

Strategic Habitats for Biodiversity Conservation in Florida

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Abstract: *Privately owned lands support a large portion of the biodiversity in some areas, but procedures for identifying those private lands critical to the maintenance of biodiversity vary tremendously. We used habitat-based distribution maps in combination with population conservation goals to help identify strategic habitats on private lands in Florida. We used a vegetation map, occurrence data, and published life-history information to create habitat-based distribution maps for 179 rare taxa. We estimated the security of 130 of the taxa by overlaying public land boundaries on habitat maps and then estimating whether conservation lands satisfied a population goal of supporting at least 10 populations of approximately 200 breeding adults. The remaining taxa were evaluated in terms of number of occurrence records on conservation lands. Of the 179 taxa evaluated, existing conservation lands did not adequately protect 56. We then identified habitats on private lands that could best satisfy the minimum conservation goal or else significantly enhance the survival potential of inadequately protected taxa. Strategic habitats included a mix of large and small sites, incorporated some corridor or stepping-stone connections among habitat patches, and protected multiple species. Additional strategic habitats were identified for shorebirds, four natural plant communities, and 105 globally rare plants. The strategic habitats identified in Florida cover 1.65 million ha (12% of the land area) and would cost \$8.2 billion (about 15% of Florida's annual state budget) to purchase and \$122 million per year to manage. Existing conservation lands account for 3.07 million ha (22% of the land area).*

Hábitats Estratégicos para la Conservación de la Biodiversidad en Florida

Resumen: *Las tierras de propiedad privada albergan una porción grande de la biodiversidad en algunas áreas, pero los procedimientos para identificar aquellas tierras privadas críticas para el mantenimiento de la biodiversidad varía tremendamente. Nosotros utilizamos mapas de distribución basados en hábitats, en combinación con metas de conservación poblacional que ayudan a identificar hábitats estratégicos en tierras privadas en Florida. Usamos un mapa de vegetación, datos de ocurrencia e información publicada sobre historias de vida para crear mapas de distribución basados en hábitats de 179 taxones raros. La seguridad de 130 de los taxones fue estimada al sobreponer límites de tierras públicas en mapas de hábitat y estimando si las tierras para conservación satisfacían las metas poblacionales de albergar por lo menos a 10 poblaciones de aproximadamente 200 adultos reproductores. Los taxones restantes fueron evaluados con base en el número de registros de ocurrencias en tierras de conservación. De los 179 taxones evaluados, las tierras para conservación existentes no fueron adecuadas para proteger a 56 de ellas. Se identificaron los hábitats en tierras privadas que podrían satisfacer de mejor manera la meta mínima de conservación o por lo menos mejorar significativamente el potencial de supervivencia de taxones protegidos inadecuadamente. Los hábitats estratégicos incluyeron una mezcla de sitios grandes y pequeños, incorporando algo de corredor o conexiones clave entre los parches de hábitat y protegiendo múltiples especies. Hábitats estratégicos adicionales fueron identificados para aves playeras, cuatro comunidades naturales de plantas y 105 plantas mundialmente raras. Los hábitats estratégicos identificados en Florida cubren 1.65 millones de ha (12% del área terrestre) y costarían 8.2 mil millones de dólares (cerca del 15% del presupuesto estatal anual para Florida) para comprar y 122 millones de dólares por año para manejar. Las tierras para conservación existentes involucran 3.07 millones de ha (22% del área terrestre).*

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Introduction

Florida is well recognized as a biologically rich state (Ewel 1990; Noss & Peters 1995) that contains species common to temperate North America and the tropical West Indies. The number of continental species progressively decreases, and the number of tropical species increases, moving from north to south along the Florida peninsula. Due to geologic events that created a series of ancient islands along the central ridges of Florida, the state also supports numerous endemic species that evolved in response to isolation over thousands of years.

The biological diversity of Florida includes three major ecoregions divided into 13 subcoregions (Griffith et al. 1994), 82 natural communities (Marois 1997), 542 mammals, birds, reptiles, and amphibians (Millsap et al. 1990), 126 freshwater fishes (Millsap et al. 1990), over 1000 marine and estuarine fishes (Comp & Seaman 1985), about 3500 vascular plants (Ward 1979), and unknown numbers of invertebrates (Deyrup & Franz 1994) and nonvascular plants. The endemic and nearly endemic biota of Florida includes 275 vascular plants, 11 freshwater fishes, 10 amphibians, 37 reptiles, 1 bird, 58 mammals, 410 terrestrial and freshwater invertebrates, and 13 plant communities (Muller et al. 1989; Rodgers et al. 1996). Comp and Seaman (1985) report that 78 marine and estuarine fishes are known only from Florida waters.

As in many regions of the globe, native habitats in Florida are rapidly disappearing. Florida currently supports a human population of over 15 million and hosts over 40 million tourists each year. Noss and Peters (1995) ranked Florida as the state with the greatest degree of risk for loss of biodiversity. Over the last 150 years, 13 vertebrates have either gone extinct or been extirpated (Kautz 1993). The state of Florida now lists 117 animals and 413 plants as endangered, threatened, or of special concern (Logan 1997), and many more species are rare or imperiled (Ward 1979; Humphrey 1992; Moler 1992; Deyrup & Franz 1994; Rodgers et al. 1996). Millsap et al. (1990) estimated that populations of 44% of Florida's vertebrates are declining. Moreover, both formerly common natural communities (e.g., sandhills, marshes) as well as perennially rare communities (e.g., pine rocklands, tropical hardwood forests) have been drastically reduced in area (Kautz et al. 1993; Kautz 1998), and stormwater runoff, invasive non-native plants and animals, and human disturbance have degraded many aquatic ecosystems.

Several authors have cited the need to identify critical habitats that support rare species and other components of biodiversity before they are lost to development (Scott et al. 1993; Noss & Cooperrider 1994). The procedures offered to date have often been academic. Scott et al. (1993) outlined a procedure for locating hot spots of vertebrate diversity, but the technique stops short of actually recommending areas for conservation. Other at-

tempts to identify important lands for biodiversity conservation on a statewide scale in Florida have produced very generalized conceptual maps (Noss 1987; Noss & Cooperrider 1994) that have minimal application in land acquisition, land-use planning, development regulation, and private landowner conservation initiatives.

We identify privately owned lands in Florida that, if conserved, would best serve the long-term habitat needs of key components of the state's biological diversity. The underlying concept was to focus conservation on species and rare communities not adequately protected by existing conservation lands. To assess whether or not species were adequately protected, we developed estimates of habitat availability using geographic information systems (GIS). We then made an overlay of potential habitat with conservation lands to assess whether conservation lands could satisfy guidelines for population viability. In cases where conservation lands failed to meet guidelines for population viability, we assessed habitats on private lands for their capacity to enhance the viability of the species under consideration.

Methods

Our methods involved two phases, each with a distinctive set of procedures. Results derived in the first phase played a role in the methods used in the subsequent phase. For that reason, some results are presented with the discussion of methods.

Data Layers of Geographic Information Systems

SPANS (Tydac 1996) raster-based GIS software was the principal analytical tool used to perform spatial analyses. The GIS data layers used to model wildlife habitats were (1) a 22-class vegetation and land-cover map of Florida created with 1985-1989 Landsat Thematic Mapper imagery (30-m pixels) (Kautz et al. 1993); (2) the STATSGO generalized soils data set for Florida digitized from 1:250,000 quadrangle maps (U.S. Department of Agriculture 1991); (3) boundaries of public and private conservation lands digitized from 1:24,000 quadrangle maps (Blanchard & Jue 1997); (4) boundaries of lands proposed for public acquisition digitized from 1:24,000 quadrangle maps and obtained from Florida Natural Areas Inventory (FNAI); (5) tracts of privately owned lands of >130 ha digitized from 1:126,720 county highway maps; (6) digital coverages of federal, state, and county roads obtained from the Florida Department of Transportation; (7) plant and animal occurrence records digitized from 1:24,000 quadrangle maps and obtained from FNAI; (8) known locations of high-quality examples of rare natural plant communities obtained from various sources; (9) vertebrate species occurrence records digitized from source maps with varying scales and maintained by the Florida Game and Fresh Water Fish Com-

mission (FGFWFC); and (10) breeding bird atlas (BBA) records digitized from 1:24,000 quadrangle maps (Kale et al. 1992).

Use of Indicator Species and Communities

The first phase of this project, completed in 1994, involved the evaluation of 54 vertebrate taxa, 105 globally rare plants, and four rare natural plant communities. The 54 vertebrate taxa (Table 1), also referred to as focal species, were treated as indicators of biodiversity and met one or more of the following criteria: (1) feasibility of mapping habitats using available data layers, (2) wide-ranging species that, if protected, would benefit other species with smaller area requirements, (3) indicators of rare community types, (4) endangered and threatened species whose survival is jeopardized by habitat loss, (5) keystone species that are closely linked to many other rare species (Mills et al. 1993), and (6) species typically associated with habitats that support diverse populations of wildlife.

The plant species we evaluated met two conditions. First, the species were listed as either "imperiled globally because of extreme rarity" or as "imperiled globally because of rarity" by FNAI. Second, each plant occurred on fewer than 10 conservation areas in Florida. A total of 105 globally rare plants, represented by 947 FNAI occurrence records, met both of these conditions. A list of plants species meeting these conditions is available from FNAI (<http://www.fnai.org>).

We evaluated four natural plant communities: sandhill, scrub, tropical pine rockland, and tropical hardwood hammock. Each of these community types is known to support significant components of Florida's native biological diversity (Myers 1990; Snyder et al. 1990), and each has been dramatically reduced in area (Kautz 1993; Kautz et al. 1993).

Population Viability Analyses

Although populations go extinct for several reasons (Soulé & Simberloff 1986), environmental variability (including catastrophic events) and loss of genetic diversity are usually listed as the primary threats to small populations (Shaffer 1987). We used computer simulations (Shaffer 1987) to evaluate the influence of environmental variability on population persistence in 11 focal species. We constructed a computer model that followed females over time and simulated year-to-year changes in fecundity and survival over a 200-year period. The specific values of survival and fecundity experienced by individuals in a population in a given year were drawn at random from a pseudo-normal distribution. If literature searches indicated a need, simulations also included "catastrophic" events with a frequency of 15–25 years in which survival or reproduction, or both, were markedly lowered.

Initial population sizes entering simulations ranged from 10 to 350 individuals, and 200 trials were conducted for each set of unique demographic conditions (Harris et al. 1987). Population viability was reported as the proportion of the 200 trials for which the population persisted for at least 200 years (Goodman 1987a). A population was considered effectively "extinct" when only one female remained. Because there was variation in many of the population parameters obtained from literature searches, we used a range of "unfavorable," "moderate," and "favorable" survival and reproductive parameters to assess how such variation affected estimates of population persistence.

Estimates of the smallest population sizes having a 90% chance of persistence for 200 years ranged from as low as 46 individuals under favorable environmental conditions to a high of 365 individuals under harsh conditions (Table 2). Increasingly favorable environmental conditions led to decreasing viable population sizes for all species. The mean survey population size for all species under all conditions was 159 individuals, and the median was 139 individuals.

