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Habitat Model for the Florida Scrub Jay on John F. Kennedy Space Center

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Habitat Model for the Florida Scrub Jay on John F. Kennedy Space Center

David R. Breininger
The Bionetics Corporation
Kennedy Space Center, Florida 32899

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Abstract

The Florida Scrub Jay (Aphelocoma coerulescens coerulescens) is endemic to Florida. The John F. Kennedy Space Center (KSC) provides habitat for one of the three largest populations of the Florida Scrub Jay. This threatened bird occupies scrub, slash pine flatwoods, disturbed scrub, and coastal strand on KSC. Densities of Florida Scrub Jays have been shown to vary with habitat characteristics but not necessarily with vegetation type. Relationships between Florida Scrub Jay densities and habitat characteristics were used to develop a habitat model to provide a tool to compare alternative sites for new facilities and to quantify environmental impacts. This model is being tested using long term demographic studies of colorbanded Florida Scrub Jays. Optimal habitat predicted by the model has ≥50% of the shrub canopy comprised of scrub oaks, 20-50% open space or scrub oak vegetation within 100m of a ruderal edge, ≤15% pine canopy cover, a shrub height of 120-170cm, and is ≥100m from a forest. This document reviews life history, social behavior, food, foraging habitat, cover requirements, characteristics of habitat on KSC, and habitat preferences of the Florida Scrub Jay. Construction of the model and its limitations are discussed.

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Acknowledgements

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Introduction

The Florida Scrub Jay (Aphelocoma coerulescens coerulescens) is listed as a threatened species by the U.S. Fish and Wildlife Service (USFWS). One of the three largest Florida Scrub Jay populations is located on John F. Kennedy Space Center (KSC) (Cox 1984, 1987; Breininger 1989). The other two large populations are also on federal property; these include Cape Canaveral Air Force Station (CCAFS) and Ocala National Forest. Federal agencies with jurisdiction on KSC are legally mandated by the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) to consider the effects of their operations on the Florida Scrub Jay population (USFWS 1990). Lands and waters of KSC not being used by the space program are managed as Merritt Island National Wildlife Refuge and Canaveral National Seashore by the USFWS and National Park Service, respectively.

Florida Scrub Jays occupy areas mapped as oak/palmetto scrub, slash pine, disturbed scrub, coastal strand, and ruderal; these comprise most of the uplands on KSC (Provancha et al. 1986). The most recent estimate of the size of the Florida Scrub Jay population on KSC is 1400-3600 birds or about 800 territories (Breininger 1989). Florida Scrub Jay population size naturally fluctuates even when habitat conditions remain relatively constant (Woolfenden and Fitzpatrick 1984). Accurate determination of the population size of an area requires colorbanding all the birds and territory mapping (Verner 1984); this is a time-consuming process and is not practical for all environmental evaluations.

Population size is influenced by the amount of available habitat and habitat suitability. An inventory and map of primary and secondary habitat on KSC has been prepared (Breininger et al. 1991). Primary habitat is defined as scrub and pine flatwoods that occurs on well drained areas and has the potential to support scrub oak cover that is optimal for the Florida Scrub Jay. For 1985-1986, it was estimated that 57% of the KSC population occurred in 1600 ha of primary habitat which represented approximately 15% of the total habitat that had potential to support Florida Scrub Jays. Nearly all primary habitat was suitable for Florida Scrub Jays and only half of the secondary habitat was suitable (Breininger et al. 1991). Secondary habitat was mapped as scrub and slash pine on poorly drained soils and coastal strand within 300 m of scrub or coastal woodlands. Only a small portion of secondary habitat has potential to be optimal.

Florida Scrub Jay population centers were defined as areas including all primary habitat and adjacent (within 300 m of primary habitat) secondary habitat. Population centers were estimated to comprise 4785 ha (44%) of the total potential habitat area including 86% of the population. For maintenance of Florida Scrub Jay populations it is necessary to minimize facility development in population centers and manage them appropriately. The inventory of potential primary and secondary habitats is one tool to evaluate environmental impacts of individual projects and cumulative effects. A site specific tool is needed because management practices influence the suitability of primary and secondary habitat, and because it is seldom possible to determine the suitability of secondary habitat without field studies. A habitat model was developed to estimate the existing suitability of project areas and evaluate alternative sites and scenarios for environmental planning and habitat management.

Habitat Evaluation Procedures (HEP) have been developed as a standardized procedure using habitat as the basis for environmental assessment to provide a quantifiable uniform assessment of project impacts on fish and wildlife (Hirsch et al. 1979). The procedures rely upon the development of a Habitat Suitability Index (HSI) for particular species based on physical and biological characteristics of the habitat. Standards have been developed to construct indices that can be used to quantify the habitat suitability of a site within the range of 0 to 1.0, with 0 being unsuitable and 1.0 being optimal. The Habitat Units (HU) or value of an area being evaluated can be found by determining the HSI value of the habitat and multiplying this value by the acreage of concern. The HEP procedures are standardized in Parts 101, 102, and 103 of the Ecological Services Manual (USFWS 1980a, b, 1983).

This model is a hypothesis of species habitat relations and is not a statement of proven cause and effect. The KSC model is based upon several years of study on KSC beginning in 1978, and the incorporation of information obtained from a review of studies conducted elsewhere. The model-building process involved judgement. Assumptions used in the model construction process are discussed in Appendix E. The next phase is to test the model; current and future data acquisition will probably result in modifications to the model.

The model can be used to evaluate whether a site on KSC is suitable habitat and provide an estimate of the habitat suitability. It provides a range of conditions of habitat used by Florida Scrub Jays. The loss of primary habitat should often be considered a more significant impact than the loss of secondary habitat, regardless of habitat suitability at the time of evaluation. The model has certain limitations that are presented in Appendix F. In general, it is important to minimize the effects of habitat fragmentation, but they are not considered by this model. Exceptions occur where fragments of primary habitat, isolated by human development, occur near operational areas and along some roads. These fragments may often be less important to the population than some secondary habitat if Florida Scrub Jays in these fragments are subject to high road mortality or if these fragments can not be managed. Impacts may be greater than predicted by the model in a project area that serves as a source (where Florida Scrub Jay reproductive rates exceed mortality rates) within a landscape dominated by sinks (areas where mortality rates exceed reproductive rates) (see Appendix F). Large scale development will need to consider the spatial distribution of population demographic (reproduction and survival) topics to quantify the significance to the population. Any areas that serve as corridors between population centers require special considerations (Appendix F). Roads where speeds exceed 35 mph may result in the adjacent habitat (within 300m of the edge) becoming a population sink due to road kills (Dreschel et al. 1990). Thus biological assessments must address additional considerations including the existing habitat suitability estimated by the model.

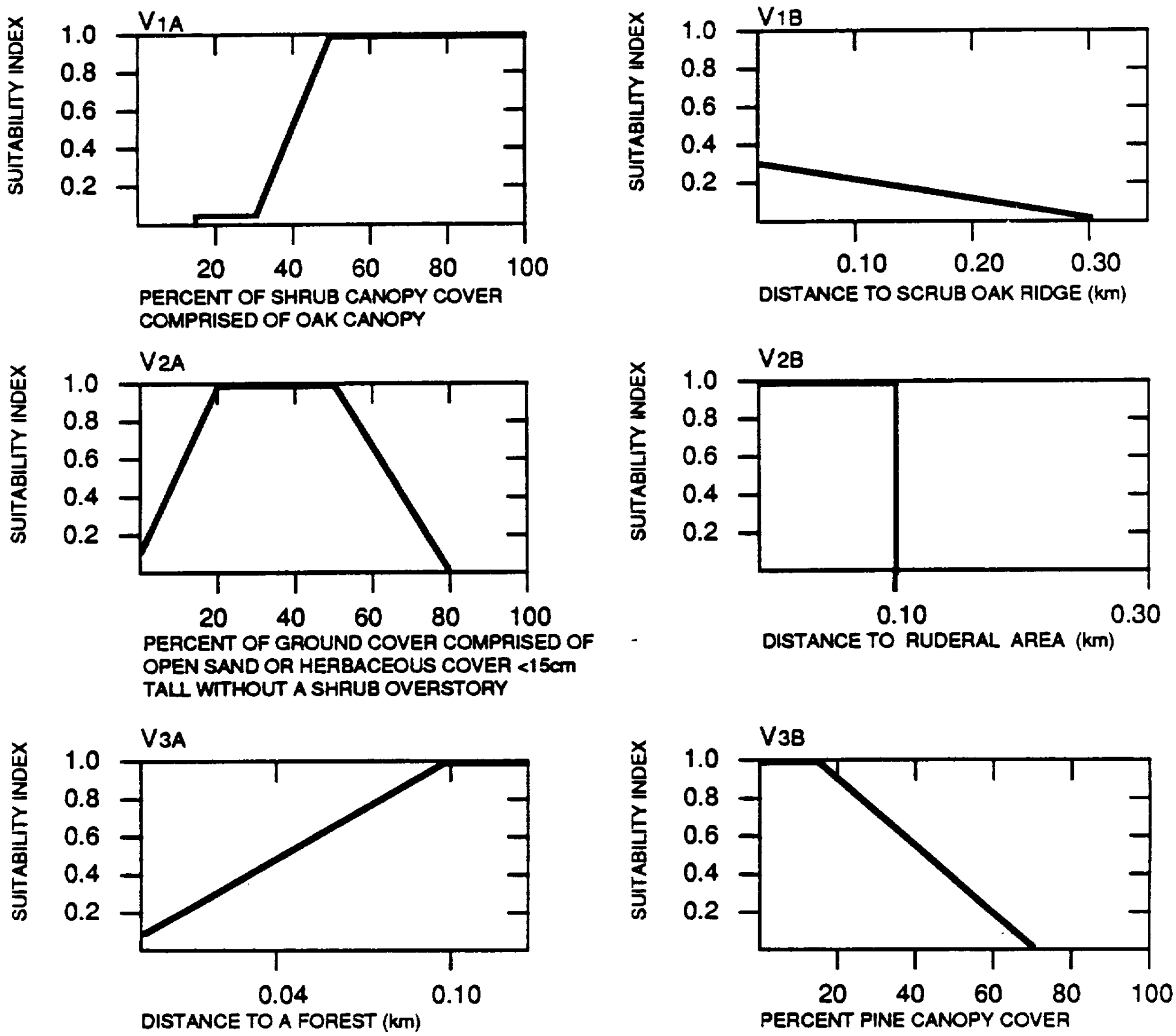
This document provides information relevant to Florida Scrub Jay biology and the KSC environment, and it is organized to provide frequent users quick access to the model in the front of the document. Readers familiar with Florida Scrub Jay biology should skip Appendices A and B. Readers familiar with habitat at KSC should also skip Appendix C. Appendices D and E are only important for readers interested in how the model was developed. Appendix D provides a summary of studies on habitat preference performed elsewhere and on KSC prior to the KSC upland bird study, which is described as the starting point for model development in Appendix E. Appendix E provides documentation of the assumptions and approaches used to develop the model. All model users should be familiar with limitations discussed in Appendix F.

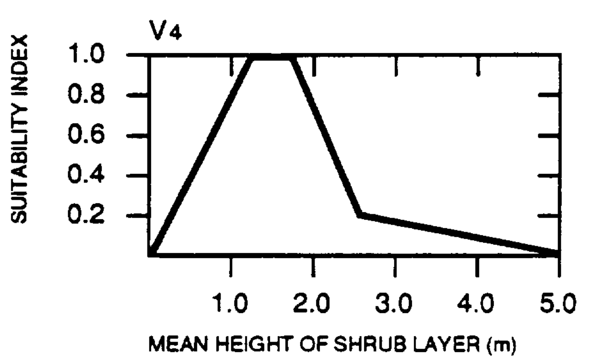
Model Use

The model is presented in Figure 1. The variables are summarized in Table 1. Application of the model will usually involve sites having patches of scrub and slash pine that differ with respect to habitat structure and vegetation composition. Patches having different habitat charactersitics should be mapped as seperate polygons. Polygons represent areas of homogenous vegetation identified on aerial photography. These may be further subdivided based on distances to scrub oak ridges or ruderal edges (see below). HSI values should be determined for each polygon. HSI values for each polygon are multiplied by the acreage of each polygon to determine the number of habitat units associated with the polygon. The total habitat units are the sum of habitat units from the different polygons (Figure 2). The habitat units present in the project area should be determined before and after the project. Procedures for performing HEP evaluations are provided in HEP 101 and 102 [USFWS (1980) and the USFWS HEP Workbook (undated)]. Users should be familiar with these procedures.

Evaluating the effects of some proposed projects may best be performed by mapping territories of colorbanded residents and mapping habitat types using the recommendations provided below. Thus HSI and HU values can be determined for each patch within each territory in a project area.

Figure 1. Habitat Model for the Florida Scrub Jay on John F. Kennedy Space Center





