Average vegetation height (cm) in airboat-track vehicle marl marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	62	100	100	109	139	119
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	R	R
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	50	R	R	R	R
Fast	R	R	R	R	R	R
TRACK VEHICLE						
One Pass	13	0	0	80	57	100
Medium Impact						
Slow	-	-	-	-	-	-
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	43	47	33
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 92. Vegetation height in airboat-track vehicle marl marsh and peat marsh test plots expressed as a percent of actual control values (cm).

Sampling Period	Airboat-Track Vehicle Marl Marsh Post- Growing Season Fall 1979			Peat Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	109	139	119	261	178	161
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	R	R	R	R	*	*
Fast	R	R	R	R	R	R
Heavy Impact						
Slow	R	R	R	R	*	*
Fast	R	R	R	R	*	*
TRACK VEHICLE						
One Pass	*	41	*	R	R	R
Medium Impact						
Slow	-	-	-	*	30	41
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	40	34	28	*	6	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
* Treatment was not significantly different from control (P=.05)

Table 93. Duncan's new multiple range tests of vegetation height in individual peat marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	abc	a	a	a	a	a
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	abc	ab	a	R	a	a
Fast	a	b	ab	R	R	R
Heavy Impact						
Slow	cd	b	bc	R	a	a
Fast	bcd	b	bc	R	a	a
TRACK VEHICLE						
One Pass	ab	a	bc	R	R	R
Medium Impact						
Slow	d	c	c	a	b	b
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	d	c	c	a	b	b
Fast	-	-	-	-	-	-
	30	30	30	15	24	24

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 94. Average vegetation height (cm) in peat marsh test plots.

Sampling Period	Pre- Growing Season Winter 1979			Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	179	167	206	261	178	161
AIRBOAT						
One Pass	R	R	R	R	R	R
Medium Impact						
Slow	183	133	200	R	175	183
Fast	267	100	140	R	R	R
Heavy Impact						
Slow	83	100	67	R	175	200
Fast	100	101	83	R	175	200
TRACK VEHICLE						
One Pass	200	150	57	R	R	R
Medium Impact						
Slow	17	0	7	233	53	67
Fast	-	-	-	-	-	-
Heavy Impact						
Slow	0	0	0	167	10	0
Fast	-	-	-	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

heights in all one-pass lanes had recovered, while except for plot 1, the medium and heavy impact lanes were still significantly different from the controls (Table 93). There was a distinct decline in vegetation height with increasing level of impact at this time (Table 94). Recovery of the medium impact lanes appears to be possible within several years, but two of the three heavy impact lanes are recovering much more slowly (Table 92).

Standing Litter

We collected standing litter primarily to account for 1979 growing season production that had died prior to our October sampling period. In some cases where 1978 and earlier production had been only lightly impacted by our treatments, we found few differences in standing litter between control and lane samples. However, where the pre- treatment production had been severely damaged, we found little or no standing litter in the lanes because the 1979 production had not yet died. The absence of 1979 litter production also made it impossible to evaluate recovery rates of this component.

Small Cypress

Standing litter during October 1979 was not significantly different from control values in most plot 1 one-pass lanes and in all one-pass ATC lanes (Table 95). Most other lanes were not significantly different from one another, since 87 percent of them had no litter (Table 96).

Marl Marsh (Wheeled-Vehicle)

The one-pass ATC and plot 1 lanes were not significantly different from controls (Table 95). None of the remaining lanes were significantly different from one another, but most exhibited a general decline in litter standing crop associated with increased level of impact (Table 96). All of the one-pass and most of the medium impact lanes had at least some litter, but only 43 percent of the heavy impact lanes had any in our sample plots.

Sand Marsh

Litter standing crops in all one-pass and most plot 1 and ATC lanes had recovered or were not significantly different from controls (Table 97). Most of the other lanes were not significantly different from one another, and no real trends of decreased litter with increased level of impact were evident (Table 98).

Pine

Litter standing crops had recovered or were statistically similar to the controls in all but the plot 1 medium and heavy impact buggy lanes (Table 97), where they were only 10-40 percent of the controls (Table 98).

Table 95. Duncan's new multiple range tests of standing litter in individual small cypress and wheeled-vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Small Cypress Post- Growing Season Fall 1979			Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	a	a	a	a	a	a
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	b	b	R	b	b
Smooth	-	-	-	-	-	-
Chain	R	b	b	R	b	b
Tractor	b	b	b	R	b	b
Heavy	R	b	b	R	-	b
MEDIUM IMPACT						
ATC	R	b	b	b	b	b
Light	b	b	-	b	b	b
Smooth	-	-	-	-	-	-
Chain	-	-	-	b	b	b
Tractor	-	-	-	b	-	-
Heavy	-	-	-	b	-	b
HEAVY IMPACT						
ATC	b	b	b	b	b	b
Light	b	b	b	b	b	b
Smooth	-	-	-	-	-	-
Chain	b	b	b	b	b	b
Tractor	b	b	b	b	b	b
Heavy	b	b	b	b	-	b
n	29	42	39	40	37	49

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 96. Average standing litter (g/m^2) in small cypress and wheeled-vehicle marl marsh.

Sampling Period	Small Cypress Post- Growing Season Fall 1979			Wheeled-Vehicle Marl Marsh Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	19	143	164	177	235	171
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	0	69	R	71	38
Smooth	-	-	-	-	-	-
Chain	R	0	0	R	82	37
Tractor	0	0	0	R	19	33
Heavy	R	0	16	R	-	39
MEDIUM IMPACT						
ATC	R	0	17	59	51	39
Light	3	0	-	48	31	0
Smooth	-	-	-	-	-	-
Chain	-	-	-	28	38	5
Tractor	-	-	-	25	-	-
Heavy	-	-	-	77	-	11
HEAVY IMPACT						
ATC	0	0	0	59	65	4
Light	0	0	0	39	0	0
Smooth	-	-	-	-	-	-
Chain	0	0	0	12	0	0
Tractor	0	0	0	0	0	0
Heavy	0	0	0	66	-	0

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 97. Duncan's new multiple range tests of standing litter in individual sand marsh and pine test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Sand Marsh Post- Growing Season Fall 1979			Pine Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	b	a	a	a	***	a
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	R	R	R	R	R
Smooth	R	R	R	R	R	R
Chain	R	R	R	R	R	R
Tractor	R	R	R	R	R	R
Heavy	R	R	R	R	R	R
MEDIUM IMPACT						
ATC	R	R	R	R	R	R
Light	R	R	ab	-	-	-
Smooth	R	b	bc	b	R	a
Chain	R	b	bcd	b	R	R
Tractor	R	b	bcd	-	-	-
Heavy	a	b	bcd	-	-	-
HEAVY IMPACT						
ATC	R	b	R	R	R	R
Light	ab	b	bc	-	-	-
Smooth	b	b	cd	b	R	a
Chain	b	b	bcd	b	R	a
Tractor	b	b	d	-	-	-
Heavy	b	b	cd	-	-	-
n	27	39	39	21	0	17

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed
*** No treatments visible after fire

Table 98. Standing litter (g/m^2) in sand marsh and pine test plots.

Sampling Period	Sand Marsh Post- Growing Season Fall 1979			Pine Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3	1	2	3
CONTROL	25	474	160	132	***	106
ONE PASS						
ATC	R	R	R	R	R	R
Light	R	R	R	R	R	R
Smooth	R	R	R	R	R	R
Chain	R	R	R	R	R	R
Tractor	R	R	R	R	R	R
Heavy	R	R	R	R	R	R
MEDIUM IMPACT						
ATC	R	R	R	R	R	R
Light	R	R	113	-	-	-
Smooth	R	48	85	45	R	16
Chain	R	52	52	54	R	R
Tractor	R	107	59	-	-	-
Heavy	62	76	69	-	-	-
HEAVY IMPACT						
ATC	R	78	R	R	R	R
Light	29	109	92	-	-	-
Smooth	17	148	35	20	R	0
Chain	17	99	68	14	R	6
Tractor	12	4	11	-	-	-
Heavy	8	173	40	-	-	-

R Vehicle treatment recovered and no longer visible
- Treatment was not performed
*** No treatments visible after fire

Marl Marsh (Airboat-Track Vehicle)

Litter standing crops in all of the airboat lanes had recovered within one year after the treatments (Table 99).

Most of the track-vehicle lanes were still significantly different (Table 100), and had litter standing crops that were less than 40 percent of control values (Table 99).

Peat Marsh

Although control samples in peat marsh plots contained abundant litter, negligible amounts were encountered in test lanes one year after the treatments.

Taxonomic Composition

Small Cypress

All three small cypress replicate plots were dominated by three genera: *Panicum*, *Muhlenbergia*, and *Cladium* (Table 101). The taxonomic composition of one-pass test lanes and control samples was not different in winter 1979, and the differences in the medium and particularly the heavy impact lanes were due primarily to a reduction in frequency or the complete absence of some taxa from the test lanes.

Except for 12 of the 15 one-pass lanes in plot 1, which had recovered and were indistinguishable from adjacent undisturbed habitat, most of the fall 1979 test lane samples still exhibited a reduced frequency or absence of some taxa compared to the controls (Table 101). However, at this time, several new taxa had appeared or were more frequently encountered in the test lanes. *Utricularia* (a submerged aquatic) was more frequent in at least one lane in all plots and *Bacopa* (a prostrate form) and *Sagittaria*, both of which occupy moist sites, were more frequent in plot 3 lanes. The higher frequency of these taxa is probably due to the increased hydroperiod and incident sunlight in the more open and rutted test lanes. The primary genera still reduced in frequency or missing from the medium and heavy impact lanes were *Cladium* and *Muhlenbergia*.

Marl Marsh (Wheeled-Vehicle)

All of the wheeled-vehicle marl marsh study plots were dominated by *Muhlenbergia*, *Panicum*, and *Cladium* (Table 102). *Centella* and various unidentified forbs were also frequent in some plots, and *Dichromena* was common in the fall 1979 plot 1 control samples. The only differences in taxonomic composition of control and test lane samples in winter 1979 were that *Panicum* and *Muhlenbergia* exhibited a decline in frequency with increased impact level in plots 2 and 3. The fall 1979 samples showed a similar decline with increased impacts for *Cladium* and *Panicum* in plot 3 and for *Muhlenbergia* in both plots 2 and 3. We found the sedge *Dichromena*

Table 99. Average standing litter (g/m^2) in airboat-track vehicle marl marsh test plots.

Sampling Period	Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3
CONTROL	75	105	101
AIRBOAT			
One Pass	R	R	R
Medium Impact			
Slow	R	R	R
Fast	R	R	R
Heavy Impact			
Slow	R	R	R
Fast	R	R	R
TRACK VEHICLE			
One Pass	28	40	39
Medium Impact			
Slow	-	-	-
Fast	-	-	-
Heavy Impact			
Slow	6	21	0
Fast	-	-	-

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 100. Duncan's new multiple range tests of standing litter in individual airboat-track vehicle marl marsh test plots. Treatments with the same letter(s) within a column are not significantly different (P=.05).

Sampling Period	Post- Growing Season Fall 1979		
REPLICATE PLOTS	1	2	3
CONTROL	a	a	a
AIRBOAT			
One Pass	R	R	R
Medium Impact			
Slow	R	R	R
Fast	R	R	R
Heavy Impact			
Slow	R	R	R
Fast	R	R	R
TRACK VEHICLE			
One Pass	ab	b	b
Medium Impact			
Slow	-	-	-
Fast	-	-	-
Heavy Impact			
Slow	b	b	b
Fast	-	-	-
n	13	15	14

R Vehicle treatment recovered and no longer visible
\- Treatment was not performed

Table 101. Frequency (percent) of plant taxa encountered in understory samples from the individual small cypress test plots.

Taxon	Season*	1 One Pass	1 Medium	1 Heavy	1 Control	2 One Pass	2 Medium	2 Heavy	2 Control	3 One Pass	3 Medium	3 Heavy	3 Control
Sagittaria	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	25	-	7	-
Muhlenbergia	W	20	-	-	22	33	-	7	89	47	-	7	89
	F	-	67	7	56	92	33	20	78	83	100	-	100
Panicum	W	93	100	13	67	20	33	13	33	27	67	-	22
	F	100	100	27	100	-	17	20	55	75	-	20	44
Eleocharis	W	-	-	-	-	-	17	-	-	7	-	7	-
	F	-	-	-	-	-	-	-	-	-	-	-	-
Dichromena	W	7	-	-	-	-	-	-	-	-	-	-	-
	F	-	-	13	11	-	-	-	11	-	100	-	-
Cladium	W	53	17	7	33	27	17	13	44	20	-	-	67
	F	-	-	-	22	58	-	7	44	7	-	-	22
Crinum	W	-	33	-	-	-	-	-	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	-	-
Centella	W	-	17	-	11	-	-	-	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	-	-
Bacopa	W	-	-	-	-	-	-	-	11	13	-	-	-
	F	-	-	-	-	-		-	-	33	-	27	-
Utricularia	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	-	-	7	-	-	17	27	-	17	-	40	-
Pluchea	W	-	33	-	11	7	-	-	11	7	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Forbs	W	-	-	-	11	20	33	-	22	-	-	-	22
	F	-	-	-	-	-	-	-	-	-	-	-	-

Table 101. Continued.

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Number of Taxa	W	4	5	2	6	5	4	3	6	5	1	2	4
	F	1	2	4	4	2	3	4	4	6	2	4	3
Number of Samples Collected	W	15	6	15	9	15	6	15	9	15	3	15	9
	F	3	3	15	9	12	6	15	9	12	3	15	9
Number of Samples Collected From "Recovered" Lanes	W	0	0	0	-	0	0	0	-	0	0	0	-
	F	12	3	0	-	3	0	0	-	3	0	0	-

* W- Winter; F - Fall 1979

marl marsh test plots.

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Sagittaria	W	8	-	7	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	11
Muhlenbergia	W	100	100	100	100	100	78	25	100	47	8	-	67
	F	R	100	87	100	100	89	25	100	83	17	7	100
Panicum	W	100	87	60	100	42	44	25	44	87	50	7	100
	F	R	100	80	100	11	33	8	11	100	92	33	89
Eleocharis	W	-	-	-	11	-	-	-	-	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	8	-	-
Dichromena	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	R	20	-	100	11	67	17	-	-	17	-	-
Cladium	W	8	7	-	11	50	56	25	67	20	17	13	22
	F	R	80	87	56	44	89	8	89	67	33	13	56
Crinum	W	8	-	13	-	8	-	8	-	7	-	-	-
	F	R	17	-	-	-	-	17	-	-	8	7	-
Stillingia	W	-	13	7	-	-	-	-	11	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	-
Eryngium	W	-	-	13	-	-	-	-	-	-	8	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	-
Centella	W	83	33	53	67	25	-	8	11	-	-	-	-
	F	R	-	-	-	-	-	25	-	-	-	-	-
Hyptis	W	-	-	-	-	-	11	-	-	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	-
Bacopa	W	-	-	-	-	-	-	-	-	-	8	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	-

Table 102. Continued.

Taxon	Season*	1 One Pass	1 Medium	1 Heavy	1 Control	2 One Pass	2 Medium	2 Heavy	2 Control	3 One Pass	3 Medium	3 Heavy	3 Control
Utricularia	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	25	40	-
Diodia	W	-	-	7	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	-	-	-	-	-	-	-	-
Pluchea	W	-	-	-	-	8	-	-	11	-	-	-	22
	F	R	-	-	-	-	-	-	-	-	-	-	-
Unidentified Forbs	W	-	-	-	-	67	44	25	22	40	-	-	44
	F	R	-	20	-	-	22	25	-	-	-	-	-
Number of Taxa	W	6	5	8	5	7	5	6	7	5	5	2	5
	F	R	5	4	4	4	5	7	3	3	7	5	4
Number of Samples Collected	W	12	15	15	9	12	9	12	9	15	12	15	9
	F	R	15	15	9	9	9	12	9	12	12	15	9
Number of Samples not Collected from "Recovered" Lanes	W	3	0	0	-	0	0	0	-	0	0	0	-
	F	12	0	0	-	3	0	0	-	3	0	0	-

* W - Winter 1979; F - Fall 1979
R All vehicle treatments recovered and no longer visible

in a number of the plot 2 test lanes, while none occurred in the controls. In plot 3, Utricularia frequently dominated the heavy impact lanes and to a lesser extent the medium impact lanes, while not being recorded in control samples. The occurrence of Utricularia was probably due to the relatively deep and open ruts providing a more suitable habitat for it than did the densely-vegetated undisturbed marsh sites.

Sand Marsh

While most of the other habitats had replicate test plots with a more or less uniform taxonomic composition, the sand marsh plots were very different from one another (Table 103). Sand marsh plot 1 was dominated by submerged or emergent aquatic species of Panicum, Bacopa, Ludwigia, Pontederia, and Centella in the winter 1979 samples, and Panicum, Bacopa, and Sagittaria in fall 1979. The plot 2 vegetation was predominantly Spartina and Cladium, with Centella and Proserpinaca occurring occasionally. Plot 3 had mostly Muhlenbergia, Panicum, and Centella, with a smaller amount of Cladium during winter 1979. Centella was missing in the fall, while unidentified forbs joined the other three dominants at this time.

Other than an almost complete elimination of vegetation in the plot 1 heavy impact lanes, and slightly higher frequencies of some taxa in plot 2 lanes, there were no differences between the control and test lane samples in any of the plots in winter 1979 (Table 103). All of the one-pass lanes in plot 1 had recovered prior to the winter 1979 sampling period, and almost all of the other one-pass lanes and plot 1 medium impact lanes recovered during the growing season. Thus, we have to assume their taxonomic composition was essentially the same as that of the controls. During the fall sampling period, the only clear differences between lanes and control samples were that Dichromena was very common in plot 3 test lanes and there were fairly high frequencies of Pontederia and Cladium still present in the test lanes of plots 1 and 3, respectively, while none of these genera were recorded in control samples at these sites. However, since these differences in taxonomic composition were not replicated in more than one plot, it is impossible to ascribe them to ORV impacts with any degree of confidence.

