9.0 TERRESTRIAL MODULE

9.1 Overview

The Terrestrial Module addresses the impacts of additional land development activities on terrestrial habitats and species. At the outset of the study, a detailed literature search and review sought to identify, obtain and assimilate relevant scientific data regarding both terrestrial and marine ecosystems and species (Appendix A). The search focused primarily on identifying peer-reviewed publications, but it included other types of information sources, such as web sites, non-peer reviewed literature, and agency reports. The literature search yielded over 600 references. While the literature is replete with data, assertions, and inferences regarding the ecology of the ecosystems and species considered in this study, information on absolute ecological thresholds is scarce. Well-documented habitat requirements or limiting conditions exist for a handful of species.

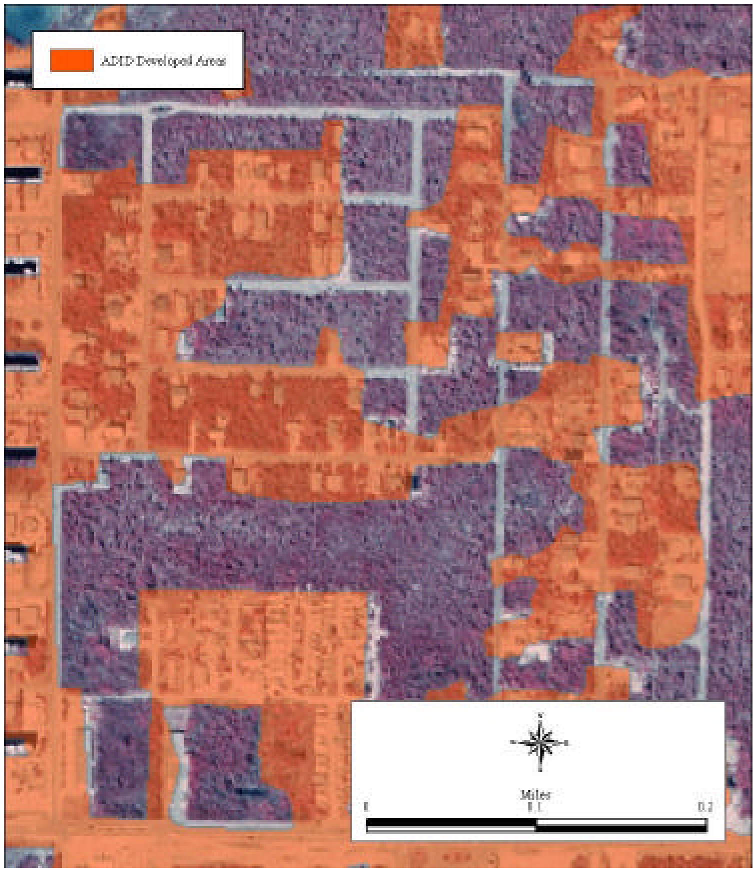
9.2 Spatial Data

9.2.1 Base Data

Several spatial databases are available for the Florida Keys. The ADID GIS layer is the best source of spatial terrestrial habitat data available (Appendix G, Map 3). It contains fifteen vegetation types and was based on photo-interpretation of 1991 DOQQs. Its main purpose was to identify wetlands in the Keys under the USACE federal criteria for delineation of wetlands (Environmental Laboratory 1987). For the purposes of this model, the ADID vegetation classification system, resolution, and spatial accuracy are superior to both the statewide FLUCCS and the Habitat and Land Cover layer by FWC. A limitation of the ADID map for the CCIAM is that some patches mapped as developed encompass smaller undeveloped patches of various habitat types (Figure 9.1).

Kruer et al. (2000) developed an exotic vegetation map of the Florida Keys based on 1996 fieldwork. The map documents nearly 7,000 acres of exotic vegetation. While the area of infestation was confirmed, the GIS spatial data was based on the Property Appraiser parcel coverage. Therefore, the preparation of the map involved "rubbersheeting" the parcel coverage (T. Armstrong letter to FMRI, dated August 25, 2000). Due to the unknown spatial inaccuracy of the exotic vegetation GIS layer, the layer was not incorporated into the model.

FIGURE 9.1
APPARENT HABITAT WITHIN ADID DEVELOPED POLYGONS



9.2.2 Historic Vegetation Map

A map of the historic distribution of habitats in the Florida Keys, developed for the FKCCS (Appendix A), provided a benchmark from which to evaluate the effect of development on the extent and distribution of habitat types in the Florida Keys. This information, in conjunction with other FKCCS data, allows for the analysis of habitat changes over time and the identification of vegetation type for restoration scenarios. The mapping approach used for this project is similar to that of Strong and Bancroft (1994). The primary sources of information used to interpret historic vegetation include three aerial photograph series, ranging from 1945 to 1959, which are the earliest available for the entire study area. Other sources included field visits, other historic maps, topography, and soils. The low resolution of the historic photography limited the number of community types identified in the historic map. Therefore, the fifteen ADID categories were aggregated into eight categories, including five vegetation types (hammocks, pinelands, freshwater wetlands, saltwater wetlands, and beach berm) as well as developed land, exotics, and open water.

The FKCCS included a second mapping effort to extrapolate vegetation types beyond the 1945 map to pre-development conditions using the same eight categories. The extrapolation effort benefited from additional ancillary historic information.

9.2.3 Species Richness Map

A species richness map was developed for the FKCCS using a combination of sources (Table 9.1). Species included in the species richness index meet the following criteria:

1. Currently listed by federal or state agencies as an endangered (E), threatened (T), or imperiled species (S2) or species of special concern (SSC) in Monroe County by the federal (F) or state (S) governments. The S2 designation includes species imperiled in Florida because of vulnerability to rarity (6 to 20 records of occurrence or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.

2. There is an existing potential habitat model for the species, for which at least a "Fair" model accuracy rating was given in the Habitat Conservation Needs of Rare and Imperiled Wildlife in Florida (FFWCC GAP II; Cox and Kautz 2000). The "Fair" model rating indicates that the potential habitat model is sufficiently accurate to allow an assessment of habitat (Cox and Kautz 2000).

3. Species for which other existing potential habitat models were readily available. These GIS layers were obtained from the USFWS and FMRI.

4. The species determined to be suitable based on the previous three criteria were further reviewed and selected to balance the representation of upland and wetland species and habitat. Mr. Randy Kautz, of the FWC kindly reviewed the list of selected species. The set of species includes an almost equal representation of upland and wetland species.

For 10 of the 17 species, habitat models used in the CCIAM were developed by the USFWS or FMRI. For the other seven species, new potential habitat maps were developed for the FKCCS using the FWC GAP II model methods. The models were re-run substituting the ADID for the FWC Habitat and Land Cover layer. Given the higher resolution of the ADID layer, the size of grid cells was reduced from 100 x 100 meters in the GAP II models to 30 x 30 feet for the FKCCS. Some of the model criteria were varied slightly to incorporate Keys-specific habitat considerations into the regionally developed model methods. An overlay of the 17 habitat models provides a measure of species richness in which the value of each location (cell) is the total number of species whose potential habitat are located in that cell. Although the maximum value possible for the species richness layer is seventeen, the maximum number of species found in a given cell in the study area was ten.

Additionally, species-specific spatial data was also used to address species impacts for the Key deer, Lower Keys marsh rabbit, and silver rice rat (Section 9.2).