$$HSI = \sqrt[4]{V_1 V_2 V_3 V_4}$$

$$V_1 = V_{1A} \text{ OR } V_{1B} \text{ (MAX)}$$

$$V_2 = V_{2A} \text{ OR } V_{2B} \text{ (MAX)}$$

$$V_3 = V_{3A} \text{ OR } V_{3B} \text{ (MIN)}$$

$$HU_1 = HSI \times \text{acreage}$$

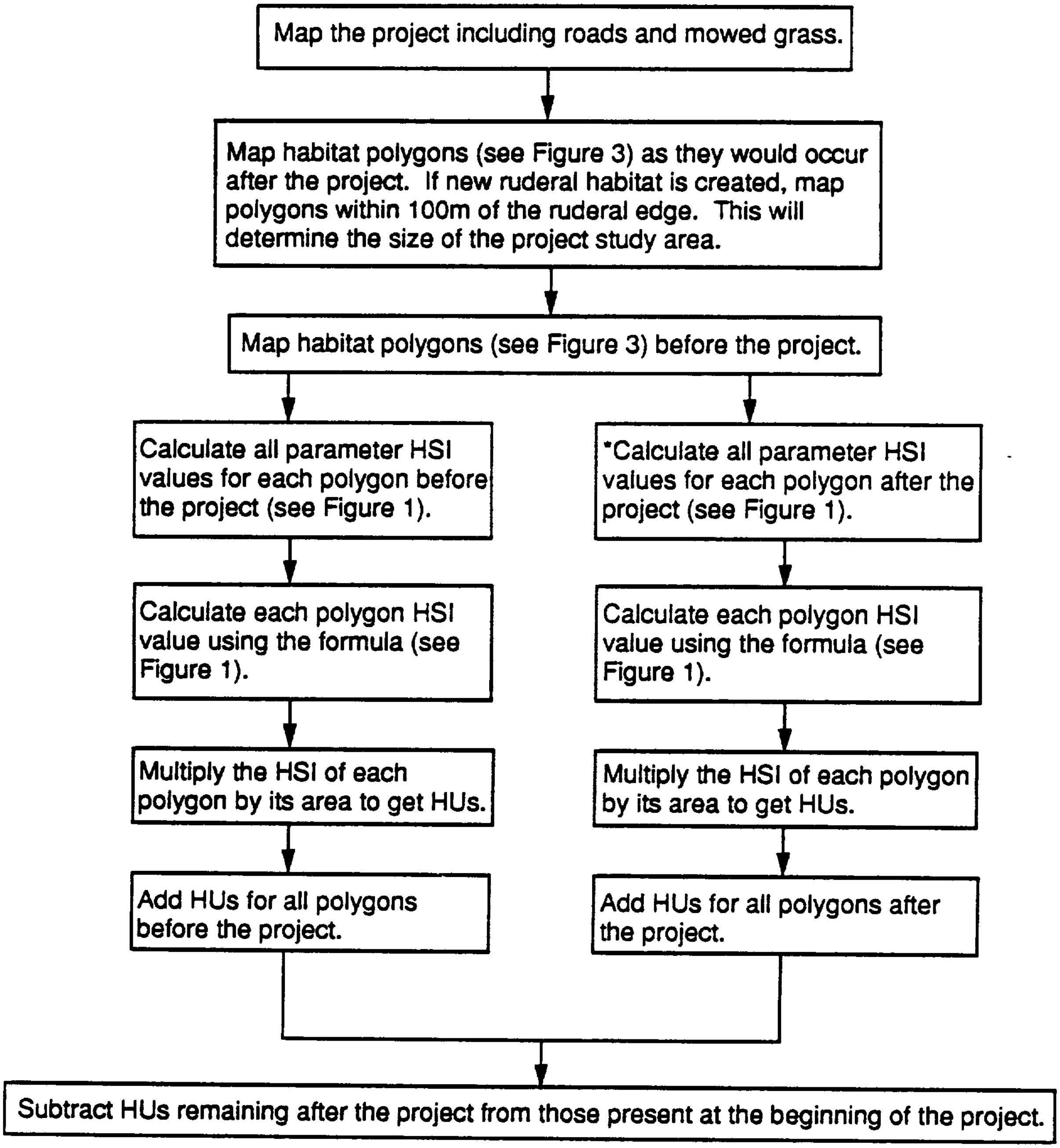
$$\text{Project HU} = \sum HU^1_N$$

$$N = \text{Number of Polygons}$$

Table 1. Summary of Habitat Suitability Variables

Habitat Requirement	Variable	Definition	Applicability	Categories	Comments
Scrub Oaks	V1A	Percent of shrub canopy cover comprised of scrub oaks (PSO). This value is determined by dividing scrub oak cover by total shrub cover x100. Scrub oaks are: _Q. myrtifolia_, _Q. geminata_, _Q. chapmanii_, and the beach dwarf variety of _Q. virginiana_	Every model application	0-14% PSO HSI = 0.0 15-30% PSO HSI = 0.05 30-50% PSO HSI increases from 0.05 to 1.0 50-100% PSO HSI = 1.0	Assume all primary habitat to have a HSI = 1.0 for V1A if model is being used to evaluate habitat loss due to construction but not effects of a frequent fire policy.
	V1B	Distance to scrub oak ridge (DSO). This is the average distance a polygon is from a scrub oak ridge. A scrub oak ridge includes all primary habitat and secondary habitat with a PSO ≥50%.	Polygons that are within 300m of a scrub oak ridge	0-300m DSO HSI decreases from 1.0 to 0.0 ≥300m DSO HSI = 0.0	Areas with ≥50% PSO have a red signature on color infrared imagery; however, some mesic shrubs also have a red signature. White sandy soil is often evident except in unburned areas.
Open Space	V2A	Percent open space (OS). This is the percent of the ground layer comprised of open sand or sparse herbaceous cover including Bahia grass that is frequently mowed and <15cm tall.	Every model application where V2B is not applicable	0-20% OS HSI increases from 0.1 to 1.0 20-50% OS HSI = 1.0 50-80% OS HSI decreases from 1.0 to 0.0	If a fire break, road, or area is within 100m, V2B may apply.
	V2B	Distance to ruderal area (DRA)	Areas within 100m of an area with a PSO ≥30% and within 100m of a suitable ruderal edge	0-100m DRA HSI = 1.0 ≥101m DRA HSI = 0.0	Suitable ruderal edge is a fire break, sandy road, or ruderal area that is ≥12m wide.
Trees	V3A	Distance to a Forest (DF)	Areas within 100m of a forest	0-100m DF HSI increases from 0 to 1.0 ≥100m DF HSI = 1.0	All hammocks and swamps are forests. A few disturbed pine stands have interlocking canopies and are pine forests.
	V3B	Percent pine canopy cover (PC)	All applications	0-15% PC HSI = 1.0 15-70% PC HSI decreases from 1.0 to 0.0 ≥70% PC HSI = 0.0	Open pine savannas usually have an optimal HSI value for V3B. All scrub has an optimal HSI value for V3B. Pine forests are unsuitable.
Shrub Height	V4	Mean Height of Shrubs (MSH)	All applications	0.00 - 120cm MSH HSI increases from 0.0 to 1.0 120 - 170cm MSH HSI = 1.0 170 - 250cm MSH HSI decreases from 1.0 to 0.2 250 - 500cm MSH HSI decreases from 0.2 to 0.0	Model applications should consider existing and optimal HSI values for preproject conditions. Model applications should consider suboptimal or unsuitable HSI values for fragments that will be difficult or impossible to burn resulting after the project.

Figure 2. Flowchart for Determining the Number of Habitat Units Associated With a Proposed Project.



* If the project will decrease the ability to burn the site, suboptimal values for V4 should be applied to the appropriate polygons. If the project results in the inability to burn some polygons, the polygons will eventually become unsuitable unless mechanical treatments can be used to maintain suitable habitat.

Mapping Habitat Types

Recommendations are provided below to partition habitat types for purposes of calculating habitat suitability; these recommendations were based on habitat suitability, vegetation composition, habitat structure, and landscape characteristics. Procedures are summarized in Figure 3.

Excluding Suitable Habitat

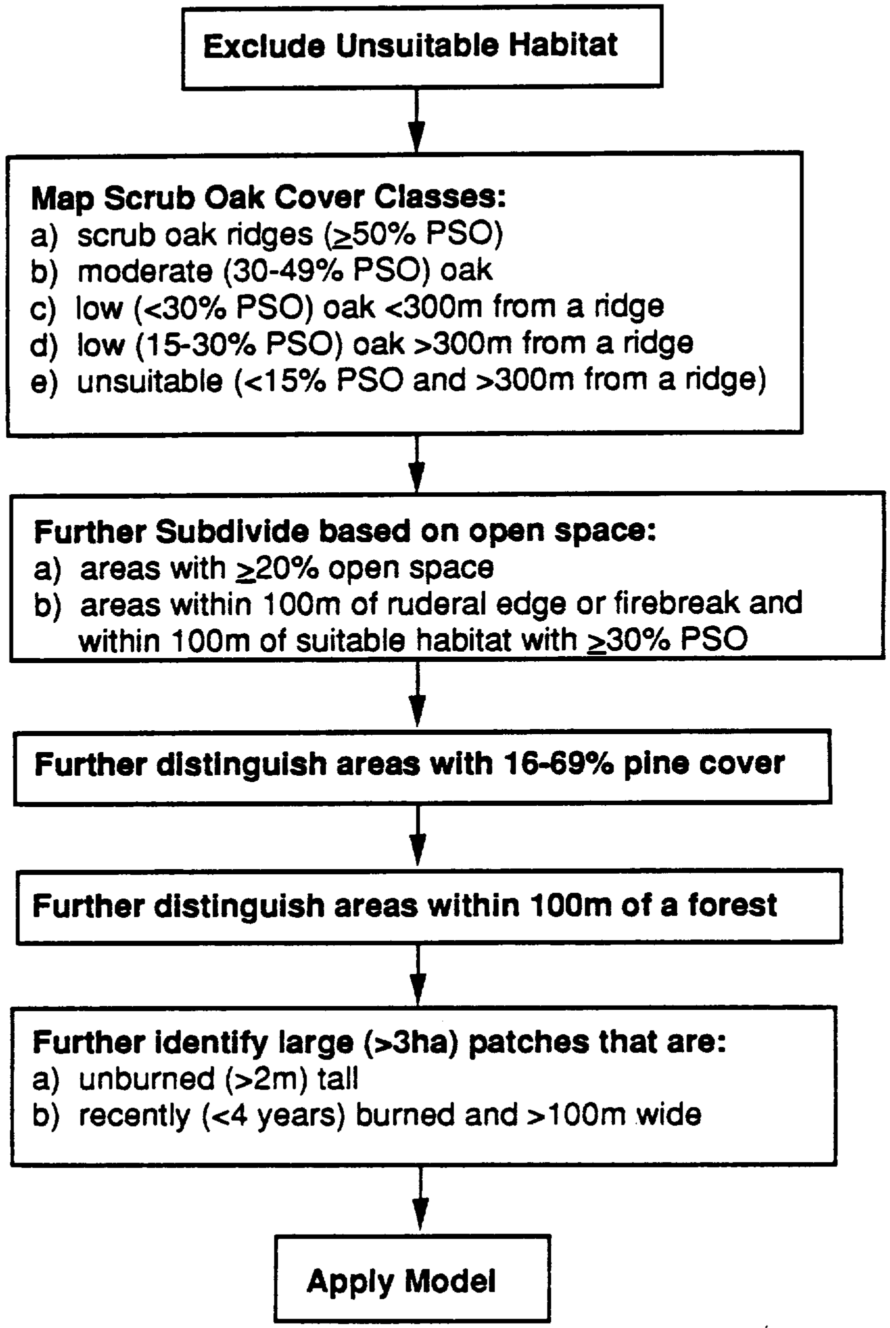
Areas assumed to be unsuitable (e.g., marshes, forests) should be excluded. Small habitat patches (< 0.05 ha) that are >100m from an edge of scrub or pine flatwoods and comprised of >80% open space are assumed to be unsuitable.

Mapping Scrub Oak Cover Classes

All scrub and slash pine flatwoods comprised of a shrub community, savanna or woodland should be identified. These areas should then be mapped into primary and secondary habitat. Primary habitat includes all scrub and slash pine flatwoods occurring on the soil types mapped (Huckle et al. 1974; Baldwin et al. 1980) as Astatula, Bulow, Canaveral sand, Canaveral urban complex, Cocoa sand, Daytona sand, Orsino, Palm Beach, Paola, Pomello, Quartzipssaments, St Lucie, and Welaka. Secondary habitat represents scrub and slash pine flatwoods on all other (poorly drained) soils.

Secondary habitat should be subdivided according to the Percent of the Shrub Canopy Comprised of Scrub Oaks (PSO). This can be performed using aerial photography and ground truthing. Classes should include areas with low scrub oak cover (0-29% PSO), moderate scrub oak cover (30-49% PSO), and

Figure 3. Flowchart for Mapping Habitat Polygons



PSO = Percent of scrub oak canopy in shrub layer high scrub oak cover (≥50% PSO). Additional subdivision is advised for areas having low oak cover that are >300m from a scrub oak ridge (areas with ≥50% PSO). Areas having 0-14% PSO should be regarded as unsuitable if they are >300 m from a scrub oak ridge. These mapping units should then be subdivided into habitat types based on past mechanical disturbance to the shrub layer, pine cover, and fire history.

Subdivision of Areas Based on Open Space

Areas with an abundance of openings should be mapped. They can usually be identified on aerial photography. Ruderal habitat refers to grassy (e.g., Bahia grass) areas that are mowed periodically. Polygons should be identified for scrub and slash pine within 100 m of habitat that has ≥30% PSO and is within 100 m of appropriate ruderal habitat. Appropriate ruderal habitat includes firebreaks or roadsides ≥12 m wide.

Mapping Pine Cover and Forests

If pine cover is heterogenous, areas should be subdivided and mapped into pine savanna (0-15% pine canopy cover) and pine woodland (16-69% pine canopy cover). Small (< 0.05 ha) closed canopy or otherwise dense clumps of pines should not be mapped as forest or woodland within a savanna. Small (<0.05 ha) areas of savanna should not be distinguished when they occur in a woodland or forest. Areas within 100 m of a forest should also be distinguished.

Subdivision Based on Fire History

Fire history should be used to separate an area into habitat types when there are single, large patches (>3 ha) of unburned areas (mean shrub height >

2 m) or certain recently (<4 years since last fire) burned areas. Recently burned areas should not be considered separately where they occur as narrow strips (<100 m wide) regardless of their size. These rules are designed to minimize the seperate treatment of areas that occur as a mosaic of different age classes with respect to fire (see discussion concerning mean shrub height in Appendix E for further explanation).

Calculating Habitat Suitability Values for Habitat Parameters

Many distance measurements between habitats can be performed from aerial photography or Geographical Information System (GIS) files. Some cover parameters such as pine canopy cover and occasionally open space can be estimated from aerial photography. Other variables require field determinations. It is often possible to classify polygons into cover classes so that field measurements are unnecessary. Field measurements of open space and scrub oak cover require line transect (Schmalzer and Hinkle 1987) or point intercept methods (Breininger et al. 1988; Breininger et al. 1991). Commonly encountered values are found in Table 2 which is discussed in Appendices C and E.

Percent of Shrub Canopy Cover Comprised of Scrub Oaks (V1A) (Figure 1)

The variable (PSO) refers to the percent of the total shrub canopy that is Quercus myrtifolia, Q. geminata, or Q. chapmanii except along the ocean beach. Near the ocean beach and on CCAFS, a dwarf variety of Q. virginiana (whose taxonomic status has not been determined) should be included in the calculation of PSO because it is usually the only scrub oak available. Q. minima and Q. pumila, which are flatwoods species, are excluded. In most

Table 2. Habitat Characteristics and Florida Scrub Jay Densities within Scrub and Slash Pine Habitat Types, 1985 - 1986.

Habitat Types	Percent Shrub Layer Comprised of Oak	Percent Open Space	Percent Pine Cover	Mean Shrub Height (cm)	Scrub Jay Density (Birds/ha)
Mapped as Scrub:					
Oak Scrub[R,W]	58	3	0	120	0.24
Unburned Oak[W,U]	91	2	0	230	0.22
*Oak/palmetto[R]	27	5	0	80	0.12
Palmetto Scrub[R]	24	2	0	120	0.10
Unburned Palmetto[U]	40	0	0	200	0.02
Mapped as Disturbed Scrub:					
Disturbed Oak[D,W]	93	23	0	190	1.27
Mesic, Disturbed[D]	43	21	8	150	0.34
Mapped as Slash Pine:					
Slash Pine/Oak[R,W]	60	10	15	90	0.57
*Pine Savanna[R]	22	3	11	90	0.47
Shrubby Pine Forest[D]	26	18	67	100	0.11
Pine Woodland[R]	30	4	39	90	0.06
Unburned Pine Woodland[U]	31	2	40	190	0.03
Grassy Pine Forest[R,D]	25	7	62	140	0.00

U = Unburned for >10 years
R = Recently burned (1-4 years since fire)
D = Once mechanically disturbed
W = Well drained soil type
* = Polygons within these habitats can be further subdivided based on scrub oak cover into ≥50% PSO, 30-49% PSO, 15-29% PSO, and <15% PSO.

undisturbed areas, PSO will be nearly equal to the amount of ground cover comprised of scrub oaks, but this will not be true in disturbed areas where open space is abundant. Much secondary habitat will have marginal (0.05) HSI values for PSO. However, many areas of secondary habitat have higher values for PSO (Breininger et al. 1991) that usually occur as patches and can be distinguished on false color infrared aerial imagery. Sandy openings are sometimes present in these areas. Shrubs with a red signature are often scrub oaks. However, other mesic shrub species also have a red signature, so that the only sure way to identify these areas is ground truthing. Selection of methods should be determined after mapping and field visits since many actual field measurements may be unnecessary and patch size of mapping units may determine the most appropriate methods.

