Change in dense forest habitat for endangered wildlife species in Costa Rica from 1940 to 1977

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ABSTRACT
Habitat availability is a key factor in biological extinctions. Existence and loss of dense forest habitat for 27 endangered wildlife species in Costa Rica is quantified and analyzed using vegetation maps, density estimates and insular ecology theory. From 1940 to 1977 species suffered an average 35% destruction of dense forest habitat. A number of species including: *Myrmecophaga tridactyla, Panthera onca, Harpia harpyja* and *Ara ambigua* will probably go extinct in Costa Rica within the next century due to lack of sufficiently large dense forest habitat areas for survival. The importance of protecting large areas of dense forest habitat for conserving genetically "viable" wildlife populations is emphasized and key areas are identified for each species. In addition species are ranked as to degree of endangerment using biological parameters.

KEY WORDS
Endangered species, dense forest, viable populations, protected areas.

RESUMEN
El hábitat es un elemento clave en la extinción de especies. Con base en mapas de vegetación, estimaciones de densidad poblacional y teoría de ecología insular analizo la pérdida de bosque denso para 27 especies de Costa Rica. Entre 1940 y 1977, sufrieron en promedio 35% de destrucción del hábitat de bosque denso. Especies como *Myrmecophaga tridactyla, Panthera onca, Harpia harpyja* y *Ara ambigua* probablemente se van a extinguir en Costa Rica dentro del próximo siglo debido a que les hace falta suficientes áreas de bosque denso para sobrevivir. Es fundamental la importancia de proteger áreas grandes de hábitat de bosque denso para conservar poblaciones "viables" de vida silvestre.

PALABRAS CLAVE
Especies en vías de extinción, bosque denso, poblaciones viables, áreas silvestres.

Of a total of 674 vertebrate species currently (1983) considered endangered with extinction on a worldwide level, 449 (67%) are in this state primarily because of habitat destruction, the most serious threat to all vertebrate groups except for certain reptiles (IUCN 1976, 1978). In tropical countries, it is estimated that 10-20 million hectares of forest cover is decreasing per year and if this trend continues, 50 % of existing tropical forests will be eliminated in the next 20 years. The principal direct causes of forest loss are: (a) poorly managed industrial logging, (b) fuel wood gathering, and (c) its conversion and use for agriculture and cattle raising (US Dept. of State 1981). Latin America contains about five million km^2 or over 50% of the worlds remaining tropical moist forests, with about 4,7 million km^2 found in South America and the rest in Central America and the Caribbean (Myers 1980). In Latin America, most countries have long endangered species lists and the major threat to these animals is considered to be habitat alteration (Fosberg 1973). Unfortunately information on tropical forest destruction (Myers 1980, Whitmore 1980) is usually general in nature and does not quantify species status (Vaughan 1978).

Recent information in insular ecology theory suggests great importance in the distribution and size of primary vegetation islands or isolates for conservation of genetically viable populations of vertebrate wildlife (Terborgh 1974, Diamond 1975, Pickett & Thompson 1978 , Wilcox 1980, Frankel & Soulé 1981).

The objective of this study is to provide data on the recent historic and present size and distribution of dense forest habitat in Costa Rica for 27 vertebrate wildlife

species, most of which are legally protected and recognized as endangered in Costa Rica. The results clarify: (a) general habitat requirements for each species, (b) the current status of endangered species, (c) the current status of endangered species in Costa Rica as relates to dense forest (80-100% forest cover) habitat destruction with emphasis in the last 40 years, (d) location of protected and unprotected dense forest habitat for each species and, e) the feasibility of conserving "viable" populations of these species in Costa Rica and elsewhere for long-term fitness defined as the minimum effective population size that provides for continuing evolutionary change in quantitative characters (Frankel & Soulé 1981).

METHODOLOGY

Most of the wildlife species discussed here are protected by Costa Rica law as endangered species (Poder Ejecutivo 1979). Identification and calculation of dense forest habitat for each wildlife species follows that suggested by Vaughan (1978) and is summarized below. First, a literature review and interviews with knowledgeable persons determined recent historic distribution, densities and habitat types for each species in Costa Rica and throughout its range. Second, trained university students using photographs of each species to aid in identification interviewed hunters and scientist throughout Costa Rica (Fig. 1 in Appendix 5) and located recent sightings (1975-1979) of endangered species on topographical maps (1:200.000 scale). A maximum of three observations for species was recorded from each person interviewed. Observations were plotted on individual maps (1:1.000.000 scale) for each species. Third, distribution of dense forest habitat (80-100% forest cover) for different years (Preconquest (1500), 1940, 1950, 1961, 1977) was mapped for each species using altitudinal and geographical limitations, interview data mentioned above and dense forest vegetation maps for those periods (Dirección General Forestal 1979). For each species, a second map for 1977 forest cover map was divided into the following vegetative habitats: (a) 90-100% forest cover, (b) 45-80% forest cover and (c) swamp forest, mangrove and subalpine paramo. Species observations (1975-1979) were also plotted on individual maps. Fourth, size of dense habitats for different years, vegetation types in 1977 and protected and unprotected island or isolates of dense forest habitat in 1977 were calculated by electronic planimeter (Hewlett-Packer 9862- X-Y Plotter).

Finally, the number of individuals for each wildlife species in dense forest habitat islands in 1977 was also estimated by multiplying those areas by densities reported in the literature for each species. Literature review (Goodwin 1946, Handley 1950, Hall & Kelson 1959, Skutch 1964, Slud 1964, Leopold, 1965, Henderson 1969, Hornocker 1969, Land 1970, Peterson & Chalif 1973, Mendez 1974, Ridgeley 1976) and interviews were carried out.

ANALYSIS

Eight of the 27 wildlife species studied were found in dense forest habitat country wide from sea level to about 3000 meter including subalpine paramo. Sixteen species were present in dense forest habitats at different elevations countrywide. The squirrel monkey, green macaw and the manatee occur in part of the Atlantic or Pacific slope. The crocodilians were grouped because of the difficulty in mapping habitat differences between them (Table 1).

This section will focus on the following points: (a) destruction of dense forest habitat up to 1977, (b) dense forest habitat in 1977, (c) altered areas and wilderness, (d) islands or isolates of dense forest habitat in 1977, (e) minimum population size for long-term species fitness, (f) the problem of calculating species densities in the tropics, (g) protected and unprotected dense forest habitat, (h) summary of important data for each species and (i) ranking of endangered wildlife species.

Destruction of dense forest habitat up to 1977

Before the Spanish Conquest, dense forest covered an estimated 49000km^2 (96%) of Costa Rica with about 2000km^2 (4%) made up of mangrove, swamp forest and subalpine paramo. The extension of clearing made by indigenous tribes is unknown. Up to 1940, only about 15000km^2 (31%) of the dense forest habitat had been altered (Table 2) and this alteration was concentrated in northwestern and central Costa Rica. Only 37 years later (1940-1977), 18000km^2 (38%) of the dense forest habitat was deforested, mostly on the Atlantic and South Pacific regions (Oficina de Planificación del Sector Agropecuario 1979).

Habitat of six widely distributed wildlife species, including the jaguar and tapir, follow the same pattern of dense forest destruction as that outlined in Table 2. Others, including the quetzal and squirrel monkey, have a more restricted distribution and occupied 25% and 15% respectively of the original dense forest habitat of wildlife species mentioned above. The squirrel monkey and giant anteater are found in lowland tropical forest habitats which have been under intense deforestation pressure since 1940, losing 45% and 39% of dense forest habitat respectively. In contrast, the quetzal, found between 1000-3000 meters elevation lost only 19% of its dense forest habitat between 1940 and 1977. On average, the wildlife species studied

TABLE 1.
General information about twenty eight endangered wildlife species in Costa Rica

Name	General Distribution	Distribution in Costa Rica	Habitat in Costa Rica	Additional Comments	Density (individuals / km^2)
Cebus capucinus White-faced Capuchin Mono carablanca	Belice through Central America to Paraguay in South America.	Both coasts in suitable habitat from sea level to approximately 3000 m.	Arboreal. Found in variable habitat types including: Primary and secondary forest, mangrove, swamp forest (*Raphia taedigera*), cloud forest and dry scrub forest.	Adaptable species. Will survive in deforested zones with secondary forest and little hunting pressure. A small troop exists in El Rodeo Protected Forest (Central Valley of Costa Rica). Legally protected	87 Manuel Antonio National Park. Costa Rica (Vaughan & McCoy 1984). 7.5 Hacienda La Barqueta, Panamá (Baldwin & Baldwin 1972). 16.0 Barro Colorado Island, Panamá (Oppenheimer 1968). 5.1-7.4 Santa Rosa National Park Costa Rica (Freese 1975).
Ateles geoffroyi Spider Monkey Mono Colorado, mono araña	Southeast México through Central America to Northern Colombia.	Both coasts in suitable habitat from sea level to approximately 2500 m.	Arboreal. Found in primary forest throughout the country to 2500 meters. A wilderness species.	First primate species to disappear with deforestation and hunting in a region. Legally protected.	6.4 Santa Rosa National Park, Costa Rica, (Freese 1975) 28 Tikal National Park, Guatemala (IUCN 1978. 45 Tikal National Parks. Guatemala (IUCN 1978).
Saimiri oerstedii Squirrel Monkey Mono ardilla	Southeast Costa Rica and Pacific coast of Panamá in the Chiriquí and Veráguas Provinces. Also is found on Almeja and Sevilla Islands in Panamá.	Southeast Costa Rica in suitable habitat from sea level to approximately 500 m.	Arboreal. Found in primary and secondary forest, mangrove, charral and perennial crop areas (banana and oil palm)	Adaptable. Survives in second growth and cultivated areas near human habitations. Legally protected.	.66 Manuel Antonio National Park, Costa Rica (Vaughan & Mc Coy1984). 13 Hacienda la Barqueta. Panamá (Baldwin & Baldwin 1972)
Alouatta palliata Howler Monkey Mono congo, mono aullador	Southern México through Central América to Colombia and Ecuador on the east side of the Andes	Both coasts in suitable habitat from sea level to approximately 2000 m.	Arboreal. Found in primary and secondary forest, and in patches of trees which follow water courses in deforested areas.	Not often hunted as a food source. Probably the most abundant wild primate in Costa Rica. Legally protected	17.5-25 Santa Rosa National Park, Costa Rica (Freese 1975) 80 Barro Colorado Island, Panama (Carpenter 1935)
Myrmecophaga tridactyla Giant anteater Oso caballo	Guatemala through Central America to Paraguay	Both coasts in suitable habitat from sea level to approximately 500 m.	Found in low land primary forest and natural sabanas	Very rare, perhaps extinct.	.12 Hato Masaguaraí, Guarico, Venezuela. (Eisenberg 1980).
Felis concolor Mountain lion Puma, León	From Canada through Central America to Patagonia	Both slopes in suitable habitat from sea level to 3820 m.	Found in a variety of habitat types including, primary and secondary forest, scrub, mangrove, open pastures subalpine paramo.	Very adaptable. Continues to be hunted. Legally protected.	.09 Hato Masaguaraí, Guarico, Venezuela. (Eisenberg 1980).

TABLE 1 (Continued...).
General information about twenty eight endangered wildlife species in Costa Rica

Name	General Distribution	Distribution in Costa Rica	Habitat in Costa Rica	Additional Comments	Density (individuals / km^2)
Felis pardalis Ocelot Manigordo, ocelote	Southern United States (Texas and Arizona) through Central America to Paraguay in South America.	Both coasts in suitable habitat from sea level to approximately 3820 m.	Found in a variety of habitat types including, primary and secondary forest, scrub, mangrove, open pastures subalpine paramo and coffee farms.	Continues to be hunted. Legally protected.	.14 Barro Colorado Island, Panama (Eisenberg 1980) .25Hato Masaguaraí, Guarico, Venezuela. (Eisenberg 1980).
Felis wiedii (a) Margay Caucel *Felis tigrina* (b) Little spotted cat Tigrillo	a) United States (Texas) through Central America, to Northern Argentina. b) Southern Costa Rica to Chile in South America.	Both coasts in suitable habitat from sea level to approximately 3820 m.	Found in a variety of habitat types including, primary and secondary forest, scrub, mangrove, open pastures subalpine paramo.	Arboreal. However reported by hunters in semi-open areas and the subalpine paramo region in Chirripó. Confusion exists concerning true distribution of each species, although *F. tigrina* is thought to inhabit southern part of the country and in greater range of habitats. Grouped for this report. Legally protected.	—
Felis yagouaroundi Jaguarundi León breñero, gatillo de monte	United States (Texas) through Central America to Argentina, but not found in Chile, Perú and Bolivia	Both coasts in suitable habitat from sea level to approximately 2000 m.	Found in a variety of habitat types including, primary and secondary forest, overgrown pasture and cultivated areas.	Considered common in altered areas. Having benefitted from deforestation. Most commonly reported wild feline. Legally protected.	.25 Hato Masaguaraí, Guarico, Venezuela. (Eisenberg, 1980). .8 Guatopo National Park, Venezuela (Eisenberg, 1980)
Panthera onca Jaguar, Tigre Jaguar	Historically from United States (Texas, New Mexico and Arizona) through Central America to Patagonia in South America.	Both coasts in suitable habitat from sea level to approximately 3820 m.	Found in primary forest near water courses, infrequently in subalpine paramo vegetation. Rarely encountered in cultivated or altered areas presumably because of hunting pressure. A wilderness species.	Occasional jaguar hunts are reported. Legally protected.	.027-.04 Mata Grosso, Brazil, (females) (Schaller and Crawshaw, 1980) .014-.020 Mata Grosso, Brazil (males) (Schaller and Crawshaw, 1980) .001 Argentina Northern border (UIUCN, 1978) .1 Guatopo National Park, Venezuela (Eisenberg, 1980)
Tayassu pecari White-lipped peccary Chancho de monte	Southern Mexico through Central America to Northeast Argentina.	Both coasts in suitable habitat from sea level to approximately 1500 m.	Found in remote, primary lowland forests. A wilderness species	Sometimes, found in herds of more than 100 individuals. Size of herd is probably indicative of environmental conditions and hunting pressure. Cover large areas while foraging.	—

TABLE 1 (Continued...).
General information about twenty eight endangered wildlife species in Costa Rica

Name	General Distribution	Distribution in Costa Rica	Habitat in Costa Rica	Additional Comments	Density (individuals / km^2)
Tayassu tajacu Collared peccary Saíno	Southern United States (Arizona, New Mexico and Texas), from Mexico through Central America, Colombia to Northwest Ecuador and from Venezuela and Surinam to Uruguay and Northern Argentina. Found on the Island of Trinidad in the West Indies.	Both coasts in suitable habitat from sea level to approximately 3000 m.	Found in a variety of habitat types including, primary and secondary forest, scrub and overgrown pasture, needs a nearby water source.	Open hunting season and under intense pressure in many areas.	8.5 Hatu Masaguari, Guarico Venezuela (Eisenberg, 1980) 2.0 Guatopo National Park, Venezula (Eisenberg, 1980) 16 Barro Colorado Island , Panamá (Eisenberg, 1980)
Tapirus bairdii Tapir Tapir, danta	Southern Mexico through Central America to the west coast of Colombia and Venezuela.	Both coasts in suitable habitat from sea level to approximately 3820 m.	Found in a variety of habitat types including, primary and secondary forest, mangrove, palm swamps and subalpine paramo. A wilderness species.	Presumably could survive in disturbed areas if not under hunting pressure. Legally protected.	.6 Guatupo National Park, Venezula (Eisenberg, 1980) .53 Barro Colorado Island , Panamá (Eisenberg, 1980) (Both Tapirus terrestres).
Trichechus manatus Sea cow Manatí, vaca marina	Eastern United States (North Carolina, South Carolina and Florida). West Indies, Eastern Mexico through Central America on the Caribbean Coast to Brazil in South America.	Found in the Caribbean coast in the principal rivers, and in the principal tributaries of the San Juan River. Altitudinally extends from sea level to only several hundred years.	Aquatic. Found in lagoons, estuaries, bays, large rivers and occasionally in the ocean near coast.	Number reduced by hunting. Rarely observed. Probably one of the rarest of wildlife species in Costa Rica. Legally protected.	—
Harpia harpyja Harpy Eagle Aguila arpía	Southern Mexico through Central America to Bolivia and Northern Argentina.	Both coasts in suitable habitat from sea level to approximately 1500 m.	Found in primary forest and swamp forest. A wilderness species.	Believe to be one of the rarest of wildlife species in Costa Rica. Legally protected.	.008-.016 Osa Península, Costa Rica (Stiles, estimation (1981).
Morphnus guianensis (a) Crested eagle Aguila crestada *Harpyhalietus solitarius* (b) Solitary Eagle Aguila solitaria *Spizaetus tyrannus* (c) Black Hawk-eagle Aguilillo negro *Spizaetus melanoleucus* (d) Black and white Hawk-eagle Aguilillo negri-blanco *Spizaetus ornatus* (e) Ornate Hawk-eagle Aguilillo denachudo	Honduras south through the rest of Central America to Perú and Northeast Argentina. Mexico through Central America to Venezuela and perú. Easter Mexico through Central America to Northern Bolivia, Northeast Argentina and Southern Brazil. Southern Mexico through Central America to Northern Argentina and Southern Brazil Eastern Mexico through Central America to Bolivia, Northern Argentina and Southern Brazil	Both coasts in suitable habitat from sea level to approximately 1500 m.	Found in primary forest and swamp forests. A Wilderness species.	Grouped for this report due to difficulty in disringuishing between them.	—

TABLE 1 (Continued...).
General information about twenty eight endangered wildlife species in Costa Rica

Name	General Distribution	Distribution in Costa Rica	Habitat in Costa Rica	Additional Comments	Density (individuals / km^2)
Crax rubra Great currasow Pavón real	Southern Mexico through Central America to Perú.	Both coasts in suitable habitat from sea level to approximately 200 m.	Found in primary and secondary forest, partially cleared areas and scrubby woodland.	One of the most persecuted of the game birds. Has been eliminated from much of its habitat.	.4-1.2 Corcovado National Park, Costa Rica, (Stiles, estimation 1981).
Ara ambigua Green macaw Guacamayo verde	Southern Mexico through Central America to Perú.	Atlantic coast in suitable habitat from sea level to approximately 1500 m.	Inhabits primary forest although is sometimes seen flying over cleared areas.	Occasionally seen in the same forest types with Ara macao in Atlantic lowlands. Covers large areas seasonally while foraging.	—
Ara macao Scarlet macaw Guacamayo rojo	Southern Mexico through Central America to Northern Bolivia and Amazon Brazil	Both coasts in suitable habitat from sea level to approximately 1500 meters altitude. Less common on Atlantic coasts.	Found in primary forest, low land dry forest and occasionally in fruiting food trees in open areas.	Relativaly abundant in Corcovado National Park where 40 have been observed in one roosting area.	.08-.24 Corcovado National Park, Costa Rica, (Stiles, estimation 1981).
Pharomachrus mocinno Quetzal Quetzal	Southern Mexico through Central America to Western Panamá. There are two sub-species of quetzal in Central America. P. mocinno mocinno is found from México to Nicaragua and P. mocinno costarricense is found in Costa Rica and Panamá.	Both coasts in suitable habitat from 1000 to 3000 m.	Found in middle and high elevation primary forests. Occasionally seen fruiting food trees in open areas near forest edges.	Undertakes yearly altitudinal migrations.	2.7-2.9 La Tigra, Honduras (Hanson 1980).
Caiman crocodilus (a) Central American caiman Caiman, lagarto *Crocodylus actus* (b) American crocodile Cocodrilo, guaipal	Pacific coasts: México Through Central America to Panamá. Atlantic Coast: Nicaragua, Costa Rica, Panamá. b)United States (southern Florida) both coasts in Mexico through Central and South America to Brazil and Perú, also found in the West Indies.	Both coasts in suitable habitat from sea level to approximately 500 m.	a) Lowland fresh water, rivers, marshes ponds and lakes. b) Lowland salts brackish or fresh water aquatic habitats. Crocodrylus acutus is considered to be a much more salt and brackish water species than Caiman cocodrilus.	Grouped because of the difficulty of separating them habitat wise and problems involved in distinguishing between them in interviews. Future research needed to locate individual range of each in Costa Rica.	—

TABLE 2
Extension of dense forest in Costa Rica up to 1977

Year	Dense forest (*) Km^2	80-100% forest cover (%)
Preconquest, (1500)	48,845 (**)	100
1940	33,538 (**)	69
1950	27,084	53
1961	23,122	45
1977	15,901	31

(*) Does not include mangrove and swamp forest.
(**) Rough estimations.

Source: Oficina de Planificación del Sector Agropecuario, 1979.

had their dense forest habitat reduced by 35% between 1940-1977 with extremes of 19% and 45%. Between the Spanish Conquest and 1940, these same species had their dense forest habitat reduced by an average of 32% with extremes of 13% and 37% (Figures 3-10). Thus, many species lost as much or more dense forest habitat from 1940 to 1977 as they did in the 400 years prior to 1940.

Dense forest habitat in 1977

In 1977, there was about 15901km^2 of dense forest in Costa Rica or about 31% of original forest cover. This was concentrated in the following regions: (a) Talamanca Mountain Range (7900km^2) from sea level to about 3000m elevation; (b) north slopes of Barva, Irazú and Turrialba Volcanoes (1406km^2) from 300 to 3000m levitation, (c) the lowland forested regions of Chambacú (2741km^2), and d) the Osa Península (1246km^2) both from about sea level to several hundred meters elevation. The amount of dense forest habitat for a species within any of these areas depends on the altitudinal and geographical distribution for that species. In 1977, the species studied had an average of about 28-30% of their original dense forest habitat (Table 3). The squirrel monkey with 30% (2143 km^2) of its original forest habitat, the giant anteater with 24% (7315km^2) and the quetzal with 60% (6730km^2) represented the extremes (Figures 11-31).

Including the 45-80% forest cover, total forest area increases dramatically (Table 3). This category of forest land contains much edge and mixed stages of habitat types, favorable for a number of species and the negative factor of human inhabitants.

Altered areas and wilderness

By studying the distribution of observations for each species (Figures 11-31), one concludes that 16 wilderness species were found almost exclusively in dense forest regions and 11 species were found in both dense forest and disturbed areas (Tables 1 and 3). A species could be found in both altered and dense forested areas for numerous and non-exclusive reasons such as: a) the altered areas alone or in combination with the dense forest area meet minimum habitat requirements, b) hunting pressure is not great, and c) the species possesses an effective escape mechanism from man in altered areas just as in dense forest habitats.

Perhaps many, if not all, species in this report could subsist in altered areas if not for hunting pressure. For instance, the tapir and jaguar occur in the forest pasture mixture in Santa Rosa National Park. If not under hunting pressure, species adapted to live or at least migrate through habitat types other than dense forest (Foster 980) could prevent their local or national extinction. A continuous distribution in a region even with density differences between habitats would assure some exchange of genetic information within the species.

Islands or isolates of dense forest habitat in 1977

Knowledge of total dense forest available in a country and throughout its range is important for each wildlife species. However, size and distribution of dense forest habitat islands determines population size with a minimum population needed in an area for long term survival.

According to insular ecology theory, habitat fragmentation can be dissected into two components: habitat loss and insularization. Habitat loss excludes a portion of a faunal type, particularly rare species because of reduced population size. Habitat insularization extinguishes "protected" species within an area by removing required resources outside the area and reduces accessibility for and sources of colonists (Wilcox 1980). In quantitative terms, it is calculated that each tenfold decrease in area could result in a 30% exclusion or regional fauna as described by the species-areas curve (MacArthur & Wilson 1967). Table 4 presents a list of the largest protected and unprotected islands of dense forest vegetation in Costa Rica in 1977 for each species. Appendices 1, 2 and 3 show approximate size of dense forest habitat for each species within protected wildlands in 1977.

TABLE 3
Size of forest habitat of endangered wildlife species in Costa Rica (1940-1977)

Species	Altitudinal range (meters)	Dense forest (80-100% cover) (km^2) %					Forest 45-80% cover) (km^2) (1977)	Mangrove, swamp-forest (km^2) (1977)
		Preconquest	1940	1950	1961	1977		
Cebus capucinus[1]	0-3000	48845 (100%)	33538 69%	27084 55%	23122 47%	15901 33%	7882	1979
Ateles geoffroyi	0-2500	47783 (100%)	32476 68%	26022 55%	22060 46%	14839 31%	7882	—
Saimiri oerstedii[1]	0-500 Southern Pacific	7255 (100%)	5434 75%	4435 61%	3400 47%	2143 30%	1278	—
Alouatta palliata[1]	0-2000	46188 (100%)	29378 64%	24352 53%	20545 45%	14507 31%	7882	1979
Myrmecophaga tridactyla	0-500	30000 (100%)	18738 63%	15304 51%	12400 41%	7315 24%	5661	1979
Felis concolor[1, 2]	0-3820	48845 (100%)	33538 67%	27084 55%	23122 47%	15901 33%	7882	1979
Felis pardalis[1, 2]	0-3820	48845 (100%)	33538 67%	27084 55%	23122 47%	15901 33%	7882	1979
Felis wiedii[1, 2] Felis tigrina	0-3820	48845 (100%)	33538 67%	27084 55%	23122 47%	15901 33%	7882	1979
Felis yagouaroundi[1]	0-2000	46188 (100%)	29378 64%	24352 53%	20645 45%	14507 31%	7882	1979
Panthera onca[2]	0-3820	48845 (100%)	33538 67%	27084 55%	23122 47%	15901 33%	7882	1979
Tayassau pecari	0-1500	42501 (100%)	28131 66%	23231 55%	18298 43%	12422 29%	7409	1979
Tayassau tajacu[1]	0-3000	48845 (100%)	33538 67%	27084 55%	23122 47%	15901 33%	7882	1979
Tapirus bairdii[2]	0-3820	48845 (100%)	33538 69%	27084 55%	23122 47%	15903 33%	7882	1979
Trichechus manatus	—	—	—	—	—	—	—	—
Harpia harpyja	0-1500	42501 (100%)	28131 66%	23231 55%	18298 43%	12422 29%	7409	1979
Eagles and Hawk-eagles[3]	0-1500	42501 (100%)	28131 66%	23231 55%	18298 43%	12422 29%	7409	1979
Crax rubra[2]	0-2000	46188 (100%)	29838 64%	24352 53%	20645 45%	14507 31%	7409	1979
Ara ambigua	0-1500 Atlantic	18894 (100%)	16530 87%	14518 76%	12658 67%	8410 45%	—	—
Ara macao	0-1500	42501 (100%)	28131 66%	28231 55%	18298 43%	12422 29%	7409	1979
Pharomachrus mocinno	1000-3000	11143 (100%)	8801 79%	8266 55%	7314 66%	6730 60%	870	—
Caiman crocodilus[1]	0-500	30000 (100%)	18738 63%	15304 51%	12400 41%	7315 24%	5661	1979
Crocodylus acutus	0-500	30000 (100%)	18738 63%	15304 51%	12400 41%	7315 24%	5661	1979

(1) Adaptable to alterede environments; (2) Found in subalpino paramo vegetation; (3) Except Harpia harpyja.

