OFF-ROAD VEHICLE IMPACTS IN THE BIG CYPRESS NATIONAL PRESERVE

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All commonly used types of off-road vehicles were tested in major Big Cypress habitats. The primary factor influencing vehicle impacts was soil moisture, which was inversely related to numbers of passes required to produce specific levels of impact. Variation in vehicle characteristics was less important. Cypress habitats were impacted at the lowest use intensities, pine only at the highest, and marshes at intermediate intensities. Swamp buggies and track vehicles produced the most rapid and severe impacts and ATCs and airboats the least. Woody vegetation impacts increased with plant size and use intensity. Engine type and rpm determined noise levels.

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 people, 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, techniques, 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 (Godfrey et al. 1975, Harrison 1974), symposia (Committee on Environment and Public Policy 1977), and reports (U.S. Dept. of the Interior 1971, Baldwin 1970, 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 in the Big Cypress National Preserve (BICY) is limited. Schemnitz and Schortemeyer (1973) 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, a discussion of when and why they are used, an analysis of the historical development of ORV trails, and a qualitative assessment of obvious impacts. 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.

In order to develop a data base for decisions on the future role of ORVs in the BICY, the National Park Service (NPS) contracted the National Audubon Society Ecosystem Research Unit to evaluate ORV impacts and recovery rates in all 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 marshes. Initial impacts were evaluated, and during the following winter we made quantitative measurements of soil and vegetation impacts. Other aspects of the study that will not be reported here include: monitoring recovery of trails that have been in use for many years; evaluating the effects of deeply rutted trails on natural surface water flows; and determining when and where different types of ORVs are used.

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 represented by a single vehicle each, while five vehicles were chosen to represent the highly variable swamp buggy type (Figures 4-6). The swamp buggies chosen represent the wide range of total weights, weight per unit area (pounds per square inch [psi]) on ground surface, and tread types used in the Big Cypress. The sample includes one low and one high psi buggy, and three intermediate psi examples with the most common tire tread types used in the Big Cypress, smooth, smooth with chains, and tractor. All buggies were two axle, four-tired, 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.

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. A total of twelve plots (3 each in sand marsh, marl marsh, small cypress and pine habitats) were established for wheeled vehicle treatments, and six plots (3 each in peat and marl marshes) for the airboat and track vehicle treatments.

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 few 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. Treatments were made at 4 m intervals along the baseline in marsh habitats, and at 6 m intervals in pine and cypress habitats. 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 treatments in marshes). Each vehicle treatment was at least 70 m long through undisturbed habitat. This was several times the distance needed for vegetation sampling 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 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 an intermediate 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. Our smooth-tired swamp buggy would not run in marl prairies 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 run 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.

Impact Assessment

Immediately after all treatments, rut depths were estimated and visual impacts on vegetation were rated on a numerical scale: zero for no discernable impact; one for slight visual impact but little actual disturbance, such as vegetation bent over but not removed; two for moderate impact, less than half of the vegetation in ruts severely damaged or removed; three for severe impact, more than half but not all of the vegetation in ruts severely damaged or removed; and four, all vegetation in trail removed. 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 of the 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.

Detailed measurements of impacts in wheeled vehicle treatment plots were done during the month of February approximately four months after impacts were made. Airboat and track vehicle impacts were not measured until the middle of March, five and one half months after airboat treatment and three months after track 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 impacts showed no recovery at all. 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.

The first set of quantitative measurements, the pre-growing season sample, involved rating visual effects at 30 random 0.5 m segments along the test lane using the numerical system described above. The depth of the rut and height of the adjacent ridge of displaced soil, where present, was measured at the same 30 points. Three individual plots 10x100 cm (shaped to fit vehicle tracks) were located randomly along one track of each vehicle treatment. Nine control plots of the same shape were randomly located adjacent to the vehicle tracks in each study plot. Percent cover and height of vegetation was measured, and species and their relative abundance noted. Living vegetation was clipped, dried at 105°C, and weighed.

