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Development and Implementation of a Scrub Habitat Compensation Plan for Kennedy Space Center

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Abstract

Kennedy Space Center (KSC), located on Merritt Island on the east coast of central Florida, is one of three remaining major populations of the Florida Scrub Jay (Aphelocoma coerulescens coerulescens), listed as threatened by the U.S. Fish and Wildlife Service (USFWS) since 1987. Construction of new facilities by the National Aeronautics and Space Administration (NASA) on KSC over the next five years has the potential to impact up to 193 ac (78.1 ha) of Scrub Jay habitat. Under an early consultation process with the Endangered Species Office of the USFWS, NASA agreed to a compensation plan for loss of Scrub Jay habitat. The compensation plan required NASA to restore or create scrub on KSC at a 2:1 ratio for that lost. The compensation plan emphasized restoration of scrub habitat that is of marginal or declining suitability to Scrub Jays because it has remained unburned. Although prescribed burning has been conducted by the USFWS Merritt Island National Wildlife Refuge (MINWR) for more than ten years, significant areas of scrub remain unburned because they have been excluded from fire management units or because landscape fragmentation and a period of fire suppression allowed scrub to reach heights and diameters that are fire resistant. For such areas, mechanical cutting followed by prescribed burning was recommended for restoration. A second part of the restoration plan is an experimental study of scrub reestablishment (i.e., creation) on abandoned, well drained agricultural sites by planting scrub oaks and other scrub plants. The compensation plan identified 260 ac (105 ha) of scrub restoration in four areas and a 40 ac (16 ha) scrub creation site. Monitoring of restoration sites required under the plan included: 1) establishing permanent vegetation sample transects before treatment and resampling annually for ten years after treatment, and 2) colorbanding Scrub Jays to determine territories prior to treatment followed by monitoring reproductive success and survival for ten years after treatment. Monitoring scrub creation sites included determining survival of planted material for five years and establishing permanent transects to follow vegetation development for ten years after planting. Scrub Jay monitoring of creation sites is incorporated with that of adjacent restoration sites.

Scrub restoration began with work at the Happy Creek site; 56.8 ac (22.6 ha) of scrub were cut between August 1992 and January 1993, primarily using a Brown tree cutter, and these areas were burned in February 1993. Vegetative regrowth has been vigorous. No Scrub Jay families abandoned their territories within the restoration area. Mechanical treatment of the Shiloh restoration site occurred between January and March 1993 and covered 52.5 ac (21.2 ha). Due to the large size of oaks at this site, a D-6 Caterpillar with a V-blade was used to cut the scrub. The site was burned in November 1993. Only three families of Scrub Jays (7 individuals) occupied portions of the area where restoration was performed; none abandoned the area during or after mechanical treatment. Site preparation of the initial 10 ac (4 ha) planting site included removal of cabbage palms (Sabal palmetto), mowing, and two herbicide applications. Oak tublings were planted in early August 1992. Initial survival was 66% (late August), but this declined to 50.7% by May 1993. Sand live oak (Quercus geminata) survived much better than myrtle oak (Quercus myrtifolia), perhaps due to their larger size at planting. In the summer of 1993 additional scrub oak tublings were planted; initial survival was 56.0%. One gallon pot size saw palmetto (Serenoa repens), rusty lyonia

(Lyonia fruticosa), shiny blueberry (Vaccinium myrsinites), and South Florida slash pine (Pinus elliottii var. densa) were planted in the summer of 1993; initial survival was 100%. Initial results of scrub restoration are encouraging and may have applicability to other scrub sites degraded by fire exclusion; long-term data are required to determine Scrub Jay population responses.

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Acknowledgments

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Introduction

Legal Status of the Florida Scrub Jay

The Florida Scrub Jay (Aphelocoma coerulescens coerulescens) was listed as threatened by the U.S. Fish and Wildlife Service in 1987. Under Section 7 of the Endangered Species Act, other federal agencies are required to consult with the Endangered Species Office regarding any impacts to species listed as threatened or endangered.

Scrub and Scrub Jays on Kennedy Space Center

John F. Kennedy Space Center (KSC) supports one of three remaining major populations of the Florida Scrub Jay (Cox 1984, Breininger 1989). KSC is located on the northern part of Merritt Island and consists of approximately 140,000 ac (57,000 ha) of land and open water lagoons. The National Aeronautics and Space Administration (NASA) acquired the northern part of Merritt Island in 1962 to support the space program and provide a safety and security buffer area (NASA 1979). Lands not actively used in the space program are managed by the U.S. Fish and Wildlife Service (FWS) as Merritt Island National Wildlife Refuge (MINWR) or by the National Park Service as Canaveral National Seashore.

Scrub is a major vegetation type on KSC. The vegetation map of KSC (1:9600) (Provancha et al. 1986) estimated that 16,876 ac (6,830 ha) of scrub occur on KSC of which about 3,173 ac (1,284 ha) were oak scrub and 13,704 ac (5,546 ha) were saw palmetto scrub (Schmalzer and Hinkle 1985). These types vary along environmental gradients with oaks dominant on drier sites and saw palmetto (Serenoa repens) dominant on wetter sites (Schmalzer and Hinkle 1987, 1992b; Breininger et al. 1988). About 1,247 ac (505 ha) of disturbed scrub also occurs. Disturbed scrub was once cleared and revegetated with scrub oaks and other shrubs (Breininger and Schmalzer 1990). Slash pine (Pinus elliottii) flatwoods occupy 12,381 ac (5,011 ha) (Provancha et al. 1986). Slash pine flatwoods vary in canopy density and understory composition (Breininger et al. 1988). Scrubby flatwoods occur on drier sites and have an understory of scrub oaks (myrtle oak - Quercus myrtifolia, sand live oak - Q. geminata, Chapman oak - Q. chapmanii), saw palmetto, ericaceous shrubs, and wiregrass (Aristida stricta) (Schmalzer and Hinkle 1985). On wetter sites, saw palmetto, gallberrry holly (Ilex glabra), and fetterbush (Lyonia lucida) are dominant shrubs. Coastal strand occurs on recent dunes of the barrier island and is dominated by saw palmetto, sea grape (Coccoloba uvifera), wax myrtle (Myrica cerifera), and other shrubs; it occupies about 878 ac (355 ha) on KSC.

Nearly half of the scrub and slash pine flatwoods on KSC is marginal Scrub Jay habitat due to dense pine canopy cover or sparse oak cover (Breininger 1989). A map of primary and secondary habitats and population centers was prepared to inventory habitat and identify locations important for the population on KSC (Breininger et al. 1991). Primary habitat was defined as scrub and slash pine occurring on well-drained soils. These areas can support scrub oak cover that is optimal for Scrub Jays.

Secondary habitat was defined as coastal strand and poorly-drained scrub and slash pine flatwoods. Population centers were defined as primary habitat and adjacent secondary and ruderal habitats; nearly 86% of the KSC population occurred in these centers. The remainder was in secondary habitat not near primary habitat. Primary habitat occupied 3,954 ac (1,600 ha) and secondary habitat 22,661 ac (9,171 ha). Primary habitat comprised 15% of scrub and slash pine flatwoods but accounted for 57% of the Scrub Jay population.

Scrub Habitat Loss Due to NASA Construction

Construction of new facilities on KSC has the potential to impact Scrub Jay habitat. For example, construction of the Space Station Processing Facility at KSC removed 28 ac (11.3 ha) of Scrub Jay habitat. Under the Biological Opinion issued by the Endangered Species Office of the U. S. Fish and Wildlife Service (Wesley 1991a), NASA was required to purchase 56 ac (22.7 ha), or restore or create 84 ac (34 ha) of Scrub Jay habitat as compensation for that lost. Any one or a combination of these measures could be selected. In addition, other proposed new construction in the next five years may remove up to 165 additional acres (66.8 ha) (193 ac [78.1 ha] total) of Scrub Jay habitat (Table 1), based on preliminary analyses. Federal agencies may enter into an early consultation process (50 CFR 402.11) in which a preliminary biological opinion may be issued to the agency by the Endangered Species Office as a guide related to projects expected to impact a threatened or endangered species. NASA (1992) chose to enter such a consultation process with the USFWS (Wesley 1991b) regarding scrub impacts of current and future construction and chose to perform compensation that would benefit the Scrub Jay population on its property. This required a plan that included scrub restoration and creation on KSC.

Habitat Compensation Plan

NASA (1992) proposed a phased approach to compensation for future projects that would restore and create up to 300 ac (121.5 ha) of scrub habitat at several areas on KSC (Table 2, Figure 1). As used here, restoration is the mechanical treatment and prescribed burning of existing scrub of marginal or declining habitat value for Scrub Jays and creation is reestablishment of scrub vegetation on abandoned, well drained agricultural sites. The first year NASA would restore 74 ac (30 ha) of existing habitat and create 10 ac (4 ha) for a total of 84 ac (34 ha) of compensation. In each succeeding year as new projects are approved and designed, their impacts to scrub habitat will be determined by a project-specific Biological Assessment. Actual impacts may be greater or less than those originally estimated. Some projects planned now may not be built at all. Each Biological Assessment will be submitted to the USFWS under the Section 7 consultation process. Depending on the total area impacted in a given year, compensation sites will be selected so that an appropriate amount of scrub habitat will be restored or created. The final ratio of compensation will be 2:1. Ratios are higher in the initial year of the program and decline toward the end. Not all of the potential 193 ac (78.1 ha) of impact are covered in the present plan. NASA will be required to identify additional compensation acreage when 150 ac (60.7 ha) of impacted habitat is reached. Phasing of compensation is required because: 1) the exact nature, extent, and timing of all future projects is not known now; and 2) monies

Table 1. Proposed construction projects which may impact Scrub Jay habitat over a five year period.

Project	Vegetation	Estimated Construction Area (acres)	{ha}	Estimated Impacted Area (acres)	{ha}
Space Station Processing Facility	mixed scrub	28.0	11.3	28.0	11.3
IFLOT camera site	scrub/wetlands/ruderal	2.0	0.8	1.4	0.6
Payload Spin Test Facility	mixed	11.0	4.5	6.0	2.4
Advanced Solid Rocket Motor dock	*Vitis*/scrub	4.0	1.6	2.0	0.8
Railroad car unloader	scrub/wetlands mixed	2.0	0.8	1.0	0.4
New landfill	disturbed/scrub	67.0	27.1	35.0	14.2
Space Station Hazardous Processing Facility	oak scrub	5.5	2.2	5.5	2.2
Assured Crew Return Facility	oak scrub	5.5	2.2	5.5	2.2
Astronaut crew quarters	mixed scrub (site a)	10.0	4.0	10.0	4.0
Astronaut crew quarters	pine woodland (site b)	10.0	4.0	0.0	0.0
Line Replaceable Unit repair depot	scrub/ruderal	9.0	3.6	9.0	3.6
LC 39 incremental improvement	mixed scrub	40.0	16.2	40.0	16.2
Space Station logistics warehouse	mixed	10.0	4.0	7.0	2.8
Space Station maintenance & repair building	scrub	6.0	2.4	4.0	1.6
Duct tray	mixed/ruderal	40.0	16.2	2.0 a	0.8
New Streets South of 5th Street	oak scrub	36.6	14.8	36.6	14.8

Totals ---------------------------------- 183 - 193 impacted acres (74.1 - 78.1 ha).

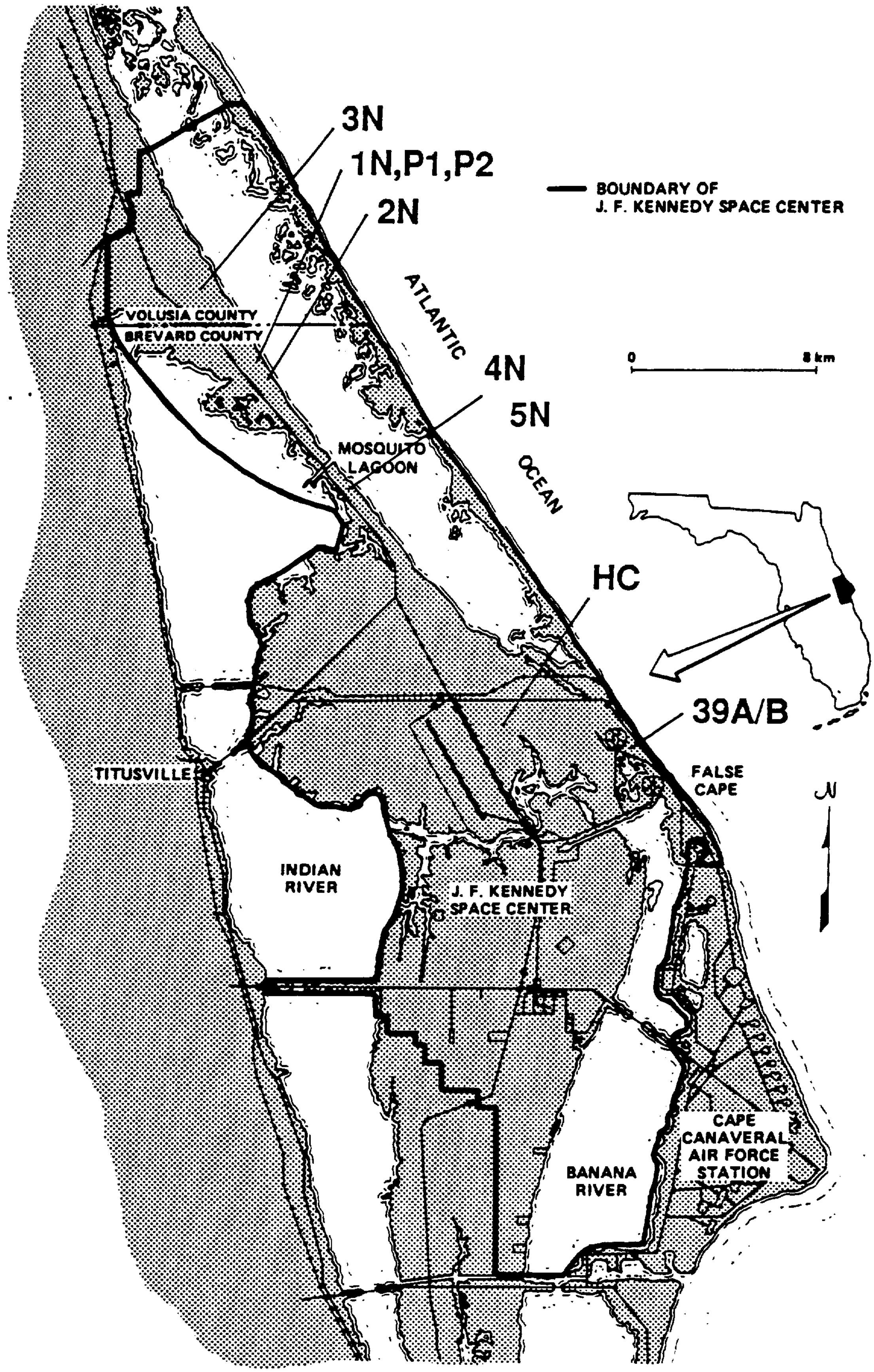
a Duct tray should impact this acreage provided it is only installed along existing rights-of-way.