TABLE 4
Information on dense forest habitat and populations of twenty seven Costa Rican wildlife species (1977)

	Dense forest habitat (80-100% forest cover) (km²) (1977)		Largest areas of dense forest habitat			Largest protected wildland areas					
Species	(a) Protected (b) Unprotected (c) Total	(a) National parks and biol. reserves (b) Forest reserves and protected areas (c) Indian reservations (d) Total	Location	Dense forest habitat (km²)	Estimated Population[1]	Location	Dense Forest Habitat (km²)	Estimated Population[1]	Size of area required for 500 individuals[1] (km²)	General	Protected
Cebus capucinus	8479 (52) a 7422 (48) b 15901 (100) c	3745 (44) a 3854 (43) b 1080 (13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	40290-687300 13979-238467 7171-122322 6355-108402	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR	1900 920 593 533	9690-165300 4692-80040 3024-51591 2718-46371	5-98	14-25	19-36
Ateles geoffroyi	7565 (51) a 7274 (49) b 14839 (100) c	2240 (43) a 3282 (43) b 1043 (14) c 7565 (100)d	Talamanca Chambacú Irazú Osa	6123 2741 1388 1246	38208-275535 17104-123345 8661-62460 7775-56070	La Amistad NP Río Macho FR Golfo Dulce FR Cord. Volc. Cent.	1647 686 593 515	10211-74115 4281-30870 3700-26685 2214-23175	11-80	16-23	20-34
Saimiri oerstedii	1055 (49) a 1088 (51) b 2143(100) c	462 (44) a 593 (56) b 1055 (100) c	Osa Costeña Fila	1246 351	16198-82236 4563-23166	Golfo Dulce FR Corcovado NP	593 391	7709-39138 5083-25806	7-38	4-6	3
Alouatta palliata	6381 (44) a 8126 (56) b 14507 (100) c	2526 (40) a 2884 (45) b 971 (15) c 6881 (100) d	Talamanca Chambacú Osa Irazú	3974 2741 1246 1187	69545-317920 47968-219280 21805-99680 20773-94960	La Amistad NP Golfo Dulce FR Cord. Volc. Cent. Rio Macho FR	1133 593 493 461	19828-90640 10378-47440 8628-39440 8068-36880	6-29	20-27	27-35
Myrmecophaga tridactyla	1697 (23) a 5618 (77) b 7315 (100) c	842 (50) a 766 (45) b 89 (5) c 1697 (100) d	Chambacú Osa	2741 1246	329 150	Golfo Dulce FR Corcovado NP Tortuguero NP	593 391 100	71 47 12	4167	0	0
Felis concolor	8479 (53) a 7422 (47) b 15901 (100) c	3745(44) a 3654 (43) b 1080(13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	715 247 127 112	La Amistad NP Rio Macho FR Golfo Dulce FR Los Santos FR	1900 920 593 533	171 8353 48	5556	1	0
Felis pardalis	8479 (53) a 7422 (47) b 15901 (100) c	3744(44) a 3654 (43) b 1080(13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	1106-1975 384-685 197-352 174-312	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR.	1900 920 593 533	266-475 129-230 83-148 72-129	2.000-3,571	1-2	0
Felis wiedii (2) *Felis tigrina*	8479 (53) a 7422 (47) b 15901 (100) c	3744(44) a 3654 (43) b 1080(13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	1106-1975 384-685 197-352 174-312	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR.	1900 920 593 533	266-475 129-230 83-148 72-129	2,000-3,571	1-2	0

TABLE 4 (Continued...)
Information on dense forest habitat and populations of twenty seven Costa Rican wildlife species (1977)

	Dense forest habitat (80-100% forest cover) (km^2) (1977)		Largest areas of dense forest habitat			Largest protected wildland areas					
Species	(a) Protected (b) Unprotected (c) Total	(a) National parks and biol. reserves (b) Forest reserves and protected areas (c) Indian reservations (d) Total	Location	Dense forest habitat (km^2)	Estimated Population[1]	Location	Dense Forest Habitat (km^2)	Estimated Population[1]	Size of area required for 500 individuals[1] (km^2)	General	Protected
Felis yagouaroundi	6381 (44) a 8176 (56) b 14507 (100) c	2528 (40) a 2884 (45) b 971 (15) c 6381 (100) d	Talamanca Chambacú Irazú Osa	3974 2741 1246 1187	994-3174 685-2193 312-997 297-950	La Amistad NP Golfo Dulce FR Cord. Volc. Cent. Río Macho FR	1133 593 493 461	283-906 148-474 123-394 115-369	625-2000	2-7	0-2
Panthera onca	8479 (53) a 7422 (47) b 15901 (100) c	3475 (44) a 3654 (43) b 1080 (13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	111-790 38-274 20-141 17-125	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR.	1900 920 593 533	27-190 13-92 8-59 7-53	5000-35714	0-1	0
Tayssau pecari	4937 (40) a 7485 (60) b 12422 (100) c	1789 (36) a 2364 (48) b 785 (16) c 4937 (100) d	Talamanca Chambacú Osa Irazú	3271 2907 1246 944	6542 5814 2492 1888	Golfo Dulce FR La Amistad NP Corcovado NP Cord. Volc. Cent.	593 578 418 381	1186 1156 836 762	250	10	5
Tayassau tajacu	8479 (53) a 7422 (47) b 15901 (100) c	3744 (44) a 3654 (43) b 1080 (13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	15800-126400 5482-43856 2812-22496 2492-19936	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR.	1900 920 593 533	3800-30400 1840-14720 1186-9488 1066-8525	31-250	9-18	11-28
Tapirus bairdii[3]	8479 (53) a 7422 (47) b 15901 (100) c	3744 (44) a 3654 (43) b 1080 (13) c 8479 (100) d	Talamanca Chambacú Irazú Osa	7900 2741 1406 1246	4187-7440 1453-1645 745-844 660-748	La Amistad NP Río Macho FR Golfo Dulce FR Los Santos FR.	1900 920 593 533	1007-1140 488-552 314-356 282-320	833-943	4	1-2
Harpia harpyja	4937(40) a 7485 (60) b 12422 (100) c	1789 (36) a 2364 (48) b 785 (16) c 4937 (100) d	Talamanca Chambacú Osa Irazú	3271 2907 1246 944	26-52 23-47 10-20 8-15	Golfo Dulce FR La Amistad NP Corcovado NP Cord. Volc. Cent.	593 578 418 381	5-9 5-9 3-7 3-6	31250-62500	0	0
Eagles and Hawk-eagles	4937(40) a 7485 (60) b 12422 (100) c	1789 (36) a 2364 (48) b 785 (16) c 4937 (100) d	Talamanca Chambacú Osa Irazú	3271 2907 1246 944	26-52 23-47 10-20 8-15	Golfo Dulce FR La Amistad NP Corcovado NP Cord. Volc. Cent.	593 578 418 381	5-9 5-9 3-7 3-6	31250-62500	0	0
Crax rubra	6831 (44) a 8126 (56) b 14507 (100) c	2526 (40) a 2889 (45) b 971 (15) c 6381 (100) d	Talamanca Chambacú Irazú Osa	3974 2741 1246 1187	1590-4769 1096-3289 498-1495 475-1424	La Amistad NP Golfo Dulce FR Cord. Volc. Cent. Río Macho FR	1133 593 493 461	453-1360 237-711 197-592 184-553	417-1250	1-9	0-6

TABLE 4 (Continued...)
Information on dense forest habitat and populations of twenty seven Costa Rican wildlife species (1977)

	Dense forest habitat (80-100% forest cover) (km^2) (1977)		Largest areas of dense forest habitat			Largest protected wildland areas					
Species	**(a) Protected (b) Unprotected (c) Total**	**(a) National parks and biol. reserves (b) Forest reserves and protected areas (c) Indian reservations (d) Total**	**Location**	**Dense forest habitat (km^2)**	**Estimated Population[1]**	**Location**	**Dense Forest Habitat (km^2)**	**Estimated Population[1]**	**Size of area required for 500 individuals[1] (km^2)**	**General**	**Protected**
Ara ambigua	3197 (35) a 5932 (65) b 8410 (100) c	1123 (35) a 1289 (40) b 785(25) c 3197 (100) d	Chambacú Irazú	2907 944	233-698 76-227	La Amistad NP Cord. Volc. Cent. Río Macho FR Braulio Carillo NP	578 381 213 200	46-139 30-91 17-51 16-48	2083-6250	0-2	0
Ara macao	4937 (40) a 7485 (60) b 12422 (100) c	1789 (36) a 2364 (48) b 785 (16) c 4937(100) d	Talamanca Chambacú Osa Irazú	3271 2907 1246 944	262-785 233-698 100-299 76-277	Golfo Dulce FR La Amistad NP Corcovado NP Cord. Volc. Cent.	593 578 418 381	47-142 46-139 33-100 30-91	2083-6250	0-2	0
Pharomachrus mocinno	5412 (80) a 1388 (20) b 6730 (100) c	2541 (48) a 2314 (40) b 557 (12) c 5412(100) d	Talamanca Irazú San Ramón	4766 835 579	12868-13821 2255-2422 1563-1679	La Amistad NP Río Macho FR Cord. Volc. Cent. Los Santos FR	1723 877 468 436	4652-4997 2368-2543 1264-1357 1177-1264	172-185	3	9
Caiman crocodilus	1697 (23) a 5618 (77) b 7315 (100) c	842 (50) a 766 (45) b 89 (5) c 1697(100) d	Chambacú Osa	2741 1246	—	Golfo Dulce FR Corcovado NP Tortuguero NP	593 391 100	—	—	—	—
Crocodylus actus	1697 (23) a 5618 (77) b 7315 (100) c	842 (50) a 766 (45) b 89 (15) c 1697(100) d	Chambacú Osa	2741 1246	—	Golfo Dulce FR Corcovado NP Tortuguero NP	593 391 100	—	—	—	—

(1) Based on density extremes; (2) Density based on 14 and 25 individuals /km2 from F. pardalis; (3) Density based on 2 individuals /km2 from T. tajacu.

Minimum population size for long-term species fitness

Most endangered species are susceptible to extinction because habitat loss and insularization lower population sizes below a minimum necessary to maintain an evolutionarily viable population (or long-term fitness) (Frankel & Soulé 1981). Franklin (1980) using data from Lande (1976) on bristle number variation in Drosophila, proposed a minimum effective population size of 500 as needed for effective genetic variation. He based this number on the fact that: (a) phenotypic traits in conservation biology are quantitative and because the average gene effect is small, most variation is additive, (b) erosion of additive genetic variation does not occur at a significant rate by stabilizing selection, and (c) mutation and genetic drift are important evolutionary forces and a population below some minimum size will lose more variation by drift faster than can be gained by mutation. Frankel & Soule (1981) arrive at a similar figure by simple genetic theory. It is important to experimentally monitor some species and test this theory. However, implications of this important figure for long term conservation of animal populations within wildland areas are obvious (Frankel & Soule 1981). The actual number may be several times larger or smaller than this. However for the present report, all discussion and conclusions are based on this figure.

The problem of calculating species densities in the tropics

Few densities were found in the literature for the wildlife species studied. They are probably unreliable in general because: (a) tropical environments are difficult areas to census species, (b) wildlife species in forested tropical areas are difficult to census because of their habitat, (c) temperate zone sampling techniques are not generally suitable for use in the tropics, (d) few accurate sampling techniques have been developed for tropical species, and (e) interest in estimating densities for tropical species is recent.

Also, densities of wildlife species vary greatly in time and space. The first is a result of the population dynamics of the species. The second factor is influenced by a fluctuating resource base both within and between major vegetation types and successional stages. Eisenberg (1980) showed how *Alouatta palliata* populations fluctuate widely on Barro Colorado Island due in part to successional stages of vegetation. Johnson & Vaughan (1993) found small rodent populations highly variable between five habitat types in the Talamanca Mountain Range (Costa Rica) at 2700m.

I expected that *Cebus capucinus* could be 10 to 100 times as abundant in a given area of lowland rain forest as an equivalent sized area of high oak forest (2500m elevation) where it is an infrequent visitor. Even within a natural area such a Corcovado National Park with more than 20 recognized vegetation types, differences in population densities of wildlife species may exist between mangrove swamp, dense forest, *Raphia* swamp forest(Vaughan 1981), or species may indiscriminately use adjoining vegetation types. Stratification of sampling is needed but seldom done (Caughley 1977). For the present report, several species had none or at most one density reported (Table 1.) In some cases densities were estimated from the number of individuals in a given area. Other densities were taken from supposedly similar species (*Felis pardalis-Felis wiedii*). No data was available for density differences between habitat types. In many cases densities were given with no explanation of the sampling technique used. Until sampling techniques are improved, the densities in Table 1 should be considered very tentative.

Protected and unprotected dense forest habitat

Within a relatively small area (50900km^2), Costa Rica has a well established system of protected wildlands which total some 11679km^2 or 22,9% of the national territory (Table 5) (Vaughan et al. 1982).

The 26 wildland areas under the supervision of the National Parks Service total 4130km^2 (8,1%) and in general are well protected and largely covered by dense forests. The Forestry Service manages some 24 areas which include 4790km^2 (9,4%). They are covered in most cases by 60-90% dense forest cover, but allow resource exploitation. The Indian Reservations cover some 2693km^2 (5,3%); however quantity of dense forest cover is unknown and intense hunting pressure exists on wildlife species with some probably locally extinct. Only three Indian Reservations in the Talamanca Mountain Range were used for this report because they are thought to be mostly forest covered.

Wildlands may adjoin each other and together make up a much larger protected area for a species then each one separately. This is the case in Talamanca where Chirripó and La Amistad National Parks, Chirripó, Talamanca, and Tayni Indian Reservations, Río Macho and Los Santos Forest Reserves, Tapantí National Wildlife Refuge and Las Tablas and Barbilla Protected zones together make up some 5179km^2 of protected dense forest for a species such as the jaguar or tapir.

Appendices 1, 2 and 3 summarize protected dense forest habitat area for each species and Table 4 details the largest protected and unprotected vegetation islands,

TABLE 5
General information on wildland areas in Costa Rica

Responsible agency	Wildland category	Quantity	Total area (km^2)	% of national territory
Forestry Service	Forest Reserve	11	3865,9	7,59
	Protected zone	10	849,0	1,67
	Wildlife refuge	3	75,3*	0,15
National Parks Service	National Park	14	3938	7,74
	Recreational Area	5	6,7	0,01
	Biological Reserve	6	182,7	0,36
	National Monument	1	2,2	0,00
Agricultural Development Institution	Indian Reservations	16	2693,4	5,29
University of Costa Rica	Biological Reserve	1	750*	0,01
Organization for Tropical Studies	Scientific Reserve	2	17,4	0,02
Tropical Science Center	Biological Reserve	1	22,5	0,04
	Total	**70**	**11678,9**	**22,9**

* Tapantí National Wildlife Refuge and Tres de Junio Biological Reserve, so their areas are not computed in the total.

estimates population sizes within them and estimates the number with genetically viable populations for long-term fitness. Although several wildand areas were created after 1977 when the last dense forest cover map was made, most areas still were under dense forest cover in 1982 (Figs. 32, 33, 34)

Summary of important data for each species

Cebus capucinus

This species is adaptable to a variety of forest habitats from sea level to almost 3,000 meters including primary and secondary forest, mangrove swamp, and palm swam (Table 1). Between 1940 and 1977, dense forest habitat for the white-faced monkey was reduced 36% (69-33%) (Table 3, Figure 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (52%) was protected in wildlands (Table 4 and Fig. 11).

The largest areas or "isolates" of dense forest habitat for this species in 1977 were found in: Talamanca (7900 km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246km^2), while the largest protected areas included La Amistad International Park (1900km^2), Rio Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2) (Table 4)

Between 40290 and 687300 white-faced monkeys inhabit the largest isolate (Talamanca) and 9690-165300 individuals the largest protected area (La Amistad) based on size of the area and density extremes (5,1-87 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 98km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently 14 "isolates" and 19 protected areas of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The presence of Cebus in altered habitats indicates its adaptability. The white-faced monkey is not under hunting pressure as a game species and although presently legally protected, it is not endangered with extinction in Costa Rica.

Ateles geoffroyi

The spider monkey inhabits large tracts of dense forest from sea level to about 2500m and is considered a wilderness species (Table 1). At Santa Rosa National Park, it is found in 40-60 year old secondary succession forest.

Between 1940 and 1977, dense forest habitat for the spider monkey was reduced 37% (68-31%) (Table 3, Figs. 1 and 8). In 1977 there was about 14839km^2 of dense forest habitat for the species of which 7565km^2 (51%) was protected in wildlands (Table 4 and Fig. 11).

The largest areas or "isolates" of dense forest habitat for this species as of 1977 were found in: Talamanca (6123km^2), Chambacú (2741km^2), Irazú (1388km^2) and Osa

(1246 km^2), while the largest protected areas included: La Amistad International Park (1647km^2), Rio Macho Forest Reserve (686 km^2), Golfo Dulce Forest Reserve (593km^2) and Corcovado National Park (418km^2) (Table 4)

Between 38208 and 275535 spider monkeys inhabit the largest isolate (Talamanca) and 10277-74115 individuals the largest protected area (La Amistad), based on size of the area and density extremes (6,2-45 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 80km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. As of 1979, there were 16 "isolates" and 20 protected areas of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The spider monkey is under hunting pressure and is the first primate to be extirpated from a region. It is currently given legal protection and should be considered an endangered species.

Saimiri oerstedii

The squirrel monkey inhabits a variety of forest habitat from sea level to about 500 meters in southwestern Costa Rica which include primarily and secondary forests, mangrove and cultivated areas such as banana and African oil palm (Table 1).

Between 1940 and 1977, dense forest habitat for the squirrel monkey was reduced 45% (75-30%) (Table 3, Figs. 1 and 4). In 1977 there was about 2143km^2 of dense forest habitat for the species of which 1055km^2 (49%) was protected in wildlands (Table 4 and Fig. 13). Because it only occurs in southwest Costa Rica, historically it had the smallest total area of dense forest habitat of any of the species studied.

The largest "isolates" of dense forest habitat for this species as of 1977 were found in: the Osa Peninsula (1246km^2) and along the Fila Costeña (351km^2), while the largest protected areas were: Golfo Dulce Forest Reserve (593km^2) and Corcovado National Park (391km^2) which adjoin each other (Table 4). Between 16198-82236 squirrel monkeys inhabit the largest isolate (Osa Peninsula) and 7709-39138 individuals the largest protected area (Golfo Dulce) based on size of the area and density extremes (13-66 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 8km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently 4 isolates and 3 protected areas in Costa Rica of this size or larger which could maintain such a genetically viable population for long-term species fitness (Table 4).

The squirrel monkey is not under hunting pressure and is found close to human settlements. It is legally protected.

Alouatta palliata

The howler monkey is found in a variety of forested habitats from sea level to 2000 meters including primary and secondary forest in thin bands of trees along water courses in deforested areas (Table 1).

Between 1940 and 1977, dense forest habitat for the howler monkey was reduced 33% (64-31%) (Table 3, Figs. 1 and 7). In 1977 there was about 14507km^2 of dense forest habitat for the species of which 6381km^2 (44%) was protected in wildlands (Table 4 and Fig. 14).

The largest areas or "isolates" of dense forest habitat for this species in 1977 were found in: Talamanca (3974km^2), Chambacú (2741km^2), Irazú (1187km^2) and Osa (1246km^2), while the largest protected areas included: La Amistad International Park (1133km^2), Golfo Dulce Forest Reserve (593km^2), Cordillera Volcanic Central Forest Reserve (493km^2) and Río Macho Forest Reserve (461km^2), (Table 4)

Between 69545 and 317920 howler monkeys inhabit the largest isolate (Talamanca) and 19828 to 90640 individuals the largest protected area (La Amistad) based on size of the area and density extremes (17,5-80 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 29km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently 20 "isolates" and 27 protected areas of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The howler monkey is not threatened in Costa Rica and is found near many rural towns (ie. Nicoya and Upala). Because of its adaptability to altered habitats, and low preferences as a food item by human beings, it is probably the most abundant wild primate in Costa Rica. It is legally protected.

Myrmecophaga tridactyla

The giant anteater is found in undisturbed swamp forest and dense forest from sea level to about 500 meters elevation (Table 1).

Between 1940 and 1977, dense forest habitat for the giant anteater was reduced 39% (63-24%) (Table 3, Fig. 1 and 3). In 1977 there was about 7315km^2 of dense forest habitat for the species of which 1697km^2 (23%) was protected in wildlands (Table 4 and Fig. 15).

The largest areas or "isolates" of dense forest habitat for this species in 1977 were found in: Chambacú (2741km^2) and Osa (1246km^2), while the largest protected areas included: Golfo Dulce Forest Reserve (593km^2), Corcovado National Park (391km^2) and Tortuguero National Park (100km^2) (Table 4)

Three hundred and twenty nine (329) giant anteaters could inhabit the largest isolate (Chambacú) and 71 individuals the largest protected area (Golfo Dulce) based on size of the area and density (0,12 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 4167km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently no "isolates" nor protected areas in Costa Rica of that size or larger which could maintain such a genetically viable population for long-term species fitness (Table 4). Observations of giant anteaters on Fig. 15 were unfortunately confused with *Tamandua tetradactyla* invalidating that section of the map.

Felis concolor

The mountain lion is found in a variety of forested habitats from sea level to 3800 meters including primary and secondary forest scrub, mangrove, swamp forest and subalpine paramo (Table 1). Between 1940 and 1977, dense forest habitat for the mountain lion was reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 4 and Fig. 16).

The largest areas or "isolates" of dense forest habitat for the mountain lion were found in: Talamanca (7900km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246 km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Rio Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2) (Table 4).

Seven hundred and eleven (711) mountain lions could inhabit the largest isolate (Talamanca) and 171 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,09 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 5556km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There is presently 1 "isolates" and no individual protected areas in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The mountain lion has one of the lowest densities reported of all the species studied but continues throughout much to the country because of its adaptability to habitat types. Hunting has extirpated the species or reduced it considerably in many areas. The puma should be considered endangered because of low population densities and the fact that it is high on the food chain. It is legally protected.

Felis pardalis

The ocelot is found in a variety of forested habitats from sea level to 3800 meters including heavily forested areas, secondary forest scrub, mangrove, scrub, pasture, subalpine paramo and even rarely in coffee plantations (Table 1).

Between 1940 and 1977, dense forest habitat for the ocelot was reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 4 and Fig. 17).

The largest areas or "isolates" of dense forest habitat for this species in 1977 were found in: Talamanca (7900km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Rio Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2).

Between 1106 and 1975 ocelots could inhabit the largest isolate (Talamanca) and 266 to 475 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,14-0,25 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 3571km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There is presently 1 "isolate" and no individual protected areas of that size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The ocelot is adaptable to habitat alteration, however all spotted cats have been intensively hunted for their valuable skins and are probably less abundant than formerly. Because of hunting pressure and the existence of only one area large enough to maintain a viable population in Costa Rica, the ocelot should be considered endangered with extinction. It is legally protected.

Felis wiedii, Felis tigrina

The margay and the little spotted cat are found in a variety of forested habitats from sea level to 3800 meters

including heavily forested areas, secondary forest scrub (charral), and mangrove and semi open areas (Table 1).

Between 1940 and 1977, dense forest habitat for the margay and the little spotted cat was reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 4 and Fig. 18).

The largest areas or "isolates" of dense forest habitat for this species in 1977 were found in: Talamanca (7900km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Rio Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2).

No densities area reported in the literature, so those for *Felis pardalis*, were used, although I have doubts as to its validity. Between 1106 and 1975 margay and little spotted cats inhabit the largest isolate (Talamanca) and 266 to 475 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,14-0,25 individuals / km^2) for the ocelot (Table 4).

An area of approximately 3571km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There is presently 1 "isolate" and no individual protected areas of that size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The margay and the little spotted cat utilize altered habitats and have been subject to intensive hunting pressure for their valuable skin. Densities are thus probably much lower than in similar habitats where there are not hunted. The species continue to survive in Costa Rica in part because they are found in altered habitats countrywide. They are legally protected.

Felis yagouaroundi

The smallest of the wild felines is the most variable in habitat use and found from sea level to about 2000 meters elevation in primary and secondary forest, overgrown and grazed pastures (Table 1).

Between 1940 and 1977, dense forest habitat for the jaguarundi was reduced 33% (64-31%) (Table 3, Figs. 1 and 7). In 1977 there was about 14507km^2 of dense forest habitat for the species of which 6381km (44%) was protected in wildlands (Table 4 and Fig. 19).

The largest areas or "isolates" of dense forest habitat for the jaguarundi as of 1977 were found in: Talamanca (3974km^2), Chambacú (2741km^2), Irazú (1246km^2) and Osa (1189km^2), while the largest protected areas included: La Amistad International Park (1133km^2), Golfo Dulce Forest Reserve (593km^2), Cordillera Volcánica Central and Los Santos Forest Reserve (493km^2) and Rio Macho Forest Reserve (461km^2) (Table 4).

Between 994 and 3179 individuals inhabit the largest isolate (Talamanca) and 283 to 906 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,25-0,8 individuals/km^2) for the species (Table 4).

An area of approximately 2000km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently two large "isolates" and no individual protected areas in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The jaguarandi is found in altered habitats and is under less hunting pressure compared to the other felines because it does not have a valuable fur. In Costa Rica, it will continue to survive especially in altered habitat types and should not be considered an endangered species. It is legally protected.

Panthera onca

The jaguar is a species found principally in primary forest habitat, from sea level to about 3800 meters elevation in Costa Rica, although it is infrequently reported in the subalpine paramo (Vaughan 1981) and semi-altered areas (in Santa Rosa National Park).

Between 1940 and 1977, dense forest habitat for the jaguar reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 4 and Fig. 19).

The largest areas or "isolates" of dense forest habitat for the jaguar were found in: Talamanca (7900km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Rio Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2) (Table 4).

Between 110 and 790 jaguars inhabit the largest isolate (Talamanca) and 27 to 190 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,014-0,1 individuals / km^2) for the species (Tables 1 and 4). An area of approximately 35714km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently no large "isolates" nor protected areas in Costa Rica of this size which could mantain

such a genetically viable population for long-term species fitness (Table 4).