Impact on Shrubs and Trees

A numerical rating system was developed to assess damage to shrubs and small trees struck by vehicles during test treatments: 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 wheeled vehicle tracks in pine, cypress, and sand marsh study plots, and airboat and track vehicle trails in peat and marl marshes were inspected for impacted woody vegetation. Impacts on each tree and shrub species in various size classes present were evaluated according to the rating system.

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 [10 ft] of vehicle) and end (approximately 100 m [300 ft] away from vehicle) of five replicate test runs in each plot.

Site Characteristics

In general, soils and plant communities differed only slightly among replicate plots (Table 2), and in most cases, these differences were not felt to have significantly affected vehicle impacts.

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

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.

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 aquatic species. Sand marsh plots 2 and 3 had no surface water throughout the treatment period, however 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*.

The only differences in the peat marsh plots were

Table 2. Characteristics of ORV study sites in Big Cypress National Preserve.

Wheeled Vehicle Study Plots	Depth to Rock (cm) x̄	Range	Water Depth (cm)*	Soil Description	Vegetation
Small Cypress 1	18.3	5-35	3-10	3-5cm periphyton over grey-brown to grey sandy marl, interspersed recent freshwater shell.	Grass and sedge understory, Panicum, Muhlenbergia, Cladium, Dichromena. Dwarf cypress, Taxodium overstory 3-7 m, smaller 1-2 m scattered cypress present.
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 grey clay-like marl with interspersed freshwater shell.	Grass and sedge understory as above but with Muhlenbergia dominant. Cypress slightly smaller, up to 5 m.
Small Cypress 3	21.0	10-45	8-13	3-5 cm periphyton over grey sandy marl with interspersed freshwater shell.	See Small Cypress 2b
Marl Marsh 1	25.1	0-76	0**	Soil variable, some areas marl from surface to bedrock while other areas mostly sand, generally 3-10 cm grey marl over grey brown sandy marl.	Treeless grassland, Muhlenbergia and Panicum dominant grasses, Centella dominant forb, Cladium common sedge.
Marl Marsh 2	14.5	5-45	0**	Dark grey sandy marl over dense light grey marl.	See Marl Marsh 1

Table 2. (cont.)

Wheeled Vehicle Study Plots	Depth to Rock (cm) $\bar{x}$	Range	Water Depth (cm)*	Soil Description	Vegetation
Marl Marsh 3	18.0	5-50	0**	3 cm periphyton over slightly sandy grey-brown marl.	See Marl Marsh 1
Sand Marsh 1	30+	20-25		5-10 cm dark organic stained sand over brown sand.	Forbs *Ludwigia*, *Bacopa*, *Centella* dominant, *Panicum* present. Scattered buttonbush, *Cephalanthus*.
Sand Marsh 2	30+	0		3-5 cm dark organic sand over brown sand.	*Spartina* and sawgrass dominant, *Centella* common forb, *Panicum*, *Proserpinaca* present.
Sand Marsh 3	30+	0		Uniform medium brown sand, trace of marl mixed in.	*Muhlenbergia* and panicums dominant, *Centella* common
Pine 1	13.5	0-25	0	3-5 cm salt-pepper sand, 5-10 cm brown sand (slight marl content) over brown sand with rusty mottling.	Wire grass, *Aristida*, and *Panicum* dominant understory, scattered saw palmetto, *Serenoa*, estimated 20% of total cover. Overstory 7-15 m pine.
Pine 2	10.9	0-30	0	3-7 cm dark organic sand over light brown sand, some marl mixed in last 3 cm before rock, 5-10% of plot is rock at surface.	See Pine 1

Table 2. (cont.)

