REGIONAL ASSESSMENT OF REMOTE FORESTS AND BLACK BEAR HABITAT FROM FOREST RESOURCE SURVEYS

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Abstract: We developed a spatially explicit modeling approach, using a county-scaled remote forest (i.e., forested area reserved from or having no direct human interference) assessment derived from 1984–90 forest resource inventory data and a 1984 black bear (*Ursus americanus*) range map for 12 states in the southern United States. We defined minimum suitable and optimal black bear habitat criteria and geo-referenced remote forest classification with existing black bear range. Using a suitable habitat criterion, we classified 97.2% of occupied and 9.7% of unoccupied range (38.9% of the south. U.S. region's area). Using optimal habitat criteria, we classified 69.8% of occupied and 60.1% of unoccupied range (63.3% of the region's area), interpreted occupied range without optimal habitat as suboptimal areas (9.9% of the region's area), and unoccupied range with optimal habitat as areas with repopulation potential (26.8% of the region's area). There was a lack of high-density (≥34%) optimal habitat linkages among existing black bear populations, which we construed as a limitation on interpopulation gene flow. We recommend expansion of future regional land surveys to (1) address large carnivore mammal habitat and broad home ranges of other species that may conflict with humans or domestic animals, (2) include field inventories of woodland and reserved areas, (3) use standard measures to assess remote forests, and (4) organize available data in a geographic information system.

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Conservation of viable large carnivore populations such as the black bear, mountain lion (*Felis concolor*), red wolf (*Canis rufus*), and other mammal species with broad home ranges requires extensive blocks of habitat (Lowman 1975). Human influence in this habitat should be minimal to limit accidental mortality of low density and low birth-rate species and because large carnivores are a perceived threat to humans and their domestic animals.

Given continual conversion of land to human uses, retention of wild land for large carnivore conservation requires regional planning. Spatial analysis is central to assessing adequate protected habitat, identifying repopulation areas, and recognizing opportunities for connecting habitat blocks. Large carnivores' habitat requirements are broad and probably can be detected with a coarse-scaled, regional model.

We illustrate a spatially explicit approach to modeling habitat for large carnivore conservation, using the black bear as an example and the southern United States as a focal region. Our objectives were to (1) describe forest type, seral stage, and ownership of nonreserved, potential habitat for large carnivores in an extensive region; (2) develop a classification algorithm to identify blocks of potential habitat; (3) compare these blocks with observed species occurrence; and (4) identify locations with potential for species reintroduction and connectivity among habitat blocks.

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METHODS

Forest Surveys

U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) surveys were primary sources of forest resource data. The FIA survey defined forestland as land with ≥10% tree crown cover (including land temporarily with <10% tree crown cover [e.g., recent clear-cut stands] not developed for other uses [Anderson et al. 1976]), ≥0.4 ha, and ≥37 m in width, and classified forestland as timberland, reserved timberland, and woodland. Timberland was forestland capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot year^{-1}$ and was not reserved from timber production. Reserved timberland, such as national parks, federal and state wilderness areas,

[1] Deceased.

and selected state parks, was reserved from timber production. Woodland was forestland incapable of producing industrial wood products because conditions were too hydric or xeric to support industrial wood production ≥ 1.4 $m^3 \cdot ha^{-1} \cdot year^{-1}$. Sampling error associated with individual state area estimates for timberland was typically <1% (McWilliams and Lord 1988, Bechtold et al. 1990).

The FIA survey estimated forestland area from aerial photographs and interpreted land cover from national high-altitude, color, aerial photography at 1:58,000 scale for inventories between 1986 and 1990 (Ala., Ark., Miss., Okla., Tenn., Tex., Ga., N.C., and Va.), and at 1:40,000 for color or 1:24,000 for black-and-white photographs for 1984 (Fla., S.C., La., and portions of east. Tex.). For the southeastern United States (Fla., Ga., N.C., S.C., and Va.), FIA surveys used photographs twice their original scale.