The jaguar is a wilderness species. Unfortunately it will probably become extinct in Costa Rica because of habitat destruction and the fact that it is presently under hunting pressure here. The jaguar would probably have a chance for survival if allowed to exist in altered areas.

Tayassu pecari

This species is found in humid primary forest from sea level to about 1500 meters but occasionally has been observed in the tropical dry forest in Santa Rosa National Park (Table 1).

Between 1940 and 1977, dense forest habitat for the white-lipped peccary was reduced 37% (66-29%) (Table 3, Figs. 1 and 5). In 1977 there was about 12442km^2 of dense forest habitat for the species of which 4807km^2 (39%) was protected in wildlands (Table 4 and Fig. 21).

The largest areas or "isolates" of dense forest habitat for the species in 1977 were found in: Talamanca (3271km^2), Chambacú (2741km^2), Irazú (944km^2) and Osa (1246km^2), while the largest protected areas included: Golfo Dulce Forest Reserve (593km^2), La Amistad International Park (570km^2), Corcovado National Park (418km^2) and Cordillera Volcánica Central Forest Reserve (381km^2) (Table 4).

Approximately 6524 white –lipped peccaries in inhabit the largest isolate (Chambacú) and 1186 individuals the largest protected area (Golfo Dulce) based on size of the area and density extremes (2 individuals/km^2) for the collared peccary (Tables 1 and 4).

An area of approximately 250km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the collared peccary. At presently there are 10 large "isolates" and four protected areas in Costa Rica of this size which could maintain such a genetically viable population for long-term species fitness (Table 4).

White –lipped peccaries probably forage in large groups (100 individuals or more) over several hundred km^2 area while collared peccaries remain in one to four km^2 blocks in smaller herds (20-25) which is why I am not convinced of the validity of using this density but did so for discussion purposes. This wilderness species needs extensive tracts of forest habitat to survive and should be classified as an endangered species. It is not currently protected.

Tayassu tajacu

The collared peccary is found from sea level to almost 3000m in a variety of habitats from primary and secondary forest to scrub and overgrown pasture (Table 1).

Between 1940 and 1977, dense forest habitat for the white-lipped peccary was reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 3 and Fig. 22).

The largest areas or "isolates" of dense forest habitat for the species in 1977 were found in: Talamanca (7900km^2), Chambacu (2741km^2), Irazu (1406km^2) and Osa (1246 km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Río Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2) (Table 4)

Between 15800 and 126000 collared peccaries inhabit the largest isolate (Talamanca) and 3800 to 30400 individuals the largest protected area (La Amistad) based on size of the area and density extremes (2-16 individuals/ km^2) for the species (Tables 1 and 4).

An area of approximately 250km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently nine large "isolates" and eleven protected areas in Costa Rica of this size which could maintain such a genetically viable population for long-term species fitness (Table 4).

The collared peccary is under intensive hunting pressure and is one of the six most important game species in Costa Rica. Its adaptability to altered habitat conditions and high reproductive rate favor continue survival in the country.

Tapirus bairdii

The tapir is found in a variety of undisturbed habitat types from sea level to about 3800m (Table 1) including primary forest, mangrove, palm swamp, and subalpine paramo. It has been observed in pastures in Santa Rosa National Park. Between 1940 and 1977, dense forest habitat for the tapir was reduced 34% (67-33%) (Table 3, Figs. 1 and 9). In 1977 there was about 15901km^2 of dense forest habitat for the species of which 8479km^2 (53%) was protected in wildlands (Table 4 and Fig. 23).

The largest areas or "isolates" of dense forest habitat for the species in 1977 were found in: Talamanca (7900km^2), Chambacú (2741km^2), Irazú (1406km^2) and Osa (1246km^2), while the largest protected areas included: La Amistad International Park (1900km^2), Río Macho Forest Reserve (920km^2), Golfo Dulce Forest Reserve (593km^2) and Los Santos Forest Reserve (533km^2) (Table 4).

Between 4187 and 4740 tapirs inhabit the largest isolate (Talamanca) and 1007 to 1140 individuals the largest protected area (La Amistad) based on size of the area and

density extremes (0,53-0,6 individuals / km^2) for T*apirus terrestris* (Table 1 and 4).

An area of approximately 943km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. At presently there are 4 "isolates" and one protected area in Costa Rica of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The tapir is a wilderness species infrequently reported from altered areas where it is probably not under hunting pressure. It maintains scattered populations throughout Costa Rica because of it distribution in large, dense forested areas.

Trichechus manatus

The sea cow is an aquatic species inhabiting lagoons, estuaries, bays and large rivers on the Atlantic coast of Costa Rica. Attitudinally it is found from sea level to several hundred meters (Table 1 and Fig. 24). It is difficult to calculate habitat destruction because of its specialized aquatic habitat, although the largest dense forest areas are: Chambacú (2741km^2), Tortuguero (567km^2) and areas of palm swamp include Barro Colorado (994km^2). The three areas together from a 4302km^2 block of dense forest and palm swamp habitat with low human density. The most important protected area is Tortuguero National Park. The manatee is probably one of Costa Rica´s rarest wildlife species due to past and present hunting pressure and suspected low densities under natural conditions. Densities were not found in the literature. The sea cow is protected as an endangered species.

Harpia harpyja

This species is found in a habitats of primary forest areas from sea level to about 1500. (Table 1)

Between 1940 and 1977, dense forest habitat for the harpy eagle was reduced 37% (66-29%) (Table 3, Figs. 1 and 5). In 1977 there was about 12442km^2 of dense forest habitat for the species of which 4937km^2 (40%) was protected in wildlands (Table 4 and Fig. 25).

The largest areas or "isolates" of dense forest habitat for the species in 1977 were found in: Talamanca (3271km^2), Chambacú (2741km^2), Osa (1246km^2) and Irazú (944km^2), while the largest protected areas included: Golfo Dulce Forest Reserve (593km^2), La Amistad International Park (579km^2), Corcovado National Park (418km^2) and Cordillera Volcánica Central Forest Reserve (381km^2) (Table 4).

Between 26 and 52 harpy eagles inhabit the largest isolate (Talamanca) and 5 to 9 individuals the largest protected area (Golfo Dulce) based on size of the area and density extremes (0,008-0,016 individuals/km^2) for the species (Table 4).

An area of approximately 62500km^2 (larger than Costa Rica) of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently no isolates nor protected areas of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 1 and 4).

It is probably one of the rarest species studied in this report and very few have been reported in Costa Rica in the last five years (Fig. 25). Because it is a wilderness species which needs large extensions of dense forest and is under hunting pressure, the harpy eagle should be classified as an endangered species.

Eagles and Hawk-Eagles (except *Harpia harpyja*)

These species are believed to inhabit dense forest areas from sea level to about 1500. (Table 1)

Between 1940 and 1977, dense forest habitat for the eagles and hawk-eagles was reduced 37% (66-29%) (Table 3, Figs. 1 and 5). In 1977 there was about 12442km^2 of dense forest habitat for the species of which 4937km^2 (40%) was protected in wildlands (Table 4 and Fig. 26).

The largest areas or "isolates" of dense forest habitat for the species in 1977 were found in: Talamanca (3271km^2), Chambacú (2741km^2), Osa (1246km^2) and Irazú (944km^2), while the largest protected areas included: Golfo Dulce Forest Reserve (593km^2), La Amistad International Park (579km^2), Corcovado National Park (418km^2) and Cordillera Volcánica Central Forest Reserve (381km^2) (Table 4).

Between 26 and 52 eagles or hawk-eagles for each species are found in the largest isolate (Talamanca) and 5 to 9 individuals in the largest protected area (Golfo Dulce) based on size of the area and density extremes (0,008-0,016 individuals / km^2) for the species (Tables 1 and 4).

An area of approximately 62500km^2 (larger than Costa Rica) of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. There are presently no isolates nor protected areas of this size or larger in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

Most of these species are considered rare in Costa Rica and need large tracts of dense forest habitat. Also they are usually shot on sight. Probably all eagles and hawk-eagles will go extinct in Costa Rica before the end of the century except for remnant populations found in large protected isolated areas.

Crax rubra

This species is found in a variety of forested habitats from sea level to about 2000 meters which include primary and secondary forests, partially cleared areas and scrubby woodlands (Table 1).

Between 1940 and 1977, dense forest habitat for the curassow was reduced 33% (64-31%) (Table 3, Fig. 1 and 7). In 1977 there was about 14507km^2 of dense forest habitat for the species of which 6247km^2 (43%) was protected in wildlands (Table 4 and Fig. 27).

The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Talamanca (6123km^2), Chambacú (2741km^2), Osa (1246km^2) and Irazú (1187km^2) while the largest protected areas included: La Amistad International Park (1133km^2), Golfo Dulce Forest Reserve (593km^2), Cordillera Volcánica Central Forest Reserve (493km^2) and Río Macho Forest Reserve (461km^2).

Between 1590 and 4769 curassows inhabit the largest isolate (Talamanca) and 453 to 1360 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,40-1,2 individuals km^2) for the species (Table 1 and 4).

An area of approximately 1250km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation of the species. There are presently one large isolate and no protected area of this size or large in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The great curassow is a favorite game bird and for this reason should be considered endangered. It is not legally protected.

Ara ambigua

This species is found from sea level to about 1500m in the Atlantic coast of Costa Rica in dense tropical lowland forest (occasionally in isolated fruiting trees) (Table 1).

Between 1940 and 1977, dense forest habitat for the green macaw was reduced 42% (87-45) (Table 3, Figs. 1 and 6). In 1977 there was about 8410km^2 of dense forest habitat for the species of which 3197km^2 (38%) was protected in wildlands (Table 3 and Fig. 28).

The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Chambacú (2907km^2) and Irazú (944km^2) while the largest protected areas included: La Amistad International Park (578km^2), Cordillera Volcánica Central Forest Reserve (381km^2), Rio Mach Forest Reserve (213km^2) and Braulio Carrillo National Park (200km^2).

Between 232 and 698 green macaws inhabit the largest isolate (Chambacú) and 46 to 139 individuals the largest protected area (La Amistad) based on size of the area and density extremes (0,8-0,24 individuals km^2) for the scarlet macaw (Table 1 and 4).

An area of approximately 6250km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation for the species. At present there are not large isolates nor protected areas in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The great green macaw probably covers large areas in feeding. Very little is understood of its biology. It should be considered an endangered species.

Ara macao

This species is found from sea level to about 1500 meters in tropical lowland forest and occasionally in tall trees in pasture regions (Table 1).

Between 1940 and 1977, dense forest habitat for the green macaw was reduced 37% (66-29%) (Table 3, Figs. 1 and 5). In 1977 there was about 12422km^2 of dense forest habitat for the species of which 4937km^2 (40%) was protected in wildlands (Table 3 and Fig. 29).

The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Talamanca (3271km^2). Chambacú (2907km^2), Osa (1246km^2) and Irazú (944km^2) while the largest protected areas included: Golfo Dulce Forest Reserve (593km^2), La Amistad International Park (578km^2), Corcovado National Park (418km^2) and Cordillera Volcánica Central Forest Reserve (381km^2) (Table 4).

Between 262 and 785 scarlet macaws inhabit the largest isolate (Talamanca) and 47 to 142 individuals the largest protected area (Golfo Dulce) based on size of the area and density extremes (0,08-0,24 individuals km^2) for the species (Table 4).

An area of approximately 6250km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation of the species. At present there are not large isolates nor protected areas in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

Pharomachrus mocinno

This species is found between 1000 and 3000 meters elevation in primary forest and occasionally in isolated fruiting trees near forests. (Table 1)

Between 1940 and 1977, dense forest habitat for the green macaw was reduced for only 19% (79-60%) (Table 3, Figs. 1 and 10). In 1977 there was about 6730km^2 of dense

forest habitat for the species of which 5412km^2 (80%) was protected in wildlands (Table 3 and Fig. 30).

The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Talamanca (4766km^2) and Irazú (835km^2) and San Ramón (579km^2) while the largest protected areas included: La Amistad International Park (1723km^2), Río Macho Forest Reserve (870km^2), Cordillera Volcánica Central Forest Reserve (468km^2) and Los Santos Forest Reserve (436km^2) (Table 4).

Between 12868 and 13821 quetzals inhabit the largest isolate (Talamanca) and 4652 to 4997 individuals the largest protected area (La Amistad) based on size of the area and density extremes (2,7-2,9 individuals/ km^2) for the species (Table 4).

An area of approximately 185km^2 of dense forest habitat would support a population of 500 individuals based on the lowest density estimation of the species. There are presently three large dense forested areas and nine protected areas in Costa Rica which could maintain such a genetically viable population for long-term species fitness (Table 4).

The quetzal is found in forested highland mountains (watersheds), the least altered vegetation type in the country. It is not endangered in Costa Rica, although it is occasionally shot.

Caiman crocodilus

This species is found in low land freshwater rivers, marshes and lakes in Costa Rica from sea level to about 500 meters.

Between 1940 and 1977, dense forest habitat for the caiman was reduced 39% (63-24%) (Table 3, Figs. 1 and 3). In 1977 there was about 7315km^2 of dense forest habitat for the species of which 1697km^2 (23%) was protected in wildlands (Table 3 and Fig. 30).

There also exists approximately 1979km^2 of mangrove and swamps and an unknown quantity of riparian habitats. The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Chambacú (2741km^2), Osa (1246km^2), Tortuguero (567km^2) and that of palm swamp, including Barro Colorado (994km^2). Chambacú, Tortuguero, and Barro Colorado together form a 4305km^2 block of dense forest and palm swamp habitat with low human density. The largest protected areas with dense forest habitat included Golfo Dulce Forest Reserve (593km^2) Corcovado National Park (391km^2) and Tortuguero National Park (100km^2). Densities for this species were not found in the literature. Its status is unknown although it is frequently hunted and its populations have been reduced in many areas where it was formally abundant.

Crocodylus acutus

The crocodile is an inhabitant of low land salt, brackish or freshwater habitat from sea level to about 500 meters.

Between 1940 and 1977, dense forest habitat for the green macaw was reduced 39% (63-24%) (Table 3, Figs. 1 and 3). In 1977 there was about 7315km^2 of dense forest habitat for the species of which 1697km^2 (22%) was protected in wildlands (Table 3 and Figure 31).

There also exists approximately 1979km^2 of mangrove and swamps and an unknown quantity of river habitats. The largest areas or isolates of dense forest habitat for this species in 1977 were found in: Chambacú (2741km^2) Osa (1246km^2), Tortuguero (567km^2) and that of palm swamp, including Barro Colorado (994km^2). Chambacú, Tortuguero, and Barro Colorado together form a 4305km^2 block of dense forest and palm swamp habitat with low human density. The largest protected areas with dense forest habitat included Golfo Dulce Forest Reserve (593km^2), Corcovado National Park (391km^2) and Tortuguero National Park (100km^2). Densities for this species were not found in the literature. It is considered endangered throughout its range because of hunting pressure and habitat destruction.

Ranking of endangered wildlife species studied

The objectives of this section are to determine and compare the status of species in Costa Rica based principally on biological data presented thus far.

Other ideas have been presented to classify endangered species (see Ehrenfeld 1972 & Wilcox 1980).

The criteria used here include: (a) species relative density, (b) dense forest habitat in 1977, (c) rate of destruction of dense forest habitat, (d) hunting pressure, (e) adaptability to altered habitats, (f) biotic potential and (g) number of dense forest areas in Costa Rica with possible genetically viable populations for the species (Table 6). For each parameter, the animal was classified on a 1 to 4 scale, with 4 indicating low density, small amount of dense forest habitat, great hunting pressure, and 1 being the opposite extreme.

Admittedly it is difficult to know which factors are the most important for the survival of a species. For instance, *Saimiri oerstedii* is apparently not threatened compared to other species (Table 7). However, it has the smallest quantity of dense forest habitat area of any species studied and only three vegetation islands with supposed genetically viable populations. On the other hand, troops survive in altered habitats and hunting pressure is low. However, *Trichechus manatus* and *Myrmecophaga tridactyla* are both rare, unadaptable to altered conditions, with low biotic

TABLE 6
Status of endangered wildlife species in Costa Rica based on major contributing biological factors

Species	Relative density	Dense forest habitat (1977)	Rate of dense forest destruction	Hunting pressure	Adaptability to altered habitats	Biotic potential	Number of areas with genetically viable populations	Total
Cebus capucinus	1	1	2	2	2	2	1	11
Ateles geoffroyi	3	2	2	4	4	2	2	19
Saimiri oerstedii	1	4	3	2	2	2	4	18
Alouatta palliata	1	3	2	2	2	2	1	13
Myrmecophaga tridactyla	4	4	2	3	4	4	4	25
Felis concolor	4	1	2	4	2	3	4	20
Felis pardalis	4	1	2	4	3	3	4	21
Felis wiedii (a) *Felis tigrina (b)*	4	1	2	4	3	3	4	21
Felis yagouaroundi	3	3	2	3	2	3	4	20
Panthera onca	4	1	2	4	4	3	4	22
Tayssau pecari	3	3	2	4	4	2	4	22
Tayassau tajacu	2	1	2	4	2	2	4	16
Tapirus bairdii	3	1	2	4	3	4	4	21
Trichechus manatus	4	3	3	4	4	4	4	26
Harpia harpyja	4	3	2	4	4	4	4	25
Eagles and Hawk-eagles	4	3	2	4	4	4	4	25
Crax rubra	3	3	2	4	3	3	3	21
Ara ambigua	3	3	2	3	3	3	4	21
Ara macao	3	3	2	3	3	3	4	21
Pharomachrus mocinno	2	3	1	2	3	3	4	18
Crocodylus acutus	4	4	4	4	3	2	3	24
Caiman crocodiles	2	4	4	4	2	2	3	21

potential and the giant anteater has little remaining dense forest habitat and no areas for genetically viable populations. The manatee is also under extreme hunting pressure.

Results from Table 7 indicate that the most threatened wildlife species are: *Trichechus manatus, Myrmecophaga tridactyla, Harpia harpyja* and all other Eagles and Hawk-eagles, *Panthera onca* and *Tayassu pecari*. This could have been predicted from previous sections. None of these species will probably maintain genetically viable populations in Costa Rica and in the next decades or centuries will probably become extinct (Wilcox 1980). At the other extremes of ranking, *Cebus capucinus, Alouatta palliata*, and Tayassu tajacu are species thought to have sizable populations in Costa Rica, large extensions of dense forest habitat, adaptable to secondary (altered) habitats and with several areas of dense forest habitat large enough for genetically viable populations.

TABLE 7
Ranking of endangered wildlife species in Costa Rica based on biological data

Species	Rank
Trichechus manatus	26
Myrmecophaga tridactyla	25
Harpia harpyja	25
Eagles and Hawk eagles	25
Crocodylus acutus	24
Panthera onca	22
Tayssau pecari	22
Crax rubra	21
Felis pardalis	21
Tapirus bairdii	21
Ara macao	21
Ara ambigua	21
Caiman crocodilus	21
Felis wiedii - Felis tigrina	21
Felis yagouaroundi	20
Felis concolor	20
Ateles geoffroyi	19
Saimiri oerstedii	18
Pharomachrus mocinno	18
Tayassau tajacu	16
Alouatta palliata	13
Cebus capucinus	11

CONCLUSIONS

1. It is possible to quantify existence and loss of dense forest for some wildlife species and it clarifies to some degree the endangered species concept.
2. Recent developments in the field of insular ecology have shown the importance of carefully planning the creation of wildland areas as habitat islands for the existence and perpetuation of wildlife species.
3. Most of the wildlife species studied suffered around 35% dense forest habitat destruction from 1940-1977 with the extremes being *Saimiri oerstedii* (45%) and Pharomachrus mocinno (19%).
4. If dense forest block sizes, densities and the idea that 500 individuals are necessary for long term fitness are correct as presented, a number of wildlife species will become extinct within 50-150 years in Costa Rica because there are no dense forest areas large enough for 500 individuals. These wildlife species included: *Myrmecophaga tridactyla*, all *Felis* except *Felis yagouaroundi, Harpia hapyja*, Eagles and Hawk-eagles, *Ara ambigua* and *Ara macao*. Several other species are adaptable to altered conditions which may increase their probabilities of survival.
5. Most other species have at least one protected area where a genetically viable population can persist. Unfortunately many sizable areas of their habitat are not being protected at present and thus the opportunity for ensuring a viable population will be lost.
6. The most important protected areas in Costa Rica for the survival of the species studied are: low elevation: (0-750m) Corcovado National Park-Golfo Dulce Forest Reserve Complex. Middle and high elevations: (200-3400m) Braulio Carrillo National Park-Cordillera Volcánica Central Forest Reserve-La Selva Protected Zone-La Selva Biological Reserve Complex. Middle and high elevations: (2000-3800m) Chirripó National Park-La Amistad International Park-Río Macho and Los Santos Forest Reserves-Barbilla and Las Tablas Protected Zones-Talamanca, Chirripó, Ujarrás and Tayni-Telire Indian Reservations Complex.
7. Another area currently not under protection but important for wildlife species is Chambacú near the Nicaraguan border which could include all swamp and dense forest areas to Tortuguero National Park.
8. Those species considered most endangered according to biological parameters include: *Trichechus manatus, Mymecophaga tridactyla, Harpia harpyja*, other Eagles and Hawk-eagles, *Crocodylus acutus, Panthera onca* and *Tayassu pecari*.
9. Much research is needed on the wildlife species studies to determine more accurately their distribution in Costa Rica, densities and population dynamics. Present information is inadequate, and this report represents an initial effort in this direction.
10. Most species could probably survive in altered areas if they were not under hunting pressure. Management programs should take this into account.

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APPENDIX 1

Estimated dense forest habitat (80-100% forest cover) for endangered wildlife species in National parks and Biological reserves[1]

			Estimated habitat area for species (km^2)									
Protected areas	**Area (km^2)**	**Altitud range meters**	***Myrmecophaga tridactyla Caiman crocodilus Crocodilus acutus***	***Ara ambigua***	***Saimiri oerstedii***	***Trichechus manatus***	***Tayassu pecari Harpia harpyja Eagles, Hawk-eagles Ara macao***	***Aloutta palliata Crax rubra Felis yagouaroundi***	***Ateles geoffroyi***	***Cebus capucinus Felis concolor Felis pardalis Felis wideii Felis tigrina Phantera onca Tayassu tajacu Tapirus bairdii***	***Pharomachrus mocinno***
Chirripo National Park[2]	501,50	1300-3820	0	0	0	0	13,98	7341	206,70	427,08	427,09
Corcovado N.P.	417,89	0-745	380,73	0	390,73	0	417,89	417,89	417,89	417,89	0
Braulio Carillo N.P.	319,36	500-2906	1,92	200	0	0	200	272,32	307,84	319,36	236
Tortuguero N.P. [3]	189,47	0-100	100	100	0	100	100	100	100,00	100	0
Rincon de la Vieja N.P.	140,83	400-1916	0	125,39	0	0	125,39	140,03	140,83	140,83	68,80
Santa Rosa N.P.[4]	219,14	0-315	100	0	0	0	100	100	100	100	—
Volcan Poas National Park	44	1500-2704	0	0	0	0	0	14,04	44	44	44
Irazu N.P.	24	2100-3432	0	0	0	0	0	0	0	20	20
Isla del Coco N.P.	24	0	?	?	0	0	?	?	?	?	—
Cahuita N.P.	10,68	0-10	11	0	—	—	—	—	—	11	—
Manuel Antonio N.P.	6,90	0-120	6,90	0	6,90	0	6,90	6,90	6,90	6,90	—
Barra Honda N.P.	22,95	50-400	—	—	—	0	—	—	—	—	
Palo Verde N.P.	94,67	10	40,00	0	0	0	40	40	40	40	—
Hitoy Carere Biological Reserve	91,45	400-1000	70,81	91,45	0	0	91,45	91,45	91,45	91,45	
Carara Biological Reserve	76	10-1000	64,37	0	64,37	0	76	76	76	76	
Isla Guayabo / Negritos/Pajaros Biological Reserve	1,48	0-50	?	?	?	0	?	?	?	?	

APPENDIX 1 (Continued...)

Estimated dense forest habitat (80-100% forest cover) for endangered wildlife species in National parks and Biological reserves[1]

Protected areas	Area (km^2)	Altitud range meters	Estimated habitat area for species (km^2)								
			Myrmecophaga tridactyla *Caiman crocodilus* *Crocodilus acutus*	*Ara ambigua*	*Saimiri oerstedii*	*Trichechus manatus*	*Tayassu pecari* *Harpia harpyja* *Eagles, Hawk-eagles* *Ara macao*	*Aloutta palliata* *Crax rubra* *Felis yagouaroundi*	*Ateles geoffroyi*	*Cebus capucinus* *Felis concolor* *Felis pardalis* *Felis wideii* *Felis tigrina* *Phantera onca* *Tayassu tajacu* *Tapirus bairdii*	*Pharomachrus mocinno*
Cabo Blanco Biological Reserve	11,70	0-200	11,70	0	0	0	11,70	11,70	11,70	11,70	0
La Selva Biological Reserve	16	0	16,0	16	0	0	16	16	16	16	0
Monte Verde Biological Reserve	22,42	0	0	0	0	0	0	22,42	22,42	22,42	22,42
La Amistad International Park[2]	1920		28,71	578	0	0	578,85	1133,04	1646,82	1900	1723
Total	—	—	**842,14**	**1122**	**462**	**100**	**1789,16**	**2526,20**	**3239,55**	**3744,63**	**2541,3**

N.P. = National Park

(1) Based on 1977 dense forest cover map; (2) Includes areas of subalpine paramo; (3) Includes large areas of palm swamp forest; (4) includes large areas of pasture in various successsional stages.