Wheeled Vehicle Study Plots	Depth to Rock (cm) $\bar{x}$	Range	Water Depth (cm)*	Soil Description	Vegetation
Pine 3	19.0	5-50	0**	5-10 cm dark organic sand over light brown sand.	See Pine 1
Airboat and Track Study Plots					
Marl Marsh 1	18.5	5-50	10-15	3-5 cm periphyton over dark grey marl with interspersed freshwater shell.	Sawgrass, 1 m or less dominant, some spike rush, *Eleocharis*, opening Few scattered dwarf cypress, 1-3 m.
Marl Marsh 2	17.3	10-30	10-15	See Marl Marsh 1	See Marl Marsh 1
Marl Marsh 3	19.3	10-35	8-13	5-10 cm crumbly light grey marl interspersed with freshwater shell.	Sawgrass, 1 m or less dominant.
Peat Marsh 1	27.9	5-50	20-35	Peat soil highly variable in depth, occasionally 3-5 cm of marl below peat over bedrock.	Sawgrass and cattail, *Typha*, 2-3 m dominant. Occasional small cypres and willow, *Salix*.
Peat Marsh 2	24.4	10-50	20-35	Sandy peat variable in depth.	Sawgrass 2-3 m, scatter willow and cypress.

Table 2. (cont.)

Airboat and Track Study Plots	Depth to Rock (cm) $\bar{x}$	Range	Water Depth (cm)*	Soil Description	Vegetation
Peat Marsh 3	25.1	10-45	20-30	Peat; variable in depth, deeper soil has 3-5 cm marl below peat over bed-rock.	See Peat Marsh 2

* Relative depth during wet season.

** Water table approximately at ground surface.

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.

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 cypress sites.

Use Intensity Related 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 7).

The smallest number of passes necessary to create significant impacts occurred in small cypress habitats, where heavy and intermediate psi (tractor-tired and chain-equipped) buggies quickly impacted the sites. The light psi vehicle took only slightly longer to produce equivalent impacts compared to the other buggies. Smooth-tired intermediate psi buggies could not run 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 passes broke up the surface root mat. The ATC however, because of its low psi, did not displace soils as quickly as the other wheeled vehicles. Since its impacts were more gradual, relatively fine differences in the resistance of 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 2) and longer hydroperiods. Thus, not only were cypress plots in general more susceptible to impact than other relatively drier habitats, but within this habitat the wetter sites were more susceptible.

In marl marsh study plots, the intermediate psi tractor-tired and chain-equipped 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 psi vehicle performed similarly to the tractor-tired and chain-equipped 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 run in plot 2. The light psi vehicle again required somewhat higher numbers of runs 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 vehicles in marl marshes and itself in cypress plots, the number of passes by ATCs required to produce impacts were considerably higher at two of the marl marsh sites, where they did not achieve heavy impacts after even 100 passes. However, numbers of ATC passes required for medium and heavy impacts in plot 3 were comparable to the cypress plots. We feel these results were significantly influenced by soil moisture conditions when the tests were made. Tractor and chain buggies were the first vehicles tested in marl marsh plots when they were wettest. This probably influenced the numbers of passes required for medium and heavy impacts and resulted in their being similar to the cypress plot results. As the dry season progressed soil moisture in plot 1 probably 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.

All swamp buggies made comparable numbers of runs to achieve medium impacts in sand marsh plots, and in all cases, these averaged somewhat higher than runs to medium impact in marl marsh plots. The ATC however averaged slightly fewer runs to 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 impact in the inundated sand marsh plot 1.

Only three vehicles were used to make medium and heavy impacts in pinelands. Intermediate psi chain-equipped and smooth-tired 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 medium impact in all pine plots, also averaging slightly higher than in sand marsh plots. Neither of the buggies tested achieved 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 averaged higher than in any other habitat.

In the separate marl marsh plots for airboat and track vehicle tests, 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. The same vehicle required a considerably larger number of passes to produce medium and heavy impacts in peat marsh plots. In general, the peat marshes appeared to tolerate as much or more use as most other habitats used by wheeled vehicles, despite the fact that it is one of the wettest habitats (Table 2).