Primary habitat should be given optimal PSO values for environmental evaluations. If a site in primary habitat does not have optimal scrub oak cover at the time of the evaluation, it probably has been recently burned and is likely to have optimal oak cover soon thereafter as the scrub oaks sprout and regain their dominance (Appendices C and D). Optimal values should not be assumed if this model is to be used to explore the potential effects of frequent fire management where extensive fires burn the same patches every three to eight years. Actual PSO values should be used for such purposes because the assumption that all primary habitat has optimal PSO will need modification.

Distance to Scrub Oak Ridge (V1B) (Figure 1)

This variable refers to the distance a site is from primary habitat (scrub and slash pine on well drained soils) or secondary habitat with ≥50% PSO. This variable is to be compared with V1A to determine which produces the highest value for a site. Studies are currently being conducted to provide additional recommendations concerning the mapping and definition of scrub oak ridges.

Percent Open Space (V2A) (Figure 1)

This parameter refers to the percent ground cover that is open sand or herbaceous cover that is relatively sparse and averages <15 cm tall. Open space can include ruderal habitat (mowed grass), V2B is to be considered appropriate where ruderal habitat occurs as an edge along undisturbed scrub and is ≥12 m wide.

The percent of a polygon that is open space is measured as V2A where openings occur as a mosaic among patches of scrub, or where narrow (<12 m) ruderal areas, sandy roads, or trails intercept polygons of homogeneous scrub or pine flatwoods. If the polygon has between 20-50% open space, the HSI value is 1.0 (optimal) and field measurements are unnecessary. Several methods may be used for measuring open space. One approach uses line transects (Schmalzer and Hinkle 1987) or point intercept methods (Breininger et al. 1988) to measure the percent open space. This would be performed in undisturbed habitat or in scrub that was once cleared (or otherwise mechanically disturbed) but has since revegetated. The other approach uses aerial imagery or GIS files to measure the acreage of ruderal habitat or open sand that occurs within a polygon of homogeneous scrub or pine flatwoods. This is useful where narrow (<12 m wide) sandy roads or trails intercept the landscape; the percent open space is 100 times the acreage of open areas divided by the area of the polygon of otherwise homogeneous scrub or pine flatwoods.

Optimal values for V2 occur for polygons within 100 m of some edges, regardless of the amount of open space contained within a polygon (see V2B), if the polygon is within 100 m of habitat with ≥30% PSO. If no polygons have a PSO of ≥30% within 100 m of the appropriate edge, V2A is to be applied.

Distance to Ruderal Area (V2B) (Figure 1)

This variable is used for polygons within 100 m of a sufficiently wide (≥12 m) firebreak, sandy road, or ruderal area (with >20% open space). It is only to be used where there are polygons of ≥30% PSO within 100 m of the ruderal edge. Habitat not within 100 m of suitable habitat with ≥30% PSO should consider V2A.

Distance to a Forest (V3A) (Figure 1)

This variable refers to the distance a polygon of scrub or pine flatwoods is from a forest, which is any polygon with an interlocking tree canopy. Areas mapped as hammocks, willow swamps, hardwood swamps, and coastal woodlands on the KSC vegetation map (Provancha et al. 1986) should be considered forests. There are other areas mapped as slash pine that should be classified as forests for this model. These areas can be identified on aerial photography. Small patches (< 0.05 ha) of interlocking pine canopies are not considered forests. Polygons further than 100 m from a forest have a HSI value of one for V3A.

Percent Pine Canopy Cover (V3B) (Figure 1)

Pine canopy cover can be measured in the field using line intercept or point intercept procedures. Alternatively, pine canopy cover classes can be estimated using aerial photography. If a scrub or open pine savanna exists throughout the project area, the HSI value for V3B will be one.

Mean Height of Shrub Layer (V4) (Figure 1)

This parameter can be measured where point intercept or line transect measurements are being performed. It should not be determined in areas that have just (within three to six months) been burned until vegetation has sprouted. Visual estimates are suitable for many applications.

Calculation of Habitat Suitability

The HUs for each polygon are calculated by multipying the corresponding HSI value for each polygon by the corresponding acreage. A summation of HUs is then determined by summing the HUs for all polygons in the study area. The HSI value represents the geometric mean of V1, V2, V3,and V4. The value for V1 is either V1A or V1B, whichever is highest. The value for V2 is determined by V2A or V2B; the choice between the two is based on landscape characteristics. The value for V3 is either the value of V3A or V3B, whichever is lowest.

Several constraints (e.g., natural landscape heterogeneity, proximity to sensitive operations, and landscape fragmentation caused by human development) make management for optimal habitat conditions a difficult task in many areas. It is informative to calculate not only the existing habitat suitability but also to calculate the habitat suitability if the area was managed optimally. This can be estimated by substituting optimal values for shrub height into the equation for KSC.

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Appendix A

Life History and Social Behavior

Much of what is known about Florida Scrub Jay demography, social behavior and several other biological attributes has been derived from over 20 years of intensive study of the species on the Lake Wales Ridge at the Archbold Biological Station (ABS) in Highlands County (Woolfenden 1973, 1975, 1976, 1978, Woolfenden and Fitzpatrick 1977, 1978, 1984, 1986; Fitzpatrick and Woolfenden 1986, 1988; DeGange 1976; DeGange et al. 1989). Another early study was performed at Hiccoria on the Lake Wales Ridge a few miles from ABS (Westcott 1970). Much of the basic biology of the Florida Scrub Jays at KSC appears similar to ABS, although there are differences in territory size, densities, reproductive success, and mortality parameters (Breininger and Smith unpublished data); these vary spatially due to the habitat variation present at KSC. Differences in the territory sizes, reproduction and mortality between KSC and ABS may be due to differences in vegetation composition and habitat structure that occur between even the most similar habitat types for KSC and ABS (Abrahamson 1984; Abrahamson et al. 1984a, b; Abrahamson and Hartnett 1990; Breininger 1981; Breininger et al. 1988; Breininger and Schmalzer 1990; Schmalzer and Hinkle 1987,1991).

Florida Scrub Jays live within territories defended year-round and occupied by one breeding pair. The number of birds occupying a territory varies in size from a single mated pair to 8 adults and 4 juveniles. The average group size is 3 birds at ABS (Woolfenden and Fitzpatrick 1984). The Florida Scrub Jay, unlike the western Scrub Jay, has a cooperative breeding system where young jays remain in their natal territory for at least one year, assisting the breeding pair in territory defense, predator identification and mobbing, and in the care of nestlings.

Many young, especially males, remain within their natal territories for several years. Nonbreeders are referred to as helpers. Eventually some helpers become breeders in their natal territories or in nearby areas; long distance dispersal is a rare event. Mean dispersal distances at ABS are 1,163 m for females and 304 m for males (Woolfenden and Fitzpatrick 1984). At ABS all suitable habitat is defended by Florida Scrub Jays. At KSC all typical habitat appears defended, but there is much habitat that is marginal and occupancy of some areas is questionable. The sighting of Scrub Jays within such an area may not imply the area is defended because helpers can be seen outside their territories during certain times of the year. Presumably, these forays are to determine opportunities for breeding, except when associated with predator mobbing activities.

Average territory size at ABS is 9 ha, but fluctuates slightly on a yearly basis. Locations of most territories are relatively stable from one year to the next. At ABS, small territories are the most unstable. Territory size at ABS is positively correlated with group size. Woolfenden and Fitzpatrick (1984) suspect that minor habitat differences may also influence territory size. Given the magnitude of habitat variation at KSC, it is not surprising that territory sizes vary greatly in different locations (Breininger and Smith 1989 a,b, unpublished data). For example, at the Happy Creek study area, seven territories occurring in an area of mowed grass surrounded by scrub oak vegetation had an average size of 2.4 ha, which was significantly ($p<0.01$) different from 14 territories in an adjacent area which had an average size of 6.9 ha. Other locations on KSC have been found to have small territories where mowed grass or open sandy areas were adjacent to scrub oak vegetation. In the Tel 4 study area, territory sizes have been larger than at ABS. Other habitat conditions, such as the abundance of scrub oaks, also seem to influence territory size on KSC, but these data are preliminary. Group size was not correlated with territory size at Happy Creek, probably because habitat variation has exerted a greater influence on territory size (Breininger and Smith 1989a).

Long-term data at ABS indicate that the number of pairs with helpers varies yearly beween 41 to 57% (Woolfenden and Fitzpatrick 1984). A frequently cited advantage to living in groups is that the predation rate is lower, since there are more eyes to detect and signal predators. Breeders living as pairs die at about 1.5 times the rate of those living in groups of three or more (Woolfenden and Fitzpatrick 1984). Pairs of Florida Scrub Jays with helpers fledge 1.5 times more young than pairs without helpers at ABS. These are important advantages to having a group size larger than 2 birds.

At the Happy Creek study area on KSC in 1988, group size in territories with mowed grass averaged 3.7 birds; in territories with minor amounts of open sandy areas but no mowed grass, group size averaged 3.5 birds; in territories without any open space, group size averaged 3.0 birds (Breininger and Smith 1989a). Scrub oak vegetation was abundant at the Happy Creek study area and much of it was recently burned. Only 8 of the 20 territories had a group size of 2; all of these territories included large areas of tall, unburned vegetation. All but one of six territories had a group size >2 birds at the Playalinda Beach Access Roads Crossing study area (Breininger and Smith 1989b). This area had abundant open space and oak scrub but included large expanses of unburned vegetation. Average group size in 1989 at the Tel 4 study area was 2.5 birds (Breininger and Smith unpublished data); this area was recently burned and had much open space but had low oak cover. Average group size at KSC appears to vary with habitat.

The nesting season extends from February through June. Most Florida Scrub Jays are nesting by late March/early April and most nesting is complete by late May/early June. Few nests have nestlings in March, few have eggs in June. At ABS, double broods occur only about 4% of the time (pair-years); although double broods have been more common at another study area in Indian River County (Brian Toland pers. comm.). At ABS, the average number of nest attempts is 1.4/pair/season. Renesting after nest failure is a regular event. Clutch size is typically 3-4 eggs and average fledglings produced per pair per year is 2. Only about 35% of the fledglings reach one year of age (Woolfenden and Fitzpatrick 1984).

Nesting success has been much lower at KSC. Nesting success varies greatly from one year to the next, so that conclusions regarding the suitability of an area for reproduction can not be made using one year of data. Fitzpatrick and Woolfenden (1988) reported that 80% of all new breeding jays in the population at ABS were produced during 5 of 13 breeding seasons. This suggests that humans can impact the population for several years if they negatively influence reproduction during a single season that would have otherwise produced a large number of young.

Nest failure and loss of fledglings usually occurs through predation. The number of young produced varies with the annual predation rate at ABS. Reproductive success does not appear to be uniform across the landscape at KSC (Breininger and Smith unpublished data) or at ABS (presentation by John Fitzpatrick at fall of 1989 Florida Ornithological Society meeting). Areas associated with high reproductive sucess may be responsible for maintaining the population. It is important to determine the habitat factors that distinguish areas that have high reproductive success.

Several snakes including the Eastern Coachwhip (Masticophis flagellum) and Indigo Snake (Drymarchon corias) prey on eggs, young and adults (Webber 1980). Mammalian predators include Racoon (Procyon lotor), Bobcat (Lynx rufus), and the Cotton Rat (Sigmodon hispidus) which sometimes take eggs (Woolfenden and Fitzparick 1984). Several avian predators prey on eggs and young. These include Great Horned Owl (Bubo virginiana), Eastern Screech-Owl (Otus asio), Red-tailed Hawk (Buteo jamaicensis), Northern Harrier (Circus cyaneus), American Crow (Corvus brachyrhynchos), Fish Crow (C. ossifragus), Blue Jay (Mumme 1987), and possibly the Cooper's Hawk (Accipiter cooperii). Frequent avian predators on adults are probably the Sharp-shinned Hawk (Accipiter striatus), Cooper's Hawk, Merlin (Falco columbarius), Northern Harrier, (Woolfenden and Fitzpatrick 1984) and perhaps occasionally Kestrels (F. sparverious).

Breeder survival at ABS averages 0.82 annually; helper survival is lower and varies with age and sex. Senescence may occur after 16 years. At ABS, median age for breeders is 5-6 years, and 20% of the breeders are older than 10 years. Breeder mortality peaks in June/July at ABS (Woolfenden and Fitzpatrick 1984). Breeder mortality at Happy Creek has not been uniform across the study area. Breeder mortality has been high during spring (March/April) and fall (October/November) during accipiter migration (Breininger and Smith unpublished data). Seasonal mortality rates may differ from ABS because accipter migration is concentrated near the coast.

Annual variation at ABS for both reproductive success (fledglings per pair: 1.05-2.71) and mortality (e.g. annual breeder mortality rates: 0.04-0.45) is substantial, resulting in fluctuations in population size and structure. However, the population density of breeding pairs changes little at ABS (3.59-4.04 pairs per 40.5 ha) which is low compared to most birds (Woolfenden and Fitzpatrick 1984). Helpers provide a buffering to the effective breeding size of the population; these birds must wait and compete for entry as breeders because the habitat there is saturated with breeders.

Catastrophic events occur to populations and these can have devastating effects to small populations (Soule' 1988). For Florida Scrub Jays, data are available for only one catastrophic event. An apparent epidemic spread through the ABS population when water levels were abnormally high throughout the scrub (Woolfenden and Fitzpatrick 1984). In all, 128 of 184 adults died. Only one juvenile produced during the epidemic year survived the epidemic. This demonstrates the importance for maintaining a large population, especially considering the potential effects of a large hurricane.

Appendix B

Food, Foraging Habitat, and Cover Requirements

Insects and other arthropods, taken from leaves or leaf litter in shrub vegetation, form much of the diet of Florida Scrub Jays. A wide variety of small vertebrates such as tree frogs, lizards, and small snakes are also eaten (Woolfenden and Fitzpatrick 1984). Most time spent foraging at ABS occurs within scrub oak vegetation, although palmettos, sandy openings, mixed oak/palmetto, and grass are also used. Forested habitat, low flatwoods, and thick stands of gallberry and fetterbush are avoided [data collected by Stallcup cited by Woolfenden and Fitzpatrick (1984)]. Florida Scrub Jays on KSC spend considerable time searching for prey in some open areas, especially areas of mowed grass that occurs adjacent to scrub oaks (Breininger pers. obs.). Few data are available on how animal food availability and catchability is related to habitat variation. Recently burned areas have a much higher biomass of insects, especially grasshoppers which are an important food item, than areas not recently burned (Breininger 1981). Insect biomass is much lower in winter than in summer (Breininger 1981).