TABLE 9.1
SPECIES INCLUDED IN THE SPECIES RICHNESS MAP[1]

Taxonomic Class	Scientific Name	Common Name	Model Source
Reptiles	*Alligator mississippiensis*	American alligator	Cox and Kautz 2000
	Malaclemys terrapin rhizophorarum	Mangrove terrapin	Cox and Kautz 2000
	Drymarchon corais couperi	Eastern indigo snake	Cox and Kautz 2000
	Kinosternon baurii	Lower Keys striped mud turtle	USFWS
	Crocodylus acutus	American crocodile	USFWS
	Chelonia mydas (nesting habitat)	Green sea turtle	FMRI ESI
Birds	*Pelecanus occidentalis*	Brown pelican	Cox and Kautz 2000
	Plegadis falcinellus	Glossy ibis	Cox and Kautz 2000
	Pandion haliaetus	Osprey	Cox and Kautz 2000
	Dendroica discolor paludicola	Florida prairie warbler	Cox and Kautz 2000
	Columba leucocephala	White-crowned pigeon	FMRI/ESI
Mammals	*Oryzomys paustris natator*	Silver rice rat	USFWS
	Sylvilagus palustris hefneri	Lower Keys marsh rabbit	USFWS
	Odocoileus virginianus clavium	Florida Key deer	USFWS
	Neotoma floridana smalli	Key Largo woodrat	USFWS
	Peromyscus gossypinus allapaticola	Key Largo cotton mouse	USFWS
Vascular Plant	*Pilosocereus robinii*	Key tree cactus	USFWS

[1] Models were re-run, using the ADID as the base habitat layer, for the American alligator, mangrove terrapin, Eastern indigo snake, brown pelican, glossy ibis, osprey, and Florida prairie warbler.

9.3 Habitat and Species-Specific Data Gathered During Literature Review

The literature on terrestrial ecosystems and species indicate that habitat availability and quality are primary factors in determining the presence of viable populations of species in the Florida Keys (Table 9.2). Very few papers, however, provided clear data on habitat or other ecological requirements. For example, Schaus' swallowtail butterfly (*Papilio aristodemus ponceanus*) requires mature hammocks and the presence of sufficient stands of its primary larval host plant, torchwood (*Amyris elemifera*; Emmel 1995a,b). Minimum habitat patch size requirements or home ranges have been quantified for a few species such as the Lower Keys marsh rabbit (*Sylvilagus palustris heffnerii*), fledging white-crowned pigeons (*Columba leucocephala*), black-whiskered vireos (*Vireo altiloquus*) and other forest nesting birds (Bancroft et al. 1995, Forys and Humphrey 1994, 1996). Garber's spurge (*Euphorbia garberi*) is restricted to pineland sites that undergo frequent burns (USFWS 1999). The CCIAM addresses species-specific impacts for 11 species.

TABLE 9.2
SPECIES-SPECIFIC REQUIREMENTS AND LIMITING FACTORS FOR SELECTED TERRESTRIAL SPECIES

Species	Chief Requirements or Limiting Conditions	Key References
Lower Keys Marsh Rabbit	Require both low marsh and high marsh (buttonwood) habitat. Minimum home range is 0.3 ha of continuous habitat. Marsh rabbits require vegetative cover to successfully disperse. Chief cause of mortality is predation by feral cats (53 percent); one-third of mortality is due to automobile collisions. FWS recommends a 500-m buffer zone around areas of suitable habitat in order to insure future protection of the species. This distance is based on the use of upland areas by this species and the estimated range of domestic cats.	Forys and Humphrey 1994, 1996
Roseate Spoonbill	Require mangroves for nesting. Nesting success in Florida Bay has declined since the 1960s, primarily due to loss of mangrove habitat and changes in prey availability. Because of water management practices and channelization, prey fish no longer concentrate in dry season flats in large enough numbers to support fledgling spoonbills.	J. Lorenz, unpublished data
White-Crowned Pigeon	White-crowned pigeons nest primarily on mangrove islands, but must disperse to hardwood hammocks to meet foraging needs. Young white-crowned pigeons show a strong preference for hardwood hammock areas 5.0 ha. or greater within the first 72 hours of fledging. After this, white-crowned pigeons generally stay within hardwood hammocks, avoiding urban areas. White-crowned pigeons are considered critical seed-dispersers for many hardwood hammock species.	Strong and Bancroft 1994
Silver Rice Rat	The main threat to the silver rice rat is degradation and loss of habitat due to urbanization. Secondary threats to the silver rice rat include habitat fragmentation, an increase in the densities of predators (especially domestic cats) and the introduction of non-native competitors (e.g., black rats).	Forys et al. 1996 USFWS 1999
Schaus' Swallowtail Butterfly	The development-driven loss of mature hardwood hammock habitat is the chief cause of rarity for Schaus' swallowtail butterfly. The survival of this species depends on the survival of sufficient stands of its primary larval host plant, torchwood, and its secondary host plant, wild lime. Small clearings or trails seem to promote proliferation of host plant species. However, adult females apparently prefer the deep shade of hammock interiors.	Emmel 1995 a, b
Bartram's Hairstreak	The distribution and abundance of Bartram's hairstreak is a direct function of the availability of its larval hostplant, *Croton linearis*, a herbaceous plant found primarily in frequently burned rockridge pinelands.	Emmel and Minno 1993
Florida Leafwing	The distribution and abundance of the Florida leafwing is a direct function of the availability of its larval hostplant, *Croton linearis*, a herbaceous plant found primarily in frequently burned rockridge pinelands.	Emmel and Minno 1993

TABLE 9.2 (CONTINUED)
SPECIES-SPECIFIC REQUIREMENTS AND LIMITING FACTORS
FOR SELECTED TERRESTRIAL SPECIES

Species	Chief Requirements or Limiting Conditions	Key References
Tree Snails	Tree snails occur in tropical hardwood hammocks of South Florida and the Florida Keys. Within the hammocks, they prefer smooth-barked trees (Emmel 1986). Tree snails appear to be moisture-limited, with some species (e.g., Florida tree snail) entering diapause during the dry season. Adult snails forage primarily on tamarind and other smooth-barked trees, scraping epiphytic lichens, fungi, and algae from the bark. The amount of food available to foraging tree snails is largely a function of moisture. Primary causes for rarity in the Stock Island tree snail (which is nearly extinct in its original range) and other tree snails include widespread destruction of hardwood hammock habitat and collection pressure.	USFWS 1999 Emmel 1986
Forest Nesting Birds	Black-whiskered vireos require a minimum of 0.2 ha of seasonal deciduous forest. White-eyed vireos require a minimum of 2.3 ha of seasonal deciduous forest. Yellow-billed cuckoos require a minimum of 7.5 ha of seasonal deciduous forest. Mangrove cuckoos require a minimum of 12.8 ha of seasonal deciduous forest.	Bancroft et al. 1995
Florida Prairie Warbler	The Florida race of the prairie warbler is largely restricted to mangrove forests.	Prather and Cruz 1995
Key Largo Wood Rat	The Key Largo woodrat requires mature, tropical, hardwood hammocks with trees of 10 to 12 inches trunk diameter-at-breast-height; it is rarely found in young or recovering hammocks. Species decline is due to extensive habitat destruction and fragmentation by human development. Other threats associated with human encroachment include predation by feral cats, dumping of trash, and competition with black rats. FWS recommends a 500-m buffer zone around areas of suitable habitat in order to insure future protection of the species. This distance is based on the use of upland areas by this species and the estimated range of domestic cats.	USFWS 1999 Humphrey 1988
Lower Keys Striped Mud Turtle	The striped mud turtle occupies small, usually temporary, freshwater ponds that are deep enough to penetrate into the fresh ground water lens. Suitable ponds are usually found along the edge of elevated hardwood hammocks. The turtle can only tolerate salinities below 15 ppt. The Lower Keys striped mud turtle is listed as endangered primarily due to a loss of suitable habitat from intensive development throughout the lower Florida Keys, especially the destruction of the hammock pond habitat essential for the species' survival. Future filling of mosquito control ditches, as recommended for the management of the Key deer, will negatively impact the Lower Keys striped mud turtle if suitable natural habitat is not available or restored in its place.	Dunson 1992
Mangrove Diamondback Terrapin	Suitability of nesting areas is the primary limiting factor for terrapin populations.	Palmer and Cordes 1988