Medium impacts in peat and marl marsh plots were reached in 14 passes by airboats. Airboats never produced heavy impacts in any test plots.

In summary, the numbers of passes required to produce comparable levels of impact on vegetation and soils varied primarily according to moisture conditions, habitat, and vehicle types. The wetter a site is, both in terms of water depth and hydroperiod, the more quickly impacts occur. The most quickly impacted BICY habitats, in decreasing order were small cypress, marl marsh, sand marsh, and pine. Peat marshes appeared to withstand well the types of vehicles normally using them. While showing some minor differences, all types of swamp buggies caused similar rates of impact in each habitat. ATCs were generally slowest to produce impacts. Track vehicles quickly impacted marl marshes, but peat marshes relatively slowly. Because they float, airboats did not significantly affect soils, although a sufficient number of passes eventually eliminated the vegetation.

Rut Depth

The deepest average rut depths at all three impact intensities were produced in small cypress test plots (Table 3). This is also the only habitat where buggies frequently made ruts in a single pass, and consistently penetrated to bedrock at the heavy impact level. ATCs made no ruts in cypress or any other habitat on a single pass, and made ruts to bedrock only in cypress plot 3. The marl marsh plots were the next most severely impacted. While the one pass tests resulted in almost no rutting, most of the buggies tested eventually reached bedrock in two or more plots. ATCs did not produce ruts at any level, probably because the dense vegetation and litter was never penetrated by these low psi vehicles. In pine and sand marsh habitats, no ruts resulted from the one-pass tests. At greater impact levels, rut depth increased, but never became as severe as in the marl marsh and cypress sites. ATC rutting impacts were again negligible, except in the inundated sand marsh plot 1 at medium and heavy impacts. Pine plots 1 and 2 were not rutted by any vehicle at any impact intensity. However, the wetter pine plot 3 was rutted at medium and heavy impact levels by the two buggies tested. In general, among the different types of buggies, the one with tractor tires produced the deepest initial ruts and the light buggy produced the shallowest (Table 3).

Track vehicle ruts averaged 8 cm after a single pass in marl marsh and went to bedrock in all three test plots at the heavy intensity treatment level (Table 3). A single pass in peat left no rut, but all heavy impacts were to bedrock. Airboats made no ruts in any habitat at any impact level.

Rut depths measured during the pre-growing season sampling period (3 to 5 months after vehicle test runs) were sometimes dramatically shallower than the initial rut depths (Table 4). In all of the one pass and medium use intensity lanes, at most a few centimeters difference remained between the bottom of the rut and the ground surface. The deepest rut remaining in wheeled vehicle test plots was made by the light buggy in small cypress

Table 3. Average rut depth (cm) immediately after vehicle treatment.

								AIRBOAT	
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	16*	-	6	3	2	0			
Marl Marsh	2	-	0	0	0	0			
Sand Marsh	0	0	0	0	0	0			
Pine	0	0	0	0	0	0			
Marl Marsh							8	0	-
Peat Marsh							0	0	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	3	1			
Marl Marsh	3	-	6	4	2	0			
Sand Marsh	2	2	1	0	0	1			
Pine	-	2	2	-	-	0			
Marl Marsh							-	0	0
Peat Marsh							8	0	0
HEAVY IMPACT									
Small Cypress	19*	-	19*	19*	19*	12			
Marl Marsh	14*	-	19*	9	11*	0			
Sand Marsh	9	8	7	6	3	5			
Pine	-	6	3	-	-	0			
Marl Marsh							18*	0	0
Peat Marsh							27*	0	0

* All or most of replicate plots reached bedrock

Table 4. Percent decrease of rut depths 3-5 months after treatment.