With respect to maintenance of genetic diversity, Franklin (1980) and Soulé (1980) suggested that an effective population size (N_e) of 50 individuals would have acceptably low levels of inbreeding over the short term (i.e., 3–20 generations), but Vucetich and Waite (1998) cited experimental evidence that an N_e of approximately 50 may be inadequate to ensure short-term viability. Franklin (1980) and Soulé (1980) also suggested that an N_e of 500 should be large enough to maintain adaptive genetic variation and ensure long-term viability. Lande (1995) indicated, however, that an effective population size of 500 may be inadequate to maintain genetic variation over the long term and that an N_e of at least 5000 may be necessary to maintain normal levels of potentially adaptive genetic variance over longer periods of time. Vucetich and Waite (1998) suggested that an N_e in the range of 1000–5000 might be sufficient to maintain adaptive variation over time. Proposals have also been made that effective populations in the range of 5000–50,000 may actually be needed to ensure genetic viability over many generations (Lande 1995; Vucetich & Waite 1998).

We incorporated a genetics component into our population viability analysis by using the technique described by Reed et al. (1988) to estimate the size of a survey population needed for an N_e of 50, the minimum suggested size to prevent extinction due to inbreeding depression over the short term. Although we acknowledge that effective populations on the order of 100–1000 times larger than this may be needed to ensure genetic variability over the long term, for our conservation planning purposes we have elected to estimate the smallest population sizes likely to persist in the short term. We assume that if we can at least plan for populations that dip no lower than N_e of 50, there will be oppor-

Table 1. Focal species selected as indicators of biological diversity in Florida for phase 1 analyses.

Common name	Scientific name	State ^a	FNAI ^b	Score ^c	FCREPA ^d
Pine barrens treefrog	<i>Hyla andersonii</i>	S	G4/S3	24	R
Florida bog frog	<i>Rana okaloosae</i>	S	G2/S2	26	R
American crocodile	<i>Crocodylus acutus</i>	E	G2/S1	30	E
Gopher tortoise	<i>Gopherus polyphemus</i>	S	G3/S3	27	T
Gulf salt marsh snake	<i>Nerodia clarkii clarkii</i>		T3/S3		R
Atlantic salt marsh snake	<i>Nerodia clarkii taeniata</i>	T	T1/S1	37	E
Florida scrub lizard	<i>Sceloporus woodi</i>		G3/S3	27	T
Roseate Spoonbill	<i>Ajaia ajaja</i>	S	G5/S2	25	R
Louisiana Seaside Sparrow	<i>Ammodramus maritimus fisberi</i>		T4/S1	24	S
Wakulla Seaside Sparrow	<i>Ammodramus maritimus juncicolus</i>	S	T2/S2	24	S
Smyrna Seaside Sparrow	<i>Ammodramus maritimus pelonotus</i>		T2/S1	44	S
Scott's Seaside Sparrow	<i>Ammodramus maritimus peninsulae</i>	S	T2/S2	26	S
Cape Sable Seaside Sparrow	<i>Ammodramus maritimus mirabilis</i>	E	T1/S1	27	E
Florida Grasshopper Sparrow	<i>Ammodramus savannarum floridanus</i>	E	T1/S1	32	E
Mottled Duck	<i>Anas fulvigula</i>				
Florida Scrub Jay	<i>Aphelocoma coerulescens</i>	T	G3/S3	30	T
Limpkin	<i>Aramus guarauna</i>	S	G5/S3		S
Great Egret	<i>Ardea alba</i>		G5/S4		S
Short-tailed Hawk	<i>Buteo brachyurus</i>		G4/S3	36	R
Crested Caracara	<i>Caracara plancus</i>	T	G5/S4	38	T
Snowy Plover	<i>Charadrius alexandrinus</i>	T	G4/S2	37	E
Piping Plover	<i>Charadrius melodus</i>	T	G3/S2	35	E
Wilson's Plover	<i>Charadrius wilsonia</i>				S
Mangrove Cuckoo	<i>Coccyzus minor</i>		G5/S3		R
Wild Turkey	<i>Melagris gallopavo</i>				
White-crowned Pigeon	<i>Columba leucocephala</i>	T	G3/S3	30	T
Little Blue Heron	<i>Egretta caerulea</i>	S	G5/S4		S
Reddish Egret	<i>Egretta rufescens</i>	S	G4/S2	25	R
Snowy Egret	<i>Egretta thula</i>	S	G5/S4		R
Tricolored Heron	<i>Egretta tricolor</i>	S	G5/S4		R
American Swallow-tailed Kite	<i>Elanoides forficatus</i>		G4/S2	30	T
White Ibis	<i>Eudocimus albus</i>	S	G5/S4		S
Southeastern American Kestrel	<i>Falco sparverius paulus</i>	T	T3/S3		T
Florida Sandhill Crane	<i>Grus canadensis pratensis</i>	T	T2/S2	33	T
American Oystercatcher	<i>Haematopus palliatus</i>	S	G5/S3	29	T
Bald Eagle	<i>Haliaeetus leucocephalus</i>	T	G4/S3	26	T
Wood Stork	<i>Mycteria americana</i>	E	G4/S2		E
Red-cockaded Woodpecker	<i>Picoides borealis</i>	T	G3/S2	30	E
Snail Kite	<i>Rostrhamus sociabilis plumbeus</i>	E	T1/S1	47	E
Florida Burrowing Owl	<i>Speotyto cunicularia floridana</i>	S	T3/S3	24	S
Black-whiskered Vireo	<i>Vireo altiloquus</i>		G5/S3		R
Florida panther	<i>Puma concolor coryi</i>	E	T1/S1	42	E
Southeastern bat	<i>Myotis austroriparius</i>		G3/S3		R
Gray bat	<i>Myotis grisescens</i>	E	G2/S1	36	E
Choctawhatchee beach mouse	<i>Peromyscus polionotus allopbrys</i>	E	T1/S1	37	E
Santa Rosa beach mouse	<i>Peromyscus polionotus leucocephalus</i>		T1/S1	28	
Southeastern beach mouse	<i>Peromyscus polionotus niveiventris</i>	T	T1/S1	31	T
Anastasia Island beach mouse	<i>Peromyscus polionotus phasma</i>	E	T1/S1	41	E
Perdido Key beach mouse	<i>Peromyscus polionotus trissyllepsis</i>	E	T1/S1	41	E
Mangrove fox squirrel	<i>Sciurus niger avicennia</i>	T	T2/S2		T
Sherman's fox squirrel	<i>Sciurus niger sbermani</i>	S	T2/S2	24	T
Southeastern fox squirrel	<i>Sciurus niger niger</i>				
Florida black bear	<i>Ursus americanus floridanus</i>	T	T2/S2	33	T
Bobcat	<i>Lynx rufus</i>				

^aListing status by the state of Florida (Wood 1992).

^bFlorida Natural Areas Inventory ranking (Marois 1997).

^cBiological score of Millsap et al. (1990).

^dFlorida Committee on Rare and Endangered Plants and Animals ranking (Humphrey 1992; Moler 1992; Rodgers et al. 1996).

tunities to achieve larger populations and avoid genetic problems through patch recolonization, translocation of individuals, or removal of environmental constraints on

a population through management. We estimated that survey populations in the range of 65–200 are needed to achieve an N_e of 50 for 10 of our focal species (Table 2).

Table 2. Estimates of survey population sizes necessary to achieve an effective population size (N_e) of 50, and estimates of the smallest population sizes that have a 90% chance of persistence for 200 years based on computer simulations of populations experiencing favorable, moderate, and harsh environmental conditions.

Species	Viable population size			Survey population needed for $N_e = 50$
	favorable	moderate	harsh	
Florida panther	63	76	84	100-200
Florida black bear	46	82	114	71-126
Bobcat	113	169	239	156-190
Fox squirrel	216	285	365 ^a	104-147
Bald Eagle	57	114	126	100-150
Sandhill Crane	66	85	113	99-133
Wild Turkey	63	134	229 ^a	—
Florida Scrub Jay	121	132	179	65± ^b
Red-cockaded Woodpecker	139	155	260	102±
Snowy Plover	197	288	346 ^a	130-170
Gopher tortoise	159	213	234	90±
Range of values	46-216	76-288	84-365	65-200
Mean	112.7	157.6	208.1	

^a Population size was extrapolated.

^b Based on $N_e = 0.767 (N)$ presented by Woolfenden and Fitzpatrick (1984).

The estimated survey population needed to achieve an effective population size of 50 was comparable to the population size needed to provide a 90% chance of persistence for 200 years.

Population Conservation Goals

Results from the population viability analyses above suggested that, for most species, a survey population of 200 breeding adults would have high chances of persistence for 200 years under most environmental conditions and should be able to withstand the adverse effects of inbreeding depression for at least a few generations. Therefore, we consider a survey population of 200 breeding adults to be a legitimate conservation goal for single populations. Protection of a single minimally viable population, however, risks the extirpation or extinction of a species as a result of harsh environmental conditions, catastrophic events, or genetic deterioration over several generations. To reduce the risk of extinction through these processes, it is important to establish multiple copies of protected populations (Soulé & Simberloff 1986; Goodman 1987b; Shaffer 1987; Lande & Barrowclough 1987; Harrison & Quinn 1989). Through protection of multiple populations across the landscape, rare species can be managed as metapopulations in which the individuals in a habitat patch may go extinct, but dispersal or translocation of individuals allows for recovery of the population in vacant patches (Wiens 1996). From a genetic standpoint, multiple populations across a broad landscape should be large enough to maintain adaptive genetic variation and ensure long-term viability. For example, if several preserves containing populations of around 200 breeders are established, the level of genetic diversity preserved throughout all

populations becomes extremely high (Chesser 1981; Chesser & Ryman 1986; Lacy 1987; Lande & Barrowclough 1987).

To satisfy the need for multiplicity, we selected 10 populations of 200 breeding adults as our population conservation goal. Even if the chances of each individual population persisting are only 30%, the establishment of 10 independent populations could provide >90% chances of at least one of the populations persisting (Quinn & Hastings 1987). The conservation of 10 populations of 200 individuals would also result in a total metapopulation size of at least 2000, which is in the range of effective population sizes needed to ensure adaptive genetic variation over longer periods of time (Lande 1995; Vusetich & Waite 1998). This strategy would likely conserve >95% of the genetic variation across all populations over many generations (Ballou et al. 1989) and enable a portion of the genetic variation to be maintained within individual populations (e.g., Manlove et al. 1979; Chesser et al. 1982; Osterhoff et al. 1983).

Species and Community Distribution Maps

Distribution maps were created for each focal species (Table 1) based on available occurrence records and land-cover data, plus information on a species' range, habitat requirements, home-range size, dispersal capabilities, and other life-history characteristics. In addition, we obtained digital maps of sites known to support globally rare plants and four imperiled plant communities from various sources. Based on techniques used in phase 1 to model natural communities and potential habitats for species, we found a need for additional habitat conservation efforts (Appendix).

Phase 1: Assessment of Focal Species Security

Focal species in need of additional habitat protection were identified by one of two methods. The first method involved determining those species with <10 populations of 200 individuals protected by the current system of conservation lands. Digital boundaries of public and private conservation lands were overlaid on the habitat-distribution map created for each focal species, and the total area of habitat protected by each parcel of conservation land was tallied. We used data from the literature to estimate population densities in appropriate habitats. Focal species estimated to have sufficient habitat to support 10 populations of 200 adults within existing conservation lands were presumed secure. Species presumed secure may be in critical need of habitat and population management within existing conservation lands, but conservation of additional habitat is not a high priority. Of the 54 focal species evaluated, 30 had <10 populations of 200 individuals protected by conservation lands (Appendix).