The FIA survey estimated forest area from 1,248,291 photo-interpreted points, verified interpretation with a subsample of 92,667 points on the ground, and subtracted enumerated area of reserved timberland and hydric woodland to obtain remaining area of timberland and woodland. The USFS National Forest System and other federal agencies supplied enumerated area of reserved timberland and hydric woodland.

The FIA survey obtained ownership information on forested plots from county records and field observations from 44,117 plots classified as timberland. Reserved timberland and woodland area lacked comparable field observations. For other details, see field manuals for the south-central (Ala., Ark., La., Miss., east. Okla., Tenn., and east. Tex.) (For. Inventory and Anal. Res. Work Unit 1989) and southeastern United States (For. Inventory and Anal. Work Unit 1991).

Black Bear Needs

Black bears occupied 5–10% of their historic range in the southeastern United States (Maehr 1984, Pelton 1986) by the 1980s. Bears occurred chiefly in remote forest tracts in public ownership (Maehr 1984, Pelton 1986).

Foraging and Denning.—Black bears use a variety of seral stages and forest types for foraging and denning. More productive foraging areas included bottomland hardwood forests and forests with large mast crops (Hellgren et al. 1991). The autumn hard mast crop is important to black bear winter survival (Pelton 1986). In mild climates (e.g., Fla.), important autumn feeding includes soft mast, such as saw palmetto (*Serenoa repens*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) (Maehr and Brady 1984). In summer, bears use soft mast from species that are typical of recently clear-cut areas, forest edges, and other disturbed areas. Pelton (1986) and Weaver et al. (1990) did not believe soft mast was a limiting factor in historic black bear range.

Dens occur in logging slash, dense vegetational thickets, road culverts, hollow logs, tree or rock cavities, and caves (Hellgren and Vaughan 1989*a*). There is a preference by black bears for winter dens in large trees for areas of the southern United States with severe winters (Johnson and Pelton 1981, Pelton 1986, Weaver et al. 1990). Where tree dens are not available and in regions with mild winters, black bears often create ground nests (Hamilton and Marchinton 1980, Johnson and Pelton 1981, Hellgren and Vaughan 1989*a*).

Dispersal Movements.—Dense ground vegetation is preferred escape cover (Dusi et al. 1987, Mollohan and LeCount 1989). Bears traverse nonforested agricultural areas, but corridors of dense vegetation 10–60 m wide facilitate safe short-range movement among feeding and denning sites (Weaver et al. 1990). During limited mast crop years, such corridors permit secure movement among dispersed food sources.

Habitats used for long-distance travel among populations are not well known. In the southern United States, contiguous habitat blocks are thought to be effective long-distance travel corridors (Black Bear Conserv. Comm. 1993).

Behavior.—Black bears avoid human contact but often are attracted to features such as trash dumps. Bears caught disturbing human settlements are either moved elsewhere or destroyed. Roads are attractive travel corridors in dense vegetation (Hellgren et al. 1991). In areas with roads, however, frequent encounters with humans (i.e., collisions with motor vehicles, hunting, poaching, and other threats to safety) limited bear use of roads (Pelton 1986, Brody and Pelton 1989, Hellgren et al. 1991).

Home Range and Density.—Home range and density vary with availability of escape cover and food quality, and with dispersion of food supplies. In the Great Dismal Swamp of Virginia-North Carolina, for example, Hellgren and Vaughan (1990) estimated black bear home range from 550 to 10,540 ha (median 2,140 ha)

for females and 1,680–42,760 ha (median 7,900 ha) for males. In Arizona, bear home ranges in contiguous habitat averaged 4,000 ha for females and 19,400 ha for males; in fragmented habitat, averages were 10,400 and 60,900 ha, respectively (Mollohan and LeCount 1989).