								AIRBOAT	
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	94*	-	100	33*	100	N**			
Marl Marsh	50*	-	N	N	N	N			
Sand Marsh	N	N	N	N	N	N			
Pine	N	N	N	N	N	N			
Marl Marsh							12	N	-
Peat Marsh							N	N	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	83*	100			
Marl Marsh	67*	-	83*	100	50*	N			
Sand Marsh	75*	100	100	N	N	100			
Pine	-	50*	85*	-	-	N			
Marl Marsh							-	N	N
Peat Marsh							12	N	N
HEAVY IMPACT									
Small Cypress	89*	-	74	68	53	92*			
Marl Marsh	57	-	74	67	73	N			
Sand Marsh	44	25	29	33	33*	40			
Pine	-	67*	33*	-	-	N			
Marl Marsh							33	N	N
Peat Marsh							22	N	N

* Only ≲ 2 cm deep ruts remaining.
**N indicates no initial ruts.

habitat, and was only 9 cm deep. Tractor buggy ruts, which in this same habitat had initially penetrated over 16 cm to bedrock, had recovered to within 2 cm of the ground surface. Although the sand marsh had relatively shallow initial ruts, it showed relatively little recovery. This suggests that while marl substrates can be more severely impacted, they recover more rapidly than do sand substrates. However, actual rut depths were comparable between marl and sand substrates about four months following the test runs.

Track vehicle rut depths were difficult to measure because while the ruts appeared to have filled in, the material in them was not consolidated enough to support the weight of a meter stick. Percent recovery of track vehicle ruts was based on measurements to the bottom of this unconsolidated material, and thus indicates little recovery.

Vegetation Impacts

As observed for the initial rut depth data, initial qualitative estimates of vegetation impacts from wheeled vehicles were highest in small cypress habitat, and least in sand marsh and pine habitats (Table 5). There were no consistent differences in impacts between the different types of buggies, and the ATC produced only slightly lower initial impacts. Track vehicle impacts were basically similar to wheeled vehicles. Airboat impacts were also comparable for one pass, but were lower at medium and heavy use intensities. Most initial impacts involved only slight disturbance following one pass, less than half of the vegetation severely damaged as a result of medium use, and more than half of the vegetation severely damaged following heavy use.

Wheeled vehicle treatments showed little vegetation recovery in the three to five months following the test runs, which is not surprising since this was the non-growing season (Table 6). All track vehicle treatments with any living vegetation remaining after the initial runs, subsequently received higher visual impact ratings three months later, while those with complete kills initially still had no living vegetation. A single pass by the track vehicle in the marl marshes initially resulted in lanes in which less than half of the vegetation appeared to be severely damaged, but three months later had no living vegetation. Apparently a single pass by

Table 5. Degree of impact to understory vegetation immediately after treatment based on a scale from 0 (no impact) to 4 (mortality).

								AIRBOAT	
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	3.7	-	2.3	2.3	2.0	1.0			
Marl Marsh	1.7	-	1.0	1.0	1.0	1.0			
Sand Marsh	1.0	1.0	1.0	1.0	1.0	0.3			
Pine	1.0	1.0	1.0	1.0	1.0	1.0			
Marl Marsh							2.0	1.0	-
Peat Marsh							1.0	1.0	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	2.5	2.7			
Marl Marsh	2.0	-	2.3	2.5	2.0	2.0			
Sand Marsh	2.0	2.0	2.0	2.0	2.0	2.0			
Pine	-	2.0	2.0	-	-	2.0			
Marl Marsh							-	1.0	1.0
Peat Marsh							2.0	2.0	2.0
HEAVY IMPACT									
Small Cypress	4.0	-	4.0	4.0	4.0	3.3			
Marl Marsh	3.7	-	4.0	3.0	3.3	2.3			
Sand Marsh	3.3	3.3	3.3	3.0	3.0	2.6			
Pine	-	3.0	3.0	-	-	2.0			
Marl Marsh							4.0	1.0	1.0
Peat Marsh							4.0	2.0	2.0

Table 6. Percent recovery of understory vegetation 3-5 months after treatment based on our rating scale of from 0 (no impact) to 4 (mortality).