APPENDIX 2

Estimated dense forest habitat (80-100% forest cover) for endangered species in forest reserves, wildlife refuges and protected areas in Costa Rica (1977)[1]

			Estimated habitat area for species (km^2)									
Protected areas	**Area (km^2)**	**Altitud range meters**	***Myrmecophaga tridactyla* *Caiman crocodilus* *Crocodilus acutus***	***Ara ambigua***	***Saimiri oerstedii***	***Trichechus manatus***	***Tayassu pecari* *Harpia harpyja* *Eagles, Hawk-eagles* *Ara macao***	***Aloutta palliata* *Crax rubra* *Felis yagouaroundi***	***Ateles geoffroyi***	***Cebus capucinus* *Felis concolor* *Felis pardalis* *Felis wideii* *Felis tigrina* *Panthera onca* *Tayassu tajacu* *Tapirus bairdii***	***Pharomachrus mocinno***
Rafael Lucas Rodriguez National Wildlife Refuge	75,24	10-230	50	0	0	0	50	50	50	50	0
Rio Macho F.R.	919,92	800-3400	0	214,43	0	0	213,43	460,89	686,29	919	876,69
Los Santos F.R.	620	300-3491	0	0	0	0	185,32	296,84	405,90	533	436,24
Golfo Dulce F.R.	790	0-647	593,02	0	593,02	0	593,02	593,02	593,02	593,02	0
Matina F.R.	4,4,	0-1	3,52	3,52	0	3,52	3,52	3,52	3,52	3,52	0
Cordillera Volcanica Central F.R.	723	500-33,29	47	381,03	0	0	381,03	493,10	514,79	514,79	467,79
Grecia F.R.	28,48	1600-2300	0	0	0	0	22,78	22,78	22,78	22,78	22,78
San Ramon F.R.	78,96	600-1495	0	0	0	0	78,96	78,96	78,96	78,96	46,98
Juan Castro F.R.	144,36	900-2122	5,97	142,15	0	0	142,15	142,15	142,15	142,15	30,83
Arenal F.R.	170,44	900-2122	5,97	142,15	0	0	142,15	142,15	142,15	142,15	30,83
Cordillera Volcanica Guanacaste F.R.	371,53	—	—	—	0	0	—	—	—	—	—
Orosi	100,00	540-1659	1,49	100	0	0	100,00	100,75	100,75	100,75	29,09
Tenorio	165,33	500-11918	15,54	150,78	0	0	150,78	154,75	154,75	154,75	47,02
Miravalles	105,52	1500-2028	0	59,20	0	0	59,20	70,07	70,07	70,07	50,65

APPENDIX 2 (Continued...)

Estimated dense forest habitat (80-100% forest cover) for endangered species in forest reserves, wildlife refuges and protected areas in Costa Rica (1977)[(1)]

			Estimated habitat area for species (km^2)								
Protected areas	**Area (km^2)**	**Altitud range meters**	***Myrmecophaga tridactyla* *Caiman crocodilus* *Crocodilus acutus***	***Ara ambigua***	***Saimiri oerstedii***	***Trichechus manatus***	***Tayassu pecari* *Harpia harpyja* *Eagles, Hawk-eagles* *Ara macao***	***Aloutta palliata* *Crax rubra* *Felis yagouaroundi***	***Ateles geoffroyi***	***Cebus capucinus* *Felis concolor* *Felis pardalis* *Felis widei* *Felis tigrina* *Panthera onca* *Tayassu tajacu* *Tapirus bairdii***	***Pharomachrus mocinno***
Taboga F.R.	2,95	50-100	1,48	0	0	0	1,48	1,48	1,48	1,48	0
El Roble P.F.	23,50	600-850	0	0	0	0	11,75	11,75	11,75	11,75	0
Caraigres P.F.	40,00	1400-2000	—	—	0	0	—	—	—	—	—
Barbilla P.A.	128,30	400-1600	28,30	128,30	0	0	128,30	128,30	128,30	128,30	50,00
Las Tablas P.A.	190,30	—	0	0	0	0	131,02	135,94	190,30	190,30	190,30
La Selva P.A.	60,00	—	20	60	0	0	60	60	60	60	0
Total	**4742,23**	**—**	**766,32**	**1288,65**	**593,02**	**3,52**	**3363,58**	**2883,56**	**3289,74**	**3653,88**	**2313,82**

P.F.= Protected Forest; F.R.= Forest Reserve; P.A.= Protected Area

(1) Based on 1977 dense forest cover map; (2) Dense forest habitat is between 10-50% for many areas (Morales, 1981).

APPENDIX 3

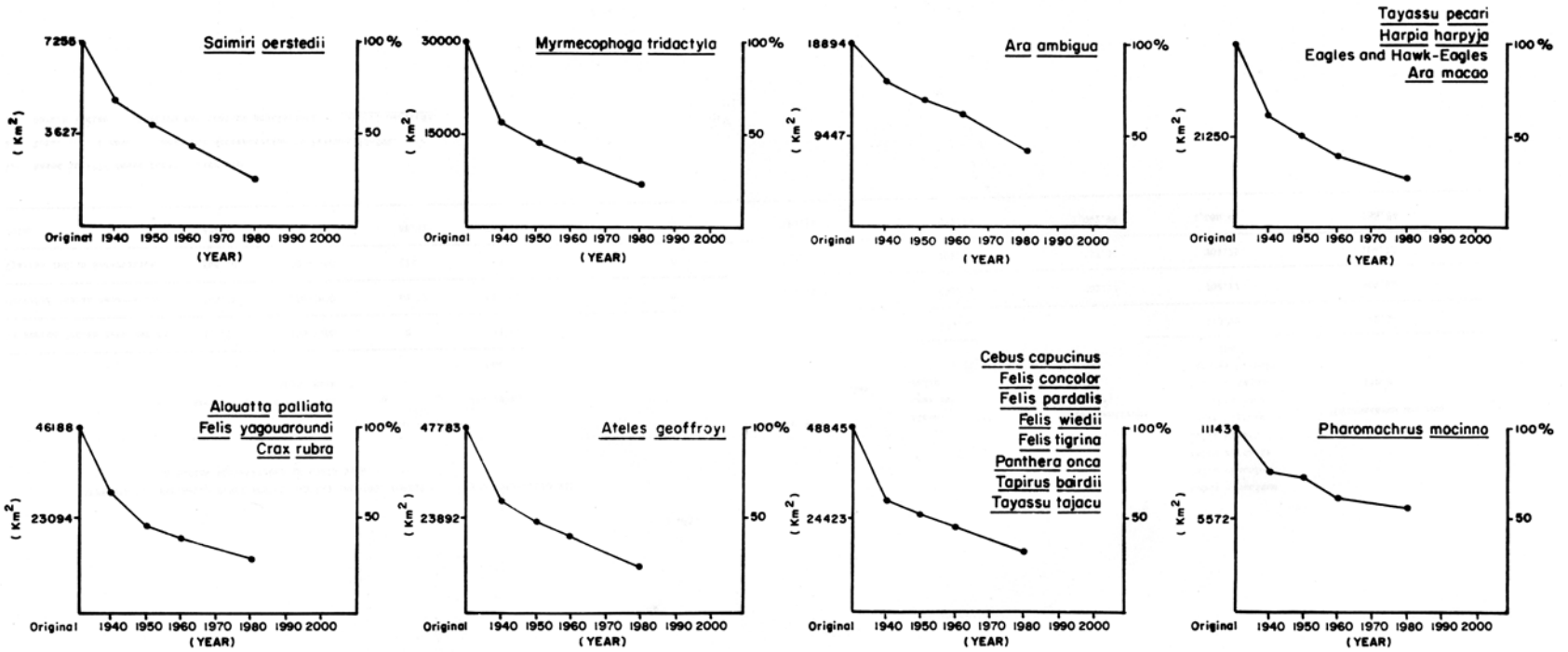
Estimated dense forest habitat (80-100% forest cover) for endangered wildlife species in indian reservations in Costa Rica[1, 2]

			Estimated habitat area for species (km^2)							
Area (km^2)	**Altitud range meters**	***Myrmecophaga tridactyla* *Caiman crocodilus* *Crocodilus acutus***	***Ara ambigua***	***Saimiri oerstedii*[3]**	***Trichechus manatus***	***Tayassu pecari* *Harpia harpyja* *Eagles and Hawks eagles* *Ara macao***	***Aloutta palliata* *Crax rubra* *Felis yagouaroundi***	***Ateles geoffroyi***	***Cebus capucinus* *Felis concolor* *Felis pardalis* *Felis wideii* *Felis tigrina* *Panthera onca* *Tayassu tajacu* *Tapirus bairdii***	***Pharomachrus mocinno***
Talamanca Indian Reservation	627,50	100-1400	0	173,49	0	0	173,49	173,49	173,49	42,34
Chirripo Indian Reservation	702,18	200-1800	88,92	611,65	0	0	611,55	695,10	702,17	309,80
Ujarras Indian Reservation	565,10	300-3100	(2)	0	0	0	(2)	102,75	167,33	204,75
Total	**1894,81**	**—**	**88,92**	**785,14**	**0**	**0**	**785,14**	**971,34**	**1042,99**	**556,89**

(1) Based in 1977 dense forest cover map; (2) Total forest cover unknown but deforestation is between 10-50%; (3) Boruca Indian Reservation may contain populations of Saimiri ***oerstedii***.

APPENDIX 4

FIG. 1. Forest habitat in Costa Rica for endangered wildlife species (1940-1977)



APPENDIX 5
Figures 2-33.

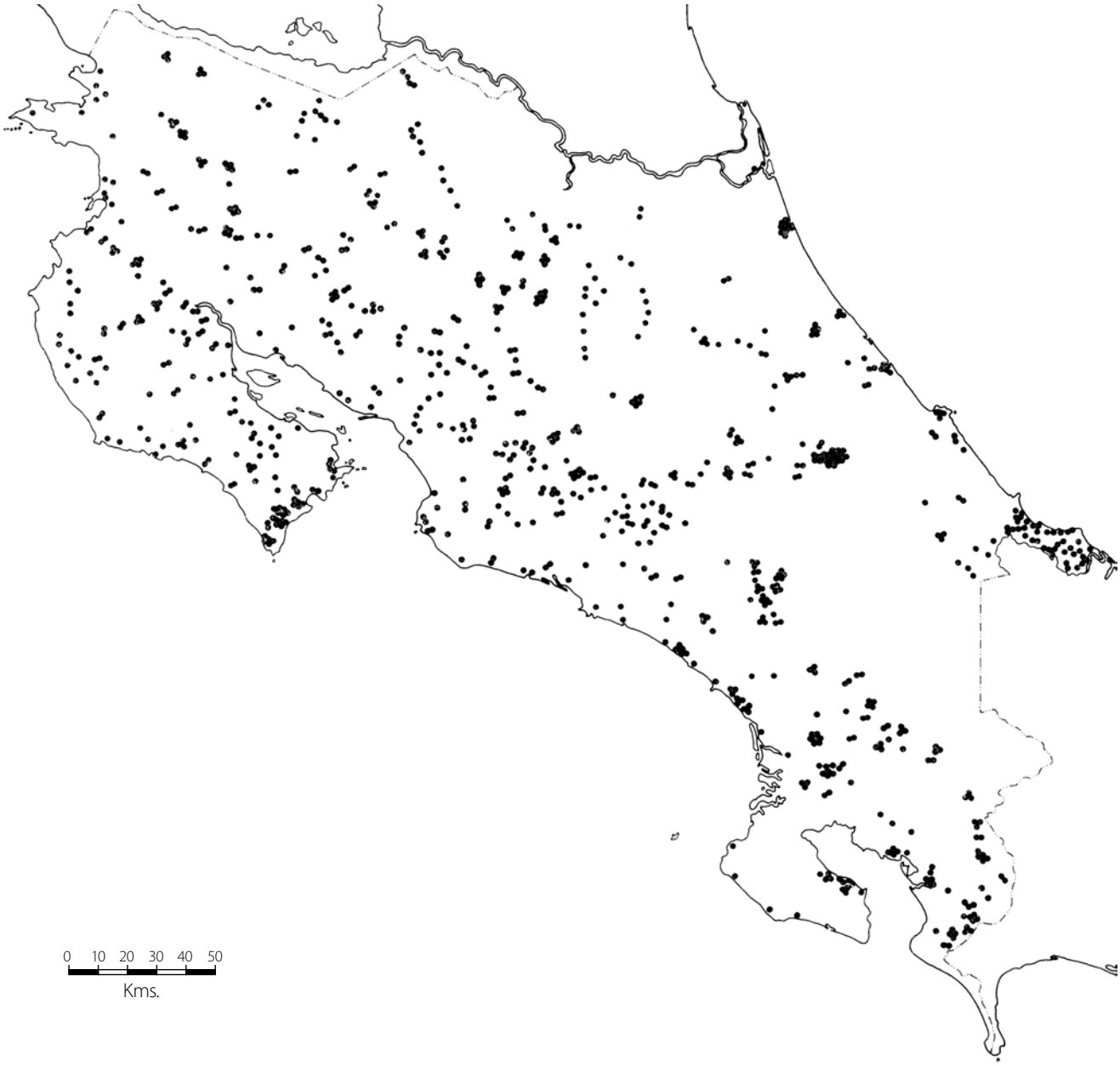


FIG. 2. Interview sites.

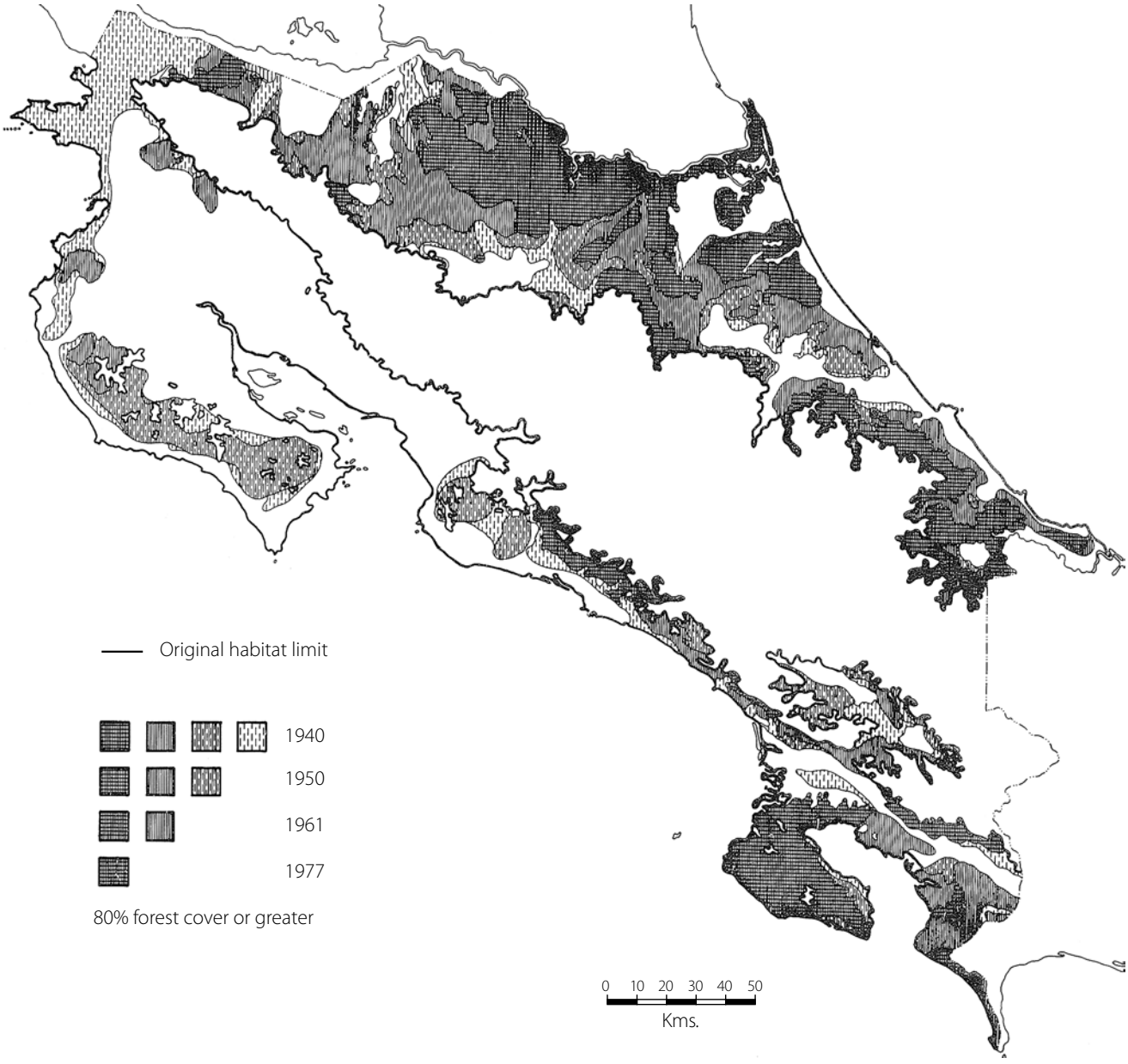


FIG. 3. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Myrmecophaga tridactyla, Crocodylus acutus* and *Caiman crocodilus*.

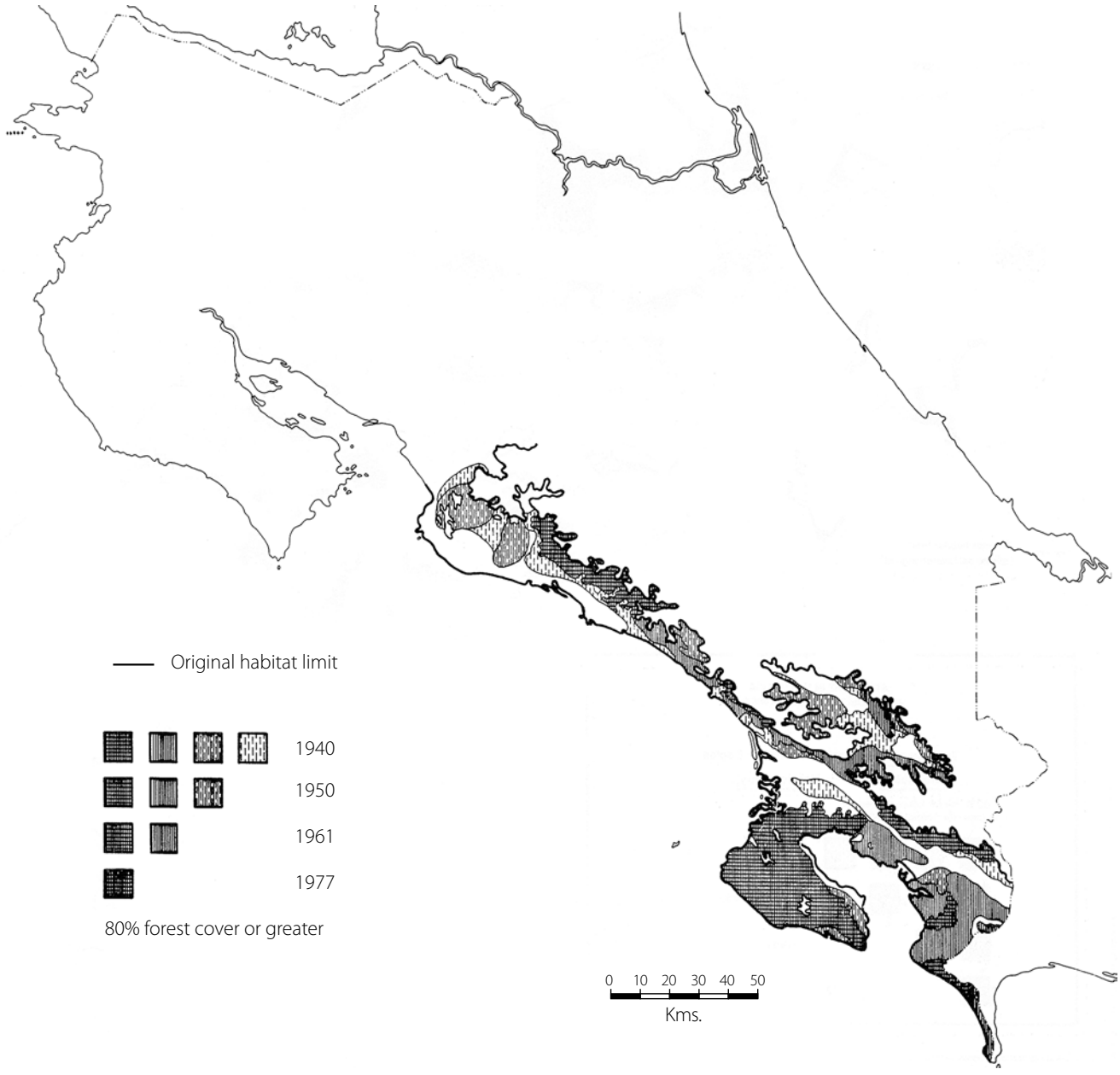


FIG. 4. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Saimiri oerstedii*.

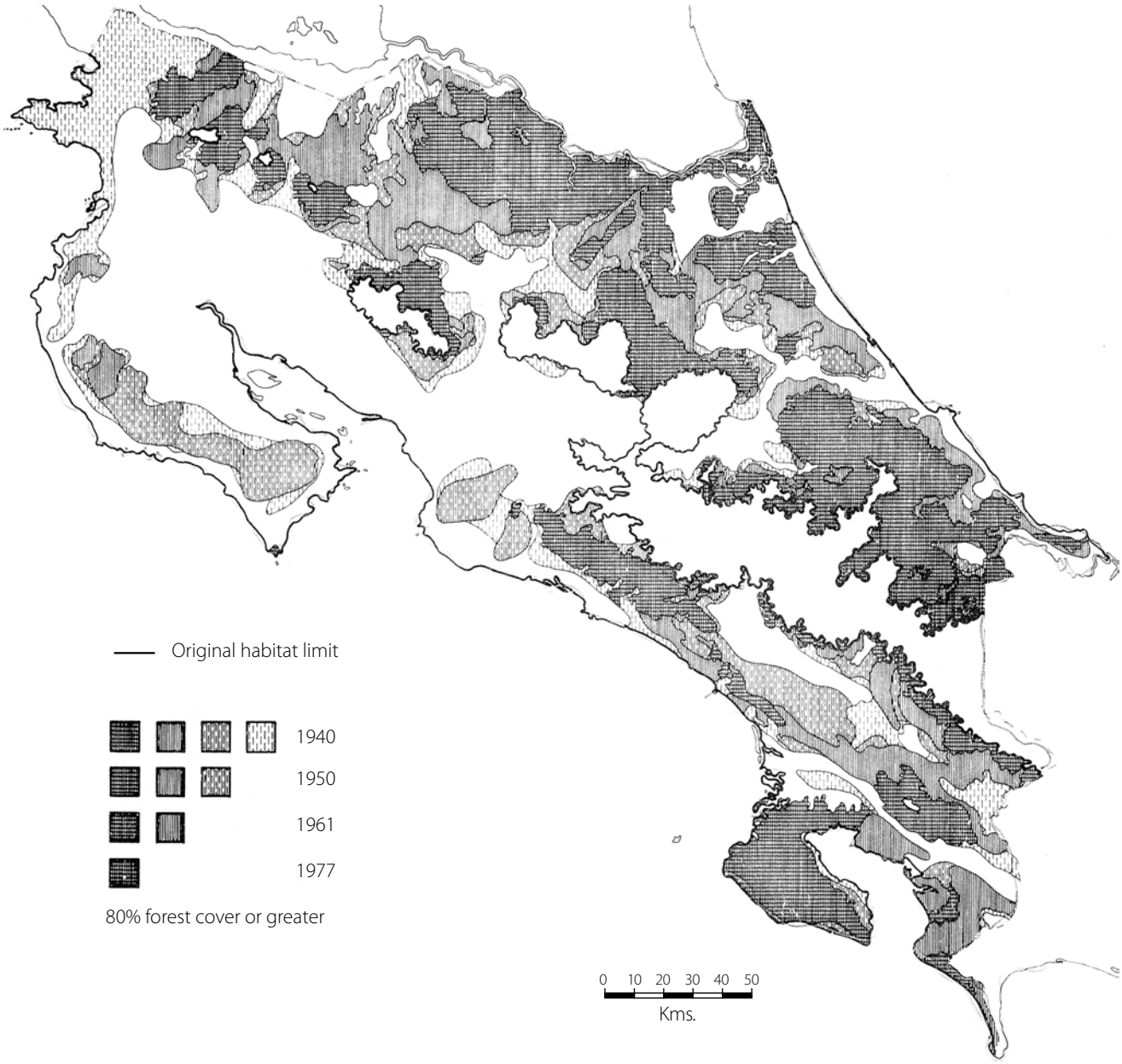


FIG. 5. Forest habitat in Costa Rica (1940-1950-1961-1977) for Eagles and Eagle-hawks, and the species *Tayassu pecari, Ara macao* and *Harpia harpyja*.

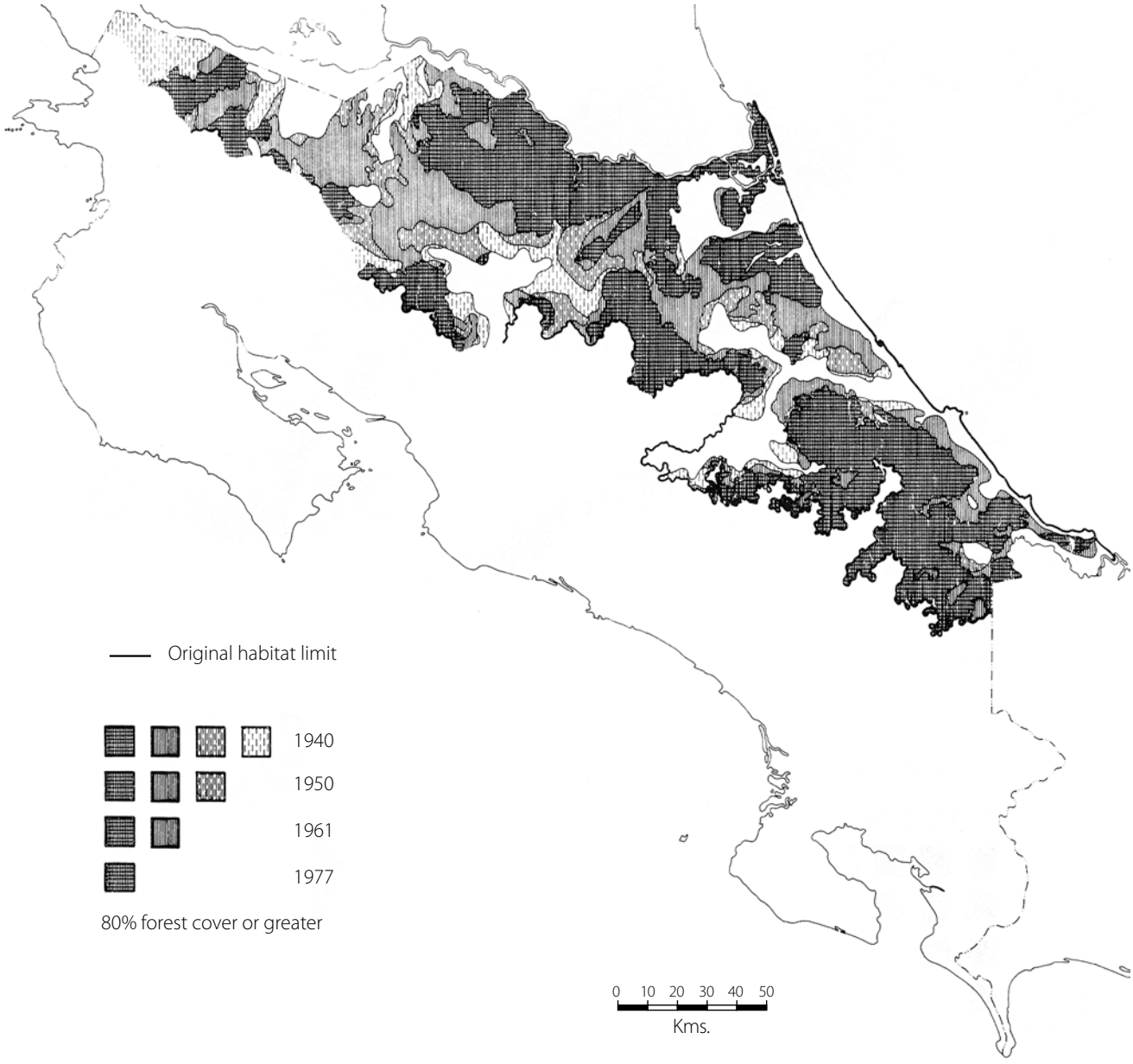


FIG. 6. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Ara ambigua*.

