# An Adaptive Approach to Managing Florida Scrub-Jay Habitat

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**Abstract**

This document reviews and synthesizes recent biological studies relevant to scrub management to assist natural resource managers meet Florida Scrub-Jay recovery goals. Prescribed fire is the primary tool to restore and manage scrub, although mechanical intervention is often needed. Landcover maps often underestimate potential habitat so that new approaches for identifying potential habitat and population size are described. These approaches partition potential habitat into primary, secondary, and tertiary scrub ridges based on soils and the size of scrub ridges. The approach for evaluating the management needs of oak scrub relies on partitioning ridges into potential territories and then classifying the territories into one of four shrub height arrangement categories. Classifying the landscape into potential territories is useful because landscapes are often comprised of scrub patches with many different shrub heights and fire histories. Florida Scrub-Jay territory boundaries often do not directly coincide with the boundaries of scrub ridges or coincide with the boundaries of scrub patches having different shrub heights. Optimal territories have a combination of medium-height scrub (120-170 cm) and open sandy areas that are within scrub that is usually recently burned and short. Other territory quality categories related to shrub height arrangements are completely short, have too much tall scrub, or lack open sandy areas. The shrub height arrangement categories described herein are directly related to fire management needs and source-sink dynamics within landscapes. Brief suggestions for integrating uncertainties with adaptive management are provided.

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## 1.0 INTRODUCTION

The document first reviews Florida Scrub-Jay territories as the basic population unit that directly links to spatial and temporal variation in habitat quality and source-sink dynamics. The importance of fire as the primary habitat management tool is then discussed. Information regarding Florida Scrub-Jay habitat requirements and habitat management needs is provided. Approaches to identify all potential territories, target population size, and other management constraints regarding biological diversity are reviewed. A territory classification system, based on the arrangements of shrub heights, is described as a simplified rapid assessment and monitoring approach for describing spatially explicit fire management needs. Other habitat characteristics (open sandy area, tree cover, forests) are also discussed as important attributes for determining fire management needs. Approaches for incorporating uncertainty and monitoring to develop site-specific adaptive management are discussed.

### *1.1 Florida Scrub-Jay biology*

Florida Scrub-Jays are the only species of bird unique to Florida and are a threatened species under the federal Endangered Species Act. The species is a flagship, indicator, umbrella, and surrogate for much of the biological diversity of the scrub ecosystem, which is one of the most unique and endangered ecosystems in North America (Noss et al. 1997). Although threatened by habitat loss and fragmentation (Stith et al. 1996), reduced fire frequency is also causing population declines and extinction (Woolfenden and Fitzpatrick 1991; Root 1998; Breininger et al. 1996, 1999, 2003).

Mean territory size is approximately 10 ha when habitat is optimal and saturated by breeding pairs that have an average population growth rate of approximately 1.0 (Woolfenden and Fitzpatrick 1984, 1996; Breininger et al. 1995). Therefore, conservation planning generally assumes that the total area of potential habitat divided by 10 ha (or 25 acres) approximates the number of territories and their distribution (U.S. Fish and Wildlife Service 2004). It is reasonable to partition landscapes into territory units for habitat management evaluations because Florida Scrub-Jays are permanently territorial and breeders usually occupy a territory for their entire lives once they become breeders (Woolfenden and Fitzpatrick 1984, Breininger and Carter 2003). The area within territories to fulfills all life requisites, such as finding and storing food, escaping predators, and raising new generations of young. Florida Scrub-Jays rely on small prey items (e.g., grasshoppers, amphibians) within these territories, except during winter periods of low prey abundance when cached acorns supplement their diet (Degange et al. 1989).

Florida Scrub-Jays are cooperative breeders and usually delaying breeding for 1-3 years where there are few breeding vacancies. Most Florida Scrub-Jays that delay breeding help breeders spot and mob predators, defend territory boundaries, and assist in raising future generations (Woolfenden and Fitzpatrick 1984). Helpers not only enhance demographic success of breeders but represent a buffer of potential breeders that often keep the breeding population stable (Woolfenden and Fitzpatrick 1984; Mumme 1993; Breininger et al. 1999, 2003). Helpers are an important pool of potential breeders following the restoration of unoccupied habitat. Most Florida Scrub-Jays disperse to an adjacent territory to breed; long distance dispersal is rare (Fitzpatrick et al. 1999, Breininger and Carter 2003). Optimal territories that occur within a sparsely populated and restored landscape can remain vacant for long periods when they are not near a source of potential immigrants (Breininger et al. 2003). Florida Scrub-Jays prefer to use open scrub or flatwoods during dispersal forays and some types of landscape conditions (e.g., wide forests, open water) can be relatively impermeable even over short distances (e.g., 300m; Stith 1999).

It is unreasonable to assume that every territory will be optimal even under the best management history because fire patterns have great spatial and temporal variability. Habitat variation within landscapes can often be described by partitioning the landscape into source and sink territories (Breininger and Carter 2003, Breininger and Oddy 2004). Source territories are needed to sustain the population because they are net exporters of individuals and have births that exceed deaths (Holt 1985, Pulliam 1988, Howe et al. 1991). Sink territories must be sustained by sources because they are net importers and have deaths that exceed births. Potential breeders are exported to sink territories by active dispersal and by “territory quality transitions” where territories produce an excess of potential breeders while in optimal condition and then became marginal because of shifting territory boundaries and habitat conditions (Breininger and Carter 2003). Sinks contribute to population stability because they “buffer” population sizes in the best territories (Wiens and Rotenberry 1981, Pulliam 1988, Howe et al. 1991). Short dispersal propensities can explain why Florida Scrub-Jays disperse into adjacent sink territories even when optimal territories are only a kilometer away or on the other side of a relatively impermeable landscape feature (Breininger et al. 2003, Breininger and Carter unpublished data). There are limits to the types of sink territories that Florida Scrub-Jays will disperse into; for example, Florida Scrub-Jays rarely disperse into some scrubs that are unburned for excessively long periods (Woolfenden and Fitzpatrick 1984).

Conservation must focus on maintaining viable local populations for species, such as Florida Scrub-Jays, that have poor dispersal and low recruitment (Drechsler and Wissel 1998). Managing small reserve units carefully is particularly important because there are many uncertainties regarding population dynamics within fragmented systems. Uncertainty occurs because most studies have occurred within large natural landscapes (Woolfenden and Fitzpatrick 1984, 1996; Schaub et al. 1992; Breininger et al. 1995, 1998) or suburbs (Thaxton and Hingtgen 1996, Breininger 1999; Bowman and Woolfenden 2001; Fleischer et al. 2003; Reynolds et al. 2003, in press). Potential sources (i.e., recruitment exceeds mortality) might not rescue all suboptimal habitats. For example, suburbs often supply Florida Scrub-Jays into reserves but Florida Scrub-Jays rarely disperse from reserves into suburbs (R. Bowman and J. Thaxton, personal communication). Suburbs have mortality that exceeds reproductive success so that jays should eventually be extirpated from suburbs (Stith 1999). Not all suburbs can be counted on as temporary suppliers of colonists into new reserves (e.g., Breininger et al. 2003).