	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	AIRBOAT SLOW	AIRBOAT FAST
ONE PASS									
Small Cypress	43	-	13	-9	15	0			
Marl Marsh	6	-	0	-50	0	30			
Sand Marsh	30	30	70	-30	30	100			
Pine	0	0	0	0	0	30			
Marl Marsh							-100	100	-
Peat Marsh							-70	100	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	16	37			
Marl Marsh	40	-	13	40	25	35			
Sand Marsh	25	50	15	15	35	50			
Pine	-	25	55	-	-	50			
Marl Marsh							-	100	100
Peat Marsh							-65	50	50
HEAVY IMPACT									
Small Cypress	15	-	7	2	0	12			
Marl Marsh	3	-	15	17	21	13			
Sand Marsh	9	18	30	33	33	23			
Pine	-	20	23	-	-	0			
Marl Marsh							0	0	100
Peat Marsh							0	50	50

a track vehicle, although it did not remove all vegetation, damaged it enough to cause complete mortality. Single pass and medium impacts in peat marshes were not as severe, but mortality did increase three months later. Airboat treatments in marl marshes were only slightly visible initially, and had completely disappeared five months later. Impacts were slightly more severe in peat marshes where medium and heavy use intensity treatments were the only airboat runs even slightly visible five months later.

Quantitative measurements of vehicle impacts on vegetation were generally comparable to the qualitative visual estimates. A preliminary analysis comparing percent cover, biomass, and height of vegetation data between control and individual treatment plots at each site again demonstrated small cypress habitats were most severely impacted (Tables 7-9). The other habitats were more or less similar in their degree of impact, although in terms of vegetation height and biomass the sand marsh test plots differed less from their controls than did those in marl marsh and pine habitats.

One pass by a vehicle had little effect on percent cover and biomass of vegetation, but because of a vehicle's ability to push over vegetation while not actually removing it, height was frequently reduced by even one pass. Virtually all vehicle treatments produced significant vegetation impacts in all habitats at heavy use intensities. Percent cover was typically affected least and vegetation height most. There were no consistent differences in pre-growing season vegetation impacts between vehicle types, although the airboat treatments generally did not differ from the controls, particularly in the marl marsh sites.

Species composition in all test lanes and control plots at each site were comparable. This is not surprising since, although three to five months had elapsed between the treatment and sampling dates, these data were collected prior to the growing season. Thus, no species would have had an opportunity to respond to new conditions created by the vehicle impacts.

Shrub and Tree Impacts

In general, ORV impacts on particular species of shrubs and small trees are directly related to plant size

Table 7. Number of replicate plots in which percent cover of vegetation in treatment lanes did not differ significantly from control plots. The maximum possible number of replicate plots is three unless otherwise indicated by the number in parentheses.

								AIRBOAT	
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	0	-	1	0	1	2			
Marl Marsh	2	-	2	1(2)	3	2			
Sand Marsh	3	3	3	3	3	3			
Pine	3	3	3	3	3	3			
Marl Marsh							0	3	-
Peat Marsh							3	3	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	0	0			
Marl Marsh	0(1)	-	1	1(2)	0(2)	2			
Sand Marsh	0	0	0	0	3	0			
Pine	-	0	3	-	-	3			
Marl Marsh							-	3	3
Peat Marsh							0	3	3
HEAVY IMPACT									
Small Cypress	0	-	0	0	0	0			
Marl Marsh	0	-	1	0(2)	1	1			
Sand Marsh	0	0	0	0	0	0			
Pine	-	0	0	-	-	0			
Marl Marsh							0	0	3
Peat Marsh							0	0	0

Table 8. Number of replicate plots in which biomass of live vegetation in treatment lanes did not differ significantly from controls. The maximum possible number of replicate plots is three unless otherwise indicated by the number in the parentheses.