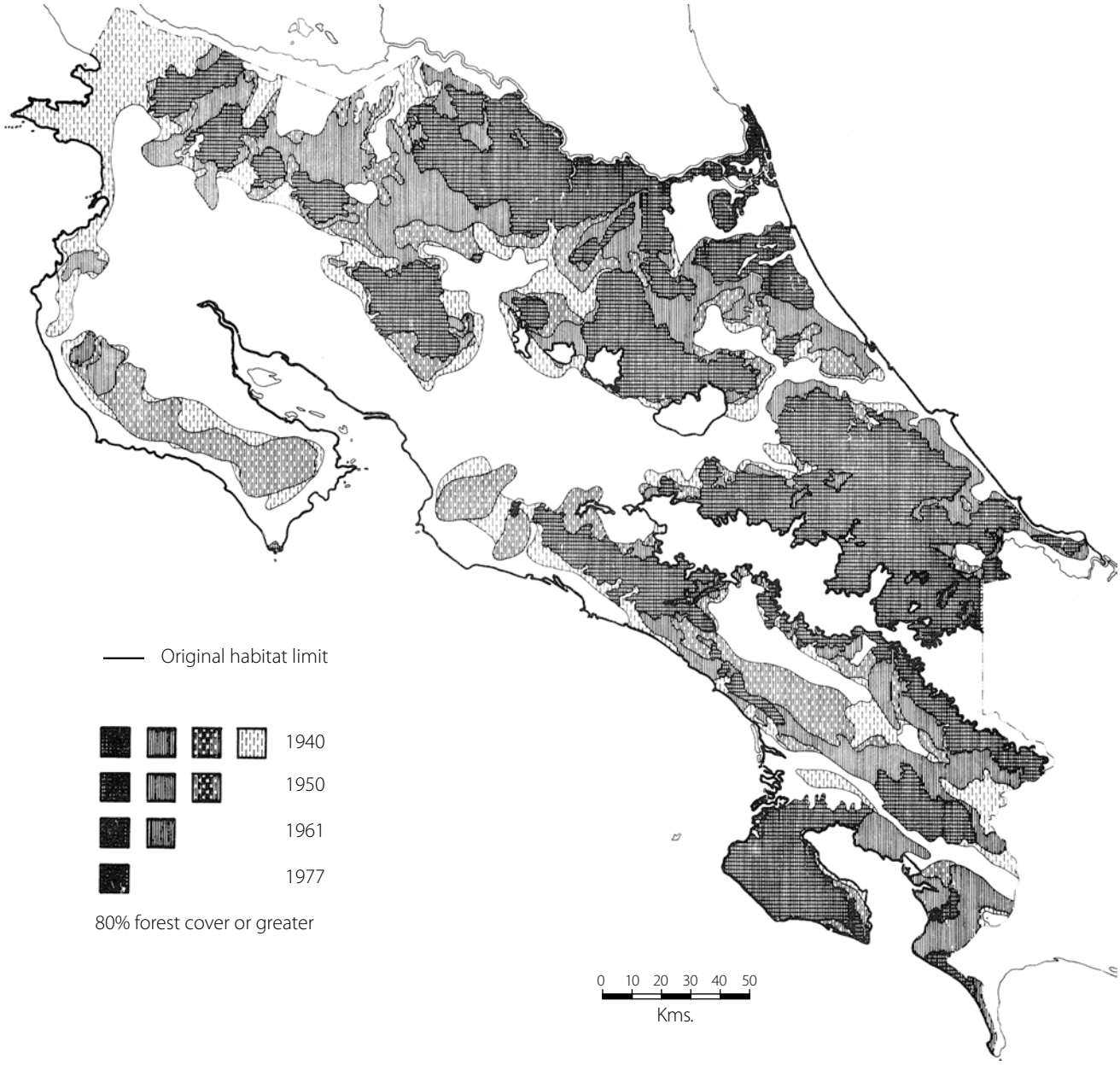


FIG. 7. Forest habitat in Costa Rica (1940-1950-1961-1977) for Eagles and Eagle-hawks, and the species *Allouatta palliata, Felis yagouaroundi* and *Crax rubra*.

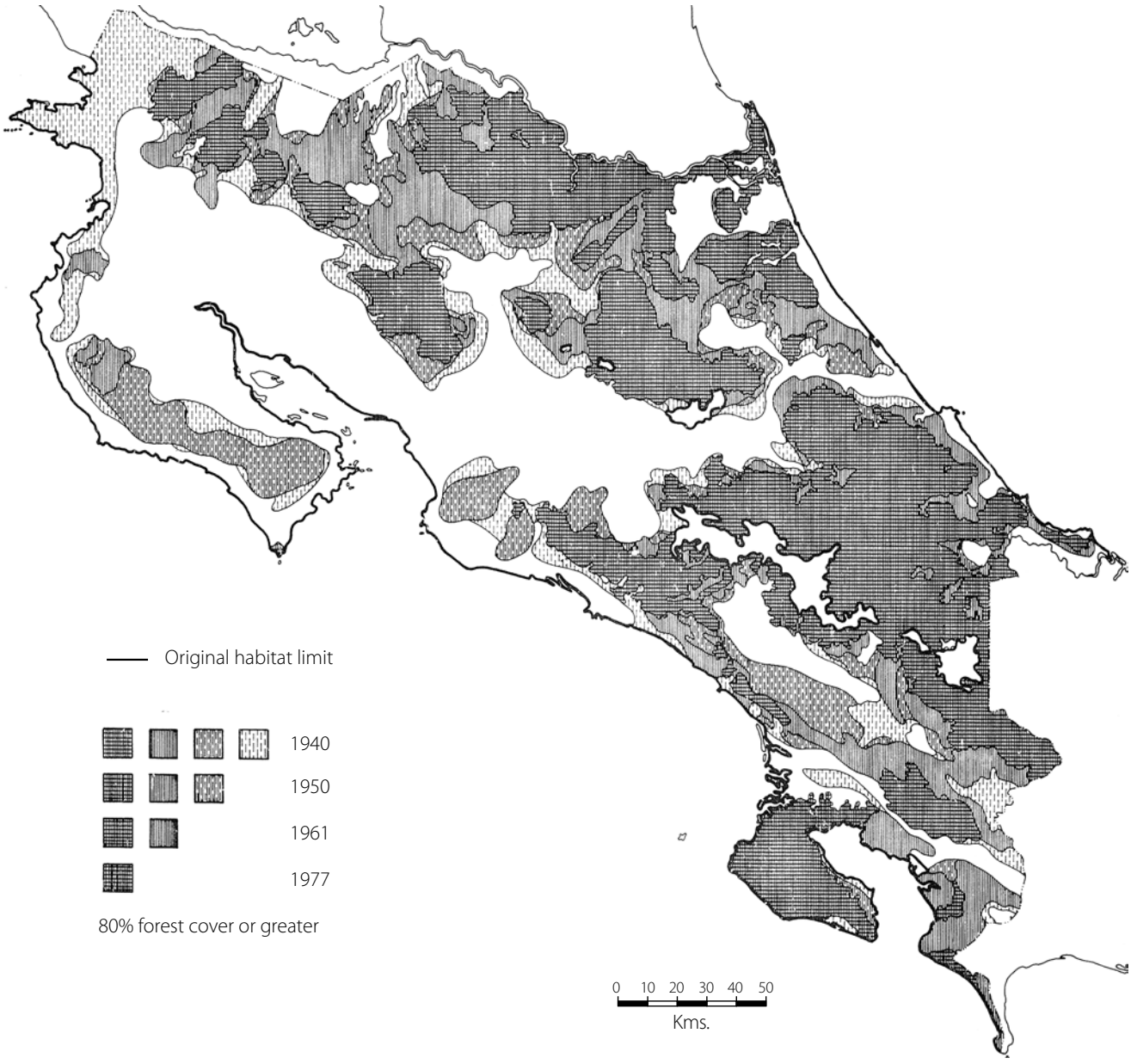


FIG. 8. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Ateles geoffroyi*.

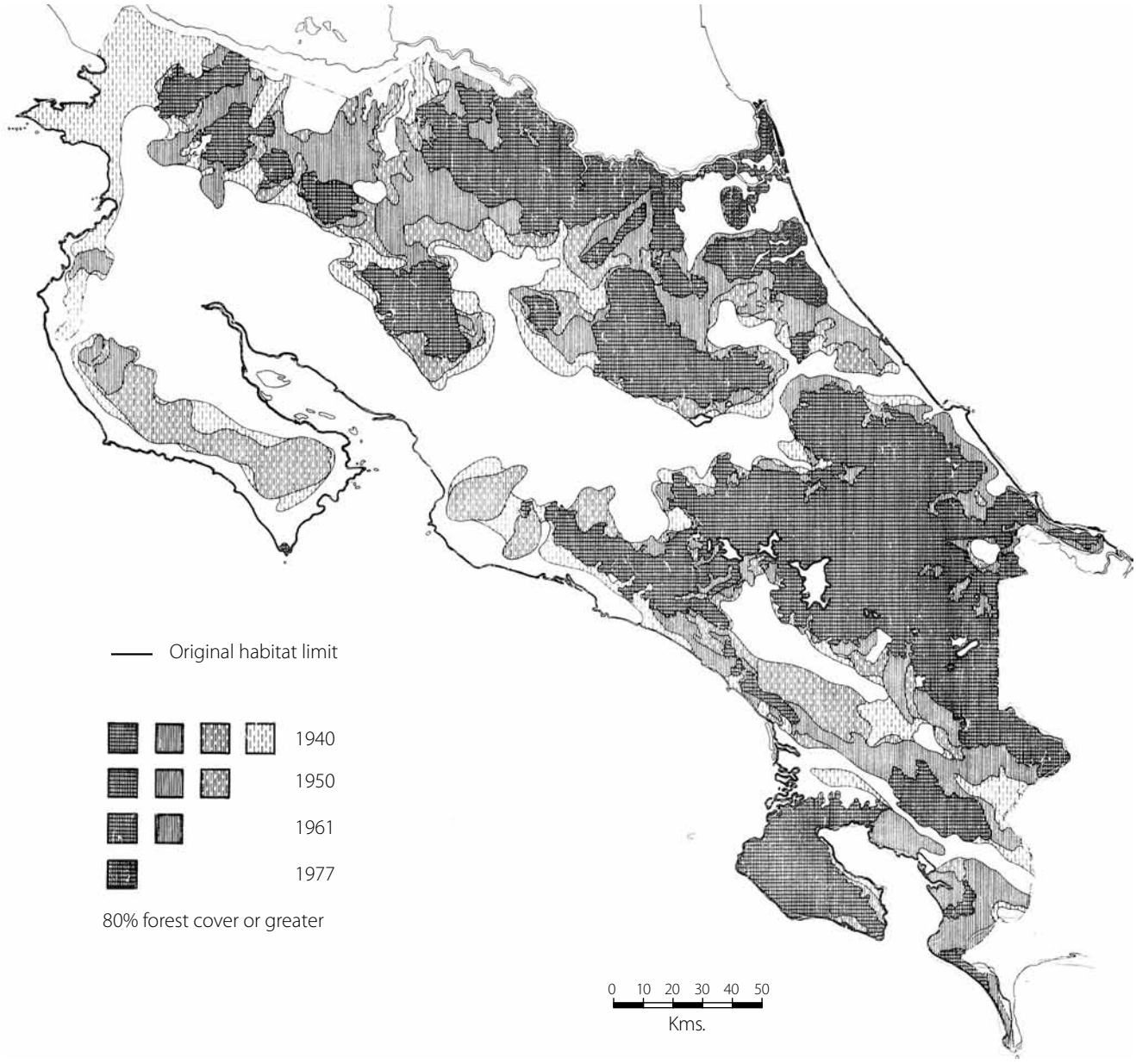


FIG. 9. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Cebus capucinus, Felis pardalis, Panthera onca, Felis concolor, Felis wiedii, Felis tigrina, Tayassu tajacu* and *Tapirus bairdii*.

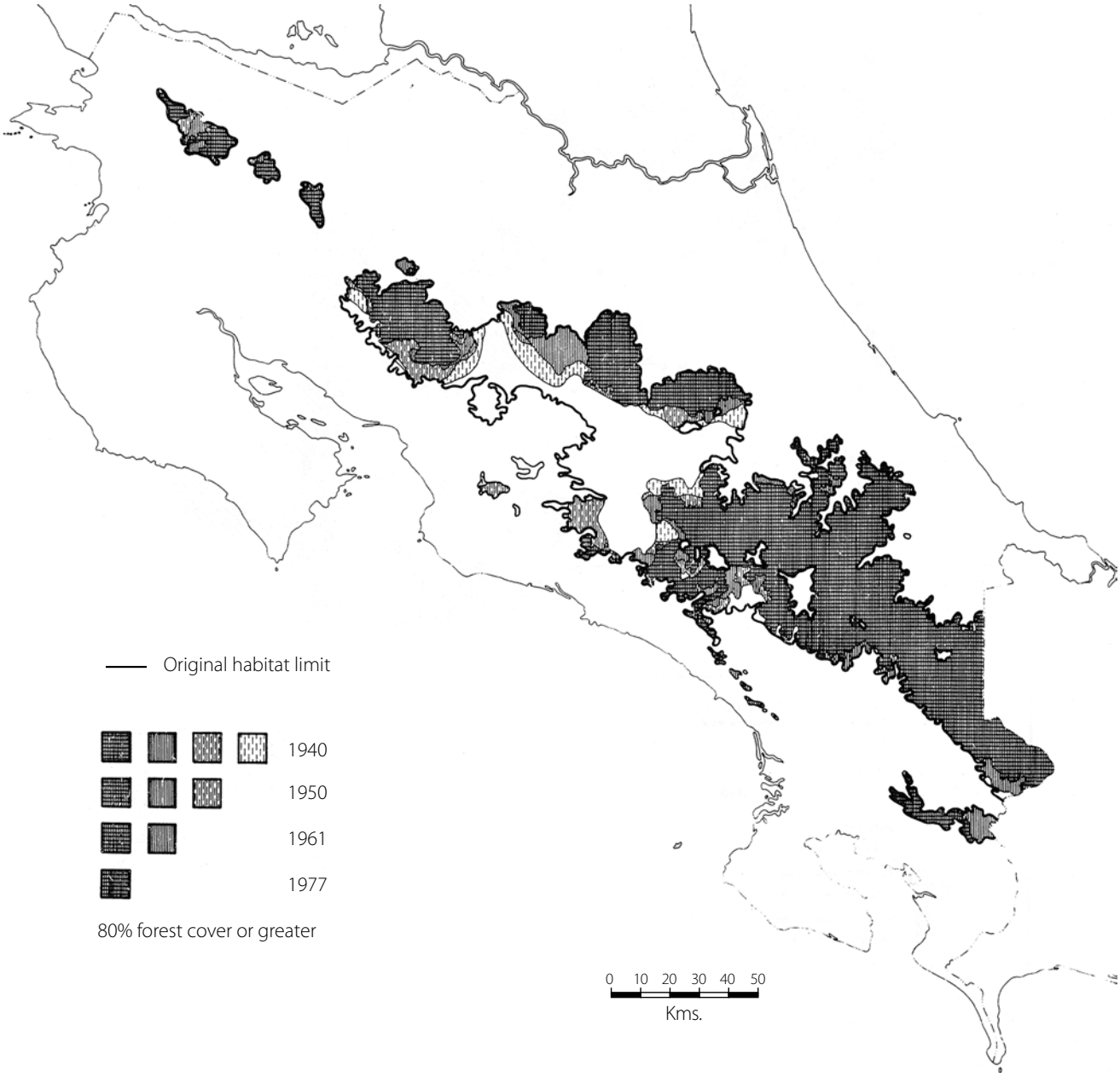


FIG. 10. Forest habitat in Costa Rica (1940-1950-1961-1977) for the species *Pharomachrus moccino*.

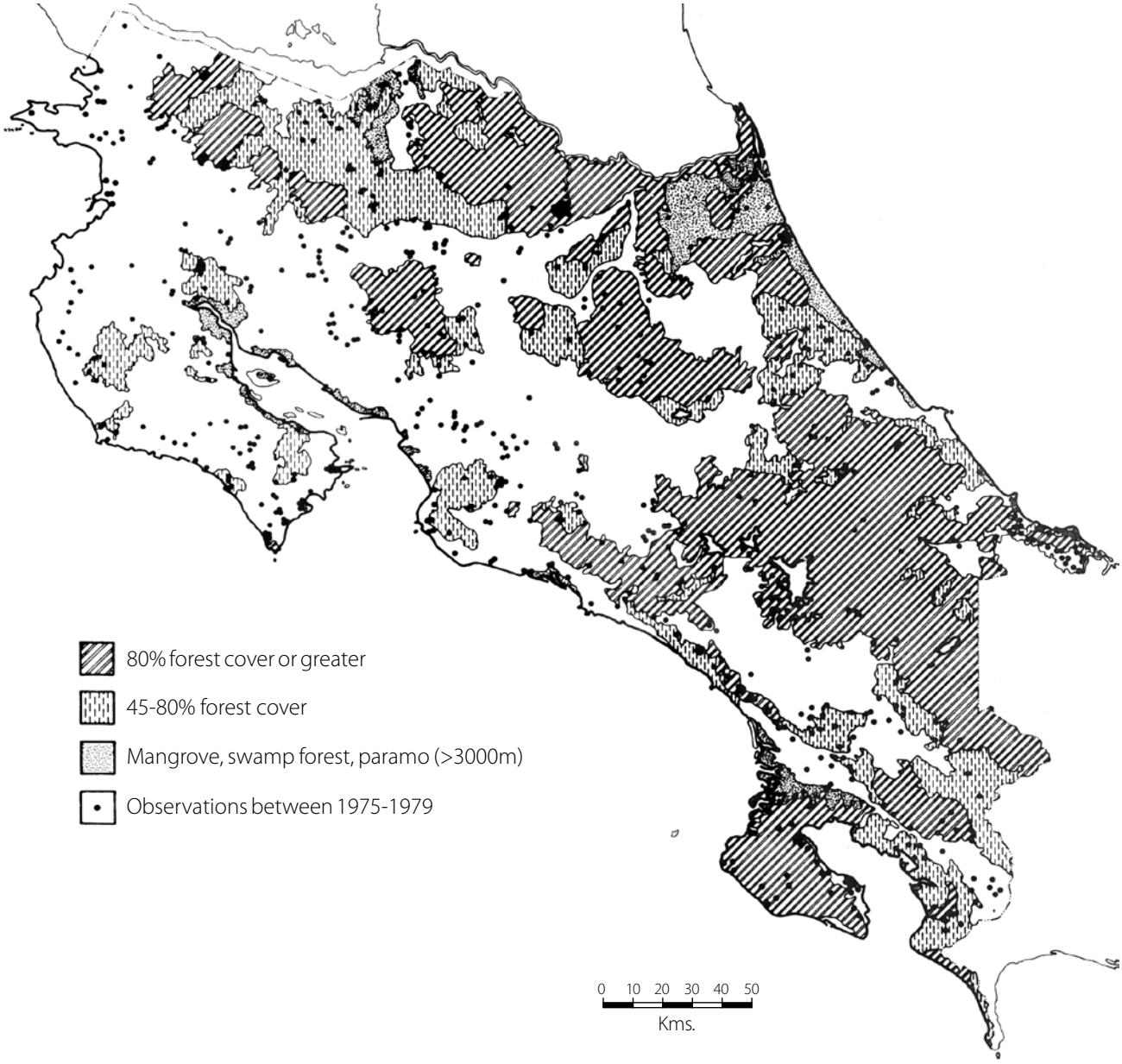


FIG. 11. Forest habitat in Costa Rica (1977) for the species *Cebus capucinus.*

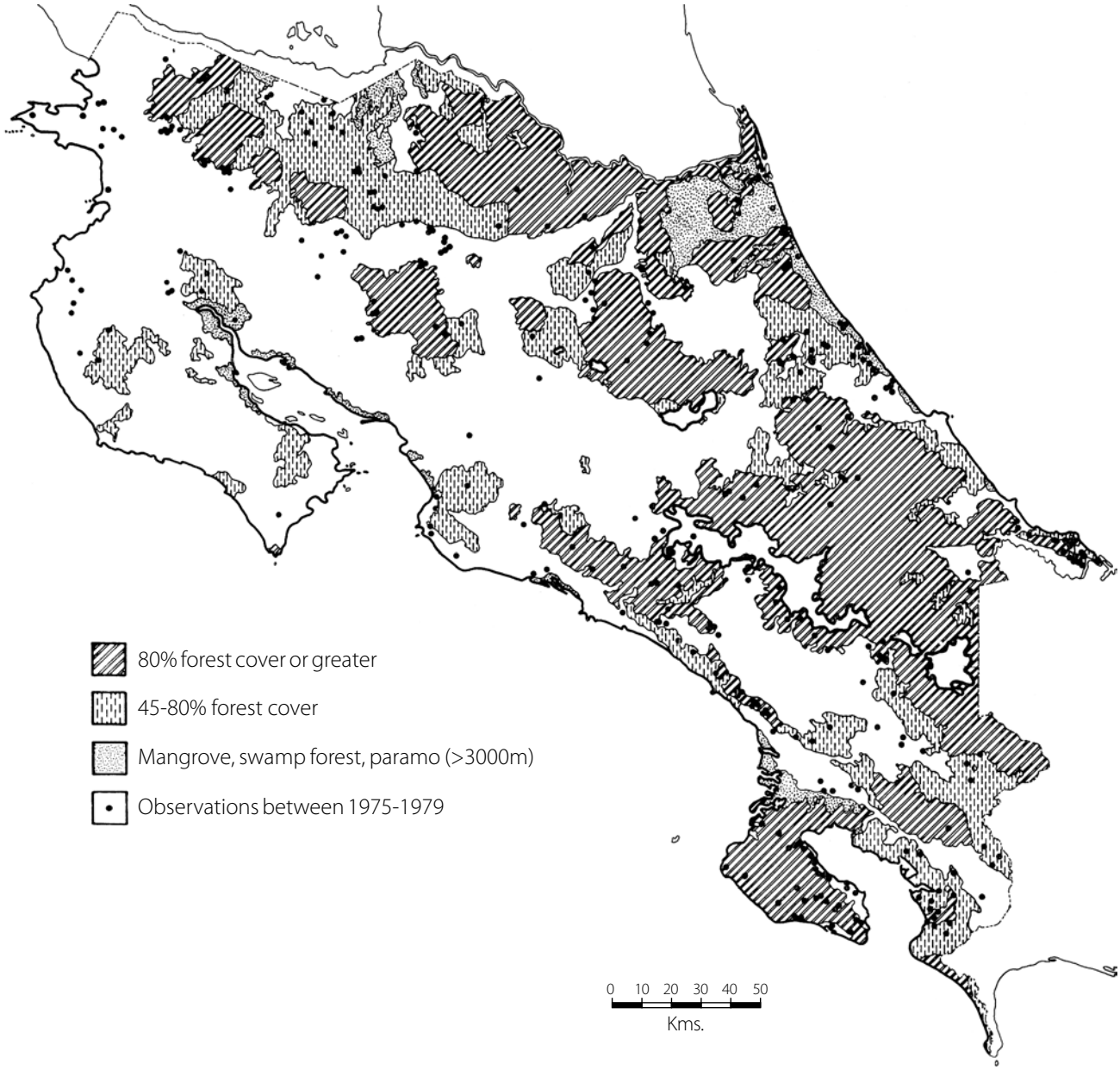


FIG. 12. Forest habitat in Costa Rica (1977) for the species *Ateles geoffroyi*.