Table 2. Sites proposed for scrub habitat restoration and creation.

Site	Type	Size (ac)	(ha)	Location
1N-1	Restoration	27.7	11.2	Brevard/Volusia County Line
1N-2	Restoration	17.7	7.2	Brevard/Volusia County Line
2N	Restoration	10.4	4.2	South of Site 1N
3N	Restoration	7.8	3.2	Volusia County
4N-1	Restoration	30.0	12.1	Haulover Canal
4N-2	Restoration [a]	30.8	12.5	Haulover Canal
5N	Restoration	36.3	14.7	Haulover Canal
HC	Restoration	54.0	21.9	Happy Creek
39A/B-1	Restoration	22.5	9.1	Pad 39A/B
39A/B-2	Restoration	22.5	9.1	Pad 39A/B
P1	Creation	10.0	4.0	Brevard/Volusia County Line
P2	Creation	30.3	12.3	Adjacent to P1
TOTAL		300	121.4	

[a] Restoration at this site may require some supplemental planting of scrub species

Figure 1. Location of scrub habitat restoration and creation sites. Scrub restoration and creation are planned for these sites over the next five years.



for compensation come from Construction of Facilities funds for each project, and these funds are not available until the final design is complete. Funds will be provided to the USFWS-Merritt Island National Wildlife Refuge for restoration and creation activities and to the KSC Biomedical Operations and Research Office for monitoring. There will be an annual review of the program between NASA and the USFWS Endangered Species Office. Changes in schedule of compensation sites will be addressed at this meeting.

If after implementation of this program it is demonstrated that habitat restoration and creation efforts are not successful, i.e., Scrub Jays are not or cannot use these areas, NASA agreed to pursue acquisition of occupied Scrub Jay habitat off of KSC to compensate for habitat lost on KSC, and this compensation will be at a 2:1 ratio. Success will be determined ten years after restoration or creation of a site.

In the following sections, the rationale for scrub restoration and creation will be presented and early implementation of the project documented.

Potential for Habitat Restoration

Scrub Jay Habitat Requirements

Scrub Jays require recently burned, well drained or moderately drained areas that have an abundance of scrub oaks, numerous sandy openings, and few or no trees (Woolfenden and Fitzpatrick 1984, 1991). Studies on KSC have compared densities of Scrub Jays with habitat features (Breininger 1981, Breininger and Schmalzer 1990, Breininger et al. 1991, Breininger and Smith 1992) and found that: 1) Scrub Jays on KSC occupy a broad range of habitat conditions; 2) Scrub Jays inhabit many areas that are marginal for them; and 3) most areas on KSC do not represent optimal habitat as described by Woolfenden and Fitzpatrick (1984, 1991). Since 1988, spatially explicit studies of reproductive success and survival of colorbanded Scrub Jays have been performed. These studies now include ten study areas including nearly 100 territories. Densities of Scrub Jays and reproductive success and survival suggest that optimal habitat on KSC has similar structural features to optimal habitat defined by Woolfenden and Fitzpatrick (1984, 1991). Demographic success studies suggest that mortality exceeds reproductive success in many areas on KSC that do not have habitat conditions similar to those described as optimal (Woolfenden and Fitzpatrick 1984, 1991, Cox 1984, Breininger 1992).

Animal populations can be maintained by sources, where reproduction exceeds mortality, that contribute individuals to sinks, where mortality exceeds reproduction (Wiens and Rotenberry 1981, Pulliam 1988, Pulliam and Danielson 1991, Howe et al. 1991). The presence of Scrub Jays in an area does not indicate that they are successful in that area; large areas may be demographic sinks provided sources are nearby. Appropriate measures of habitat quality include considerations of survival, reproductive success, and density data (Van Horne 1983), and these often require spatially explicit study since habitat conditions and the arrangement of habitats vary temporally and spatially (Pulliam et al. 1992). For example, areas with low oak cover but within 300 m of a scrub oak ridge may have four times higher densities of Scrub

Jays than areas with similarly low oak cover but greater than (>) 300 m from a scrub oak ridge (Breininger et al. 1991, Breininger 1992).

Scrub adjacent to forests often has lower densities of Scrub Jays and lower demographic performance (breeder survival + yearling production) than areas > 100 m from a forest (Breininger 1992, Breininger et al. unpublished m.s.). Optimal habitat allows Scrub Jays to scan their surroundings for long distances (Woolfenden and Fitzpatrick 1984). Scrub Jays have a keenly developed sentinel system for detecting predators such as hawks (McGowan and Woolfenden 1989). Breeder mortality could vary spatially where the ability to spot predators is poor or where the availability of cover to escape predators is low. At KSC, large numbers of Sharp-shinned Hawks (Accipiter striatus) and Cooper's Hawks (A. cooperii) regularly occur in September and October when the Atlantic coastline serves as a major autumn migration route (Heintzelman 1986). Evidence suggests that accipiters may significantly influence Scrub Jays on KSC, since breeder mortality at KSC appears to be high during spring and fall accipiter migration peaks (Breininger et al. unpublished m.s., Breininger, Larson, Smith, Oddy, and Barkaszi unpublished data). These landscape issues are relevant to restoration because: 1) areas for management of a demographically successful Scrub Jay population are limited to regions on KSC that have an abundance of scrub oak ridges; and 2) restoration and creation design must incorporate landscape issues even though actual restoration and creation actions may involve small acreages for any one site during any one year.

The objective of Scrub Jay habitat restoration or creation is to design and manage for conditions where reproduction exceeds mortality. This may involve restoring habitat that is currently unoccupied due to degradation in habitat structure but may also involve restoration to enhance demographic performance in areas that are currently sinks but have the potential to be optimal habitat. Although Scrub Jays occupy broad habitat conditions, their demographic performance in areas that are not optimal habitat is not understood sufficiently to identify all conditions where reproduction exceeds mortality ("sources") and all conditions where mortality exceeds reproduction ("sinks"). The KSC program will monitor scrub vegetation, habitat structure, and Scrub Jay demographic performance to evaluate success and to provide data needed to make necessary adjustments given that these are new endeavors in natural resource management.

The rationale for restoration to enhance demographic performance was based on demographic studies in the Happy Creek area which is one of the largest population centers of Scrub Jays on KSC (Breininger et al. 1991). This area includes some habitat fragments that have been unmanaged because they are outside Fire Management Units (FMUs) but is mainly habitat within a FMU. The study area was subject to about 20 years of fire suppression before 1981, but since then the area within the FMU has been prescribed burned approximately four times in 12 years. These fires have not restored the habitat to conditions prior to fire suppression because much scrub remains unburned and lacks openings except where previously mechanically disturbed. During a five year period, breeder mortality exceeded reproductive success for each year across most of the study area. When no recent (< 20 years) fires have occurred, the decline in Scrub Jay demographic success with time since the last fire, has been demonstrated; at Archbold Biological Station extinction occurred after 40-60 years without fire (Woolfenden and Fitzpatrick 1984).

A review of historical literature and analyses of historical photographs indicate that scrub on KSC as late as the 1950s, at least in some areas, had an abundance of open sandy areas among scrub oaks. The landscape was not as fragmented by forests as it is today; some scrub and marshes have become forests since the 1950s (Breininger et al. in preparation). These habitat conditions closely represent descriptions of optimal habitat. Target conditions for restoration and creation are to develop habitat conditions representing native habitat assuming these are optimal for Scrub Jays. Optimal conditions for Scrub Jays are assumed to be where open sandy areas comprise 20% of the scrub, scrub is 120-170 cm high, scrub is > 100 m from a forest, and slash pine canopy cover is < 15% (Breininger 1992). Openings are important for Scrub Jays and other species (Breininger 1981, Breininger and Smith 1992). Slash pine trees are useful habitat features for Scrub Jays because they provide perch sites and fuels to carry fires; however, fire suppression and soil disturbance have resulted in pine stands that are too dense for Scrub Jays, gopher tortoises (Breininger et al. 1988), and Bald Eagles (Hardesty and Collopy 1990). One objective of scrub restoration is to reduce pine cover in areas with abnormally high pine density except for scattered stands that represent existing, historic, or future Bald Eagle nest sites. Snags or fallen stems from pines may eventually produce openings in the shrub layer when they burn (Myers 1990).

Fire Ecology of Scrub

Scrub is a pyrogenic vegetation type, fire-adapted and fire-maintained. Fire frequencies for sand pine scrub are generally given as 20 to 70 years (Austin 1976), although this probably varied with site conditions (Myers 1990). Scrub in which Ceratiola ericoides (rosemary) is important also may have burned at > 20 year intervals (Johnson 1982, Johnson and Abrahamson 1990). Requirements for other obligate seeding shrub species (e.g., Dicerandra spp., Conradina spp.) are poorly known. Natural fire frequencies for oak scrub, oak-saw palmetto scrub, or scrubby flatwoods, all dominated by sprouting species, are not known with certainty. It is generally believed that oak scrub burned more often than sand pine scrub but less often than the 2-5 year cycle of longleaf pine/wiregrass sandhill community (Abrahamson et al. 1984, Abrahamson and Hartnett 1990, Myers 1990). Several factors contribute to the lower frequency of fire in scrub than in sandhill or flatwoods including the evergreen nature of the shrubs, the relative lack of grasses and herbs in the community, and lack of extensive litter buildup on the ground under the stand (Webber 1935). Over time, sufficient fuel builds up to carry fire, at least under dry conditions. Scrub communities are frequently imbedded in a matrix of more flammable vegetation such as sandhill or pine flatwoods, and fires spreading into scrub from these types are important ignition sources (Myers 1990). Much of the well-drained scrub on KSC occurs in a matrix dominated by more flammable habitats such as marshes and flatwoods that probably burned more often than the broad patches of oak scrub (Breininger et al. 1991).

Scrub oaks, palmettos, and ericaceous shrubs regenerate after fire by sprouting, and this recovery is rapid (Abrahamson 1984a, b, Schmalzer and Hinkle

1991, 1992a). Species composition and richness change little. Dominance may shift initially because growth rates differ among shrub species. Saw palmetto recovers more rapidly after fire than the oaks, but oak dominance is reestablished within five years (Schmalzer and Hinkle 1992a, c). Vegetation height recovers more slowly than species presence or cover. Open space does not persist long after fire in undisturbed scrub on Merritt Island, at least after winter burning (Schmalzer and Hinkle 1987, 1991, 1992a, b, Breininger et al. 1988, Breininger and Schmalzer 1990).

Fire exclusion from communities in which fire was historically a periodic occurrence can result in changes in community composition and structure. Laessle (1942) suggested that sand pine scrub and scrubby flatwoods would eventually become xeric hammock in the absence of fire. Veno (1976) studied permanent quadrats established by Laessle (1958) in communities of the Welaka Reserve which had been protected from fire since 1939. Scrub showed no change in species composition; density and basal area of the scrub species increased greatly and woody litter increased over the 20 year period of the study. Givens et al. (1984) reported little change in species composition of sand pine scrub or scrubby flatwoods in ten years in a section of Archbold Biological Station which had been protected from fire since 1927. Structural changes included height and crown diameter growth; density of most shrubs decreased due to thinning mortality. Menges et al. (1993) resampled the same sites ten years later. Tree size oaks, particularly _Q. geminata_, greatly increased in scrubby flatwoods. Substantial sand pine mortality occurred in the sand pine scrub. Decreased shrub density in scrubby flatwoods and sand pine scrub reported by Givens et al. (1984) increased 10 years later. Menges et al. (1993) concluded that sand pine scrub would probably become xeric hammock with continued fire exclusion, but that changes in scrubby flatwoods were too slow to determine if it would eventually become xeric hammock. Peroni and Abrahamson (1986) found that scrubby flatwoods, sand pine scrub, and rosemary scrub on the southern Lake Wales Ridge remained relatively stable in the absence of fire, although one scrub site apparently changed to xeric hammock over 40 years. Although rates of change may be slow, continued height and diameter growth of scrub oaks appears to favor the development of xeric hammocks on many sites with continued fire exclusion (Stout and Marion 1993). These changes result in declining habitat suitability for Scrub Jays (Woolfenden and Fitzpatrick 1984).