Minimum Area Needs.—Minimum area needs for groups of black bears differ with respect to density, habitat quality, conservation goals, and assumptions about minimum viable populations. On the basis of known and apparently viable black bear population reports for small, geographically isolated forests, M. R. Pelton (Univ. Tenn., Knoxville, pers. commun., 1991, 1994) suggested 32,000 ha in forested wetlands (Dismal Swamp, N.C.; White River Nat. Wildl. Refuge, Ark.; and Tensas Nat. Wildl. Refuge, La.) and 80,000 ha in forested uplands (Shenandoah Natl. Park, Va.) as the minimum area needed to support a black bear population. Zeveloff (1983) suggested 40,000 ha as sufficient for territories of 6 males in eastern North Carolina pocosin habitat.

Shaffer (1983) defined a minimum viable population as the smallest isolated population having a 95% probability of surviving ≥100 years. Without detailed information, Thomas (1990) recommended that a population of 1,000 individuals was sufficient to maintain genetic viability for many birds and mammals. Lande (1988) stated that genetics and demographics were important in deciding minimum sizes. Using simulation procedures that considered demographics, J. R. Cox (Fla. Game and Fresh Water Fish Comm., Tallahassee, pers. commun., 1991) suggested that a black bear population comprising 5 geographically distinct groups and 1,000–1,500 individuals was a minimum conservation goal for Florida.

Given black bear densities reported for southeastern United States wetland forests (Hellgren and Vaughan 1989*b*), a population of 50 individuals required 7,580–83,300 ha, 200 black bears required 30,300–333,000 ha, and 1,000 individuals required 152,000–1,670,000 ha. In upland forests, the same population sizes would require larger areas.

The southern United States contained ≥3 subpopulations, including subspecies *U. a. americanus*, *U. a. luteolus*, and *U. a. floridanus* (Hall 1981). Maintaining a metapopulation (i.e., a system of genetically distinct geographically separate subpopulations) could alter minimum area needs.

Black Bear Habitat Modeling

On the basis of black bear habitat needs, potential bear habitat was a remote forest (i.e., a forested area reserved from or having no direct human interference). Because FIA surveys did not identify these areas directly, we classified remote forests as all woodland areas and reserved and remote timberland. We examined remote and nonremote timberland frequencies by ownership, forest type, and stand diameter (a proxy for seral stage), and used Chi-square tests of association to evaluate differences.

Measures used to assess remote forests were different for south-central and southeastern United States FIA survey regions. The FIA surveys originated these measures independently during the 1970s in response to within-region concerns about timber accessibility rather than concerns about wildlife habitat.

For the south-central FIA region, we defined remote timberland as a contiguous forested tract ≥1,000 ha. South-central FIA surveys defined forestland as contiguous until interrupted by nonforested areas ≥37 m wide. Nonforested areas included roads, railroad tracks, fields, pastures, and waterways. The southeastern FIA survey had no contiguous forest tract size measure. Here, we defined remote timberland as ≥0.8 km from urban or developed land (i.e., intensive use areas with much of the land covered by structures [Anderson et al. 1976]), and ≥0.8 km from 2-wheel drive, all-weather roads.

We subdivided remote timberland into bottomland hardwood and upland (conifer, oak-pine [*Quercus-Pinus* spp.], upland hardwoods) timberland. In upland timberland, we assumed human-bear encounters were associated with road access. We grouped upland timberland into areas ≥0.8 and <0.8 km from 4-wheel drive, truck-operable or better roads (i.e., unimproved, dry-weather only roads, including those needing only minor improvement, such as downed tree removal).

Because geo-referencing varied with data sources, we chose the county scale of resolution to estimate spatially dependent mapping criteria. To control for differences in county area, we used an area-independent density measure (i.e., % potential habitat area/county area). We used a software package (SAS Inst. Inc. 1991) to map classified counties.

We used Maehr's (1984) black bear range map, overlaid county boundaries onto Maehr's

map, registered black bear occupied (occasional sightings and permanently occupied) and unoccupied (no sightings, including unknown) range at the county-scale of resolution, and compared results with classification of potential habitat (Chi-square tested weighted by county area). We used Pearson product-moment correlations (Pearson's $r \pm 2$ SE) to assess direction and strength of associations (SAS Inst. Inc. 1985). Potential repopulation areas were black bear unoccupied counties with potential habitat. Misclassified areas were black bear occupied counties without potential habitat.