## 2.0 HABITAT MANAGEMENT PRACTICES

### *2.1 Prescribed fire*

Prescribed fires are essential to sustain Florida Scrub-Jay populations because anthropogenic features limit fire spread (Duncan and Schmalzer 2004) and regulations generally require that wildfires be extinguished. Fire return intervals have often been described as 8-25 years (Florida Natural Areas Inventory 1995), 10-20 years (Fitzpatrick et al. 1991), and 5-20 years (Menges and Hawkes 1998). These may be too short in landscapes that include pine flatwoods or in scrub sites with open sandy areas that persist for only 1-2 years after fire (Breininger et al. 2002). A fire return interval of every 1-8 years recommended for mesic flatwoods (Florida Natural Areas Inventory 1990, Stout and Marion 1993, Main and Menges 1997). Fire suppression longer than 10 years might have been unusual in the evolutionary history of many flatwoods species and can produce pronounced changes in community structure (Maliakal et al. 2000). Periods of reduced fire frequency favor hardwood forests (Platt and Schwartz 1990) that can replace the open canopy structure of pine flatwoods and their associated marshes within 20 years (Duncan et al. 1999). Periods much greater than 20 years without fire often result in a structure that is difficult or impossible to reverse by only prescribed fire (Schmalzer and Boyle 1998, Duncan et al. 1999). No species require unburned flatwoods but a few scrub species require infrequent fire (Means and Campbell 1981, Auffenberg and Franz 1982, Layne 1990, Breininger and Smith 1992, Menges and Kohfeldt 1995, Hawkes and Menges 1996, Menges and Hawkes 1998).

Determining fire frequency is not as simple as specifying fire return intervals based on one community type because fire management units are often comprised of different plant communities that have different fire return intervals (Breininger et al. 2002). Furthermore, it is best to not burn all of a territory in one fire (Fitzpatrick et al. 1991). Scrub is often difficult to ignite without cutting ignition strips or using head fires under dry conditions with sufficient winds (Florida Natural Areas Inventory 1995, Adrian and Farinetti 1995). Wiregrass, gallberry holly, saw palmetto, and pine needles have long been recognized for having the fuel structure and chemistry that gives pine flatwoods a high propensity to burn (Shafizadeh et al., 1977, Myers 1990, Platt et al. 1991, Platt 1999). Flatwoods marshes are also comprised of species that burn readily, accumulate fuels faster than oak scrub, and are probably important for increasing fire frequency in scrub (Myers 1990, Yahr et al. 2000). Therefore, including flatwoods and marshes within and along the boundaries of fire management units might be important to promote fires in scrub. Burning flatwoods frequently might be especially important for maintaining open sandy areas in scrub (Breininger et al. 2002). Conservation planning requires the consideration of natural processes, such as fire (Noss and Cooperider 1994).

At least 3 types of prescribed burns should be considered. One is a mosaic fire that partially relies on differences in flammability among vegetation types. This fire should burn most of the flatwoods and imbedded marshes but only a small portion of the oak scrub. More extreme burning conditions generally are needed for scrub to burn, such as higher temperatures, higher winds, lower humidity and lower fuel moistures. The second fire is a hot fire that burns nearly everything. A ring fire is an example of an advanced burning technique that can be used to extensively burn scrub (U. S. Fish and Wildlife Service 2004). A third fire is intermediate and might need sufficient winds and low enough fuel moistures to drive a head fire through areas that need burning without burning everything.

Most fire managers rely on fuels models to model fire behavior to determine conditions suitable for burning. Two fuels models are often considered for flatwoods. Model 7 is used for modeling when palmetto dominates 50% or more of surface fuel cover. Model 2 is used when palmetto cover is less than 50% and grasses dominate (Anderson 1982). The Nature Conservancy suggests using Fuel Model 6 for short and optimal shrub heights and Fuel Models 4 or 7 for scrub that has been unburned for long periods (http://www.eelbrevard.com/eel/education/fire/firemanual/index.html).

The season of prescribed fire can be important within some plant communities, such as pine flatwoods (Robbins and Myers 1992). There is no evidence that season of burning influences vegetation dynamics within scrub (Foster and Schmalzer 2003). However, growing season fires that stimulate wiregrass might promote the flammability of the entire landscape (Pedro Quintana-Ascencio personal communication) and summer fires may have important implications for maintaining flatwoods (Shriver et al. 1996, S. Orwell personal communication).

### *2.2 Mechanical*

Fire managers often need fire breaks and ignition strips (Main and Menges 1997, Adrian and Farinetti 1995). Without flatwoods, scrub often has little chance of being burned except under dangerous meteorological conditions if it has gone unburned for long periods and exceeds a mean height of 2.0 meters (Schmalzer et al. 1996, Schmalzer and Boyle 1998, Duncan et al. 1999). Therefore, a one time mechanical cutting application is often necessary so that subsequent prescribed fires can be used to manage habitat (Schmalzer et al. 1994). Determining the height and structure where fires can no longer be used to restore scrub depends on the context to human development and requires experience.

Timbering is often useful because woodlands and forests have replaced many open savannas because of anthropogenic reductions in fire frequency (Duncan et al. 1999). Breininger and Duncan unpublished data). Cool winter burns can also result in increased pine density (S. Orwell personal communication). Tall shrubs that are difficult to burn often get knocked down during timbering operations. Piled fuels produce local hot spots that kill the roots and rhizomes of sprouting species and represent a mechanism to reestablish open sandy areas (Schmalzer and Adrian 2001).

Although there is great interest in the use mechanical techniques as fire surrogates, these do not replace fire. For example, the thatch that remains might inhibit seedling emergence of rare scrub plants (Menges 2001). Florida Scrub-Jays probably prefer open sand and not the debris from mechanical treatment, possibly because the debris provides refuge and camouflage for predatory snakes. Saw palmetto is sensitive to excessive mechanical disturbances and is important for carrying fire in many systems (Breininger and Schmalzer 1990, Schmalzer and Adrian 2001). Other concerns about mechanical techniques include exotics (Schmalzer et al. 1994, 2003; Menges 2001) and stress to gopher tortoise populations exposed to a respiratory disease (Rich Seigel, personal communication).

## 3.0 FLORIDA SCRUB-JAY HABITAT REQUIREMENTS

This section first identifies habitat attributes that define potential territories and then identifies attributes of territory quality that are influenced by habitat management techniques.

### *3.1 Potential habitat***.**

Florida Scrub-Jay territories are often not dominated by oak scrub but include flatwoods and marshes (Breininger et al. 1995, 1998). Potential population size can be greatly underestimated if one assumes that Florida Scrub-Jays are entirely restricted to oak scrub, as distinguished on most landcover maps (Breininger et al. 1991, 1995, 2003; Breininger and Oddy 2004). Florida Scrub-Jays generally require scrub or pine flatwoods that contain scrub oaks, although they will use coastal strand, maintained grass, and many other shrub-dominated or sandy areas near oak scrub. Mixtures of oak scrub and flatwoods are sometimes termed “scrubby flatwoods” or oak-palmetto scrub (Abrahamson and Hartnett 1990, Schmalzer and Hinkle 1992a, b). Here, potential territories within oak, scrub or flatwoods are termed primary, secondary, or tertiary. Territories can be described as primary (oak), secondary (oak-palmetto), or tertiary (palmetto-oak). Primary territories intersect well-drained scrub ridges (large or primary ridges). Secondary and tertiary territories do not intersect well-drained ridges and are often not distinguished on land cover maps that use large minimum mapping units or that rely on soils maps to identify scrub. Secondary territories intersect secondary ridges but not primary ridges (well drained soils). Secondary ridges are mapped as poorly drained on soils maps but have patches with $\geq$50% scrub oak cover that are $\geq$0.4 ha. These ridges are easily observed on 1.0 m resolution digital orthophoto quads, which have been produced across the species range. Scrub oak patches smaller than 0.4 ha are termed tertiary ridges. Tertiary territories have only tertiary ridges, which are often difficult to detect without field investigation. Primary and secondary territories can function as sources if habitat quality associated with fire history is optimal, whereas tertiary territories are usually sinks (Breininger and Oddy 2004, Breininger et al. 2003).