							AIRBOAT		
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	0	-	0	0	3	3			
Marl Marsh	0	-	3	2 (2)	3	3			
Sand Marsh	3	3	2	3	3	3			
Pine	3	0	0	3	3	3			
Marl Marsh							0	3	-
Peat Marsh							1	0	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	0	0			
Marl Marsh	0 (1)	-	0	0 (2)	0 (2)	0			
Sand Marsh	1	3	1	2	2	2			
Pine	-	0	0	-	-	3			
Marl Marsh							-	3	3
Peat Marsh							0	2	2
HEAVY IMPACT									
Small Cypress	0	-	0	0	0	0			
Marl Marsh	0	-	0	0 (2)	0	0			
Sand Marsh	0	0	1	0	0	0			
Pine	-	0	0	-	-	0			
Marl Marsh							0	3	3
Peat Marsh							0	1	1

Table 9. Number of replicate plots in which vegetation height in treatment lanes did not differ significantly from controls. The maximum possible number of replicate plots is three unless otherwise indicated by the number in parentheses.

								AIRBOAT	
	TRACTOR	SMOOTH	CHAIN	HEAVY	LIGHT	ATC	TRACK	SLOW	FAST
ONE PASS									
Small Cypress	0	-	0	0	0	0			
Marl Marsh	3	-	1	1 (2)	1	1			
Sand Marsh	2	3	1	2	2	3			
Pine	3	3	0	0	0	0			
Marl Marsh							0	3	-
Peat Marsh							3	3	-
MEDIUM IMPACT									
Small Cypress	-	-	-	-	0	0			
Marl Marsh	0 (1)	-	2	1 (2)	0 (2)	0			
Sand Marsh	0	1	0	1	2	1			
Pine	-	0	0	-	-	0			
Marl Marsh							-	3	3
Peat Marsh							0	3	3
HEAVY IMPACT									
Small Cypress	0	-	0	0	0	0			
Marl Marsh	0	-	0	0 (2)	0	0			
Sand Marsh	0	0	0	0	0	0			
Pine	-	0	0	-	-	0			
Marl Marsh							0	0	3
Peat Marsh							0	0	0

and number of vehicle passes. Vehicle characteristics within the range of wheeled vehicle types we tested had no obvious effect on severity of impact.

In small cypress test plots the only woody plants struck by test vehicles were cypress trees in the 0.5-3 m (1.5-10 ft) height range. Impacts resulting from a single pass were minor to trees less than 1 m (3 ft) tall, while larger trees were severely damaged (Table 10). Heavy use levels further increased the severity of the impacts (Table 11). Trees in the middle of the test lanes, which passed under the vehicle frame, but were not run over by the wheels, showed little or no impact in any size class.

A variety of woody plant species were impacted in pinelands, but the majority were small pine seedlings, 1 m (3 ft) or less tall. We divided saw palmetto into two 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 (3 ft) tall. The dominant species of pineland woody plants show the same trends as were observed in the small cypress habitats, that is, degree of impact increases with plant size and vehicle use intensity (Table 10). At heavy use levels, impacts were more severe on pine seedlings than on cypress (Table 11). However, comparing the pine and cypress data is somewhat misleading, since vehicles made many more passes in pinelands at the heavy use level. Impacts on palmetto were similar to those for cypress.

Wax myrtle, *Myrica cerifera*, and willow, *Salix caroliniana*, were also more severely impacted by heavier levels of use, but in contrast to cypress and pine, there was no consistent trend of increasing impacts associated with increasing size (Table 10). Myrtles were frequently killed, particularly at heavy use levels, but some were even killed by only one pass (Table 11). Willows appeared to be more resistant to damage, since none were killed by either airboat or track vehicle treatments. Airboat impacts were greater at higher speeds.