To estimate black bear habitat quality, we empirically determined criteria for 2 potential habitats: suitable and optimal. The suitable habitat criterion was the largest remote forest density that maximized classification of black bear occupied range. Optimal habitat criteria were the largest suitable and likely productive habitat area that maximized classification of black bear unoccupied range without potential habitat and black bear occupied range with potential habitat, and that contained ≥1 county in or adjacent to counties where black bears occurred.

Likely productive habitat for black bears was bottomland hardwood timberland, hydric woodland, and reserved timberland. In the southern United States, bottomland hardwood timberland was more likely to contain den trees, as it was, on average, older than upland timberland (McWilliams and Lord 1988, Bechtold et al. 1990) and had greater densities of dead and large-diameter (>51-cm diam at 1.4 m) live trees (Rudis 1988*a*,*b*) than other forest types. We assumed that hydric woodland and reserved timberland contained large and old trees with potential den cavities and that bears in reserved timberland were protected from human-caused mortality. We also assumed bottomland hardwood timberland and hydric woodland had no direct human interference due to limited access during seasonal flood periods.

RESULTS

We found reserved timberland (1 million ha) scattered (Fig. 1a), woodland (0.9 million ha) concentrated at the edges of the region (Fig. 1b), and timberland abundant but unevenly distributed (Fig. 1c). Representing 1% of total forestland, reserved timberland by itself was too small and widely scattered to support a black bear population of 1,000 individuals (i.e., <152,000–1,670,000 ha cited above).

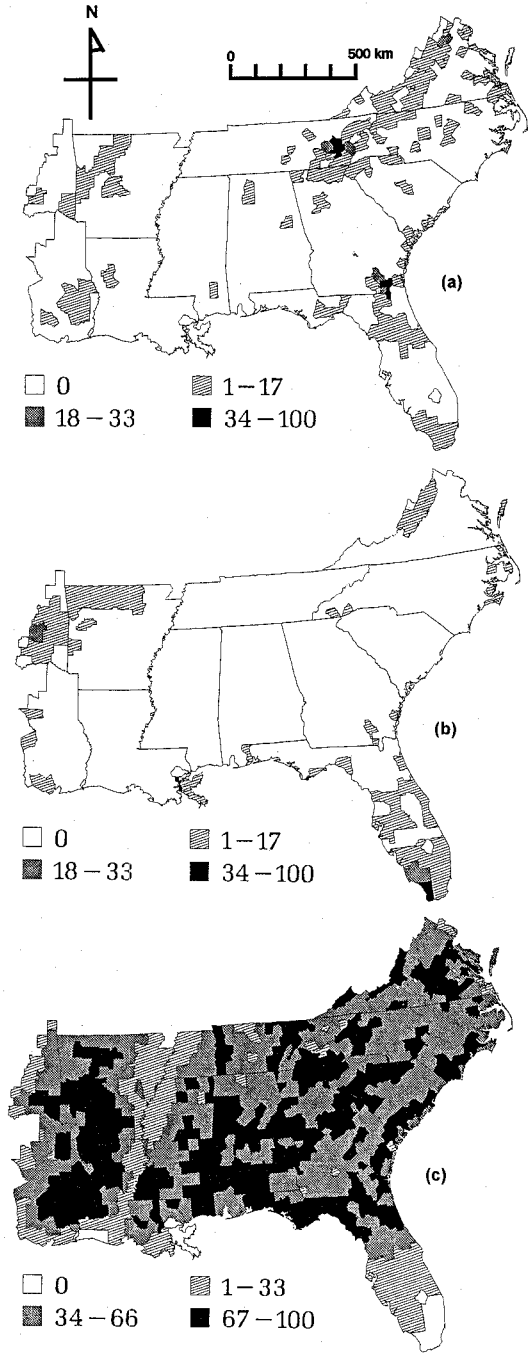
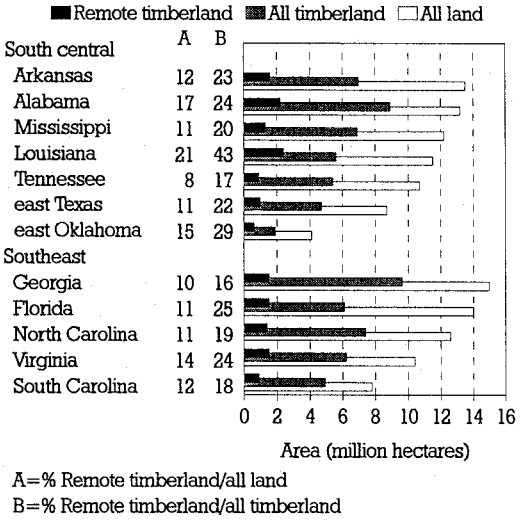