Fire exclusion can cause suitable habitat to become forested and unoccupied by Florida Scrub-Jays (Duncan et al. 1999). Potential habitat might appear as forest, which can be identified using historical aerial photographs that are available for almost everywhere since 1943.

### *3.2 Shrub height arrangements*

Shrub height arrangements at the territory scale (Table 1) are useful surrogates for evaluating habitat quality and fire management needs (Breininger and Carter 2003, Breininger et al. 2003, Breininger and Oddy 2004). Shrub height arrangements are introduced here as a classification system and to monitor and evaluate fire management needs (section 5.0). It is assumed that one can approximate 10 ha territories in the field with the aid of aerial photographs but that one would preferably overlay a grid of territories over aerial imagery. Some areas will have actual territory boundaries, which can be overlaid over DOQs. Territories can be unusually large or unoccupied if a population decline has occurred so that it be most useful to grid the potential landscape into territories to evaluate management needs even if actual territory maps are available.

**TABLE 1. Florida Scrub-Jay territory quality based on shrub height arrangements**

| | **Description** |
|---|---|
| Short | Entire territory was <120 cm tall; optimal scrub (120-170 cm) was <0.13 ha. |
| Optimal | Mix of short scrub and $\geq$0.13 ha optimal scrub. No patch of scrub taller than 170 cm was $\geq$0.4 ha. |
| Tall mix | Mix of tall scrub and short and/or optimal scrub. |
| Tall | Entire territory was > 170 cm tall. |

*Notes*: Adapted from Breininger and Carter (2003).

This classification system simplifies the evaluation process for Florida Scrub-Jays. Much more is known about Florida Scrub-Jay habitat specificity, but there are many quantitative uncertainties regarding the spatial arrangements of different types of habitats and the different fire history conditions of oak scrub, especially where patches are smaller than individual territories (Burgman et al. 2001). Detailed habitat suitability maps are difficult for managers to develop and apply unless they are proficient at remote sensing and geographical information systems analyses and stll have many uncertainties (Duncan et al. 1995, Breininger et al. 1998).

Uncertainties associated with the classification system and recommendations for considering uncertainty are provided in section 5.0. Although, more research is needed on refining the separation of these categories, it will take many years to achieve sufficient sample sizes. Most sites deviate greatly from optimal, and it will take many years to reach recovery goals regarding habitat quality. In the beginning stages of management, territories are often distinct within particular categories. The distinctions could become more difficult as a greater percentage of the territories approach optimal.

It is hoped that management will be coupled with monitoring of the jay population so that the initial direction proposed herein can be refined as scrub management becomes better formulated.

The relationships between habitat factors and demography are probably continuous and not discrete as suggested by the categories. Recruitment nearly matches mortality at the separation between short and optimal territories (Figure 1). There are no similar published data to separate optimal and tall mix territories. Habitat quality definitions must often combine data with professional judgment until empirical studies clarify the relationships (Burgman et al. 2001). A dominance of tall mix territories can cause a long-term population decline (Breininger and Carter 2003). However, the difference between recruitment and mortality is often small for tall mix territories in other areas (Stevens and Young 2002, Breininger et al. 2003). There might also be a compensatory relationship between an abundance of open space and shrub heights that are too tall (Burgman et al. 2001). Error in distinguishing optimal and tall mix categories might be of minor concern if the population is at carrying capacity or where mortality and recruitment are approximately equal. In areas below carrying capacity, too many tall mix territories might prevent population growth. An abundance of tall scrub interspersed throughout optimal scrub is not the desired state, but might be a better interim state than having all territories short because short territories can function as population sinks (see 5.0).

### *3.3 Other habitat factors*

There are other important habitat factors to consider depending on site characteristics. One concern is that tree densities are often greater than optimal, especially in areas with reduced fire frequency (Breininger et al. 2003). Sparse pine cover instead of no tree cover might be advantageous because live and dead pines might promote hot spots during fires and subsequently open sandy areas (Breininger 1992). Evidence suggests that habitat suitability declines rapidly with increasing pine cover once more than 1-3 pines per hectare are present (Breininger et al 1995).

Areas with optimal shrub height arrangements could have too few open sandy areas (Breininger and Schmalzer 1990). Mechanical techniques can produce open sandy areas but these can be long-lasting and might destroy the fuels continuities making areas difficult to burn (Breininger and Schmalzer 1990). The approach herein assumes that frequent mosaic fires are the best technique for restoring open sandy areas in the landscape but carefully designed research is needed to further investigate how open sandy areas can be increased in landscapes where they have become rare (Duncan et al. 1999).

Another change induced by anthropogenic fire suppression includes the replacement of grassy marshes between scrub ridges with forests (Duncan et al 1999) that impede fire spread (Duncan and Schmalzer 2004). Forests degrade Florida Scrub-Jay habitat suitability for 100-600 m (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995, Burgman et al. 2001). Historical photographs should be used to review whether forests between scrub or flatwoods patches are natural or the result of anthropogenic alterations.

### *3.4 Reserve edge effects*

There is broad range of possible edge effects along the borders of reserves when the borders include housing or roads (Breininger 1999, Mumme et al. 2000, Bowman and Woolfenden 2001, Schoech and Bowman 2001, Reynolds et al. 2003, Fleishcer et al. 2003, Reynolds et al. in press, Thorington and Bowman in press). Florida Scrub-Jays are attracted to edges, but roadsides can be population sinks sustained by interior territories (Mumme et al. 2000). The study of edge effects is complicated because demography along some edges is influenced habitat quality related to shrub height arrangement (Breininger et al. 2003). Although managers often prefer to leave buffers along edges, it is best to manage habitat to be optimal beginning at the border of potential reserves because of the relatively low number of core territories in most large reserves and because some reserve edge territories can be population sources (Breininger et al. 2003). It is probably best to keep scrub short immediately along roadsides for 50-100 m so that roadsides do not become the most important location for openings and to enhance firefighter safety and reduce potential for fire escape.