Guerin (1988, 1993) examined oak domes, clumps of scrub oaks (sand live oak or myrtle oak), in longleaf pine-wiregrass communities of Ocala National Forest. She found that domes with oaks > 2 m tall had a high probability of survival of above-ground stems after fire, and oaks > 4.5 m tall were nearly fire resistant. Domes < 2 m tall typically burned to the ground but resprouted from below-ground roots and rhizomes. Fire had been suppressed in this area for about 20 years prior to the initiation of prescribed winter fires in the 1950s. This period of fire suppression allowed some oak domes to become fire resistant. Some sand live oaks were fire resistant at 7-16 years. Myrtle oak appeared to be less fire resistant than sand live oak.

Reduced fire frequencies have been associated with substantial increases in slash pine densities in flatwoods at the southern end of the Lake Wales Ridge (Peroni and Abrahamson 1986). Tree canopy cover also has been shown to increase in dry prairie and associated wetlands due to the exclusion of fire (Huffman and Blanchard 1991). Little of the mesic flatwoods and scrub on KSC is identical to the typical dry prairie habitat of south Florida; however, there is some resemblance, and these mesic scrub associations are sometimes mapped as dry prairies (Larson 1992).

Effects of Fire Exclusion on KSC Scrub

A general policy of fire suppression was in effect on KSC between 1963 and 1975 at which time limited prescribed burning was initiated. After severe wildfires during the 1981 drought, a more extensive prescribed fire program was instituted providing a three year fire cycle for most upland vegetation (Lee et al. 1981, Adrian et al. 1983). As initial fuel reduction goals were achieved, fire prescriptions have been modified to meet natural resource management goals (Fred Adrian, pers. comm.). Although an active prescribed burning program has been in effect for more than a decade, areas of long-unburned scrub and scrubby flatwoods remain. Two factors contribute to this: one is that some areas have been excluded from fire management; the other is that landscape fragmentation and the period of fire exclusion resulted in some areas reaching heights and tree sizes that made reintroduction of fire difficult or unsuccessful.

Areas within scrub and scrubby slash pine flatwoods that have remained unburned for long periods (> 30 years) are dominated by tree-size scrub oaks that are able to survive fires. Nearly 2,700 ac (1,093 ha) of unburned habitat occur outside Fire Management Units (FMUs) on KSC. The acreage of tall, unburned habitat within FMUs is not currently known but may increase because NASA operations limit the ability of the USFWS to use prescribed fire in several areas. Anticipated industrial development may increase this problem. Many projected facilities that need not be isolated due to hazardous operations have been relocated to habitat fragments of low suitability for Scrub Jays; thus, planning and the use of fragments for construction may minimize additional fragmentation.

In most KSC scrub during the last 12 years, open space has occurred along ruderal edges, in disturbed scrub, and around snags which may burn for days after fires (Breininger 1981, Schmalzer and Hinkle 1984, 1987, 1992a, b, Breininger et al. 1988, Breininger and Schmalzer 1990, Breininger and Smith 1992). Homogeneous patches of oak and oak-palmetto scrub lack openings 24 months after a fire (Schmalzer and Hinkle 1987, 1992a, b). In the Tel 4 study area which burned at least once during the period of fire suppression, openings were common along ridges adjacent to saw palmetto-lyonia vegetation, and the oaks were often ≥ 1 m tall along ridges (Breininger et al. unpublished m.s.). Frequent fires reduce underground carbohydrate storage and can kill underground rhizomes (Guerin 1988). Relatively frequent fires may be important for maintaining openings between patches of the flammable saw palmetto-lyonia vegetation and the xeric, nutrient impoverished oak scrub which burns less frequently (Schmalzer and Hinkle 1987, Myers 1990). Openings between the scrub types may slow fires when fuels are relatively low, perhaps explaining how scrub oaks of sufficient stature occur adjacent to openings. Fire suppression results in continuous fuel loadings. Growing season fires are more effective than dormant season fires in reducing resprouting in many hardwoods including deciduous oaks, but seasonal effects on scrub oaks are unknown (Robbins and Myers 1992).

Potential Effects of Scrub Restoration and Creation on Other Species of Conservation Concern

Scrub restoration and creation have the potential to affect other scrub vertebrates. Although some species may require different landscape components within scrub landscapes, habitat conditions (e.g., time since fire, pine cover, and habitat structure) suitable for Scrub Jays are suitable for most other amphibians, reptiles, birds, and small mammals occurring in scrub. Gopher tortoises tolerate conditions suitable for Scrub Jays, although they may prefer more frequently burned habitat (Breininger et al. 1988, 1994 in press). Tortoises occur in slightly higher densities in more mesic flatwoods and scrub than preferred by Scrub Jays, and these habitats burn more frequently than xeric scrub and scrubby flatwoods (Breininger et al. 1988). Tortoises do poorly in unburned conditions (Auffenberg and Franz 1982). Many herpetofauna that occupy scrub use the middle successional phase that is preferred by Scrub Jays (Campbell and Christman 1982). Indigo snakes use all habitats within the scrub and pine flatwoods landscapes and may occur far from well drained areas (Kehl et al. 1991). The average homerange has been nearly 121 ha for males and 31 ha for females (Kehl et al. 1991). Individual indigo snakes require large amounts of habitat, and population size may be of special concern given the frequency of road mortality. We recognized that mechanical treatment for restoration has the potential to crush some herpetofauna or at least tortoise burrow entrances. Studies have shown that tortoises have the ability to dig out from forestry operations that produce much more soil damage than equipment used for scrub restoration (Joan Berish, Florida Game and Fresh Water Fish Commission, pers. comm.). We reasoned that any incidental mortality occurring from mechanical restoration was better than allowing scrub communities to continue becoming less suitable for scrub species.

Some birds prefer areas more recently burned than do Scrub Jays, and others prefer older burned sites. Those that prefer unburned scrub are not threatened or endangered species restricted to scrub but birds common in hammocks and swamps and widespread across their range (Hamel et al. 1982, Breininger 1990). Habitat suitable for Scrub Jays is suitable for most scrub and pine flatwoods birds (Breininger and Smith 1992). Species that require pine trees include the Bald Eagle (Haliaeetus leucocephalus), Downy Woodpecker (Picoides pubescens), and Red-cockaded Woodpecker (Picoides borealis). Scrub Jays tolerate open tree canopies and appear to occur in higher densities where there is a sparse tree canopy, perhaps because burning snags result in numerous openings in the shrub layer (Breininger 1992). Several species, Red-cockaded Woodpecker, Red-headed Woodpecker (Melanerpes erythrocephalus), Loggerhead Shrike (Lanius ludovicianus), American Kestrel (Falco sparverius), and Bachman's Sparrow (Aimophila aestivalis), prefer very open understories and were either known to occur or may have occurred in Brevard County scrub and pinelands. All are now rare or extirpated, probably due to logging, fire suppression, and isolation and perhaps because some were never common. No species of special conservation concern are known to require unburned scrub and pinelands.

Bald Eagles select for the largest trees within a relatively open stand (20-47 trees/ha) (Hardesty and Collopy 1990). Scrub Jay densities decline with increasing slash pine density between 25 and 50 trees/ha. There is not only an area of overlap in pine density among both species, but eagles use open pine stands for nesting that are often not very large. Dense pine stands associated with soil disturbance and fire suppression are detrimental to Scrub Jays, gopher tortoises, and Bald Eagles (Breininger et al. 1988).

Florida mouse (Podomys floridanus) populations may be sustained within well-drained areas, but they do occasionally occur within some poorly drained areas (Stout 1980). The Florida mouse appears to tolerate a wider range of successional conditions with respect to time since fire than the Scrub Jay (Jim Layne, Archbold Biological Station, pers. comm.). The Scrub Jay appears to tolerate a wider range of conditions along the moisture gradient than the Florida mouse. Long-term research at Archbold Biological Station suggests that habitat suitable for Scrub Jays is suitable for small mammal species within well-drained scrub and pine flatwoods since small mammals have a broader successional tolerance and are divided into groups that prefer older or more recently burned areas (Layne 1990).

Approaches to Scrub Restoration

Mechanical treatments alone have not been demonstrated to substitute for fire in the long-term maintenance of scrub vegetation (Myers 1990). However, tall, unburned scrub habitats that will not burn successfully in most prescribed fires could be restored by mechanical cutting followed by prescribed burning of the slash. The restored scrub can thereafter be managed by prescribed burning. Work on using mechanical methods in Scrub Jay habitat restoration has been done at Oscar Scherer State Recreation Area (Smyth 1991). Mechanical cutting reduces vegetation height and creates openings, but nutrients may not recycle in the same manner as occurs from fire. Mechanical cutting by itself may not result in an optimal habitat structure. For example, the understory in scrub is often open once scrub oaks have sprouted and grown for several years. An unnatural amount of debris may remain after mechanical treatment. Fire has been such an integral component of Scrub Jay habitat that it may be important in ways not readily apparent. For example, Scrub Jays prefer to forage in open conditions without litter, and fires consume litter and debris. Most scrub researchers agree that Scrub Jay habitat should be managed by fire (Woolfenden and Fitzpatrick 1991) unless long-term studies justify other substitutes for certain situations.

Selection criteria for choosing restoration sites included tall, unburned areas of well drained scrub or scrubby flatwoods that have high potential to be optimal habitat based on intrinsic site characteristics. Restoration design should prevent detrimental impact to Scrub Jays already residing in the general area. This may require either sequential treatments over a period of years or selecting narrow (e.g., 50-100 m) strips or blocks of habitat to be treated once. These often include scrub adjacent to edges because edges often tend to be taller than interior areas. After initial restoration is completed, the intent is that areas be managed by prescribed fire. Additional small applications of mechanical cutting may be necessary if areas of high scrub remain. Height reduction is important because mortality of Scrub Jays tends to exceed reproductive success in such areas (Woolfenden and Fitzpatrick 1984, 1991). Furthermore, even patches of tall, unburned scrub may reduce the ability of Scrub Jays to detect predators and appear to be exploited by hunting accipiters to attack Scrub Jays (David Breininger, pers. obs.). Scrub Jays whose territories border forests appear more vulnerable to accipiters, or at least more cautious, than Scrub Jays living in territories bordering other territories (David Breininger, pers. obs.), presumably because each territory has a sentinel that provides an early detection system concerning the location of accipiters. Because Scrub Jay territories are large (300 m wide), this requires large, open landscapes.

Patches of vegetation within a territory typically include different age classes with respect to time since fire, in part due to natural landscape variation and the large size of territories. Different age classes vary in their suitability for nesting, feeding, and for providing cover to escape predators (Woolfenden and Fitzpatrick 1984). If the entire territory burned (or was mechanically cut) at once, there would be no scrub oaks of the appropriate size to provide cover or acorns (a major food resource) for several years.

The reintroduction of openings among scrub oaks is considered important, but it is not known whether restoration in combination with fire will accomplish this objective. Initial plans are to quantify the habitat after restoration and fire to determine whether other management actions may be needed to reintroduce openings. Intense summer fires or hand application of herbicides in spots where openings occurred in the native landscapes offer possibilities but are untested on KSC. Mechanical means that create linear openings are suspect. Although these edges appear attractive to Scrub Jays, they may represent a simplified habitat structure that allows predators to search more systematically for nests, young, or adults than would occur in a natural mosaic. Presumably, travel time and energy expenditure for predators decrease resulting in greater success as the habitat becomes simplified.

Approaches to Scrub Creation

In addition to areas of long-unburned scrub, there are substantial areas of well drained soils in the northern part of KSC that are abandoned agricultural lands, particularly citrus groves. These areas once probably supported scrub or scrubby flatwoods. Succession is not returning these areas to scrub vegetation. Rather, cabbage palms (Sabal palmetto) are established in many, and large areas are rapidly becoming dominated by grape vines (Vitis spp.). These resulting communities do not provide good habitat for Scrub Jays or many of the other species dependent on scrub or slash pine flatwoods. Such areas may remain permanently dominated by vines (e.g., Hegarty and Caballe 1991, Putz 1991).

By removing competing species and planting scrub plants into such sites, it is thought that scrub can be reestablished. Some areas of scrub that were cleared 20-30 years ago have revegetated into scrub, indicating that scrub vegetation can develop in areas that were once cleared. Reestablishment of scrub vegetation on phosphate mines has been attempted with varying success (Poppleton et al. 1983, Feiertag et al. 1989, King 1989). Techniques used have included transferring mulch including top soil and root material from sites being mined to restoration sites and planting nursery stock. Abandoned agricultural lands (i.e., citrus groves) have been disturbed much less than surface mines.

Scrub creation was listed in the USFWS biological opinion (Wesley 1991a, b) as an option for compensating for future habitat loss, but the technique and its success have not been established. Unanswered questions concerning scrub habitat creation involve not only the success in establishing the appropriate vegetation but the success in developing a habitat structure that can be managed by prescribed fire. Some disturbed sites (especially areas cleared > 30 years ago that have revegetated naturally) have not developed a sufficient fuel structure to successfully carry fire (Breininger and Schmalzer 1990). In particular, saw palmetto frequently does not reestablish in mechanically cleared sites; saw palmetto is important in providing fuel to carry fire through scrub. Therefore, scrub creation is being considered as an experimental pilot project in this plan.

Plan Development

In this section we describe the restoration plan as developed (NASA 1992). Changes made during implementation at the Happy Creek and Shiloh sites are described in the following section.