Fig. 1. Land area (% by cty) in forestland (land with ≥10% tree crown cover [and land temporarily with <10% tree crown cover not developed for other uses], ≥0.4 ha, and ≥37 m wide): (a) reserved timberland (capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ but reserved from timber production), (b) woodland (incapable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$), and (c) timberland (capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ and not reserved from timber production), southern United States, 1984–90 inventories.

Table 1. Forestland area (1,000s of ha) by region, state, and land use classification, southern United States, 1984–90 inventories.[a]

Region and state	Total forestland[b]	Timberland[c]	Reserved timberland	Woodland[d]
South central	41,020	40,311	299	412
Ala.	8,889	8,876	13	0
Ark.	7,158	6,979	83	96
Miss.	6,875	6,872	3	0
La.	5,692	5,614	4[e]	73[e]
Tenn.	5,505	5,368	137	0
East. Tex.	4,774	4,680	48	46
East. Okla.	2,127	1,921	9	197
Southeastern	36,054	34,768	767	520
Ga.	9,766	9,563	196	7
N.C.	8,169	7,966	186	17
Fla.	6,697	6,063	163	471
Va.	6,461	6,247	189	25
S.C.	4,961	4,929	32	0
Both regions	77,074	75,079	1,066	932

[a] Rows and columns may not sum to totals due to rounding errors.
[b] Land with ≥10% tree crown cover (and land temporarily with <10% tree crown cover that was not developed for other uses), ≥0.4 ha, and ≥37 m wide.
[c] Capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ and not reserved from timber production.
[d] Incapable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$.
[e] Includes U.S. Soil Conserv. Serv., 1987 Nat. Resour. Inventory estimates for 5 La. parishes.



A=% Remote timberland/all land
B=% Remote timberland/all timberland

Fig. 2. Area of land, timberland (land with ≥10% tree crown cover [and land temporarily with <10% tree crown cover not developed for other uses], ≥0.4 ha, ≥37 m wide, capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$), and remote timberland (part of contiguous forests ≥1,000 ha [south central], ≥0.8 km from urban or built-up land and 2-wheel drive roads [southeast]) and percent remote by region and state, southern United States, 1984–90 inventories.

Of all forestland, 97% was timberland (Table 1). Area in remote timberland (22% of 75 million ha of timberland) varied with the state's land and timberland area (Fig. 2). Remote timberland represented 24% of total timberland in south-central and 19% in southeastern United States.

Remote timberland included a variety of forest type and stand-diameter classes (Table 2). Remote and nonremote timberland differed by stand-diameter class ($\chi^2 > 66.4$, 2 df, $P < 0.001$) and forest type ($\chi^2 > 48.6$, 4 df, $P < 0.001$). In sapling-seedling, poletimber, and sawtimber stand-diameter classes, proportions were 24, 25, and 51% for remote and 30, 27, and 43% for nonremote timberland, respectively. In planted conifer, natural conifer, oak-pine, upland hardwood, and bottomland hardwood forest types, proportions were 9, 19, 18, 40, and 14% for remote and 9, 19, 17, 33, and 22% for nonremote timberland, respectively. Twenty percent of remote timberland was bottomland hardwood; two-thirds was composed of upland forest types <0.8 km from roads (Table 3).