Vehicle Noise Levels

Sound level measurements for each vehicle type were very similar in all habitat types (Table 12). Of the

Table 10. Degree of impact on small trees and shrubs struck during off-road vehicle treatments based on a scale from 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	-	-	-	-	-	-	-
Willow									
One Pass	-	1.0	1.0	1.0	-	-	-	-	-
Medium Impact	-	1.0	1.5	1.5	-	1.7	-	-	-
Heavy Impact	-	-	-	2.0	-	2.0	-	-	-

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

Table 11. Percent mortality of small trees and shrubs struck by test vehicles. Numbers in parentheses represent the sample sizes.

POSITION IN LANE	CYPRESS	PINE	PALMETTO		MYRTLE	
			Small	Large	Pine Plots	Sand Marsh
IN TIRE TRACK						
One Pass	6 (49)	3 (131)	0 (9)	4 (67)	0 (24)	22 (18)
Medium Impact	-	32 (104)	0 (5)	28 (33)	18 (11)	32 (19)
Heavy Impact	20 (40)	77 (125)	13 (31)	20 (35)	70 (24)	33 (3)
BETWEEN TIRE TRACKS						
One Pass	3 (60)	10 (10)	-	-	-	0 (2)
Medium Impact	-	-	-	-	-	0 (6)
Heavy Impact	8 (48)	50 (4)	-	-	-	-

Table 12. Range of average sound levels (db) produced by vehicles during test runs.

VEHICLE	PROXIMITY TO SOUND METER Near*	Far**
Light	82-84	41
ATC	78-81	53-56
Tractor	73-79	37-40
Chain	68-74	39-44
Heavy	68-70	37-43
Track	91-92	43-60
Airboat		
Fast	91-92	74-75
Slow	86	63-69

* approximately 2 m away.
** approximately 100 m away.

wheeled vehicles, the light buggy had slightly higher "near" values, while the ATC had "far" readings that were about 15 db higher than the swamp buggies. 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, was the only one with an automatic transmission, and its engine rpm was consistently higher than the other buggies which probably accounted for the higher readings. The ATC had a much smaller muffled engine, but in order to provide enough power, it was run at a very high rpm. The resulting high-pitched "whining" sound seemed to carry farther, producing the high readings measured at the far end of the test plots. The two vehicles 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.

"Near" readings for the track vehicle and airboat in marl and peat marshes were very similar, which is surprising since the airboat seemed much louder during the test runs. Airboat operators normally wear earplugs to protect against excessive noise while track operators do not. These measurements were greatly influenced by vehicle performance and position of the noise 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 track vehicle readings. Airboats produced much greater sound levels at the far end of the test plots than track vehicles. Location of the unshrouded engine and propeller, both of which are significant sound producers, high above the water surface and most vegetation probably allowed the sound to travel farther.

CONCLUSIONS

This paper describes some of the initial results from our study of ORV impacts in the BICY, and the following points summarize our conclusions to date. We are continuing to monitor the treatment plots and the results should further elucidate some of these points, as well as detail the recovery process.

1) Soil moisture was the most important factor influencing severity of initial vehicle impacts. In general, it was inversely related to the number of passes required to reach a specific level of impact.

2) Variations in swamp buggy characteristics (psi, tread type, etc.) had a minor effect on their ability to impact study sites compared to soil moisture.

3) Swamp buggies and track vehicles generally produced the most severe impacts. ATCs had the least impact of the wheeled vehicles, and airboats the least of all vehicles.

4) Of the quantitative measures of initial ORV impacts on vegetation, average height of understory vegetation was most affected by ORVs while percent cover was least affected and biomass was intermediate.

5) Degree of impact on shrubs and small trees increased with plant size and vehicle use intensity level.

6) Noise levels were dependent primarily on engine type and rpm. Swamp buggies had similar low noise levels except when an automatic transmission resulted in higher rpms. The airboat produced the highest overall noise levels.

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