TABLE 9.2 (CONTINUED)
SPECIES-SPECIFIC REQUIREMENTS AND LIMITING FACTORS
FOR SELECTED TERRESTRIAL SPECIES

Species	Chief Requirements or Limiting Conditions	Key References
Rare Plants	Key tree cactus: The Key tree cactus is limited to hardwood hammocks on Upper Matecumbe Key, Lower Matecumbe Key, Long Key, and Big Pine Key. Chief cause of rarity is habitat loss. Garber's spurge: The Garber's spurge is limited primarily to rockridge pineland sites that undergo frequent burns. It is known to occur at four sites in the Keys.	USFWS 1999
Keystone Plants	Red Mangrove: Development has resulted in a 15 percent reduction in mangrove coverage and has decreased average mangrove patch size from 67.5 ha to 28.1 ha in the Florida Keys over the past 50 years. Impoundment and other activities that restrict water circulation can harm or kill mangroves by disrupting oxygen flow through the roots. Torchwood: Torchwood is locally abundant along disturbed edges of Keys' hammocks; however, Schaus swallowtail butterfly oviposits only on torchwood growing in the hammock interior. Croton: Crotons do not tolerate heavy shade. Herbaceous pineland plants are shaded out by overgrowing hardwood shrubs within 10 to 15 years in the absence of fire.	Strong and Bancroft 1994 Odum and Johannes 1975 Emmel 1995 a and b Nellis 1994
Wading Birds	Wading bird declines in the Florida Keys are largely influenced by direct loss of nesting habitat (mangrove forests) and increases in dry-season water depths caused by freshwater discharge. Increases in water depths decrease the birds' ability to successfully forage. Degradation in water quality in foraging sites has been implicated as a main limiting factor on wood stork population sizes.	J. Lorenz, unpublished data

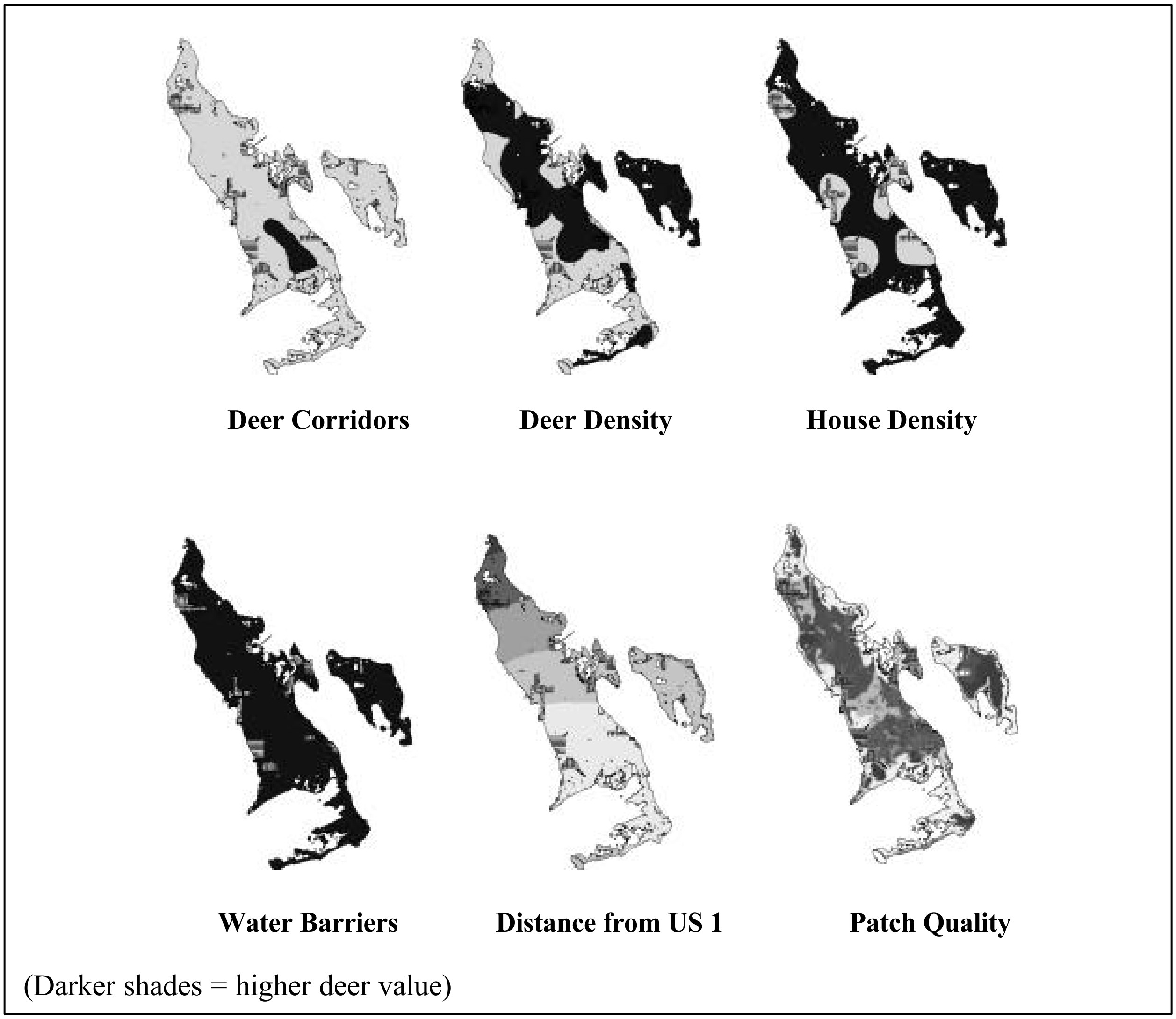
9.3.1 Key Deer Population Viability Analysis

The most studied terrestrial species in the Florida Keys is the Florida Key deer (*Odocoileus virginianus clavium*), yet existing detailed population studies were over 20 years old (e.g., Silvy 1975). Recent population research revealed that the Key deer population has tripled since the 1970s (Lopez 2001). The Key deer is the subject of an ongoing Habitat Conservation Plan (HCP), which addresses the species in detail. As part of the HCP, URS Corp. and Dr. Roel Lopez (Texas A&M University), on behalf of the FDOT, DCA, and Monroe County developed a population viability analysis for the Key deer. The PVA model included two main components: a matrix model of population dynamics and a spatial habitat model of carrying capacity and secondary impacts.

Lopez (2001) studied the ecology and population dynamics of the Key deer for three years (1998-2000). As part of the HCP studies, the movement, habitat utilization, and fate of over 150 individual deer were followed for the three years of the study. Quantitative information on mortality and fecundity for deer of different ages was used to create a matrix model, which allows for simulating the fate of the population under different scenarios. In the matrix model, changes in mortality or fecundity result in changes in the way the population fluctuates through time.