Pine

Virtually all vegetation samples taken in pine test plots were dominated by grasses of the genera Aristida and Panicum (Table 104). Genera taken less frequently included Cladium and Centella, primarily in plot 3, and a variety of small unidentified forbs in plot 1. Taxonomic composition in test lane samples was generally similar to control samples in each test plot on both sampling dates. Actually, only four of the original 35 lanes had not recovered by the end of the first growing season, and thus most could not even be distinguished from the surrounding undisturbed habitat during the fall sampling period. The only differences of any interest were the sporadic slightly higher frequencies of Cladium, Centella, and Hyptis in lanes of some or all plots, and the decline in frequency of Panicum and Aristida with increasing level of impact in plot 3.

Table 103. Frequency (percent) of plant taxa encountered in understory samples from the individual sand marsh test plots.

Taxon	Season*	1 One Pass	1 Medium	1 Heavy	1 Control	2 One Pass	2 Medium	2 Heavy	2 Control	3 One Pass	3 Medium	3 Heavy	3 Control
Sagittaria	W	R	6	-	-	-	-	-	-	-	-	-	-
	F	R	33	27	67	R	-	-	-	R	-	-	-
Aristida	W	R	-	-	-	7	-	11	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Muhlenbergia	W	R	-	-	-	-	-	-	-	100	100	67	100
	F	R	-	-	-	R	-	-	-	R	80	60	56
Spartina	W	R	-	-	-	93	89	50	100	-	-	-	-
	F	R	-	-	-	R	100	89	100	R	-	-	-
Panicum	W	R	78	-	100	13	17	17	22	100	83	83	89
	F	R	100	60	100	R	17	-	-	R	100	100	100
Cyperus	W	R	-	-	-	-	-	-	-	-	-	-	-
	F	R	67	7	11	R	8	22	11	R	-	-	-
Dichromena	W	R	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	87	93	-
Cladium	W	R	-	-	-	93	50	50	78	25	28	22	44
	F	R	-	-	-	R	50	50	89	R	33	13	-
Eriocaulon	W	R	-	-	-	-	-	-	22	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Pontedaria	W	R	6	-	33	-	-	-	-	-	-	-	-
	F	R	-	40	-	R	-	-	-	R	-	-	-
Ludwigia	W	R	67	17	78	7	11	-	-	-	-	-	-
	F	R	-	7	-	R	-	-	-	R	-	-	-

Table 103. Continued.

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Proserpinaca	W	R	-	-	-	60	11	28	44	-	-	-	-
	F	R	-	-	-	R	17	17	44	R	-	-	-
Centella	W	R	39	-	56	67	61	78	33	100	83	94	100
	F	R	-	-	-	R	-	6	11	R	-	-	-
Hydrocotyl	W	R	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	11	R	-	-	-	R	-	-	-
Nymphoides	W	R	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	13	-	R	-	-	-	R	-	-	-
Ipomea	W	R	-	-	-	7	-	-	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Lippia	W	R	-	-	-	7	-	-	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Hyptis	W	R	-	-	-	13	22	17	11	25	-	6	11
	F	R	-	-	-	R	-	-	-	R	-	-	-
Bacopa	W	R	78	6	100	7	-	6	-	-	-	-	-
	F	R	100	73	100	R	-	-	-	R	-	-	-
Utricularia	W	R	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	7	-	R	-	-	-	R	-	-	-
Pluchea	W	R	-	-	-	47	22	28	33	-	-	17	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Mikania	W	R	-	-	-	7	-	-	-	-	-	-	-
	F	R	-	-	11	R	-	-	-	R	-	-	-

Table 103. Continued.

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Eupatorium	W	R	-	-	-	-	-	6	22	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Unidentified Forbs	W	R	-	-	-	-	-	-	-	-	33	-	-
	F	R	-	-	-	R	-	-	-	R	27	20	33
Number of Taxa	W	R	6	2	5	13	8	10	9	5	5	6	5
	F	R	4	8	6	R	5	5	5	R	5	5	4
Number of Samples Collected	W	R	18	18	9	15	18	18	9	12	18	18	9
	F	R	3	15	9	R	12	18	9	R	15	15	9
Number of Samples not Collected From "Recovered" Lanes	W	18	0	0	-	3	0	0	-	3	0	0	-
	F	18	15	3	-	15	6	0	-	12	3	3	-

* W - Winter 1979; F - Fall 1979
R All vehicle treatments recovered and no longer visible

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Pteridium	W	-	-	11	-	-	-	-	-	-	-	-	-
	F	R	-	-	22	R	R	R	R	R	-	-	-
Zizaniopsis	W	-	11	-	11	-	-	-	-	-	-	-	-
	F	R	-	17	-	R	R	R	R	R	-	-	-
Aristida	W	78	56	67	78	94	67	100	100	80	89	22	89
	F	R	100	86	100	R	R	R	R	R	67	17	100
Spartina	W	6	-	11	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Panicum	W	83	56	78	89	50	56	67	56	67	33	-	67
	F	R	67	83	67	R	R	R	R	R	-	33	33
Dichromena	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	33	11
Cladium	W	6	-	-	11	-	-	11	-	33	33	22	11
	F	R	-	-	-	R	R	R	R	R	33	17	22
Rubus	W	-	-	11	-	-	11	-	-	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Stillingia	W	-	-	-	-	6	-	-	-	7	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Proserpinaca	W	-	-	-	-	-	-	-	-	7	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Eryngium	W	-	-	-	-	6	-	-	-	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-

Table 104. Continued.

Taxon	Season*	1 One Pass	1 Medium	1 Heavy	1 Control	2 One Pass	2 Medium	2 Heavy	2 Control	3 One Pass	3 Medium	3 Heavy	3 Control
Centella	W	-	-	-	-	17	22	33	-	7	44	33	22
	F	R	50	17	11	R	R	R	R	R	33	-	22
Lippia	W	-	-	-	-	-	-	-	11	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Hyptis	W	-	-	-	-	17	11	11	-	7	-	-	-
	F	R	-	-	-	R	R	R	R	R	-	-	-
Bacopa	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	R	R	R	R	33	-	-
Pluchea	W	-	11	-	-	6	33	-	11	20	-	11	-
	F	R	-	-	-	R	R	R	R	R	-	-	11
Unidentified Forbs	W	28	67	44	33	6	-	-	-	60	-	-	-
	F	R	50	33	44	R	R	R	R	R	-	-	22
Number of Taxa	W	5	5	6	5	8	6	5	4	9	4	4	4
	F	R	4	5	5	R	R	R	R	R	4	4	7
Number of Samples Collected	W	18	9	9	9	18	9	9	9	15	9	9	9
	F	R	6	6	9	R	R	R	R	R	3	6	9
Number of Samples not Collected from "Recovered" Lanes	W	0	0	0	-	0	0	0	-	3	0	0	-
	F	18	3	3	-	18	9	9	-	18	6	3	-

* W - Winter 1979; F - Fall 1979
R All vehicle treatments recovered and no longer visible

Marl Marsh (Airboat-Track Vehicle)

All of the test plots were dominated by Cladium, Bacopa, Panicum, and Eleocharis during 1979 (Table 105). There was very little data available for meaningful comparisons of taxonomic composition between ORV lanes and controls at these sites, since airboat treatments generally recovered completely and were not sampled, and track-vehicle test lanes had little or no vegetation during the winter 1979 sampling period. By fall 1979, a number of taxa had become partially reestablished in some of the track-vehicle lanes, particularly in the one-pass treatments. Eleocharis exhibited by far the greatest recovery.

Peat Marsh

Cladium dominated all of the peat marsh plots during both sampling periods (Table 106). Other genera that were significant in one or more plots were: Pontederia and Typha in plot 1 during both sampling periods, and ferns in plot 1 and Pontederia in plot 2 during the fall 1979 sampling period.

Except that Typha was missing from the plot 1 heavy impact lanes, the composition of the airboat test lanes was very similar to the control samples in winter 1979 (Table 106). The frequent occurrence of Pontederia and Panicum in the plot 2 control samples and their absence from the airboat test lanes was the only major difference in composition we found during the fall sampling period.

The complete, or almost complete, absence of taxa from the track-vehicle medium and heavy impact lanes was the most obvious effect of these vehicles on taxonomic composition (Table 107). While the number of taxa found during winter 1979 was reduced in the one-pass lanes of two of the three peat marsh plots, the frequency of the remaining taxa was not affected. All of the one-pass lanes had recovered by the end of the first growing season. Among the fall 1979 samples, only Typha in plot 1 and Utricularia in plot 2 seem to have either survived or been benefitted by, respectively, the two higher impact level track-vehicle treatments in peat marshes. Because of its dominance in the controls, Cladium was the most drastically affected taxon.

Shrub and Tree Impacts

In general, ORV damage to shrubs and small trees is directly related to plant size and number of vehicle passes. Vehicle characteristics within the range of types we tested had no obvious effect on severity of damage.

In small cypress plots, the only woody plants struck by test vehicles were cypress, Taxodium distichum, in the 0.5-3 m height range. During our February evaluation, damage resulting from a single pass was minor to trees less than 1 m tall, but severe for larger trees (Table 108). Heavy impact levels further increased the severity of damage, and also increased mortality (Table 109). Trees in the middle of the test lanes, which passed under the vehicle frame but were not run over by the wheels,

Table 105. Frequency (percent) of plant taxa encountered in understory samples from the individual airboat-track vehicle marl marsh test plots. Frequencies are for track-vehicle lanes only, unless otherwise indicated.

		1				2				3			
Taxon	Season*	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Panicum	W	-	-	-	44	-	-	(33**)	44	-	-	-	44
	F	-	-	33	22	-	-	-	-	-	-	-	-
Eleocharis	W	33	-	-	89	-	-	(67**)	11	-	-	-	-
	F	100	-	100	100	67	-	100	67	100	-	33	100
Cladium	W	-	-	-	78	-	-	(67**)	89	-	-	-	100
	F	-	-	-	56	33	-	-	78	100	-	-	100
Crinum	W	-	-	-	-	-	-	-	11	-	-	-	22
	F	-	-	-	-	-	-	-	-	-	-	-	-
Bacopa	W	-	-	-	22	-	-	(100**)	-	-	-	-	56
	F	100	-	-	67	-	-	33	22	33	-	-	-
Utricularia	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	-	-	-	-	100	-	-	22	-	-	-	-
Number of Taxa	W	1	-	0	4	0	-	0(4**)	4	0	-	0	4
	F	2	-	2	4	3	-	2	4	3	-	1	2
Number of Samples Collected	W	3	-	3	9	3	-	3(3**)	9	3	-	3	9
	F	3	-	3	9	3	-	3	9	3	-	3	9
Number of Samples not Collected from "Recovered" Samples	W	0	-	0	-	0	-	0(0**)	-	0	-	0	-
	F	0	-	0	-	0	-	0	-	0	-	0	-

* W - Winter 1979; F - Fall 1979
** Airboat - heavy impact, slow speed

Table 106. Frequency (percent) of plant taxa encountered in airboat lane samples from the individual peat marsh test plots.

		1						2						3					
Taxon	Season*	One Pass	Medium		Heavy		Control	One Pass	Medium		Heavy		Control	One Pass	Medium		Heavy		Control
			Sl**	Fa**	Sl	Fa			Sl	Fa	Sl	Fa			Sl	Fa	Sl	Fa	
Ferns	W	R	-	-	-	-	11	R	-	-	-	-	-	R	-	-	-	-	-
	F	R	R	R	R	R	56	R	-	R	-	-	-	R	-	R	-	-	-
Typha	W	R	67	67	-	-	56	R	-	-	-	-	-	R	-	-	-	-	-
	F	R	R	R	R	R	56	R	-	R	-	-	-	R	-	R	-	-	-
Panicum	W	R	-	-	-	-	-	R	33	-	-	-	11	R	-	-	-	-	-
	F	R	R	R	R	R	-	R	-	R	-	-	33	R	-	R	-	-	-
Eleocharis	W	R	33	-	-	-	22	R	33	-	-	-	11	R	-	-	-	-	-
	F	R	R	R	R	R	11	R	-	R	-	-	-	R	-	R	-	-	-
Cladium	W	R	67	67	67	67	56	R	100	100	100	100	100	R	100	100	67	67	100
	F	R	R	R	R	R	100	R	100	R	100	100	100	R	100	R	100	100	89
Pontederia	W	R	33	-	-	33	44	R	-	-	-	-	11	R	-	-	-	-	-
	F	R	R	R	R	R	22	R	-	R	-	-	78	R	-	R	-	-	-
Crinum	W	R	-	-	-	33	11	R	-	-	-	-	-	R	-	-	-	-	-
	F	R	R	R	R	R	11	R	-	R	-	-	-	R	-	R	-	-	-
Polygonum	W	R	-	-	-	-	11	R	-	-	-	-	-	R	-	-	-	-	-
	F	R	R	R	R	R	-	R	-	R	-	100	-	R	-	R	-	-	-
Ludwigia	W	R	-	-	-	-	-	R	-	-	-	-	11	R	-	-	33	-	-
	F	R	R	R	R	R	-	R	-	R	-	-	-	R	-	R	-	-	-
Proserpinaca	W	R	-	-	-	-	-	R	33	33	-	-	22	R	-	-	-	-	-
	F	R	R	R	R	R	-	R	-	R	-	-	-	R	-	R	-	-	-
Bacopa	W	R	67	-	-	-	-	R	-	-	-	-	-	R	-	-	-	-	-
	F	R	R	R	R	R	-	R	-	R	-	-	-	R	-	R	-	-	-

Table 106. Continued.

Taxon	Season*	1						2						3					
		One Pass	Medium		Heavy		Control	One Pass	Medium		Heavy		Control	One Pass	Medium		Heavy		Control
			Sl**	Fa**	Sl	Fa			Sl	Fa	Sl	Fa			Sl	Fa	Sl	Fa	
Number of Taxa	W	R	5	2	1	3	7	R	4	2	1	1	6	R	1	1	2	1	1
	F	R	R	R	R	R	6	R	1	R	1	2	3	R	1	R	1	1	1
Number of Samples Collected	W	R	3	3	3	3	9	R	3	3	3	3	9	R	3	3	3	3	9
	F	R	R	R	R	R	9	R	3	R	3	3	9	R	3	R	3	3	9
Number of Samples not Collected from "Recovered" Lanes	W	3	0	0	0	0	-	3	0	0	0	0	-	3	0	0	0	0	-
	F	3	3	3	3	3	-	3	0	3	0	0	-	3	0	3	0	0	-

* W - Winter 1979; F - Fall 1979
R All vehicle treatments recovered and no longer visible
** Sl - Slow speed; Fa - Fast speed

Table 107. Frequency (percent) of plant taxa encountered in track-vehicle lane samples from the individual peat marsh test plots.

		1				2				3			
Taxon	Season*	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Ferns	W	-	-	-	11	-	-	-	-	-	-	-	-
	F	R	33	-	56	R	-	-	-	R	-	-	-
Typha	W	100	-	-	56	-	-	-	-	-	-	-	-
	F	R	67	67	56	R	-	-	-	R	-	-	-
Panicum	W	-	-	-	-	-	-	-	11	-	-	-	-
	F	R	-	-	-	R	-	-	33	R	-	-	-
Eleocharis	W	33	33	-	22	-	-	-	11	-	-	-	-
	F	R	-	-	11	R	-	-	-	R	-	-	-
Cladium	W	33	-	-	56	67	-	-	100	100	-	-	100
	F	R	33	-	100	R	33	-	100	R	33	-	89
Pontederia	W	-	33	-	44	33	-	-	11	33	-	-	-
	F	R	-	-	22	R	-	-	78	R	-	-	-
Crinum	W	-	-	-	11	-	-	-	-	33	33	-	-
	F	R	-	-	11	R	-	-	-	R	-	-	-
Polygonum	W	-	-	-	11	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Ludwigia	W	-	33	-	-	-	-	-	11	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Proserpinaca	W	-	-	-	-	-	-	-	22	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-
Bacopa	W	-	-	-	-	33	-	-	-	-	-	-	-
	F	R	-	-	-	R	-	-	-	R	-	-	-

Table 107. Continued.

Taxon	Season*	1				2				3			
		One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control	One Pass	Medium	Heavy	Control
Utricularia	W	-	-	-	-	-	-	-	-	-	-	-	-
	F	R	-	-	-	R	33	100	-	R	-	-	-
Number of Taxa	W	3	3	0	7	3	0	0	6	3	1	0	1
	F	R	3	1	6	R	2	1	3	R	1	0	1
Number of Samples Collected	W	3	3	3	9	3	3	3	9	3	3	3	9
	F	R	3	3	9	R	3	3	9	R	3	3	9
Number of Samples not Collected from "Recovered" Lanes	W	0	0	0	-	0	0	0	-	0	0	0	-
	F	3	0	0	-	3	0	0	-	3	0	0	-

* W - Winter 1979; F - Fall 1979
R All vehicle treatments recovered and no longer visible

Table 108. Average degree of impact on small trees and shrubs struck during off-road vehicle treatments. Impacts were evaluated in February 1979 on a scale of 0 (no impact) to 3 (mortality).

Plant Height(m)	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
Pine									
In Tracks									
One Pass	1.0*	1.2*	-	2.0	-	-	2.0	-	-
Medium Impact	2.2*	2.2*	-	-	-	-	-	-	-
Heavy Impact	1.9*	2.8*	-	-	-	3.0	-	-	-
Between Tracks									
One Pass	-	-	2.0	0	-	0	2.5	2.0	2.0
Medium Impact	-	-	-	-	-	-	-	-	-
Heavy Impact	-	-	3.0	1.0	-	-	-	-	-
Cypress									
In Tracks									
One Pass	0.8	0.6	2.0	1.5	2.0	-	-	-	-
Heavy Impact	1.2	1.8	1.0	2.2	-	3.0	-	-	-
Between Tracks									
One Pass	-	0	0	0.5	-	-	-	-	-
Heavy Impact	0	0.3	0	0.8	1.0	-	-	-	-
Wax Myrtle									
In Tracks									
One Pass	1.0	1.4	-	1.7	-	1.0	-	-	-
Medium Impact	2.0	2.0	-	2.3	-	-	-	-	-
Heavy Impact	3.0	2.5	-	-	-	-	-	-	-
Between Tracks									
One Pass	1.0	0	-	-	-	-	-	-	-
Medium Impact	2.0	2.0	-	-	-	-	-	-	-
Heavy Impact	-	-	-	-	-	-	-	-	-
Willow									
Track Vehicle									
One Pass	-	1.0	1.0	1.0	-	-	-	-	-
Medium Impact	-	-	-	-	-	-	-	-	-
Heavy Impact	-	-	-	2.0	-	2.0	-	-	-
Airboat									
Medium Slow	-	1.0	1.0	1.0	-	-	-	-	-
Medium Fast	-	-	2.0	2.0	-	1.7	-	-	-

* 0.5 values are actually for the range 0-0.1 m, and 1.0 m values are for the range 0.1-1.0 m

Table 109. Percent mortality of small trees and shrubs struck by test vehicles during the fall 1978 treatments. Numbers in parentheses are the sample sizes.