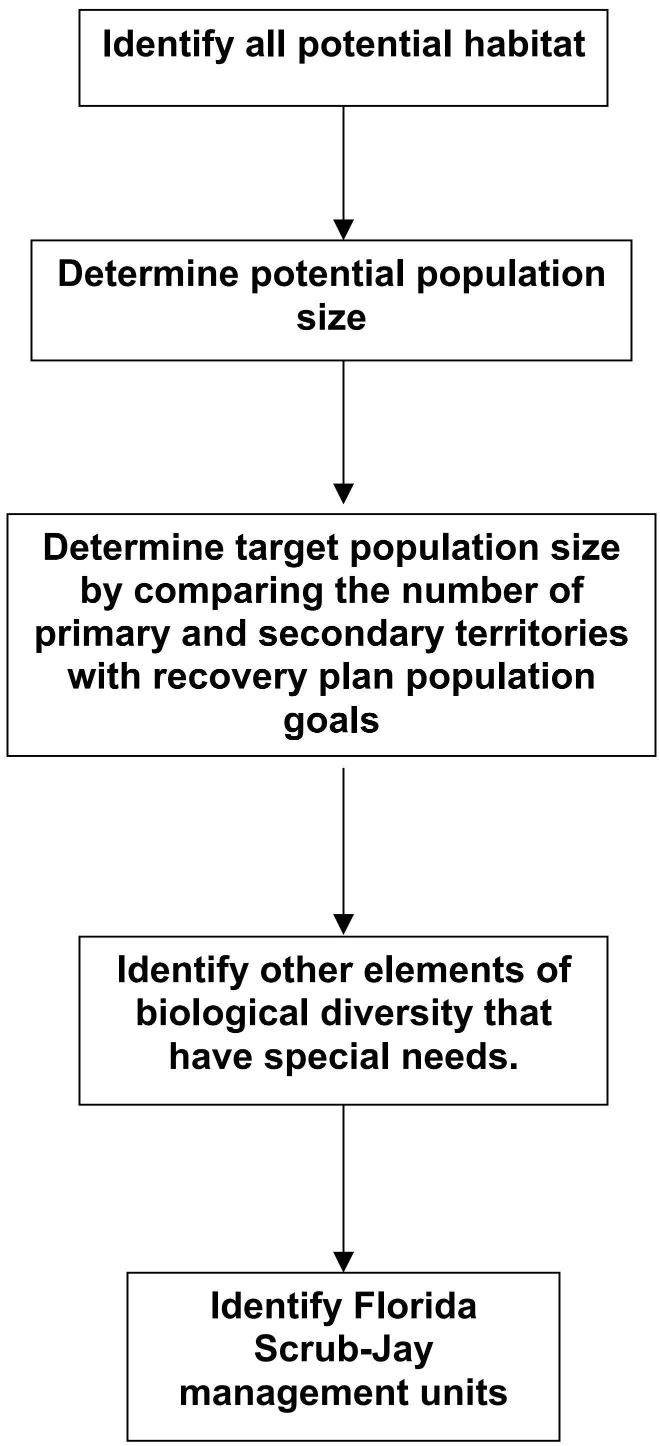
## 4.0 DEFINING TARGET POPULATION SIZE AND LOCATION

This should be performed at the beginning stages of a plan (Figure 1).

### *4.1 Identify potential habitat.*

There are different approaches to map potential habitat and the best approaches vary depending on how distinct potential habitat is within the planning area and what mapping resources are available. One approach is the detailed mapping of all scrub oak patches > 20m$^2$, which is seldom practical across large areas (i.e., Breininger et al. 1995, 1998; Duncan et al. 1995; Breininger and Oddy 2004). Landcover and/or soils maps often identify primary ridges. The boundaries of secondary ridges should be explicitly mapped using 1.0 m DOQs or they should be identified as attributes of 10 ha grid cells laid out across all potential habitat (such as all pine flatwoods and scrub). Most secondary ridges are often <1.0 km of a primary ridge along the Atlantic coast (Breininger et al. 2003). Most potential tertiary territories are within pine flatwoods or pineless flatwoods <1.0 km from primary or secondary ridges. Except where tertiary territories provide connectivity between subpopulations or primary or secondary territories, tertiary territories >1.0 km from primary or secondary territories might be of little value given that Scrub-Jays have limited dispersal and that most tertiary territories are sinks. Pine flatwoods between potential primary and secondary territories should be identified regardless of their scrub oak cover because these are potentially important for facilitating dispersal. Historical aerial photography dating back to 1943 should be obtained to determine whether any forests (e.g., sand pine or xeric hammock) were open savannas suitable for Florida Scrub-Jays. The ability to restore forests that were scrub and flatwoods should be evaluated if they occur on, between, or adjacent to ridges.

**Figure 1. Define Florida Scrub-Jay target population size and location.**



***4.2 Determine potential population size***.

The number of potential primary and secondary territories should be used to estimate a potential population size . Occupancy of tertiary territories may depend on many factors related to dispersal propensities, population density, habitat quality, habitat arrangement, and the overall productivity of the population. Estimating the potential number of primary and secondary territories can be performed at least two different ways. One approach is to buffer all primary and secondary territories by 160 m and calculate all scrub and flatwoods within the buffer and divide by an average territory size of 10 ha. Primary and secondary territory boundaries might rarely extend further than 160 m from a primary and secondary ridge (Breininger et al. 2003). An alternative approach is too count the number of 10 ha grid cells that intersect primary and secondary ridges.

Maps of territories can be useful if they are available. Even if territory maps are available, it will probably best to grid the landscape into potential territories given that many areas are unoccupied or have territories that are unusually large because of population declines. Using grid cells to partition the landscape into territories is useful across large areas but will never perfectly represent actual territories.

Excluding tertiary territories here does not indicate that all tertiary territories are always less important than primary and secondary territories. Tertiary territories that facilitate the conservation and management of large and intact landscapes might have greater value than some small clusters of primary and secondary territories subject to edge effects. Although tertiary territories might be unoccupied or be sinks, they have value because they buffer potentially optimal territories from edge effects and they facilitate the spread of fire across the landscape.

***4.3 Determine target population size.***

The new draft recovery plan provides specific goals regarding the number of breeding pairs for a particular population (U. S. Fish and Wildlife Service 2004). If the potential population size determined in 4.2 is greater than the recovery plan target goals, review the goals and vulnerabilities within the entire recovery unit. The recovery plan describes that many populations need greater population size than was known possible at the time of plan preparation. The plan often identifies whether greater population size is needed to reduce extinction risk for particular recovery units. Habitat mapping applications, at the time of plan preparation, ddmight not have been sufficient to identify all potential habitat within the population, especially where fires had been suppressed and the spectral signatures of potential habitat are not easy to distinguish. It is important to evaluate whether many areas identified as important within the recovery plan are unlikely to be conserved. An increased number of potential territories in a particular fire management unit might be important if other territories in the population are being destroyed by human development. Recovery biologists should be consulted to determine a minimum target population for the planning area if there is a potential population size that exceeds the target.

There will be greater flexibility in the planning process where the potential population size exceeds the target population. This will be particularly important if there are conflicting management goals. The recovery goal generally assumes that 70% of the breeding pairs occur in optimal territories and that 30% of the breeding pairs occur in suboptimal territories. Suboptimal territories are tertiary territories, border roads, or have not burned enough or have burned too extensively. Attaining the 70% ratio in a timely manner might be challenging in landscapes subject to fire suppression or where smoke management issues make prescribed fire difficult. If a lower ratio of optimal territories is needed, then it may be necessary to increase total population size so that the expected number of optimal territories remains the same. Once population goals regarding the number of breeding pairs and a mean family size of 3.0 are met, it should be possible to deviate from this ratio for short periods of time because helpers can buffer population size and that there are often lags in population responses.

### *4.4 Other elements of biological diversity*.

The Florida Scrub-Jay has served as a basis for scrub management but the life history traits of the several plant and animal species contrast greatly because of habitat preferences, seed banks, vagility, and the scale of metapopulation responses to landscape structure (Quintana-Ascencio and Menges 1996; Quintana-Ascencio et al. 1998; Branch et al. 1999; Hokit et al. 1999, 2001). Although optimal Florida Scrub-Jay habitat requirements overlap with most scrub species, there are several species that have different optimal habitat requirements. Here, the requirements of species of conservation concern are reviewed to identify additional habitat management considerations. It is first important to determine which unique elements of biological diversity occur in the planning area. It is also important to determine whether scrub, flatwoods, or dry prairie species of conservation concern rely upon particular topographic locations within the landscape. Understanding the topographic variation, area requirements, and potential metapopulation dynamics of these elements will be critical to identifying an arrangement of habitat conditions optimal to all species. Spatially constrained populations might require intensive planning to meet objectives.