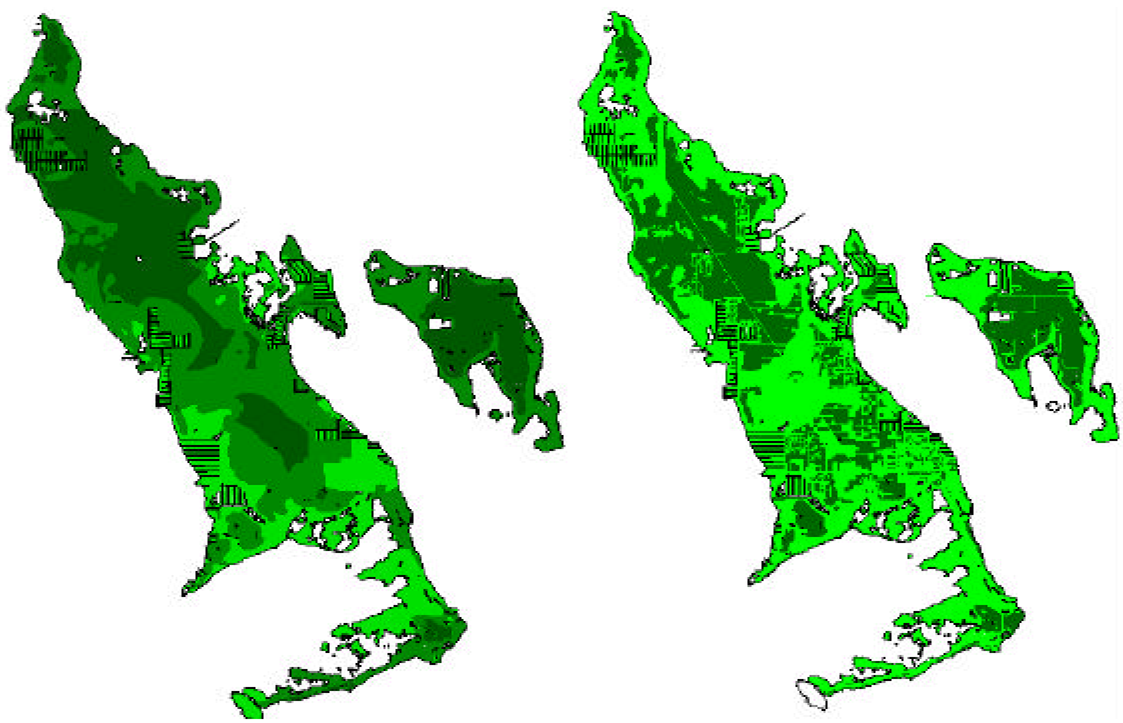
Coupled with the matrix model, the habitat preferences of the Key deer and data on Key deer mortality due to vehicle collisions and other human effects were used to determine the contribution of different habitats to the carrying capacity (i.e., the number of deer the area can support) and the "harvest" (i.e., contribution to mortality due to human impacts) for Big Pine and No Name Keys. The spatial model included six layers that represented different habitat characteristics for the Key deer, including deer corridors, deer density, house density, water barriers, distance from U.S. 1, and patch quality (Figure 9.2).

FIGURE 9.2
SIX GRID LAYERS USED TO GENERATE WEIGHTING FACTOR GRID FOR THE KEY DEER PVA



The values representing the habitat characteristics in the six layers were normalized. A weighting factor was then generated to weight the expected deer impacts in two forms - primary impacts (e.g., loss of habitat or change in carrying capacity) and secondary impacts (e.g., increase in traffic) (Figure 9.3).

FIGURE 9.3
KEY DEER PVA MODEL GRID LAYERS – FOR ANY GIVEN SCENARIO, THE LOCATION AND INTENSITY OF DEVELOPMENT AFFECT BOTH THE CARRYING CAPACITY (CARRYING CAPACITY GRID) AND THE MORTALITY (HARVEST GRID) OF THE KEY DEER

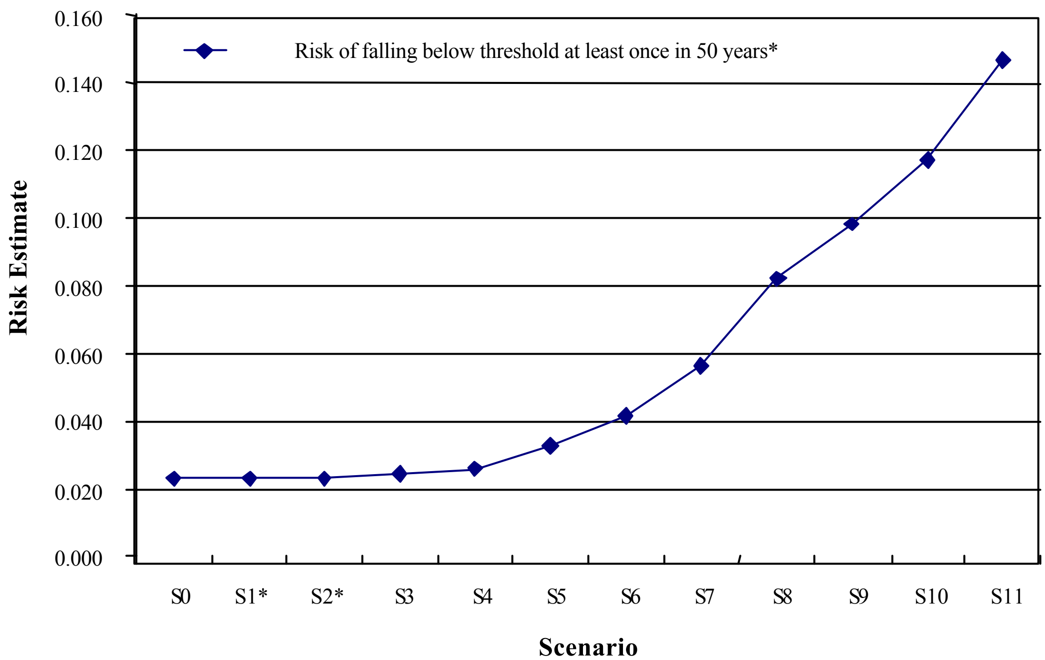


Harvest Grid **Carrying-Capacity Grid**

(Darker shades = higher deer value)

The PVA model evaluated twelve development intensities. In each scenario, the model "chooses" parcels to be developed beginning with those of lowest quality for the Key deer. Risk of extinction increases with development intensity (Figure 9.4, Table 9.3). Risk increases faster as higher-quality parcels become developed.

FIGURE 9.4
KEY DEER POPULATION VIABILITY ANALYSIS
POTENTIAL EFFECT OF DEVELOPMENT ON THE KEY DEER POPULATION
(SCENARIOS PER TABLE 9.3)