Although the above criterion for population security works for species distributed somewhat evenly across the landscape, it does not work for species whose reproductive strategies depend on large numbers of individuals gathering in one or a few localities. Of the 54 focal species evaluated, eight wading birds, two bats, and the gopher frog fell into this category. The reproductive success of wading birds depends on the social interactions among large numbers of individuals gathering in a few locations (Bildstein et al. 1991). Southeastern bats gather in the tens of thousands in a few caves for the birth and rearing of young (Humphrey & Gore 1992). Gopher frogs may travel 1.6 km to a single isolated wetland to breed (Godley 1992), making the simple presence of the wetland as important as the number of breeders to the reproductive success of the species. The habitat conservation needs of these species were evaluated in terms of the number, diversity, and distribution of potential breeding sites on conservation lands, and criteria for assessing the security of these species were developed on a case-by-case basis. Of the 11 species evaluated by the second method, only the gopher frog was found to be adequately protected by existing conservation lands.

In the end, 40 focal species, four natural communities, and 105 plants were found to be in need of additional habitat conservation efforts. Information to support this finding appears in the Appendix under the heading of status.

Phase 1: Identification of Strategic Habitats

For each of the 40 focal species inadequately protected by existing conservation lands, we identified strategic habitats on privately owned lands. Strategic habitats were lands that, if conserved, would have the best chances of enhancing the long-term survival potential of the 40 focal species as well as other components of

biodiversity in Florida. A primary goal for the inadequately protected species was to locate enough habitat to support 10 populations of 200 individuals for each focal species, but this goal is unattainable for some species with large area requirements (e.g., Florida panther). For animals like the panther, we identified lands with the best chances of significantly increasing the long-term survival potential of the species.

Examples of the criteria used to select strategic habitats are described below. Additional details are given by Cox et al. (1994); however, seven general guidelines were used for all species:

- (1) Strategic habitats should protect other rare species as well as the focal species in question.
- (2) Strategic habitats should incorporate a mix of large and small preserves, as necessary to maintain geographic distribution and meet the needs of individual focal species.
- (3) Wildlife corridors, preserves arranged as stepping stones, and other types of landscape linkages should be designed to meet the needs of focal species for movement.
- (4) Strategic habitats designed to foster movement must lie within frequently reported dispersal distances for the species in question and should have good chances of actually being used.
- (5) Corridors and other linkages should consider the sizes of the populations to be linked.
- (6) To the extent possible, corridors and linkages intended to meet the movement needs of wide-ranging species should also meet the basic habitat needs of other focal species with smaller area requirements.
- (7) Strategic habitats should expand or maintain existing core populations and the ecological processes important to these populations, acknowledging that not all individuals of every population can be protected.

The methods used to identify strategic habitats for the 40 focal species, four natural communities, and rare plants are detailed in the Appendix. Identification of strategic habitats was relatively easy for some species. All endangered subspecies of beach mice exist on <10 conservation areas, and few of these support 200 adults. All privately owned habitat of beach mice (i.e., beach dunes) contiguous with existing conservation areas supporting beach mice is critical to the long-term survival potential of beach mice. Therefore, all remaining beach mouse habitat outside of public ownership was designated as strategic habitat.

For other species, identification of strategic habitat was more complicated. For example, suitable black bear habitat is widely distributed in Florida. As a result, a method was developed to focus on areas most critical to the long-term survival of black bears. With densities of black bears in the southeastern United States in the

range of 0.05–0.10 breeding individuals per km², a population of 200 black bears would require conservation lands of 2000–4000 km² in area. The chances of establishing 10 black bear conservation areas in Florida are remote because the four largest conservation lands provide only 810–1620 km² of potential habitat. Moreover, few privately owned lands are large enough to create independent conservation areas for black bears, so we limited our review of private lands to those areas surrounding five large public land parcels that had good chances of supporting stable black bear populations over the long term. Our conservation planning for black bears would result in the protection of only five viable populations of black bears over the long term.

Once our efforts to identify strategic habitats for 40 focal species were complete, it was clear that some components of Florida's biodiversity would not be protected by the focal species approach, namely four rare natural communities (i.e., sandhill, scrub, pine rocklands, and tropical hardwood hammocks) and 105 globally rare plants. We reviewed available information to identify strategic habitats for these imperiled communities and plants.

The strategic habitats identified for 40 inadequately protected focal species, four imperiled natural communities, and 105 globally rare plants were added together to create a single map. The statewide strategic habitats map depicted those privately owned lands in Florida in 1994 that we believed to be the minimum areas that should be conserved to enhance the long-term persistence of most components of biological diversity in Florida based on a focal species approach.

Phase 2: Identification of Other Rare and Imperiled Vertebrates

The first phase of the project was an attempt to identify priority conservation lands for biological diversity in

Florida using a focal/indicator species and communities approach. The second phase, completed in 1998, was an effort to determine whether or not additional lands should be protected to meet the habitat needs of rare and imperiled vertebrates whose habitats were not adequately protected by indicator species. To accomplish this, we developed a list of 125 Florida vertebrates (except fishes, sea turtles, and marine mammals) (Tables 3–6) that met at least one of the following criteria: (1) taxa listed as endangered, threatened, or species of special concern by the state of Florida (Logan 1997) and not addressed in phase 1; (2) vertebrate taxa identified by the Florida Committee on Rare and Endangered Plants and Animals (Humphrey 1992; Moler 1992; Rodgers et al. 1996) as endangered, threatened, species of special concern, rare, or status undetermined; and (3) vertebrate taxa having a biological score of ≥ 24 , the median score for species listed as species of special concern by the state of Florida (Millsap et al. 1990). The new list includes all Florida vertebrates that have been identified as rare or imperiled in Florida by wildlife experts. Although not all species on this list are rare throughout their range, they are rare or imperiled in Florida.

Phase 2: Identification of Strategic Habitats

The process of identifying strategic habitats for the 125 new vertebrates followed methods similar to those detailed in the Appendix. For 76 taxa for which sufficient information existed, we used available occurrence records, information on life history and habitat requirements, and GIS data layers to create a habitat distribution map for each taxon. Then we overlaid conservation-area boundaries and tallied the area of habitat on each parcel of conservation land. Next, we estimated the population size of each taxon on each parcel from information on population density. For those vertebrates with <10 populations

Table 3. Rare and imperiled amphibians evaluated for security on public lands and strategic habitats during phase 2.

Common name	Scientific name	State ^a	FNAI ^b	Score ^c	FCREPA ^d
Gopher frog	<i>Rana capito</i>	S	G4/S3	25	T
Pickerel frog	<i>Rana palustris</i>				U
Carpenter frog	<i>Rana virgatipes</i>		G5/S2		R
Flatwoods salamander	<i>Ambystoma cingulatum</i>		G2/S2		R
Tiger salamander	<i>Ambystoma tigrinum</i>		G5/S3		U
One-toed amphiuma	<i>Amphiuma pholeter</i>		G3/S3		R
Seal salamander ^e	<i>Desmognathus monticola</i>		G5/S1	24	R
Georgia blind salamander ^e	<i>Haideotriton wallacei</i>	S	G2/S2	24	R
Four-toed salamander ^e	<i>Hemidactylum scutatum</i>		G5/S2		R
Many-lined salamander	<i>Stereochilus marginatus</i>		G5/S1		R
Striped newt	<i>Notophthalmus perstriatus</i>		G2/S2	29	R
Gulf Hammock dwarf siren	<i>Pseudobranchius striatus lustricolus</i>		T1/S1		U

^a Listing status by the state of Florida (Wood 1992).

^b Florida Natural Areas Inventory ranking (Marois 1997).

^c Biological score of Millsap et al. (1990).

^d Florida Committee on Rare and Endangered Plants and Animals ranking (Moler 1992).

^e Strategic habitat identified in phase 2.

Table 4. Rare and imperiled reptiles evaluated for security on public lands and strategic habitats during phase 2.

Common name	Scientific name	State ^a	FNAI ^b	Score ^c	FCREPA ^d
American alligator	<i>Alligator mississippiensis</i>	S	G5/S4		
Alligator snapping turtle	<i>Macrolemys temminckii</i>	S	G3/S2		S
Spotted turtle	<i>Clemmys guttata</i>		G5/S3		R
Barbour's map turtle	<i>Graptemys barbouri</i>	S	G2/S2	30	R
Alabama map turtle	<i>Graptemys pulchra</i>				R
Carolina diamondback terrapin	<i>Malaclemys terrapin centrata</i>			30	
Ornate diamondback terrapin	<i>Malaclemys terrapin macrospilota</i>			30	
Mississippi diamondback terrapin	<i>Malaclemys terrapin pileata</i>			30	
Mangrove terrapin	<i>Malaclemys terrapin rhizophorarum</i>		T2/S2	34	R
Florida east coast terrapin	<i>Malaclemys terrapin tequesta</i>			32	
Suwannee cooter	<i>Pseudemys concinna suwanniensis</i>	S	T3/S3	30	S
Key mud turtle ^e	<i>Kinosternon bauri</i>	E	T2/S2		E
Gulf coast smooth softshell	<i>Apalone mutica calvata</i>		G5/S2		R
Mimic glass lizard	<i>Opbisaurus mimicus</i>				U
Coal skink	<i>Eumeces anthracinus pluvialis</i>		G5/S3		R
Florida Keys mole skink ^e	<i>Eumeces egregius egregius</i>	S	T2/S2	33	
Cedar Key mole skink ^e	<i>Eumeces egregius insularis</i>		T1/S1	33	R
Bluetail mole skink	<i>Eumeces egregius lividus</i>	T	T2/S2	32	E
Peninsula mole skink	<i>Eumeces egregius onocrepis</i>			24	
Sand skink	<i>Neoseps reynoldsi</i>	T	G2/S2	36	T
Key ringneck snake ^e	<i>Diadophis punctatus acricus</i>	T	T1/S1	30	T
Eastern indigo snake	<i>Drymarchon corais couperi</i>	T	T3/S3	25	S
Lower Keys red rat snake	<i>Elaphe guttata guttata</i>	S	T2/S2		S
South Florida rainbow snake	<i>Farancia erythrogramma seminola</i>		T1/S1	26	U
Mole kingsnake	<i>Lampropeltis calligaster</i>		G5/S2		R
Apalachicola kingsnake	<i>Lampropeltis getula goini</i>		T2/S2		R
Mangrove salt marsh snake	<i>Nerodia fasciata compressicauda</i>			24	
Florida pine snake	<i>Pituophis melanoleucus mugitus</i>	S	T3/S3	24	U
Short-tailed snake	<i>Stilosoma extenuatum</i>	T	G3/S3	30	T
Lower Keys brown snake	<i>Storeria dekayi victa</i>	T	T1/S1		T
Rim rock crowned snake ^e	<i>Tantilla oolitica</i>	T	G1/S1	37	T
Central Florida crowned snake	<i>Tantilla relicta neilli</i>			31	
Coastal dunes crowned snake	<i>Tantilla relicta pamlica</i>			35	
Peninsular crowned snake	<i>Tantilla relicta relicta</i>			33	
Lower Keys ribbon snake	<i>Thamnophis sauritus sackeni</i>	T	T1/S1		T
Eastern diamondback rattlesnake	<i>Crotalus adamanteus</i>		G5/S?	24	
Southern copperhead	<i>Agkistrodon contortrix</i>		G5/S2		R

^a Listing status by the state of Florida (Wood 1992).

^b Florida Natural Areas Inventory ranking (Marois 1997).

^c Biological score of Millsap et al. (1990).