Some seeds and berries are eaten, but acorns are the only important plant food. Florida Scrub Jays cache 6500-8000 acorns/year from scrub oaks. These caches are usually within loose sand at edges of small clearings or between clumps of shrubs in their own territories (DeGange et al. 1988). Each autumn, Florida Scrub Jays spend much of their time and energy harvesting, eating and caching acorns; those cached are often retrieved and consumed later. Acorns are a necessary food source in winter to carry the birds through low periods of arthropod abundance (DeGange et al. 1988). Few published data are available on the effects of habitat variation on acorn production. Fires can make acorns temporarily scarce in burned territories so that resident jays must harvest acorns from neighboring territories (DeGange et al. 1988).

Studies are underway to examine spatial and temporal variation in acorn production at ABS. Acorns are not produced within the first year after a fire; production is highest several years after a fire and then gradually declines (Bob Curry, pers. comm.). In at least some species, acorn production along edges also appears higher (Bob Curry, pers. comm.). This appears true at KSC; some small areas, particularly in disturbed areas, have especially high production. Some small patches may contain thousands of acorns (Breininger pers obs.). Acorn studies have not been performed at KSC to investigate how prevalent such productive patches are in the landscape, whether the same patches are productive each year, whether particular site features are correlated to production, or whether the difference might be genetic since one patch may be comprised of one oak clone.

Florida Scrub Jays usually nest within scrub oaks. Mean nest height at ABS is 1.0 m. Nests are often in a dense shrub at the edge of a thicket, bordering open areas (Woolfenden and Fitzpatrick 1984). Nests are not always adjacent to openings on KSC. At the Happy Creek study area, scrub oak vegetation comprises about 1/3 of the total scrub present, all of which is defended. Most nest attempts have occured in areas dominated by scrub oaks (Breininger and Smith unpublished data). Not all scrub oaks appear of equal value for nesting. Florida Scrub Jays prefer scrub oaks that have a dense distribution of twigs. At ABS nests typically are within Q. myrtifolia or Q. inopina (Woolfenden 1973). At KSC, Q. myrtifolia is typically used for nesting. Though buckthorn (Bumelia tenax) and other shrubs are used for nesting along the immediate KSC coastline and on CCAFS. The oak (a dwarf form of Q. virginiana whose taxonomic status is undetermined) found in beach areas is seldom used for nesting, probably because of its structure.

Appendix C

Characteristics of Scrub, Pine Flatwoods, and Coastal Strand on KSC

Areas occupied by the Florida Scrub jay include plant associations given various names depending on the authors (Cox 1984, 1987). These associations share in common a shrub layer dominated by scrub oaks and typically occur on well drained soils. Well drained sites are ideal for residential and industrial development. Federal and state laws and regulations direct further development away from wetlands and discourage development in floodplains. As a result of this far-reaching policy, development on KSC has been inclined to occur in potential Florida Scrub Jay habitat.

Most scrub occurs along present coastlines or along dunes in interior Florida that were formed when sea levels were higher (Laessle 1942; Harper 1914,1921,1927; Mulvania 1931; Webber 1935; Kurz 1942). Laessle (1958a) used the designation scrub only for sand pine scrub where there was a canopy of sand pine (Pinus clausa). Webber (1935) emphasized the importance of the shrub layer when defining scrub. Kurz (1942) also used the term more broadly; his "scrub" referred to communities dominated by evergreen shrubs occurring on coastal and inland dunes. Sand pine scrub is the most known Florida scrub community (Laessle, 1958ab; Austin 1976). Classification of scrub vegetation that lacks a tree canopy has varied (Cox 1984, Schmalzer and Hinkle 1987, Breininger and Schmalzer 1990). Laessle (1942) used the term scrubby flatwoods to refer to communities dominated by the shrubs that comprised the understory of sand pine scrub, but lacked the sand pine canopy. Scrub communities that are dominated by scrub oaks have also been termed "scrubby flatwoods" by others (Laessle 1942, Abrahamson 1984ab, Woolfenden and Fitzparick 1984), or "oak scrub" (Westcott 1970), or simply "scrub" (Kurz 1942) or "coastal scrub" (Stout 1980) when near the coast. The Florida Natural Areas Inventory recognized eight scrub types: sand pine scrub, sand pine/turkey oak scrub, slash pine scrub, oak scrub, rosemary scrub, saw palmetto scrub, and tropical scrub. Saw palmetto scrub occurs on poorly drained sites.

Vegetation on KSC has been studied only recently (Sweet 1976, Stout 1980, Schmalzer and Hinkle 1987). Scrub, except palmetto scrub, is often described as a excessively drained desert-like habitat (Woolfenden and Fitzpatrick 1984). Most scrub on KSC differs by having a water table that is near the surface for much of the year (Breininger et al. 1988) which is an important habitat difference that may affect the composition and productivity of the habitat (Breininger and Schmalzer 1990).

Most mature sand pine scrub has a pine canopy that is too dense for Florida Scrub Jays (Cox 1984, 1987). Sand pine scrub stands on KSC are small and have a very open tree canopy. We have included sand pine areas with well drained oak/palmetto scrub for Florida Scrub Jay habitat mapping applications on KSC (Breininger et al. 1991). Only minor amounts (<9 ha) of sand pine scrub are present on KSC (Provancha et al. 1986). One reason for this may be that the depth to the water table at KSC (Schmalzer and Hinkle 1987, Breininger et al. 1988, Drew Bennett unpublished) is closer to the surface than characteristic for other sand pine scrub areas (Simonds et al. 1980). Sand pine reproduces from seed following fire (Austin 1976). Lightning strikes are particularly common on KSC (Eastern Space and Missile Center 1982); natural and man-made fires may have occurred too frequently to allow the extensive establishment of sand pine. Sand pine scrub has been transformed elsewhere into "scrubby flatwoods" by frequent fire (Richardson 1977, Peroni and Abrahamson 1985). Sand pine is a short-lived species and fire exclusion can eliminate it. Rosemary (Ceratiola ericoides) is another common scrub plant elsewhere in Florida but it is rare on KSC (Schmalzer and Hinkle 1987). Rosemary requires a fire cycle of 10 to 40 years to successfully reproduce (Johnson 1982). Whether the lack of rosemary on KSC is due to water tables, fire frequency, or some other factor is unknown.

Most scrub on KSC is mapped as oak/palmetto scrub or disturbed scrub, which was oak/palmetto scrub that was once cleared and has revegetated (Provancha et al. 1986, Breininger and Schmalzer 1990). Slash pine on KSC is essentially scrub with a pine canopy which is usually open. Depth to water table and soil type are major determinants of species distribution within the shrub and herbaceous layers of scrub and pine flatwoods on KSC (Schmalzer and Hinkle 1987, 1991; Breininger et al. 1988). Scrub oaks (Quercus myrtiflolia, Q. geminata, Q. chapmanii) dominate drier sites, while saw palmetto dominates the wet end of the scrub (Schmalzer and Hinkle 1987, 1991; Breininger et al. 1988). On most sites, a mixed oak/palmetto shrub layer occurs (Breininger et al. 1988).

Oak/palmetto scrub occurring on well drained soils is termed oak scrub (Breininger et al. 1988). It has been mapped as well drained scrub and is considered primary habitat (Breininger et al. 1991). Sweet (1976) recognized oak scrub on KSC by the term "scrubby flatwoods" whereas Stout (1980) used the term "coastal scrub". Oak scrub on KSC is comparable to "scrubby flatwoods", at ABS (Abrahamson 1984a,b), the Welaka Reserve (Laessle 1942) and to the "evergreen oak scrub" described in the Cross Florida Barge Canal Study (Florida Game Fresh Water Fish Commission 1976), however certain differences exist. Few open areas occur in oak scrub on KSC unlike openings described for sand pine scrub (Mulvania 1931, Webber 1935) or scrubby flatwoods at ABS (Abrahamson 1984a,b; Woolfenden 1973; Woolfenden and Fitzpatrick 1984). Compared with ABS, oak scrub at KSC lacks scrub palmetto (Sabal etonia), and myrtle oak replaces scrub oak (Quercus inopina) (Schmalzer and Hinkle 1987,1991; Breininger et al. 1988; Breininger and Schmalzer 1990).

Saw palmetto scrub has received little study although it also occurs in south Florida (Robertson 1955, Wade et al. 1980). It sometimes is referred to as dry prairie (Wade et al 1980, Duever 1986). Many regard scrub as xeric communities (Myers 1990), so saw palmetto communities on KSC would not be considered scrub. Many dry prairies elsewhere have more herbaceous cover without as an extensive cover of saw palmetto than is typical for KSC where saw palmetto coverage averages 60% (Breininger et al. 1988). Most of the remaining cover is comprised of shrubs such as gallberry holly (Ilex glabra) and Lyonia spp. Shrub cover on KSC is much higher than transitional mixed oak-palmetto-wiregrass and gradual interdunal slope described for ABS (Woolfenden and Fitzparick 1984). Many of the animal species associated with dry prairies (Duever 1986, Abrahamson and Hartnett 1990) are characteristic of more open dry prairies than for saw palmetto scrub on KSC. On KSC, saw palmetto scrub was described by Sweet (1976) as "pineless flatwoods"; Stout (1980) included it within slash pine flatwoods though it lacked the pine canopy. On KSC, oak/palmetto scrub occuring on poorly drained soils has sometimes been termed saw palmetto scrub (Breininger et al. 1988). Even though small patches dominated by scrub oaks may occur within scrub on poorly drained soils, palmetto scrub is considered secondary habitat for the Florida Scrub Jay (Breininger et al. 1991). Because of the historical occurrence of saw palmetto vegetation in central Florida (Harper 1921) and the lack of data on its successional relationship to slash pine flatwoods, it has been treated as a separate type on KSC (Schmalzer and Hinkle 1987) using the Florida Natural Areas Inventory nomenclature.

Some believe that dry prairies and saw palmetto scrub were once pine flatwoods because the understories are practically identical (Wade et al. 1980, Duever 1986). Some saw palmetto scrub and dry prairies may once have been pine flatwoods but pines were eliminated as the result of presettlement Indian fires, extensive logging, drainage and/or by frequent fires associated with cattle management (Duever 1986, Abrahamson and Hartnett 1990). Short burning rotations of 3 years or less to improve grazing habitat eliminate pine seedlings, thereby perpetuating palmetto prairies (Wade et al. 1980). Furthermore, cattle themselves can influence pine seedling establishment (Abrahamson and Hartnett 1990). Thus, some areas that are saw palmetto scrub today on KSC may have been pine flatwoods before settlement. Some of the conversion of pine flatwoods to saw palmetto scrub has been more recent due to one or more of the following: fire suppression and fuels accumulation, subsequent wild fires, or frequent prescribed fire. Once pine trees and seedlings are eliminated, establishment of pine stands may be difficult (see below). Much saw palmetto scrub may also be natural; some dry prairies may never have had pines (Wade et al. 1980).

Pine flatwoods occur throughout Florida and into the coastal plain of adjacent states (McNab et al. 1978, Christensen 1979a,b). Pine flatwoods was the most extensive terrestrial ecosystem in Florida. It may be the one most influenced by humans historically (Abrahamson and Hartnett 1990). A number of slash pine flatwood types occur in Florida with considerable site variation

(Duever 1984, FNAI unpublished; Abrahamson and Hartnett 1990). Classifications of different types usually fail to account for such variation because there often is a gradient among types (Abrahamson and Hartnett 1990). Slash pine has been planted extensively over former longleaf pine sites in both flatwoods and sandhill in much of Florida (Bechtold and Knight 1982). Most slash pine stands on Merritt Island are natural (Harper 1921).

Slash pine occurring on well drained soils has been termed slash pine/oak (Breininger et al. 1988) and has been mapped as well drained slash pine, which is also considered primary Florida Scrub Jay habitat (Breininger et al. 1991). This habitat type on KSC is probably most similar to scrubby flatwoods at ABS, except for previously described differences in vegetation composition and that it occurs as narrow strips on KSC. On KSC, its understory is essentially the same species composition as oak scrub, but there are more sandy openings. It has also been referred to as slash pine scrub (Duever 1986).

Slash pine occurring on poorly drained soils has sometimes been termed slash pine/palmetto (Breininger et al. 1988) even though some areas may have small patches of scrub oaks; slash pine mapped on poorly drained soils is considered secondary Florida Scrub Jay habitat (Breininger et al. 1991). Other oaks, especially Q. pumila and Q. minima, are common in poorly drained slash pine on KSC and often in poorly drained scrub. Slash pine with a palmetto understory has been reported in other areas of Florida (Harper 1921, Maehr and Marion 1985, Woolfenden and Fitzpatrick 1984, Robertson 1955, Hough 1965, 1981, Hough and Albini 1978, McNab et al. 1978). The understory of this habitat on KSC is similar to palmetto scrub (Breininger et al. 1988).

Oak scrub and slash pine/oak comprise 15% of the total scrub and slash pine on KSC (Breininger et al. 1991). These well drained ridges occur as a series of long narrow strips formed on relict dunes oriented north-to-south and are interspersed with poorly drained scrub and slash pine. Average slash pine cover in slash pine/oak is 15% (Breininger et al. 1988). Nearly all of the oak scrub and slash pine oak has oak cover that is suitable ($\geq$30%) for Florida Scrub Jays (Breininger et al. unpublished). Open space is often abundant at the boundary of slash pine/oak ridges and the surrounding more flammable slash pine/palmetto. Frequent fires burning through the more flammable poorly drained scrub may burn into the edges of slash pine/oak but the fires often burn out before proceeding far into the scrub oak vegetation ridges (Davidson and Bratton 1986, Simon 1986). Scrub has been previously referred to as a "fire fighting" association due to the lower flammability of scrub oaks (Webber 1935). A marked ecotone between some Florida pinelands and scrub communities has been discussed by many authors (Mulvania 1931, Harper 1914, Kurz 1942, Laessle 1958, Snedaker and Lugo 1972, Myers 1985, Webber 1935, Myers 1990). Snags are vulnerable to fires. Open space is often abundant around snags (pers. obs.) perhaps by providing "hot spots" for fires. Underground rhizomes of scrub oak species are in the upper 25 cm of soil (Guerin 1988). These may be damaged by hotter fires that are associated with larger fuels thereby creating open spaces (Myers 1990). The abundance of open space in slash pine/oak may also be due to past turpentine or logging practices where the soil layer was disturbed. The colonization of gaps in (xeric) scrub appears to be very slow (Myers 1990).