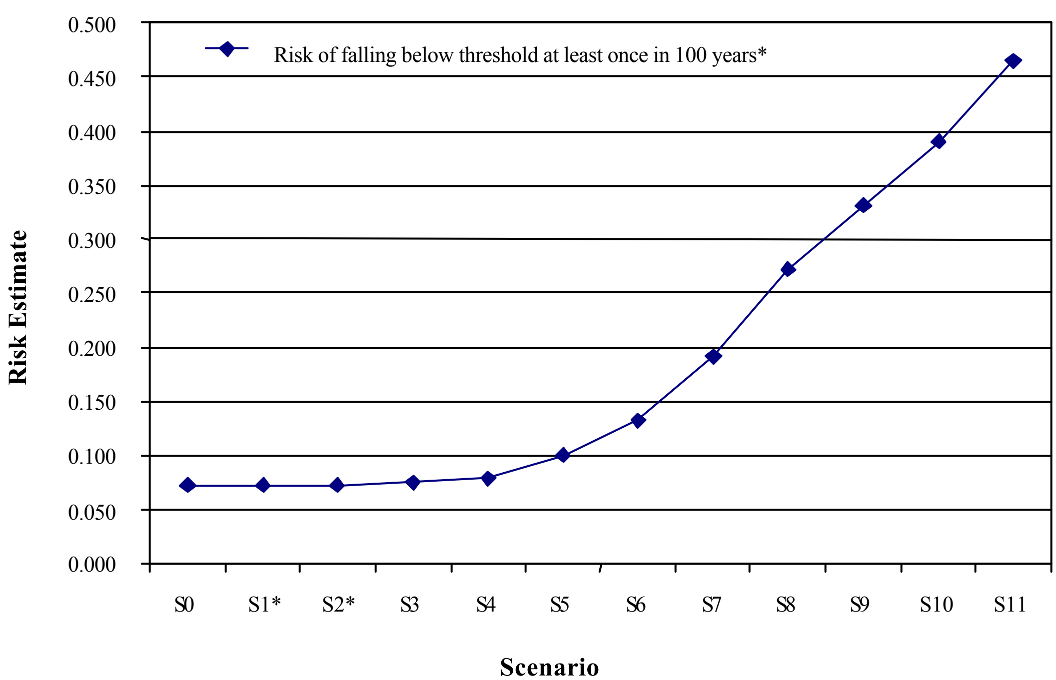


TABLE 9.3
KEY DEER POPULATION VIABILITY ANALYSIS
POTENTIAL EFFECT OF DEVELOPMENT ON THE KEY DEER POPULATION

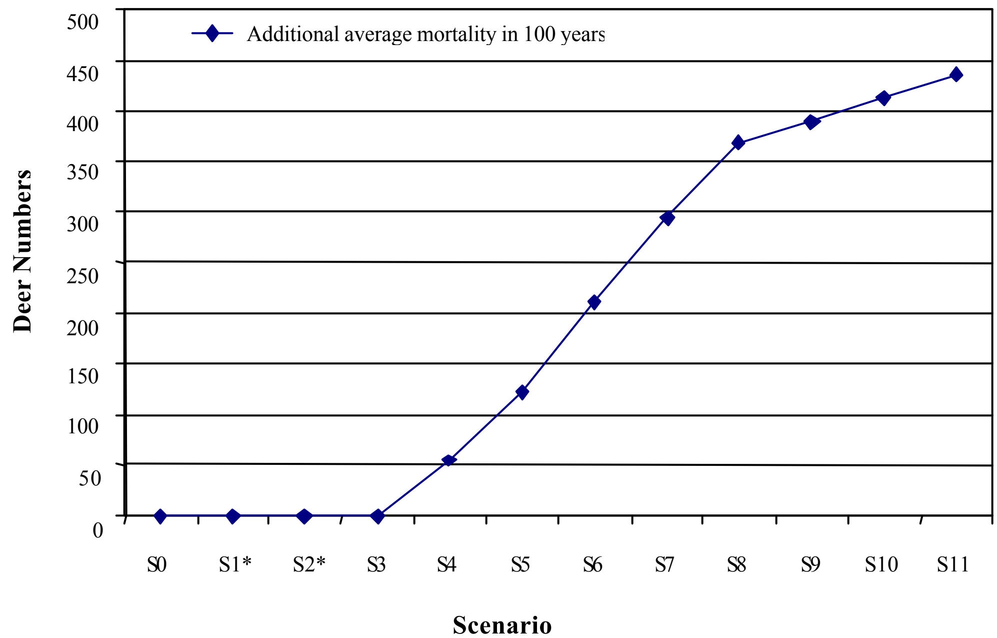
Scenario	Building Units	Habitat Loss (acres)	Habitat Loss (*K* decrease) **	Total Harvest **	Extinction Risk in 100 Years (%)	Risk (%) of Falling Below Threshold at Least Once In 50 Years***	Additional Average Mortality in 100 Years
S0	0	0	0	0.0000	0.05	0.23	0
S1*	0	0	0	0.0000	0.05	0.23	0
S2*	0	0	0	0.0000	0.05	0.23	0
S3	200	74	4	0.0003	0.05	2.42	0
S4	300	111	6	0.0034	0.06	2.63	55
S5	400	148	8	0.0068	0.07	3.27	124
S6	500	185	10	0.0108	0.11	4.16	210
S7	600	222	12	0.0160	0.17	5.67	295
S8	700	259	14	0.0220	0.28	8.23	368
S9	800	297	24	0.0251	0.66	9.81	389
S10	900	334	27	0.0288	0.73	11.73	412
S11	1000	371	30	0.0331	0.98	14.70	435

Notes:

* S1 = Ongoing U.S. 1 improvements (wildlife underpasses and intersection improvement).
S2 = Ongoing U.S. 1 improvements plus cross-island road. All other scenarios include the U.S. 1 and cross-island road improvements.
** K = carrying capacity; habitat loss and harvest are estimated by the spatial component of the model.
*** The threshold refers to 50 animals.

The PVA model also provides an estimate of additional mortality, which represents an estimate of "take" due to the level of development. The test model runs suggest that annual take increases linearly with the intensity of development (Table 9.3, Figure 9.5).

FIGURE 9.5
KEY DEER POPULATION VIABILITY ANALYSIS
EFFECT OF DEVELOPMENT ON THE LEVEL OF TAKE OF KEY DEER



9.3.2 Lower Keys Marsh Rabbit Population Biology and Viability

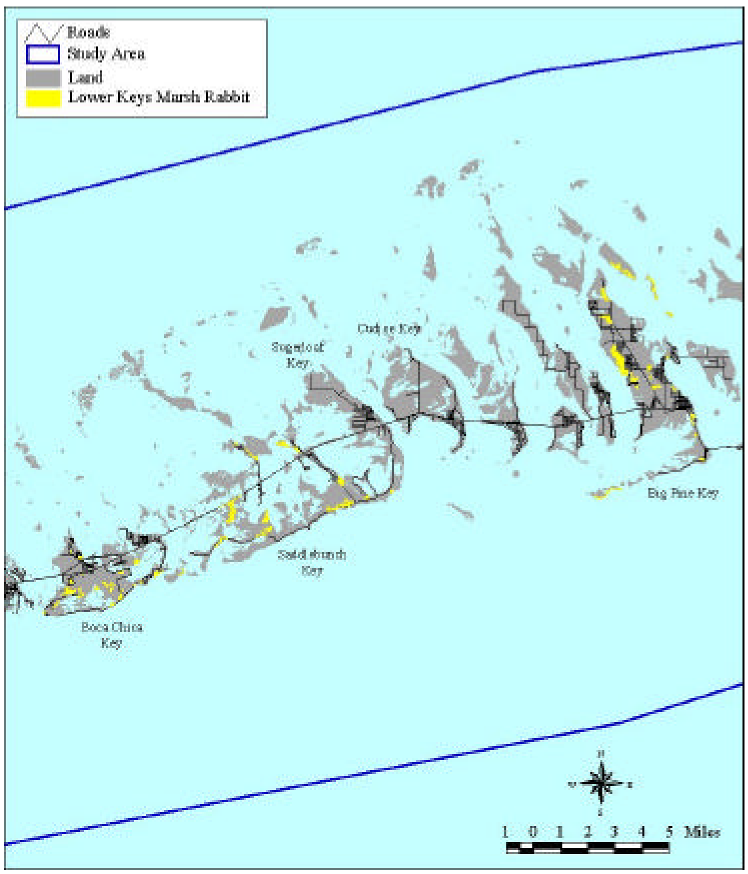
Recent literature documents the population biology and population viability of the endangered Lower Keys marsh rabbit. Forys and Humphrey (1999) developed a PVA for the marsh rabbit in order to estimate the threat of extinction faced by the marsh rabbit and determine the necessity and efficacy of different management strategies. The sampling phase of the study occurred from March 1991 through July 1993 at six habitat patches on Boca Chica Key and Saddlebunch Key. The marsh rabbit was known from 41 patches (or sub-populations) of transition zone habitat on three keys (or metapopulations) of the 12 main Lower Keys.

The marsh rabbit uses transitional saltmarsh habitat dominated by cordgrass and buttonwood located between the mangrove community and upland hardwood or pine hammocks. Populations have diminished since first being described as abundant by dePourtales (1877). Rapid development activities through the 1970s and 1980s left a patchwork of habitats across the Lower Keys. Analysis of marsh rabbit home range and movements led to the calculation of a minimum patch size of 0.5 hectares. Typically, the only movements observed are dispersing sub-adult males moving from their natal patch to another patch.