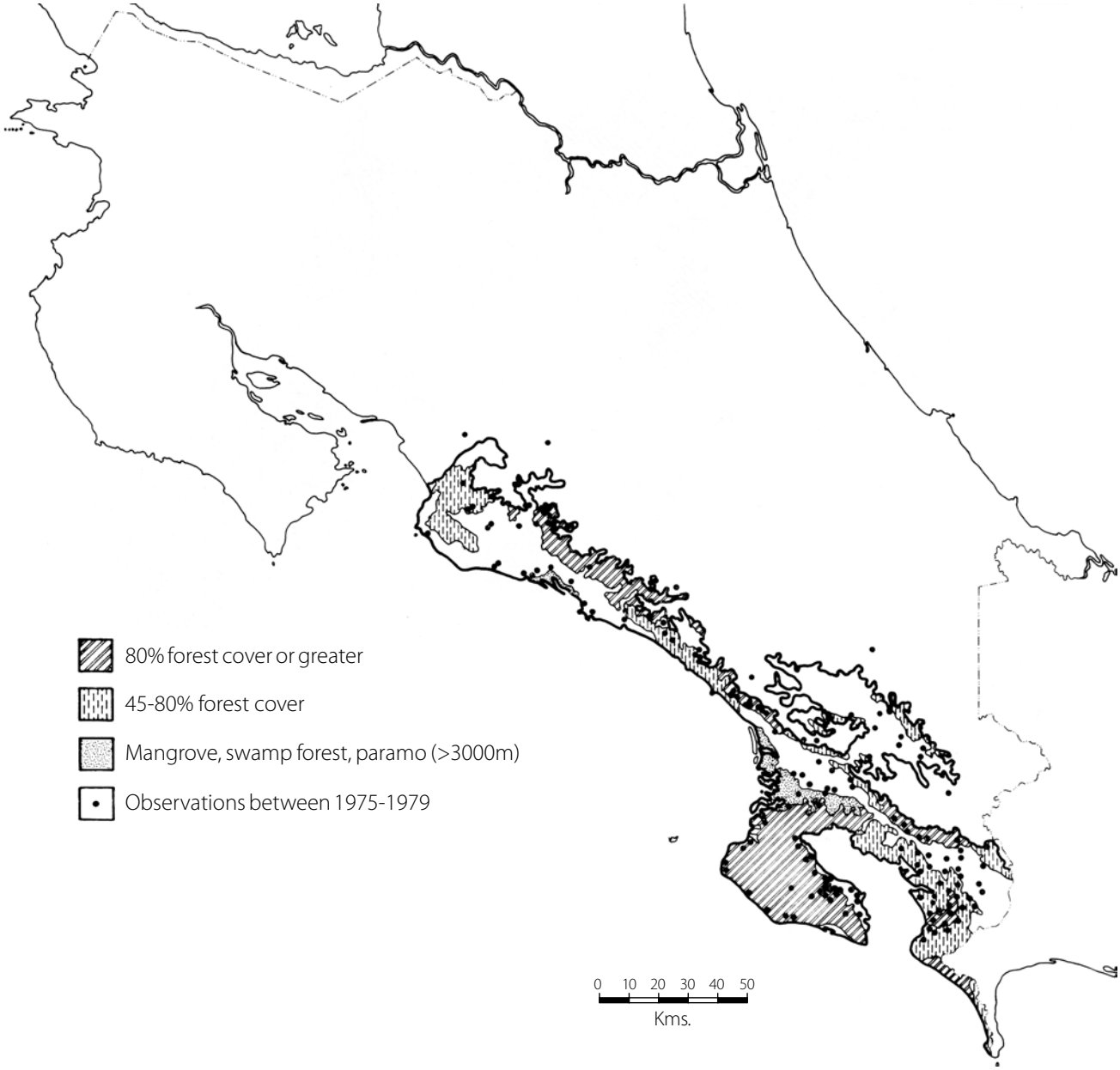


FIG. 13. Forest habitat in Costa Rica (1977) for the species *Saimiri oerstedii*.

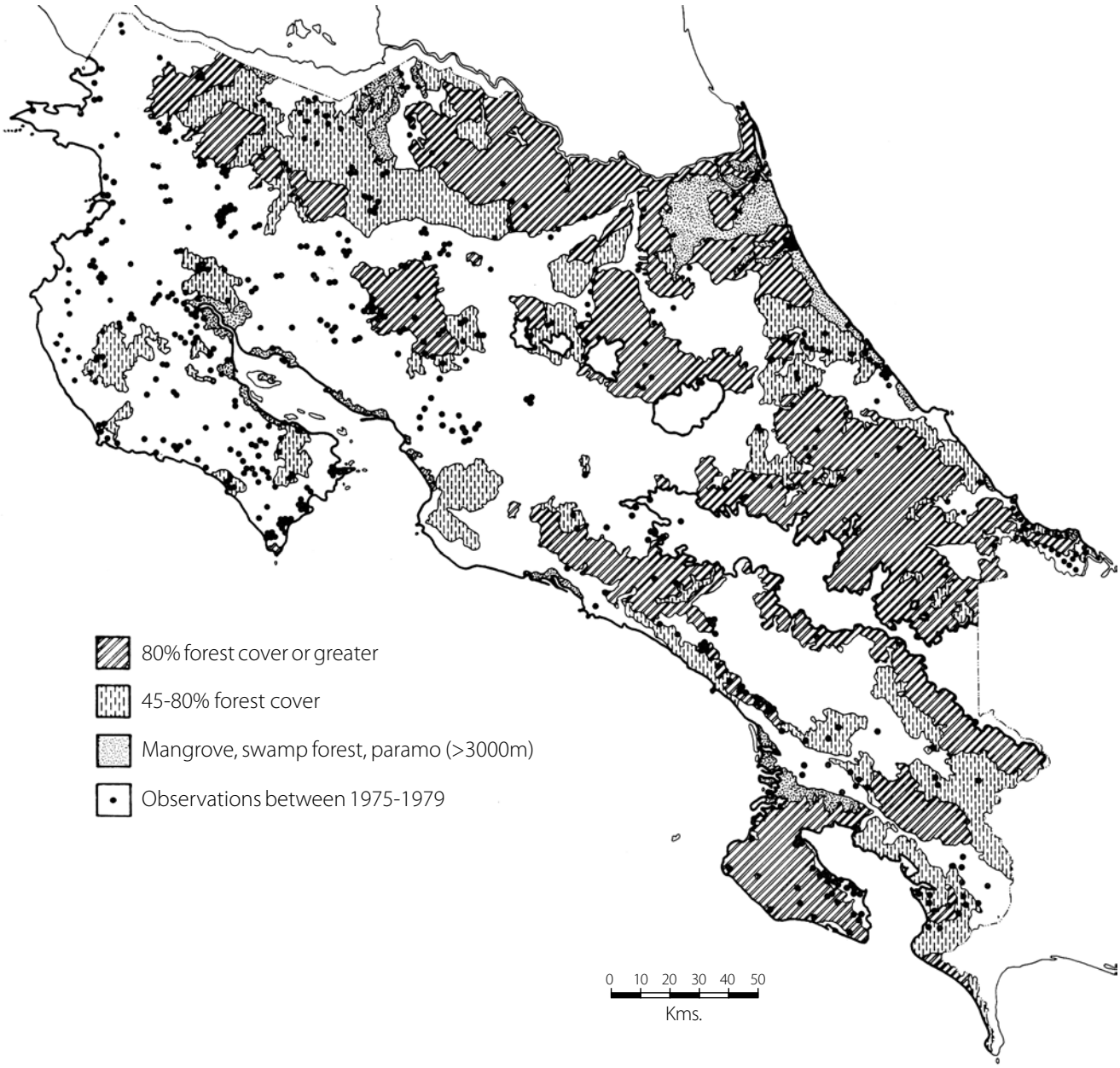


FIG. 14. Forest habitat in Costa Rica (1977) for the species *Alouatta palliata.*

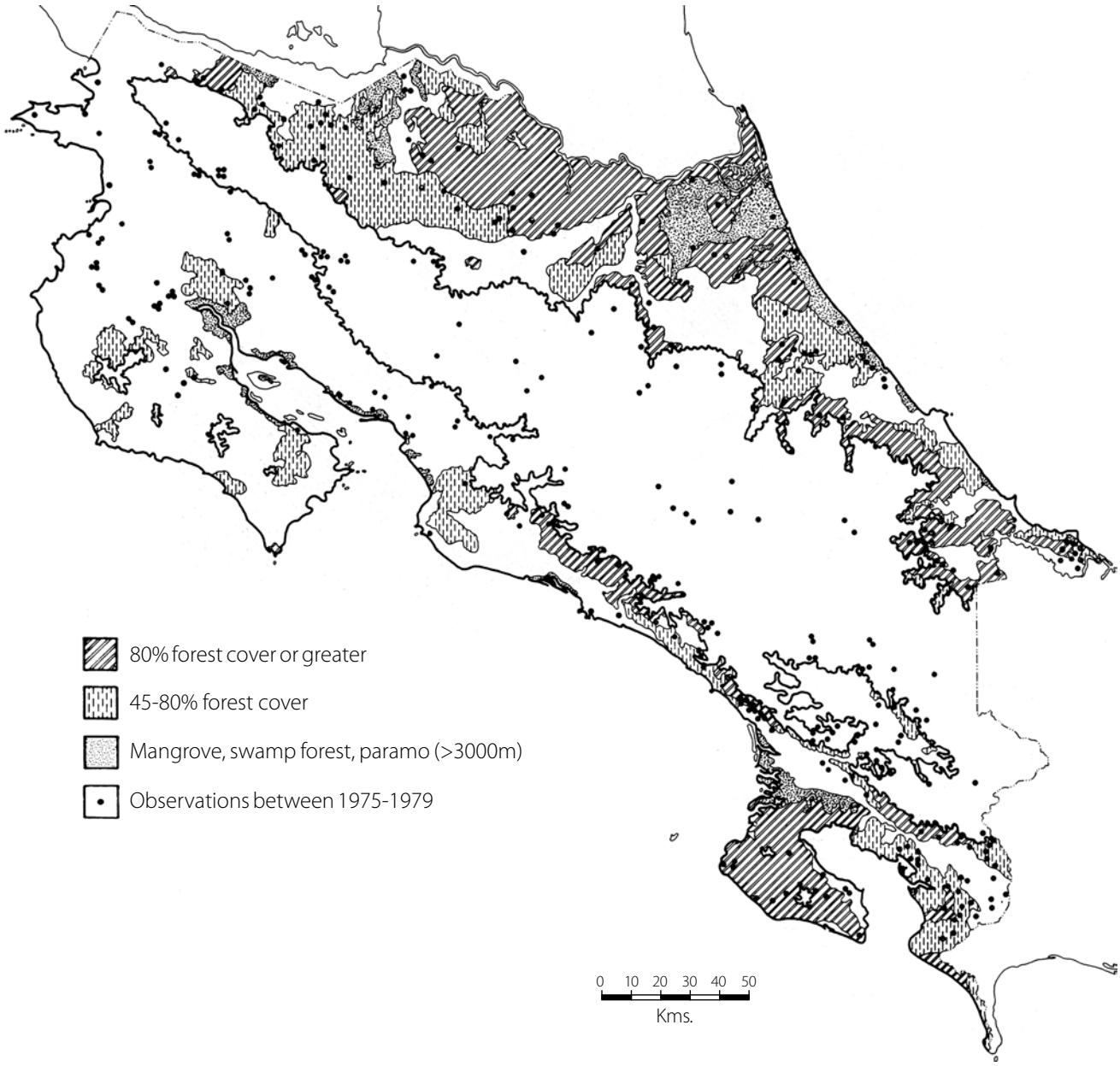


FIG. 15. Forest habitat in Costa Rica (1977) for the species *Myrmecophaga tridactyla*.

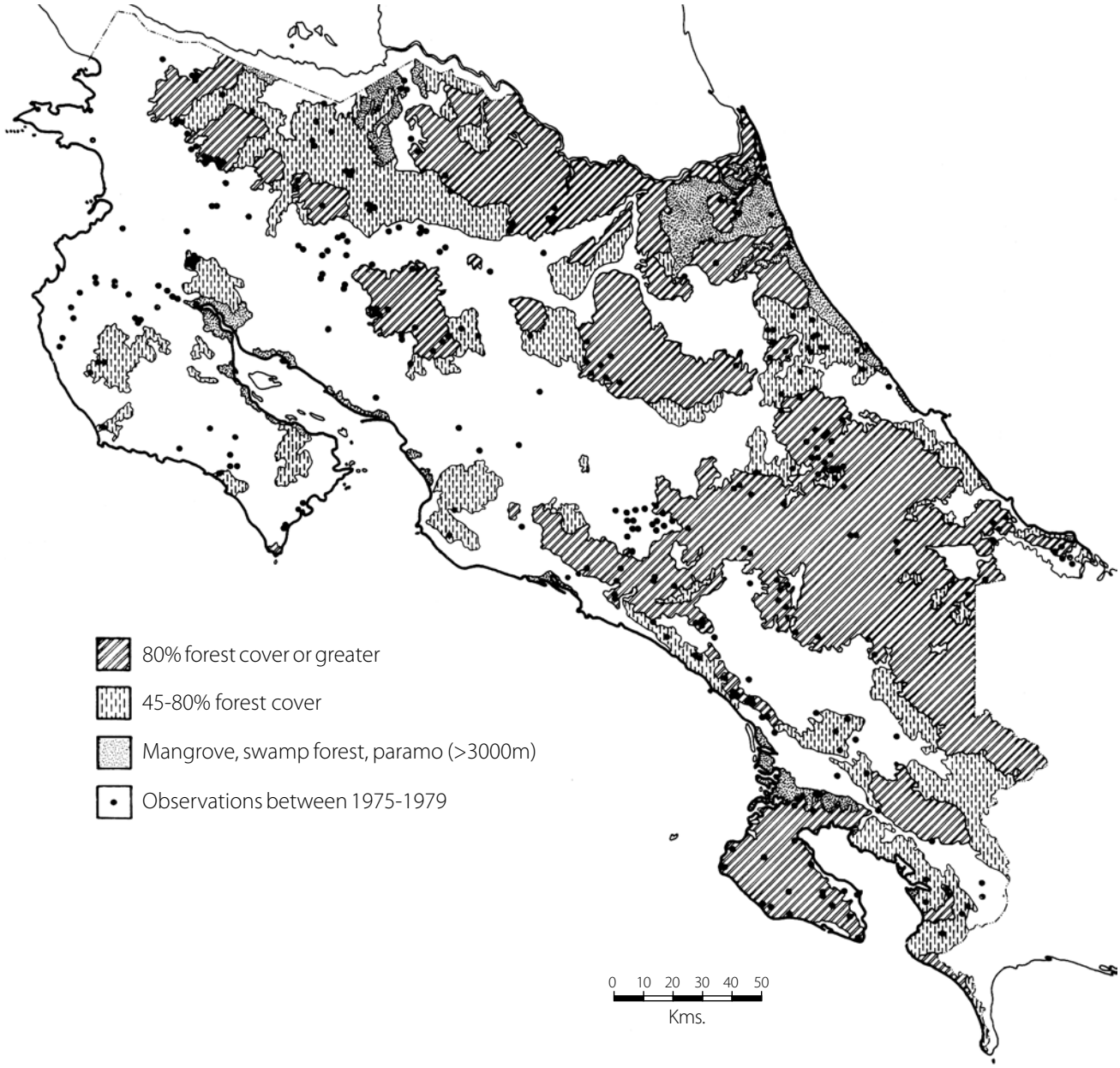


FIG. 16. Forest habitat in Costa Rica (1977) for the species *Felis concolor.*

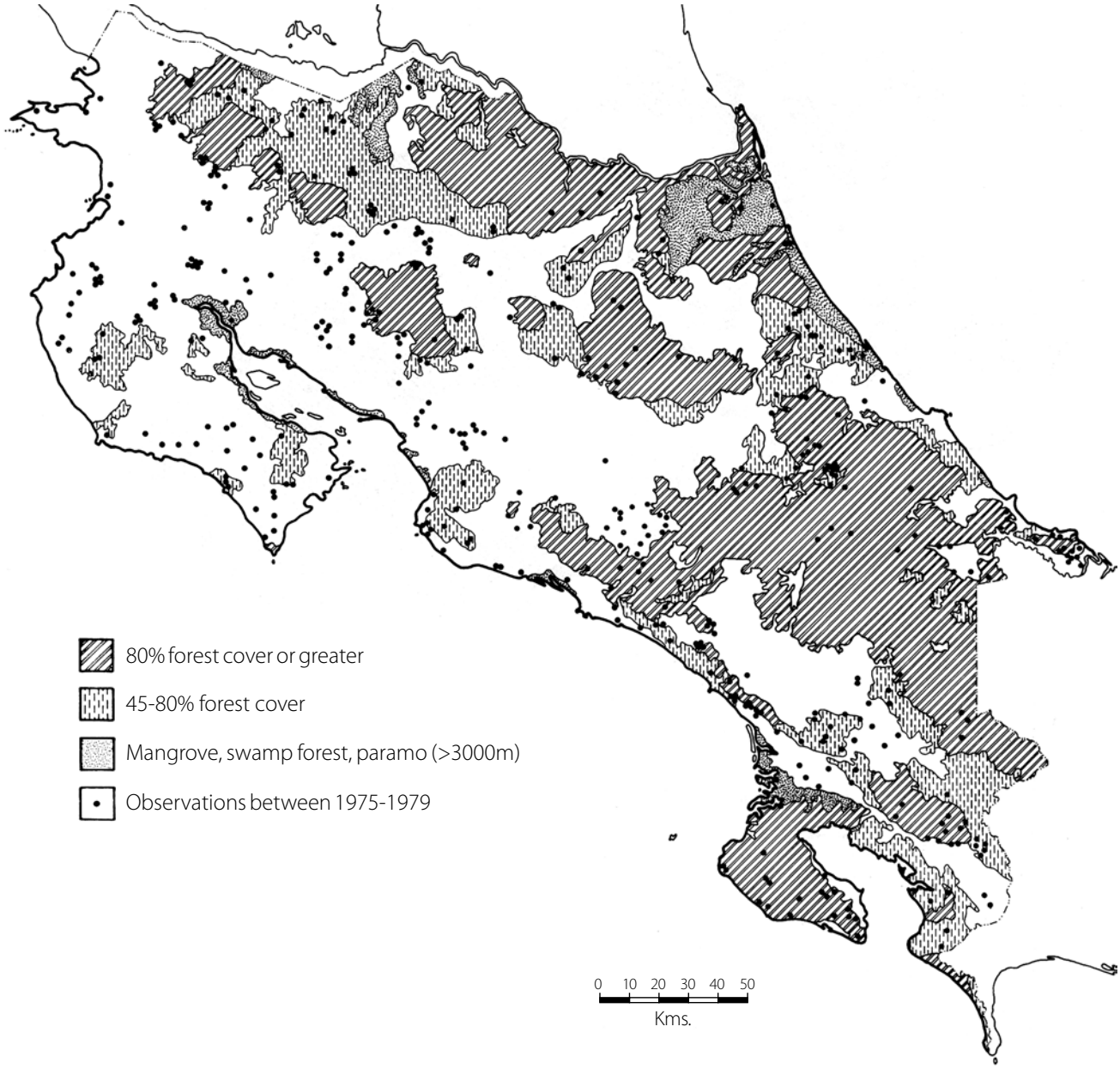


FIG. 17. Forest habitat in Costa Rica (1977) for the species *Felis pardalis*.

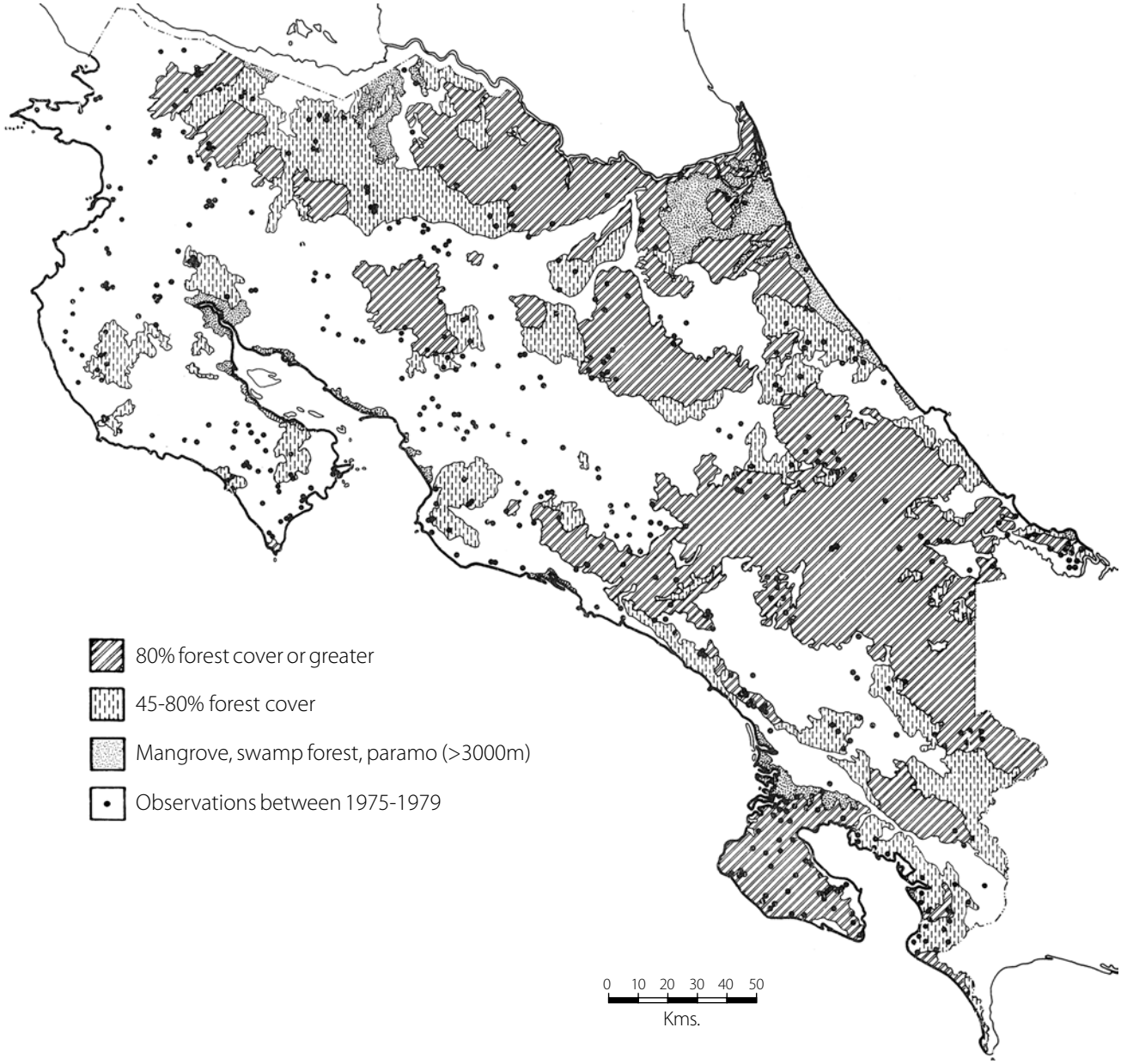


FIG. 18. Forest habitat in Costa Rica (1977) for the species *Felis wiedii* and *Felis tigrina*.

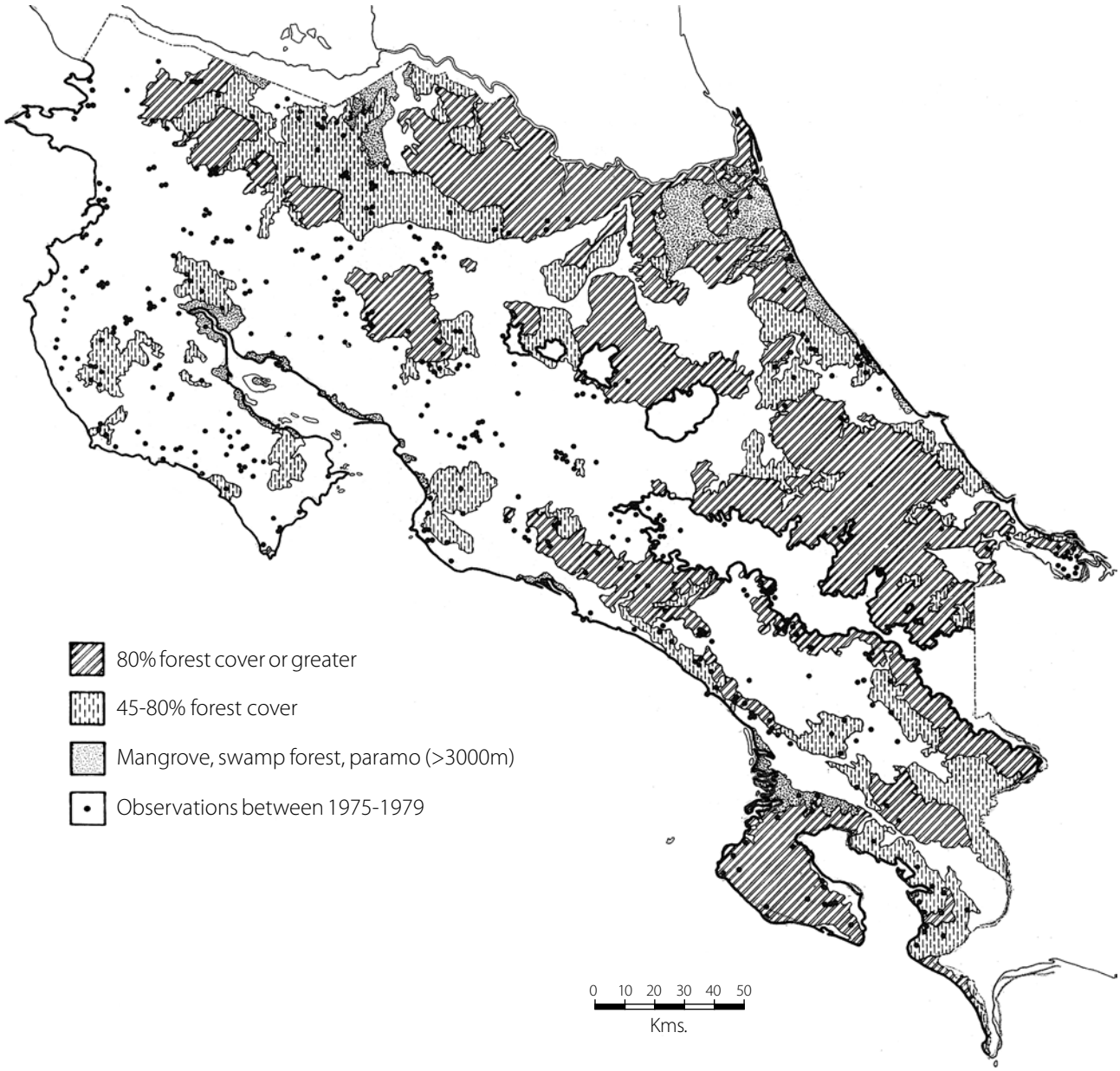


FIG. 19. Forest habitat in Costa Rica (1977) for the species *Felis yagouaroundi*.