Slash pine/palmetto has been subdivided into two categories based on pine cover: slash pine flatwoods and slash pine/palmetto woodland (Breininger and Smith unpublished data). Oak and palmetto cover are similar in each but slash pine cover averages 11% in the flatwoods and 40% in the woodlands, the latter representing marginal conditions for Florida Scrub Jays. No data are available on the extent of each of these slash pine/palmetto types on KSC.

A policy of fire suppression was in effect on KSC from 1963 until 1975, when the USFWS began a limited prescribed fire program. After severe wildfires during 1981, a more extensive prescribed fire program was instituted to reduce fuel levels and the possibility of wildfires. The plan included a three-year fire cycle for uplands. Most of KSC has been subdivided into 33 fire management units (FMUs) by the USFWS allowing the potential development of fire prescriptions for each unit. Eleven percent of primary Florida Scrub Jay habitat (well drained scrub and slash pine) occurs outside all FMUs; these areas often are adjacent to facilities. Twenty-four FMUs contain primary habitat, but 96% of the primary habitat is within 13 FMUs that had 10 ha or more of the primary habitat within each (Breininger et al. 1991).

Various vegetation types which respond differently to fire occur within individual FMUs. Scrub and slash pine within FMUs are often 1/3 or less of the total acreage of each FMU; primary habitat may represent little to most of the potential habitat within FMUs. Under dry conditions, prescribed fires can burn primary habitat more frequently than is believed to be natural (Schmalzer and Breininger pers. obs).

Many studies on the effects of fire in Florida involved areas where shrubs were a minor component of the overall community due to frequent fires (Robertson 1955, Emlen 1970, Snedaker 1963). Frequent fires are important for maintaining natural community structure in longleaf pine/wiregrass and longleaf pine/turkey oak communities. Habitat differences between unburned and burned areas in these habitats are often of short duration (Emlen 1970) except where fire suppression practices have occurred. Fire suppression in these areas results in dramatic changes in habitat structure where open pinelands are replaced by closed forests (Engstrom et al. 1984). Sand pine scrub is a closed canopy forest with a scrubby understory. It has a natural fire frequency of 20-40 or more years and habitat stuctural changes are dramatic and of long duration (Austin 1976). Scrubby flatwoods and some scrub types without a sand pine canopy are believed to have an intermediate natural fire frequency (Abrahamson 1984 a,b; Schmalzer and Hinkle 1987).

Natural fires within vegetation types surrounding oak scrub and slash pine/oak probably occur more frequently than fires that actually burned through oak scrub and slash pine oak. Characteristics of primary habitat, including the evergreen nature of the scrub oak, slow accumulation of litter, and lack of abundant grass and forb cover (Webber 1935), make it less prone to burn than adjacent communities with high cover of flammable grasses and forbs (Webber 1935) or saw palmetto (Schmalzer and Hinkle 1987). Even the litter from scrub oaks appears to be less flammable than litter from surrounding habitat types (Guerin 1988). Oak scrub does not usually burn well during the wet summer months when lightning is most common, so that fires tend to be small because lightning ignitions are often accompanied by rain (Davidson and Bratton 1986). Webber (1935) described scrub as a fire-fighting association because it did not burn as readily as longleaf pine/wiregrass habitats adjacent to oak scrub. Major fires in oak scrub may have been most common during periodic droughts that last 3-7 years and occur roughly every 20 years (Davidson and Bratton 1986) although this periodicity is not well established. Scrub fires during drought years tend to be extensive and intense.

The season for prescribed burning has historically been controversial regarding wildlife management. Summer fires were criticized by some (e.g., Stoddard 1935) because they destroy young animals, the growing food supply, and cover. Others have said that the traditional fires occurred in summer and that animals have adapted to them (Komarek 1965). There are little data on the influence of season on fire effects (Robbins and Myers 1988). Fire-caused mortality is by far the most frequent objection to growing season burns, yet the reason to burn is to improve habitat (Robbins and Myers 1988). Fires during the rainy, humid growing season can be patchy and regrowth can occur more quickly; both of these characteristics and others have advantages for wildlife (Christman 1983, Robbins and Meyers 1988).

Growing season burns can be divided into dry months (spring) and wet months (summer) with the transition between them representing the height of the fire season (Robbins and Meyers 1988). More areas burn during spring drought than burn during wet summer months when moisture levels are high and the primary fuels available are living volatile vegetation such as wiregrass, saw palmetto and gallberry holly.

In north Florida, April and March are usually the driest following a winter rainfall peak, but this winter peak diminishes as one proceeds to south Florida where there is a distinct wet/dry climate (Jordan 1984). Most lightning fires in

Florida occur March-September, particularly in June and July (Robbins and Meyers 1988). Before the Indians arrived [10,000-12,000 years ago (Milanich and Fairbanks 1980)] most Florida plant communities experienced natural lightning fires. Indians may have burned during other seasons.

Recent fires caused by man on KSC occur throughout the year, but have been especially common in the winter (Davidson and Bratton 1986). Most rainfall occurs in June to October (Mailander 1990). Ground water levels are often highest in fall and winter when transpiration is low (Breininger et al. 1988, Drew Bennett unpublished data). Scrub burns readily in winter when fuel moisture levels are low due to low rainfall and humidity. Winter fires are not natural to native vegetation (Davidson and Bratton 1986). Many scrub species fruit heavily after a summer burn, but many are irregular and fruit with little success after a winter burn (Abrahamson 1984a,b). However, saw palmetto sprouts well after winter burns; fire stimulates saw palmetto to sprout from its large rhizomes and stems increasing its coverage (Hilmon 1969).

Recent studies in burned areas have shown that primarily the structure and not the composition of scrub were affected by fire (Schmalzer and Hinkle 1987). A relatively continuous shrub canopy developed within 6 months of fires by the sprouting of shrubs (Schmalzer and Hinkle 1991). It took 4-7 years for scrub to reach a height of 1 m (Schmalzer and Hinkle 1987; Breininger et al. 1988). Scrub oaks recover more slowly after fires than saw palmetto; there have been positive correlations between time since fire and scrub oak cover (Schmalzer and Hinkle 1991, Breininger et al. 1988). Some scrub oaks, such as Q. myrtifolia, do not recover as quickly as others (Abrahamson 1984b, Guerin 1988, Schmalzer and Hinkle 1991).

Scrub oaks show clonal growth which allows them to resprout readily after a fire (Webber 1935, Laessle 1958, Snedaker and Lugo 1972). Clonal growth is favored where water and nutrients are in short supply, allowing an individual to laterally exploit soil volume, sacrificing vertical growth (Noble et al. 1979). This is an advantage where seedling establishment is hindered by dense vegetation subject to sporadic or patchy causes of death such as fire (Huenneke 1985). At times two-thirds of the biomass of scrub oaks can be below the ground, exluding times immediately after a fire when nearly 100% is below-ground (Johnson et al. 1986, Guerin 1988). Recovery of scrub oaks is much slower than saw palmetto which can regain its former coverage quickly. Its above ground rhizomes remain alive, allowing them to resprout within months after a fire (Schmalzer and Hinkle 1987, Simon 1986). Saw palmetto does not appear to recover as quickly where there is an overstory (Davidson 1984). Scrub oaks must usually resprout from the ground. Scrub oaks sprout prolifically after some fires, so that overall ground cover can increase (Garren 1943). At ABS scrub oaks can recover to preburn dominance within 2-4 years (Abrahamson 1984b). Repeated winter burns may select against oaks and for saw palmetto (Davidson and Bratton 1986). Fire induces saw palmetto to sprout from rhizomes in winter and can stimulate growth of this otherwise dormant plant (Hilmon 1969).

The effects of single fires must be appraised in relation to the fires preceding them. Fires occurring every few years can eventually kill scrub oaks (Robbins and Meyers 1989, Wade et al. 1980, Mobley et al. 1978). Fire kills above-ground biomass which is normally replaced by resprouting, but fires more frequent than every five years prevent root carbohydrate restoration, thereby depleting their stores (Davidson and Bratton 1986). Repeated fires may kill the underground rhizome system, killing the entire plant (Guerin 1988). Conventional wisdom suggests that a frequent fire rotation can kill oaks or reduce acorn production. Data have shown that above-ground growth of scrub oaks has been rapid for the first year after fire but then slows (Schmalzer and Hinkle 1987, 1991), presumably because the reserves provided for fast growth initially. Scrub oaks have not shown the rapid regrowth in areas that have been burned 3 times in 10 years when compared to regrowth from fires that occurred in areas unburned for >20 years (Breininger pers. obs.). Fires have burned areas where the height of the scrub oaks was <0.7 m; these areas appear to retain more openings for several years after fire.

Invasion of slash pine flatwoods by mesic hardwoods, as occurs in northern Florida in the absence of frequent fire (Edmisten 1963), does not appear to occur rapidly on KSC (Schmalzer and Hinkle unpublished data). Similar stablity in species composition was reported for scrubby pine flatwoods protected from fire at ABS (Givens et al. 1984, Abrahamson et al. 1984). When unburned for long periods, fuel levels accumulate to the extent that when fires occur, they burn with such intensity that flames reach the canopy and kill the trees (Duever 1985). Saw palmetto and gallberry recover rapidly from fires and compete with slash pine trees for nutrients, interfering with tree reproduction (Hough 1965).

Little is known about slash pine regeneration within natural stands of slash pine (Hebb and Clewell 1976). Slash pine seedlings and saplings are unable to survive many surface fires (McCulley 1950) but slash pine seedlings may require bare soil for establishment (Fowells 1965). Davidson and Bratton (1986) suggested that slash pine reproduces best in wet areas that afford some protection from fire. Regeneration following logging has been quicker in wetter depressions and around pond margins than in drier uplands (Wade et al. 1980). Saw palmetto scrub can occur without a slash pine overstory because of the lack of a sufficient seed source nearby which has been eliminated by logging (Wade et al. 1980).

Slash pine, particularly the south Florida variety, is resilient to fire (Abrahamson 1984b, Wade et al. 1980, Hare 1965). Interpreting slash pine distribution in Florida is complicated by two varieties of slash pine that differ in their fire tolerances and is complicated by the apparent clinal variation in their traits (see review by Abrahamson and Hartnett 1990). Fire can result in little change in the pine canopy, at least where the understory is dominated more by herbaceous plants than shrubs (Emlen 1980). Even on KSC, where fuel levels are extremely high due to fire suppression, prescribed fires can occur that are not devastating to a pine stand (Simon 1986). Humidity and other weather conditions greatly influence fire intensity. Robbins and Meyers (1989) review studies that show that growing season burns are more likely to result in pine mortality, but that low intensity fires resulting in low mortality can be performed year round.

Much study of the slash pine understory has been conducted for purposes of forestry management. In theory, eradication of the understory vegetation before stand establishment removes a nutrient sink, thereby allowing pines to more fully use available resources. However, this is costly and could lower site quality by destroying soil structure and organic matter. Less site preparation could result in a more favorable decomposition rate best for nutrient cycling (Hough 1982). Excessive fires or mechanical disturbance can result in invasion of Brazilian pepper, Australian pine or melaleuca (Wade et al. 1980).

Intense fires have directly caused high mortality of sapling and mature slash pines across much of KSC (Paul Schmalzer and Breininger pers. obs.) and probably indirectly by making trees susceptible to pine bark beetle infestation (Fowells 1965). Many areas of KSC that were formerly stands of slash pine now are comprised of dead slash pines. Once a stand has been destroyed it appears difficult to manage for restablishment. Shrubs such as gallberry holly and saw palmetto can develop fuel loadings within 5-8 years that can cause considerable damage to any slash pine trees that are present if a fire occurs (Croker 1968, Christensen 1978, Hilmon 1968, Wade et al 1980).

The effects of mechanical disturbance involving the soil layer often last for at least 20 years (Breininger and Schmalzer 1990). Mechanical site treatments within pine flatwoods result in considerable changes to community structure (Abrahamson and Hartnett 1990). Many past disturbance practices on KSC by humans before NASA purchased the land, have involved mechanical clearing of shrubs and disturbance to the upper soil layer. Sites once cleared have been the location of sampling stations termed "disturbed" that are part of the KSC long-term environmental monitoring program (e.g., Breininger et al. 1988, Breininger and Schmalzer 1990). More recently, many areas on KSC have been disked to encourage pine restablishment to provide future bald eagle nesting habitat. Disturbed sites (hereafter including sites once cleared and not recently disked) frequently have scattered pine when they occur far from a seed source but have a high density of pines when adjacent to a pine stand. Many areas of disturbed slash pine have a pine canopy too dense for

Florida Scrub Jays (Breininger unpublished data); these sites appear to occur primarily on poorly drained soils. Pine needles and herbaceous plants [which are especially abundant in these disturbed areas (Breininger et al. 1988)] provide a flammable ground layer for low intensity fires that can eliminate scrub oaks without being hot enough to cause widespread pine mortality.

Scrub oaks revegetate well drained disturbed sites and are often the dominant shrub species in these areas. Saw palmetto does not revegetate these areas abundantly for at least 20 years (or any areas that have been cleared). Well drained, disturbed areas have a discontinuous fuel structure and often do not burn well when surrounding areas burn extensively. Herbaceous cover provides a discontinuous fuel source that does not result in fires that are as intense as those provided by saw palmetto. As a result, the shrub cover in these areas is usually taller than adjacent undisturbed areas. Eventually oaks grow into small trees so that these areas can become unsuitable for Florida Scrub Jays and other scrub species of special concern. These areas may require special management for them to return to scrub. When some scrub oak species (i.e., Q. geminata) reach a certain stature, the above-ground trunks and stems may not be killed by normal fires (Guerin 1988). Survivability of oaks is not identical; Q. myrtifolia has thinner bark and an overall plant structure that results in more susceptibility to fire. Different species of scrub oaks may respond differently to fire suppression. At least one species, Q. inopina, appears to do poorly in areas that remain unburned for long periods (Bob Curry pers. comm.). Undisturbed areas typically are dominated by Q. myrtifolia and Q geminata with lesser amounts of Q. chapmanii (Schmalzer and Hinkle 1987). Because scrub oaks respond differently to fire suppression and fire frequency, extremes in fire management practices may favor one scrub oak over the other.

Poorly drained disturbed areas often have a continuous herbaceous layer with many flammable shrubs such as gallberry holly and do burn readily (Breininger et al. 1988; Breininger unpublished data).

Successional relationships in scrub and slash pine are unclear and complicated by site factors such as soil type, drainage patterns, proximity to other vegetation types and other landscape features. A mesic hardwood forest has often been regarded as the climax community for many Florida vegetation types, including pinelands (Monk 1968). The more mesic pine flatwoods may be the most likely to undergo succession into hammocks (Edmisten 1963, Alexander 1967). Once converted to hammocks, pine flatwoods can not be converted to pine flatwoods by fire due to the relative inflammability of most hammock species (Wade et al 1980). Some authors have suggested that the more xeric longleaf pine-turkey oak communities succeed to either a xeric or mesic hardwood forest in the absence of fire (Laessle 1957, Snedaker and Lugo 1972, Monk 1968, Veno 1976). Veno suggested that pineland vegetation first will succeed to scrub, then xeric hammock (dominated by live oak), and finally to mesic hammock (dominated by laurel oak).