Results of the simulations indicate survival, particularly for adult females, must be increased for the marsh rabbit to persist. Other than development, domestic cats represent the main threat to the Lower Keys marsh rabbit and are the principal cause of mortality. Since the rabbit occurs in small, relatively disjunct populations, has a low population density, and is subject to predation by domestic predators, the species is in danger of extinction.

The USFWS maintains a GIS data layer (provided by Dr. Phil Frank, USFWS), which documents the status of every suitable habitat patch for the Lower Keys marsh rabbit (Figure 9.6).

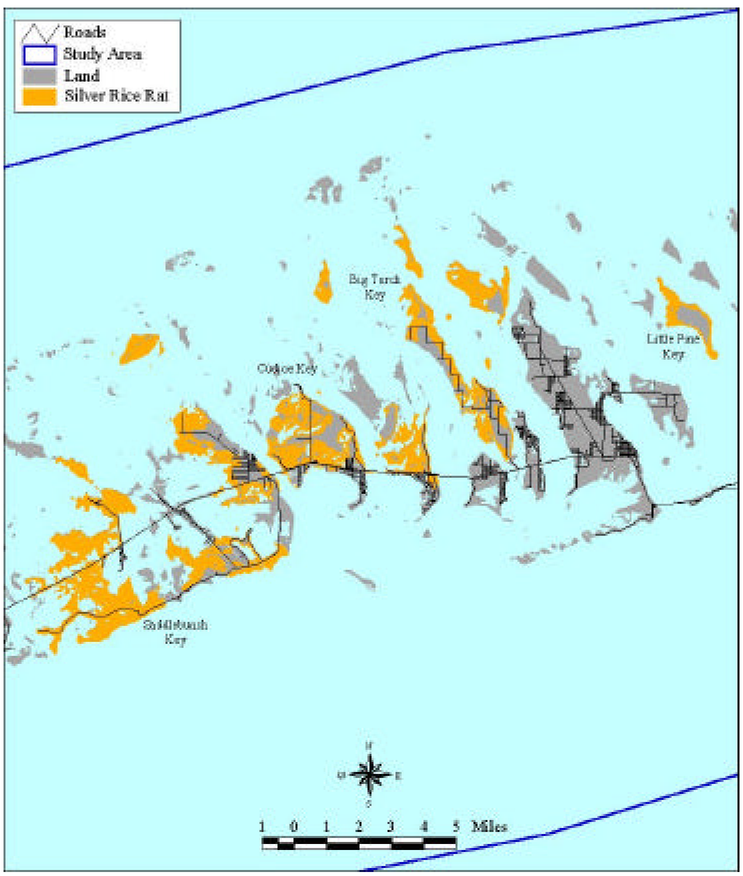
FIGURE 9.6
LOWER KEYS MARSH RABBIT HABITAT



9.3.3 Silver Rice Rat

The silver rice rat (*Oryzomys palustris natator*) is a medium-sized, semi-aquatic rat known to occur on 12 islands of the Lower Keys (Forys, et. al. 1996). Viable populations require large, contiguous mangrove and salt marsh habitats for foraging and salt marsh habitats for nesting. Freshwater marshes that lie adjacent to salt marshes are also used along with buttonwood transitional vegetation. The silver rice rat is primarily nocturnal with large home ranges commonly traveling 325 meters in a day (Forys, et. al. 1996). They prefer animal material for forage but are omnivorous, including a variety invertebrates and seeds (Spitzer 1983, Goodyear 1992). Threats to their survival are habitat loss and non-native predators including black rats and domestic cats (Forys, et. al. 1996). The USFWS maintains a GIS data layer (provided by Dr. Phil Frank, USFWS), which documents the status of every suitable habitat patch for the silver rice rat (Figure 9.7).

FIGURE 9.7
SILVER RICE RAT HABITAT

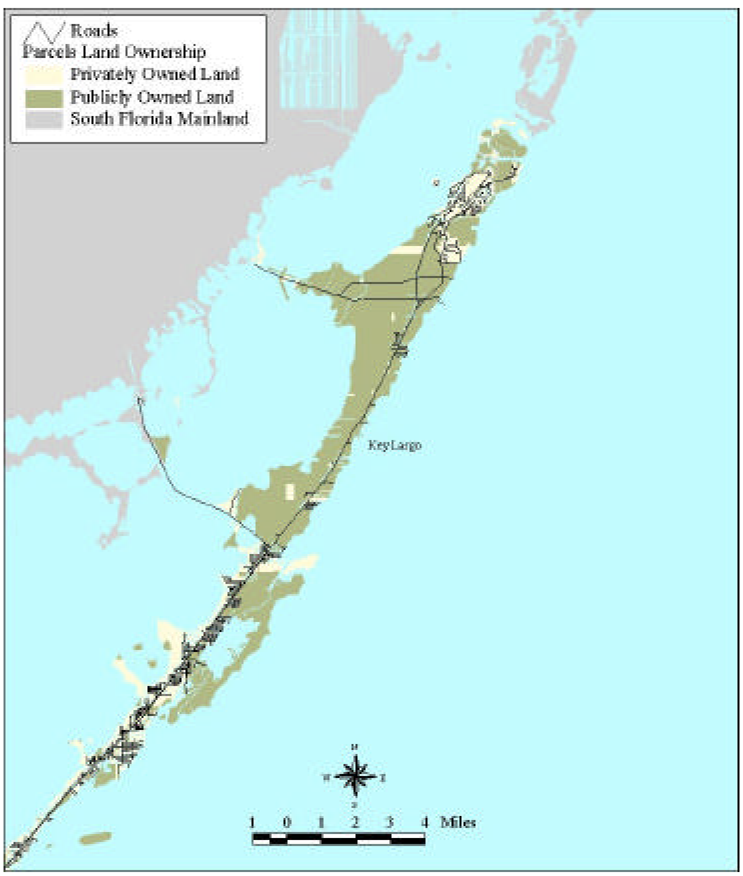


9.3.4 Key Largo Woodrat

The Key Largo woodrat (*Neotoma floridana smalli*) is a small rodent, currently limited to northern Key Largo, but it once ranged over the entire island. The woodrat builds large stick nests for resting, feeding, and breeding. Females are on average much smaller than the males (Hersh 1981). Key Largo woodrats are active climbers (Goodyear 1985) and have overlapping home ranges. They have defined trails and fallen trees are often used to move through the hammocks. The Key Largo woodrat is capable of reproducing all year although winter peaks are evident (Hersh 1981). They are nocturnal omnivores but feed primarily on plant material (Brown 1978). The primary threat to their survival is habitat loss and fragmentation. Natural and increased levels of predation are a threat including raccoons and domestic and feral cats.

The Multi-Species Recovery Plan for South Florida (FWS 1999) cites 4,445 acres (91 percent) of suitable Key Largo woodrat habitat is in public ownership and, therefore, protected; the remainder is in private ownership (Figure 9.8).

FIGURE 9.8
LAND OWNERSHIP IN KEY LARGO



9.3.5 Schaus Swallowtail Butterfly

Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*) is a large blackish-brown and yellow butterfly; antennae are black but males have a yellow knob. Historically they are known from hardwood hammocks from southern Miami to Lower Matecumbe Key in the Middle Keys. Their current range is largely diminished. Two unconfirmed sightings occurred over 20 years ago in the Lower Keys (FWS 1982, Covell 1976). Males prefer trails and edges of the hammock and females typically fly within the hammocks (Rutkowski 1971). The butterflies are diurnal and short-lived. They have a single annual flight-season from May to June, and there is only one generation per year (Emmel 1985). The Schaus swallowtail butterfly population has been in general decline for many years primarily because of habitat destruction but also from pesticides, road kill, extreme climatic conditions, and collectors.