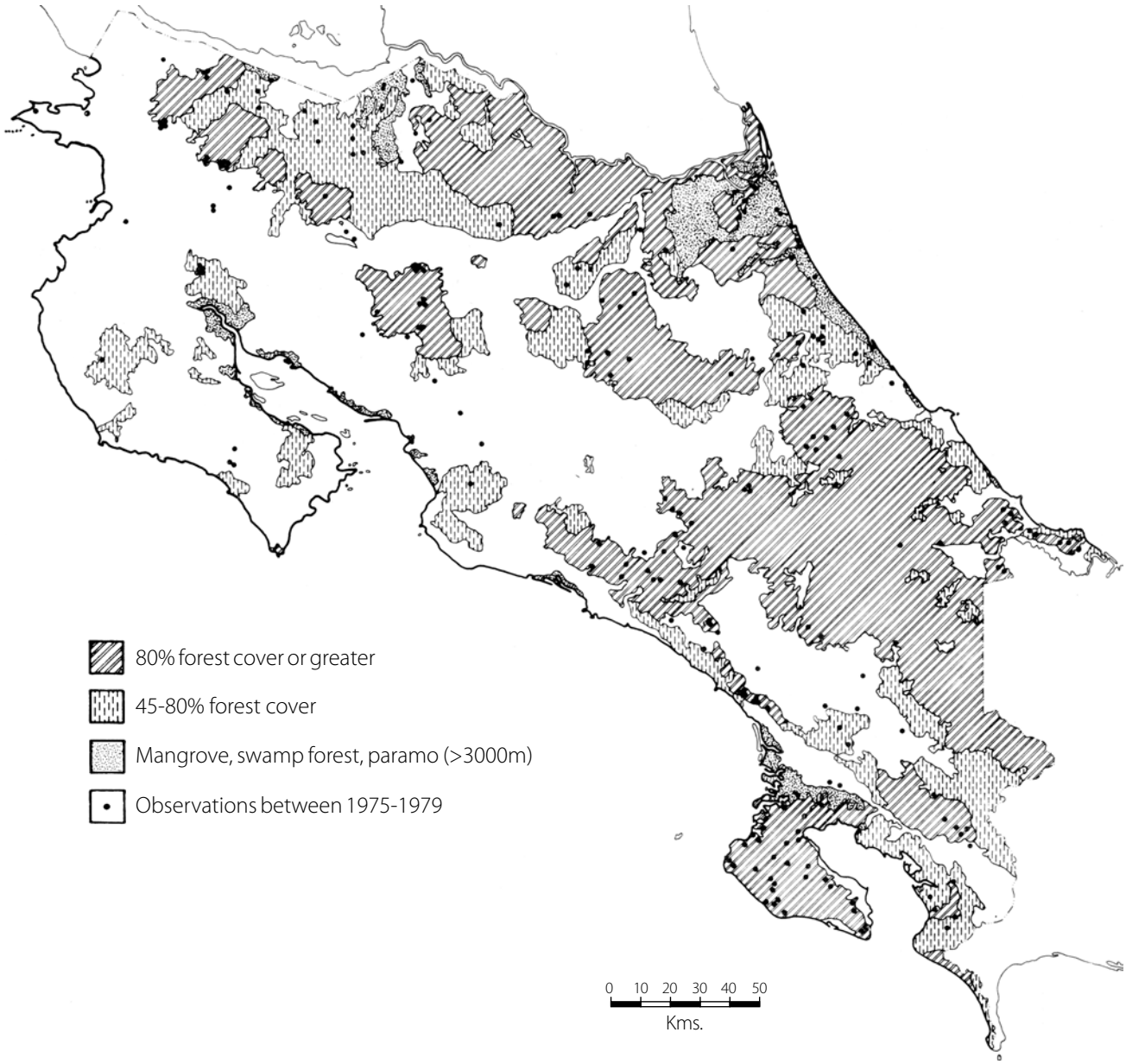


FIG. 20. Forest habitat in Costa Rica (1977) for the species *Panthera onca*.

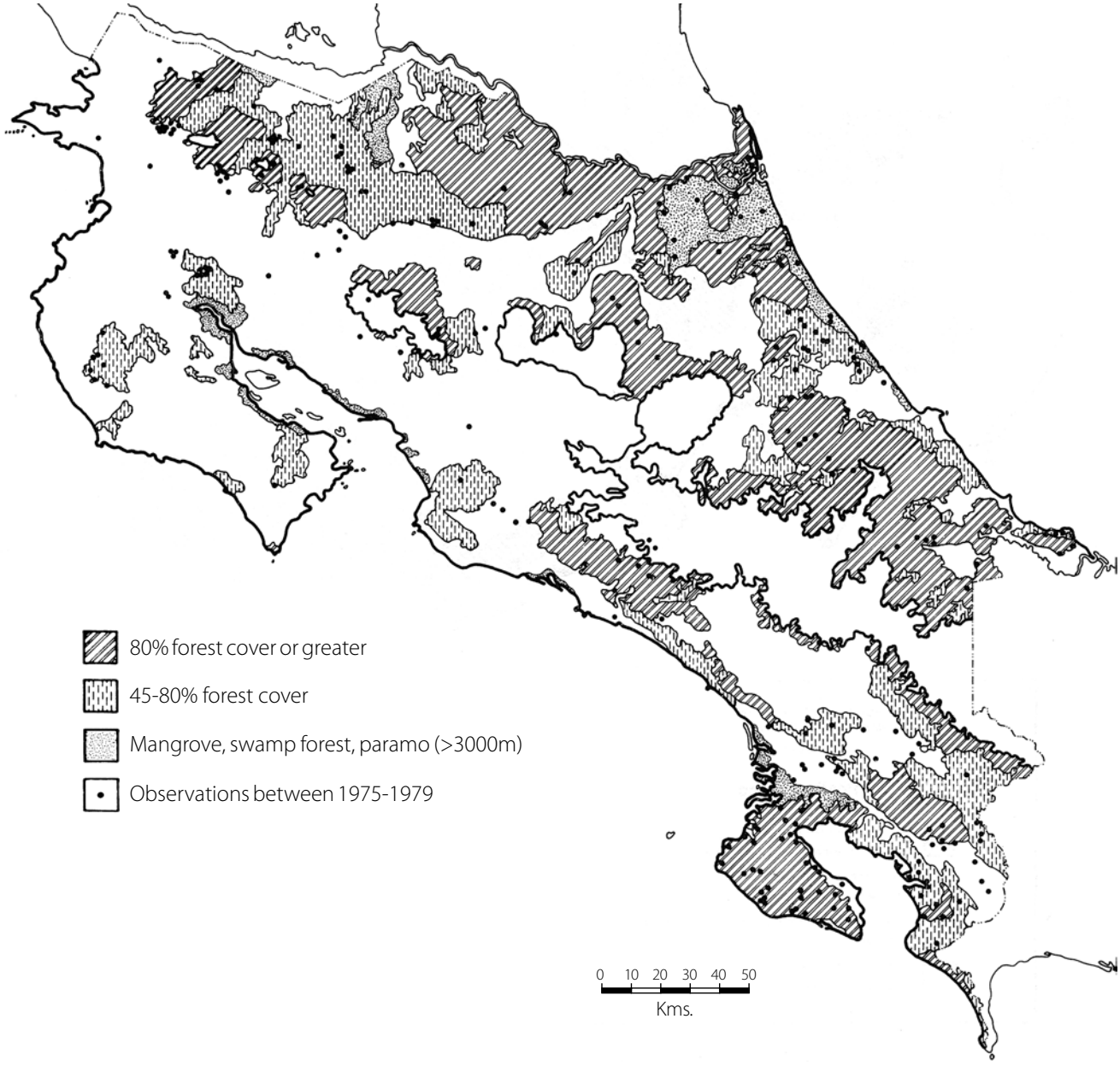


FIG. 21. Forest habitat in Costa Rica (1977) for the species *Tayassu pecari.*

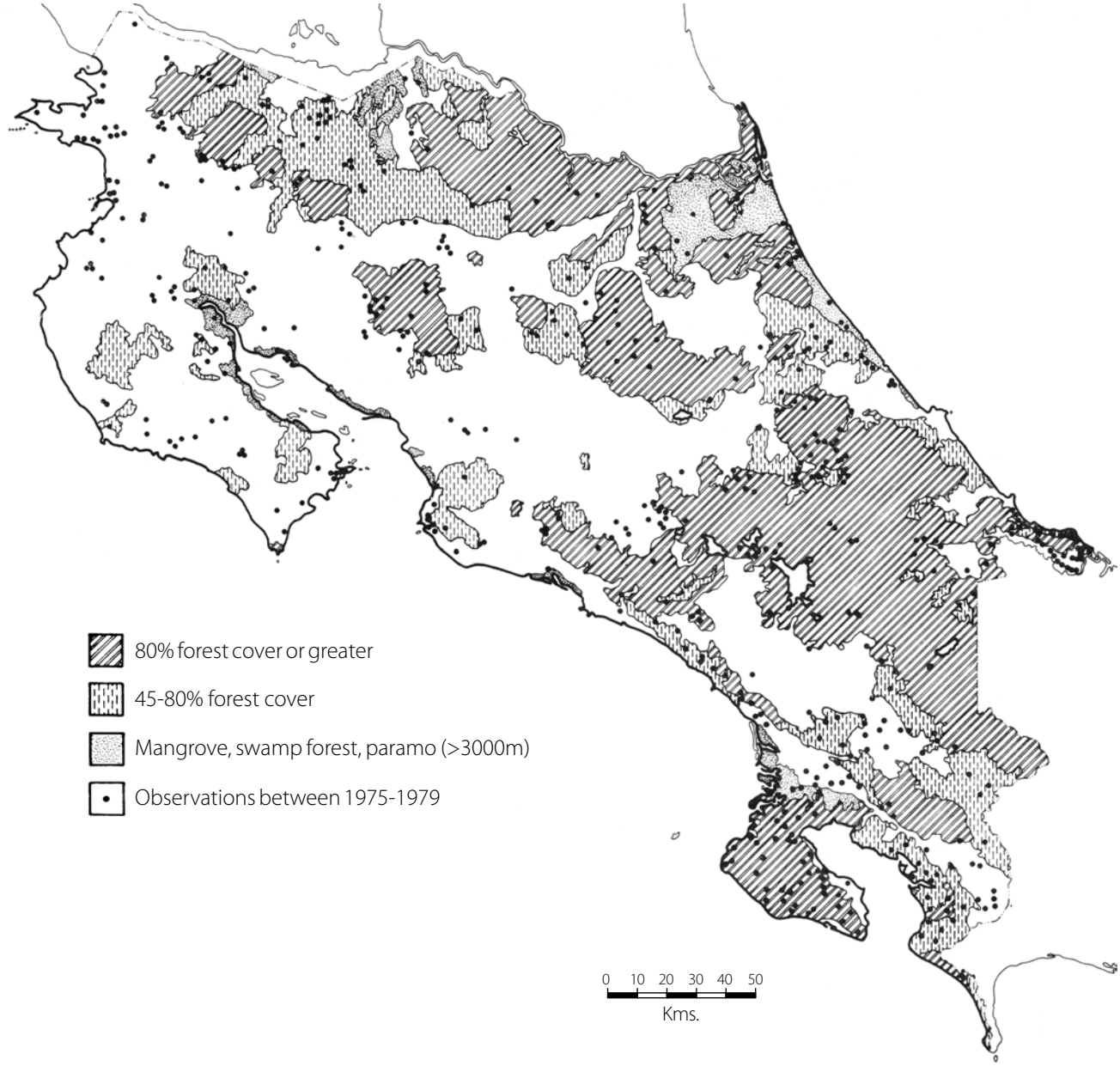


FIG. 22. Forest habitat in Costa Rica (1977) for the species *Tayassu tajacu.*

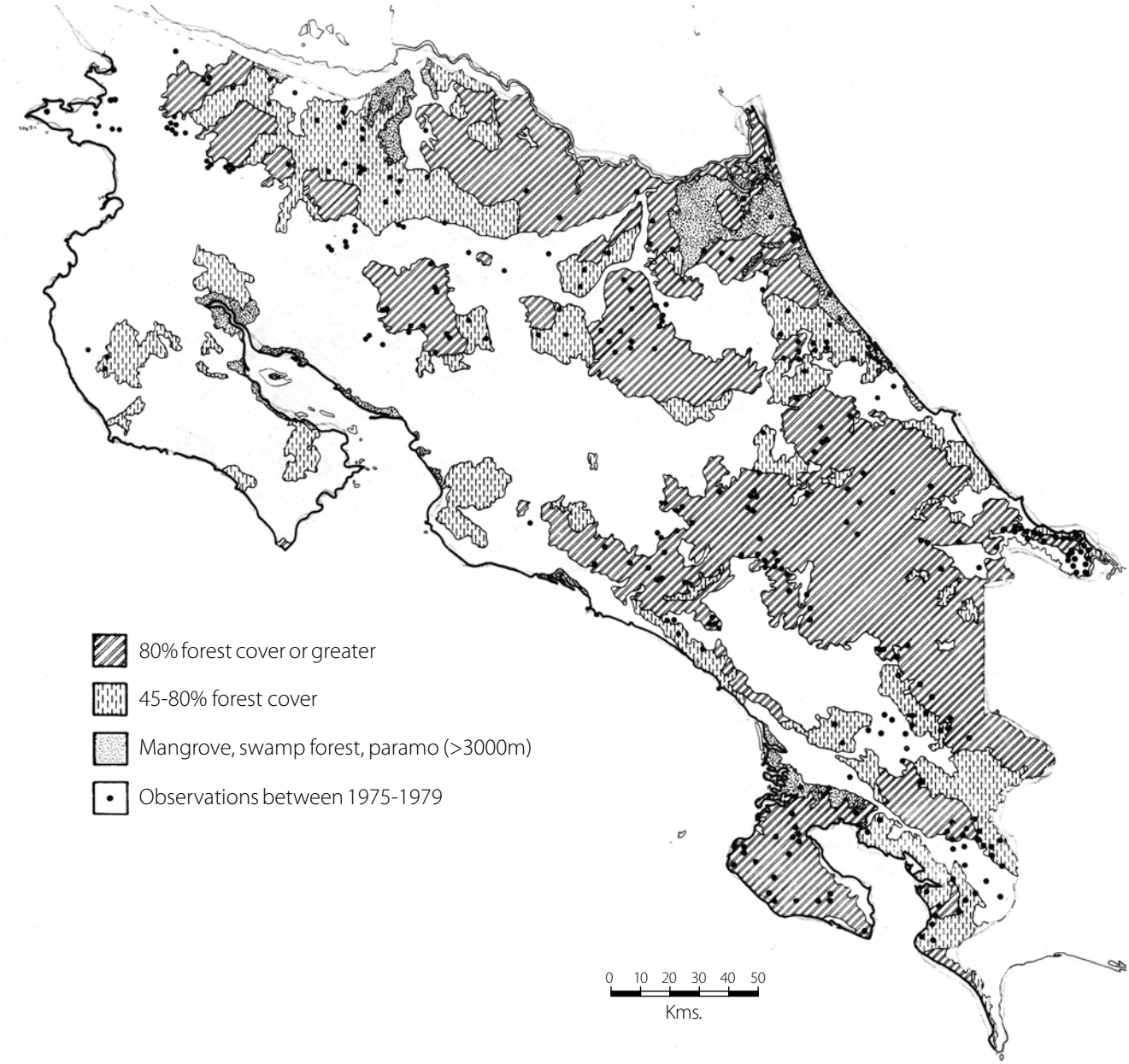


FIG. 23. Forest habitat in Costa Rica (1977) for the species *Tapirus bairdii*.

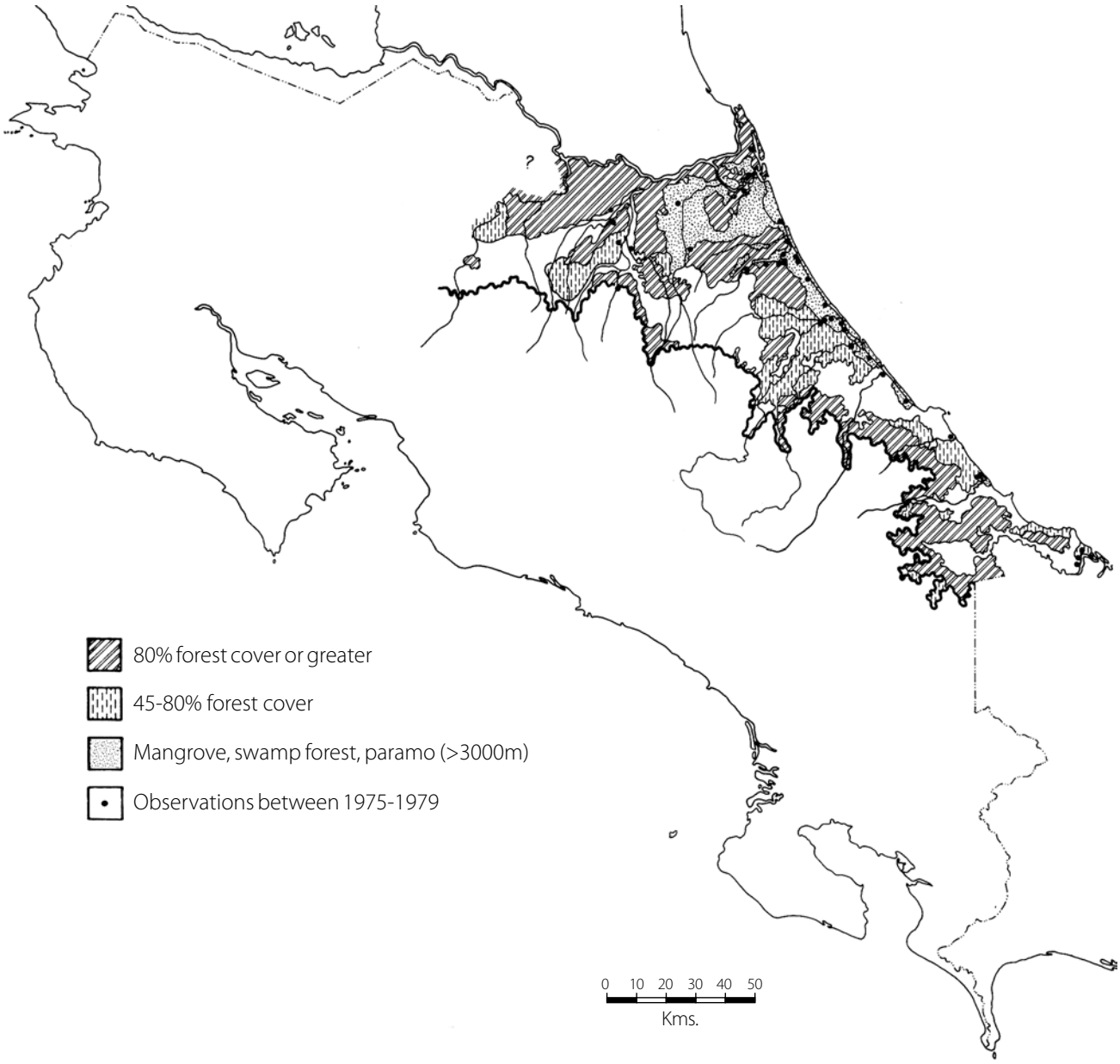


FIG. 24. Forest habitat in Costa Rica (1977) for the species *Trichechus manatus.*

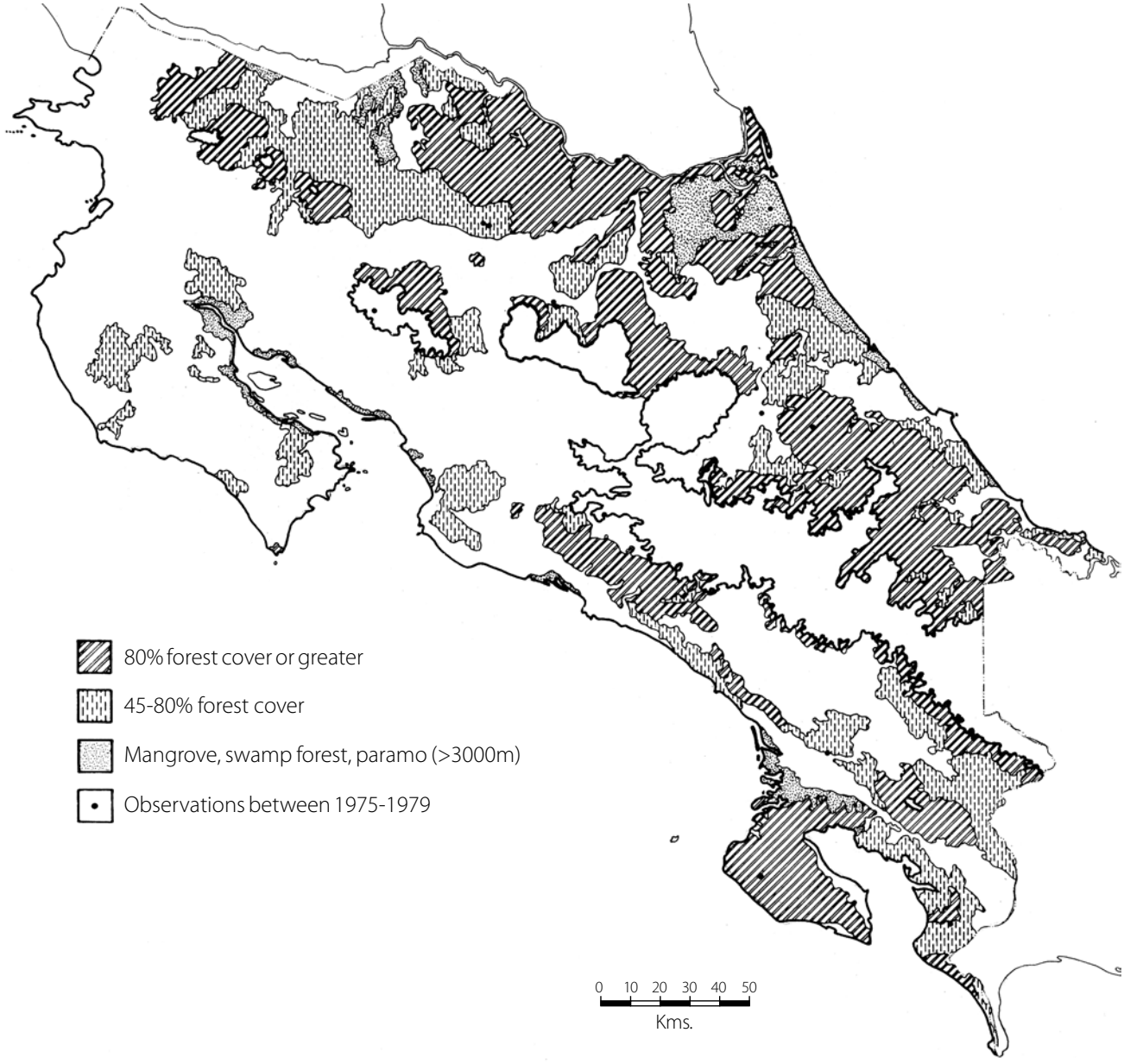


FIG. 25. Forest habitat in Costa Rica (1977) for the species *Harpia harpyja*.

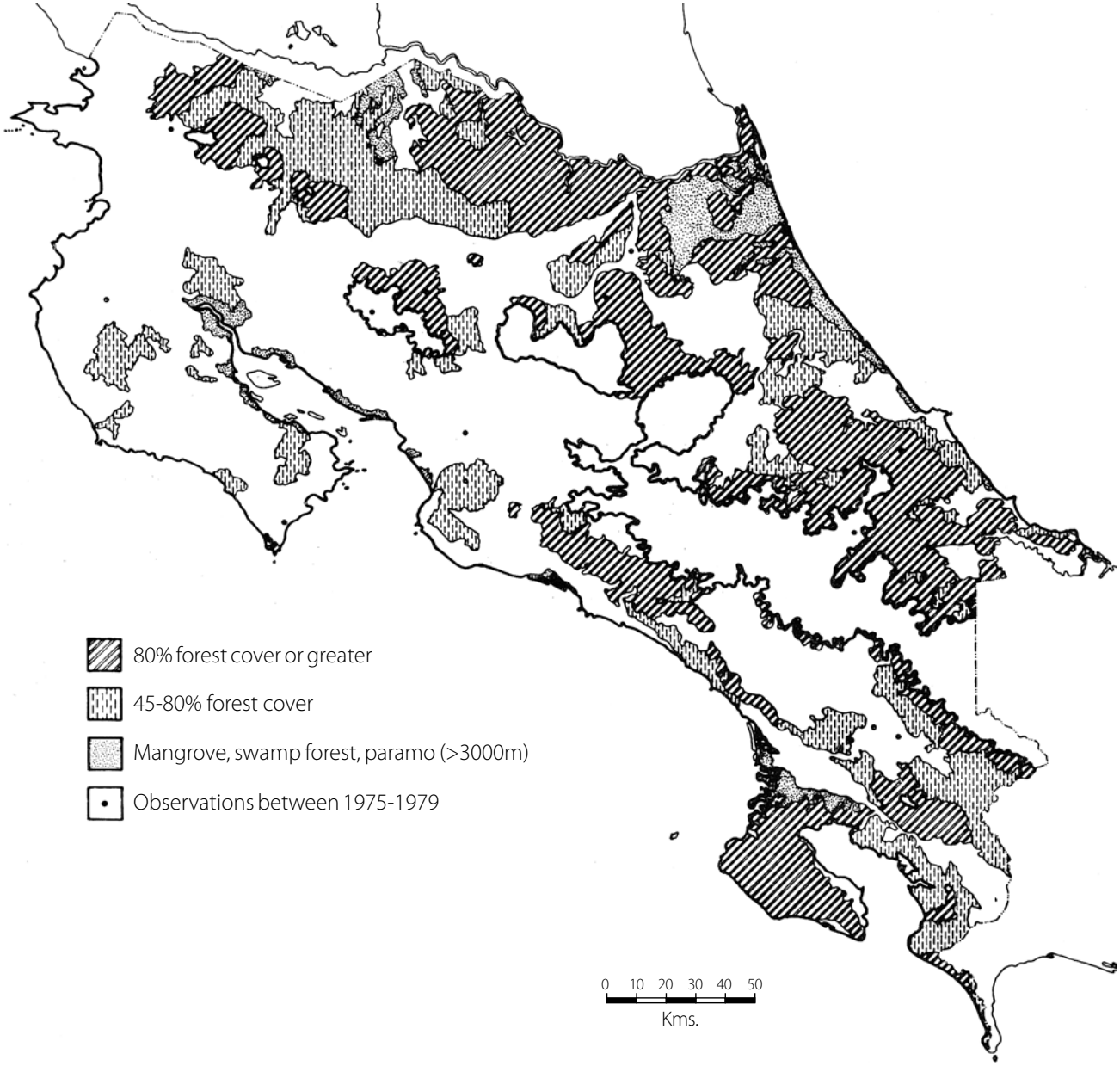


FIG. 26. Forest habitat in Costa Rica (1977) for Eagles and Hawk-eagles.