^d Florida Committee on Rare and Endangered Plants and Animals ranking (Moler 1992).

^e Strategic habitat identified in phase 2.

of 200 individuals on the existing system of conservation lands, we determined whether or not the strategic habitats identified in phase 1 might provide for the long-term habitat needs of each species. If phase 1 strategic habitats and existing conservation lands adequately protected a taxon, no additional strategic habitats were proposed.

For 48 taxa, available information was insufficient to create potential habitat maps. For example, shorebirds often use mud flats exposed at low tides, and we had no GIS coverages depicting the locations of these features. Other species (e.g., Keys mole skink, Keys mud turtle) select habitat features below the resolution of our land-cover data. For species such as these, we overlaid available occurrence records with maps of public lands and phase 1 strategic habitat boundaries, and we used the number of occurrences already on conservation lands or strategic habitats to assess habitat conservation needs.

Of the 125 new vertebrates evaluated, 16 had <10 populations of 200 individuals or lacked adequate representation of occurrence records on public lands plus phase 1 strategic habitats. These 16 were deemed in need of additional habitat conservation, and new strategic habitats were proposed for each. In addition, congregation sites used by 25% of observed populations of wintering shorebirds (Sprandel et al. 1997) were included as strategic habitats.

Results

With the exceptions of fishes, sea turtles, and marine mammals, our conservation planning process considered the habitat conservation needs of all vertebrate taxa that have been identified as rare, imperiled, or in need of

Table 5. Rare and imperiled birds evaluated for security on public lands and strategic habitats during phase 2.

Common name	Scientific name	State ^a	FNAI ^b	Score ^c	FCREPA ^d
Common Loon	<i>Gavia immer</i>			25	
Brown Pelican	<i>Pelecanus occidentalis</i>	S	G4/S3	24	T
Magnificent Frigatebird	<i>Fregata magnificens</i>		G5/S1		T
Least Bittern	<i>Ixobrychus exilis</i>		G5/S4		S
Great White Heron	<i>Ardea herodias occidentalis</i>		T2/S2		S
Yellow-crowned Night-Heron	<i>Nyctanassa violacea</i>		G5/S3		S
Black-crowned Night-Heron	<i>Nycticorax nycticorax</i>		G5/S3		S
Glossy Ibis	<i>Plegadis falcinellus</i>		G5/S2		S
Osprey	<i>Pandion haliaetus</i>	S	G5/S3		T
White-tailed Kite	<i>Elanus leucurus</i>				R
Swainson's Hawk	<i>Buteo swainsoni</i>			24	
Cooper's Hawk ^e	<i>Accipiter cooperii</i>		G4/S3		S
Merlin	<i>Falco columbarius</i>		G5/SU		U
Peregrine Falcon	<i>Falco peregrinus</i>	E	G4/S2	24	E
Yellow Rail	<i>Coturnicops n. noveboracensis</i>			35	
Black Rail	<i>Laterallus jamaicensis</i>		G4/S3	31	R
Black-bellied Plover	<i>Pluvialis squatarola</i>			24	
American Avocet	<i>Recurvirostra americana</i>		G5/S1		S
Sanderling	<i>Calidris alba</i>			24	
Red Knot	<i>Calidris canutus rufa</i>			26	
White-rumped Sandpiper	<i>Calidris fuscicollis</i>			26	
Western Sandpiper	<i>Calidris mauri</i>			24	
Pectoral Sandpiper	<i>Calidris melanotos</i>			28	
Semipalmated Sandpiper	<i>Calidris pusilla</i>			26	
Short-billed Dowitcher	<i>Limnodromus griseus griseus</i>			26	
Marbled Godwit	<i>Limosa fedoa</i>			24	
Whimbrel	<i>Numenius phaeopus hudsonicus</i>			34	
Gull-billed Tern	<i>Sterna nilotica</i>			21	U
Least Tern	<i>Sterna antillarum</i>	T	G4/S3	24	T
Caspian Tern	<i>Sterna caspia</i>		G5/S2		S
Roseate Tern	<i>Sterna dougallii</i>	T	G5/S1	28	T
Sooty Tern	<i>Sterna fuscata</i>		G5/S1		S
Royal Tern	<i>Sterna maxima</i>		G5/S3	26	S
Sandwich Tern	<i>Sterna sandvicensis</i>		G5/S2		S
Brown Noddy	<i>Anous stolidus</i>		G5/S1		S
Black Skimmer ^e	<i>Rynchops niger</i>	S	G5/S3	24	S
Antillean Nighthawk	<i>Chordeiles gundlachi</i>		G4/S3		R
Hairy Woodpecker	<i>Picoides villosus</i>		G5/S3		S
West Indian Cave Swallow	<i>Hirundo fulva fulva</i>				R
White-breasted Nuthatch	<i>Sitta carolinensis</i>		G5/S2		S
Worthington's Marsh Wren	<i>Cistothorus palustris griseus</i>	S	T3/S2	26	
Marian's Marsh Wren	<i>Cistothorus palustris marianae</i>	S	T3/S3		
Bachman's Warbler	<i>Vermivora bachmanii</i>	E			E
Florida Prairie Warbler	<i>Dendroica discolor paludicola</i>		T3/S3	30	U
Stoddard's Yellow-throated Warbler	<i>Dendroica dominica stoddardi</i>		T3/S3	29	
Kirtland's Warbler	<i>Dendroica kirtlandii</i>	E	G1/S1		E
Cuban Yellow Warbler	<i>Dendroica petechia gundlachi</i>		T4/S3		R
Worm-eating Warbler	<i>Helminthos vermivorus</i>		G5/S1		R
Louisiana Waterthrush ^e	<i>Seiurus motacilla</i>		G5/S3		R
American Redstart	<i>Setophaga ruticilla</i>		G5/S3		R
Painted Bunting ^e	<i>Passerina ciris</i>				U

^a Listing status by the state of Florida (Wood 1992).

^b Florida Natural Areas Inventory ranking (Marois 1997).

^c Biological score of Millsap et al. (1990).

^d Florida Committee on Rare and Endangered Plants and Animals ranking (Rodgers et al. 1996).

^e Strategic habitat identified in phase 2.

conservation attention by wildlife experts in Florida, and it also addressed the needs of rare plants and natural communities. Of the 179 vertebrates evaluated, 56 were inadequately protected by the current system of conser-

vation lands. In addition, nesting and winter congregation sites used by 11 taxa of shorebirds were candidates for habitat protection efforts. All strategic habitats identified in phases 1 and 2 are depicted in Fig. 1 in relation

Table 6. Rare and imperiled mammals evaluated for security on public lands and strategic habitats during phase 2.

Common name	Scientific name	State ^a	FNAI ^b	Score ^c	FCREPA ^d
Sherman's short-tailed shrew	<i>Blarina carolinensis sbermani</i>	S	T1/S1	34	U
Homosassa shrew	<i>Sorex longirostris eionis</i>	S	T3/S3	30	
Indiana bat	<i>Myotis sodalis</i>	E	G2/SA		E
Rafinesque's big-eared bat	<i>Corynorhinus rafinesquii</i>		G3/S3		R
Big brown bat	<i>Eptesicus fuscus</i>		G5/S3		U
Florida mastiff bat	<i>Eumops glaucinus floridanus</i>	E	T1/S1	33	T
Northern yellow bat	<i>Lasiurus intermedius floridanus</i>				U
Brazilian free-tailed bat	<i>Tadarida brasiliensis cynocephala</i>				U
Southeastern weasel	<i>Mustela frenata olivacea</i>		T4/S3		R
Florida long-tailed weasel	<i>Mustela frenata peninsulæ</i>		T3/S2		R
Gulf salt marsh (=Florida) mink	<i>Mustela vison halimmetes</i>		T3/S3	33	
Atlantic salt marsh (=Florida) mink	<i>Mustela vison lutensis</i>		T3/S2	33	
Everglades (=southern) mink	<i>Mustela vison mink (=evergladensis)</i>	T	T2/S2	24	R
River otter	<i>Lutra canadensis vaga</i>			26	
Eastern chipmunk	<i>Tamias striatus</i>	S	G5/S2		R
Key Largo cotton mouse	<i>Peromyscus gossypinus allapaticola</i>	E	T1/S1	26	E
St. Andrews beach mouse	<i>Peromyscus polionotus peninsularis</i>	E	T1/S1	37	E
Florida mouse	<i>Peromyscus floridanus</i>	S	G3/S3		T
Key Largo woodrat	<i>Neotoma floridana smalli</i>	E	T1/S1	32	E
Silver rice rat ^e	<i>Oryzomys argentatus</i>	E	T2/S2	36	R
Sanibel Island rice rat ^e	<i>Oryzomys palustris sanibeli</i>	S	T1/S1	34	
Saltmarsh vole ^e	<i>Microtus pennsylvanicus dukecampbelli</i>	E	T1/S1	27	E
Round-tailed muskrat	<i>Neofiber alleni</i>		G3/S3		S
Lower Keys marsh rabbit ^e	<i>Sylvilagus palustris hefneri</i>	E	T1/S1		E
Key deer ^e	<i>Odocoileus virginianus clavium</i>	E	T1/S1	47	E

^a Listing status by the state of Florida (Wood 1992).

^b Florida Natural Areas Inventory ranking (Marois 1997).

^c Biological score of Millsap et al. (1990).

^d Florida Committee on Rare and Endangered Plants and Animals ranking (Humphrey 1992).

^e Strategic habitat identified in phase 2.

to the current system of public and private conservation lands.

The strategic habitats identified at the end of phase 1 in 1994 totaled 1.95 million ha, or 13% of the land area of Florida. The total area of conservation lands in our database at that time was 2.81 million ha, or 20% of the land area of the state. Taken together, the phase 1 results indicate that 33% of the land area of Florida should be devoted to some degree of conservation management or protection if remaining components of biodiversity are to be sustained. Even if the additional 13% in strategic habitats could be conserved, there would still be a tremendous decline in the populations of many species and communities if all other lands in Florida were eventually developed. If the strategic habitats are properly located, however, the chances of extinction will be significantly lowered for key taxa.

The phase 2 analysis determined that another 24,213 ha of strategic habitats should be added to the Florida conservation land system to ensure that 16 additional vertebrates would also have greater chances of long-term persistence and that known congregation areas for nesting and wintering shorebirds would be protected. Between 1994 and 1998, the end dates for phase 1 and phase 2, respectively, government land-acquisition programs brought into public ownership 0.32 million ha of

strategic habitats identified in phase 1. As a result, by 1998 the total area of strategic habitats remaining in private ownership was 1.65 million ha. Based on the per-hectare price of land between 1994 and 1998, the current cost to purchase all 1.65 million ha of strategic habitats would be \$8.20 billion, or 16% of Florida's 1998 state budget of around \$50 billion. If purchased, additional funds would be needed for management. The Florida Land Acquisition Advisory Council (1991) recommends that \$74.10/ha/year is needed to manage state forests and wildlife management areas in Florida. Thus, we estimate that \$122.3 million/year would be needed to manage the identified strategic habitats for biodiversity conservation. The cost of conserving these areas could be reduced somewhat through the purchase of conservation easements instead of outright acquisition.