Position in Lane	Cypress	Pine	Palmetto		Myrtle		Willow	
			Small	Large	Pine Plots	Sand Marsh	Airboat	Track
February 1979								
In Tire Track								
One Pass	6 (49)	3 (131)	0 (9)	4 (67)	0 (24)	22 (18)	-	0(8)
Medium Impact	-	32 (104)	0 (5)	28 (33)	18 (11)	32 (19)	0 (11)*	-
Heavy Impact	20 (40)	77 (125)	13 (31)	20 (35)	70 (24)	33 (3)	0 (8)**	0(3)
Between Tire Tracks								
One Pass	3 (60)	10 (10)	-	-	-	0 (2)	-	-
Medium Impact	-	-	-	-	-	0 (6)	-	-
Heavy Impact	8 (48)	50 (4)	-	-	-	-	-	-
October 1979								
In Tire Track								
One Pass	0 (24)	-	-	-	-	-	-	-
Medium Impact	-	20 (17)	0 (5)	3 (33)	6 (18)	0 (14)	17 (6)*	11 (9)
Heavy Impact	3 (39)	54 (11)	0 (11)	6 (53)	31 (16)	0 (15)	43 (7)**	43 (7)
Between Tire Tracks								
One Pass	0 (49)	-	-	-	-	0 (7)	-	-
Medium Impact	-	0 (10)	0 (4)	-	-	0 (6)	-	-
Heavy Impact	0 (52)	23 (13)	0 (5)	-	-	-	-	-

* Medium slow treatment
** Medium fast treatment

showed little or no damage in any size class (Table 108) and a lower mortality (Table 109). Damage to cypress (Table 110) and percent mortality (Table 109), both in and between tracks, tended to be lower in October. A major factor was that only one dead cypress was observed at this time. The rest of the trees which we listed as dead in February had root-sprouted during the growing season.

A variety of woody plant genera were found to be affected in our pineland treatment plots during February 1979, but the majority were pine, _Pinus elliottii_, 1 m or less tall. We also evaluated saw palmetto, _Serenoa repens_, in two size groups; those without visible trunks were listed as "small", while those with trunks were "large". All other shrubs, unless otherwise indicated, were less than 1 m tall. Pine showed the same trends as were observed in the small cypress habitat; that is, percent mortality and degree of damage was a factor of plant size, impact level, and whether the plant was hit by the wheels or vehicle frame (Tables 108 and 109). At heavy impact levels, damage was more severe to pine seedlings than to cypress. However, comparing the pine and cypress data is somewhat misleading, since vehicles made many more passes in pinelands to achieve the heavy impact level. Percent mortality of saw palmetto was also a function of plant size and level of impact (Table 109).

Complete recovery of the majority of pineland test lanes, particularly all of the one-pass lanes, greatly reduced the October woody plant sample size. However, each of the dominant taxa in the remaining medium and heavy impact lanes still showed essentially the same general trends (Tables 109 and 110). Pines 2 m or less tall exhibited little damage, while larger trees exhibited damage comparable to that observed in February. Percent mortality of pines and saw palmetto at all impact levels, both in and between tracks, was lower in October (Table 109). Resprouting was not a factor here, but it more likely resulted from the smaller sample size and disappearance of small dead individuals into the understory litter.

During February, wax myrtle, _Myrica cerifera_, and willow, _Salix caroliniana_, were also more severely damaged by heavier impact levels, but in contrast to cypress and pine, there was no consistent trend of increasing damage associated with increasing plant size (Table 108). While wax myrtle seemed particularly sensitive to ORV impacts, some being killed by only one pass, at least initially, willows appeared to be more resistent since none were killed by any of the airboat or track-vehicle treatments (Table 109). Airboat impacts on willow were greater at higher speeds.

Wax myrtle generally exhibited much less damage in October (Table 110) as well as a lower percent mortality due to root sprouting by plants that appeared to be dead in February (Table 109). Willow was the only species exhibiting more damage and a higher percent mortality in October. All size classes in the airboat-track vehicle medium and heavy impact lanes were affected, although damage was generally greater for larger size classes (Table 110). While no dead willows were observed in February, substantial numbers were recorded in October, when percent mortality was found to increase with increasing track-vehicle impact level and airboat speed (Table 109).

Table 110. Average degree of impact on small trees and shrubs struck during off-road vehicle treatments. Impacts were evaluated in October 1979 on a scale of 0 (no impact) to 3 (mortality).

Plant Height(m)	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
Pine									
In Tracks									
One Pass	-	-	-	-	-	-	-	-	-
Medium Impact	0*	1.2*	-	-	-	-	-	-	-
Heavy Impact	-	2.0*	-	1.5	-	3.0	-	-	-
Between Tracks									
One Pass	-	-	-	-	-	-	-	-	-
Medium Impact	0*	0*	-	-	-	-	-	-	-
Heavy Impact	-	-	-	0	-	3.0	-	-	-
Cypress									
In Tracks									
One Pass	0.1	1.0	-	1.1	2.0	2.0	-	-	-
Heavy Impact	0.4	1.0	0	1.3	-	2.0	-	-	-
Between Tracks									
One Pass	-	0	0	0.2	-	-	-	-	-
Heavy Impact	-	0.4	0	0.4	-	1.0	-	-	-
Wax Myrtle									
In Tracks									
One Pass	-	-	-	-	-	-	-	-	-
Medium Impact	0	0.8	-	1.4	-	-	-	-	-
Heavy Impact	2.0	0.1	-	0	-	-	-	-	-
Between Tracks									
One Pass	-	-	-	-	-	-	-	-	-
Medium Impact	-	1.0	-	1.2	-	-	-	-	-
Heavy Impact	-	0	0	0.5	-	-	-	-	-
Willow									
Track Vehicle									
One Pass	-	-	-	-	-	-	-	-	-
Medium Impact	-	2.0	2.1	-	-	-	-	-	-
Heavy Impact	-	-	-	2.3	-	3.0	-	-	-
Airboat									
Medium Slow	-	2.0	2.3	2.0	-	-	-	-	-
Medium Fast	-	-	2.5	2.3	-	2.5	-	-	-

* 0.5 values are actually for the range 0-0.1 m, and 1.0 m values are for the range 0.1-1.0 m

DISCUSSION

The previous analyses provide abundant detail on the initial impacts and first year's recovery of the ORV test lanes, which is valuable in documenting the results of our work. However, it is very difficult to interpret these data because of the complex of interacting factors that it was necessary to discuss in order to account for the variability we encountered. As a result, the following synthesis will address a number of simpler and more specific questions of interest. What is the relative sensitivity of the various habitats to ORV impacts? Which ORVs cause the most or least impact? How much recovery occurs within one year?

Impacts

In order to summarize our results in terms of (1) the relative ability of different types of ORVs to create impacts and (2) relative habitat sensitivity, we developed a four point rating system in which we assigned a 1 to relatively low-impacting vehicles or to a relatively insensitive habitat and a 4 to the opposite end of each spectrum. This rating system was applied to each parameter we measured, on the basis of our detailed data analysis. Most parameters exhibited approximately the same relationships between vehicle types or habitats, although some tended to sort out more differences than others (Table 111). Only standing litter was similarly impacted by all vehicles. This was due to the fact that most litter standing at the time the treatments were applied was knocked down along with much of the living vegetation, and little of the 1979 production had died when we sampled in October.

Habitat Sensitivity

The small cypress and airboat-track vehicle marl and peat marshes proved to be the habitats most sensitive to ORV impacts. The wheeled-vehicle marl marshes were only slightly less sensitive. The pine habitat was least sensitive and the sand marsh only slightly more so. The degree of these habitats' sensitivity was closely related to their hydrologic characteristics, where the most easily impacted sites were the wettest.

Not only were the wettest habitats most sensitive, but within each habitat type those sites with water above or near the ground surface at the time when our treatments occurred were also more sensitive to ORV disturbance than were sites with lower water levels. While substrate was obviously a major factor associated with degree of impact, the existence of the relatively easily disturbed marl and peat soils is ultimately a product of extended inundation, and even these soil types are less sensitive to ORV disturbance during periods when they are dry. The major significance of water levels and/or soil moisture content to degree of impact has also been pointed out in all of the other studies we have seen that dealt with ORV use in wetland habitats (Brodhead and Godfrey 1979, Schemnitz and Schortemeyer 1974, Rula et al. 1963).

Table 111. Relative sensitivity of habitats to impacts and relative impacting ability of vehicles. A 1 equals low sensitivity or impacting ability and a 4 equals high sensitivity or impacting ability. A 0 indicates no impacts occurred.

	Habitat						Vehicle							
								Swamp Buggy						
	Small Cypress	Marl Marsh	Sand Marsh	Pine	Marl* Marsh	Peat* Marsh	ATC	Light	Heavy	Chain	Tractor	Smooth	Airboat	Track Vehicle
Visual Impacts	3	3	2	2	4	4	2	3	3	3	3	3	1	4
Impact/Pass	4	3	1	1	4	3	2	3	4	4	4	4	1	4
Soil Impacts														
Rut Depth	4	3	2	1	4	4	1	4	3	3	4	3	0	4
Ridge Height	4	3	2	1	0	0	1	2	2	3	3	2	0	0
Soil Compactness	2	1	0	0	4	4	1	2	2	2	3	2	0	4
Subtotal	10	7	4	2	8	8	3	8	7	8	10	7	0	8
Vegetation Impacts														
Biomass	4	3	2	1	4	4	1	2	3	3	4	3	1	4
Percent Cover	4	3	2	1	4	4	2	3	3	3	3	3	1	4
Height	4	3	2	1	4	4	2	3	3	3	3	3	1	4
Standing Litter	4	3	2	1	4	4	3	4	4	4	4	4	4	4
Taxonomic Composition	4	3	2	2	4	4	3	3	3	3	3	3	1	4
Subtotal	20	15	10	6	20	20	11	15	16	16	17	16	8	20
Total	37	28	17	11	36	35	18	29	30	30	34	30	10	36

* Based on track vehicle impacts, since airboat impacts were always similar or less significant

A more quantitative method for analyzing the degree to which the different wheeled-vehicle habitats were susceptible to damage involved summing the numbers of significant differences between controls and the combined plot means for each habitat-vehicle combination individually for our rut depth, ridge height, and visual rating data (Table 112). All three parameters exhibited trends which were essentially identical to the patterns described on the basis of our rating system (Table 111). The small cypress plots, with their wet almost bare marl substrates, were typically more damaged than any other wheeled-vehicle habitat, while the marl marshes, even with their dense ground cover, were only slightly less affected. There were relatively minor differences in degree of damage in the sand marsh and pine habitats, which were much less affected than the two marl substrate habitats, particularly at the lower impact levels. These data indicate that once significant damage has been done to a habitat by a particular vehicle type, it will remain significant for at least one year. Significant damage resulting from one-pass and medium impact tests were uncommon in terms of rut depth and ridge height, but were common in terms of visual ratings. Most of the heavy impact tests produced significant damage in terms of all three measures.

Vehicle Impacting Ability

Our rating system indicated that the track vehicle caused the most severe impacts of all ORVs tested, partially because it is the only vehicle type normally capable of operation throughout the year in the most easily impacted habitats. The swamp buggies produced only slightly less severe impacts, and those produced by the tractor buggy in the marl substrate habitats were actually almost as severe as those made by the track vehicle. The relatively more severe impacts caused by the tractor buggy compared to the other buggies seemed related to depth of its tread, which tended to chop up understory vegetation and its root mat, thereby making the underlying soil more vulnerable to displacement during subsequent passes. Airboats were by far the least impacting, primarily because they did not affect substrates. The relative lack of soil disturbance was also the main factor minimizing impacts from ATCs, which of the wheeled vehicles, consistently affected all habitats least.

These data indicate that no ORV can be considered non-impacting in any BICY habitat. (Of course, the same could be said for hikers or any activity that impinges on vegetation or substrates.) Even airboats can alter the taxonomic composition of trail vegetation and eliminate the standing litter which serves as fuel for fires. And, they are the noisiest ORVs. Also, there really seems to be little that would be gained by regulating any particular characteristics of the buggy types presently used in the preserve, although obviously the larger the buggy (or track vehicle) the larger the trees and shrubs it can push down, climb over, or plow through.

Table 112. The percentage of tested wheeled vehicle types that resulted in environmental conditions significantly different from the controls.

	Number of Vehicles Tested	Impact Parameters						
		Rut Depth			Ridge Height		Visual	
		1978	1979		1979		1978	1979
		Fall	Winter	Fall	Winter	Fall	Fall	Fall
One Pass								
Cypress	5	20	40	40	40	40	100	80
Marl Marsh	5	0	0	20	20	20	100	80
Sand Marsh	6	0	0	0	0	0	100	0
Pine	6	0	0	0	0	0	100	0
Medium Impact								
Cypress	2	0	0	0	0	0	100	100
Marl Marsh	5	0	0	40	20	20	100	100
Sand Marsh	6	0	0	0	0	0	100	80
Pine	3	0	0	30	0	30	100	70
Heavy Impact								
Cypress	5	100	100	100	100	100	100	100
Marl Marsh	5	60	80	80	60	60	100	100
Sand Marsh	6	0	100	80	50	50	100	100
Pine	3	0	70	70	70	30	100	70

Recovery

Another important management consideration is the recovery rate from ORV impacts in terms of each major BICY habitat and each major type of vehicle used in the BICY. Again, the complexity of the already presented data makes interpretation of overall trends very difficult, so we have summarized the dominant patterns of recovery that occurred during the first year following the treatments. We felt this time period was particularly important because it is the interval at which the most intensive ORV activity in the preserve occurs, and any impacts that have not essentially recovered within this time will contribute to a cumulative impact on the BICY. This is most significant in areas or for vehicles where drivers do not tend to follow established trails, so that each year's impacts will affect more and more of any area that is regularly used. Although recovery is obviously related to degree of impact, it is a distinct measure of sensitivity of a habitat or the impacting ability of a vehicle, since it evaluates the duration over which an impact parameter remains significantly different from similar undisturbed habitat, as opposed to a measure of degree of impact. However, the rate at which the degree of impact is changing is also significant when estimating how long recovery will take. Whether the rate of recovery is linear or increases or decreases with time is impossible to estimate on the basis of our one year's data. The only parameter with more than two data points which could give even some indication of the recovery rate curve are rut depth and visual ratings. Both parameters tend to indicate that where recovery is not complete during the first year, its rate was fastest immediately after the treatments and thereafter slowed. Knowledge of whether these impacts from the various vehicles will take two, three, ten, or a hundred years to recover in the various habitats will be important in making decisions for regulation of numbers and types of vehicles as well as when, where, and for how long they can be used in the BICY. It would be particularly valuable information upon which to base estimates of the duration of rest periods for the various areas that would allow maintenance of natural communities by rotating use areas over time. In some habitats the necessary rest period may be so long that the only alternative may be to designate permanent ORV use areas and/or routes in certain habitats, if at least some types of ORVs are to be allowed to operate in these situations within the BICY.

While the degree of initial substrate impact was closely correlated with the degree of visual and vegetation impact, substrates in the test lanes exhibited substantially greater recovery than did the other parameters in the year following the treatments. Of the individual parameters, recovery of ridge heights was complete at more sites than for any other parameter after one year, while the visual rating and standing litter showed the least recovery. Among the measures of live vegetation recovery, height recovered more completely and at more sites during the first year, percent cover less completely and at fewer sites, while biomass was intermediate (although more similar to height). Since the taxonomic composition was measured largely in terms of presence or absence and only over one growing season, these data were not sufficiently detailed to allow an analysis of recovery patterns at this time.

Recovery Related to Habitat Type

Among the various habitats, pine was the only one for which most of the parameters we measured indicated complete recovery within one year (Table 113). The only parameters that had not recovered were standing litter and visual ratings in medium and heavy impact lanes. As discussed in the results, the low recovery of the visual rating was due at least partially to the bias of the method. However, the visual rating is also a sensitive measure of disturbance, since it tends to integrate all structural aspects of the environment. In our pine plots, it may be related to the reduction of standing litter which had been knocked down during the treatments and and not yet been replaced by 1979 production at the time our October samples were collected. This lack of litter undoubtedly affected the density and color of the plant community and would be visually apparent. Since fire is an important aspect of natural pine ecosystem dynamics, the loss of this litter component could influence fire frequency, intensity, and spread in or near ORV lanes. However, since ORVs tend to follow well-used trails through pinelands, and fires normally have little trouble jumping these narrow lanes, the impacts of ORVs on fire in pinelands is probably of minimal significance.

Recovery in sand marshes one year after the treatments was generally similar to that in pines, although a few parameters did indicate incomplete recovery, particularly in the heavy impact lanes. The interaction between visual rating and standing litter described above for pines was probably also a factor in this habitat. However, the general lack of trees in sand marshes allows vehicles to travel cross-country more freely and results in more widespread impacts on standing litter, which potentially could reduce the possibility of fires moving across more heavily-used marshes.

Few parameters in the other habitats indicated complete recovery during the first year after the treatments at any impact level, although there was a general trend of increasing percent recovery with decreasing impact levels.