Many well drained scrubs have shown no invasion by hammock species except in some coastal areas (Laessle 1967). Veno (1976) found increases in woody litter and the density and basal area of scrub species, but no change in scrub composition after sampling a scrub surveyed 20 years earlier (Laessle 1958). Peroni and Abrahamson (1986) also found relatively stable species composition of sand pine and "scrubby flatwoods" at ABS. The vegetation response to time since fire can vary across sites (Simon 1988). Xeric hammocks typically occur in areas unburned for long periods, often along ridges adjacent to wetlands that serve as firebeaks (Duever 1984, 1986).

Coastal woodlands are not very suitable for Scrub Jays or as potential habitat. Normal fires do not necessarily convert this habitat back into a scrub community due the large stature of the trees. This community is believed to be natural in at least some places, possibly because it receives considerable protection from fires from adjacent landscape features that burn poorly. Some woodlands may have resulted from fire suppression activities.

Coastal strand occurs immediately behind the coastal dunes. It is often dominated by saw palmetto, although other common shrubs occur such as rapanea (Rapanea punctata), naked wood (Myrcianthes fragrans), tough buckthorn (Bumelia tenax), and snowberry (Chicocco alba). Proceeding inland, an undescribed scrub oak often is found forming a scrub oak or coastal woodland community. However, the outer coastal strip is narrow and salt marsh or mangroves border the coastal strand with few or no oaks. Approximately 100 ha of coastal strand on KSC has been estimated to contribute to the Florida Scrub Jay population (Breininger et al. 1991).

Appendix D

Habitat Preferences

Typical Scrub Jay habitat has been described as "low, dense, largely evergreen oak thickets for nesting and extensive open space for feeding" (Westcott 1970) or "oak scrub, composed of low, dense thickets with numerous open sandy spaces," and that "critical factors in the habitats they avoid seem to be the abundance of trees and the absence of open sandy spaces" (Woolfenden 1973). These descriptions have caused other biologists, less familiar with the bird, to conclude that some areas are unsuitable to Florida Scrub Jays, when in fact they are inhabited, and can have successful reproduction at least some of the time (e.g. Breininger and Smith 1989b; Brian Toland and Ray Fernald pers. comm.) Indeed there are many areas throughout KSC (pers. obs.) and Florida that are inhabited by Florida Scrub Jays but are atypical (Cox 1984, 1987; Ray Fernald and Brian Toland pers. comm.). Cox (1987) writes "Before I began the statewide survey of Florida Scrub Jays ....I had a fairly specific idea of what types of habitats I should search for Scrub Jays. Once I began the survey, I was quickly disabused of the notion that Scrub Jays are found only in typical oak scrub."

Most atypical areas occupied by Florida Scrub Jays include patches of scrub either as remnants in a human altered landscape or scattered within poorly drained flatwoods. Studies at KSC (Breininger 1981) at Ocala National Forest (Cox 1984) were conducted to quantify habitat preferences. A study not previously reported was performed at KSC by the author; this study is presented in Appendix E where the results are used as the primary basis for developing the HSI model. This latter study occurred over a wider range of habitat conditions than had been performed previously. The discussion below summarizes earlier studies prior to the study used to develop the model.

Scrub oak cover is an important indicator of potential Scrub Jay habitat (Westcott 1970, Woolfenden 1973, Breininger 1981, Cox 1984, 1987, Woolfenden and Fitzpatrick 1984). Open space, which refers to open sandy areas or areas of sparse herbaceous vegetation <15 cm tall, was positively correlated with Florida Scrub Jay density where oak cover was sufficient (Breininger 1981). Where there was open space there was no oak cover, so the percent of shrub vegetation comprised of scrub oaks (PSO) was a better predictor of Florida Scrub Jay density (r=0.63) than oak cover alone (r=0.38) (Breininger 1981). The range of PSO was 4.3-71.0% and total oak cover was 3.6-65.9% (Breininger 1981).

Cox (1984) found significant correlations between Florida Scrub Jay density and the cover of oaks at a height of 2.0-3.0 m tall (r=0.78). The range for oak cover 2.0-3.0 m tall was 0.4-25.6%. Florida Scrub Jay density was also correlated with total oak cover (r=0.79), which ranged from 17.0-68.8%. It is important to note here that the ground cover of oaks 2.0-3.0 m was never a large percent in the study by Cox.

No published data yet suggest that Florida Scrub Jay density is more highly correlated with one scrub oak species than another. Except along the immediate coastline and on CCAFS, there is a mix of scrub oak species, although this varies in areas mechanically cleared (Breininger and Schmalzer 1990) and may vary under extremes of fire frequency and fire suppression (Appendix D). Different oak species vary in their acorn production, nutritional value, tannin content and suitability for nesting (Appendix B, C and D). Focal animal studies at ABS revealed that Q. inopina was the preferred foraging habitat and Q. myrtifolia was used little in comparison with other scrub oak habitats (Bob Curry pers. comm.). Since Quercus inopina does not occur on KSC, it is interesting to note that some of the worst habitat at ABS is the best habitat available at KSC. The understory of Q. inopina is open and open spaces frequently surround patches of Q. inopina. Perhaps this explains why open space is a good predictor of Florida Scrub Jay density on KSC.

Saw palmetto cover was negatively correlated (r=-0.63) with Florida Scrub Jay density (Breininger 1981). Areas with high palmetto cover have low oak cover (Schmalzer and Hinkle 1987, Breininger et al. 1988). Cox (1984) found negative correlations between Florida Scrub Jay density and non-oak shrubs 0.0-0.5 m tall (r=-0.79) and 0.5-1.0 m tall (r=-0.88); the ranges for the non-oak parameters were 1.4-12.6% and 1.8-19.5%, respectively. The only variable that Cox (1984) found statistically different between habitats with and without Florida Scrub Jays was the cover by non-oak shrubs 1.0-2.0 m tall. Florida Scrub Jays preferred areas with lower cover of non-oak shrubs 1.0-2.0 m tall; average cover values for areas with jays was 2.6% with a range of 0.4-5.45%. For areas without jays, the average was 8.6% with a range of 1.4-16.6%. Florida Scrub Jays dc not avoid saw palmettos. They sometimes forage around them, temporarily store acorns in them, and use palmetto thickets for cover when hawk alarm calls are given. Dense saw palmetto areas or other areas of dense vegetation, such as wiregrass, near the ground surface may be underutilized in proportion to their occurrence because snakes are easily concealed in such dense vegetation.

Scattered patches of bare sand have been described as being essential to Florida Scrub Jays and they appear to avoid or use infrequently areas without bare sand (Westcott 1970, Woolfenden 1974). A curvilinear relationship with percent cover of open space and Florida Scrub Jay density (r=0.88) was found where the highest densities were between 20-50% open space (Breininger 1981) which here includes mowed grass. Florida Scrub Jays extensively use mowed grass areas, especially on well drained soils, for hunting prey and storing acorns. Territory sizes were unusually small (Breininger and Smith 1989ab) and densities unusually high (Breininger 1981) in areas where mowed grass and oak scrub dominated the landscape. In areas of mowed grass and oak scrub where road mortality was no problem and the shrub layer was not too tall, group size has been high (Breininger and Smith 1989), reproductive success has been high, and mortality of breeders has been average or low (Breininger and Smith unpublished data). Reproductive success has been low and breeder mortality has been high where areas are dominated by tall (>2 m) oaks adjacent to mowed grass. These observations were based on three years of study; it will take a long-term data base to verify these relationships.

Cox (1984) found no significant correlation between Florida Scrub Jay density and open space, but none of his study areas had >16% open space. Areas that had the most open space were most recently logged for sand pine. Oaks had not yet reached a height of 1m, the minimum height Cox believed was necessary for a stand to be occupied by Florida Scrub Jays. Cox thought an optimal amount of open space was between 10-30% ground cover.

Large, intense fires occurring every few years can be detrimental to Scrub Jays (Cox 1984, Breininger et al. 1988, Fitzpatrick et al. 1991). Not only would shrub height be too low, but acorn production might also be low and oaks could be eliminated by the continuation of such a fire regime (Appendix D). Cox

(1984) reported that oaks less than 1 m tall provide less protection from weather and predators and are inferior nest sites. Florida Scrub Jays frequently hunt for insects and other prey in recently burned areas, particularly when adjacent to sufficient cover. They may avoid these areas in fall and winter when hawks are abundant and nearby.

Positive linear (r=0.53) and curvilinear (r=0.55) relationships were found between average shrub height and Florida Scrub Jay densities on KSC. The study (Breininger 1981) was conducted after nearly 20 years of fire suppression. No areas were sampled where shrub height averaged >3.5 m or <1.0 m. All areas with high (>1.0 bird/ha) Florida Scrub Jay densities were in disturbed areas, which were the only areas where open space was abundant. Height accounted for only 2% of the variance in a multiple regression equation once open space and oak cover were included in the equation. Densities were low in areas of tall scrub with little or no open space that were undisturbed. The shrub layer is usually higher in disturbed areas than in undisturbed areas (Breininger 1981, Breininger et al. 1988, Breininger and Schmalzer 1990). Thus, the positive correlation between Florida Scrub Jay density and shrub height at this range (1-3.5 m) probably was misleading because of the interactions between open space, shrub height, and Florida Scrub Jay density.

Areas remaining unburned for 20-35 years can become unsuitable for Florida Scrub Jays (Westcott 1970, Cox 1984, Woolfenden and Fitzpatrick 1984). There is little information on demographic parameters within atypical habitat. The only published information is from Woolfenden and Fitzpatrick (1984) in an area of scrubby flatwoods at ABS that was unburned for over 35 years and eventually became unsuitable for Florida Scrub Jays. The number of territories occupying the site went from four to zero. They suggested that the site was eventually recognized as unsuitable and the low reproductive success of the area may have been attributed to the activities of Blue Jays. Scrubby flatwoods at ABS have a widely scattered slash pine overstory, unlike undisturbed scrub on KSC (Schmalzer and Hinkle 1987). Blue Jays on KSC are associated primarily with hammocks and swamps (Breininger 1990) and slash pine, but not scrub unless it is disturbed (Breininger and Schmalzer 1990, Breininger and Smith 1992, Breininger and Smith in preparation).

Florida Scrub Jays appear to behave differently in areas where high shrubs are abundant when accipiters are present. Below are some opportunistic observations in 2 study areas where the shrub height was typically 1.0-1.5 m in a slash pine area (Tel 4) and 2.0-4.0 m in a area of tall scrub and mowed grass (Happy Creek) during the peak fall migration of accipiters. In the Tel 4 area, 22 and 28 events within two 30-minute periods were seen where sharp-shinned hawks attempted to capture Florida Scrub Jays. The accipiters were clearly visible and could be located quickly by vision and alarm calls given by the jays. Florida Scrub Jays that were not being chased often remained in the open and continued with their activities, although remaining alert. Individuals that were "chased" often resumed normal activities within minutes. This is greatly different from ABS where an individual may remain hidden for many hours after such an event (Woolfenden pers. comm.). In tall scrub (>2 m) at the Happy Creek study area, jays immediately hid when an alarm call was given in the vicinity. They resumed their activities slowly and not before spending several minutes closely monitoring their surroundings. In this area, it was not possible to monitor movements of accipiters. On one occasion a peanut bit was thrown 3 m from the edge of tall scrub; it was immediately taken by a Florida Scrub Jay. Immediately thereafter, a sharp-shinned hawk crashed into the scrub, pursuing the bird until the hawk noticed the observer and flew away. The jays did not come out of hiding for the 30 minute period that the observer remained at the site. Differences may occur locally depending the ability for jays to spot aerial predators as a function of habitat visibility.

Florida Scrub Jays appear to respond more seriously to the presence of a Cooper's Hawk than Sharp-shinned Hawks (pers. obs.). On almost a daily basis during the spring of 1988, a Cooper's Hawk was seen flying just above the canopy of an area of tall (>3 m) oaks. One morning a great amount of scolding and alarm calls were given in this area. A Cooper's Hawk was sighted and appeared to be carrying something while being harassed by 15-25 Florida Scrub Jays. A while later a visit was made to a nest site in the area where the nest was covered by several adult Florida Scrub Jay feathers. The female breeder was missing and one of the eggs in the nest was broken. The nest was intact the day before, and the breeder female was present. Within two weeks, a helper female in the territory joined the remaining breeder male and was observed carrying nest materials. One week later she was missing (and was never seen again). The territory was eventually split among three adjacent territories. The breeder male disappeared for a few months and later was observed as a helper in another territory; he eventuallly became a breeder male in another territory upon the apparent death of its breeder male.

A curvilinear relationship (r=0.72) was found between the the number of small trees (DBH 2.5-5.1 cm) and Florida Scrub Jay density, where the optimal density of small trees ranged upward to 440 stems/ha (Breininger 1981). The data points for densities >100 trees/ha were few. High densities of Florida

Scrub Jays were found in three sites with >100 small trees/ha but these occurred in open disturbed areas. A positive correlation (r=0.42) was found between large (>5.1 cm) tree density and the density of Florida Scrub Jays, but the correlation was not significant ($p > 0.05$); the upper range of tree density was 88 stems/ha (Breininger 1981). When a family of Florida Scrub Jays is feeding, there is usually a bird that is perched serving as a sentinel to watch for trespassing jays or predators. The presence of a few trees provide good perch sites; too many can block the sentinel's view and decrease territory quality (Cox 1984).

Appendix E

Development of the Model

Habitat model development began using graphs produced from the upland bird project described below. Habitat parameters that had significant correlations (p values ≤ 0.05 and r^2 values ≥ 0.10) with Florida Scrub Jay densities were first considered. Other habitat factors that were believed important were then graphed using upland bird project data. Results were compared with other literature to determine whether modifications should be considered. The HSI functions for each habitat parameter were graphed and the overall model was drafted. Initial graphing was performed by combining habitat data into coverage classes and determining the average Florida Scrub Jay density for each class. Averages were then converted to HSI values by dividing by the highest average density of all coverage classes for that parameter. A few modifications were made using other data (Breininger 1981, Breininger and Smith unpublished data) as discussed below. Simulations were run using HEP software and habitat data from thirteen habitat types (Table 2). Model output was compared to Florida Scrub Jay densities within the types. Changes to HSI graphs of individual parameters were made so that application of the entire model and habitat data, of the 13 habitat types, generated habitat suitability output values that ranked the habitat types in an order, similar to the order based on densities. Hypothetical data were then used to determine HSI values for extreme variations of habitat. Additional modifications of several parameters were used to lower habitat suitability output for several habitat types believed to be marginal based on literature and preliminary results from territory mapping, breeder mortality, and reproductive success (Breininger and Smith 1989a,b; Breininger et al. 1990; Breininger and Smith unpublished data).

The model building process is described in more detail below, beginning with a brief overview of the upland bird project, a discussion of the development of each HSI graph, and a discussion of how the variables were constructed into a model. This discussion expands on the discussion regarding previous studies on habitat preference and seldom repeats earlier results on habitat preference; however, these earlier results were crucial to model development.