The plan relied primarily on restoration, which had a high probability of success, but also includes less certain options such as creation and combinations of restoration and creation in order to have a high chance of overall success but provide the opportunity to attempt solutions to some difficult yet common problems in the Merritt Island landscape. All treatment sites considered involve either large landscapes, having potential to support large Scrub Jay population centers, or areas that potentially serve as important linkages between population centers.

Scrub Restoration

Scrub restoration was recommended for areas of scrub or scrubby flatwoods vegetation that have remained unburned for so long that: 1) habitat quality for Scrub Jays has declined, and 2) prescribed burning by itself is unlikely to return the site to good habitat conditions.

Three areas on KSC were recommended to provide the 259.7 ac (105.1 ha) required for habitat restoration and development of the 300 acre (121.5 ha) compensation bank. Restoration was recommended for approximately 54 ac (21.9 ha) at Happy Creek, 160.7 ac (65.1 ha) in four sites in the northern part of KSC, and 45 ac (18.2 ha) in an area between Launch Complexes 39A and 39B (Table 2, Figure 1). The areas selected at Happy Creek and near the launch pads are inside the launch impact zone but outside the crawlerway for a future Pad C. This minimized the chance of future development of these sites. Happy Creek is one of the most important areas for the Scrub Jay on KSC, and detailed studies of Scrub Jays and their habitat have been performed there for five nesting seasons. Comparison of Scrub Jay density, territory size, mortality and reproductive rates, before and after restoration, will provide data useful to designing restoration projects elsewhere. The northern section of KSC contains substantial areas of well drained soils with potential to be optimal habitat (Breininger et al. 1991). It is also distant from most NASA operations. However, past agricultural uses and fire exclusion have degraded the habitat. The areas between Pad A and Pad B are fragmented and relatively small but connect populations on Merritt Island with Cape Canaveral and the outer barrier island.

Happy Creek

Restoration at Happy Creek was planned to include one major application of mechanically cutting selected areas based on a detailed vegetation map that has been developed and a knowledge of Scrub Jay territories present within the area. Some of the restoration was planned for a section previously excluded from fire management due to proximity to a facility (150 m wind tower). Areas mechanically cut were to be prescribed burned to remove excessive slash material and reduce fire danger.. The prescribed burn was to be conducted using a combination of ground and aerial techniques. Objectives of the burn were to reduce 1-hour fuels by 80-90%, 10-hour fuels by 70-80%, and 100-hour fuels by 40-50%.

Prescribed burning of these sites was the responsibility of USFWS-MINWR personnel. It is important that prescribed burning be conducted by an organization experienced in using prescribed burning for wildlife habitat management that has sufficient trained personnel and appropriate equipment to conduct the burn safely, prevent fire escape, and suppress any escaped fires. Prescribed burns must meet Florida state requirements (e.g., Florida Prescribed Burning Act of 1990) and, on KSC, be coordinated with appropriate NASA authorities. Fire management on KSC is difficult logistically due to NASA and U.S. Air Force (USAF) facilities that have hazardous operations and payloads that require extremely clean surroundings. Nearby populated areas also object to smoke produced from prescribed fires on KSC.

Approximately 3-5 years after the mechanical treatment and initial prescribed burn, prescribed fire will be used to burn approximately 400 ac (161.9 ha) of scrub and marsh adjacent to areas that were cut and burned; this prescribed fire can also burn into some of the treated area as a mosaic. Fire objectives will be to achieve a 40-60% fuel reduction in the areas surrounding the mechanically cut treatment in a mosaic pattern. Exact timing of the second fire will be determined based on monitoring data of scrub regrowth and Scrub Jay responses. It is anticipated that this will result in a scrub landscape that can thereafter be maintained by prescribed burning, and additional mechanical treatment will be unnecessary. Monitoring data collected through ten years after beginning of treatment will be used to judge whether viable Scrub Jay habitat has been restored that can then be incorporated into normal management.

Shiloh

The design for the northern section of KSC involved mechanically cutting strips or blocks of unburned habitat in five different sites followed by prescribed burning of the slash and adjacent scrub where needed. Site 1N consisted of 45.4 ac (18.4 ha) adjacent to the abandoned grove being used for scrub creation. Site 1N and the adjacent planting site are collectively termed the Shiloh site. Strips about 100 m wide were to be treated; this should not result in negative impacts to Scrub Jays that reside in the area. Site 1N was divided into two subsites. Site 1N-1 was north of the sand road that passes through the center of the site. It consisted of about 46.6 ac (18.9 ha) of which 27.7 ac (11.2 ha) were to be mechanically treated and burned. The interior of this site (18.9 ac, 7.7 ha) was not be mechanically treated to retain habitat for resident Scrub Jays. The interior was planned to be burned when the slash from the initial treatment was burned. A second prescribed fire approximately 4-7 years after the initial treatment may be needed in this interior area; this prescribed fire can burn into the mechanically treated area as a mosaic. Exact timing of this burn will be determined using monitoring data. Site 1N-2 was south of the sand road; it consisted of about 17.7 ac (7.2 ha). Prescribed burning was recommended for the slash from mechanical treatment in Site 1N-2. After that, it is expected that the areas will be incorporated into the normal fire management of adjacent scrub vegetation. It is expected that this treatment will result in a scrub landscape that can be maintained by prescribed burning. Monitoring data collected through ten years after beginning of treatment will be used to judge whether viable Scrub Jay habitat has been restored that can then be incorporated into normal management.

Site 2N is a strip of 10.4 ac (4.2 ha) of scrub vegetation along a firebreak about 840 m south of Site 1N. Scrub adjacent to this strip is in good condition, but this edge is overgrown. One application of mechanical treatment followed by prescribed burning of the slash is recommended. After this, it is expected that the strip can be included with normal management of the adjacent vegetation.

Site 3N involves strips of 7.8 ac (3.2 ha) of scrub vegetation on both sides of a fire break about 1.6 km north of Site 1N. Adjacent vegetation is scrub and scrubby flatwoods in good condition, but the strips recommended for treatment are overgrown. One application of mechanical treatment followed by prescribed burning of the slash is recommended to return the vegetation to a state that can then be maintained by prescribed burning.

Haulover Canal

Site 4N is south of Haulover Canal in scrub and disturbed scrub vegetation. Two blocks, totaling about 60.8 ac (24.6 ha) and partially separated by a hammock, are recommended for mechanical cutting followed by prescribed burning of the slash. Previous burning of the area has not been sufficient to maintain the habitat that has been occupied by Scrub Jays in the past. Treatment will be done in phases so that all available habitat is not treated at the same time. About half the area will be treated in the first phase and the second half not sooner than 3-4 years later.

Site 5N is an area of about 60.4 ac (24.5 ha) south of Haulover Canal; restoration is proposed for about 36.3 ac (14.7 ha) of this site. Before NASA's acquisition of this land, several small canals had been cut and roads built, apparently as part of a planned subdivision. Scrub, disturbed scrub, and scrubby flatwoods exist on much of the site on well drained soil. However, roads and canals act as fire breaks complicating prescribed burning of the area, and not all previously cleared areas have revegetated with desirable species.

In order to reestablish better habitat on this site, a mix of treatments will be required, including mechanical cutting of high scrub vegetation on the edges, removal of less desirable vegetation (grape vines, cabbage palms, Brazilian pepper [Schinus terebinthifolius]), prescribed burning, and perhaps supplemental planting of scrub species. Because this site is more complex than the others, work on it will be done later in the project when experience has been gained in restoration techniques. A site specific plan will be developed by year 3 of the project.

Shuttle Pads

The final restoration site (39A/B) consists of about 45 ac (18.2 ha) located on a scrub ridge between Pad 39A and 39B outside of present Fire Management Units. Scrub in this area is occupied by Scrub Jays but is marginal habitat because of its height and density. Due to its proximity to operational areas, normal prescribed burning would be difficult on this site. With mechanical treatment, slash burning should be possible, as should the creation of smaller burning units that can then be maintained by prescribed burning. Treatment will be done in phases with about half the unit treated in the first phase and the second half at least 3-4 years later.

Mechanical Treatment

Several methods of mechanical treatment were considered. Tree size oaks could be cut by chain saw. This method has the advantage of doing little soil disturbance but is labor intensive and thus expensive for the size areas required. The Brown tree cutter has been used effectively in scrub restoration in combination with prescribed burning (Smyth 1991). Roller choppers are used extensively in silvicultural applications including post-harvest treatment of sand pine scrub in Ocala National Forest which appears to recover from this treatment (Greenberg et al. 1992). However, Greenberg (1993) found an apparent decrease in saw palmetto but not scrub palmetto (Sabal etonia) with roller chopping. Doren et al. (1987) used roller chopping to prepare sand pine scrub sites for prescribed burning; they reported little soil disturbance and good vegetation recovery. Roller chopping has been used effectively in restoring dry prairies where the intent was to reduce shrubs, particularly saw palmetto (Fitzgerald and Tanner 1992). Saw palmetto in KSC scrub is more vulnerable to mechanical disturbance than saw palmetto or scrub palmetto in sand pine scrub because the growing meristems are typically above-ground rather than buried. Saw palmetto is important in carrying fire through scrub so the objective here is not to eliminate it. Thus, care is needed in the application of roller chopping to scrub. A fourth method is to use a V-blade mounted on a crawler tractor. Data on this method have not been reported.

Scrub Creation

Shiloh

In Phase I of the creation effort, a small (10 acre, 4 ha) experimental plot was to be initiated adjacent to restoration site 1N to investigate scrub creation. This site (P1) was in an abandoned citrus grove just south of the Volusia-Brevard County line east of State Route 3 that was mainly on well drained soils (Astatula and Paola series; Huckle et al. 1974). The grove was about 50 ac (20.2 ha) in size. In Phase II, an additional 30.3 ac (12.3 ha) of the site (the remaining well drained portion) will be treated.

Site preparation (P1) required removal of about 250 small cabbage palms that have invaded the site. Scattered larger cabbage palms (one or fewer per acre) were to be left. Holes left by removal of cabbage palms were to be filled. Other required site preparation was minimal.

Growing of required horticultural material, scrub oaks and other scrub species, must be contracted for one year in advance of time of planting with a native plant nursery, because scrub oaks are not available in sufficient quantity otherwise. Arrangements have to be made by August-September of the year prior to the planned planting year, since that is when seeds mature. Plant material was to be grown as 6" tublings. Plans were to plant 500 trees per acre in two stages. In the first year, scrub oak species (400/acre) were to be planted using mechanical equipment as follows:

300 myrtle oak (Quercus myrtifolia)/acre
50 sand live oak (Quercus geminata)/acre
50 Chapman oak (Quercus chapmanii)/acre.

Planting should be done in summer during the rainy season. If planting is done at another time of year, supplemental watering is required to insure survival (Nancy Bissett, The Natives, pers. comm.).

After one year, survival of planted oaks was to be determined by sampling. If survival rate of oaks equaled or exceeded 50%, no further planting of oaks was required. If survival is less than 50%, scrub oaks will be planted by hand to bring oak density up to 200/acre. At that time, additional scrub plants (100/acre) were to be planted by hand as follows:

50 saw palmetto (Serenoa repens)/acre
30 rusty lyonia (Lyonia fruticosa)/acre
20 shiny blueberry (Vaccinium myrsinites)/acre
10 South Florida slash pine (Pinus elliottii var. densa)/acre.

Phase II of scrub creation was planned to be initiated in the third year of the project and will involve the remaining well drained portion (30.3 ac; 12.3 ha) of the old grove (P2). In addition to removing cabbage palms, some areas dominated by grape vines and areas with dense guineagrass (Panicum maximum) will need appropriate treatment to eliminate competing vegetation; this may include mowing, herbicide applications, or other treatments. Other modifications to the original procedure may be required based on experience with the initial effort.

Mulching of soil and root material from existing scrub has been used with some success in phosphate mine reclamation. However, this requires coordination of the habitat destruction and restoration activities. This is more readily achieved where both are ongoing activities, as on a surface mine, than for irregularly occurring construction events.

Monitoring

Creation and restoration are new techniques in scrub management. Proposed compensation of impacts to existing Scrub Jay habitat included not only the provision of new habitat but also the provision of habitat conditions that are of sufficient quality that reproductive success will exceed mortality rates. Additional monitoring objectives were to determine the success of developing habitat that can be maintained by prescribed fires.

Restoration Sites

Vegetation monitoring of restoration sites was to include establishing permanent line intercept sample transects (Mueller-Dombois and Ellenberg 1974) several months prior to treatment. Sample data per transect were to include vegetation composition and cover by height strata and vegetation height consistent with previous studies (Schmalzer and Hinkle 1987, 1991, 1992a, b). Sampling was to be of sufficient intensity to sample the spatial heterogeneity of the vegetation and result in statistically valid results. Resampling was to be conducted post-treatment and annually for ten years after treatment.

Scrub Jay monitoring of the northern areas was to be conducted at Shiloh (Sites 1N and 2N) and Haulover Canal (Sites 4N and 5N). Site 3N will not be monitored because it is small, remote, and is near an active Bald Eagle nest. A survey was to be conducted to color-band the resident Scrub Jays to determine the number of territories in the area of the creation/restoration sites prior to treatment. Scrub Jay monitoring was to include studies of reproductive success and survival of color-banded Scrub Jays for ten years after the project in both study sites. Scrub Jay monitoring of restoration areas at Happy Creek was to be incorporated into the ongoing long-term studies in that area. Studies involved territory mapping, nesting studies, and habitat use.