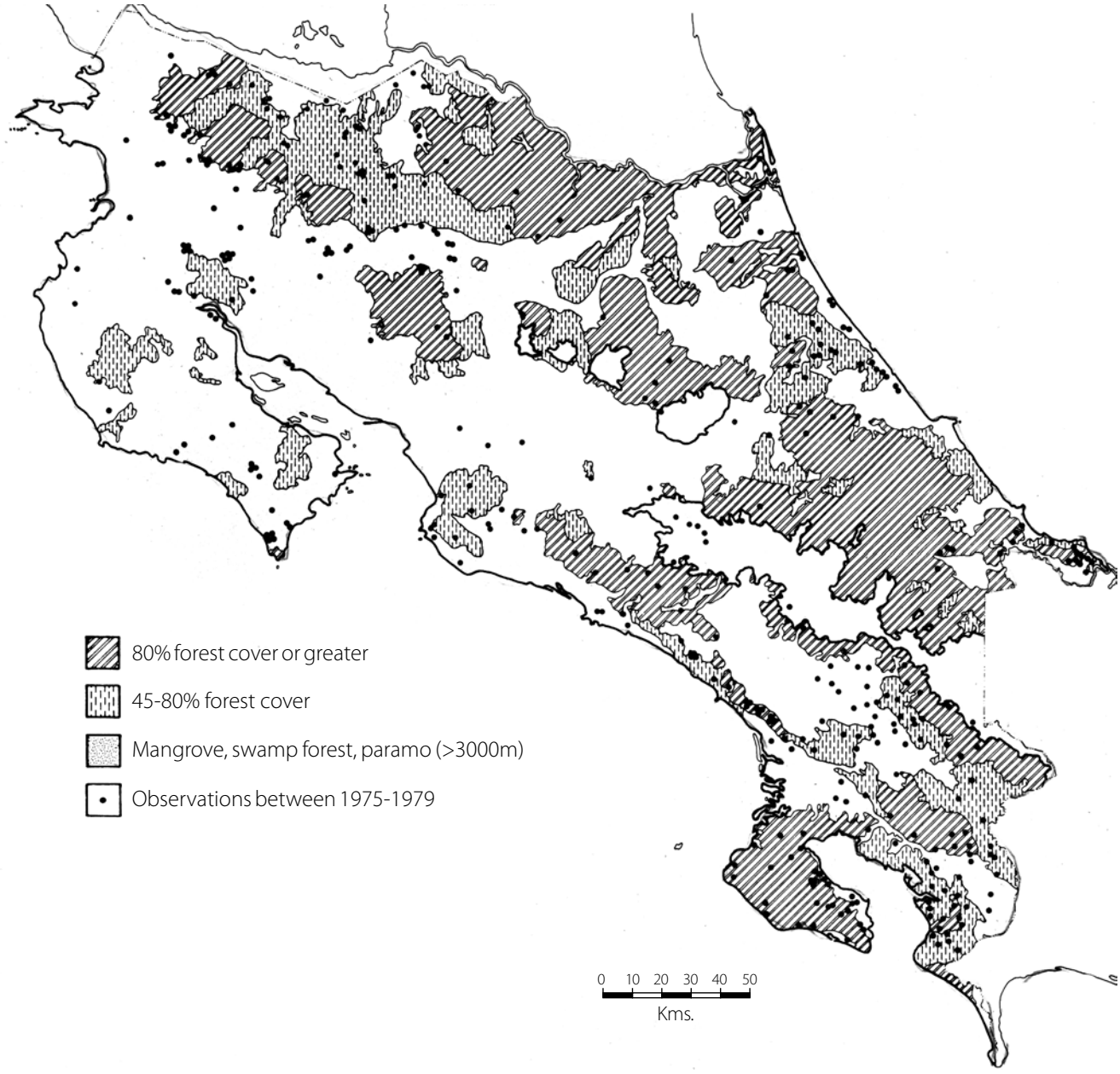


FIG. 27. Forest habitat in Costa Rica (1977) for the species *Crax rubra*.

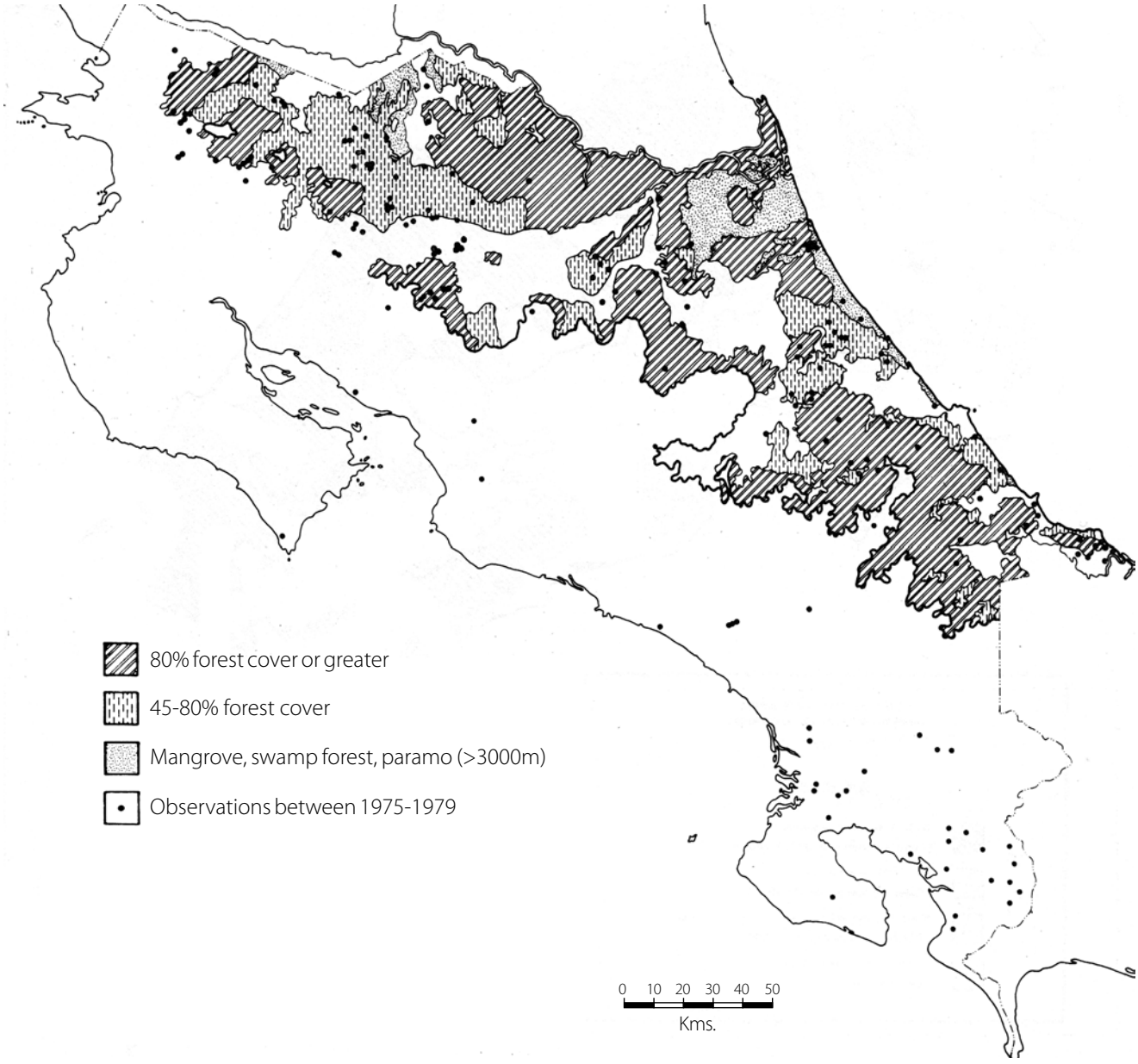


FIG. 28. Forest habitat in Costa Rica (1977) for the species *Ara ambigua*.

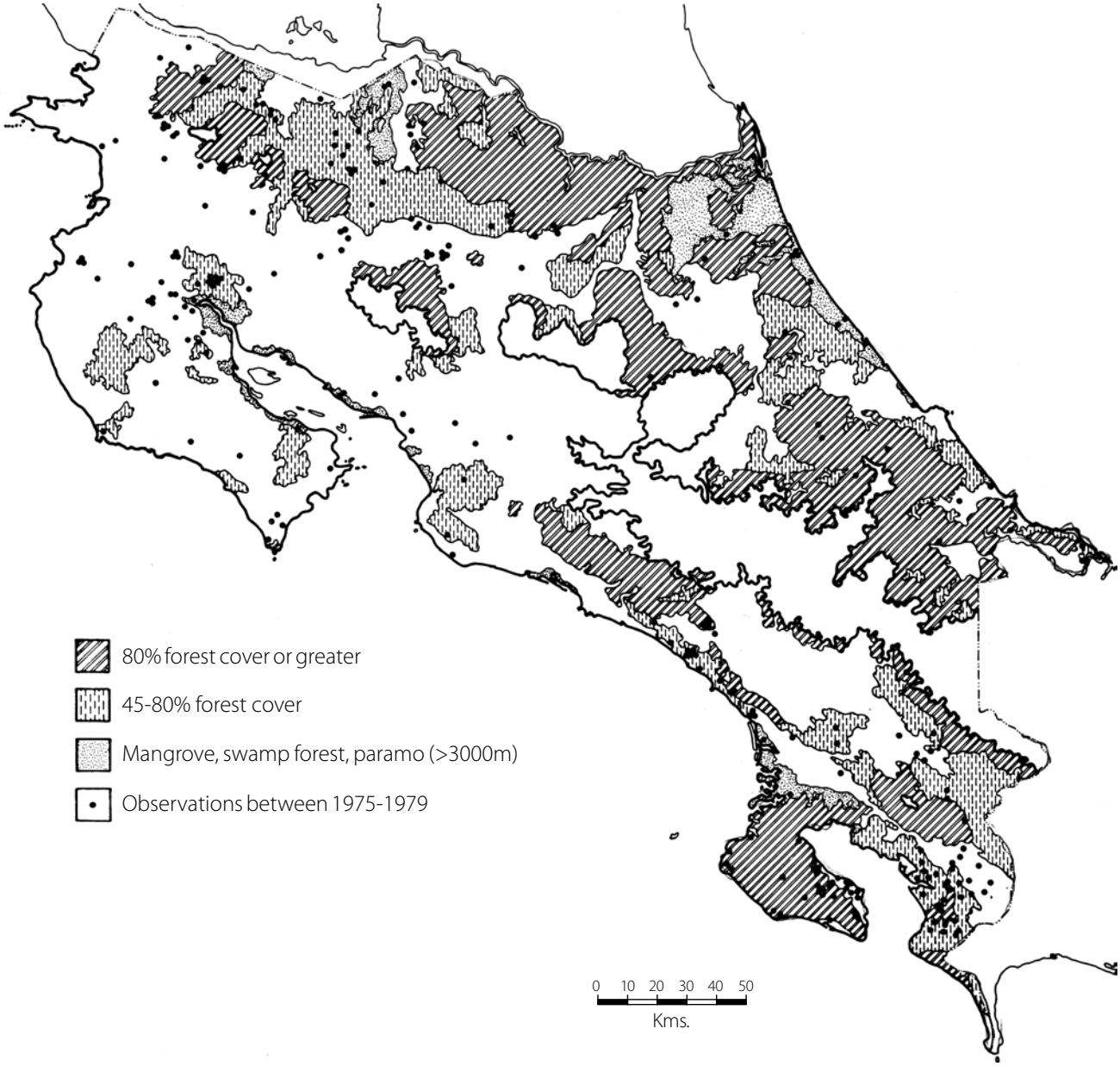


FIG. 29. Forest habitat in Costa Rica (1977) for the species *Ara macao.*

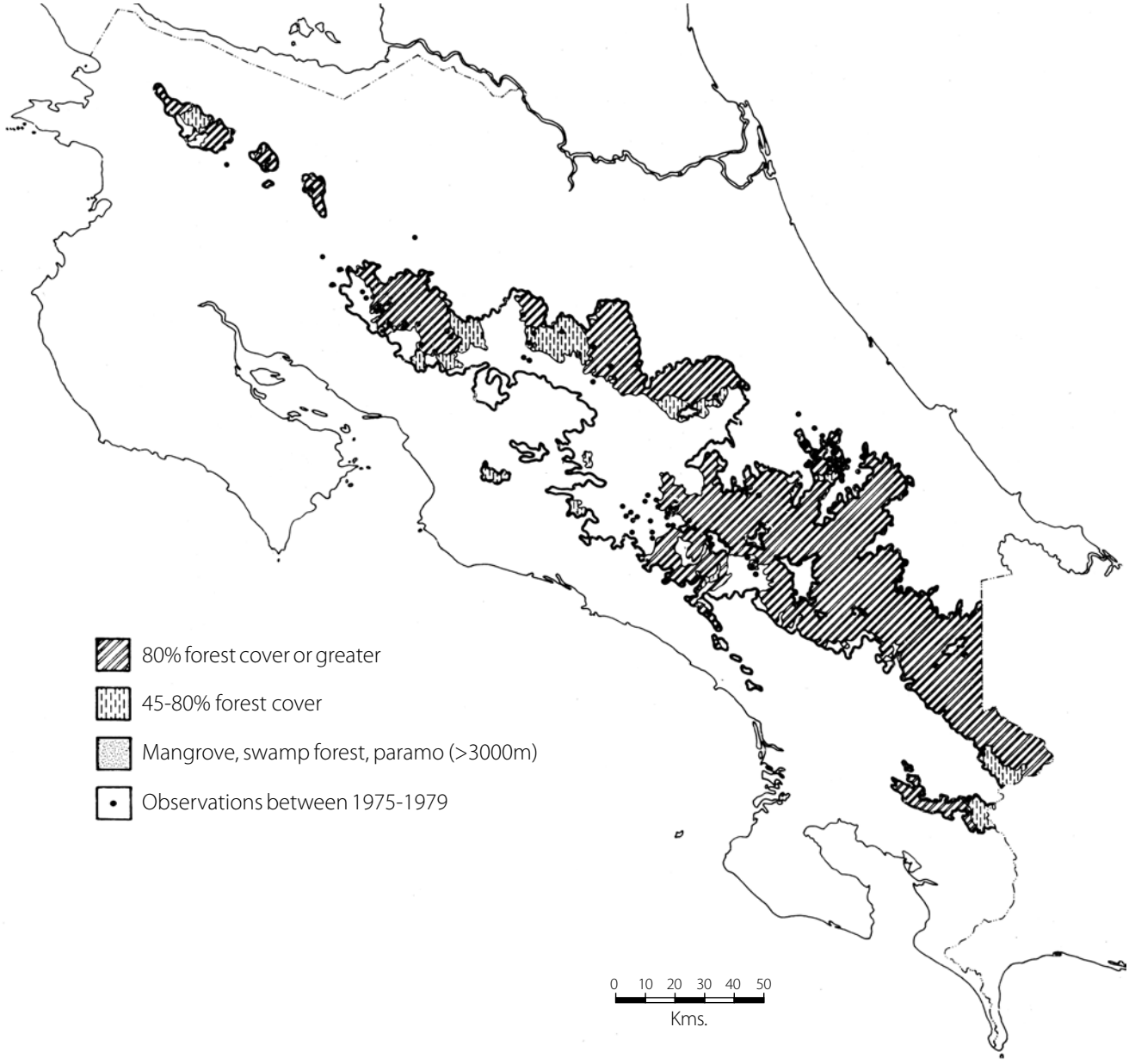


FIG. 30. Forest habitat in Costa Rica (1977) for the species *Pharomachus mocinno.*

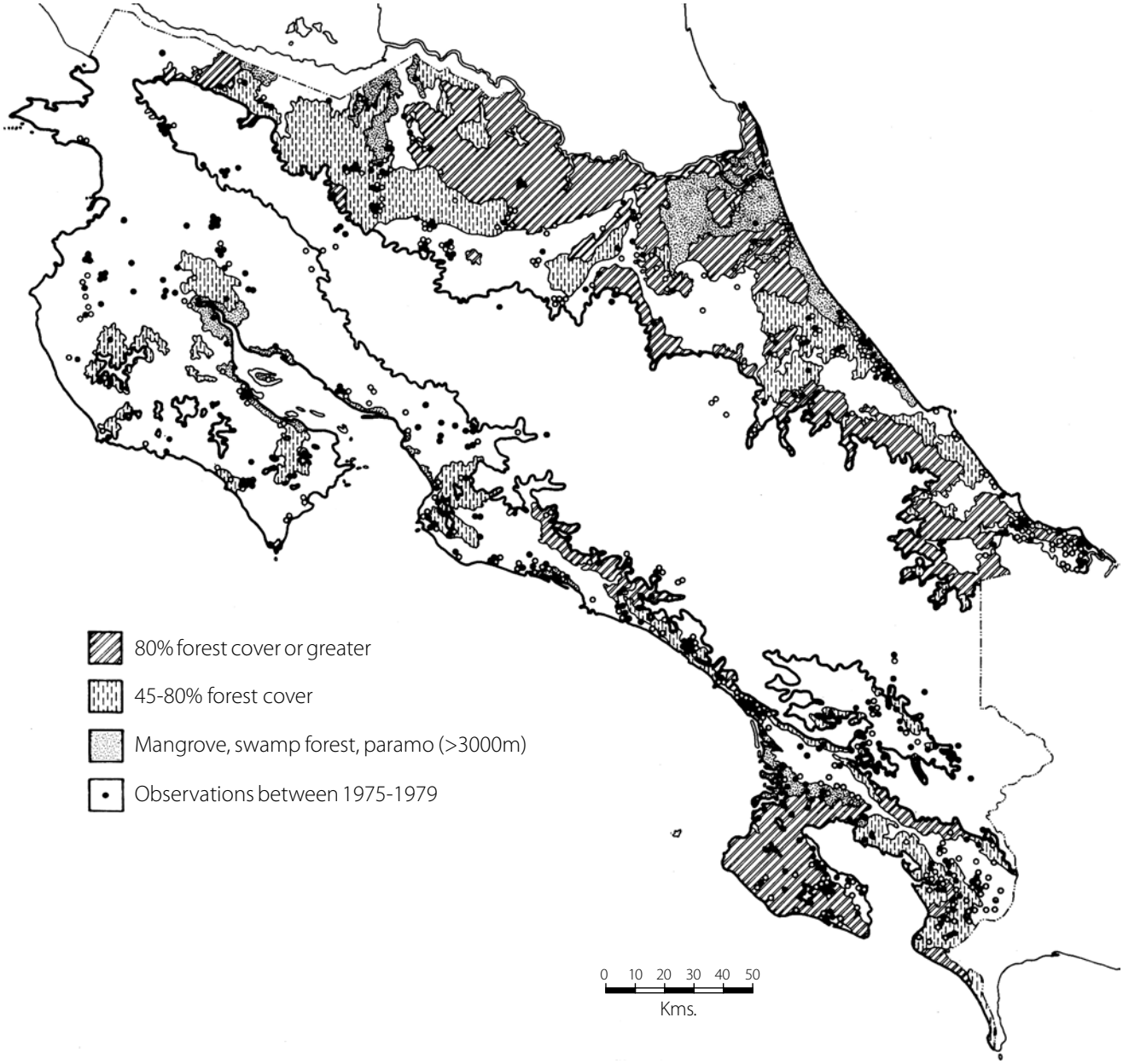


FIG. 31. Forest habitat in Costa Rica (1977) for the species *Crocodylus acutus* and *Caiman crocodilus.*

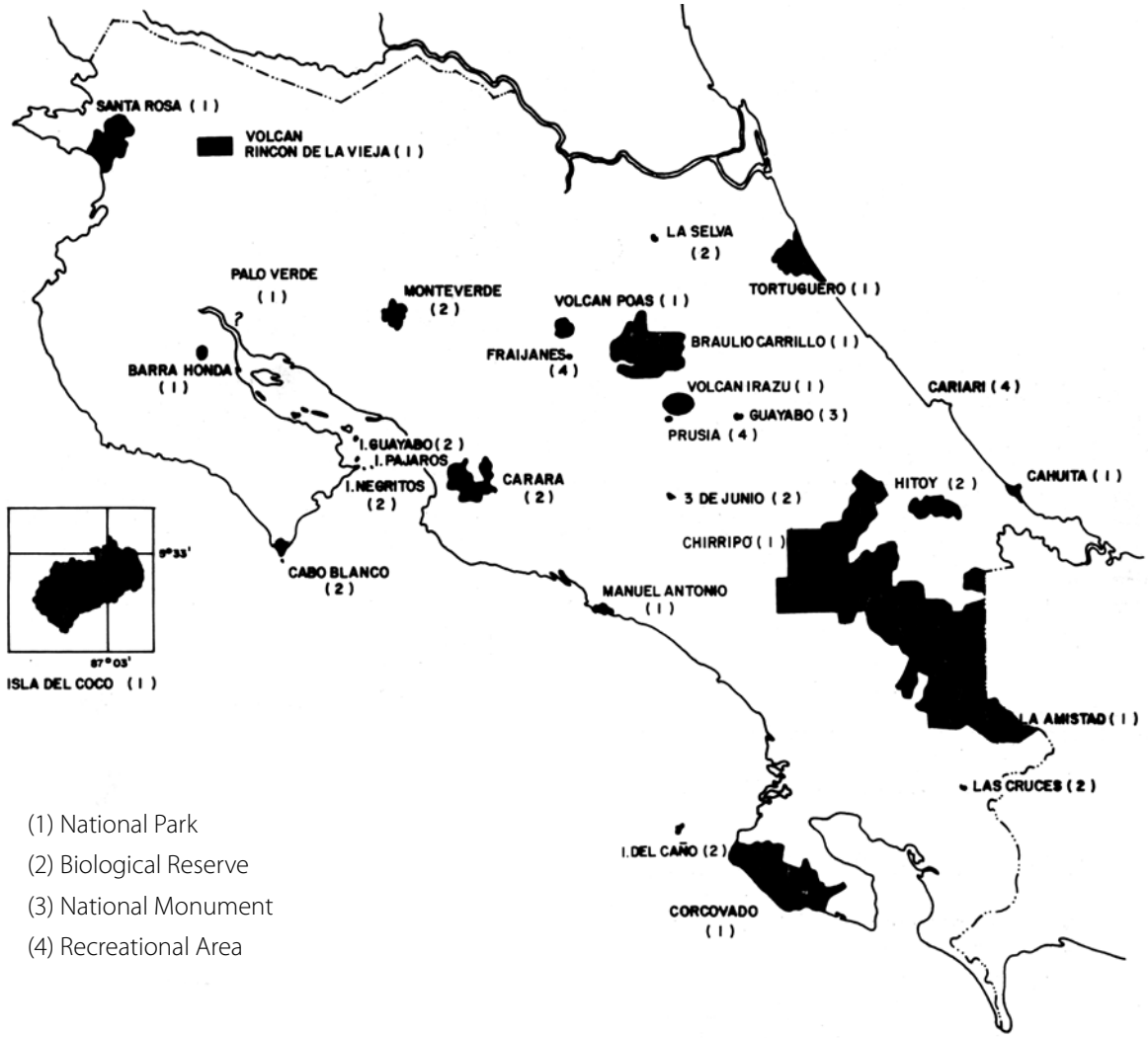


FIG. 32. National Parks, Biological Reserves and National Monuments in Costa Rica.

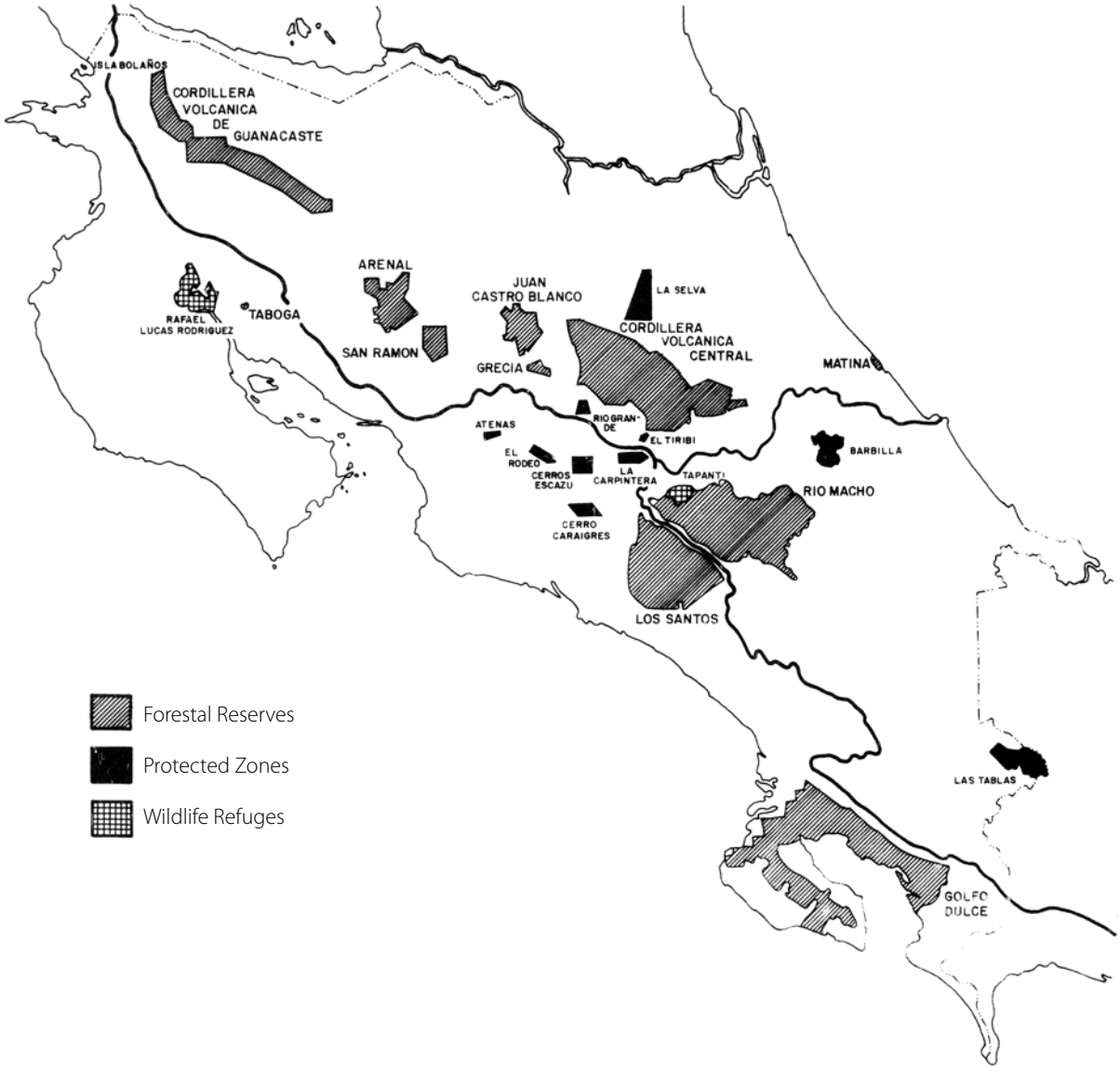


FIG. 33. Forest Reserves, Protected Zones and Wildlife Refuges in Costa Rica.

FIG. 34. Indian Reservations in Costa Rica.