The \$8.2 billion figure (plus \$122 million/year for management) is the cost of enhancing the long-term conservation of terrestrial wildlife, globally rare plants, and four imperiled natural communities in Florida. Left unaddressed are the habitat protection needs of freshwater and marine fishes, sea turtles, marine mammals, and marine and estuarine communities. In addition, we have not determined whether the conservation of strategic habitats would also protect all Florida ecosystems or would maintain the ecological processes necessary to

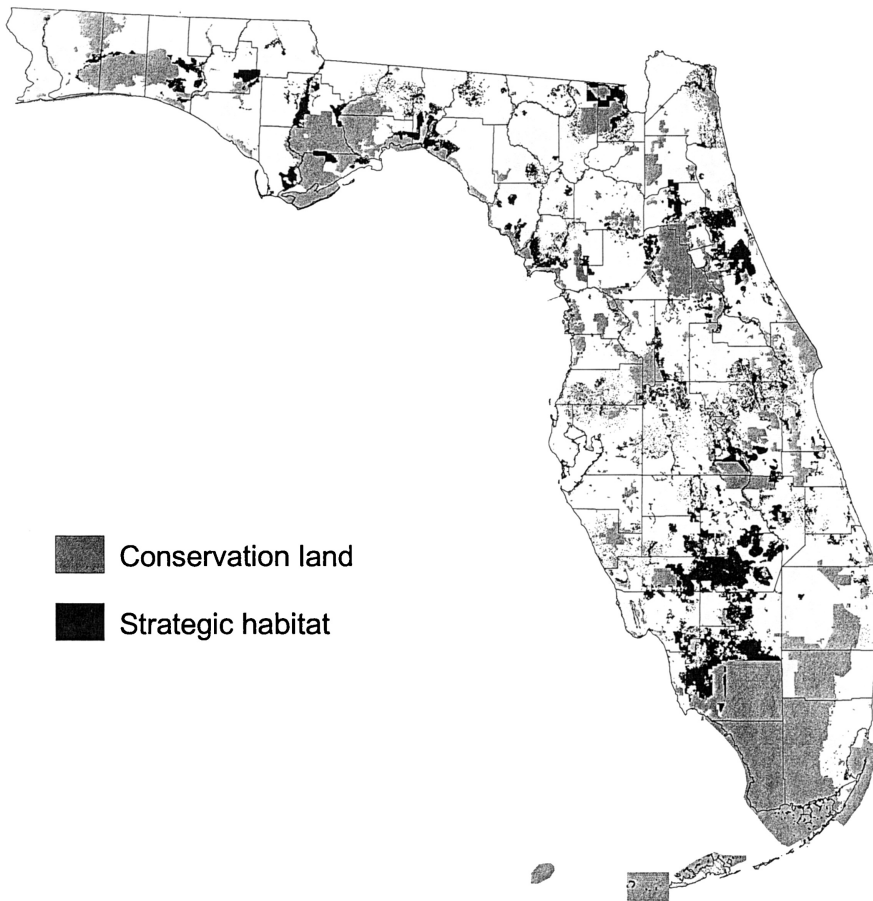


Figure 1. Florida conservation lands and strategic habitats needed to ensure the long-term persistence of most components of the state's biodiversity.

support rare and imperiled biota over extremely long time periods (e.g., 1000 years).

Discussion

Weaknesses of Land-Cover Data

The habitat affinities of some species simply could not be assessed with the data sets available, often because of shortcomings in the vegetation data of Kautz et al. (1993). Many species seek out small-scale habitat features (e.g., oyster bars, exposed mud flats, isolated wetlands) that are undetectable with remotely sensed imagery. Species such as the Red-cockaded Woodpecker occupy old-growth pines, usually longleaf pines (*Pinus palustris*), but the Landsat sensor is not capable of detecting old-growth pines from young pines in plantations, let alone one species of pine from another. Still other animals, such as the Burrowing Owl, opportunistically occupy areas dominated by herbaceous vegetation, but the grassland class in the vegetation map is far too broad of a category for accurate mapping of potential habitat. In the end, we could not make adequate determinations of population security for at least 15% of the

species considered, and the assessments for another 15% are probably inaccurate owing to the difficulties of modeling suitable habitat needs.

To counter these difficulties, the potential habitat maps created for many species were conservative representations because they relied heavily on known occurrences or breeding bird atlas information. These maps actually represent an educated guess about the potential habitat around known occurrences, and they do not generalize to all places that a species actually could occur.

Reproducibility, or Science Versus Art

The entire process of vegetation mapping, identification of focal species, population viability modeling, collection of occurrence records, potential habitat mapping, and security assessment was largely the result of application of scientific methods to conservation planning. In the end, however, the selection of strategic habitats involved a fair degree of expert opinion. This raises a question: are the results reported here reproducible? We believe that another researcher employing similar methods and databases would achieve similar results, but so few other methods actually attempt the identification of spe-

cific lands that the results will probably remain untested.

Adequacy of Focal-Species Approach

Phase 1 of this project evaluated the habitat conservation needs of 54 focal species, 105 globally rare plants, and four imperiled natural communities. These species and communities were chosen as indicators of the habitat needs of the broad range of biological diversity in Florida. In phase 1, 1.95 million ha of privately owned lands were identified as critical to the long-term survival of most components of Florida's biological diversity based on an indicator species approach. Phase 2 was an effort to evaluate the habitat conservation needs of an additional 125 taxa of vertebrates to identify remaining unmet habitat protection needs and to test the validity of the indicator-species approach.

By and large, the indicator-species approach met the needs of many other species. The strategic habitats identified in phase 1 accounted for >98% of the needs of all species evaluated over the course of the project. Phase 2 results suggest that no more than an additional 24,213 ha of habitat need be conserved for all vertebrate taxa to have good chances of long-term persistence.

Ten Populations of 200 Breeding Adults

The primary habitat-protection planning goal for this project was to achieve at least 10 protected populations of 200 breeding adults for each species evaluated. This goal cannot be achieved for some species. The Florida panther exists as a single population of 30-50 individuals in southwest Florida, and management plays a major role in maintenance of the population. Given the area requirements of the panther and the pace of development in southwest Florida, it will be difficult to maintain the extant population, let alone establish additional populations in other parts of the state. Even if reintroductions are successful, no more than one to three small populations of Florida panthers are likely. Similarly, the potential habitat map for the Florida black bear suggests that there is currently one extensive population in north Florida and a single relatively isolated population in southwest Florida. Given that continued development will likely fragment black bear habitat and sever existing habitat linkages, the black bear will eventually exist as no more than five isolated populations based around large parcels of public land.

Management of public lands will play a critical role in the long-term survival of these and many other species. The further a species falls short of the goal of 10 protected populations of at least 200 breeding adults, the greater the need to monitor and manage existing populations and the higher the overall costs of conservation.

These small populations are not necessarily doomed, but they will be more expensive to maintain. In the end, the principal factor that will determine whether or not any of these rare species persists is how well conservation lands are managed.

The goal of 10 populations of 200 adults also likely falls short of the habitat conservation needs of rare species over extremely long time periods (i.e., hundreds of years). Although we recognize concerns about the persistence of populations over geological time frames, the limits of our practical knowledge are overwhelming. The on-going debates concerning single large versus several small reserves, wildlife corridors, and population viability and metapopulation theory underscore the vast lacunae that exist in conservation planning over extensive time frames. We also find it difficult to estimate the value that might be placed on rare species and habitats by future human generations. No amount of habitat conservation will succeed if fundamental changes in human population growth rates and resource utilization do not take place. Our philosophy is based on the urgent need to secure habitats with limited funding and the goal of providing future land managers and conservationists with targets for whatever new technologies and conservation strategies emerge.

Comparison with Other Biodiversity Planning Techniques

Noss and Cooperrider (1994) presented a small-scale (1:6,812,900) conceptual map (modified from Noss 1987) of a proposed reserve network for Florida. The map depicts core preserves surrounded by buffer zones and connected by landscape linkages. The proposed network was intended to capture hotspots of endemism and large areas with low road densities and to provide for movements of wide-ranging species (Noss & Cooperrider 1994). This seminal work provided the broad framework for a conservation system for Florida, and it stimulated conservation biologists in Florida to begin planning for a future conservation system for the state. But the map of Noss and Cooperrider (1994) was too general to be applied to site-specific conservation efforts because it ignored major features of the landscape that prohibit actual implementation (e.g., landscape linkages that are severed by existing roads, inclusion of existing urban and agricultural areas as potential conservation lands).

Noss and Cooperrider (1994) also published a small-scale map of Florida showing existing public lands, private reserves, private lands that are high conservation priorities for state acquisition, and general areas of conservation interest. The map was produced by 40 biologists (including the authors) at a workshop convened in 1991. Workshop attendees identified high-priority conservation lands by drawing lines on a 1:500,000 scale map of Florida. The consensus map was more refined than that pro-

duced by Noss (1987; as revised by Noss & Cooperrider 1994) because it was based on more direct and recent field knowledge of the state. The consensus map also must be considered a conceptual conservation plan for Florida, however, because it too only outlined broad regions that, under ideal conditions, would contribute to an integrated conservation system of core areas and landscape linkages. Many areas already in urban or agricultural use were included in proposed conservation areas, and the existing interstate highway system already severed many of the proposed landscape linkages. The ecological importance of some areas identified also is open to debate. Despite these shortcomings, this map of conservation priorities has been used repeatedly to further the cause of Florida's aggressive land-acquisition programs.

Scott et al. (1993) described "gap analysis" as a means of identifying hotspots of biodiversity that are gaps (i.e., not protected or adequately managed) in the current system of conservation lands. The approach taken by gap analysis is similar to our approach, with some differences. First, gap analysis involves developing habitat-based distribution maps for all species of vertebrates (except fishes), not just rare and imperiled species. Overlaying the habitat maps of all species identifies hotspots of species richness. When all vertebrates are used to determine hotspots, common habitat generalists may swamp or bias the analysis and mask areas of importance to rare and imperiled species. In addition, species-rich areas should not necessarily be targeted for conservation (Master 1996). An advantage of the gap analysis database, however, is that species habitat maps can be manipulated in any desired fashion to produce results, such as species-richness hot spots for endangered and threatened species only. In this project we relied only on identified rare and imperiled species.

Second, species distribution maps created for gap analysis typically are based on range maps, a generalized vegetation map, and information on vegetation types used by a species. Distribution maps may be modified by information on climatic variables, elevation, and soil types, if available (Csuti 1996). But gap analysis often does not consider many of the variables we included in our models, such as habitat patch size, the area requirements of a species, the dispersal capabilities of a species, and the ability of a species to traverse intervening habitats between otherwise suitable patches of habitat.

Third, perhaps the most significant distinction between our work and gap analysis is that we use population viability goals to determine the value of individual patches of habitat to the long-term persistence of a species. This approach has allowed us to identify specific parcels of land needed to meet the long-term habitat protection needs of most components of biodiversity in Florida. Scott et al. (1993) encourage the use of gap analysis results for this purpose, but guidelines for biodiversity conservation in a state are not a standard product of gap analysis.

Finally, gap analysis can be used to evaluate the degree to which natural vegetation types are represented on conservation lands. But gap analysis results usually do not include an assessment of the status of rare plants and natural communities. Vertebrates may or may not be useful as indicators of the specific places needed to meet the long-term needs of rare plants and natural communities. In our own work, we found that known high-quality examples of four rare communities and known occurrences of 105 globally rare plants would not be protected based on an indicator species approach alone. These components of Florida's biodiversity were included in our conservation plans through a separate analysis.