4.4.1. Red-Cockaded Woodpecker. Optimal habitat for the Red-Cockaded Woodpecker includes a higher density of pine trees and potentially a less extensive shrub layer than is optimal for Florida Scrub-Jays (Hovis and Labisky 1985, James et al. 1997). Maintaining viable populations of Red-Cockaded Woodpeckers and Florida Scrub-Jays might be most challenging because both require large areas. It might be best to minimize the interspersion of their territories given that an interspersion of woodlands and forests might negatively impact Florida Scrub-Jays (Burgman et al 2001).

4.4.2. Florida Grasshopper Sparrow. This species needs more frequent fire and than Florida Scrub-Jays and is more endangered (Vickery et al. 2002). The most important areas for Grasshopper Sparrows today have minimal overlap with Scrub-Jay population centers (Shriver and Vickery 1999), though both can occur in the same landscape (e.g., Avon Park Bombing Range, Kissimmee State Preserve). Topographic context may eliminate most potential conflicts. Having Florida Grasshopper Sparrow habitat adjacent to Florida Scrub-Jay habitat will have no negative effects to Florida Scrub-Jays because it will be an open landscape.

4.4.3 Bald Eagle. This species often uses the largest pine trees within a pine stand for nesting; suitable nest trees may be rare within modern landscapes (Hardesty and Collopy 1991). It is often necessary to keep fuels low around nest trees during prescribed burning and it may be necessary to establish new pine stands in areas historically used for nesting. Pine stands needed for nesting do not need to be large and can occur in landscapes lower on the topographic gradient than are optimal for Florida Scrub-Jays.

4.4.4. Reptilian sand specialists. These include 3 species of lizards: sand skink (*Neoseps reynoldsi*), bluetail mole skink (*Eumeces egregius lividus*), and Florida scrub lizard (*Sceloporus woodi*). Most evidence suggests that these species achieve the highest densities in early successional stages of xeric scrub with large open areas created by fire and other disturbances (Campbell and Christman 1982, Enge et al. 1986, Greenberg 1993, Tiebout and Anderson 1997, Hokit et al. 2003a, b). Branch et al. (1999) showed a strong response of lizard populations to decreases in habitat quality associated with fire exclusion. The amount of bare sand in a patch and patch isolation were the most important habitat factors because of their limited vagility. Many patches are probably needed because these species might have high extinction probabilities within individual patches so that they function as metapopulations (Branch et al 1999). Sand skinks appear more likely to be found in the center of patches than along edges bordering non-scrub habitat and this edge effect may extend 50 meters (Gianopulos et al. 2001). No conflicts with Florida Scrub-Jays are expected if habitat for these sand swimmers does not require tall shrubs or many trees.

4.4.5. Rare plants. On the Lake Wales Ridge optimal fire regimes conflict among species of conservation concern (Quintana-Ascencio et al. 2003). Menges (2001) indicates that land managers need to avoid uniform prescriptions and provide spatial and temporal heterogeneity in the fire regime (pyrodiversity) to maintain biodiversity and diversity of functional groups of plants. This is compatible with Florida Scrub-Jay management as long as there is not too much tall scrub interspersed throughout 70% of the territories and as long as there is at least a hectare of medium height scrub in 70% of the territories. Most rare plants also need open sandy areas and relatively frequent fires, except on rosemary balds (Menges 2001). Fire return intervals of longer than 25 years threaten most sensitive post-fire specialists, but fires more frequent than every 10 years may eliminate Florida rosemary or sand pine before they build up a seed banks. On rosemary balds, *Eryngium cuneifolium* requires fires about every 15 years whereas *Hypericum cumulicola* requires fires at least every 30 years to avoid extinction of individual populations (Menges 2001). Areas dominated by Florida rosemary stay open for far longer than oak dominated areas. The more open, xeric patches of scrub where Florida rosemary dominates are unlikely to burn more frequently than once per 10 years (Menges 2001). Low intensity fires might seldom burn rosemary balds if fuels loadings are low around rosemary balds. Rosemary balds often comprise a small portion of a landscape and often have very low shrub or tree canopies so that their management does not conflict with Florida Scrub-Jay management. The influence of fire management is poorly known for the endangered perforate lichen *Cladonia perforata*, although most lichens prefer longer fire rotations (unpublished data by Yahr referenced in Quintana-Ascencio et al. 2003).

It might be useful to develop fire prescriptions that burn microhabitats with different propensities based on the optimal topographic location for many specialists while considering subtle differences in flammability based on vegetation composition and habitat (fuels) structure. A diversity of topography, soils, geography, and natural processes has long been noted in scrub and flatwoods (Webber 1935, Abrahamson and Hartnett 1990, Myers 1990). More research is needed to distinguish potential conflicts from site variation in habitat potential and propensities to burn among scrub and flatwoods endemics. Simply managing for diversity of shrub patches with different ages post-fire can result in declining Florida Scrub-Jay population (Breininger and Carter 2003).

### *4.5 Identify Florida Scrub-Jay management area .*

It might be necessary to distinguish areas that will be managed to fulfill Florida Scrub-Jay recovery objectives from areas that will be managed for other elements of biological diversity when other specialists require habitat conditions that are marginal or unsuitable for Florida Scrub-Jays. This might be most important in small reserves and it may be reasonable to manage a shifting mosaic of habitat suitability for different elements of biological diversity in large landscapes. Topographic patterns can be used to identify scrub and flatwoods patches into: 1) jay management areas, 2) optimal Red-Cockaded Woodpecker habitat, 3) frequent and extensively burned dry prairie, 4) rosemary scrub, and 5) sand pine forest (if necessary). Florida Scrub-Jay management areas should be as large and contiguous as possible while minimizing edge effects with forests and tall scrub because Florida Scrub-Jays have a sentinel warning system for identifying predators that works best in open landscapes (McGowan and Woolfenden 1989).