Remote timberland differed among owners (Table 4). Among public, forest industry, other corporate (i.e., corporations not primarily concerned with wood production), farmer, and other private owner classes, proportions were 18, 27, 13, 10, and 32% for remote and 8, 20, 7, 23, and 42% for nonremote timberland, respectively ($\chi^2 > 528.1$, 4 df, $P < 0.001$). Other corporate owners included groups primarily concerned with oil extraction (south La.), water management (south Fla.), and real estate investments. Timberland classed as remote among multiple owners (public, forest industry, and other corporate) was 35 versus 18% among individual owners (farmers and other private owners) ($\chi^2 > 413.3$, 1 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.096 ± 0.010). Bottomland hardwood timberland classed as remote among corporate owners was 51 versus 23% among individual owners ($\chi^2 > 148.6$, 1 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.127 ± 0.022).

Using remote forest occurrence as the predictor of black bear occupied range, we classified 97.2% of occupied and 8.6% of unoccupied range (37.7% of the south. U.S. region's area, $\chi^2 = 1{,}597.4$, 1 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.109 ± 0.004). With the suitable habitat criterion (≥0.5% remote forest density), we classified 97.2% of occupied and 9.7% of unoccupied range (38.4% of the region's area, $\chi^2 = 2{,}020.9$, 1 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.123 ± 0.004).

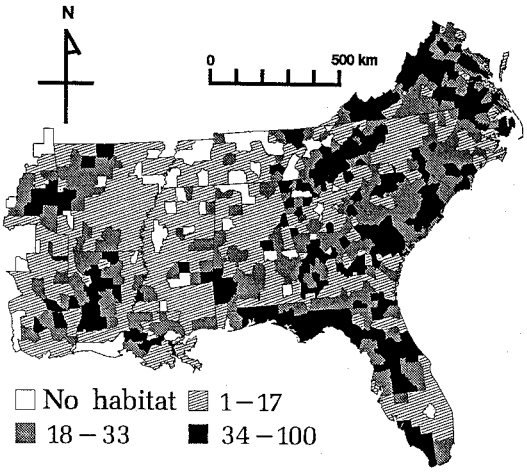


Fig. 3. Land area (% by cty) with suitable black bear habitat (≥0.5% land area in reserved timberland, woodland, and remote timberland), southern United States, 1984–90 inventories.

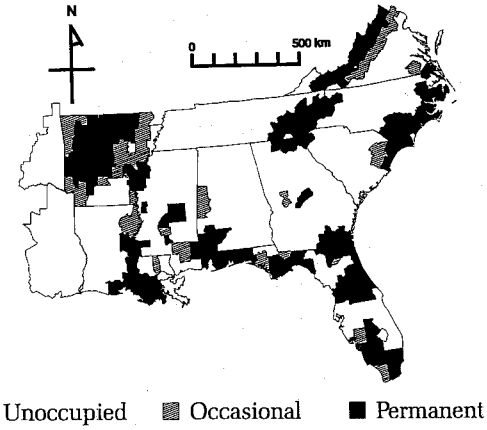


Fig. 4. Black bear occupied (occasional sightings and permanently occupied [*sic*, as understood by state biologists familiar with black bear distribution]) and unoccupied (no sightings, including unknown) range by county, southern United States (after Maehr 1984) 1984. Permanently occupied commonly meant sighting a female bear with cubs (E. P. Orff, New Hampshire Fish and Game Dep., Durham, pers. commun.).

We mapped suitable habitat estimates (Fig. 3), black bear range (Fig. 4), and compared their county distribution. There was a positive association (χ^2 = 8,518.2, 3 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.238 ± 0.006) between suitable habitat density and frequency of occupied range (i.e., county area without suitable habitat was 12% occupied; with 1–17% suitable habitat density, 27% occupied; 18–33% density, 30% occupied; 34–100% density, 53% occupied).