Applications of Results

The results of phase 1 were published in an agency technical report (Cox et al. 1994) and have been applied to public land acquisition, land-use planning, environmental impact assessments, development regulation, and private landowner initiatives in Florida. Each of these decision-making processes affects biological diversity in one way or another. But agricultural, timber, and development interests, who fear that maps of critical habitats will be used to regulate private property, have vigorously opposed the use of these results in various forums.

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Appendix

Methods used to create species and natural community habitat models, status of each component of biodiversity in Florida, and methods used to identify strategic habitats for 40 focal species, four natural communities, and 105 globally rare plants.

Bog Frog

Model: Using 1:24,000 topographic map, digitize 36.6-m contour line around 3 streams on private property with documented populations.
Status: Known to occur along only 23 streams of which all but 3 are on public lands.
Strategic habitats: All potential habitat in private ownership (i.e., all vegetation types within 36.6-m contour line).

American Crocodile

Model: (1) Digitize known breeding range. (2) Isolate mangrove swamp, salt marsh, and freshwater marsh.
Status: Total population of about 500 (including only 30 breeding females) with a limited geographic distribution.
Strategic habitats: All potential habitat in private ownership.

Atlantic and Gulf of Mexico Salt Marsh Snakes

Model: (1) Determine distributions from Florida Natural Areas Inventory (FNAI) and Florida Museum of Natural History occurrence records. (2) Isolate mangrove swamp and salt marsh. (3) Isolate freshwater marsh ≤ 150 m from cover types isolated in step 2 and add to map created in step 2 (150 m is arbitrary but intended to capture transitional marshes also used by these taxa).
Status of Atlantic salt marsh snake: Single population of unknown size restricted to 4730 ha, 30% on public lands.
Status of Gulf salt marsh snake: Extends from Texas to Cedar Key, Florida, and habitat well represented on public land, but several areas in panhandle critical to maintaining geographic distribution.
Strategic habitats: For Atlantic salt marsh snake, all potential habitat outside public ownership. For Gulf salt marsh snake, occupied habitats in Florida panhandle (i.e., Big Lagoon, near Panama City, St. Joseph Bay) to maintain current distribution.

Mottled Duck

Model: Isolate freshwater marsh within breeding bird atlas (BBA) blocks.
Status: Using density estimates 0.639 ducks/km² (Johnson et al. 1991), about 800 individuals of a single, panmictic population occur on public land.

continued

Appendix (continued)

Strategic habitats: (1) Obtain Mottled Duck survey data from 1987–1990 (Johnson et al. 1991). (2) Create contour map of Mottled Duck density. (3) Construct Voronoi tessellation (TYDAC 1991) around survey points. (4) Frequent high-use regions defined as areas with ≥ 4 ducks per survey point and Voronoi polygons of < 810 ha. (5) Isolate freshwater marsh within high-use regions outside of public ownership. (6) Isolate grassland and agriculture within 200 m of cover types isolated in step 5 (200 m is arbitrary but intended to identify lands that might be used for nesting during high-rainfall years).

Wading Birds

Model: (1) For Reddish Egret, isolate salt marsh and mangrove swamp within 10 km (i.e., foraging distance) of known nesting locations (Runde et al. 1991). (2) For Tricolored Heron, Little Blue Heron, Snowy Egret, Great Egret, White Ibis, Roseate Spoonbill, isolate appropriate wetland types within 15 km (i.e., foraging distance) of known rookery locations (Runde et al. 1991). (3) For Wood Stork, isolate all wetland types within 30 km of known rookery locations (Runde et al. 1991).

Status: Wood Stork, about 4500 pairs nest in about 30 colonies statewide. Reddish Egret, about 350–400 breeding pairs statewide. Roseate Spoonbill, about 880 pairs nest in 21 colonies statewide. Tricolored Heron, probably a few thousand pairs breeding in about 140 colonies. Little Blue Heron, $< 17,000$ birds in 243 colonies. Snowy Egret, probably no more than a few thousand pairs nesting in about 125 colonies. Great Egret, probably in the low tens of thousands of pairs nesting in an unknown number of colonies. White Ibis, probably a few ten thousand breeding birds in an unknown number of colonies.

Strategic habitats: (1) Overlay potential habitat maps for all 8 wading birds. (2) Isolate wetlands used by > 3 wading birds. (3) To make special accommodation for the endangered Wood Stork, isolate all wetlands < 15 km from known rookery locations and add to map created in step 2.

Florida Sandhill Crane

Model: (1) Digitize FNAI polygons depicting large population centers and isolate dry prairie, grass and agriculture, and freshwater marsh. (2) Create 1-km-radius circle around territory locations obtained from FNAI, Dwyer and Tanner (1992), and K. Atkins (unpublished data), and isolate dry prairie, grass and agriculture, shrub and brush, shrub swamp, and freshwater marsh. (3) Within “probable” and “confirmed” BBA blocks, (a) isolate freshwater marsh, (b) group dry prairie and grass and agriculture into single class of suitable uplands, (c) isolate edges between freshwater marsh and suitable uplands, and (d) within 250 m of edges, isolate freshwater marsh, dry prairie, and grass and agriculture and add to habitat isolated in step 3a. (4) Add maps created in steps 1, 2, and 3.

Status: Using a density of 1 territory/447 ha (Nesbitt & Williams 1990), public lands support about 200 territories.

Strategic habitats: (1) Isolate patches of potential habitat for Sandhill Cranes on public land. (2) To determine the importance of nearby habitat patches in private ownership as well as the connectedness of patches of habitat on public lands, create buffers of 3 km and 15 km around habitat patches on public lands. The “regions” within these buffers identify habitats potentially used by adult Sandhill Cranes over the course of a year and areas potentially used by dispersing juveniles, respectively (Wenner & Nesbitt 1984; Bennett 1989). (3) Identify strategic habitats based on the following criteria: (a) ability of habitats within a region to support 50–80 territories (i.e., a viable population) on conservation lands, (b) priority given to habitats that support clusters of ≥ 10 territories to facilitate social interactions important to successful nesting, (c) likelihood that identified habitats would support up to 10 other imperiled birds that also use prairie and freshwater marsh habitats, and (d) improved continuity among regional populations as a function of adult movement and juvenile dispersal patterns.

Limpkin

Model: (1) Isolate all freshwater wetland types within 250 m of occurrences recorded by FNAI and identify patches > 2 ha, an estimated territory size (Bryan 1982) (250 m is arbitrary but is large enough to include 4 Limpkin territories). (2) Isolate all freshwater wetland types within BBA blocks where Limpkins were “probable” or “confirmed” breeders and identify patches > 2 ha.

Status: Density data suggest 3000–6000 territories on conservation lands, but only four tracts have > 100 territories.

Strategic habitats: (1) Identify strategic habitats in areas adjacent to conservation lands that already support 25–100 territories. (2) Identify strategic habitats away from existing conservation lands to expand geographic distribution of conserved habitats. (3) Identify strategic habitats in areas that support high concentrations of BBA blocks.

Cuban Snowy Plover

Model: (1) Isolate coastal strand within 250 m of occurrences recorded by FNAI and Gore and Chase (1989) (250 m radius is arbitrary). (2) Within BBA blocks, isolate coastal strand, barren land within 60 m of coastal strand, and barren land within 60 m of salt marsh. The latter steps are intended to capture open beaches and tidal flats that are also used by Snowy Plovers.

Status: Population estimated at 170–200 breeding pairs; nests along beaches above high tide line; even beaches in public ownership are subject to heavy human use and disturbance of nesting pairs.

Strategic habitats: All Snowy Plover habitat remaining on private lands.

continued

Appendix (continued)

Southern Bald Eagle

Model: (1) For potential nesting habitat, isolate forested wetlands within 1 km of 1991–1992 nest-site locations surveyed by Florida Game and Fresh Water Fish Commission (FGFWFC). (2) For potential foraging habitat, isolate freshwater marsh and open water within 3 km of 1991–1992 nest-site locations. (3) Add maps produced in steps 1 and 2.

Status: Out of >800 nests (active and inactive) statewide 165 nests occur on conservation lands, and population is probably a single, panmictic population.

Strategic habitats: (1) Construct a Voronoi tessellation (Tydac 1991) using nest-site locations. (2) Isolate polygons (as defined by points) <200 km² to locate concentrations of nests (200 km² criterion is arbitrary but can be repeated in future analyses). (3) Identify strategic habitats as eight largest areas.

American Swallow-tailed Kite

Model: (1) Isolate forested freshwater wetlands, upland hardwood forests, freshwater marshes, mangrove swamps, dry prairies, and pinelands (*Pinus* spp.) within 1 km of nest-site locations obtained from Meyer and Collopy (1990) and K. Meyer (personal communication). (2) Within BBA blocks, isolate forested wetlands, upland hardwood forests, freshwater marshes, and pinelands.

Status: Meyer and Collopy (1996) estimate breeding population at 460–900 pairs; we estimate 7180 km² of potential habitat, implying a density of 0.06–0.12 pairs/km². This suggests 113–238 pairs on conservation lands.

Strategic habitats: (1) Digitize boundaries of 12 Florida areas critically important to maintaining core populations of Swallow-tailed Kites (Meyer & Collopy 1990) and isolate suitable cover types. (2) Isolate all cover types within 3 km of late-summer, pre-migration roost sites used by >100 individuals (Meyer & Collopy 1990).

Snail Kite

Model: (1) Digitize nesting and foraging sites identified by Sykes (1984), Rodgers et al. (1988), Takekawa and Beissinger (1989), and Rodgers (1992), and isolate freshwater marsh, shrub swamp, and open water. (2) Isolate dry prairie and grass and agriculture cover types within 0.5 km of habitats identified in step 1 to locate habitats that may be used in very wet years.

Status: Population estimated at <800 individuals for many years (Rodgers 1992).

Strategic habitats: All known nesting areas outside of existing conservation lands.

Short-tailed Hawk

Model: (1) Isolate all natural land-cover types plus grass and agriculture within 250 m of occurrences recorded by FGFWFC and within BBA blocks (250 m is arbitrary but is large enough to include habitat features likely to be used for nesting).

Status: Rare species for which about 30 occurrence records exist.

Strategic habitats: All potential habitat outside of existing conservation land.

Southeastern American Kestrel

Model: (1) Isolate sandhill, dry prairie, grass and agriculture, and mixed pine-hardwood forest within 500 m, an estimated territory size (Stys 1993), of occurrences recorded by FNAI. (2) Within “probable” or “confirmed” BBA blocks, isolate sandhill, mixed pine-hardwood, and dry prairie. (3) Generate 200-m buffer around habitats isolated in step 2 and isolate grass and agriculture within the buffer. (4) Add potential habitat maps created in steps 1–3.

Status: Using a density of 0.8/km², three conservation lands contain 50–200 individuals, and 52 conservation lands contain <50 individuals.

Strategic habitats: (1) To rank habitat according to relative opportunity to achieve conservation by working with few landowners, isolate potential habitat on large (>130 ha) parcels of privately owned lands, and assign a score of 1. (2) To rank habitat according to proximity to conservation lands, isolate potential habitat within 10 km (i.e., dispersal distance [J. Layne, personal communication, in Stys 1993]) and assign a score of 1. (3) Add maps created in step 4 of previous section with maps created in steps 1–2. (4) Identify high-scoring habitats as strategic habitats based on J. Cox (personal observations).

Crested Caracara

Model: (1) To identify central territory areas, isolate dry prairie, upland hardwood forest, freshwater marsh, shrub and brush, and grass and agriculture within 1 km of territory locations obtained from Millsap (1991) and FNAI. (2) Within BBA blocks, isolate dry prairie and freshwater marsh. (3) Add the maps created in steps 1 and 2.