## 5.0 EVALUATING AND MONITORING FIRE MANAGEMENT NEEDS WITHIN TARGET AREAS

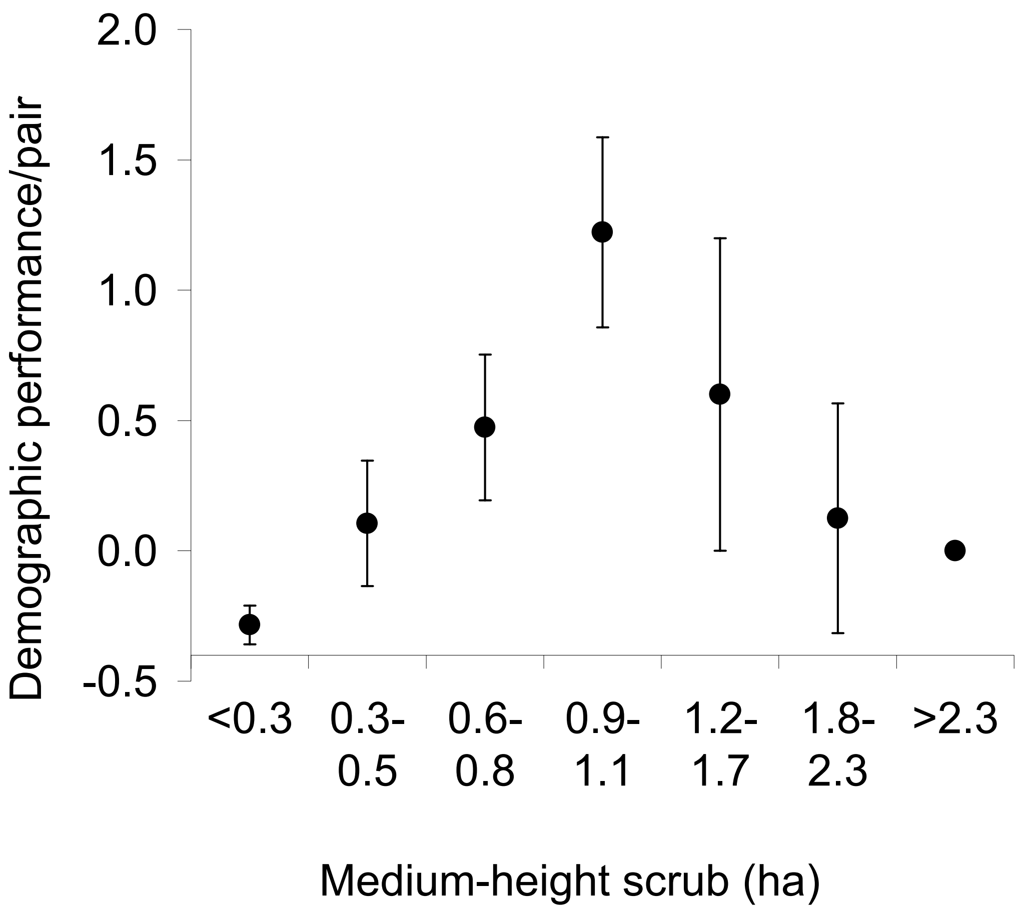
The approach here was developed from studies on Merritt Island (Breininger and Carter 2003, Breininger and Oddy 2004) and successfully described Florida Scrub-Jay demography and management needs on the mainland of Brevard County and Indian River County (Breininger et al. 2003). The approach begins by compiling management needs for individual territories in order to determine the fire management needs of individual management units. The rationale is that territories are the fundamental unit for population processes and that management must restore and maintain enough optimal territories to meet recovery goals. Many metapopulations are have undergone extensive management, but management has often not addressed Florida Scrub-Jay requirements at the territory scale so that population declines have occurred even in managed areas (Breininger and Cater 2003, Breininger et al. 2003).

### *5.1 Determine shrub height categories for individual territories.*

This involves classifying each potential territory into one of the categories in Table 1 every year or every few years. Another approach for monitoring habitat quality might be to use grid cells that are 2-4 times smaller than the average territory to insure that habitat is optimal within each grid cell. This approach might be best for smaller reserves in order to monitor habitat quality at a smaller spatial scale. The following sections (5.2.1 – 5.2.3) focus on attributes of the oak scrub and assume that flatwoods will be burned every few years if present.

5.1.1 Short territories. This category refers to oak scrub that is too short so that territories on average are population sinks (Breininger and Oddy 2004, Breininger and Carter 2003, Breininger et al. 2003). Short territories generally lack many scrub oaks >120 cm tall because of recent, extensive fire. These territories often lack enough cover for nesting, escaping predators, and acorn production. Additional studies need to define the difference between short and optimal territories because there is only one study that quantifies the relationship between demographic performance and the area of medium-height scrub (1.2-1.7 m tall) in a territory (Figure 2). Medium-height scrub here does not refer to individual scrub oaks but patches >20 $m^2$. The relationship between the area of medium-height scrub and demographic success might vary across sites but a quadratic relationship might be expected if open sandy areas do not persist for long periods after fire. The study site used to develop Figure 2 had ridges that were generally narrower than most territories so that few territories were entirely comprised of oak scrub. The decline in demographic performance with increasing medium-height scrub might occur further along the x-axis if territories were comprised of greater amounts of oak scrub than investigated above. The key to identifying optimal territories is that there is an abundance of both medium-height oak scrub and open sandy areas among scrub oaks.

**Figure 2. Mean ± 1 SE demographic performance/pair/year and the area of medium height scrub (120-170 cm) within territories. Individual samples of demographic performance were calculated by subtracting the number of breeders that died from the number of yearlings produced for each year in each territory. The means were calculated by pooling all territories across all years in each of the categories that represented increasing increments of medium-height scrub from all territories between 1989 and 2000 (Breininger and Oddy 2004). Increments were larger as the amount of medium-height scrub in a territory increased because sample sizes were low.**



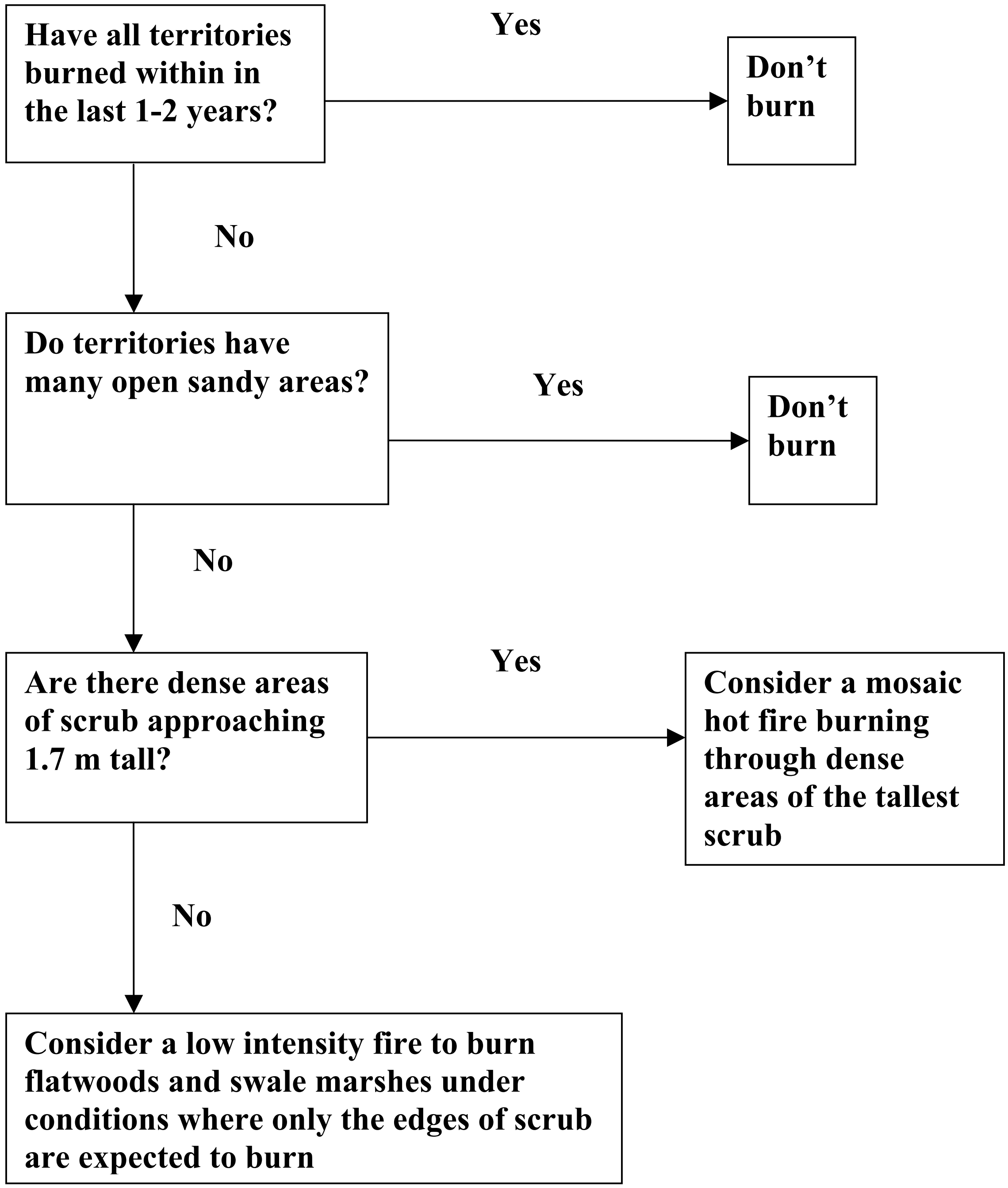
Short territories generally do need fire for many years after an extensive fire because it can take 10 years for oaks to reach 120 cm (Schmalzer 2003). Recovery can be much faster where scrub oaks were not top-killed by the last fire or where sites had been without fire for long periods (Schmalzer and Adrian 2001, Schmalzer et al. 2003). A fire return interval of 10 years for an entire management unit is probably suboptimal for most scrubby flatwoods sites, especially in areas where open sandy patches do not remain for more than 1-2 years after fire (i.e., Schmalzer and Hinkle 1992). Open sandy areas are especially important to Florida Scrub-Jays (Breininger et al. 1995), certain lizards (Branch et al. 1999), and plants (Menges and Hawkes 1998). Even on the Lake Wales Ridge, open space declines precipitously after fire in scrubby flatwoods, which have little open space within 4-5 years since fire (Menges and Hawkes 1998). The area of medium height scrub needed for a short territory to be optimal is not great, so that the decision to apply a mosaic burn to a short territory should depend on the amount of open sandy area and whether the site is densely packed with territories. A fire is not needed and might have negative effects if open sandy areas tend to be optimal within the planning area (i.e. 10-50% ground cover). A mosaic fire that burns 30% of the scrub might be beneficial if the site went through a long period without fire before the last burn and there is much standing dead or if open sandy areas persist for only a few years after fire. Such a fire might reduce the likelihood of a wildfire burning all of the area thereby setting back the attainment of medium-height for a decade. Figure 3 summarizes these considerations.