Recovery Related to Vehicle Type

The airboat was the only vehicle type that most of our parameters indicated allowed complete recovery during the first year following the treatments. Actually, it had no impact on soils even initially, and the associated undisturbed root systems quickly resprouted during the 1979 growing season. The elimination of the litter was probably the main reason that percent cover and visual rating indicated incomplete recovery of some airboat lanes. The smooth buggy lanes appeared to show more recovery than the other types of buggies, but this was an artifact of the original tests and was due to the inability of this vehicle to operate in some of the habitats where the other buggies produced the most severe impacts, resulting in their relatively low overall recovery rates for a number of parameters. Actually, no buggy consistently showed better overall recovery than any other buggy. The ATC showed slightly better overall recovery than the buggies, particularly in the one-pass lanes for the vegetation and visual rating

Table 113. General patterns of recovery during the first year following the treatments. For the parameters with incomplete recovery, we have indicated the minimum (>) or maximum (<) percent recovery. Where we have indicated a minimum value, the upper limit is complete recovery, while a maximum value has a lower limit of 0 percent recovery, or in a few cases, further degradation from our original measurements.

	Habitat						Vehicle							
								Swamp Buggy						
	Small Cypress	Marl Marsh	Sand Marsh	Pine	Marl* Marsh	Peat* Marsh	ATC	Light	Heavy	Chain	Tractor	Smooth	Airboat	Track Vehicle
Visual Rating														
One-Pass	>0	>0	R	R	0	R	R	>0	>0	>0	>0	R	R	>0
Medium Impact	>0	<35	>0	>0	-	0	>0	>0	<35	>0	>0	>0	>0	0
Heavy Impact	<25	<35	>0	>30	<20	<25	>0	<50	<40	<50	<50	<40	>0	<25
Soil														
Rut Depth														
One-Pass	R	R	R	R	≤50	R	R	R	R	R	R	R	R	>0
Medium Impact	R	R	R	R	-	≤10	R	>0	R	>30	>70	R	R	<20
Heavy Impact	>60	>70	>0	R	<50	<20	>60	>60	>70	>60	>70	>0	R	<50
Ridge Height														
One-Pass	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Medium Impact	R	≥50	R	R	R	R	R	>50	R	>65	R	R	R	R
Heavy Impact	0	>20	R	R	R	R	>30	>0	>30	>15	>15	>25	R	R
Soil Compactness														
One-Pass	>50	R	-	-	-	-	R	>75	>50	>75	>50	-	-	-
Medium Impact	>50	R	-	-	-	-	>75	>50	>85	R	R	-	-	-
Heavy Impact	<85	>50	-	-	-	-	>75	>30	>35	>45	>35	-	-	-

Table 113. Continued.

	Habitat						Vehicle							
								Swamp Buggy						
	Small Cypress	Marl Marsh	Sand Marsh	Pine	Marl* Marsh	Peat* Marsh	ATC	Light	Heavy	Chain	Tractor	Smooth	Airboat	Track Vehicle
Vegetation														
Biomass														
One-Pass	>35	R	R	R	<50	R	R	R	R	R	>35	R	R	R
Medium Impact	<50	>30	R	R	-	<20	>65	75	>40	>30	>40	>40	R	<20
Heavy Impact	<50	<60	>10	R	<20	<20	>5	>0	<20	>0	>0	>25	R	<35
Percent Cover														
One-Pass	>10	>30	R	R	<35	R	R	>20	>20	>15	>10	R	R	>30
Medium Impact	<25	<70	>10	R	-	<20	>5	>5	<45	>20	>10	>35	>55	<20
Heavy Impact	<30	<50	>35	R	<30	<60	>5	<85	<45	> 0	<85	>40	>40	<60
Height														
One Pass	>30	R	R	R	>40	R	R	>75	>80	>50	>30	R	R	>40
Medium Impact	>20	>40	R	R	-	<40	>65	>20	>60	>50	R	R	R	<40
Heavy Impact	<50	<40	R	R	<40	<10	>20	<20	<40	<40	>0	>30	R	<40
Standing Litter														
One-Pass	>0	>10	R	R	<40	0	R	>20	>0	>0	>0	R	>0	<40
Medium Impact	<20	<45	>10	>30	-	0	>0	>0	<40	>0	>10	>10	>0	0
Heavy Impact	0	<40	> 0	>10	<20	0	>0	<60	<40	>0	<10	> 0	>0	<20

R Complete recovery
- No data available
* Based on track vehicle impacts, since airboat impacts were always similar or less significant

parameters. The track-vehicle lanes generally had a lower degree of recovery than most buggy lanes during the first year, but only a slightly lower frequency of parameters showing complete recovery. Except for the airboat, all vehicles tested at heavy impact levels and most tested at medium impact levels produced impacts that had not recovered during the first year after the vehicle tests.

The only previous ORV study that is directly comparable to our work was done in the early 1970s by Schemnitz and Schortemeyer (1974), who tested airboats and track vehicles (half tracks) in Everglades marshes. Their results are comparable to ours for similar treatment levels despite differences in (1) water levels and time of year when the impacts were made, (2) time of year when the impacts were evaluated, and (3) a number of other less important aspects of their methodology. In general, their airboat tracks resulting from five or fewer passes had essentially disappeared within five months of the treatments. While all track vehicle lanes were still visible at this time, particularly from the air, only the five-pass track vehicle treatments in the three wetter plots still exhibited significant biomass impacts. Taxonomic composition was unaffected for the impact levels at which they tested either airboats or track vehicles.

PART II.

OLD TRAIL RECOVERY STUDY

METHODS

Twenty-four established ORV trail sites were selected along major trails in all principal habitats within BICY to monitor recovery following abandonment (Figure 10 and 11). Three plots were set up along wheeled-vehicle trails in each of six habitats, including hammock, pine, large cypress, small scattered cypress, marl marsh, and sand marsh. Peat marsh and separate marl marsh plots were set up along airboat trails. Each plot was a 50 m long section of trail. Since any future disturbance by vehicles would be highly detrimental to our study of these "recovery" plots, as many as possible were located with the Loop Road area and Everglades National Park (ENP), which were closed to ORV use by the public. To further minimize disturbance, the trails were blockaded and persons authorized to use the trails were notified of plot locations and requested to bypass them. During March and October 1979, we monitored the old trail plots using essentially the same parameters and techniques used in the vehicle impact study. Rut depth, ridge height, and visual impacts were measured at 30 random points along the trail at each site. Also, in three 10 x 100 cm plots randomly located in the trail and three control plots located adjacent to the trail, we determined percent cover and height of vegetation, noted dominant plant taxa present and their relative abundances, and clipped, dried, and weighed live vegetation.

Some aspects of the sampling program were modified in October 1979. Our vegetation sampling methods proved inadequate to evaluate recovery of the hammock plant community because of the relative absence of understory in the heavily shaded control sites compared to the more open trails. As a result we randomly located a 1 x 5 m plot in the trail and another in an adjacent control area at each site, and recorded total numbers, heights, and genera of all woody stems. Airboat-track vehicle trail plots were not sampled in October due to the continued use of these trails. Standing litter was collected only in the October 1979 samples.

T-tests were used to statistically compare trail and control samples in each plot on each sampling date. Probability levels were always .05.

RESULTS

Characteristics of Old Trail Study Sites

Habitat characteristics of wheeled-vehicle old trail study sites in small cypress, marl marsh, sand marsh, and pine, and of airboat-track vehicle sites in marl and peat marshes were comparable to our vehicle impact study plots described in Table 5. The sand marsh, pine and airboat-track vehicle trails were generally about 2-3 m wide, while the small cypress and wheeled-vehicle marl marsh trails were about 3-5 m wide.

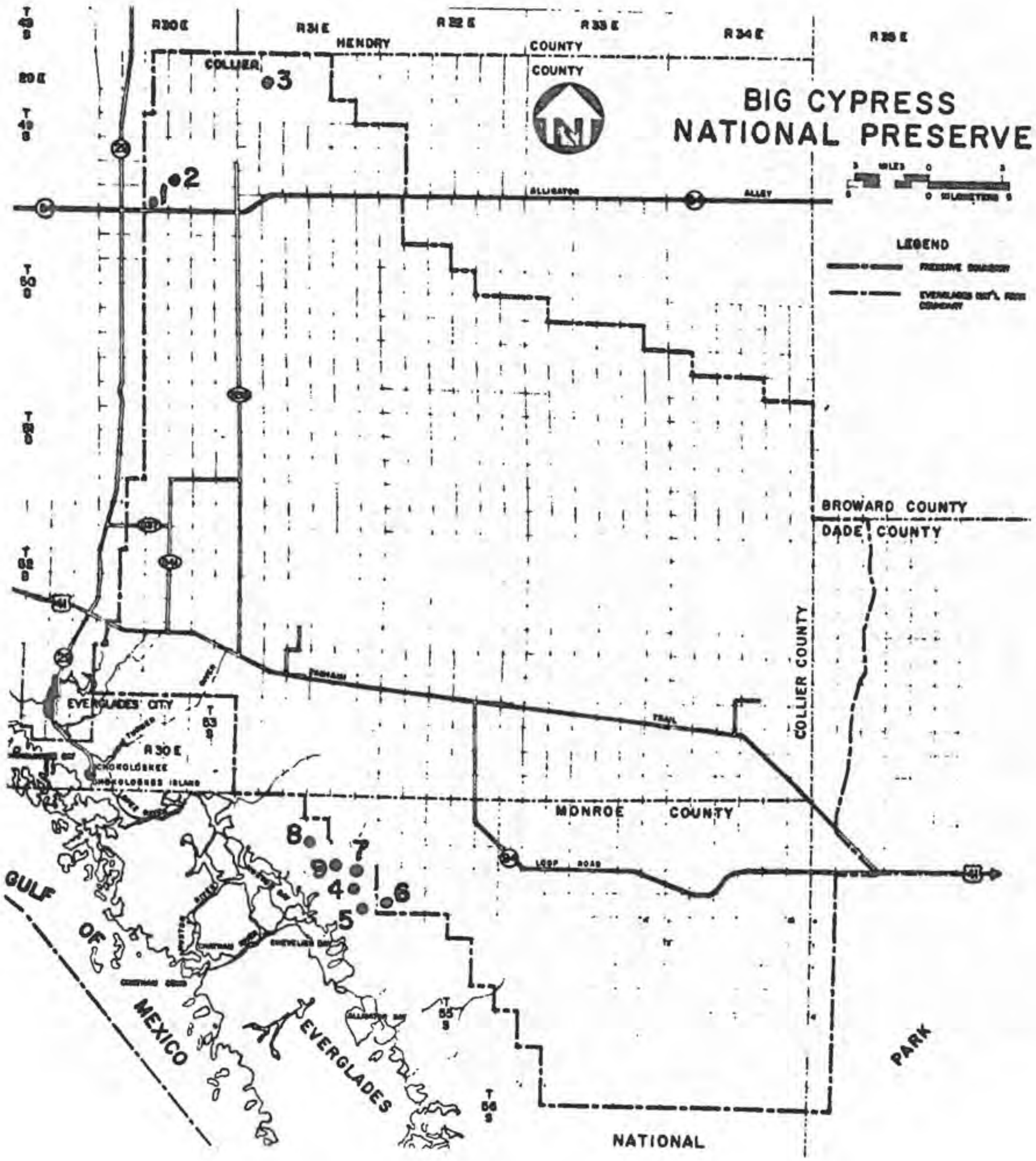
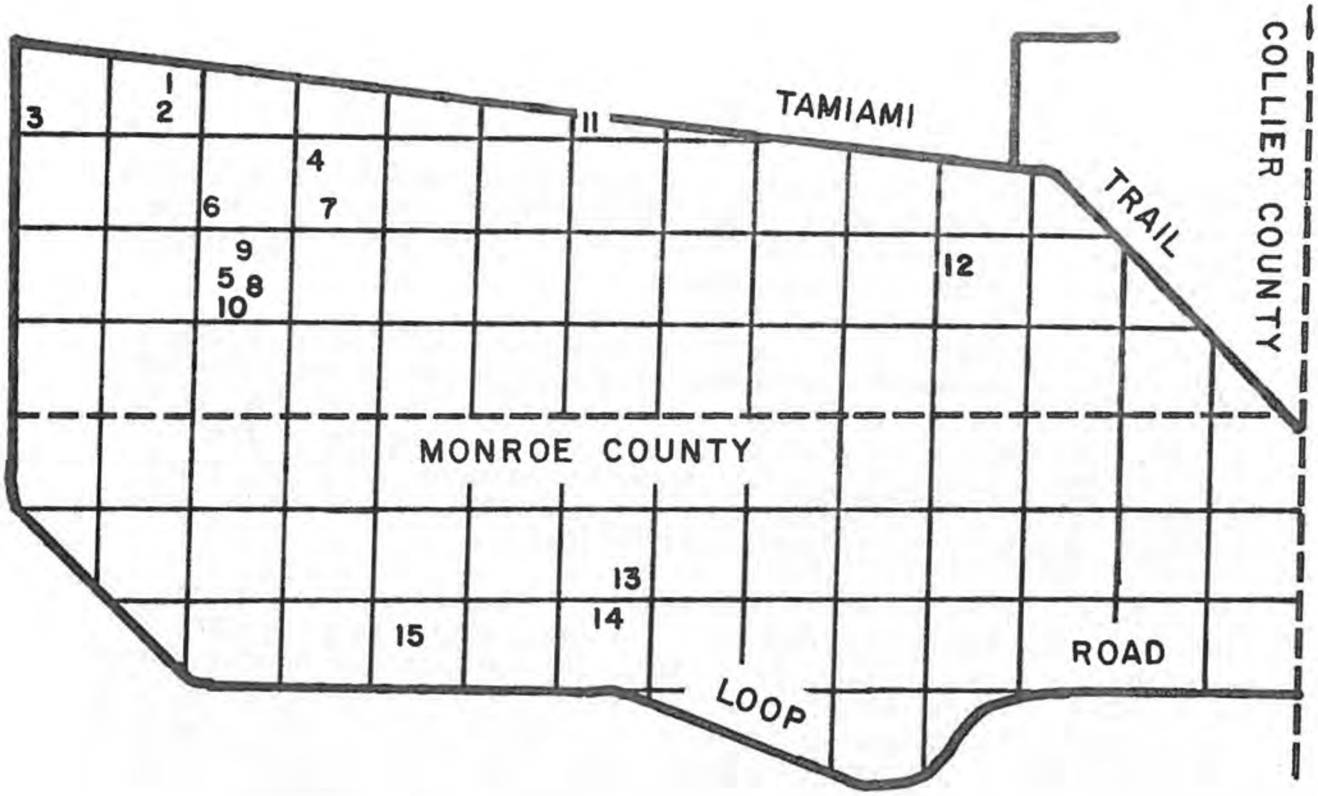


Figure 10. Locations of Bear Island (1-3) and Stair Step Trail (4-9) old trail recovery study plots.

1 Sand Marsh 1
2 Sand Marsh 2
3 Sand Marsh 3
4 Airboat-Track Peat Marsh 1
5 Airboat-Track Peat Marsh 2
6 Airboat-Track Peat Marsh 3
7 Airboat-Track Marl Marsh 1
8 Airboat-Track Marl Marsh 2
9 Airboat-Track Marl Marsh 3



1 Wheeled-vehicle Marl Marsh 1
2 Wheeled-vehicle Marl Marsh 2
3 Wheeled-vehicle Marl Marsh 3
4 Small Cypress 1
5 Small Cypress 2
6 Small Cypress 3
7 Large Cypress 1
8 Large Cypress 2
9 Large Cypress 3

10 Hammock 1
11 Hammock 2
12 Hammock 3
13 Pine 1
14 Pine 2
15 Pine 3

Figure 11. Locations of the Loop old trail recovery study plots.

The trails exhibited no consistent orientation relative to any habitat characteristics within any of these communities. Bedrock was exposed in the ruts of the wheeled-vehicle marl marsh sites, and intermittently at the small cypress and pine sites.

At all large cypress sites a major vehicle trail 3-6 m wide crossed a cypress strand perpendicular to the alignment of the strand. The soils which were typically mixtures of sand and marl, were approximately 30 cm deep. Bedrock was only occasionally exposed along the trails. Cypress, Taxodium distichum, with diameters at breast height of about 15-40 cm dominated the sites, and major understory genera included: Blechnum, Utricularia, Ludwigia, and Panicum.

Hammock sites were dominated by a variety of small to medium-sized temperate and tropical hardwoods including Quercus, Acer, Persea, Lysiloma, Myrsine, Eugenia, and others, and the sparse understory normally by seedlings of overstory genera. Generally, only a few centimeters of dark organically-stained sand covered bedrock at these sites. The hammock trails were about 2 m wide and worn down to bedrock. They exhibited no particular orientation relative to the hammock's environmental characteristics.

All old trails studied were well worn major trails and appeared to have been heavily used during the past hunting season, which had ended about two months before our first sampling period in March 1979.

Visual Impacts

The most severe visual rating possible, 4.0 for all vegetation removed, was recorded initially for all cypress and wheeled-vehicle marl marsh plots (Table 114). Except for the airboat-track vehicle marl marsh plots which were only slightly disturbed, all of the remaining sites had similar values indicating only slightly less impact than in the cypress and marl marsh plots. By definition, all of the trails were impacted and the controls were not, so that all plots exhibited significant differences. Recovery of visual ratings was generally minor during the 1979 growing season and was negligible in the large cypress sites (Table 114).

Soil Impacts

Rut Depth

All wheeled-vehicle trail plots in cypress, marl marsh, and pine were rutted, but only one hammock site had ruts and no rutting occurred in sand marsh plots or any of the airboat trail sites (Table 115). Large cypress sites had the deepest ruts while small cypress, marl marsh, and pine had shallower ruts with approximately similar depths. Impacts at these sites were much more extensive when compared to those we produced in our vehicle impact study plots, which typically were paired, narrow depressions affecting only the soil actually contacted by the vehicle tires. After years of use, much of it during high water periods, old

Table 114. Average visual ratings of individual old trail study plots and percent recovery during the 1979 growing season.