Using optimal habitat criteria, we classified 69.8% of occupied and 60.1% of unoccupied range (63.3% of the region's area, χ^2 = 10,574.4, 1 df, $P < 0.001$, Pearson $r \pm 2$ SE = 0.281 ± 0.006). We improved classification of the region's area (+24.92%) by eliminating (1) xeric woodland area (+0.03%); (2) counties with no hydric woodland, no reserved forests, and

Table 2. Remote timberland[a] area (1,000s of ha) by region, forest type, and stand-diameter class, southern United States, 1984–90 inventories.[b]

Region and forest type	All stand classes	Sapling-seedling[c]	Poletimber[d]	Sawtimber[e]
South central[f]	10,002	2,378	2,505	5,119
Plantation conifer	898	420	286	192
Natural conifer	1,874	257	349	1,268
Oak-pine	1,698	531	401	767
Upland hardwoods	3,316	944	1,109	1,263
Bottomland hardwoods	2,216	227	360	1,629
Southeastern[g]	6,841	2,042	1,796	3,003
Plantation conifer	1,008	562	357	89
Natural conifer	1,593	381	375	838
Oak-pine	757	268	155	335
Upland hardwoods	2,287	571	620	1,096
Bottomland hardwoods	1,197	260	290	646

[a] Timberland (land with ≥10% tree crown cover [and land temporarily with <10% tree crown cover that was not developed for other uses], ≥0.4 ha, ≥37 m wide, capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$, and not reserved from timber production) having no direct human interference.

[b] Rows and columns may not sum to totals due to rounding errors.

[c] <50% stocked with live trees ≥12.7 cm.

[d] ≥16.7% stocked with live trees, ≥50% stocked with live trees ≥12.7 cm, and <50% stocking in live trees <22.9 cm (softwoods) and <27.9 cm (hardwoods).

[e] ≥16.7% stocked with live trees, ≥50% stocked with live trees ≥12.7 cm, and ≥50% stocked with live trees ≥22.9 cm (softwoods) and ≥27.9 cm (hardwoods).

[f] Timberland part of contiguous forests ≥1,000 ha.

[g] Timberland ≥0.8 km from urban or built-up land (Anderson et al. 1976) and ≥0.8 km from 2-wheel drive, all-weather roads.

Table 3. Remote timberland[a] area (1,000s of ha) by region, state, bottomland hardwood forest type, and distance from roads in upland forest types, southern United States, 1984–90 inventories.[b]

Region and state	Total all types	Bottomland hardwoods	Upland forest types,[c] distance from roads[d] ≥0.8 km	Upland forest types,[c] distance from roads[d] <0.8 km
South central[e]	10,002	2,216	1,112	6,674
La.	2,417	1,046	177	1,194
Ala.	2,161	301	173	1,687
Ark.	1,612	294	210	1,109
Miss.	1,340	350	67	923
East. Tex.	1,028	179	139	710
Tenn.	889	28	235	626
East. Okla.	554	18	111	426
Southeastern[f]	6,841	1,197	724	4,921
Fla.	1,518	445	108	964
Ga.	1,482	248	92	1,142
Va.	1,477	52	196	1,228
N.C.	1,436	221	272	943
S.C.	929	230	56	643

[a] Timberland (land with ≥10% tree crown cover [and land temporarily with <10% tree crown cover that was not developed for other uses], ≥0.4 ha, ≥37 m wide, capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$, and not reserved from timber production) having no direct human interference.

[b] Rows and columns may not sum to totals due to rounding errors.

[c] Conifer, oak-pine, and upland hardwoods.

[d] 4-wheel drive, truck operable or better.

[e] Timberland part of contiguous forests ≥1,000 ha.

[f] Timberland ≥0.8 km from urban or built-up land (Anderson et al. 1976) and ≥0.8 km from 2-wheel drive, all-weather roads.