Success at Happy Creek was defined as an increase in habitat carrying capacity of Scrub Jays in the area within ten years of restoration. Success at Happy Creek should also result in areas that are now population sinks becoming population sources. Success for the northern and pad areas will be a total increase of Scrub Jays residing in both areas within ten years of restoration and creation. Relationships between mortality and reproductive success will also depend on management of surrounding areas. Nearly all the habitat created or restored is located on well drained sites so that reproduction should exceed mortality in most of these areas.

Creation Sites

Planned monitoring of scrub creation included evaluation of vegetation establishment by determining survival rate of planted shrubs annually for the first five years after planting. In addition, vegetation composition and cover by height strata and vegetation height was to be determined annually on permanent vegetation transects for ten years to determine if created scrub develops toward a system similar to natural scrub vegetation. Monitoring of Scrub Jay use of these sites was to be done in conjunction with monitoring of restoration sites.

Plan Implementation

In this section, we describe implementation of the habitat compensation plan through December 1993. This includes scrub restoration at the Happy Creek and Shiloh sites and scrub creation at Shiloh.

Scrub Restoration

Happy Creek

Mechanical Treatment. Mechanical treatment began in August 1992 and was completed in January 1993. For most of the areas within Happy Creek restoration sites, a modified Brown tree cutter, model 89-TC-72R165, mounted on a Ford 9030 Versatile tractor was used. A small portion of the area which had larger individual scrub oaks was roller chopped using a Marden M-7 roller chopper. The few remaining larger oaks and cabbage palms were pushed using a crawler tractor (Caterpillar D-6) fitted with a V-blade.

The Ford 9030 is a bi-directional tractor with articulated steering. Modifications to the tree cutter allowed it to be mounted in front of the tractor instead of being pulled, giving the operator a clear view of the cutting head while it was in operation. An additional modification was that a push bar was added to the tree cutter increasing the efficiency of the cutter's blades by bending the vegetation as it was cut. The articulated steering provided excellent maneuverability while cutting the scrub vegetation.

Initially, the production rate (area per day) was slow. It took the operator several days to determine the proper operating revolutions per minute (RPM) for the cutter and to develop techniques for cutting the varying sizes of scrub. Production was also slowed by two minor equipment problems. It was found that branches and limbs pulled coupling pins off of the three point hitch that attached the tree cutter to the tractor. The judicious application of safety wire solved this problem. The other problem was flat tires. The standard farm tires that came with the Ford 9030 were very susceptible to punctures from the sharp stems of the cut scrub. This problem was eliminated with the installation of forestry grade tires and appropriate rims.

After these difficulties were worked out, production rates increased. In areas where there was a high proportion of saw palmetto and the scrub oaks were less that 10 cm in diameter at ground level, between 1 to 1.5 ha per day could be cut. Where there were denser scrub oak populations, or when the scrub oaks were between 10 to 15 cm in diameter, rates could be a low as 0.5 ha per day. The tree cutter could cut trees up to 20 cm in diameter, but efficiency dropped off dramatically when diameters were greater than 15 cm.

Where it could be used efficiently, the Brown tree cutter provided the best results. There was almost no soil disturbance on the site using this combination of equipment. The tree cutter also produced the best fuel bed for prescribed burning of the three combinations of equipment used. The majority of the vegetation was reduced to material closely resembling mulch or wood chips in a layer less than 0.3 m thick. The majority of the fuel fragments were in the one and ten hour time lag classification. The fuel bed was continuous and cured out quickly.

The roller chopper, pulled behind a Caterpillar D-6, was used for some of the scrub oaks between 15 and 20 cm in diameter at ground level. No significant operational problems were encountered with either of these pieces of equipment. Production rates were between 0.75 and 1.25 ha per day. The action of the D-6 running over the vegetation produced some minor soil disturbance. The roller chopper reduced the height of the vegetation to less than 0.5 m but left much of the fuels in the 100 and 1,000 hour time lag classification. The fuel bed was not as uniform as that produced by the tree cutter.

The final stage of vegetation cutting utilized the D-6 with the V-blade, along with some hand cutting with chain saws. Much of this was done in the ruderal areas where individual tree diameters were larger than could be handled by the other equipment. No production rates were determined. Fuels sizes ranged up to 30 cm and distribution was very discontinuous.

Prescribed Burning. The combination of burn objectives and the physical layout of the Happy Creek site resulted in a complex prescribed burning situation. First, the stated fuel reduction objectives required that the burning be done under environmental conditions that would produce fairly intense fire behavior. Second, we needed to keep fire out of the uncut scrub to maintain sufficient habitat for the Scrub Jays in the area. Third, the mechanical treatment resulted in eight different burn areas with uncut scrub immediately adjacent. Finally, there was the need to protect the nearby NASA facilities surrounding the 150 meter wind tower. Together, these factors required careful application of fire, and a large number of resources to support the burn. As a result, it took three days to complete the prescribed burning at the Happy Creek site. The burns were conducted on February 16, 19, and 24, 1993.

Weather Conditions: The Happy Creek site received the following amounts of rainfall: between February 10th through the 12th, 1.6 cm; February 17th, 2.8 cm; and February 22nd, 1.5 cm. Mid-flame winds speeds were between 7 and 9 mph (3.1-4.0 m/s) during the majority of the burning periods, with gusts up to 15 mph (6.7 m/s). Temperatures were in the high 70's to low 80's (F) (21-27 C) on the 16th and in the 50's and 60's (F) (10-16 C) on the 19th and 24th. Lowest relative humidities were around 50%. Weather observed on the site is shown in Table 3.

Equipment and Personnel: Three light engines and one heavy engine were used during the burning to provide holding support. The light engines (U. S. Forest Service Type 6 designation) carried 200 gallons (757 L) of water, while the heavy engine carried 1,000 gallons (3,785 L). All engines had foam capability. Between ten and twelve people were on the burn each day.

Firing Strategies and Fire Behavior: On the areas burned during the first two days, no control lines were used between the cut and uncut scrub. The basic strategy was to pick units where the wind was blowing away from the uncut scrub and ignite a line of fire using drip torches along the edge between the cut and uncut scrub. A

Table 3. Observed weather conditions during the Happy Creek prescribed burns.

Day	Time	Temperature Dry Bulb (°F)	Temperature Dry Bulb (°C)	Temperature Wet Bulb (°F)	Temperature Wet Bulb (°C)	Relative Humidity %	Mid Flame Wind Speed (mph)	Mid Flame Wind Speed (m/s)	Mid Flame Wind Direction	Fuel Moisture[a] %
2/16/93										
	1000	76	24.4	65	18.3	56	10	4.5	210	16.5
	1100	77	25.0	66	18.8	53	7 (g 10)[b]	3.1 (g 4.5)	210	14.5
	1200	80	26.7	67	19.4	52	7 (g 12)	3.1 (g 5.4)	200	14
	1300	80	26.7	66	18.8	48	8 (g 14)	3.6 (g 6.3)	220	
	1500	83	28.3	69	20.6	50	7	3.1	160	12
	1600	77	25.0	67	19.4	60	5	2.2	170	
2/19/93										
	1000	53	11.7	41	5.0	34	10	4.5	350	
	1130	57	13.9	50	10.0	62	6 (g 10)	2.7 (g 4.5)	350	
	1230	58	14.4	50	10.0	58	9 (g 15)	4.0 (g 6.7)	020	
	1400	59	15.0	51	10.6	58	8 (g 12)	3.6 (g 5.4)	340	12.5
	1530	57	13.9	50	10.0	61	7	3.1	350	
	1700	55	12.7	50	10.0	70	7	3.1	350	
2/24/93										
	1030	65	18.3	54	12.2	48	7 (g 10)	3.1 (g 4.5)	360	16.5
	1130	65	18.3	54	12.2	48	8 (g 14)	(g 6.3)		
	1230	64	17.8	53	11.7	48	9	4.0	360	
	1430	64	17.8	53	11.7	48	10	4.5	350	13.5
	1700	58	14.4	49	9.4	53	5	2.2	010	14

a 10 hour time lag fuel sticks
b gusts to given speed

second line of fire was then ignited three to five m further into the cut area. The combination of the wind and the second fire would draw flames away from the uncut vegetation. For the most part, this technique worked with minimum scorching of the undisturbed scrub. Once the uncut scrub was secured, the remainder of the cut vegetation was ignited with strip head fires six to ten m apart.

This method of firing resulted in flame lengths of three to five m. Rates of spread were estimated to be about 400 m per hour. Both flame lengths and rates of spread increased when the lines of fire burned together.

There were occasions where wind shifts or irregularities in the line caused fire to burn into the uncut vegetation. For the most part, the spot-overs were suppressed quickly with limited damage to the uncut vegetation. In one instance, however, a head fire developed in the uncut scrub with flame lengths between 10 and 12 m and could not be suppressed immediately. This spot consumed 1.5 ha before it was contained.

Based on the control difficulties experienced on the first two burn days, it was decided to plow a light line around the remaining two areas. This was done with a two disk plow, and the line was rehabilitated after the fire was out. The uncut scrub was foamed just prior to ignition of the cut area. This worked well, and control problems were significantly reduced.

Results of Burn: Over 90% of the one and ten hour time lag fuels were consumed in the flaming stage of the fire. In many cases, all fuels were removed and mineral soil was exposed. Where it was safe to do so, the heavier fuels were allowed to smolder and burn down as much as possible. This resulted in over 70% of the 100 hour fuels and 40 to 50% of the larger fuels being consumed. Only the minimum mop up required to make the area safe from fire escape was done.

Smoke Management: The high winds (15 to 20 miles per hour at 20 feet [6.7-8.9 m/s at 6 m]) kept the major smoke plume below 150 m for the most part. Even though there was not good lifting, smoke dispersal during the active burning stage was rapid, and no complaints from downwind locations were reported. Although mop up was minimal, residual smoke on the area dissipated within a few hours.

Monitoring. We established and sampled 16 new vegetation transects (15 m length) in Happy Creek areas planned for restoration in June 1992. We also resampled five transects from a previous study (Schmalzer and Hinkle 1987) that were in an area scheduled for restoration; there were six transects in this stand but one could not be located prior to cutting. On all transects we determined vegetation cover in the > 0.5 m and < 0.5 m height layers. We also measured vegetation height at four points (0, 5, 10 and 15 m) along each transect and collected soil samples from the 0-15 cm and 15-30 cm depth layers for later analyses. One or more stems of a scrub oak or other shrub or tree was sectioned for age determination. Transect locations were determined using a Trimble Pathfinder Professional Global Positioning System (GPS) unit, and these data were differentially corrected.

Pretreatment vegetation data are summarized in Table 4 and Table 5. For this summary, transects were grouped into three stands. Stand 3 was to the southeast and

Table 4. Species composition (percent cover) of the scrub restoration stands before treatment, greater than 0.5 m. Data are means with standard deviations in parentheses.

Species	Shiloh			Happy Creek		
	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Befaria racemosa	-	-	-	0.45	-	2.08
				(1.10)		(4.85)
Carya floridana	-	-	3.67	-	35.68	-
			(10.69)		(27.28)	
Cassia spp.	-	-	-	-	0.33	-
					(0.65)	
Diospyros virginiana	-	-	-	-	0.5	-
					(1.0)	
Galactia elliottii	0.07	1.15	0.13	2.10	0.25	0.17
	(0.22)	(1.56)	(0.41)	(2.00)	(0.50)	(0.49)
Galactia volubilis	-	-	0.07	-	-	-
			(0.22)			
Hypericum reductum	-	-	-	-	-	0.33
						(1.15)
Hypericum tetrapetalum	-	-	-	-	-	0.06
						(0.20)
Ilex ambigua	-	-	-	-	0.33	0.03
					(0.65)	(0.09)
Ilex glabra	-	-	-	-	-	0.25
						(0.87)
Indigofera suffruticosa	-	-	-	-	1.33	-
					(2.65)	

Table 4. (Continued).

Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Lyonia ferruginea	28.03	23.73	16.24	8.77	-	3.16
	(9.06)	(16.03)	(20.64)	(10.74)		(5.86)
Lyonia fruticosa	0.53	-	-	1.12	-	4.92
	(1.68)			(1.61)		(10.78)
Lyonia lucida	1.80	9.45	-	0.57	-	2.23
	(4.65)	(9.00)		(1.08)		(5.38)
Myrica cerifera	3.17	10.18	3.77	0.62	-	0.25
	(4.10)	(12.29)	(5.79)	(1.20)		(0.59)
Osmanthus americana	7.83	4.00	6.19	-	-	-
	(7.07)	(8.00)	(14.86)			
Persea borbonia	2.03	-	-	-	-	-
	(3.00)					
Phoradendron serotinum	-	-	0.13	-	-	-
			(0.41)			
Pteridium aquilinum	-	-	-	-	-	0.23
						(0.78)
Quercus chapmanii	12.07	0.18	11.35	11.45	20.35	12.56
	(18.07)	(0.35)	(11.46)	(8.72)	(21.82)	(15.05)
Quercus geminata	53.46	44.68	31.25	40.00	24.68	27.62
	(33.57)	(11.38)	(37.60)	(32.41)	(29.20)	(18.77)
Quercus laurifolia	1.00	-	-	-	-	-
	(3.16)					
Quercus myrtifolia	30.32	6.90	47.44	66.22	25.90	51.45
	(21.46)	(9.76)	(28.80)	(7.54)	(19.79)	(29.80)

Table 4. (Continued).

Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Rhus copallina	-	-	-	-	0.83	-
					(1.00)	
Sabal palmetto	-	-	-	-	-	0.33
						(1.15)
Serenoa repens	56.01	55.75	49.79	8.22	26.18	33.89
	(15.69)	(10.14)	(20.17)	(9.25)	(30.29)	(26.28)
Smilax auriculata	1.26	-	0.14	1.22	0.18	2.86
	(2.14)		(0.30)	(1.60)	(0.35)	(3.74)
Tillandsia recurvata	0.10	-	-	1.88	0.68	0.12
	(0.32)			(4.61)	(0.53)	(0.27)
Tillandsia usenoides	0.47	-	-	0.33	-	0.06
	(1.49)			(0.82)		(0.20)
Vaccinium myrsinites	-	0.33	-	0.83	-	0.33
		(0.65)		(1.39)		(0.83)
Vaccinium stamineum	2.93	-	0.27	0.83	6.50	1.05
	(7.59)		(0.46)	(2.04)	(13.00)	(2.49)
Vitus rotundifolia	-	1.83	0.34	-	0.18	2.86
		(3.65)	(0.86)		(0.35)	(5.62)
Ximenia americana	-	-	-	-	0.43	0.23
					(0.51)	(0.78)
Total Cover	201.08	158.15	170.78	144.60	144.28	147.04
	(20.11)	(8.17)	(31.74)	(24.76)	(29.63)	(28.68)

Table 5. Species composition (percent cover) of the scrub restoration stands before treatment, less than 0.5 m. Data are means with standard deviations in parentheses.

	Shiloh			Happy Creek		
Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Andropogon spp.	-	-	-	-	2.33	1.28
					(3.83)	(2.45)
Aristida stricta	-	-	-	-	0.68	0.14
					(1.35)	(0.34)
Bare ground	-	-	-	-	2.15	0.55
					(3.49)	(1.54)
Befaria racemosa	-	0.18	-	-	-	0.17
		(0.35)				(0.41)
Carya floridana	-	-	-	-	0.75	-
					(0.88)	
Chrysopsis graminifolia	-	-	-	-	1.08	0.73
					(1.96)	(1.79)
Euthamia minor	-	-	-	-	-	0.06
						(0.20)
Galactia elliottii	0.20	0.93	-	0.38	0.18	0.31
	(0.36)	(0.29)		(0.53)	(0.35)	(0.55)
Galactia volubilis	-	-	0.13	-	0.35	-
			(0.41)		(0.40)	
Gaylussacia dumosa	-	-	-	0.05	-	0.28
				(0.12)		(0.56)
Helianthemum corymbosum	-	-	-	-	-	0.11
						(0.38)

Table 5. (Continued).

Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Ilex glabra	-	-	-	-	-	0.28
						(0.95)
Juncus scirpoides	-	-	-	-	-	0.70
						(1.95)
Lachnocaulon beyrichianum	-	-	-	-	-	0.28
						(0.95)
Liatris spp.	-	-	-	-	-	0.17
						(0.58)
Licania michauxii	-	0.18	-	-	-	1.22
		(0.35)				(3.82)
Lyonia ferruginea	0.89	0.68	-	0.12	-	-
	(0.97)	(0.94)		(0.29)		
Lyonia fruticosa	-	-	-	-	0.18	0.14
					(0.35)	(0.27)
Lyonia lucida	0.83	0.18	-	0.55	-	1.25
	(1.40)	(0.35)		(0.88)		(2.10)
Myrica cerifera	1.07	-	0.83	1.00	0.08	0.28
	(1.30)		(1.09)	(1.56)	(0.15)	(0.95)
Osmanthus americana	-	-	0.14	-	-	-
			(0.30)			
Palafoxia sp.	-	-	-	-	-	0.06
						(0.20)
Panicum sp.	-	-	-	-	-	0.03
						(0.09)

Table 5. (Continued).

Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Persea borbonia	0.53	-	-	-	-	0.06
	(1.26)					(0.20)
Petalostemon feayi	-	-	-	-	0.18	-
					(0.35)	
Pinus elliottii	-	-	-	-	0.33	-
					(0.65)	
Pteridium aquilinum	0.81	-	0.07	1.78	-	1.45
	(1.61)		(0.22)	(2.79)		(4.81)
Pterocaulon virgatum	-	-	-	-	-	0.03
						(0.09)
Quercus chapmanii	0.20	-	0.63	0.33	0.50	0.73
	(0.42)		(0.74)	(0.55)	(1.00)	(2.00)
Quercus geminata	0.03	2.48	0.16	1.57	1.43	1.17
	(0.09)	(1.96)	(0.24)	(1.25)	(1.34)	(1.42)
Quercus myrtifolia	2.87	2.18	4.26	4.43	8.93	2.58
	(2.24)	(1.48)	(5.17)	(1.93)	(6.94)	(4.47)
Quercus pumila	0.70	0.18	-	-	-	0.17
	(1.04)	(0.35)				(0.58)
Rhus copallina	-	-	-	-	0.33	-
					(0.47)	
Rhynchospora megalocarpa	-	-	-	-	0.50	1.53
					(1.00)	(2.54)
Rhynchospora plumosa	-	-	-	-	-	0.06
						(0.20)

Table 5. (Continued).

Species	Stand 1 N=10	Stand 2 N=4	Stand 6 N=10	Stand 3 N=6	Stand 4 N=4	Stand 5 N=12
Sabal palmetto	-	-	-	-	0.08	-
					(0.15)	
Scleria triglomerata	-	-	-	-	1.93	0.06
					(1.99)	(0.20)
Serenoa repens	1.19	-	0.46	0.88	0.82	0.23
	(1.68)		(0.76)	(1.61)	(1.65)	(0.78)
Seymeria pectinata	-	-	-	-	0.08	-
					(0.15)	
Smilax auriculata	-	-	-	-	0.18	0.17
					(0.35)	(0.58)
Tillandsia recurvata	0.07	-	-	-	-	-
	(0.22)					
Vaccinium myrsinites	0.03	0.50	0.13	5.00	1.50	4.08
	(0.09)	(1.00)	(0.41)	(3.22)	(1.91)	(4.20)
Vaccinium stamineum	0.57	0.18	0.07	1.00	1.83	1.13
	(1.11)	(0.35)	(0.22)	(1.63)	(3.65)	(1.70)
Vitus rotundifolia	0.07	-	-	-	-	0.83
	(0.22)					(1.76)
Ximenia americana	-	-	-	0.05	1.65	0.06
				(0.12)	(1.38)	(0.20)
Unknown aster	-	-	-	-	-	0.06
						(0.20)
Total Cover	10.06	7.63	6.88	17.15	25.83	21.83
	(3.44)	(3.85)	(6.47)	(6.08)	(8.57)	(10.75)

was previously sampled in 1983 and 1985. Stand 4 was to the south and was distinguished by the occurrence of scrub hickory (Carya floridana), and Stand 5 included all other transects. All stands were dominated by scrub oaks; saw palmetto was present throughout but was least abundant in Stand 3 (Table 4). Mean vegetation height exceeded 2.0 m in Stand 3 and exceeded 3.0 m in the other two stands (Figure 2). Depths to the water table were determined in mid-July. Depths were: Stand 3, $\bar{x}$ = 99.6 cm (sd = 11.3 cm, n = 5); Stand 4, $\bar{x}$ = 169.8 cm (sd = 62.4 cm, n = 4); Stand 5, $\bar{x}$ = 96.7 (sd = 22.6 cm, n = 12). All stands were well drained, and Stand 4 appeared to be drier than the others.

Some changes were made in the plan for Happy Creek as work proceeded. In Stand 3, five of six transects were cut; the one missing transect was relocated after cutting. In Stand 4, two of four transects were cut. In Stand 5, seven of 12 transects were cut. All cut transects burned completely in the prescribed fires. Part of one uncut transect also burned, but the other uncut transects were unaffected. Oaks, saw palmetto, and other shrubs resprouted after being cut. This regrowth burned in the prescribed fires in February. Shrubs have resprouted vigorously since then. Some saw palmettos had their terminal buds removed by the cutter; however, most of these have resprouted from elsewhere on their rhizomes. Grape vines, principally Vitis rotundifolia, were established along some edges and disturbed sites in Happy Creek prior to cutting and burning. These also resprouted. In order to prevent excessive vine dominance of the regrowing vegetation, some additional treatment, probably using spot application of herbicide, appears necessary. Along some edges, greenbriar (Smilax auriculata) regrew rapidly after cutting and burning. Some additional treatment of greenbriar may also be needed.

Transects were resampled in August 1993, six months after burning. They will be sampled again one year after burning.

After mechanical treatment and prescribed burning were completed, we determined the boundaries of the treated sites by walking them with a GPS unit. After differential correction, these data were incorporated into an ARC/INFO Geographic Information System (GIS) database. These areas are shown in Figure 3. The total area restored in Happy Creek was 56.8 ac (23.0 ha), slightly more than the 54.0 ac (21.9 ha) required in the compensation plan.

There were 13 groups comprised of 39 banded adult Scrub Jays occupying the area where restoration was performed. Most of these territories have been under study for five years. Detailed data on habitat and demographic success are being analyzed using a GIS to quantify conditions prior to restoration. Preliminary analyses indicate that most of the area where restoration is being performed was a population sink (mortality exceeded reproductive success). None of the families occupying territories within the restoration area abandoned their territories during the restoration activities. All families made at least one nest attempt in 1993 following restoration. Several years of data will be needed to determine whether restoration was successful at Happy Creek.

A prescribed burn of much of the fire management unit surrounding Happy Creek was conducted on December 14, 1993. This burn was part of planned fire

Figure 2. Height of scrub restoration stands before treatment. Shown are means and 95% confidence intervals from height measurements on vegetation transects in the Shiloh and Happy Creek restoration sites before treatment.

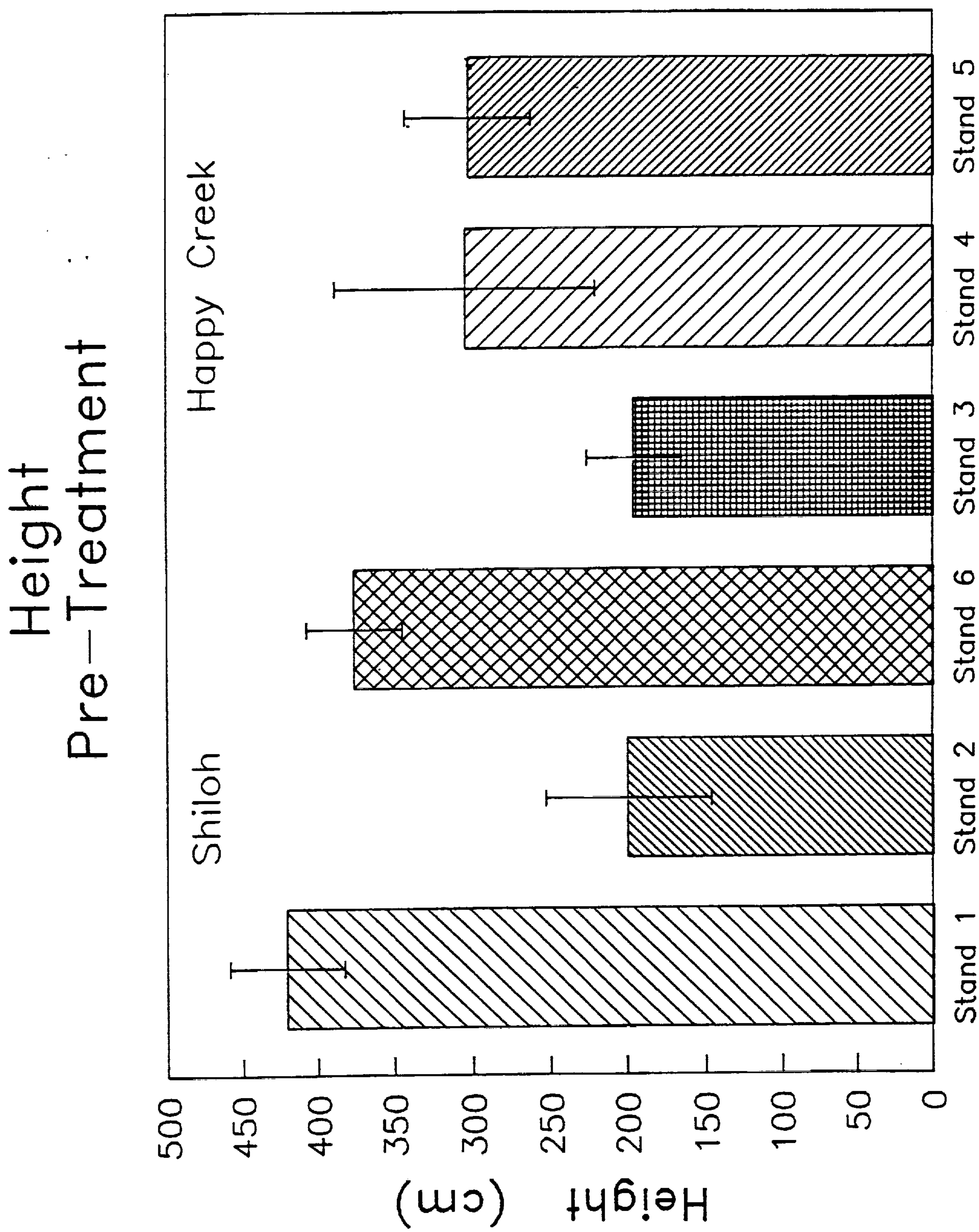
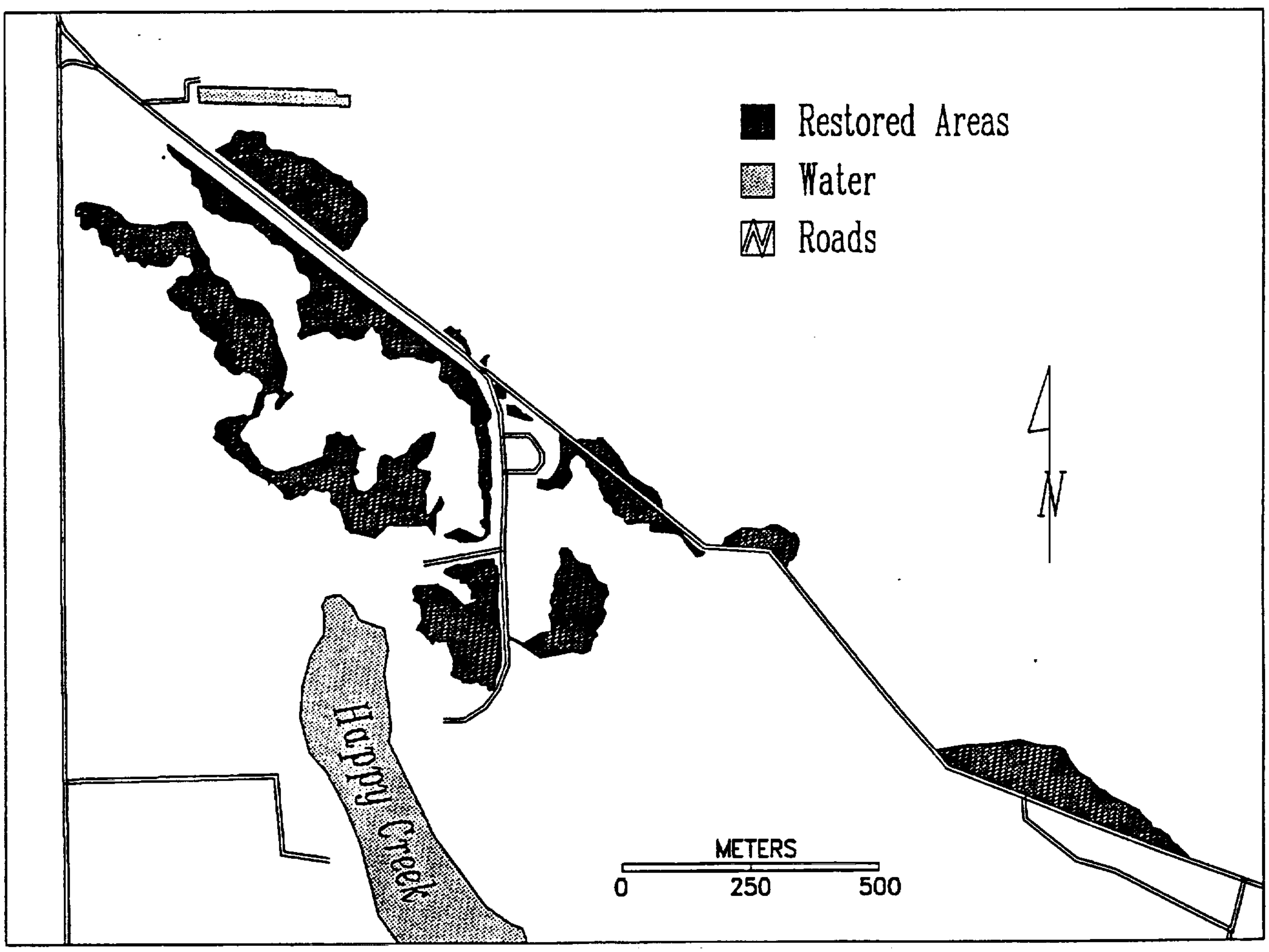