	March 1979			October 1979			Percent Recovery		
	1	2	3	1	2	3	1	2	3
Wheeled Vehicle Trails									
Large Cypress	4.0*	4.0*	4.0*	3.9*	4.0*	4.0*	3	0	0
Small Cypress	4.0*	4.0*	4.0*	3.7*	3.3*	3.3*	8	18	18
Marl Marsh	4.0*	4.0*	4.0*	3.5*	3.9*	2.7*	13	3	33
Sand Marsh	4.0*	3.0*	4.0*	3.5*	3.6*	2.2*	13	-20	45
Pine	3.7*	4.0*	3.5*	3.3*	3.2*	3.3*	11	20	6
Hammock	4.0*	3.0*	3.0*	-	-	-	-	-	-
Airboat-Track Vehicle Trails									
Marl Marsh	1.0*	1.0*	1.0*	-	-	-	-	-	-
Peat Marsh	4.0*	4.0*	3.7*	-	-	-	-	-	-

* Significantly different from controls (P=.05)

\- No data

Table 115. Average soil rut depths (cm) in individual old trail study plots and percent recovery during the 1979 growing season.

	March 1979			October 1979			Percent Recovery		
	1	2	3	1	2	3	1	2	3
Wheeled Vehicle Trails									
Large Cypress	26*	33*	35*	28*	31*	31*	-8	8	11
Small Cypress	20*	11*	19*	20*	11*	16*	0	0	16
Marl Marsh	18*	16*	8*	14*	13*	7*	22	19	13
Sand Marsh	0	0	0	0	0	0	N	N	N
Pine	14*	11*	11*	9*	13*	11*	36	-18	0
Hammock	7*	0	0	4*	0	0	43	N	N
Airboat-Track Vehicle Trails									
Marl Marsh	0	0	0	-	-	-	-	-	-
Peat Marsh	0	0	0	-	-	-	-	-	-

* Significantly different from controls (P=.05)
\- No data
N No ruts present initially

trail plots were typically 2-3 m wide corridors from which much of the soil had been flushed. These trails were usually deeper where vehicle tires normally traveled, but their entire width was lower than adjacent undisturbed soil. If a site was rutted, ruts were encountered in all of our samples. As a result, all of these types of sites were significantly different from the adjacent controls. Percent recovery of ruts in all plots was less than 50 percent and was generally less than 25 percent during the 1979 growing season (Table 115).

Ridge Height

Soil ridges adjacent to old trails were nonexistent, except for one large cypress plot with a 1 cm high ridge and one wheeled-vehicle marl marsh site with a 9 cm high ridge. Flushing associated with vehicle passage and general overland flow during the wet season is probably not conducive to ridge formation. The one significant soil ridge we did encounter seemed to have resulted from a single pass when no surface water was present at the site and it decreased in height to 7 cm during the 1979 growing season.

Vegetation Impacts

Biomass

During the March pre- growing season sampling period no vegetation was encountered in the old trail cypress and wheeled-vehicle marl marsh plots, or in two of the three sand marsh plots (Table 116). Except for the large cypress, all of these plots had significantly more vegetation in the control as compared to the trail samples. The low biomass in the large cypress control samples resulted in the lack of significant differences from the trail samples. The pine habitat trails supported very little vegetation which represented only 1-5 percent of control biomass, but still only one site exhibited significant differences, primarily because of great variability in the pine control samples. Our evaluation of understory vegetation in hammock plots is not included, since trails in these habitats tend to open the canopy which results in increased light penetration and more vegetation in the trail than in the adjacent shaded hammock. There were no real differences in biomass between airboat trail and control plots in marl marsh sites, but the same trails, when passing through the densely vegetated peat marshes, supported little or no vegetation.

Understory vegetation was consistently present in all but the large cypress trail samples during the post- growing season sampling period, although generally in relatively small quantities compared to the controls (Table 116). Despite this improvement in condition, biomass in virtually all wheeled-vehicle trails was significantly different from controls at this time.

During the pre- growing season sampling period, trail biomass in the wheeled and airboat-track vehicle peat marsh plots represented only 0-5 percent of control values (Table 116). While this range for the wheeled-vehicle plots increased to 0-30 percent following the growing season, most

Table 116. Average biomass for individual plots in old trail lanes and adjacent controls, and percentages that trail biomass was of control values.

	1			2			3		
	Biomass (g/m^2)		Test Lane / Control	Biomass (g/m^2)		Test Lane / Control	Biomass (g/m^2)		Test Lane / Control
	Control	Test Lane	(%)	Control	Test Lane	(%)	Control	Test Lane	(%)
Wheeled Vehicle									
Large Cypress									
March	5	0	0	15	0	0	4	0	0
October	182	2*	1	237	0*	0	72	0	0
Small Cypress									
March	60	0*	0	82	0*	0	77	0*	0
October	158	2*	1	150	13*	9	142	43*	30
Marl Marsh									
March	102	0*	0	160	0*	0	122	0*	0
October	183	24*	13	345	3*	1	256	70*	27
Sand Marsh									
March	68	0*	0	121	4	3	166	0*	0
October	231	25*	11	230	12*	5	337	88*	26
Pine									
March	236	7	3	268	4	1	43	2*	5
October	208	24	12	246	7*	3	175	16*	9
Airboat-Track Vehicle									
Marl Marsh									
March	55	26	47	53	71	134	47	71	151
October	-	-	-	-	-	-	-	-	-
Peat Marsh									
March	317	0*	0	806	0	0	355	4*	1
October	-	-	-	-	-	-	-	-	-

* Significantly different from controls (P=.05)

\- No data

trail biomass values were still less than 15 percent, and the large cypress values were 1 percent or less.

Percent Cover and Height

Since the absence or almost complete absence of vegetation in most trails dominated the comparisons between old trail and control biomass, the same trends are also seen in the pre- growing season percent cover (Table 117) and height data (Table 118). The only exception to this was the airboat-track vehicle marl marsh plots, which were the only sites where old trails had even approximately normal amounts of vegetation, and where there were no significant differences in biomass between trail and control samples. This was also the situation for percent cover in two of the three plots, but all plots had significantly shorter vegetation in the trails. Percent cover data from the October post- growing season sampling period also showed similar trends to the biomass data (Table 117), while those for vegetation height showed fewer differences between trails and controls (Table 118). This suggests vegetation height recovers more rapidly than does either percent cover or biomass, which is probably due to a few plants attaining their normal height in one growing season, while the community is unable to reestablish other aspects of its structure that quickly.

Percent cover in the March wheeled and airboat-track vehicle trail samples was generally 1 percent or less of control samples although a few plots ranged up to 23 percent (Table 117). By October, trail samples had percent covers ranging from 0-60 percent of controls, with considerable plot to plot variation in all habitats. Trail vegetation heights in the same plots ranged from 0-13 percent of controls in March, and from 0-96 percent in October (Table 118). Again there was much plot to plot variation within each habitat in the post- growing season sampling period.

Standing Litter

Most of our October old trail samples had no standing litter, and of the few that did, only two amounted to more than 13 percent of the control values (Table 119). Generally, where there were no significant differences between trail and control samples, standing litter occurred in only small amounts in at least some of the control plots.

Taxonomic Composition

Since few vehicle trails had any vegetation in them during March and the rest had almost none, our discussion of initial taxonomic composition is somewhat limited. The cypress and wheeled-vehicle marl marsh plots had three to five taxa in the control samples compared to none in the trails (Table 120). *Panicum*, the only vegetation found in the sand marsh trail samples, was also common in control samples, but the controls had a much greater diversity including at least nine other taxa. Trail and control samples in pine habitat were dominated primarily by *Panicum*, and the controls to a lesser extent by unidentified forbs. *Panicum* also dominated hammock trail samples, while ferns and various forbs dominated control samples. The sole genus recorded in airboat-track vehicle marl

Table 117. Average percent cover for individual plots in old trail lanes and adjacent controls, and percentages that trail percent cover was of control values.

	1			2			3		
	Percent Cover		Test Lane / Control	Percent Cover		Test Lane / Control	Percent Cover		Test Lane / Control
	Control	Test Lane	(%)	Control	Test Lane	(%)	Control	Test Lane	(%)
Wheeled Vehicle									
Large Cypress									
March	8	0	0	10	0	0	2	0	0
October	70	7*	10	40	0*	0	17	0	0
Small Cypress									
March	57	0*	0	47	0*	0	23	0*	0
October	33	<1*	<1	30	1*	3	33	10*	30
Marl Marsh									
March	40	0*	0	73	0*	0	23	0*	0
October	30	5*	17	30	0*	0	40	17*	43
Sand Marsh									
March	60	0*	0	47	4*	9	87	0*	0
October	90	5*	6	47	2*	4	83	23*	28
Pine									
March	43	10*	23	77	<1*	<1	22	<1	<1
October	53	32	60	60	27	45	53	3*	6
Airboat-Track Vehicle									
Marl Marsh									
March	7	10	143	27	15*	56	8	13	163
October	-	-	-	-	-	-	-	-	-
Peat Marsh									
March	7	0*	0	10	0	0	10	2	20
October	-	-	-	-	-	-	-	-	-

* Significantly different from controls (P=.05)
\- No data

Table 118. Average vegetation height for individual plots in old trail lanes and adjacent controls, and percentages that trail vegetation height was of control values.

	1			2			3		
	Height (cm)		Test Lane / Control	Height (cm)		Test Lane / Control	Height (cm)		Test Lane / Control
	Control	Test Lane	(%)	Control	Test Lane	(%)	Control	Test Lane	(%)
Wheeled Vehicle									
Large Cypress									
March	20	0	0	47	0	0	37	0	0
October	40	17	43	110	0*	0	60	0	0
Small Cypress									
March	73	0*	0	107	0*	0	60	0*	0
October	87	17*	20	73	27*	37	73	70	96
Marl Marsh									
March	57	0*	0	100	0*	0	37	0*	0
October	67	30	45	80	0*	0	100	47*	47
Sand Marsh									
March	10	0*	0	90	8	9	40	0*	0
October	30	8*	27	110	27*	25	67	57	85
Pine									
March	53	3	6	77	10	13	25	3	12
October	60	33*	55	40	23	58	47	27	57
Airboat-Track Vehicle									
Marl Marsh									
March	90	20*	22	50	40*	80	30	20*	67
October	-	-	-	-	-	-	-	-	-
Peat Marsh									
March	150	0*	0	167	0*	0	133	10*	10
October	-	-	-	-	-	-	-	-	-

* Significantly different from controls (P=.05)

Table 119. Average standing litter for individual plots in old trail lanes and adjacent controls, and percentages litter was of control values.

	1			2			3		
	Litter (g/m²)		Test Lane / Control	Litter (g/m²)		Test Lane / Control	Litter (g/m²)		Test Lane / Control
	Control	Test Lane	(%)	Control	Test Lane	(%)	Control	Test Lane	(%)
Wheeled Vehicle									
Large Cypress									
October	0	0	0	49	0	0	0	0	0
Small Cypress									
October	154	0	0	97	0	0	115	27*	23
Marl Marsh									
October	130	0*	0	110	0*	0	201	0*	0
Sand Marsh									
October	38	0	0	243	3 *	1	65	6*	9
Pine									
October	156	0*	0	179	60	34	141	0*	0

* Significantly different from controls (P=.05)

Table 120. Frequency (percent) of plant taxa in wheeled-vehicle old trail study plots during March 1979.

	Large Cypress		Small Cypress		Marl Marsh		Sand Marsh		Pine		Hammock	
	Trail	Control	Trail	Control	Trail	Control	Trail	Control	Trail	Control	Trail	Control
Fern	-	33	-	-	-	-	-	-	-	-	-	22
Aristida	-	-	-	-	-	-	-	11	11	22	-	-
Muhlenbergia	-	-	-	100	-	78	-	-	-	11	-	-
Spartina	-	-	-	-	-	-	-	11	11	-	-	-
Panicum	-	22	-	33	-	67	33	100	44	100	67	-
Cladium	-	-	-	22	-	33	-	11	-	11	-	-
Smilax	-	-	-	-	-	-	-	-	-	-	11	-
Parthenocissus	-	-	-	-	-	-	-	-	-	-	-	11
Ludwigia	-	33	-	-	-	-	-	-	-	-	-	-
Centella	-	-	-	-	-	-	-	78	-	-	-	-
Hydrocotyl	-	-	-	-	-	-	-	-	-	-	-	22
Lippia	-	-	-	-	-	-	-	56	-	-	-	-
Hyptis	-	-	-	-	-	22	-	-	-	-	-	-
Bacopa	-	-	-	11	-	-	-	33	-	-	-	-
Pluchea	-	-	-	-	-	-	-	44	-	-	-	-
Eupatorium	-	-	-	-	-	-	-	11	-	-	-	-
Unidentified Forbs	-	-	-	-	-	33	-	22	11	56	11	11
Total Taxa	0	3	0	4	0	5	1	10	4	5	3	4

Table 121. Frequency (percent) of plant taxa in airboat-track vehicle old trail study plots during March 1979.

	Marl Marsh		Peat Marsh	
	Trail	Control	Trail	Control
Muhlenbergia	-	22	-	-
Spartina	-	11	-	-
Panicum	-	22	-	-
Eleocharis	100	67	-	-
Cladium	-	22	-	100
Pontederia	-	-	-	11
Crinum	-	-	11	-
Total Taxa	1	5	1	2

marsh trail samples was Eleocharis, and while it was also an important component of the control samples, they contained four additional taxa (Table 121). Eleocharis was the taxon that recovered most rapidly in track-vehicle marl marsh lanes in the vehicle impact study, which further suggests its greater tolerance of disturbance as compared to other taxa in this habitat. Cladium strongly dominated the peat marsh control samples, but was not present in the trails. Thus, if intensive long-term trail use does not completely eliminate vegetation, it at least significantly decreases diversity, and what vegetation still exists is most likely to be Panicum or Eleocharis.

After one growing season only one taxon was recorded in large cypress trails, while seven were recorded in the controls (Table 122). The small cypress trails contained only Panicum and Eleocharis, the former occurring less frequently and the latter being absent in the controls. Muhlenbergia, and to a lesser extent, Cladium and Dichromena, occurred in the small cypress control plots, but were absent from the trails. The greater water depth in the trails may have been conducive to the invasion by Eleocharis and the absence of Muhlenbergia. Vegetation in wheeled-vehicle marl marsh trails was more or less similar to that in the control plots, except for the occurrence of Bacopa only in the relatively more open and deeper trails. The sand marsh trail plots had recoverd much of their diversity, and both trail and control samples were dominated by Panicum. Pine trail plots differed considerably from controls. Although both were dominated by Panicum, Aristida was also a dominant and present only in control samples, while the more aquatic genera Bacopa and Dichromena occurred only in the trails, presumably because of an increased hydroperiod.

The modified hammock sampling program in October revealed no clear pattern of trail recovery during the first year following abandonment, primarily because of plot to plot variability. Most trees and shrubs were more common in the control plots, but eight of the eleven were also found in smaller numbers and sizes in some of the trail samples (Table 123). Baccharis was the only taxon that was more common in the trails.

DISCUSSION

The old trail sites were selected specifically because of the presence of severe, long-term impacts, and as would be expected, exhibited much greater visual, soil, and vegetation disturbance than did our vehicle impact study plots. In general, the relative degree and kinds of impact in different habitats was similar to the pattern found in the vehicle impact study plots. However, the vegetation and visual impacts in the forested habitats not previously studied could be interpreted as more severe because of the removal of large trees from the trails. Recovery during the first growing season following abandonment was also much less, largely because of the extensive soil loss from the trails and the associated absence of root systems. It will obviously be a number of years before these trails "disappear". However, it must be kept in mind that these are major trails and as such, are representative of a limited portion of the many kilometers of trails that presently exist within the BICY.

Table 122. Frequency (percent) of plant taxa in wheeled-vehicle old trail study plots during October 1979.

	Large Cypress		Small Cypress		Marl Marsh		Sand Marsh		Pine	
	Trail	Control	Trail	Control	Trail	Control	Trail	Control	Trail	Control
Fern	-	44	-	-	-	-	-	-	-	-
Sagittaria	-	-	-	-	-	-	11	-	-	-
Zizaniopsis	-	11	-	-	-	-	-	-	-	-
Aristida	-	-	-	-	-	-	-	22	-	100
Muhlenbergia	-	-	-	100	33	67	-	11	-	-
Spartina	-	-	-	-	-	-	-	22	-	-
Panicum	-	-	33	100	78	44	67	78	78	89
Eleocharis	-	11	56	-	11	-	11	-	-	-
Dichromena	-	-	-	33	22	11	11	11	33	-
Cladium	-	11	-	22	22	33	-	22	-	-
Pontederia	-	11	-	-	-	-	-	-	-	-
Crinum	-	-	-	-	11	-	-	-	-	-
Ludwigia	11	33	-	-	-	-	-	-	-	-
Centella	-	-	-	-	-	-	-	33	-	-
Lippia	-	-	-	-	-	-	11	-	-	-
Bacopa	-	11	-	-	33	-	44	33	33	-
Utricularia	-	-	-	-	-	-	11	-	-	-
Mikania	-	-	-	-	-	22	-	-	-	-
Unidentified Forbs	-	-	-	-	-	-	-	22	-	-
Total Taxa	1	7	2	4	7	5	7	9	3	2

Table 123. Numbers and average heights (cm) of woody stems in individual hammock old trail study plots during October 1979.

	1				2				3			
	Number		Average Height(cm)		Number		Average Height(cm)		Number		Average Height(cm)	
	Trail	Control	Trail	Control	Trail	Control	Trail	Control	Trail	Control	Trail	Control
Sabal	-	-	-	-	-	5	-	50	-	-	-	-
Smilax	-	-	-	-	2	-	20	-	-	-	-	-
Salix	1	-	20	-	-	-	-	-	-	-	-	-
Myrica	6	-	30	-	-	7	-	265	1	2	10	110
Quercus	-	-	-	-	11	19	25	35	-	14	-	20
Persea	2	5	40	35	-	-	-	-	-	-	-	-
Ilex	-	-	-	-	-	-	-	-	-	4	-	240
Eugenia	-	-	-	-	-	-	-	-	-	1	-	30
Myrsine	2	15	25	50	-	18	-	70	-	23	-	65
Psychotria	19	3	30	50	-	36	-	15	-	50	-	25
Baccharis	21	-	25	-	5	8	65	55	42	9	60	90
Unidentified Seedling	-	-	-	-	4	4	50	40	-	15	-	35
Total Number	51	23			20	97			43	118		
Maximum Average Height			40	55			65	265			60	240

PART III.