Status: Layne (1996) estimates stable population of 400–500 individuals between 1972 and 1991; our analyses show only 20 territories on conservation lands, none of which contains >4 territories.

continued

Appendix (continued)

Strategic habitats: (1) Use territory locations to create Voronoi tessellation, and assign polygons of <4050 ha a score of 2 (i.e., high concentration of nests) and polygons of >4050 ha a score of 1. (2) Because large land ownerships tend to have better caracara habitat, cross-tabulate potential habitat map with large (>130 ha) landowner map. Assign single-owner parcels with between 100 ha and 1000 ha of habitat a score of 1 and parcels with >1000 ha a score of 2. (3) Add maps created in steps 1 and 2, but restrict to areas of potential habitat. (4) Add potential habitat maps for 10 birds also dependent on prairie habitats (i.e., Bald Eagle, Caracara, Red-cockaded Woodpecker, Burrowing Owl, Grasshopper Sparrow, Snail Kite, Scrub Jay, Mottled Duck, Limpkin, and Sandhill Crane) to identify areas that would benefit other rare species, and restrict to caracara potential habitat map. (5) Create a simple species richness map for 120 Florida vertebrates, including all taxa listed as endangered, threatened, or species of special concern (except fishes, sea turtles, and marine mammals) (Wood 1992) and all taxa having a biological score of ≥ 24 (Millsap et al. 1990). The range of each taxon was digitized from available information, appropriate vegetation types were isolated for each taxon, and the 120 potential habitat maps were added and then restricted to Caracara potential habitat. (6) Using the maps created in steps 1-5 as guides to best choices of areas, identify areas sufficient to support at least 100 breeding pairs of Crested Caracaras.

White-crowned Pigeon

Model: (1) Digitize areas of known nesting concentrations (Bancroft 1989) and isolate mangrove swamp. (2) Within BBA blocks, isolate tropical hardwood hammock.

Status: Nesting habitat on mangrove islands largely secured by public ownership, but much of tropical hardwood hammock used as foraging habitat and crucial to nesting success is in private ownership on mainline Florida Keys.

Strategic habitats: (1) Isolate mangrove swamp within BBA blocks and within nesting areas identified by Bancroft (1989). (2) To rank foraging habitat according to accessibility from nesting habitat, isolate tropical hardwood hammock in the Keys and rank as follows: assign a score of 3 to hammock patches <5 km from nesting habitat; assign a score of 2 to hammock patches 5-10 km from nesting habitat; and assign a score of 1 to patches >10 km from nesting habitat. (3) Rank foraging habitat patch size as follows, based on findings of Bancroft (1989): assign a score of 1 to hammocks <2 ha in size; assign a score of 2 to hammocks 2-4 ha in size; assign a score of 3 to hammocks >4 ha in size. (4) Add maps created in steps 2 and 3. (5) Identify as strategic habitats areas proposed by T. Bancroft (Anonymous 1992) for land acquisition plus two high-ranking patches of hammock identified by the map in step 4.

Mangrove Cuckoo

Model: (1) Within BBA blocks, isolate mangrove swamp. (2) Isolate shrub and brush, tropical hardwood hammock, xeric oak (*Quercus* spp.) scrub, and upland hardwood forest within 100 m of habitat isolated in step 1. (3) Within 500 m of occurrence records obtained from FNAI, isolate land-cover types used in steps 1-2. (4) Combine maps created in steps 1-3.

Status: Population size unknown, but Mangrove Cuckoo is considered rare and sensitive to habitat fragmentation; according to our analyses, 86% of potential habitat is on conservation lands.

Strategic habitats: To maintain current geographic distribution, identify strategic habitats as the potential habitat around Tampa Bay and Charlotte Harbor and along the coast of Collier and Dade counties.

Red-cockaded Woodpecker

Model: (1) Isolate pineland, sandhill, dry prairie, and mixed pine-hardwood forest within 500 m of occurrences recorded by FNAI, U.S. National Forest Service (Apalachicola National Forest), D. Hardin, J. Garrison, R. Progulsk, W. Baker, M. Allen, R. DeLotelle, C. Smith, K. Dryden, J. Beever, and D. Jansen. (2) Within BBA blocks lacking corresponding occurrence records, isolate contiguous patches of same cover types isolated in step 1. (3) Combine maps created in steps 1-2.

Status: Very few known occurrences outside of public ownership; only two public lands have potentially secure populations, and those populations are declining; habitat management on public lands is critical to survival.

Strategic habitats: (1) Define zones of 3, 6, and 12 km around potential habitat on conservation lands to represent very frequent, frequent, and infrequent dispersal distances, respectively (Walters et al. 1988; Cox et al. 1993). (2) Evaluate connections among Red-cockaded Woodpeckers on public and private lands based on criteria in step 1. (3) Identify strategic habitats to protect known populations in Orange, Lee, and Collier counties and in areas of favorable or restorable habitat surrounding Avon Park Bombing Range and Three Lakes and Bull Creek Wildlife Management Areas.

Florida Scrub Jay

Model: (1) Isolate xeric oak scrub, sand pine (*P. clausa*) scrub, and dry prairie within 160 m (i.e., 8 ha, the estimated territory size of a breeding pair [Woolfenden & Fitzpatrick 1984; Fitzpatrick et al. 1991]) of occurrences recorded by FNAI, K. Dryden, J. Beever, and a proposal for public land acquisition (Anonymous 1992). (2) Within BBA blocks, isolate patches of xeric oak scrub and sand pine scrub of >2 ha. (3) Within 120 m of potential habitat identified in step 2, isolate dry prairie, shrub and brush, and patches of xeric oak scrub and sand pine scrub <2 ha. (4) Combine the maps created in steps 1-3.

continued

Appendix (continued)

Status: Using a density of one territory per 16 ha, five existing conservation lands support viable populations of Scrub Jays and three of the five support very large populations.

Strategic habitats: (1) Isolate potential Scrub Jay habitat within 5 km (i.e., frequent dispersal distance [Woolfenden & Fitzpatrick 1984]) of patches of potential habitat on existing conservation lands. (2) Assess the likelihood that patches of potential habitat on conservation lands plus patches of habitat within 5 km are capable of supporting a viable population (i.e., >40 territories [Fitzpatrick et al. 1991]). (3) Identify as strategic habitats privately owned parcels of strategic habitat surrounding seven general areas, including Barge Canal lands, Wekiva River area, central Lake Wales Ridge, southeast Atlantic Coast, Cedar Key, and southwest Florida.

Black-whiskered Vireo

Model: (1) Isolate mangrove swamp within BBA blocks. (2) Isolate upland hardwood forest and tropical hardwood hammock within 100 m of potential habitat isolated in step 1. (3) Combine maps created in steps 1-2.

Status: Using a conservatively low density estimate of one breeding pair per 2000 ha based on information from Hamel (1992), we estimate that six conservation areas could support >200 individuals and another eight could support 50-200 individuals at 1 pair per 1000 ha. We estimate that eight conservation lands could support >200 individuals and 12 could support 50-200. These areas do not cover the full geographic range of the species, however.

Strategic habitats: (1) Based on work by T. Bancroft (personal communication) indicating that Black-whiskered Vireos are positively correlated with forest area, isolate patches of potential habitat that are outside existing conservation lands and >5 ha in size. (2) Identify as strategic habitat the largest blocks of potential habitat in the Florida Keys, Tampa Bay, Charlotte Harbor, Indian River, and Biscayne Bay.

Florida Grasshopper Sparrow

Model: (1) Digitize Grasshopper Sparrow locations from information presented by Delany and Cox (1986) and Delany (1993) and obtained from R. DeLotelle. (2) Within BBA blocks, isolate dry prairie within 100 m of any forest-cover type (based on recommendation from M. Delaney). (3) Combine maps created in steps 1-2.

Status: Surveys by Delany et al. (1985) and Delany and Cox (1986) found 182 Grasshopper Sparrows at nine sites, with only a few more sites added by Kale et al. (1992) and Delany (1993); three conservation lands support >50 breeding pairs.

Strategic habitats: Identify as strategic habitat all potential habitat outside of existing conservation lands.

Louisiana, Wakulla, Scott's, and Smyrna Seaside Sparrows

Model: (1) Within "probable" and "confirmed" BBA blocks, isolate salt marsh. (2) Within 100 m of potential habitat isolated in step 1, isolate freshwater marsh as potential transitional marsh that may also be used. (3) Combine the maps created in steps 1-2.

Status: Status of habitat on existing conservation lands varies among sparrow subspecies as follows: Wakulla 70%, Smyrna 40%, Scott's 25%, Louisiana 10%; each subspecies has a limited geographic distribution.

Strategic habitats: Identify as strategic habitat the potential habitat on Garcon Point (Santa Rosa County), Live Oak Point (Walton County), upper end of East Bay (Bay County), St. Joseph Bay (Gulf County), along the coasts of Citrus, Hernando, and Pasco counties, and the coastal marshes of Nassau County.

Southeastern Bat

Model: (1) Isolate forest-cover types within 100 m of the entrances to southeastern bat maternity cave locations obtained from FNAI and Hovis and Gore (1993). (2) In Jackson County, isolate streamside forested habitats within 3 km of cave locations obtained from same sources identified in step 1. (3) Combine maps created in steps 1-2.

Status: Found throughout the southeast but most abundant in Florida. Young born in caves, and survival of species dependent on suitable cave sites.

Strategic habitats: Identify as strategic habitats all forested lands within 100 m of cave sites and streamside forests within 3 km of Jackson County caves.

Gray Bat

Model: (1) In Jackson County, isolate streamside forested habitats within 3 km of cave locations obtained from FNAI and Hovis and Gore (1993).

Status: Endangered species that breeds in the northern United States, but some individuals winter at a few caves in Jackson County, and survival is dependent upon suitable winter cave sites.

Strategic habitats: Identify as strategic habitat streamside forests within 3 km of Jackson County caves.

continued

Appendix (continued)

Florida Black Bear

Model: (1) Within the state of Florida (except the Keys), isolate pineland, xeric oak scrub, sand pine scrub, mixed pine-hardwood forest, upland hardwood forest, cypress (*Taxodium* spp.) swamp, mixed hardwood swamp, bay swamp, and bottomland hardwood forest as “primary” habitat types (Wooding & Hardisky 1988; Maehr & Wooding 1992). (2) Eliminate habitat patches of <1500 ha (Mykytko & Pelton 1989) from the map produced in step 1 to create a map with only large patches. (3) Create a buffer of 1 km around the large habitat patches remaining after step 2, and add small patches of primary habitat eliminated in step 2 and within the 1-km buffer back into the map of primary habitat. (4) Isolate dry prairie, sandhill, tropical hardwood hammock, shrub swamp, and shrub and brush as “secondary” habitat types. (5) Add patches of secondary habitat within 1 km of the large habitat patches remaining after step 2 to the map created in step 3. (6) Take the following steps to account for black bear use of mangrove swamps in southwest Florida: (a) isolate mangrove swamp within 5 km of the potential habitat map created in step 5, (b) isolate the edges of the mangrove swamp and create a 300-m buffer, (c) isolate mangrove swamp within the 300-m buffer, (d) eliminate mangrove swamp within 90 m of the Gulf of Mexico to model avoidance of open waters, and (e) add the final map of mangrove swamp to the map of primary and secondary habitat created in step 5.