The vast majority of the Schaus swallowtail butterfly in the Florida Keys is under public ownership and has conservation status (Figure 9.8).

9.3.6 Other Species Directly Addressed in the CCIAM

The CCAIM incorporates habitat requirements for the white-crowned pigeon (*Columba leucocephala*) and five species of forest-nesting birds. The white-crowned pigeon occurs in several areas of the Florida Keys, and is an important seed disperser in upland forests (Bancroft et al. 1994). White-crowned pigeons nest primarily on mangrove islands (Strong and Bancroft 1994), but must disperse to hardwood hammocks to meet foraging needs. Once they have fledged, young white-crowned pigeons show a strong preference for hardwood hammocks 5.0 hectares or greater within the first 72 hours of fledging (Strong and Bancroft 1994). After this, white-crowned pigeons generally stay within hardwood hammocks, avoiding urban areas (Strong and Bancroft 1994). Viable foraging habitat represents the major limiting factor for the white-crowned pigeon (Strong et al. 1991).

Bancroft et al. (1995) determined the minimum patch size below which five forest-nesting bird species were unlikely to be found. The species studied were the white-eyed vireo (*Vireo griseus*), the black-whiskered vireo (*Vireo altiloquus*), the northern flicker (*Colaptes auratus*), the yellow-billed cuckoo (*Coccyzus americanus*), and the mangrove cuckoo (*Coccyzus monor*).

9.4 Module Components

The CCIAM measures direct and indirect impacts from land development scenarios on terrestrial habitats and species (Table 9.4). The Florida Keys consists of an elongated group of islands whose terrestrial habitats are naturally fragmented. Development has greatly increased the degree of fragmentation mainly by reducing habitat patch size, increasing distances between patches, and in some cases creating barriers to dispersal (Strong and Bancroft 1994). Thus, habitat-based parameters provide adequate criteria and are used as the basis for determining ecological thresholds for selected species of the Keys.

TABLE 9.4
TERRESTRIAL MODULE COMPONENTS AND ELEMENTS

Component	Elements
Direct Impacts	
Species Richness	Composite species richness index Areas supporting 17 individual species
Overall Habitat Statistics All Upland Habitats Greater Than 13 Acres	Number of Patches Patch Size (total area, minimum, maximum, mean) Frequency distribution of patch sizes (0-5, 5-10, 10-20, >20 acres) Number of Patches Patch size (total area, mean)
Species-specific habitat statistics	Lower keys marsh rabbit Key deer Silver rice rat Key Largo woodrat Schaus swallowtail butterfly White-crowned pigeon Black-whiskered vireo White-eyed vireo Northern flicker Yellow-billed cuckoo Mangrove cuckoo
Indirect Impacts	
Overall Habitat Statistics All Upland Habitats Greater Than 13 Acres	Number of Patches Patch Size (total area, minimum, maximum, mean) Frequency distribution of patch sizes (0-5, 5-10, 10-20, >20 acres) Number of Patches Patch size (total area, mean)

Direct loss of habitat due to development is the most recognizable and easiest impact to measure. The module evaluates direct land use impacts on terrestrial ecosystems and species by calculating a species richness index, statistics on overall habitat characteristics, and impacts on 11 individual species. Indirect or secondary impacts of development are also calculated for overall habitat characteristics. All analyses in this module are spatially explicit and are performed using GIS processes. The basic inputs for the Terrestrial Module include the user-defined land use scenario, the ADID vegetation map, a species richness map, and species habitat requirements.

9.4.1 Direct Impacts

Direct Impacts to Species Richness

The Florida Keys support many rare, endemic, and legally protected terrestrial plant and animal species. This module component estimates the direct impacts of development to seventeen selected species (Section 9.2.3). This approach provides a surrogate measure of land use effects on species richness by focusing on a subset of the terrestrial species of the Florida Keys for which sufficient data exists. The CCIAM overlays developed areas from the user-defined scenario land use map with the species richness map to calculate impacts for each planning unit.

Development effects on the 17 species are expressed as a species richness index, and for each individual species. The richness index represents an average of the number of species per cell; developed cells have a value of 0:

Species Richness Index for Direct Impacts = ? (# of species per cell)/total # of cells

Direct habitat impacts for each of the 17 species are reported as acres remaining per planning unit.

Direct Impacts to Habitat

Land use change affects the number and size of habitat patches as well as the overall amount of available habitat in terrestrial environments. Patch statistics provide a means to assess the direct habitat displacement or restoration due to land use change. Outputs, calculated as summary statistics for each habitat type, include the number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes. Together, these statistics provide a measure of habitat loss and fragmentation. The number of patches less than 5, 5 to 10, 10 to 20, and greater than 20 acres are calculated for each habitat type. For example, an increase in the number of small patches of hammock with a loss of total hammock acreage indicates that habitat has been reduced and fragmented; therefore, the hammocks may not be able to maintain ecosystem integrity or support the life history requirements of some species. Keys hammocks smaller than 13 acres are considered “all edge,” with forest interiors lacking the buffering effects of edge vegetation (Strong and Bancroft 1994). Statistics calculated and reported for each of the 15 ADID habitat categories, as well as for upland habitat types that exceed 13 acres in size include: number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes.

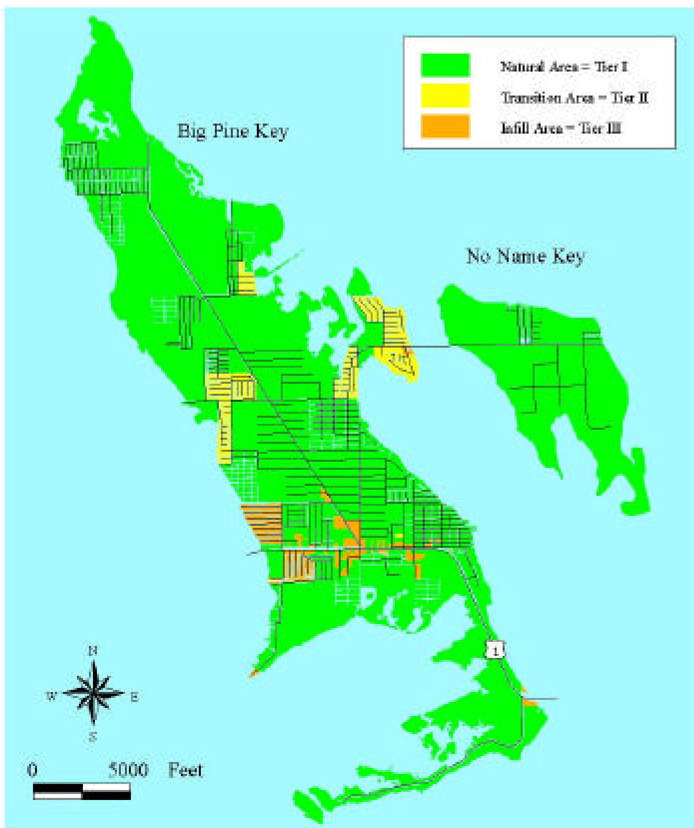
Direct Impacts on Species-Specific Habitat

GIS overlay techniques are used to analyze the direct impacts of development on 11 terrestrial species: Key deer, Lower Keys marsh rabbit, silver rice rat, Key Largo woodrat, Schaus swallowtail butterfly, white-crowned pigeon, black-whiskered vireo, white-eyed vireo, northern flicker, yellow-billed cuckoo, and mangrove cuckoo. For each user-defined scenario, the CCIAM evaluates the effects of direct habitat conversion on each of the species.