TRAIL WATER FLOWS

METHODS

We selected twelve sites to monitor ORV trail-surface water interactions (Figure 12). Six were typical trail-natural flowway intersections, while the others were trail-canal intersections typical of ORV access points in the preserve. At each flow site we put a nail in a tree to serve as a permanent elevation reference point, and at various water level stages measured water depth and flow velocity at one or more points in the trail and adjacent undisturbed habitat about 10 m from the trail.

RESULTS and DISCUSSION

The objectives of this part of our study were to determine if water flows at greater velocities in ORV trails than in surrounding habitats, and if so, how much faster, for how much longer during the year, and under what conditions, both hydrologically and topographically. The sites we monitored were selected because we expected to see significant flows at each of them and they were reasonably accessible.

The relative flow velocity data clearly indicate that trail flows consistently had higher mean velocities than flows through adjacent undisturbed habitats (Table 124). The only exceptions were sites in the center of strands or sloughs, where turbulence resulting from mixing of downstream and trail currents made it impossible to measure flows. Other than in this situation, we could not see any real differences in trail flow rates that were associated with movement into or out of canals as compared to sloughs or strands. Most average trail flow rates were about two to four times faster than flow rates in adjacent habitats. Flows also occurred in some trails at lower water levels than in the surrounding habitats, and thus they must also occur for longer periods during the year in these trails.

The limited amount of data we were able to collect in the course of this study did not provide any clear, consistent indications of a relationship between flow rates and changes in water levels. Although a few sites indicated increasing flow with water levels, most of the stage-flow comparisons suggested that flow rates were more or less constant over the range of water levels at which flows were occurring. This applied to both trail and undisturbed habitats. There were suggestions at a few sites of two types of variation in these general patterns. One variation involved high velocities in trails before flows began in nearby habitats, which then declined in the trail as habitat water flows began, but then increased to the earlier flow rates as water levels continued to increase. The other variation was a slowing of trail velocities to rates more similar to those in the adjacent habitat when water levels rose still

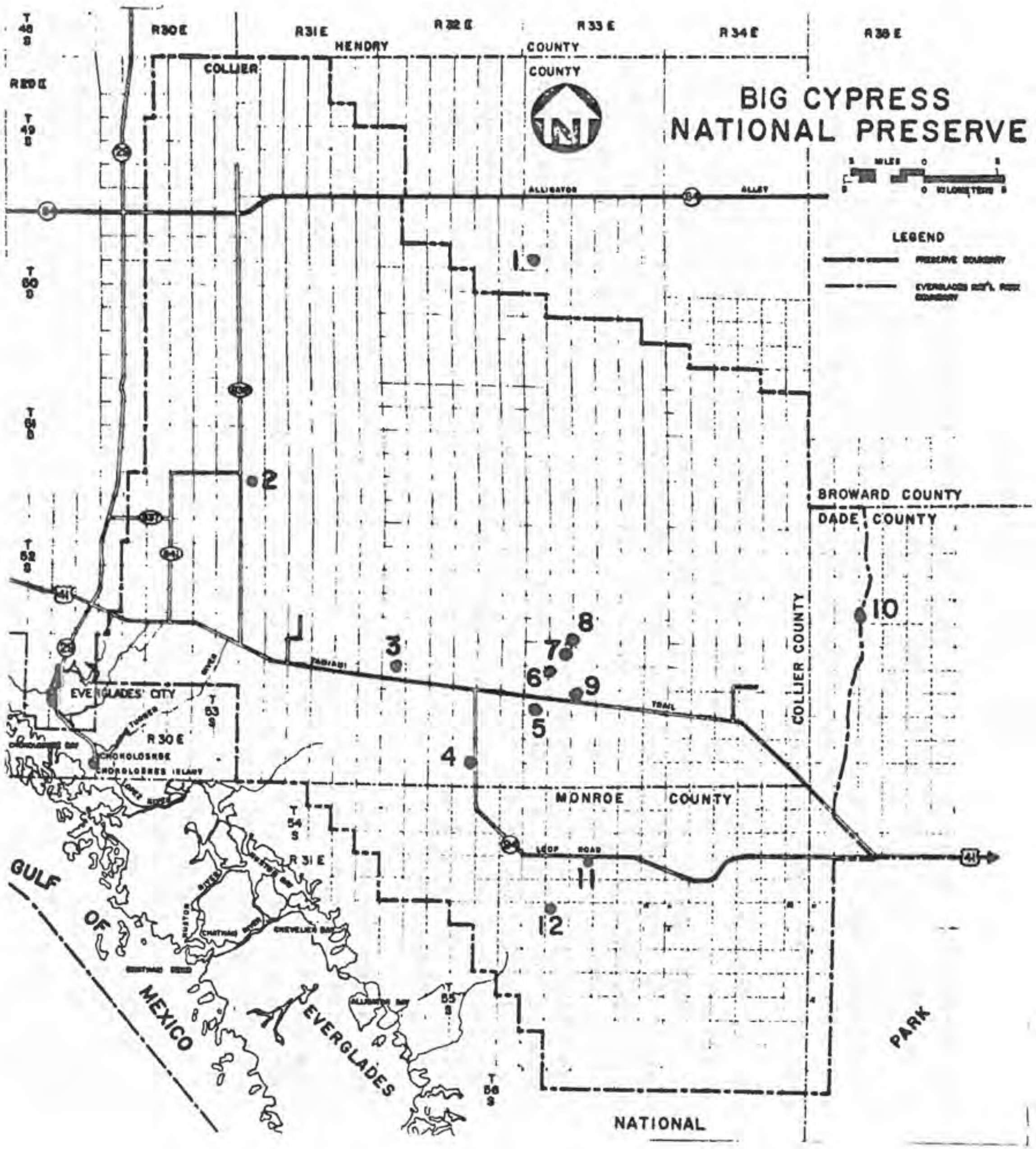


Figure 12. Locations of ORV trail water flow study sites.

1 Bamboo Strand Trail Flow Site
2 Concho Billie Trail Flow Site
3 Skillet Strand Trail Flow Site
4 Sig Walker Landing Trail Flow Site
5 Gannet Strand Trail Flow Site 1
6 Gannet Strand Trail Flow Site 2
7 Gannet Strand Trail Flow Site 3
8 Gannet Strand Trail Flow Site 4
9 Oasis Trail Flow Site
10 L-28 Trail Flow Site
11 Sawmill Road Trail Flow Site
12 Gum Slough Trail Flow Site

Table 124. Summary of BICY ORV flow site characteristics and measured flow velocities.

	L-28 Trails				Skillet Strand		Concho Billie		Sawmill Road at Paces Dike	Sig Walker Landing	Oasis	
	A	B	C	D	A	B	A	B			A	B
Flow Velocities (cm/sec)												
Trail												
n	4	4	4	4	2	2	2	2	4	4	7	7
Minimum	20.0	8.3	6.7	4.0	2.2	1.8	6.3	2.9	0.8	1.0	1.3*	1.3*
Maximum	50.0	33.3	16.7	16.7	2.9	3.3	8.3	8.3	3.3	6.7	5.0	1.7
Habitat												
n	4	3	3	4	-	2	2	2	4	4	-	7
Minimum	5.0*	0	6.3*	2.9	-	0.8	1.8	1.8	0.7	0.7*	-	0.5*
Maximum	10.0	6.3	6.3	6.3	-	1.5	2.5	2.5	1.7	1.5	-	1.7
Relative Flow Velocity (Trail/Habitat)												
Average	6.0	5.3	2.1	3.3	-	2.7	3.5	2.9	1.7	2.9	-	1.8
Minimum	3.0	-	1.8	0.8	-	1.2	2.5	1.2	1.0	1.4	-	1.0
Maximum	10.0	5.3	2.3	5.8	-	4.1	4.6	4.6	2.5	4.5	-	2.6
Maximum Water Depth(cm) Relative to Reference Point on a Flow Sampling Date	9	9	9	9	29	29	30	30	9.5	24	26	26

(Additional data for these sites continued on next page)

Table 124. Continued.

	L-28 Trails				Skillet Strand		Concho Billie		Sawmill Road at Paces Dike	Sig Walker Landing	Oasis	
	A	B	C	D	A	B	A	B			A	B
Relative Water Depth (cm) to Reference Point When Flow Began												
Trail												
No Flow	-	-	-	-	-	-	-	-	-	-	11.5	17
Flow	<0	<0	<0	<0	-	-	-	-	<0	<0	17	22.5
Habitat												
No Flow	4	4	0	0	-	-	-	-	4.5	12	11.5	17
Flow	5.5	5.5	4	4	-	-	-	-	6.5	17	17	22.5
Type of Flow Site	Canal	Canal	Canal	Canal	Canal	Canal	Near Canal	Near Canal	Canal	Canal	Canal	Trail
Flow Direction	In	In	In	In	In	In	In	In	Out	Out	Out	Diagonal Across
Relation of Flow to Increasing Water Depth												-
(C=Constant,I=Increases)	C	I	I	I	-	-	-	-	I	C	C	C

* Zero flow data not included.

Table 124. Continued.

	Sawmill Road at Gum Slough	Bamboo Strand	Gannet Strand 2	Gannet Strand 3	Gannet Strand 4	Gannet Strand 1	Range of Values Minimum	Range of Values Maximum	Extreme Maximum
Flow Velocities (cm/sec)									
Trail									
n	2	6	5	7	6	3	2	7	-
Minimum	4.5	2.9	1.4*	1.1*	2.5*	3.3	0.8	8.3	-
Maximum	4.8	6.3	2.4	4.5	7.1	5.0	1.7	33.3	50
Habitat									
n	2	6	5	7	6	3	2	7	-
Minimum	2.6	1.3*	0.5*	0.8*	0.7*	0.7*	0.5*	6.3	-
Maximum	2.8	1.6	1.6	1.8	1.7	1.7	1.5	6.3	10
Relative Flow Velocity (Trail/Habitat)									
Average	1.7	3.0	2.5	2.0	3.9	3.8	1.7	5.3	6
Minimum	1.7	2.2	0.9	1.0	1.8	2.9	0.9	3.0	-
Maximum	1.7	3.9	4.0	4.0	5.7	4.7	1.7	5.8	10
Maximum Water Depth (cm) Relative to Reference Point on a Flow Sampling Date	-	13	21.5	18.5	20.5	10	9	30	-

(Additional data for these sites continued on next page)

Table 124. Continued.

	Sawmill Road at Gum Slough	Bamboo Strand	Gannet Strand 2	Gannet Strand 3	Gannet Strand 4	Gannet Strand 1	Range of Values Minimum	Range of Values Maximum	Extreme Maximum
Relative Water Depth (cm) to Reference Point When Flow Began									
Trail									
No Flow	-	-	0	0	5	-	-	-	-
Flow	-	<0	4.5	4	8	<0	-	-	-
Habitat									
No Flow	-	0	7.5	0	5	0	-	-	-
Flow	-	2	14.5	4	8	3	-	-	-
Type of Flow Site	Slough	Strand Edge	Strand Edge	Strand Edge	Strand Edge	Strand Edge	-	-	-
Flow Direction	In	In	In	In	In	Parallel	-	-	-
Relation of Flow to Increasing Water Depth (C=Constant, I=Increases)	C	C	C	C-I	C	C	-	-	--

* Zero flow data not included

further. This probably was a result of the area becoming covered with a more or less unified body of water.

Data from an extensive survey of trail water flows (Figure 13), which was conducted to evaluate the representativeness of our intensive study sites, were divided into two groups. One group included 14 sites with flows perpendicular to the trails and the other 48 sites with flows parallel to the trails (Table 125). Trails perpendicular to flows showed essentially the same velocities as the adjacent habitat. Among the trails paralleling the flow, those entering canals exhibited relative flow velocities comparable to data from similar intensive study sites, while those entering strands were in the lower portion of the intensive study range. In a comparison of trails through different habitats, relative flow velocities in small cypress were also comparable to those in the lower portion of the intensive study range, while the marl marsh values were even lower, particularly in airboat trails which exhibited little or no rutting impact.

It is very difficult to interpret the significance of increased trail flows to the hydrology of BICY. Duever et al. (1979) observed that ORV trails had relatively insignificant effects on surface water flows in BICY. Minimal rutting and thick vegetation found in most airboat trails minimized their drainage potential, while the more abundant wheeled-vehicle trails typically stay on higher ground when possible. These trails pass through lower habitats, but the resulting channels are frequently interrupted where the trail again climbs back onto higher ground. Drainage effects are most likely where a well worn trail crosses an extensive low area such as marl marsh or dwarf cypress forest, and then intersects a canal or major strand.

An adequate interpretation requires an assessment of total quantities of water moving along all trails and through unimpacted BICY habitats at each water level increment, and then integrating these quantities over the annual distribution of water levels.

The general range of topographic differences between trails and unimpacted habitats was about 5-10 cm, but we considered these trails to be among the most severely impacted in the preserve. By selecting an average trail depth of 5 cm and a width of 3 m, we can construct a 0.15 m^2 cross-section through which water flows in a more or less typical regularly-used trail. In a 3 m wide section of unimpacted habitat, with water depths of 0.1, 0.5, and 1 m, the trail cross-section would represent a 50, 10, and 5 percent increase, respectively, in the 3 m wide flowway cross-section. While this suggests that flows, at least during low water periods, are significantly increased, it must be kept in mind that we are talking about 3 m wide cross-sections. In reality, it is unlikely that a major trail occurs more frequently than once every km in the BICY (Stubbs 1979), and most of these either cross or travel through upland habitats. Thus, the influence of these trails on regional water flows should be reduced by a factor of at least 500, which would make their effects essentially negligible in terms of overall BICY hydrology, even considering the two to four times faster velocities.

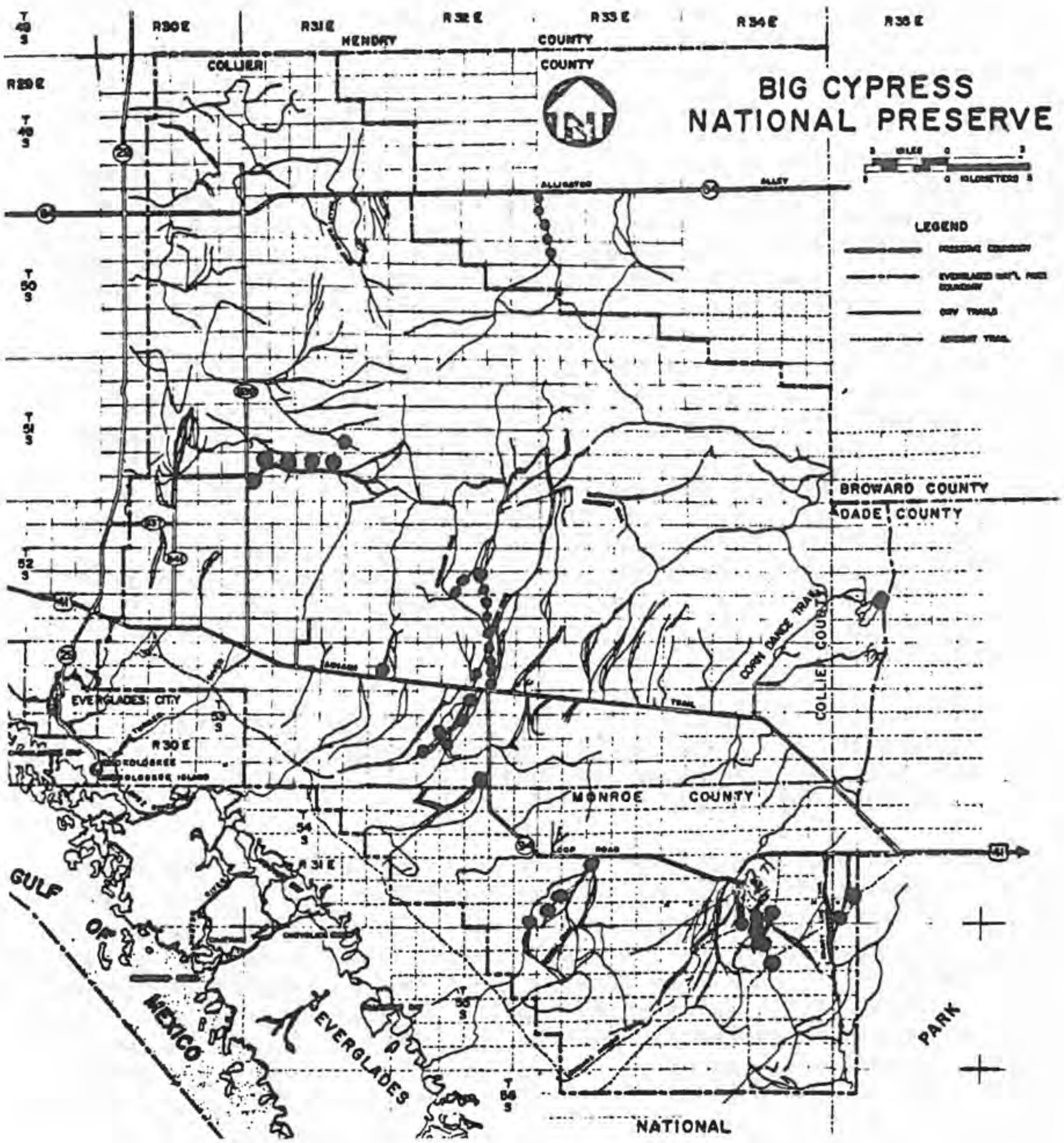
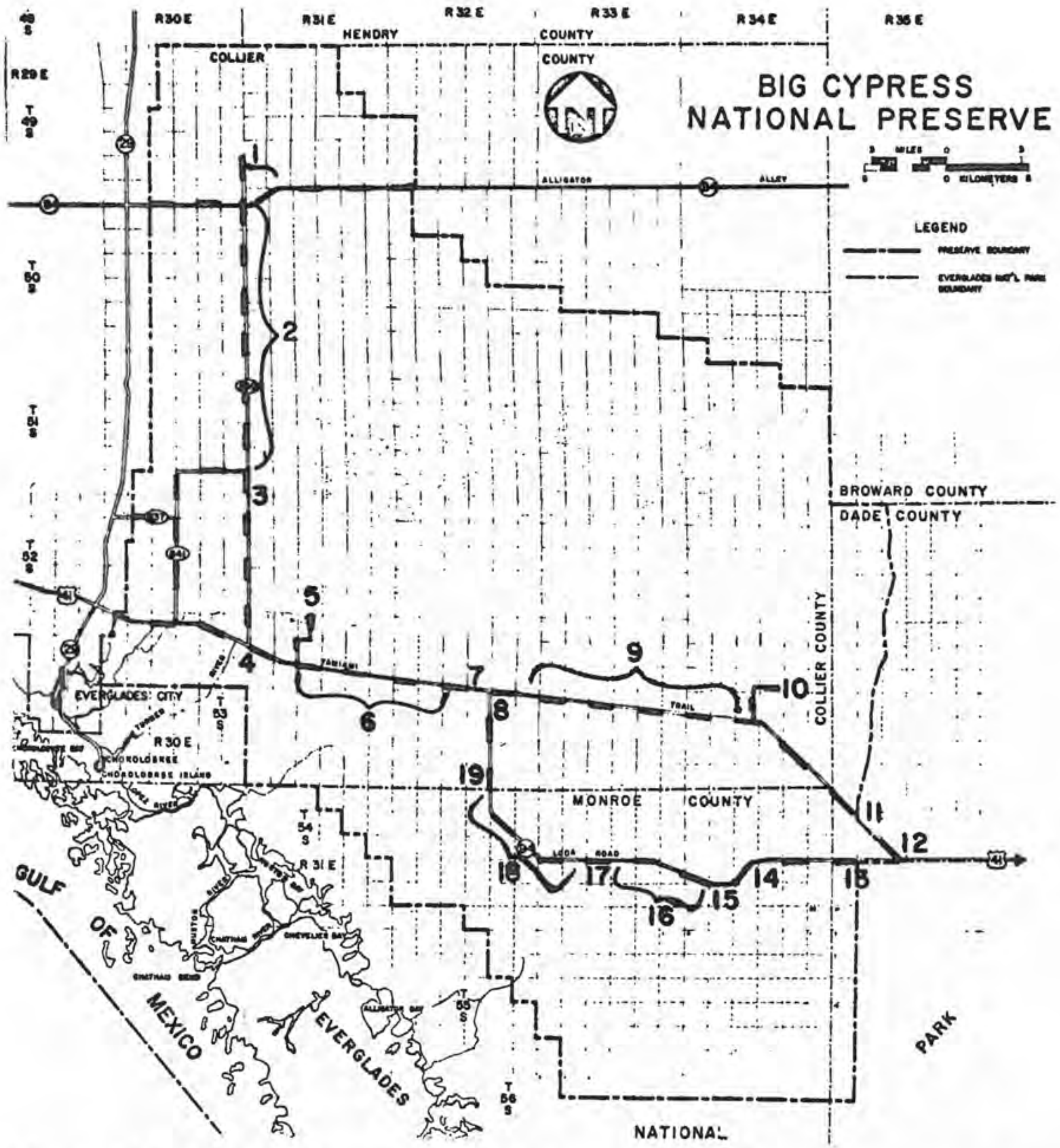