Figure 3. Happy Creek restoration sites. These sites were cut between August 1992 and January 1993 and were burned in February 1993. Restoration sites total 56.8 ac (23.0 ha).



management of the area, but efforts were made to burn areas of long-unburned scrub outside the restoration sites. Evaluation of this burn will continue as part of long term studies in Happy Creek.

Shiloh

Mechanical Treatment. Cutting of the scrub vegetation at the Shiloh site (1N) began in late January 1993 and was completed by the end of March of that year. The individual scrub oak stems were large enough at the Shiloh site to prevent the effective use of either the Brown tree cutter or the roller chopper. The V-blade mounted on the D-6 was therefore used in 95% of the cutting operation, and the remaining 5% was cut with chain saws. Production rates varied widely depending on the density of the scrub oaks and their size. A average rate overall was 1 hectare per day.

By keeping the V-blade approximately ten cm off the ground, and maintaining sufficient ground speed, the oak stems could be sliced off rather that pulled from the ground. This technique minimized soil disturbance, but required careful attention to the task and a good operator.

The resulting fuel bed was composed of nearly intact oak trees laid on the ground. The percentage of heavy fuels was quite high, and the fuel bed was discontinuous. Because of the size of the fuels they were left scattered to cure, and then piled to enhance complete burning.

Prescribed Burning. Prescribed burning on 1N-1 was accomplished on November 1, 1993, and the 1N-2 unit was burned on November 5, 1993. On these burns three light engines, a helicopter, and six to eight people were used. The interior of 1N-1 that was not cut was not burned to leave habitat for resident Scrub Jays.

Since both sites were fairly large, they were subdivided into smaller units to facilitate burning. On both sites, the strategy was to ignite the control lines by hand and then use the helicopter equipped with the Premo Mk III Aerial Ignition Device to ignite the interior. In some cases, lines of fire were strung by hand in the interior to increase fire intensity. The slash piles were ignited either by hand or with the helicopter.

On November 1, flames in the open areas burned with low intensities. Flame lengths seldom exceeded 0.6 m, and rates of spread were between 20 to 40 m/hr. On the 5th, fire intensities were moderate. Flame lenghts were between 1 to 2 m, with rates of spread of 60 to 80 m/hr. There were two spotovers on the 5th. Both of these were suppressed with helicopter bucket drops and mopped up by hand. Additional mop up was required on the 6th.

Fire behavior and percent of area burned was very different on the two burn days. This can be attributed to differences in both the fuel beds and weather conditions. The original vegetation in Site 1N-1 consisted of scrub oaks with ground level diameters of 12 to 20 cm with only a few palmettos. There was very little fine fuel available after the V-blading and piling process. This left a discontinuous fuel bed which retarded the spread of the fire. In addition, fuel moisture was fairly high, further reducing fire intensity. As result only 60 to 70% of the areas was burned. All of the slash piles burned down to white ash.

The treatment of unit 1N-2 had resulted in a more continuous fuel bed, with a larger component of fine fuels, allowing the fire to spread more evenly over the site. In addition, the three days between the burns were clear, dry and fairly warm allowing the fuels to become dryer. On the 5th, fuel moisture sticks showed only 13.5% moisture content at 1045 compared to 15% at 1120 on the 1st. The combination of finer fuels and dryer conditions significantly increased fire behavior, and about 95% of the area burned. Once again, the slash piles burned completely.

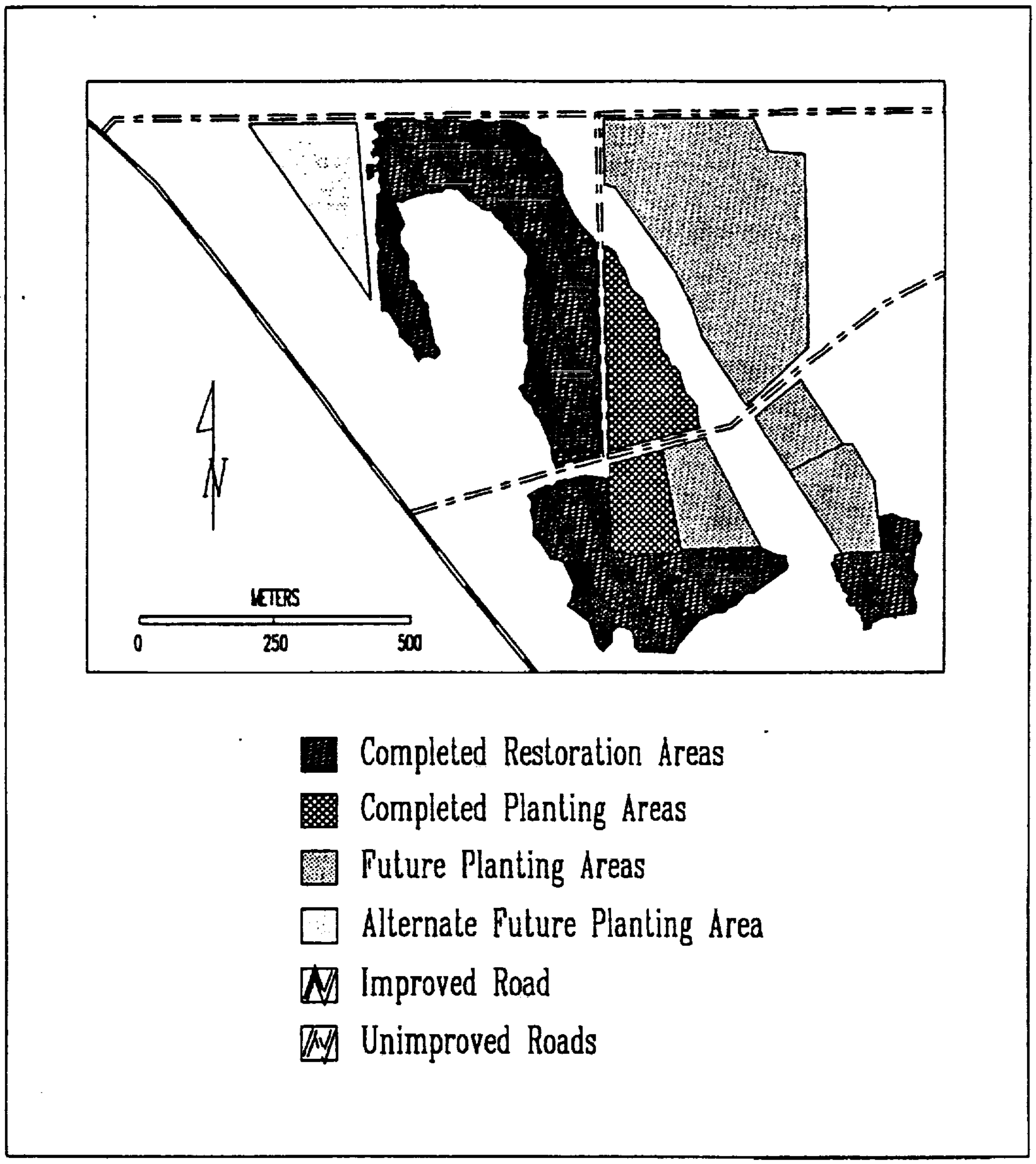
Monitoring. We sampled vegetation of Shiloh Site 1N-1 in May 1992. We placed ten transects in the section planned for restoration. We also established four transects in the center area that was to be left. We recorded vegetation cover and height on all transects, sectioned one or more stems for age determination, and collected soil samples as previously described. In July 1992, we determined depth to water table at each transect by coring. Transect locations were determined using a GPS unit. We sampled vegetation of Site 1N-2 in November 1992 using the same methods. We established and sampled six transects in the section west of the swale and four in the eastern section. Depths to the water table for these transects were determined in November 1992 and GPS coordinates obtained.

Pretreatment vegetation data are summarized in Table 4 and Table 5. For this summary, transects are grouped into three stands. Stand 1 includes the ten transects of the treatment section of Site 1N-1. Stand 2 includes the four transects of the interior section. Stand 6 includes the ten transects of Site 1N-2. Scrub oaks and saw palmetto dominated all stands. Osmanthus americana (wild olive) occurred here but not at Happy Creek. Mean vegetation height exceeded 3.5 m in Stands 1 and 6 and was about 2.0 m in Stand 2 (Figure 2). Depths to the water table were: Stand 1, $\bar{x}$ = 127.9 cm (sd = 35.5 cm, n = 10); Stand 2, $\bar{x}$ = 67.5 cm (sd = 15.5 cm, n = 4); Stand 6, $\bar{x}$ = 123.8 cm (sd = 26.0 cm, n = 10). Both stands intended for treatment were well drained. The interior of Site 1N-1 was less well drained but still dominated by scrub oaks.

All transects of Stands 1 and 6 were mechanically treated, and all the transects of Stand 2 were unaffected.

After mechanical treatment was completed, we determined the boundaries of treated sites by walking them with a GPS unit. After differential correction, these data were incorporated into an ARC/INFO GIS database. Areas of treatment were: Site 1N-1, 30.0 ac (12.1 ha); Site 1N-2, 22.5 ac (9.1 ha) (Figure 4). The treated areas of both Sites 1N-1 and 1N-2 were slightly larger than the initial estimate. The total for these two sites (52.5 ac, 21.2 ha) exceeded that required (45.4 ac, 18.4 ha) in the compensation plan.

Figure 4. Shiloh restoration and creation sites. Site 1N-1 is the restoration site located north of the east-west road; Site 1N-2 is south of the road and is separated into two sections by a wet swale. Restoration sites were cut between January and March 1993 and burned in November 1993; these sites total 52.5 ac (21.2 ha). Creation site P1 was planted in August 1992 and totals 13.9 ac (5.6 ha). Future planting of scrub may occur on up to 44 ac (17.8 ha). An alternate future planting site of 7.6 ac (3.1 ha) has been identified west of Site 1N-1.



After burning, transects were revisited. In Site 1N-1, three transects burned completely, five were partially burned, and two were unburned. In Site 1N-2, nine transects burned completely and one was unburned.

There were three groups comprised of seven banded adult Scrub Jays occupying portions of the area where restoration was performed. None of these groups bred successfully in 1992 or 1993. The low breeding success exhibited throughout this study area indicate that most of the area is a population sink. The resident Scrub Jays continued to forage in the restored area both during and after the mechanical treatment. One group nested in the slash of the restored area after the mechanical treatment was complete.