The Key deer, Lower Keys marsh rabbit, and the silver rice rat are incorporated into the CCIAM using habitat maps developed from extensive research performed in other studies (discussed in Section 9.2). The PVA for the Florida Key deer produced a habitat suitability map, which is used in the CCIAM to evaluate impacts to this species. The map shows three types of areas, or “tiers” (Figure 9.6). Development in Tiers 2 and 3 is of lower consequence to the Key deer. Development in Tier 1 results in significant impacts. A scenario is reported to exceed thresholds if any new development occurs within Tier 1. Throughout the range of the species, outside of Big Pine and No Name Keys, any habitat loss outside subdivisions is also considered to surpass a carrying capacity indicator.

The Lower Keys marsh rabbit is highly endangered, with a high probability of extinction in considerably less than 100 years (Forys and Humphrey 1999). The CCIAM assesses encroachment on marsh rabbit habitat as determined in the USFWS GIS habitat layer. The model is constructed such that no further loss of the marsh rabbit is allowed under any scenario. Thus, a scenario is reported to exceed thresholds if new development occurs on or within 500 m feet of marsh rabbit habitat.

FIGURE 9.9
HABITAT SUITABILITY FOR KEY DEER



The other nine species are incorporated in the CCIAM by assessing either encroachment into existing habitat (silver rice rat, Key Largo woodrat, Schaus swallowtail butterfly), specific habitat requirements (white-crowned pigeon, Table 9.5), or minimum patch size requirements (forest-nesting birds, Table 9.6).

TABLE 9.5
WHITE-CROWNED PIGEON HABITAT REQUIREMENTS[1]

Parameter	Threshold
Nesting areas – habitat	Mangroves
Immature – dispersal habitat	Hammock patch of at least 12 ac
Immature – dispersal distance	6.8 miles
Mature – habitat	Hammock patches of at least 2 ac

[1] Strong and Bancroft, 1994.

TABLE 9.6
HAMMOCK PATCH SIZE REQUIREMENTS FOR FOREST INTERIOR BIRDS[1]

Parameter	Threshold
Black-whiskered vireo	0.2 ac
White-eyed vireo	2.3 ac
Northern flicker	3.5 ac
Yellow-billed cuckoo	7.5 ac
Mangrove cuckoo	12.8 ac

[1] Bancroft et al., 1995.

9.4.2 Indirect Impacts

A variety of indirect and secondary impacts from adjacent developed land uses affect habitat quality. These effects include noise, domestic predators, light pollution, run off, and invasion of exotics, among others. There is ample evidence that indirect and secondary impacts do occur, and that they decrease with increasing distance from development. The available data, however, is less precise regarding the specific biological consequences of these impacts, the differential response of species, the rate at which effects decrease with distance, or differential land use effects (Table 9.7).

TABLE 9.7
EFFECTS OF DEVELOPMENT ON ADJACENT HABITATS

Effect Distance	Effect	Reference
Microclimate and Edge Effects		
98	Climatic structural edge influences into a forest (west side).	Ranney et al., 1981
300	Negative impacts on wildlife species from edge effects.	Brown and Schaefer, 1987
450	Changes in air temperature and relative humidity.	Ledwith, 1996
16,404	Edge effects within a reserve boundary.	Janzen, 1986
Surface Water Quality		
35	Less than this is not enough to sustain long-term protection of aquatic resources.	Tjaden and Weber, 1997
35-100	Most common minimum buffer widths for use in water quality and habitat maintenance.	
45	Buffers equal to or greater than this have proven effective in reducing some pesticide contamination of streamflow.	Palone and Todd, 1997
49-66	Minimum buffer for low slopes.	Karr and Schlosser, 1977
75-200	Suggested buffer width for flood control.	Tjaden and Weber, 1997
75	Wetland buffer to minimize sedimentation from coarse sand.	Brown et al., 1990
200	Wetland buffer to minimize sedimentation from fine sand.	
200	Buffer for development adjacent to Aquatic Preserves.	JEA*, 2000
300	The zone most influential to surface water quality.	Brown et al., 1990 Florida Division of Forestry, 1979
450	Wetland buffer to minimize sedimentation from silt.	Brown et al., 1990
Air Quality and Urban Glow		
492	Minimum recommended distance from beach for lights mounted higher than 16 ft.	Witherington and Martin, 2000
Noise and Vibration		
246	Distance from roadway centerline range for which the acceptable noise range for single-family residential uses is 60 to 65 dB(A), 60 to 70 dB(A) for schools, and less than 70 dB(A) for parks.	City of Monterey Park, 2001
1,640	Area within which breeding bird densities of 3 grassland bird species were significantly reduced adjacent to quiet rural roads.	Van der Zande et al., 1980
Habitat		
15 25	Minimum width to prevent secondary impacts to habitat functions of wetlands. Average width to prevent secondary impacts to habitat functions of wetlands.	St. John's River Water Management District, 1999
30	Insufficient to protect wetlands.	Miller and Gunsalus, 1997
100	Minimum width necessary to avoid significantly impacting riparian environments.	Ledwith, 1996
300	Sufficient to protect wetland functions from upland development, i.e. 50 percent of wetland-dependent wildlife and water quality from erosion of sands.	Castelle et al., 1994 Miller and Gunsalus, 1997 JEA, 2000

TABLE 9.7 (CONTINUED)
EFFECTS OF DEVELOPMENT ON ADJACENT HABITATS

Effect Distance	Effect	Reference
	Generally accepted minimum width for wildlife.	Connecticut River Joint Commissions, 2000
322	Buffer to protect saltwater and freshwater marshes in East Central Florida.	Brown et al., 1990
322-732	To protect wetland resources.	
550	Buffer to protect hammock and forested wetlands in East Central Florida.	
Wildlife		
50	Buffer landward from wetlands jurisdictional line to allow semi-aquatic species area to nest/over winter.	Brown and Schaeffer, 1987
164	To support several interior bird species.	Tassone, 1981
164-197	To support hairy and pileated woodpeckers.	
207-584	Recommended setback for 15 species of breeding colonial birds.	Rodgers and Smith, 1995
220-413	Recommended buffer for 16 species of water birds.	Rodgers and Smith, 1997
240	Minimum distance from humans tolerated by snowy egrets.	Klein, 1989
322	Wildlife in salt marsh habitats.	Brown and Orell, 1995
322-550	Wetland-dependent wildlife species in freshwater riverine systems.	
328	Buffer for neotropical migrant birds.	Triquet et al., 1990
328	Width of buffer strips to protect intrinsic wildlife value.	Tassone, 1981
492-574	Buffer for protection of 90-95 percent of bird species.	Spackman and Hughes, 1995
536	Buffer zone for wetland wildlife.	Brown and Schaeffer, 1987
750	Distance of no human activity around bald eagle's nest.	USFWS, 1999
750-1500	Distance of no buildings proximate to bald eagle's nest.	
984-1968	Nest predation into a forest.	Wilcove et al., 1986
Feral Animals		
112 ha	Home range for female cats.	Warner, 1985
228 ha	Home range for male cats.	
4 acres	Home range for dogs.	Beck, 1973
Other		
75	Set-back of septic systems (regulations in VT and NH).	Connecticut River Joint Commissions, 2000

* JEA = Jones, Edmunds & Associates, Inc.

Most studies show indirect impacts to habitat between 200 to 500 feet away from development, depending on development type and intensity. The CCIAM assumes that indirect impacts occur up to 500 feet around developed areas without attempting to quantify the magnitude of the impact. Habitat parameters calculated for indirect impacts are the same as those calculated for direct impacts. For all ADID vegetation types and upland habitat greater than 13 acres, summary statistics calculated include: number of patches, patch size (total area, minimum, maximum, mean), and frequency distribution of patch sizes. The statistics are reported for those areas not affected by the 500-foot buffer, and therefore, represent habitat in which neither direct nor indirect impacts occur.