Figure 13. Locations of extensive trail water flow survey sites.

Table 125. Flow velocity (cm/sec) measured during extensive trail water flow survey.

	Trail			Habitat			Trail / Habitat
	$\overline{X}$	S.E.	n	$\overline{X}$	S.E.	n	
Trail Oriented with Flow							
In Marl Marsh							
Buggy	3.2	1.0	11	1.9	0.2	10	1.7
Airboat	3.1	0.2	8	2.3	0.2	8	1.3
In Small Cypress	3.2	1.5	13	1.5	0.2	13	2.1
Entering Strand From Wetland	2.8	0.4	8	1.5	0.2	7	1.9
Entering Canal From Wetland	10.5	5.8	8	2.4	1.1	8	4.4
Trail Perpendicular to Flow							
In Marl Marsh	1.8	0.5	7	1.6	0.4	7	1.1
In Small Cypress	1.3	0.5	4	1.2	0.4	4	1.1
Entering Strand From Wetland	2.0	0.4	3	1.2	0.6	3	1.7

The most significant impacts of these trails might be their continued flow after water movement has ceased in the general area, which might locally reduce hydroperiods and aggravate dry season droughts to some extent. However, this impact could probably be minimized by creating occasional ridges, level with the surrounding terrain, across trails that are a problem. These ridges would impede low water flow, while not affecting ORV use or high water flows.



1 Bear Island Unit Camp Area
2 CR 839 north of CR 837
3 Concho Billie Trail
4 Turner River Canal Landing
5 Burns Lake
6 U.S. 41, Burns Road to Monument Lake
7 Monument Lake
8 Monroe Station
9 U.S. 41, Monroe Station to Jetport
10 Jetport
11 L-28 Canal
12 Forty Mile Bend
13 Park Boundary Trail
14 Lostman's Landing
15 Pinecrest
16 Loop Road, Pinecrest to Pace's Dike
17 Pace's Dike and Sawmill Road
18 Loop Road, Pace's Dike to Sig Walker Landing
19 Sig Walker Landing

▬ ▬ ORV Census Route

Figure 14. The ORV periodic census route and locations of major access points for ORVs transported to BICY.

PART IV.

OFF-ROAD VEHICLE CENSUS

METHODS

We conducted an initial inventory and periodic census of ORVs between September 1978 and March 1980 to determine the numbers of each type of vehicle used in BICY, and their major areas and periods of use. The initial one-day count of all vehicles parked in BICY was made before the hunting season in September 1978, when all roads within the preserve were cruised, and ORVs at private residences or storage areas counted. Although ORVs parked at remote camps were not included, this total is our best estimate of the number of vehicles permanently parked in the preserve. We made periodic censuses along all BICY roads and at major camping areas (Figure 14) where we counted ORVs that had been transported into BICY, or if ORVs were not present at the time, trailers or trucks capable of transporting ORVs. The once-a-month census was conducted on random alternating weekdays and weekends during the non-hunting season. Census frequency increased during the hunting season and in addition to several random weekend and weekday samples, included one day during each peak use period: opening weekend, an opening weekday, Thanksgiving weekend, and the Christmas-New Year week-long holiday. After the January 1979 sample, we normally conducted the census by plane rather than on the ground, following the same route. The plane flew at an altitude of 150 m, which allowed examination of an approximately 0.8 km wide corridor. This increased the accuracy of the census, since occasionally the exact type of ORV brought in by a particular transport vehicle could be observed, and also fishermen and others not using ORVs, but parked along the roads, could be identified.

We designed the periodic census to be as complete and objective as possible, but a number of problems reduced the accuracy of the results. Subjectivity was unavoidable in interpreting what types of ORVs were brought into the area based solely on the type of vehicle and trailer that had transported them and were parked along the roads. For example, a pickup truck-ATC trailer combination, which were commonly seen along roadways, could carry zero to four ATCs or trail bikes and since we rarely encountered the ORVs being unloaded, we had to subjectively estimate these numbers. Some ORVs were brought in on trailers which were then removed until a prearranged pickup time, which lessened the liklihood of that vehicle being included in our census. It must be remembered that the data for the periodic census represent vehicles transported into the preserve and that total ORV use of the area on any particular date would also include some vehicles normally kept at BICY storage areas, remote camps, or private property adjacent to BICY. This was most significant when considering swamp buggy use.

These data represent a minimum estimate of numbers of ORVs used in the BICY and, if comparable censuses were conducted in the future, could provide information on changing use intensities. However, since all ORVs used in BICY were not present at the same time, even our maximum number of vehicles recorded in the periodic census added to the number counted in the initial inventory should not be construed to represent the total number of individual ORVs used in BICY during the course of a year. Only a registration or permitting program could provide this type of information.

RESULTS and DISCUSSION

Initial Inventory

We observed only three vehicle types in the initial inventory of ORVs permanently parked in BICY (Figure 15). Swamp buggies were by far the most common type, while a much smaller number of track vehicles were second, and airboats third. A much higher percentage of buggy and track vehicles used in BICY are permanently located there, because the size and weight of these vehicles makes them harder to transport and store elsewhere. Airboats and ATCs are much easier to transport and were not well represented in this survey.

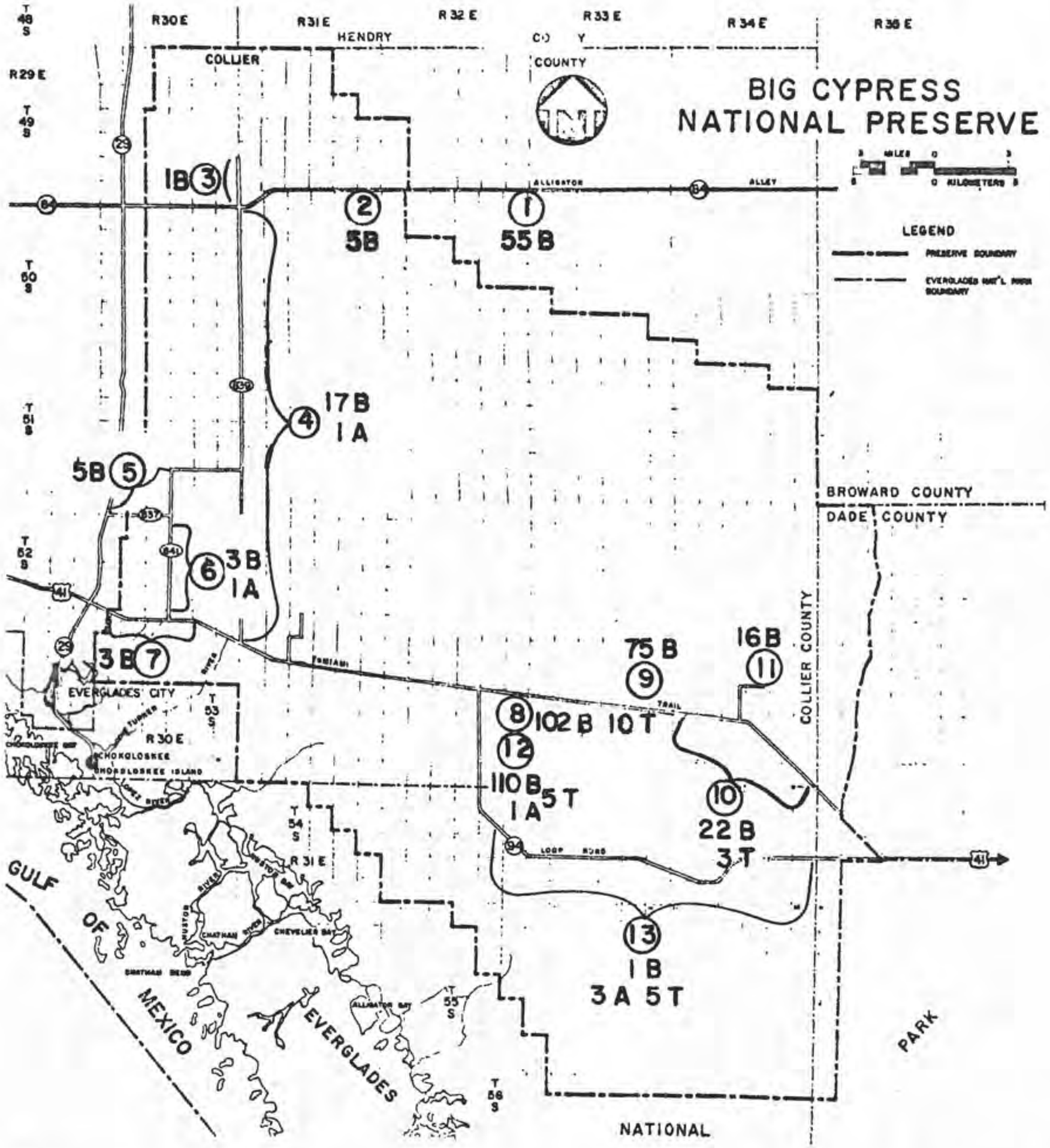
Most of the vehicles were stored along U.S. 41 between Monroe Station and Trail Center and along the Loop Road. Another important buggy parking area is actually north of the preserve boundary along Alligator Alley, but most vehicles parked there are used in the preserve. The major limitation of the initial inventory involved our inability to count ORVs parked on private property or at back-country camps. We feel that these could conservatively increase our count by 10-20 percent.

Periodic Census

Data from our periodic census indicate that ORV use follows a highly seasonal pattern, with greatest use at the beginning of the hunting season in eary November (Figure 16). Use decreased to much lower levels for the remainder of the approximately two-month-long hunting season, and was very low during the rest of the year. Weekend activity was consistently higher than weekday activity.

All vehicle types exhibited the same seasonal and weekday-weekend use patterns. Swamp buggies were consistently the most numerous type of ORV used in the preserve (Figure 17), while ATCs and airboats were usually less than half as numerous (Figure 18). Track vehicles and trailbikes were least common, except for one day when there was a rally-type trailbike gathering at Burn's Lake. All vehicles were present in approximately similar low numbers during the non-hunting season.

Although pickup trucks encountered along roadways were not really "off road" vehicles, their presence in BICY was relevant to total ORV use. While pickup trucks did not necessarily transport any ORVs into BICY, they were capable of carrying two ATCs or even more trailbikes. Since trailbike use during hunting season was generally limited by high water and boggy



1 Kissimmee Billy Parking Area
2 Cypress Road
3 North end CR 839
4 CR 839 south of Alligator Alley
5 CR 837
6 CR 841
7 U.S. 41 Ochopee
8 Monroe Station
9 Patten's
10 U.S. 41 between Patten's and Trail Center
11 Jetport
12 Everglades Conservation Club
13 Loop Road

	Total
A = Airboat	8
B - Swamp Buggy	415
T = Track Vehicle	23

Figure 15. Initial inventory of ORVs permanently parked in BICY on September 24, 1978.

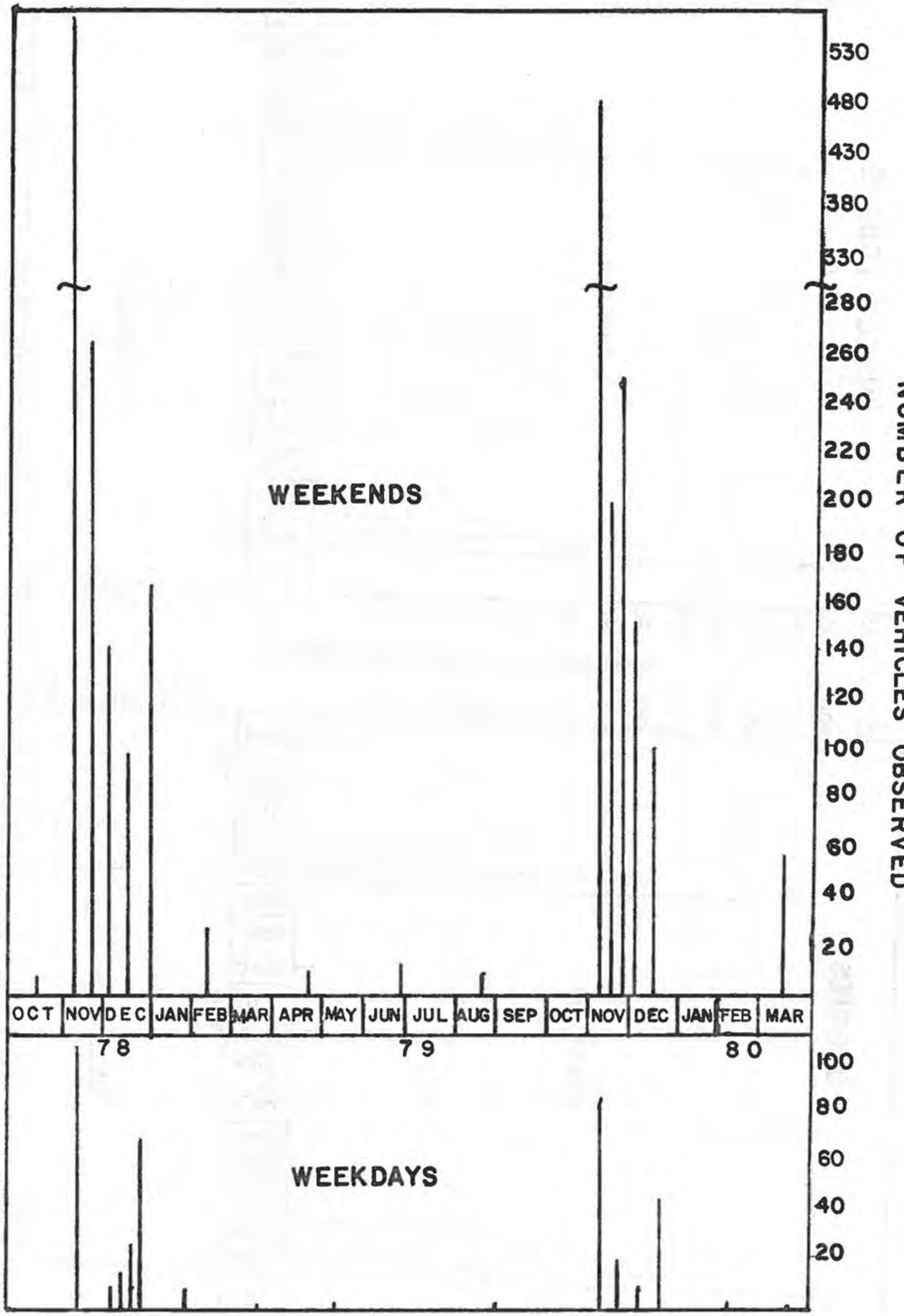


Figure 16. Total numbers of ORVs observed in BICY on each periodic census.