Upland Bird Study

The variable distance circular plot method (Reynolds et al. 1980) was used to estimate Florida Scrub Jay densities for each station. Stations were sampled eight times between March 1985 and February 1986 (Breininger 1989). Thirty-eight stations were used to sample scrub and 35 were used to sample slash pine. These stations were a subset of a larger study that sampled the bird community in many vegetation types using routes scattered throughout KSC. Stations were arranged in an elliptical pattern with stations at least 200 m apart (Breininger 1989, 1990). Stations were assigned to one of three visibility classes: 1) <4 years since fire, 2) 4-10 years since fire, and 3) >10 years since mechanical disturbance. An effective detection radius (R) was determined for each class by estimating the inflection point of a graph of the number of birds detected within 10 m concentric bands (Reynolds et al. 1980). The lowest R value among the three visibility classes was used to calculate density estimates for each species at each station. Birds/ha were estimated for each station and each habitat type by summing the density within R, dividing by the number of samples [eight station replicates times the number of stations (when calculating average density for a habitat type)], dividing by the area within R, and multiplying by 10,000.

The percent of the area surrounding the station comprised of open space, oak cover, slash pine cover, saw palmetto cover, and similar parameters were measured by a modification of the point intercept method (Hayes et al. 1981, Mueller-Dumbois and Ellenberg 1974, Breininger et al. 1988). Eight lines of four points each, 10 m apart, were established radiating from the center of each station. At each point, the presence or absence of oaks, saw palmetto, slash pine, open space and other cover measurements was recorded. Shrub height was also measured at each point. The number of points showing the presence of oaks, saw palmettos, slash pine, open space, or other cover parameters was divided by the total number of points, giving an estimate of the percent ground cover for the station. Height measurements from each point were averaged to derive an estimate of mean shrub height for the station. The number of snags and number of pine trees within a 40 m radius surrounding the station were counted and converted to the trees/ha and snags/ha.

The 73 stations were divided into 13 habitat types. The first phase of habitat division was to establish types that could be identified using aerial photography, USFWS fire records, and existing GIS files on vegetation/land use and soils maps. Criteria included the KSC vegetation map (disturbed scrub, oak/palmetto scrub and slash pine), the overlay of USDA soils maps (well drained soils, poorly drained soils), and fire history [recently burned or unburned (>10 years)]. All unburned areas were probably unburned for at least 20 years. The final habitat classes that resulted from this application were disturbed oak scrub, mesic disturbed scrub, disturbed slash pine forest with herbaceous understory, disturbed slash pine forest with a shrub understory, unburned xeric scrub, unburned mesic scrub, unburned slash pine flatwoods, recently burned oak scrub, and recently burned slash pine/oak. Reciprocal averaging ordination was used to separate the stations in undisturbed, recently burned scrub and slash pine occurring on poorly drained soils into additional habitat types. The resulting habitat types were saw palmetto scrub, oak/saw palmetto scrub, slash pine savanna (flatwoods), and slash pine/saw palmetto woodland. Habitat data and Florida Scrub Jay densities were presented in Table 2. Note that all stations were either in areas burned within four years or unburned for at least 10 years (but usually for at least 20). This distribution of stations in relation to time since fire was influenced by the time since the initiation of a three year fire cycle by the USFWS after 1981 wildfires. Between 1978-1981, only a very limited prescribed burn program was implemented. Prior to 1978 there was a long period (at least 15 years) of fire suppression. Recently burned stations were within Fire Management Units; nearly all unburned stations were outside Fire Management Units.

Model Development

Average habitat parameters for the habitat types and distinguishing criteria were provided in Table 2. It should be noted that most territories are comprised of several of these habitat types, so that density estimates better represent the proportion of use that occured in each type rather than carrying capacity.

Linear and quadratic regressions and correlation analysis were performed to investigate the influence of habitat factors on Florida Scrub Jay density using data from individual stations. Bivariate analysis also included graphical analysis as described in Breininger et al. (1988). Several parameters were highly correlated with each other. Parameters were grouped into categories representing similar habitat features; the parameter with the highest correlation was selected for further analysis. Multivariate analysis included multiple regression, logistic regression, and discriminate function analysis. Open space and oak cover predicted some of the variance ($r^2 = 0.40$; $p=0.02$) in the multiple regression . There was not enough statistical power to enter additional habitat parameters into the equation. However, many other (e.g., slash pine cover, mean shrub height, proximity to scrub oak ridge, distance to a forest, proximity to a man-made edge) were all assumed to be indicators of habitat suitability. It did not appear feasible to incorporate many nonlinear relationships into the multivariate models. Multivariate analysis often did not incorporate habitat factors that were believed important into an equation. The investigator believes that some parameters are most important along a certain range of conditions and only when other habitat conditions are suitable. The use of multivariate models with the existing data set was assumed to be ineffective at modeling these complex, non-linear relationships. Subsequently the model was developed using other approaches discussed in HEP manual 103 (USFWS 1983).

Percent of Shrub Canopy Cover Comprised of Scrub Oaks (V1A)

This variable was correlated with Florida Scrub Jay density (quadratic regression; $r=0.44$, $p=0.0001$). The habitat suitability suggested by this function differed slightly from the earlier study (Breininger 1981) where Florida Scrub densities were optimal at 40% PSO (Breininger 1981); the most recent version suggested densities were low at 40% PSO. The HSI model for V1A was developed so that habitat suitability increased between 30-50% PSO. It was assumed that optimum PSO was reached at 50% PSO. Close examination of the upland bird data suggested that many stations with 40-60% PSO had several other habitat features that were marginal (high pine cover, tall unburned oaks, or no open space). One additional change was to reduce V1A HSI output values by a factor of four within the range of 15-29% PSO. This was done so that the model output reflected low habitat suitability for areas with low PSO values. This resulted in model HSI values for scrub habitat conforming to the original PSO graph when other habitat parameters were held constant.

Sufficient empiricial data are not available for KSC to classify areas that will have no value to Florida Scrub Jays based on scrub oak cover. It was assumed that areas of no importance to Florida Scrub Jays would have <15% PSO and occur at distances greater than an average territory diameter [300 m (Woolfenden and Fitzpatrick 1984)] from an area of optimal (≥50%) PSO.

<u>Distance to Scrub Oak Ridge</u> (V1B)

Florida Scrub Jays densities were 4 times higher in secondary habitat that was within 300 m of primary habitat than within secondary habitat that was further than 300 m from primary habitat; these densities were significantly ($p= 0.005$) different (Breininger et al. 1991). Scrub oak cover was not significantly higher within these two classes of secondary habitat. The distance of 300 m was not an empirically determined difference. This distance was applied in the above habitat mapping application assuming that the average width of a territory (Woolfenden and Fitzparick 1984) would be applicable. Territory mapping studies at Happy Creek (Breininger and Smith unpublished) have shown that most territories within primary habitat also include secondary habitat and that the maximum distance such territories extend into secondary habitat from primary habitat is about 300 m.

Distance to scrub oak ridge was substituted for distance from primary habitat because areas of optimal scrub oak cover can occur within areas mapped as secondary habitat (Breininger et al. 1991). This may occur because small patches of well drained soils may not have been distinguished on soils maps. Scrub oak ridge was defined as areas with $\geq$50% scrub oak cover. Observations at the Tel 4 study area suggest that areas of low scrub oak cover are commonly used by Florida Scrub Jays when near patches of high scrub oak cover in secondary habitat.

Percent Open Space (V2A)

Results for the upland bird survey were significant (quadratic regression; $r=0.47$ $p=0.0002$) and similar to earlier results (Breininger 1981) but there was only one station in the more recent survey that had more open space than 40% ground over. The earlier data (Breininger 1981) suggested that the optimal amount of open space was 20-50%. Cox (1984) suggested optimal open space is between 10-30%. The minimum optimal value was maintained at 20% because there was an abundance of data points for the upland bird study and the earlier study (Breininger 1981) for this portion of the function. Few data are available for areas with open space >40%. The maximum optimal open space value used for the model was maintained at 50% (Breininger 1981). Habitat along edges and patches of open areas among scrub have been considered unsuitable by consultants performing environmental evaluations when these areas were successfully used for nesting, foraging, and caching acorns. Patches of oaks have been found in such areas (i.e., Happy Creek and Complex 41) that have extrordinary acorn production. Studies for Titan launch assessment (Breininger et al. 1990) indicated that areas of mostly open space with a few oaks were able to support small territories. Group size was average in these areas, mortality was low, and reproductive success was high. This study suggested that areas of mostly open space with occasional shrubby patches can be good habitat. Patches of disturbed habitat are to be mapped, since such patches are likely to be incorporated as part of a territory. No data are available for patches of sparse shrub vegetation (>80% open space or other grassy areas) that are not near (within 100 m) an undisturbed edge; the model has little applicability for such situations. Territories in some areas have been found to be much smaller than average territory size at ABS. Smaller territories in areas with a mosaic of open space and shrubs have been found at Happy Creek (Breininger and Smith 1989a), the Playalinda Beach Access Road crossover site (Breininger and Smith 1989b), and both launch complexes 40 and 41 (Breininger et al. 1990).

Considerations were given for areas with narrow sandy areas (<12 m wide). Territories observed encompassing such areas have not had small territory sizes. It does appear, however, that group size is higher in these areas than territories with little open space (Breininger and Smith 1989a). Florida Scrub Jays in such areas frequently nest, forage, and cache acorns along such sandy areas (pers. obs.). Given the landscape heterogeneity of KSC, polygons that include narrow sandy roads, firebreaks, or ruderal areas are not likely to be very wide (e.g. >100 m). It was assumed that the habitat suitability value for open space in a polygon that includes a narrow opening is equal to the percent open space within the polygon. Since little open space is present in undisturbed scrub and slash pine, polygons with narrow roads or firebreaks will tend to have higher suitability than polygons that are otherwise similar but lack such features.

Distance to Ruderal Area (V2B)

Wide ($\geq$12 m) areas of ruderal grass adjacent to roads or facilities and adjacent to scrub and slash pine are often used by Florida Scrub Jays. The distance of 12 m is the narrowest distance where small territories have been observed. This model is concerned with the habitat value of scrub and slash pine. Ruderal habitat alone can not maintain territories, so it was assumed that ruderal habitat should not be considered as part of the inventory of habitat that supports the population. Scrub or slash pine habitat adjacent to such areas may have high habitat suitability (but also high mortality if adjacent to a busy road) because of the abundance of open space. Territories often extend only about 100 m from a ruderal edge (Breininger and Smith 1989a). It was assumed that areas within 100 m of an edge (providing scrub oaks were abundant nearby) should have optimal V2 values. Smaller territories have not been found along edges comprised of low (<30%) scrub oak cover. It was assumed that V2B is applicable for a polygon only if PSO is $\geq$30% for the polygon or if there is a polygon with PSO $\geq$30% within 100 m. Areas with <30% PSO are often commonly used for foraging and are nesting when near habitat with $\geq$30% PSO.

Distance to a Forest (V3A)

This parameter was positively correlated with Florida Scrub Jay density (linear regression; $r=0.38$, $p=0.001$). Forest here refers to the distance from a broad-leaved forest (e.g. hammock or swamp) or pine forest (interlocking pine canopies). Graphical results suggested that there was no relationship beyond 100 m from the forest edge. Areas adjacent to forests frequented by Cooper's

Hawks are sometimes avoided for distances as far as 100m (pers. obs.). There have been seasons and locations where it has not been possible to map territory boundaries between neighboring families close to such forests. It also has not been possible to lure Florida Scrub Jays near some forests using peanuts. However, usually territory boundaries can be mapped up to a forest edge. Other factors that might influence this relationship is that forests are frequented by blue jays and scrub oak cover is often low immediately adjacent to forests. Proximity to forests may make Florida Scrub Jays more vulnerable to surprise attacks by accipiters. Many Florida Scrub Jays that reside in areas with several nearby forests appear unusually wary and have often been difficult to tame during the color banding process. Behavioral observations of Florida Scrub Jays and the tendency of Cooper's Hawks to frequent forests led the author to believe that the areas adjacent to forests are indeed less suitable. The model assumes that areas immediately adjacent to woodlands are nearly unsuitable and that habitat suitability increases with increasing distance from the forest to 100 m, at which distance the forest is assumed to no longer influence habitat suitability.

<u>Percent Pine Canopy Cover</u> (V3B)

This parameter had a weak negative correlation (linear regression; $r=-0.28$ $p=0.02$) with Florida Scrub Jay density. Literature suggests that Florida Scrub Jays avoid pines except where the canopy is very sparse. On KSC pines are frequently used as perch sites and the clusters of pine needles at the tips of branches are sometimes used as temporary storage sites. Small (< 1 ha) groups of pines that would be mapped as woodlands are not avoided on KSC. Florida Scrub Jays are rarely sighted in extensive slash pine woodland and pine forests. The sample size for stations with >60% pine cover was only five; the sample size of stations with pine cover 41-60% pine cover was seven. The model for pine cover between 40-80% pine cover is weak because scrub oak cover is usually low where pine cover is high on KSC. Close examination of the data suggested no relationship between pine cover and Florida Scrub Jay density between 0-15% pine cover. Pine savanna habitats had higher Florida Scrub Jay densities than scrub habitats with similar scrub oak cover. Open space was higher in these savannas. Within pine savannas, transects with pines also had higher Florida Scrub Jay densities than transects without pines in the earlier study (Breininger 1981). In recenty burned slash pine, openings are common around stumps, snags, and under living trees. Florida Scrub Jays are frequently observed flying from tree to tree in open savannas rather than flying from oak to oak. The pine trees provide Florida Scrub Jays with perches for spotting predators and territory intruders. The negative influence between increasing pine cover and habitat suitabilty is probably much more complex than stated in the model and is probably influenced by the visibility of the habitat and the size of the pine woodland. Slash pines often occur in higher densities in disturbed areas, especially along roads. Cooper's Hawks have frequently been seen using these edges as cover while hunting within slash pine. During some seasons, Florida Scrub Jays are especially wary along such edges, perhaps because of limited visibility and the stealth characteristic of the Cooper's Hawk.

The model assumes that habitat suitability is not influenced by pine cover between 0-15% cover and that habitat suitability declines in a linear manner until 70% pine cover. Due to the differences in composition and structure between slash pine flatwoods and sand pine scrub, this model may not apply to sand pine scrub. For example, the structure of young sand pines may limit visibility much more than is characteristic of young slash pines.

Mean Height of Shrub Layer (V4)

This parameter was not statistically significant. However, the author believes it is a very important parameter and it is not unusual to use a statistically insignificant parameter in a model. The relationship is unlikely to be linear and simple. Large areas with a shrub height less than 1 m have been burned repeatedly at short intervals (i.e. several times in the last ten years). Although open space and scrub oaks may be abundant in these areas, Florida Scrub jays are not. It is not known whether Florida Scrub Jays can find sufficient cover in such areas or whether there are enough acorns.