Status: Florida black bear population estimated around 1200 individuals. Based on densities of 0.05–0.10 breeding individuals/km² (Wooding & Hardisky 1988), a population of 200 would require 2000–4000 km² of habitat. Only the 2025 ha Apalachicola National Forest (NF) has sufficient area for a viable population, assuming densities are at the higher end of the range.

Strategic habitats: (1) Designate Apalachicola NF, Osceola NF, Ocala NF, Eglin Air Force Base, and Big Cypress National Preserve as the only public land parcels that, in conjunction with habitat in privately owned lands surrounding these areas, are large enough to support viable populations of black bears. (2) Rank the quality of black bear habitats according to the following criteria: (a) assign a score of 3 to sand pine scrub, xeric oak scrub, mixed pine-hardwood forest, cypress swamp, mixed hardwood swamp, bay swamp, and bottomland hardwood forest, (b) assign a score of 2 to pineland, mangrove swamp, and shrub and brush, and (c) assign a score of 1 to sandhill, dry prairie, freshwater marsh, and shrub swamp. (3) Rank black bear habitats as a function of the distance dispersing black bears are likely to travel from conservation lands with >20 km² of habitat according to the following criteria: (a) assign a score of 3 to potential habitat <10 km from conservation lands, (b) assign a score of 2 to habitat 10–20 km distant, and (c) assign a score of 1 to habitat 20–30 km distant. (4) Rank black bear habitats by size of patches bounded by Florida’s primary road network according to the following criteria: (a) assign a score of 0 to roadless patches of <10 km², the approximate size of a female home range, (b) assign a score of 1 to roadless patches of >10 km² but with <25% primary habitat types, and (c) assign a score of 2 to roadless area patches of >10 km² but with >25% primary habitat types. (5) Rank black bear habitats according to habitat diversity within 1-km² blocks by grouping habitats into four classes (i.e., forested wetlands, forested uplands, freshwater marsh, low-stature uplands), performing a neighborhood analysis on the grouped habitats, and developing the following scores: (a) a score of 2 to pixels with 3–4 habitats within the 1-km² block, and (b) a score of 1 to pixels with 1–2 habitats within the 1-km² block. (6) Add the maps created in steps 2–5. (7) Identify strategic habitats as the highest ranking habitats surrounding the public lands in step 1 with sufficient habitat area to support 200 black bears.

Florida Panther

Model: (1) South of a line extending east from Tampa Bay across the Florida peninsula, isolate pinelands, upland hardwood forest, and cypress swamp as “preferred” habitat, and eliminate patches of <40 ha. (2) Isolate hardwood swamp, dry prairie, oak scrub, shrub and brush, grass and agriculture as “secondary” habitats. (3) Within 1 km of habitat edges identified in step 1, add patches of secondary habitat plus small patches of habitat eliminated in step 1 to the map remaining at the end of step 1. Distance and patch-size criteria based on observations of D. Maehr (personal communication). (4) To model panther avoidance of barren lands, isolate barren land and eliminate patches of preferred and secondary habitat identified in step 3 that is within 300 m of patches of barren land.

Status: Florida panther population estimated at 30–50 adults. Assuming a density of 1 panther/110 km² (Maehr 1987), 18–24 panthers occur on public lands; our analyses suggest that 50–70 may be viable for 200 years and a single secure population might need 8100–16,200 km² of habitat.

Strategic habitats: (1) Rank panther habitat based on roadless-area patch size and habitat quality according to the following criteria: (a) assign a score of 1 to roadless patches of <190 km² (approximate size of a female home range [Maehr et al. 1991]), (b) assign a score of 2 to roadless patches of >190 km² but containing <15% preferred habitat types, and (c) assign a score of 3 to roadless patches of >190 km² and containing >15% preferred habitat types. (2) Rank panther habitat based on quantity and composition of habitat on private lands according to the following criteria: (a) assign a score of 1 to private parcels with >100 km² of preferred habitat, (b) assign a score of 2 to parcels with >100 km² of preferred habitat but with <15% of parcel in preferred habitat, and (c) assign a score of 3 to parcels with >100 km² of preferred habitat and with >15% of parcel in preferred habitat. (3) Rank panther habitat based on quantity of forest cover according to the following criteria: (a) assign a score of 1 to patches of preferred habitat containing <10 km² of forest cover, and (b) assign a score of 2 to patches of preferred habitat containing >10 km² of forest cover. (4) Add the maps created in steps 1–3 to produce a map of panther habitat with scores ranging from 1 to 8. (5) Identify as strategic habitat the highest ranking habitat in private ownership that, in combination with habitat in public ownership, would conserve 8100 km² of panther habitat.

Big Cypress Fox Squirrel

Model: (1) Within the range of the subspecies (Williams & Humphrey 1979; Humphrey & Jodice 1992), isolate pineland and dry prairie and consolidate into a single class. (2) Eliminate patches of <100 ha from potential habitat map created in step 1. (3) Within

continued

Appendix (continued)

300 m of the potential habitat map created in steps 1–2, isolate contiguous patches of upland hardwood forest, mixed pine-hardwood forest, cypress swamp, mixed hardwood swamp, and mangrove swamp. (4) Add potential habitat maps created in steps 1–3.

Status: Our analyses estimate that 21% of potential habitat is on conservation lands, and only five conservation lands contain potential habitat. Densities are not well known, but if they are similar to other subspecies, 1000–4000 individuals may occur on conservation lands.

Strategic habitats: (1) Most of potential habitat for Big Cypress fox squirrel is identified elsewhere as strategic habitat for Florida panther and Florida black bear. (2) Identify as strategic habitat an area of potential habitat totaling 3104 ha in northeastern Lee County (vicinity of Hickey Creek).

Choctawhatchee, Anastasia Island, and Southeastern Beach Mice

Model: (1) Digitize the geographic distributions of the subspecies based on information from Humphrey and Barbour (1979, 1981), Holler and Mason (1987), Robson (1989), the U.S. Fish and Wildlife Service (USFWS) (1987), Frank and Humphrey (1992), Holler (1992a, 1992b), Humphrey and Frank (1992), James (1992), and Gore and Schaefer (1993). (2) Within the areas described in step 1, isolate coastal strand. (3) Isolate xeric oak scrub, dry prairie, and barren land within 120 m of potential habitat isolated in step 2. (4) Combine maps created in steps 2–3.

Status: Density estimates for these subspecies range from 2 to 90/ha, and population estimates at specific locales range from 180 to 500 individuals. All subspecies are endangered or threatened, and none have 10 populations of 200 on existing conservation lands.

Strategic habitats: Identify all remaining potential habitat outside of conservation lands as strategic habitat for beach mice.

Sandhill

Model: Digitize the boundaries of seven tracts of high-quality sandhill identified by FNAI in a proposal to Florida's public land-acquisition program (Anonymous 1992).

Status: Rare community type supporting many species of plants and animals. Originally covered 28,148 km² of Florida, but now reduced to >3449 km², with 36% on conservation lands. Remainder is in rapidly disappearing small and fragmented patches.

Strategic habitats: Identify as strategic habitats all seven tracts of known high-quality examples of sandhill.

Scrub

Model: (1) Digitize boundaries of known examples of high-quality scrub on the Lake Wales Ridge as identified by representatives of Archbold Biological Station, FNAI, FGFWFC, USFWS (1992), and others. (2) Digitize boundaries of larger patches of scrub along the lower southeast coast, as identified by Fernald (1989). (3) Isolate xeric oak scrub and sand pine scrub on privately owned lands in the northeast, northcentral, Withlacoochee, eastcentral, and Tampa Bay regions.

Status: Originally estimated to cover about 3963 km² of Florida but now reduced to 1710 km², with 63% of remainder on public land; most in private ownership is small, isolated patches. Ancient scrubs of the Lake Wales Ridge support high numbers of endemic plants and animals, but only 150 km² remain, of which only 33% are on conservation lands.

Strategic habitats: (1) Rank patches of scrub isolated in step 3 of the habitat model on the basis of size according to the following criteria: (a) assign a score of 1 to patches of <10 ha, (b) assign a score of 2 to patches 10–40 ha, and (c) assign a score of 3 to patches of >40 ha. (2) Rank scrub patches isolated in step 3 of the habitat model on the basis of number of FNAI occurrence records according to the following criteria: (a) assign a score of 1 to patches with <3 occurrences, (b) assign a score of 2 to patches with 3–5 occurrences, and (c) assign a score of 3 to patches with >5 occurrences. (3) Add the ranked maps created in steps 1–2. (4) Identify as strategic habitat the patches of scrub identified in steps 1–2 of the habitat model and the 13 highest-ranking patches of scrub as identified in step 3 above.

Pine Rocklands

Model: (1) Digitize boundaries of lands in Dade County proposed for acquisition by the state of Florida as examples of pine rocklands. 2. Isolate pineland and mixed pine-hardwood in the Florida Keys.

Status: Fire-maintained tropical community harboring many rare species. Formerly occupied the Miami Ridge and areas of the lower Florida Keys. Originally estimated to cover 940 km², now reduced to >6017 ha with 65% on public lands.

Strategic habitats: (1) Rank patches of pineland and mixed pine-hardwood forest in the Florida Keys on the basis of number of on-site FNAI occurrence records according to the following criteria: (a) assign a score of 1 to patches with <5 records, (b) assign a score of 2 to patches with 6–10 records, and (c) assign a score of 3 to patches with >10 records. (2) Identify as strategic habitat all Dade County pine rocklands proposed for public acquisition plus patches of habitat on Big Pine and No Name keys with >5 occurrence records.

Tropical Hardwood Hammock

Model: Isolate patches of tropical hardwood hammock found in the Florida Keys.

Status: Climax community of tropical south Florida that supports many rare species. No estimate available of the original extent of tropical hardwood hammock but now reduced to 15,345 ha with 49% on public lands, mostly in the Florida Keys.

continued

Appendix (continued)

Strategic habitats: (1) Rank patches of tropical hardwood hammock on the basis of size according to the following criteria: (a) assign a score of 1 to patches <2 ha, (b) assign a score of 2 to patches 2–4 ha, and (3) assign a score of 3 to patches >4 ha. (2) Rank patches of tropical hardwood hammock on the basis of number of FNAI occurrence records according to the following criteria: (a) assign a score of 1 to patches with <7 occurrences, (b) assign a score of 2 to patches with 8–15 occurrences, and (c) assign a score of 3 to patches with >15 occurrences. (3) Add the maps created in steps 1–2. (4) Identify as strategic habitat the 12 highest-scoring patches of tropical hardwood hammock.

Globally Rare Plants

Model: Isolate FNAI occurrence records for plants meeting the following criteria: (a) taxa listed as imperiled globally because of extreme rarity, (b) taxa listed as imperiled globally because of rarity, or (c) taxa with <10 occurrence records on Florida conservation lands.

Status: Isolated data set includes 105 taxa and 947 occurrences; 23% of occurrences, representing 79 of the taxa, are on existing conservation lands; 25% of taxa are not known from any conservation land. Identification of strategic habitat is complicated by a lack of information on the minimum areas needed to maintain plants, the uncertainty involved in whether or not all locations of rare plants are known, and inaccurate or imprecise geographic coordinates in the location records

Strategic habitats: Identify as strategic habitats 13 projects on the state of Florida acquisition list for conservation lands that would protect 124 (13%) occurrences of globally rare plants (strategic habitat recommended for other species and communities would protect an additional 199 rare-plant occurrences).