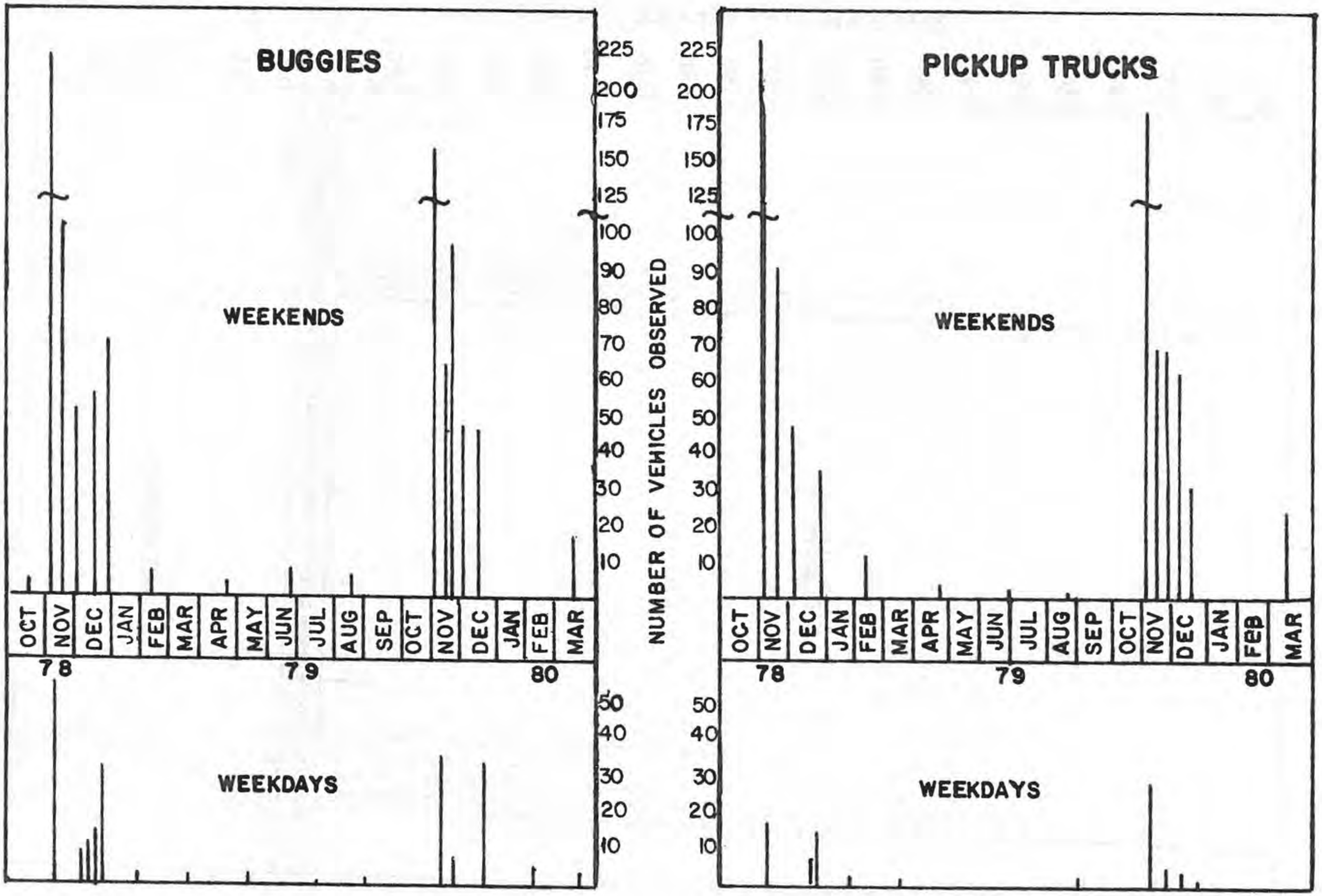


Figure 17. Number of buggies and pickup trucks observed in BICY on each periodic census.

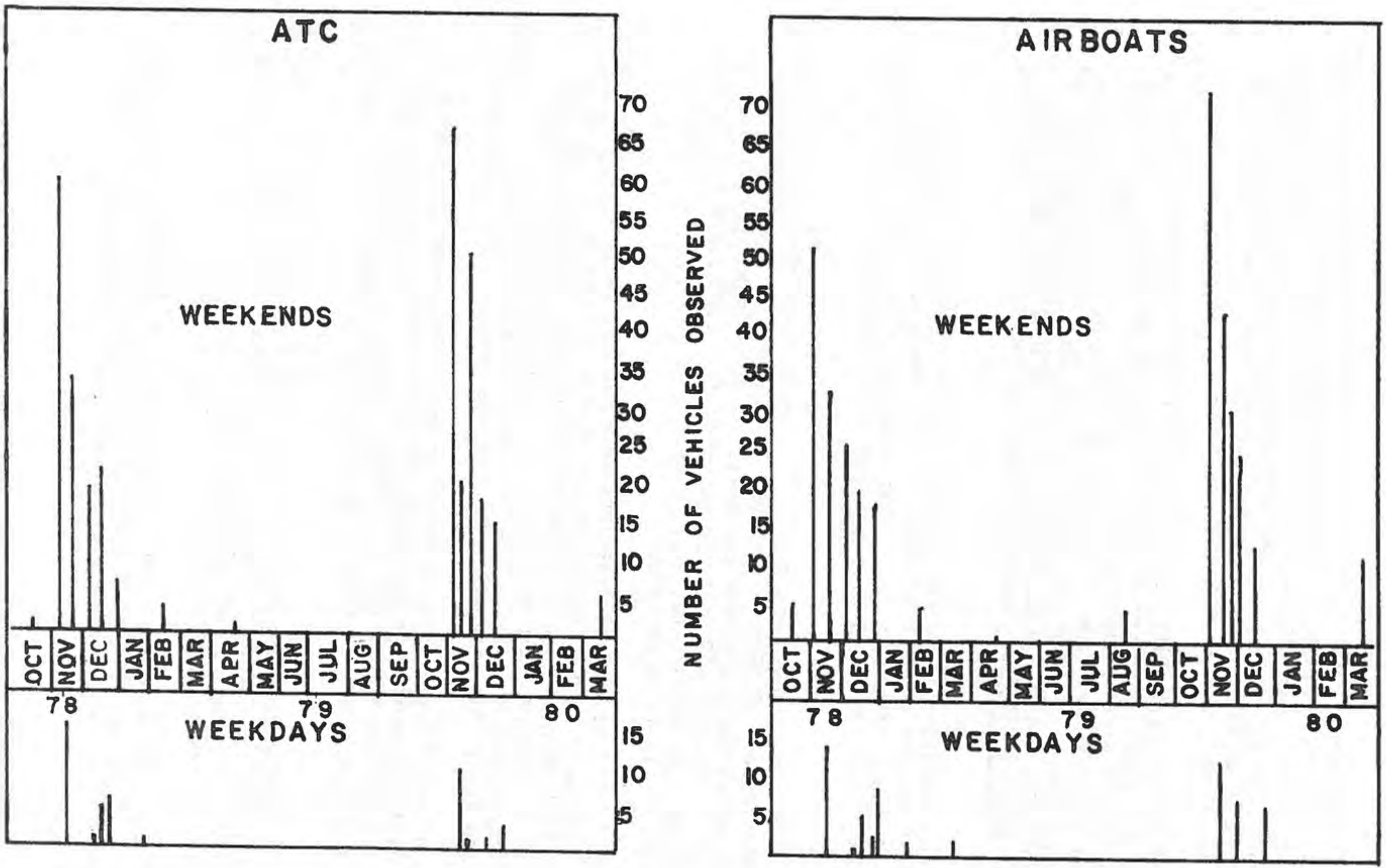


Figure 18. Numbers of ATCs and airboats observed in BICY on each periodic census.

soil, we feel pickup truck numbers were more relevant to ATC use, although we have no data on the numbers carried into BICY by pickup trucks. (ATC numbers in Figure 18 are totals for actual ATC and ATC trailer sightings). We estimate however, that a significant number of uncounted ATCs were transported by pickup trucks, and that our ATC count could probably be doubled to achieve a more realistic estimate.

The locations of major BICY access points for ORVs transported into the preserve are shown in Figure 14, while Table 126 provides a breakdown of the kinds of vehicles that use these locations. The "other sites" represent observations made at a number of additional widely scattered locations. The main ORV access points within BICY include Bear Island Unit Camp Area, Concho Billie Trail, U.S. 41 from Burns Road to Monroe Station, the Jetport, and Loop Road from Park Boundary Trail to Pace's Dike.

Most swamp buggies entered the preserve either along U.S. 41 between Burns Road and the Jetport or along CR 839 from Concho Billie Trail to Bear Island. Five sites receiving major use were: Bear Island Unit Camp Area, Concho Billie Trail, Monument Lake, Monroe Station, and the Jetport.

ATC use was also highest along U.S. 41 between Burns Road and the Jetport. Legal prohibition of ATCs in the Bear Island Unit during the 1978-1979 hunting season and low public awareness of the change legalizing their use there in the 1979-1980 season was probably responsible for the few observations of them in that area. The reason for the lack of ATCs on Concho Billie Trail is not known.

The majority of airboat observations were made at two sites on the Loop Road. Lostman's Landing accounted for nearly half of all airboats censused, and the Park Boundary Trail for nearly 25 percent. Airboat trailers recorded at Pinecrest probably also used Lostman's Landing. Other significant airboat access sites included Sig Walker Landing on the Loop Road, and Turner River Canal Landing at the junction of U.S. 41 and CR 839.

The majority of track vehicle sightings were also along the Loop Road. The private properties in the Pinecrest area and the Loop Road west of Pinecrest to Pace's Dike had the highest numbers. Park Boundary Trail was the only access site with high percentages of both track and airboat use.

Very few trailbikes were seen on a regular basis in the preserve, and what activity did occur was at a variety of points along U.S. 41. As mentioned previously, this was a very difficult ORV to inventory since it is small and easy to transport and conceal in a truck or van.

All outboard motor boats we observed were at the junction of L-28 canal and U.S. 41 or at Forty Mile Bend. Very few boats were ever observed in the U.S. 41 canal and we feel virtually all activity was in the L-28 canal.

Table 126. Total numbers of each vehicle type and the percentage of each counted at BICY access points during the periodic ORV census.

Location	Swamp Buggy	ATC	Airboat	Track Vehicle	Trail Bike	Outboard Boat	Pickup Truck
1 Bear Island Unit Camp Area	23	2	-	-	-	-	6
2 CR 839 north of CR 837	7	7	-	2	-	-	4
3 Concho Billie Trail	13	1	-	-	-	-	3
4 Turner River Canal Landing	1	1	11	-	3	-	3
5 Burns Lake	1	5	-	-	54	-	3
6 U.S. 41, Burns Road to Monument Lake	5	9	-	-	4	-	11
7 Monument Lake	11	27	-	-	15	-	11
8 Monroe Station	10	5	<1	7	8	-	5
9 U.S. 41, Monroe Station to Jetport	4	7	-	-	1	-	6
10 Jetport	17	12	-	-	4	-	9
11 L-28 Canal	-	1	<1	-	3	40	4
12 Forty Mile Bend	-	-	-	-	-	58	1
13 Park Boundary Trail	-	-	23	17	-	-	<1
14 Lostman's Landing	-	4	46	3	-	-	-
15 Pinecrest	1	2	6	22	-	-	1
16 Loop Road, Pinecrest to Pace's Dike	1	6	4	19	-	-	11
17 Pace's Dike, Sawmill Road	1	-	-	6	-	-	4
18 Loop Road, Pace's Dike to Sig Walker Landing	<1	2	<1	-	-	-	2
19 Sig Walker Landing	-	1	6	8	-	-	1
20 Other Sites	5	8	2	16	8	2	14
Total Observations	1,110	371	422	42	72	55	895

Pickup trucks, without vehicle trailers, or ORVs in them, were observed at nearly all points along the survey route. Most observations were made along U.S. 41 between Burns Road and the Jetport, but all major roads had significant numbers of sightings.

CONCLUSIONS

Part I. Vehicle Impact Study

(1) Habitat type did not generally influence noise levels.

(2) Noise levels were dependent primarily on engine type and rpm. Swamp buggies had similar relatively low noise levels except when an automatic transmission resulted in higher rpms. The airboat produced the highest overall noise levels, while the ATC and track vehicle produced intermediate noise levels.

(3) Water level was the single most important environmental factor influencing severity of intial vehicle impacts, and was inversely related to the number of passes required to reach a specific level of impact. When water is above ground or near the soil surface at the time ORV impacts occur, the degree of impact and time required for recovery are greatly increased. Water levels also indirectly influence ORV impacts by controlling vegetation and soil characteristics.

(4) Small cypress and airboat-track vehicle marl and peat marshes were most sensitive to ORV impacts. Wheeled-vehicle marl marshes were only slightly less sensitive. Pineland was the least sensitive, and sand marsh just slightly less so.

(5) Pine plots showed the greatest recovery, which was complete after one year for most parameters measured, and sand marsh showed only slightly less recovery. In all other habitats recovery was incomplete for most parameters measured at all impact levels. There was a general trend of decreasing recovery with increasing impact level.

(6) The most severe visual impacts were associated with the track vehicle and the least with the airboat. Of the parameters we measured, this showed the least recovery during the first year.

(7) Among the types of soil impacts, soil compressibility was least affected. Soil compaction never occurred, while soils in some lanes were still a loose slurry one year after the tests.

(8) Rutting was the most severe soil impact. However, rut depths tended to decrease rapidly following the tests, and were generally quite shallow, if detectable, one year later.

(9) The height of ridges along the test lanes were minor initially and generally undetectable one year after the treatments.

(10) Of the quantitative measures of ORV impacts on live vegetation, initially average height of understory vegetation was most affected by ORVs, while percent cover was least affected and biomass was intermediate. Of the three parameters, recovery was greater for height and biomass than percent cover during the first growing season.

(11) Standing litter was still severely reduced in the vehicle lanes one year after the tests. This was accentuated by the fact that the current year's production had not yet died.

(12) Taxonomic composition was altered with the gain or loss of one or more dominant species in at least the medium and heavy impact lanes in virtually all plots. Small cypress plots had both missing taxa and reduced numbers of other taxa compared to the controls, while wheeled-vehicle marl marsh plots had only reduced numbers. New taxa had appeared and/or the frequency of others had increased to levels greater than were present in the controls in all of the wheeled-vehicle plots by the end of the first growing season. Plant diversity was decreased only in track vehicle treatments, which also consistently eliminated or at least reduced the number of taxa in test lanes. Only the airboat treatments exhibited essentially no change in taxonomic composition during the vehicle impact study. However, few differences between test lane and control samples were consistent enough to allow us to predict the long-term direction or duration of these changes.

(13) The degree of overall impact generally depended on the amount of soil disturbance, and thus measurement of soil parameters would provide the most sensitive means of quantifying initial impacts. However, the soil recovered much more quickly than did the vegetation, and thus measurement of vegetation parameters would be the most sensitive means of quantifying recovery from impacts.

(14) Degree of impact on shrubs and small trees increased with plant size and impact level. Recovery of cypress and wax myrtle was facilitated by resprouting during the growing season, while willow tended to show increased mortality.

(15) Variations in swamp buggy characteristics (weight per unit area and tread type) had a minor effect on their ability to impact study sites compared to water levels, and most were not important in terms of recovery rates after one year. In marl substrate habitats, the tractor buggy produced heavy impacts in slightly fewer passes than the chain and heavy buggies. The light buggy required two to four times as many passes to reach the same level of impact, and the resulting relatively severe ruts, which still existed one year later, were a function of the increased number of passes.

(16) Swamp buggies and the track vehicle generally produced the most severe impacts and showed least recovery after one year. The ATC had the least impact of the wheeled vehicles, but had only slightly better recovery rates. The airboat had the least impact of all vehicles and showed complete recovery after one year for most parameters.

(17) In general, once significant damage has been done to a habitat by a particular vehicle type, it will continue to be a significant impact for at least one year. Thus, unless a long-term increase in significant impacts is acceptable on portions or all of BICY, it will be necessary to implement

management practices that will minimize the creation of significant impacts wherever they are deemed inappropriate.

Part II. Old Trail Recovery Study

(1) Initially the old trail sites were 2-6 m wide, and all exhibited severe visual impacts. Most were deeply rutted across their whole width and/or worn to bedrock. All, but one of the wetter sites had little or no vegetation in the lanes, while the drier sites generally had some. Soil ridges were rarely seen along the trails. Taxonomic composition in old trails was consistently less diverse than in adjacent control areas at all sites.

(2) Airboat trails through marl marshes were the only sites exhibiting relatively little or no impact, except in terms of taxonomic composition, which was greatly reduced in diversity in the trails.

(3) Percent recovery of virtually all parameters in old trail study plots was less than 30 percent and frequently less than 15 percent after one growing season. Vegetation height was the only parameter that consistently showed considerably more recovery.

Part III. Trail Water Flows

(1) While surface water flow velocities in trails perpendicular to the direction of natural flow were generally not affected, flow velocities in trails oriented with the flow were increased by a factor of two to four times.

(2) Flows in some trails continued after they had ceased in the the surrounding habitat due to water table decline.

(3) Once flows began, their velocity tended to remain more or less constant.

(4) The small increase in cross-sectional flowway area associated with rutted trails suggests that ORV trails have a very minor impact on the total water budget of BICY. The most significant impacts might be associated with a shortened hydroperiod in localized areas where a slightly more rapid decline in the water table may occur as it approaches and then initially declines below the general ground surface.

Part IV. Off-Road Vehicle Census

(1) Of the ORVs permanently parked in or near the preserve, the majority were swamp buggies, with much smaller numbers of track vehicles and airboats.

(2) Of the ORVs transported to the preserve, again the majority were swamp buggies. ATCs and airboats each totaled about one third the number of buggy observations, while track vehicles were much less frequently encountered.

(3) Use of all types of ORVs was largely concentrated within the early November-early January hunting season, with twice as many vehicles counted on opening day as compared to any other day of the year.

(4) Vehicle use was consistently greater on weekends than on weekdays.

(5) Access points for ORVs were located along the Loop Road, Tamiami Trail, and Turner River Road. There were no major access points along Alligator Alley within BICY.

(6) Airboat and track vehicle use was concentrated south of the Loop Road and south of Tamiami Trail west of Monroe Station, where buggies and ATCs were less common.

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