Patches of recently burned scrub adjacent to taller patches of scrub of optimal height should have adequate cover and acorn supply, and recently burned patches will frequently be used for foraging. The author assumes that V4 should be applied using the average height for relatively large patches that include a mosaic of burn classes and not on each small or narrow patch in such a mosaic. More studies are needed to determine how to identify mapping units for appropriate application of this model.

Different age classes (with respect to fire) often occur within the same area or same territory. This is likely given the large size of most territories. It was assumed that the selection of different age classes should depend on their landscape pattern. Habitat subdivisions based on oak cover, open space, and pine cover should be sufficient where there is a mosaic of many patches of different fire history within an area the size of a territory. It was assumed that recently burned (4 years since the last fire) patches could represent optimal conditions where they were adjacent to other patches of sufficient height. If considered as separate patches, implementation of the habitat suitability relationship for V4 could make the patches appear to be of low habitat suitability when they were part of an area of good habitat suitability. Patches of poor habitat are often contained within a territory, they are defended but rarely used for foraging or nesting. It is possible that Florida Scrub Jays defend a much larger territory than is actually needed at any one time; different parts of their territory may be used at different times because of changes in habitat associated with time since fire. Woolfenden and Fitzpatrick (1984) suggested that variations in territory quality may occur, and studies are ongoing at ABS to quantify such changes. Studies have been proposed for KSC; some preliminary work was done.

It was assumed that fire history should be used to further separate an area into habitat types when there are single, large patches of unburned areas (>15 years) or recently burned areas (<4 years since last fire) that comprise an area as large as 1/3 or more of a territory (>3 ha in size). However, it was assumed that no special considerations should be given where recently burned areas occur as narrow strips (<100 m wide) regardless of their size. It is assumed that at distances <50 m Florida Scrub Jays would have sufficient time to escape to dense vegetation for cover if a hawk was present. The same exception was not assumed for tall, unburned areas because it was perceived that such areas would influence the ability of jays to spot predators, regardless of the width of such areas. In summary, the HSI for shrub height in an area with a mosaic of low patches and patches with optimal height was assumed to be high. If other parameters are optimal, the model produces this effect.

Territories frequently consist of two breeders and no helpers in tall unburned areas (Breininger and Smith 1989b, unpublished data, Breininger et al. 1990). Several years of data have suggested high breeder mortality and low reproductive success at Happy Creek in territories comprised of tall (2.5 m) unburned vegetation (Breininger and Smith unpublished data). Where openings are abundant in tall unburned areas at Happy Creek, territory sizes have been small, resulting in moderate densities, but these areas appear to be population sinks (Breininger and Smith unpublished data). Woolfenden and Fitzpatrick (1984) have also discussed the low habitat suitability attributed to tall, unburned areas.

The model was constructed by first graphing densities with mean shrub height using upland bird data. Densities were highest between 120-170 cm. Habitat suitability was assumed to decline to zero where the mean shrub height was zero. Little data were available for areas with a height <70 cm because such areas were rare given previous fire suppression practices, and because saw palmettos quickly recover their original height after fire. It was assumed that habitat suitability attributed to shrub height was low where a mean shrub height was 2.5 m or greater and that habitat became unsuitable when the shrubs reached 5.0 m (Breininger 1981). Due to compensatory relationships associated with geometic mean, the HSI value for 2.5 m was reduced to half to make total model output similar to the original graph.

Development of the Model Equation

Four parameters were believed important for predicting habitat suitability: scrub oaks, open space, tree cover, and shrub height. Although several (open space and PSO) had higher correlation coefficients, sites will not be occupied if the tree cover is too dense or the areas are unburned for especially long periods. Although open space had the highest correlation in the upland bird study and the earlier study (Breininger 1981), Florida Scrub Jays occupy areas and territories that have no (<1.0%) open space (Breininger 1981, Breininger and Smith unpublished data). A geometric mean was selected as the final equation because a weak compensatory relationship (USFWS 1983) was believed to occur among the habitat parameters and because the site would be unsuitable (HSI value of zero) if any of the parameters had a zero value. An example of a compensatory relationship involves open space and shrub height. Areas with high shrubs support many Florida Scrub Jays if there are many openings. Several areas had marginal conditions for several parameters (e.g. oak cover and slash pine cover) and had fewer Florida Scrub Jays than would be expected from either of the parameters being marginal alone. The geometric mean was sensitive to these marginal conditions. However, the geometric mean was assumed to overcompensate for VIA and V4 so that the HSI models for those individual parameters were adjusted as described earlier.

Appendix F

Model Limitations

There has been a proliferation of wildlife habitat suitability models, but their use has many shortcomings due to inadequate testing (Cole et al. 1983; Lancia et al. 1983). Data used to develop or test wildlife habitat models are often based on densities or habitat use observed from sitings or radio tracking; however, these measurements are not always accurate indicators of habitat suitability (Van Horne 1983; Hobbs and Hanley 1990). Long-term study of population dynamics is needed to define habitat suitability or at least test assumptions that density and habitat use are valid indicators of habitat suitability (Van Horne 1983; O' Connor 1981, 1986; Hobbs and Hanley 1990). Some of the assumptions used to construct this model are being tested using long-term studies of color-banded Florida Scrub Jays in 50 of an estimated 800 families present on KSC. Short term (1-2 years) studies are being conducted on an additional 5-15 territories each year. These studies cover only a small portion of the habitat variation present and provide for little replication of conditions that are under investigation. Replication is important given that individuals are likely to vary genetically, so that locations inhabited by superior or inferior individuals may influence demographic parameters regardless of habitat suitability.

The average territory size for the Florida Scrub Jay is large (9 ha) (Woolfenden and Fitzpatrick 1984). Optimal habitat allows Florida Scrub Jays the ability to scan their surroundings for long distances (Woolfenden and Fitzpatrick 1984). This vigilance is coordinated among territory members and is important for the detection of predators, especially hawks (McGowan and Woolfenden 1989). Landscape fragmentation results in edges of habitat and small fragments that have a discontinuous fuel structure so that these areas often bum poorly (Breininger and Schmalzer, 1990) and have a tall shrub layer

(Breininger et al. 1988). Patches of tall vegetation may interfere with the ability to spot hawks. Blue jays, which are nest predators (Woolfenden and Fitzpatrick 1984), are attracted to disturbed areas (Breininger and Schmalzer 1990). Mortality of adult Florida Scrub Jays has been high and reproductive success has been poor in tall, disturbed areas (Breininger and Smith unpublished data). Habitat fragmentation resulting from a project should be evaluated and minimized. The effects of habitat fragmentation, however, are not considered by this model. Another important consideration is that a project may increase the difficulty or cost of burning an area, especially to burn the area properly. It is often better to locate the project in a manner that reduces landscape fragmentation.

Landscape fragmentation will sometimes be associated with increased road mortality for Florida Scrub Jays and other wildlife (Dreschel et al. 1990, Fitzpatrick et al. 1991). Roads where speeds exceed 35 mph may result in the adjacent habitat (within 300 m of the edge) becoming a population sink. Broader shoulders may reduce road mortality but broader shoulders result in more habitat being destroyed. Habitat that would be lost to develop broader shoulders may be of more net value if it remains rather than if it is destroyed.

At least some Florida Scrub Jays occur in areas that are population sinks (areas of marginal quality where net reproductive rates are lower than mortality rates). Long-term persistence of populations in such habitat is dependent on source areas (where reproduction exceeds mortality) that provide individuals to subsidize the sink population (Pulliam 1988, Pulliam and Danielson 1991, Howe 1991). The identification of sources and their management is crucial to consider for habitat evaluations because long-term persistence of the KSC population is dependent upon the sources.

Cumulative impacts can be evaluated using habitat models and GIS applications. Habitat that will be lost to construction can be digitized to evaluate the loss resulting from individual projects relative to the total habitat available. Files from many projects can be combined to quantify cumulative losses of habitat. Problems arise when populations are maintained by source areas that are not treated as separate mapping classes (especially where the source areas are small, relative to the total habitat occupied by the population; Pulliam 1988, Pulliam and Danielson 1991, Breininger et al. 1991). A project that will remove a small source area may appear insignificant relative to the remaining habitat, but the overall impact of the project could be greater than the estimate produced from a HEP evaluation.

Presently, primary habitat when it has suitable structure, is assumed to provide most of the source areas for the population (Breininger et al. 1991). Long-term reproductive success and survival studies are necessary to evaluate this assumption. The loss of primary habitat is often more significant than the loss of most secondary habitat, regardless of habitat suitability at the time of evaluation. Exceptions occur where fragments of primary habitat, isolated by human development, occur near operational areas and along some roads where road mortality is a problem. Much primary habitat is outside fire management units (FMUs); many unburned areas may be population sinks but could become good habitat if burned. Not only is the cost of managing these patches expensive, but it is often difficult to burn these areas due to nearby NASA operations.

Patches of optimal habitat often occur within secondary habitat (Breininger et al. 1991); these patches may be of special importance where there are few scrub oaks. Loss of such areas may impact a much larger area because they may be a source of individuals. Secondary habitat provides a buffer and enhances opportunity for fires to burn into primary habitat due to its greater flammability. Secondary habitat provides important corridors of habitat between population centers allowing subpopulations to be interconnected (Whitcomb et al. 1976; Fritz 1979; Noss 1983, 1987a, b; Soule' 1988; Adams and Dove 1989). This may be critical for maintaining populations given the weak flying powers and dispersal abilities of Florida Scrub Jays. Dispersal of individuals to distances of a few kilometers is a rare event (Westcott 1970, Woolfenden and Fitzpatrick 1984). The importance of areas that serve as corridors is not incorporated into the HSI model but possible corridors can be identified by observing the map of Florida Scrub Jay population centers (Breininger et al. 1991). Field surveys are needed to confirm habitat that is suitable for corridor management.

Population models suggest that even population sinks contribute to the viability of wildlife subpopulations (Pulliam 1988, Pulliam and Danielson 1991, Holt et al. 1991). Sinks can contribute to the security of a population that is larger than would be maintained by optimal habitat alone. Larger populations are less susceptible to catastrophic events, epidemics, and inbreeding (Soule' 1988). Almost half of the secondary habitat had oak cover that was suitable or optimal, so that much of it was capable of supporting Florida Scrub Jays.

Conditions that define preferred habitat for the Florida Scrub Jay as defined by investigators elsewhere (Appendix C) are found in few areas on

KSC (Appendix D). Habitat tolerances of Florida Scrub Jays are either broader than believed, or much of the KSC population occurs in marginal habitat. Population models suggest that entire populations sometimes will be maintained by source populations that are small relative to the total population (Pulliam 1988, Howe 1991). Data are not currently available to define the habitat charactersitics where average reproductive success is equal to average mortality rates, except for conditions that are optimal at ABS.

The model was not developed for use across Florida; its applicability beyond KSC may be limited. Many other considerations are necessary for its use outside of KSC. These include topics such as, the role of the site in maintaining a minimum viable population size for the region or the effects of management actions on the entire population that is within a suitable dispersal distance of the site in question. Furthermore, habitat relationships may not be the same across the Florida Scrub Jay range. Predation effects may vary depending on location, and there may be additional habitat factors that are important at KSC which have not been identified as predictors of habitat suitability. One such example is provided below. Florida Scrub Jays at KSC line the inside of their nest with fibers taken from cabbage palms (Sabal palmetto), which are common over most of the landscape. At ABS, fibers from the scrub palmetto (Sabal etonia) are used as a nest lining.

Florida Scrub Jays respond to specific habitat features that are not necessarily defined by plant community nomenclature (Breininger 1981). For example "pine flatwoods" are usually occupied by Florida Scrub Jays on KSC, but not everywhere else in Florida. This problem has long been recognized for amphibians and reptiles in Florida (Campbell and Christman 1982). Many areas that would be expected to be marginal based on studies elsewhere are occupied on KSC. The model predicts that these areas will be occupied. Perhaps marginal habitats are occupied on KSC because there is a large source population that contributes individuals.

Some projects that occur in areas that lack openings in the shrub layer have been regarded as beneficial because the project will provide openings; this sometimes was justified based on improper applications of the results from an earlier study (Breininger 1981). Application of this HSI model, for pre- and post-project evaluations, can result in an increase in HSI values for some patches of habitat near a ruderal edge, but the net number of HUs will decrease for most projects. This is expected, since Florida Scrub Jays may frequent edges of ruderal habitat and scrub oak vegetation, but the net result of the project is a loss of scrub and slash pine that is necessary to support the species. Thus, the provision of open space by project implementation may sometimes offset some of the HUs lost due to construction, but few projects will actually increase the carrying capacity of Florida Scrub Jays within the area. The provision of openings by mechanical disturbance to offset impacts is not only unproven, but can have long-term negative effects (e.g., Breininger and Schmalzer 1990).

Evaluation of project impacts should be based primarily on the effects on resident territories. This approach is necessary because the functional size of a Florida Scrub Jay population is determined by the number of territories that can be supported over long periods of time. Sometimes the Endangered Species Office of the USFWS requires colorbanding and territory mapping in the proposed project area. The model is useful in these applications because it provides a mechanism to evaluate habitat suitablility of patches of habitat within territories. Some habitat within a territory is of little value to the residents. The model alone does not consider territory requirements. The state of knowledge currently does not provide a simple formula to quantify all environmental impacts to Florida Scrub Jays.

The model, combined with maps of primary and secondary habitat, provides a method to evaluate the habitat suitability of a site on KSC. The accuracy of the model to predict habitat suitability needs testing. Testing can partially be performed during territory mapping excercises, since territory characteristics are essential to predicting project impacts. However, habitat suitability determinations require the knowledge of long-term reproductive success and survival measurements (Van Horne 1983), such studies are essential for model testing. A few years of territory mapping and demographic studies do not provide sufficient information to evaluate reproductive success and survival at a site. They do provide information that contribute to developing an understanding of how territory size is related to variations in habitat characteristics.

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13. ABSTRACT *(Maximum 200 words)*
The Florida Scrub Jay (Aphelocoma coerulescens coerulescens) is endemic to Florida. The John F. Kennedy Space Center (KSC) provides habitat for one of the three largest populations of the Florida Scrub Jay. This threatened bird occupies scrub, slash pine flatwoods, disturbed scrub, and coastal strand on KSC. Densities of Florida Scrub Jays have been shown to vary with habitat characteristics but not necessarily with vegetation type. Relationships between Florida Scrub Jay densities and habitat characteristics were used to develop a habitat model to provide a tool to compare alternative sites for new facilities and to quantify environmental impacts. This model is being tested using long term demographic studies of colorbanded Florida Scrub Jays. Optimal habitat predicted by the model has ≥50% of the shrub canopy comprised of scrub oaks, 20-50% open space or scrub oak vegetation within 100m of a ruderal edge, ≤15% pine canopy cover, a shrub height of 120-170cm and is ≥100m from a forest. This document reviews life history, social behavior, food, foraging habitat, cover requirements, characteristics of habitat on KSC, and habitat preferences of the Florida Scrub Jay. Construction of the model and its limitations are discussed.

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