Scrub Creation

Site Preparation and Planting

Site preparation began with removal of cabbage palms. Examination of the site indicated that potential weed problems were more serious than anticipated. Weeds included clumps of guineagrass (Panicum maximum), pepper vine (Ampelopsis arborea), and passion-flower vine (Passiflora incarnata). Therefore, site preparation also included mowing and two applications of glyphosate herbicide to reduce potential competition from herbs, vines, and shrubs. The first application, at a rate equivalent to 0.5 L/ha of glyphosate, was completed in early June of 1993. Although grass growth was retarded, and some discoloration of vine foliage was observed, the desired degree of control of the unwanted vegetation was not achieved. After discussion with weed control experts, it was decided that a rate equivalent to 10 L/ha would be necessary. This was applied during the second week of July 1993. This application was generally effective.

Nursery-grown tublings were planted on August 12th and 13th, 1992 using a semi-automatic tree planter. The sand live and Chapman oaks did not present any problems, but some difficulty was experienced with the myrtle oaks because of their small size (6 to 10 cm top growth). This required that great care be taken in placing them in the planting fingers, lest they be planted at the incorrect depth. Otherwise, the operation went smoothly.

Monitoring

We established ten line intercept transects (15 m) length in the planting site in late August 1992 after planting was completed. We recorded vegetation data and obtained soil samples for later analyses. At this initial sampling, vegetation cover was primarily dead grass and bare ground resulting from herbicide treatment, and remaining weedy species (e.g., Cynodon dactylon, Panicum maximum). A few scrub oaks were present that naturally established on the site. Galactia elliottii (milk pea) was relatively common. Depths to the water table were determined by coring in mid-September 1992. Mean depth to the water table was 115.4 cm (sd = 27.4 cm, n = 10), confirming that the site was well drained. Transect locations were recorded using a GPS unit and the data differentially corrected.

Transects were relocated and resampled in early September, 1993. Nine of ten were resampled. One could not be relocated because the marking posts were missing. This transect will be reestablished when a real-time, differentially correcting GPS unit is available. Vegetation transects were dominated by weedy herbaceous species including natal grass (Rhynchelytrum repens), guineagrass (Panicum maximum), crab grass (Cynodon dactylon), camphorweed (Heterotheca subaxillaris), ragweed (Ambrosia artemisiifolia), and others.

To determine survival of planted oaks, ten sections of planted rows were selected and 15 planted tublings in each were tagged individually in late August 1992, two weeks after planting. The species of each tagged oak was determined and status was recorded as live or brown. We thought that some oaks that were brown or had shed leaves initially might resprout. Of the 150 oaks sampled, 96 (64.0%) were sand live oak, 46 (30.7%) were myrtle oak, and 8 (5.3%) were Chapman oak. Overall survival then was 66%; the range among transects was 46.7-86.7%. Survival was not uniform among species. Because of the small sample size, Chapman oaks were included with myrtle oak in this analysis. Initially, 71 of 96 sand live oaks were alive but only 28 of 54 myrtle plus Chapman oaks. These differences in initial survival were significant (Chi-square test, $X^2 = 7.53$, $p < 0.01$) (SPSS Inc. 1988).

Tagged oaks were resampled in early May 1993. Results then were 50.7% overall survival; the range among transects was 20.0-86.7%. Six tublings that were brown at the initial sampling were alive when resampled. Differences in survival among species persisted. Of sand live oaks, 66 of 96 were alive but only 10 of 54 myrtle plus Chapman oaks. These differences were significant (Chi-square test, $X^2 = 34.89$, $p < 0.0001$) (SPSS Inc. 1988).

Sand live oak tublings appeared larger and more robust when planted than those of myrtle oak. That may, in part, explain the differences in survival. Some myrtle oak tublings were not fully inserted in the ground by the planting equipment, probably due to their small size. Large clumps of guineagrass in the eastern part of the planting site appeared to interfere with the planting equipment. An additional cause of mortality between August and May was rooting by feral hogs (Sus scrofa). Rooting impacted one of ten transects and was not species specific.

Boundaries of the creation site (P1) were determined in May 1993 using a GPS unit (Figure 4). The area planted was 8.7 ac (3.5 ha) north of the sand road and 5.1 ac (2.1 ha) south of the sand road; the total (13.9 ac, 5.6 ha) exceeded the intended size of the planting site.

Since the site was larger and the initial planting included fewer oaks than planned, an additional 2000 oaks were hand planted in the site on August 31 and September 1, 1993. From the second planting of scrub oaks, 50 individuals were randomly selected and tagged in early September 1993 to follow survival. These included 20 sand live oaks and 30 myrtle oaks. Initial apparent survival was 56.0%. Some individuals had brown leaves but still had live buds and may resprout. Differences between species occurred but were not significant (Chi-square test, $p > 0.2$). Apparent survival of sand live oak was 65% and that of myrtle oak was 50%.

In the second phase of scrub planting on the P1 creation site, a mixture of species were planted as 1 gallon pots between July 27 and August 18, 1993. These included 500 saw palmettos, 300 rusty lyonias, 200 shiny blueberries and 100 South Florida slash pines. Fifty of these additional shrubs or trees were randomly selected and tagged in early September 1993 to follow survival. These included 34 saw palmettos, 6 slash pines, 4 shiny blueberry, and 6 rusty lyonias. All were alive when sampled.

During early monitoring of the Shiloh restoration and creation sites it was noted that the southeastern part of planting site P2 had a high density of gopher tortoise burrows, and gopher frogs (Rana areolata) occurred in some burrows (NASA 1993). Both species are listed as species of special concern by the Florida Game and Freshwater Fish Commission and are candidates for listing by the U.S. Fish and Wildlife Service (Wood 1992). Scrub creation requires reduction of competing vegetation using mowing, herbicide applications, or other techniques. These could negatively impact gopher tortoises through loss of available food and amphibians like the gopher frog through skin absorption of herbicides. Scrub creation on Site P2 was originally scheduled for FY 1994 (NASA 1992), but probably will be delayed to FY 1997 due to changes in construction schedules (NASA 1993). Alternatives to using the southeastern section of P2 include substituting a site to the west of restoration site 1N-1 or delaying scrub creation on the southeastern section while it occurs on the northern section. The alternate site west of Site 1N-1 is 7.6 ac (3.1 ha) in size, larger than the southeastern section (5 ac, 2 ha). However, recent GIS analysis of the planting sites indicate that their areas exceed initial estimates and that the required additional 30 ac of scrub creation could be accommodated in Site P2 north of the sand road and in the unplanted section west of the swale.

It is likely that the high tortoise densities in part of the old grove relate to abundant herbaceous growth there and the lack of herbs in the adjacent, long-unburned scrub. With restoration of this scrub, more food resources for tortoises may be available outside the old grove and some dispersal of tortoises may occur. Delay in the schedule for scrub creation on this site allows time for additional observations.

Summary

1. Habitat fragmentation and other disruptions of fuel continuity caused by past agricultural practices and development have altered the ability for fires to spread through the landscape as they once did. The flora and fauna of scrub, pinelands, and marshes are dependent on fire and are greatly influenced by fire regimes. Habitat structure needed for maintaining threatened and endangered species is often not readily restored once natural habitats are degraded by fire exclusion. In degraded scrub habitat, the application of prescribed fire alone is not always adequate to provide for the low, open scrub that represents native habitat conditions and is required by the Scrub Jay. Once scrub oaks reach a certain stature they are often able to survive fire and resprout from trunks above-ground. This results in a forest vegetation structure rather than a shrubland.

2. Mechanical cutting of oak trees, followed by prescribed fire, appears to be the only reasonable measure to restore some scrub sites.

3. The generation and maintenance of open areas in scrub is a poorly understood process. It appears that natural openings most often occur near snags and between scrub oak ridges and more flammable flatwoods vegetation. Once openings were lost due to fire suppression, repeated winter fires have not reestablished openings, perhaps because fuel discontinuity at the fine scale has been lost and fires burn continuously through the landscape reducing scrub oaks to low stature but not producing openings. The generation of openings, mimicking the native landscape, remains problematic across most of KSC, except in pinelands.

4. Restoration activities, which may occur in relatively small areas, should be directed towards their importance at the landscape scale. For example, restoration of small patches of scrub in a landscape dominated by unsuitable habitat will be of little value. Restoration of small patches in otherwise suitable habitat may improve the visibility for Scrub Jays to spot predators thus improving the restored patch and scrub surrounding the treatment site.

5. The development of a restoration program specific to KSC relied heavily upon: 1) data generated from a long term research program that used successive refinement of data collection to investigate vegetation, habitat, and species responses to habitat disturbance and prescribed fire specific to KSC; 2) the use of scientific literature on natural processes, historical literature, and time sequences of historical aerial imagery; and 3) close interaction with a land management agency with extensive experience in prescribed burning and other techniques of habitat management.

6. A range of low to high risk restoration activities will generate information to evaluate the success of restoration techniques on a wide variety of degraded areas and should provide opportunities to solve numerous problems associated with the degradation of natural habitat conditions and processes. The implementation of an experimental habitat restoration program combined with monitoring and research should be of considerable value to other organizations and programs such as the Brevard County Scrub Jay habitat conservation planning effort.

7. Initial results of the Happy Creek restoration are highly encouraging. Use of the Brown tree cutter produced little soil disturbance and created a continuous fuel bed that burned well. Vegetation is recovering well. Initial results at the Shiloh restoration sites are also encouraging. The fuel bed left by the V-blade treatment was less continuous and did not burn as well, but the regenerating system is a shrubland with the potential for long term management. Proliferation of vines in some areas of both restoration sites was greater than expected, and additional spot controls of these vines are needed. Long term data are required to determine effects on Scrub Jays, but no territories were abandoned during restoration activities.

8. Scrub establishment in abandoned citrus groves may be more difficult than anticipated. More intensive site preparation and use of larger, more mature planting stock may be required. Sand live oak tublings appear to survive planting much better than myrtle oak.

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13. ABSTRACT *(Maximum 200 words)*

Kennedy Space Center (KSC), located on Merritt Island on the east coast of central Florida, is one of three remaining major populations of the Florida Scrub Jay (Aphelocoma coerulescens coerulescens), listed as threatened by the U.S. Fish and Wildlife Service (USFWS) since 1987. Construction of new facilities by the National Aeronautics and Space Administration (NASA) on KSC over the next five years has the potential to impact up to 193 ac (78.1 ha) of Scrub Jay habitat. Under an early consultation process with the Endangered Species Office of the USFWS, NASA agreed to a compensation plan for loss of Scrub Jay habitat. The compensation plan required NASA to restore or create scrub on KSC at a 2:1 ratio for that lost. The compensation plan emphasized restoration of scrub habitat that is of marginal or declining suitability to Scrub Jays because it has remained unburned. Although prescribed burning has been conducted by the USFWS Merritt Island National Wildlife Refuge (MINWR) for more than ten years, significant areas of scrub remain unburned because they have been excluded from fire management units or because landscape fragmentation and a period of fire suppression allowed scrub to reach heights and diameters that are fire resistant. For such areas, mechanical cutting followed by prescribed burning was recommended for restoration. A second part of the restoration plan is an experimental study of scrub reestablishment (i.e., creation) on abandoned, well drained agricultural sites by planting scrub oaks and

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other scrub plants. The compensation plan identified 260 ac (105 ha) of scrub restoration in four areas and a 40 ac (16 ha) scrub creation site. Monitoring of restoration sites required under the plan included: 1) establishing permanent vegetation sample transects before treatment and resampling annually for ten years after treatment, and 2)colorbanding Scrub Jays to determine territories prior to treatment followed by monitoring reproductive success and survival for ten years after treatment. Monitoring scrub creation sites included determining survival of planted material for five years and establishing permanent transects to follow vegetation development for ten years after planting. Scrub Jay monitoring of creation sites is incorporated with that of adjacent restoration sites.

Scrub restoration began with work at the Happy Creek site; 56.8 ac (22.6 ha) ofscrub were cut between August 1992 and January 1993, primarily using a Brown tree cutter, and these areas were burned in February 1993. Vegetative regrowth has been vigorous. No Scrub Jay families abandoned their territories within the restoration area. Mechanical treatment of the Shiloh restoration site occurred between January and March 1993 and covered 52.5 ac (21.2 ha). Due to the large size of oaks at this site, a D-6 Caterpillar with a V-blade was used to cut the scrub. The site was burned in November 1993. Only three families of Scrub Jays (7 individuals) occupied portions of the area where restoration was performed; none abandoned the area during or after mechanical treatment. Site preparation of the initial 10 ac (4 ha) planting site included removal of cabbage palms (_Sabal palmetto_), mowing, and two herbicide applications. Oak tublings were planted in early August 1992. Initial survival was 66% (late August), but this declined to 50.7% by May 1993. Sand live oak (_Quercus geminata_) survived much better than myrtle oak(_Quercus myrtifolia_), perhaps due to their larger size at planting. In the summer of 1993 additional scrub oak tublings were planted; initial survival was 56.0%. One gallon pot size saw palmetto (_Serenoa repens_), rusty lyonia (_Lyonia fruticosa_), shiny blueberry (_Vaccinium myrsinites_), and South Florida slash pine (_Pinus elliottii_ var. _densa_) were planted in the summer of 1993; initial survival was 100%. Initial results of scrub restoration are encouraging and may have applicability to other scrub sites degraded by fire exclusion; long-term data are required to determine Scrub Jay population responses.