5.1.2. Optimal territories. Territories should have at least 1.0 ha of medium height scrub and no 0.4 ha patches of tall scrub. Thus, only 10% of a territory may need to have medium height scrub. Optimal territories function as sources (e.g., (Breininger and Carter 2003, Breininger et al. 2003, Breininger and Oddy). Optimal territories dominate Woolfenden and Fitzpatrick's (1984) long-term study tract at Archbold Biological Station. There is uncertainty about how much tall scrub (>1.7 cm) reduces territory quality (Burgman et al. 2001). For example, a single tall patch of oak scrub in the middle of an open landscape probably does not degrade territory quality because it does not limit visibility.

Maintaining optimal scrub depends on using mosaic fires before open sandy areas become rare and before patches of tall scrub develop. Small populations might require extensive management to optimize the number of optimal territories. Optimization involves focused burning of patches that are becoming too tall or dense while keeping optimal or future optimal patches unburned so that a combination of medium-height scrub and open sandy area are always available. If the burn unit includes flatwoods, it also means burning the flatwoods every few years knowing that some of the fires will burn into or through the oak scrub (Breininger et al. 2002).

Abrahamson and Layne (2002a, b) report that acorn production will be maximized at a frequency and intensity of prescribed fire that maintains a mosaic of unburned, lightly burned, and intensively burned patches with a predominance of intermediate-sized oaks (Abrahamson and Layne 2002a, b).

**Figure 3. Flowchart for management units where most territories are short and/or optimal.**



5.1.3 Tall mix. These territories usually have a mixture of short, medium-height, and tall scrub because they represent areas that were once subject to infrequent fire that have since been burned. The tall vegetation limits the ability of Florida Scrub-Jays to spot accipiters and may attract Blue Jays (*Cynanocitta cristata*). These areas may also have few openings. The delineation between optimal and tall mix categories is uncertain because tall mix territories studied so far have included many patches of tall scrub even when most of the landscape had been recently burned (Breininger and Carter 2003). Demographic success within tall mix territories suggests they are sinks vulnerable to significant population declines on Merritt Island (Breininger et al. 1996b, Breininger and Carter 2003). Recruitment nearly matches mortality on Cape Canaveral (Stevens and Young 2002, Stevens personal communication). The abundance of xeric soils and open sandy areas on the mainland might partially compensate for scrub that is taller than optimal (Burgman et al. 2001, Breininger et al. 2003).

Management of areas with tall mix territories depends on differences in target and current population size as well as population and habitat responses to management (Figure 4). Eliminating tall scrub is often difficult because it burns poorly and requires mechanical treatment (Schmalzer et al. 1994, Schmalzer and Boyle 1998), although an extensive and hot fire might eliminate the patches. Some areas may burn poorly because of site variation so that extensive fires might occasionally be useful to keep tall areas from developing. Large populations near carrying capacity can decline following infrequent, extensive fires, but they can also quickly recover (Breininger and Oddy 2004, Breininger and Carter unpublished data).

Tall mix territories have greater demographic success than short territories so that it might be better to perform successive management actions to eliminate tall patches without performing an extensive fire if all potential territories are occupied. The problem with this approach is that few managers can perform one or more fires each year until all tall scrub is eliminated. Site specific data on recruitment and survival of colorbanded Florida Scrub-Jays will greatly enhance the planning process, but management will probably need to proceed because many years of data will be needed to address these uncertainties given that relationships can be confounded by other factors, such as density dependence (Breininger and Oddy 2004) or presumed epidemics (Woolfenden and Fitzpatrick 1984, Breininger et al. 2003).

If there is much tall scrub within a unit and the population is far below carrying capacity, it is probably best to perform an extensive fire to eliminate as much of the tall scrub as possible. If tall scrub is not greatly interspersed among short or medium-height scrub, it may be possible to selectively burn tall scrub without extensive fire. Widely distributed patches of tall scrub a few hectares in size that are not near forests or dense pine stands probably have no detrimental effect on habitat quality.

Small populations in relatively small reserves need more careful attention because restoration should focus first on enhancing the survival of existing breeders (Breininger et al. 1999). Small populations may be vulnerable to stochastic extinction risks if all scrub is extensively burned. The decision to perform an extensive fire depends on the management unit and its surroundings. Nearby (e.g., < 300 m) habitat might hold jays over if such habitat is not in eminent danger of destruction.

<u>5.1.4. Tall scrub</u>**.** It has been known for decades that tall territories have mortality that exceeds recruitment (Woolfenden and Fitzpatrick 1984, 1991; Breininger and Carter 2003; Breininger et al. 2003). Some tall territories may function as population sinks because jays disperse into them (Breininger and Carter 2003), but these eventually become tall enough that jays die out or leave them (Woolfenden and Fitzpatrick 1984). Tall territories need to be extensively burned. Most areas will be far below carrying capacity so little unburned scrub will need to be retained. If areas are occupied, retaining small patches of scrub might best be accomplished by finding many of the best habitat patches and mechanically cutting areas around them to minimize fires spreading into them. Often tall scrub is heterogeneous and it is possible to find shorter patches. Many potential unburned islands should be planned given that fires often do not burn as intended. It is best to keep unburned areas away from roads, forests, or other patches of tall shrubs or dense trees.

### *5.2 Evaluate tree canopy.*

Areas with tall mix and tall territories often have suboptimal pine cover (>20%; Breininger et al. 1995) because these areas have not burned (Breininger et al. 2003). Timbering or selective tree removal is an option for many dense pine stands; otherwise, hot fires might be used to reduce pine cover and create many openings. A widely scattered pine canopy is advantageous because snags and pine needles help generate or maintain openings; areas without pines often have fewer open sandy areas (Breininger 1992).

Hot head fires should be used to eliminate forests that fragment scrub patches where these forests did not occur in the landscape before fire frequencies were reduced. Single fires might only burn part way through narrow forests so that it might be necessary to use repeated fires over time and run them into the different sides of a forest. The scrub bordering marshes often becomes tall and dense so that it might be possible to mechanically cut it before the fire.

### *5.3 Set objectives for fire management units.*

Fire management units will often be a mosaic of territories that occur with different shrub height arrangement categories. If territories are all short and/or optimal no fire may be needed for another year. The need for a mosaic fire depends on whether there are flatwoods that need fire, whether some territories are loosing their open sandy areas, or whether some tall scrub might soon develop. A mosaic fire might be needed to burn the flatwoods and partially burn oak scrub in particular territories. Managers might consider a hotter, mosaic fire that focuses on tall mix territories if units are comprised of a combination of optimal and tall mix territories . Units comprised of mostly tall mix or tall territories might need a hot fire that burns most territories extensively. The size of the units, its surroundings, and the size of the overall population can be important considerations. Patches of scrub at or near medium height can occur even if most of the scrub is tall because of site variation. An extensive fire for small populations with no surrounding habitat could have detrimental effects if the population approaches its carrying capacity. It might be best to leave some scrub unburned for such populations. It would be best to keep scrub short near forests and roads. Despite all these considerations for optimizing habitat quality, a hot extensive fire might often be effective in a management unit if there is much tall scrub that is difficult to eliminate.

## 6.0 MONITORING AND ADAPTIVE MANAGEMENT

Shrub height arrangement categories can be approximated annually for every potential territory, although this might be difficult for large areas that lack annual photography. Information about meeting management objectives can be obtained by calculating Markov Chain probabilities for grid cells between successive measures of shrub height categories (Breininger and Carter 2003). Separately for each height category of the first time step, these simple calculations involve summing the number of grid cells that become a particular height category or remain the same during the next time and dividing these sums by the total for that category during the first time step until a matrix of transition probabilities is generated. The matrix can be multiplied by the original vector of abundances among height categories to get predictions for subsequent time steps. The new vector form these calculations can repeatedly be multiplied by the matrix until a stable distribution is reached. These calculations can help describe changes in territory quality for particular sites or management regimes and help predict the expected relative proportions of territory quality categories if management regimes and vegetation responses remain the same.

No simple formula will restore fire-maintained ecological communities that have been degraded by anthropogenic fire suppression. Restoration requires an adaptive management process where the consequences of decisions are monitored. Success should be judged by progress towards achieving 70% of the territories in optimal condition and achieving the target population size provided by the recovery plan. Ideally, most Florida Scrub-Jays will be color-banded to map territories and quantify survival, recruitment, and dispersal. Ideally, monitoring involves mapping all fires, shrub height arrangements, and other measurements of territory quality to better refine how habitat quality influences demography and dispersal. A number of demographic studies are needed across the species range to better define how much open sand is needed, how tall is medium-height scrub, how much medium-height scrub is enough, how tall is too tall, and how much tall scrub is too much.

**Figure 4. Should an extensive fire or hot, mosaic fire be applied to tall mix and/or tall territories?**

**Reasons to apply a mosaic fire:**

1. The population is small and isolated.
2. There is no scrub adjacent to the unit that jays can use.
3. There are resources for spatially explicit mechanical cutting to eliminate tall patches or develop temporary fuel breaks to (hopefully) contain hot fires from becoming extensive.
4. Resources are available to conduct another burn within a year.
5. Site-specific demographic data indicates that recruitment and mortality are approximately equal in tall mix territories and nearly all potential territories are occupied.

**Reasons to apply an extensive fire:**

1. The unit is small and adjacent to other scrub that jays can use.
2. Resources limit mechanical site preparation.
3. Frequent fires are limited resources by resources or disruptions to traffic patterns and local communities.
4. The local Florida Scrub-Jay population is large and able to buffer temporary population catastrophes.
5. Tall scrub is too extensive to be eliminated by mosaic fires.
6. Site-specific demographic data indicates that mortality greatly exceeds recruitment in tall mix territories.
7. Low- intensity fires may eliminate the fuels needed to burn scrub.
8. A hot extensive fire is needed to create open sandy areas and get enough of the site burned.
9. The Florida Scrub-Jay population is small relative to the size of the unit and the some patches of scrub will probably not burn.

All sites will probably not be monitored by detailed color-banding studies. Surveys of birds without banding provide some information. Florida Scrub-Jays survey techniques to survey are described by Fitzpatrick et al. (1991; http://northflorida.fws.gov/Scrub-Jays/survey-guide.htm). These surveys provide information on the number of pairs, group size, and the centers of territory occupancy. Juveniles are relatively conspicuous in July so that their numbers/breeding pair can also be estimated for different habitat quality categories. These can be compared with literature values to estimate whether recruitment might match mortality. Such an approach can be performed separately for each shrub arrangement category. Habitat specific survival rates should be applied given that jays in suboptimal habitats are likely to have lower survival than jays in suboptimal habitats (Woolfenden and Fitzpatrick 1991, Breininger et al. 2003, Breininger and Oddy 2003).

Potential problems must be considered when relying only on surveys of unbanded birds. Species densities by themselves can be misleading indicators of habitat quality and are not always indicative of habitats suitable for population persistence because species can be abundant where the habitat cannot sustain their population without immigration (Lidicker 1975, Van Horne 1983, Hanski 1999, Garshelis 2000). Time lags in population responses can mask the consequences of habitat change for long periods (Nagelkerke 2002). Monitoring without distinguishing survival and dispersal might not reveal a serious population decline if surveys are conducted in the best habitats and jays actively disperse into them (Howe et al. 1991, Pulliam et al. 1992, Pulliam 1996). Florida Scrub-Jays are attracted to edges that are often limiting in many landscapes (Breininger et al. 1995, 1998; Mumme et al. 2000). If monitoring of unbanded jays is only conducted along edges, firebreaks, and trails, the results might not adequately predict population declines if these areas are the best habitat but are of insufficient quality to sustain the population. Increases in jay abundance might not necessarily result from recruitment within the management unit because of occasional pulses of immigrants from other locations (Breininger and Oddy 2004).

One reason for collecting data on jay abundance is that managers often must prioritize. Management priorities should be where Florida Scrub-Jays still remain and at sites that have helpers (Breininger et al. 1999). Immediate population responses cannot always be expected with improvements in habitat quality. Low dispersal, low population growth rates, and the importance of helpers often cause slow Florida Scrub-Jay recover rates once populations have declined following restoration, especially in sites that are not within 3 territory widths of a source of potential breeders (Breininger et al. 1999, 2003).

Managers and researchers should collaborate to develop a long-term, spatially explicit program to manage and understand scrub biology and the uncertainties. Greater collaboration is also needed among the scientists that study various taxa and processes within scrub.

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