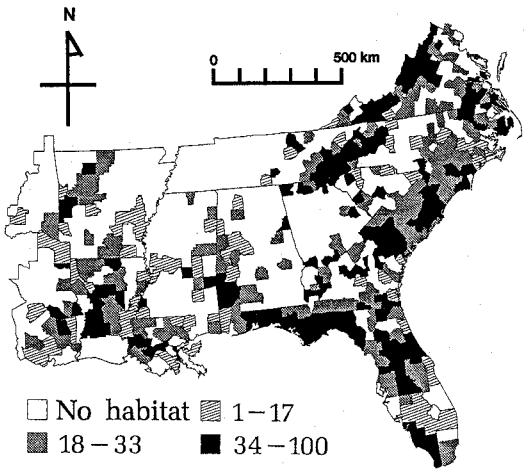


Fig. 5. Land area (% by cty) with optimal black bear habitat (≥0.5% land area in reserved timberland, hydric woodland, and remote timberland; ≥5,000-ha bottomland hardwood; and ≥16,000 ha in reserved timberland, hydric woodland, and remote timberland), southern United States, 1984–90 inventories.

<5,000 ha remote bottomland hardwood timberland (+22.32%); and (3) counties with <16,000 ha of remote forests (+2.57%, [item 3 alone, +13.85%]).

We mapped optimal habitat estimates (Fig. 5) and compared their county distribution with black bear range (Fig. 4). There was a positive association ($\chi^2 = 15{,}046.9$, 3 df, $P < 0.001$, Pearson $r \pm 2$ SE $= 0.323 \pm 0.006$) between optimal habitat density and frequency of occupied range (i.e., county area without optimal habitat was 20% occupied; with 1–17% optimal habitat density, 36% occupied; 18–33% density, 36% occupied; 34–100% density, 61% occupied).

Our model classified 2.8% of black bear occupied range (0.9% of the region's area) as having no suitable habitat (Fig. 6a) and 30.2% of black bear occupied range (9.9% of the region's area) as having no optimal habitat (Fig. 6b). This misclassification occurred for counties bordering the central portion of the Pearl (southeast. Miss.) and Mississippi (west Miss., east Ark., and east La.) rivers. For optimal habitat, misclassification also occurred in Arkansas (Fig. 6b).

County area in black bear occupied range with high density (≥34%) suitable (Fig. 6a) and optimal (Fig. 6b) habitat signified area potentially suited to long-term survival of bear populations. County area in unoccupied range with suitable (Fig. 7a) and optimal (Fig. 7b) habitat showed areas with repopulation potential (60.7 and 26.8% of the region's area, respectively). For locations disjunct from the bear's occupied range, multiple counties or counties with extensive areas of high-density (≥34%) optimal habitat indicated locations with reintroduction potential (i.e., southwest. La. and east. Tex., the south. Coastal Plain between Ga. and S.C., and the Cumberland Plateau in Tenn.).

High-density (≥34%) optimal habitat in unoccupied range was scarce or disjunct from multi-county clusters of black bear occupied range. This scarcity and limited connectivity was pronounced between occupied range in the Florida-southwestern Alabama-southeastern Mississippi cluster and potential habitat to the north and west, the northwest Arkansas cluster and potential habitat to the south, and the central Appalachian Mountain cluster and potential habitat to the east, south, and west.

DISCUSSION

Our modeling approach provided a coarse-scaled estimate of black bear optimal habitat areas in occupied range, areas with repopulation and reintroduction potential in unoccupied range, and areas with scarce optimal habitat that

Table 4. Remote timberland[a] area (1,000s of ha) (frequency [%]/area of timberland) by region, ownership class, bottomland hardwood forest type, and distance from roads in upland forest types, southern United States, 1984–90 inventories.[b]

Region and owner class	Total all types	Bottomland hardwoods	Upland forest types,[c] distance from roads[d]	
			≥0.8 km	<0.8 km
South central[e]	10,002 (25)	2,219 (6)	1,109 (3)	6,674 (17)
Public	1,803 (43)	344 (8)	248 (6)	1,213 (29)
Forest industry	2,657 (30)	502 (6)	268 (3)	1,888 (21)
Other corp.[f]	1,298 (39)	542 (16)	99 (3)	657 (20)
Farmer	1,051 (13)	213 (3)	110 (1)	727 (9)
Other private	3,194 (20)	618 (4)	385 (2)	2,189 (14)
Southeastern[g]	6,841 (20)	1,197 (3)	724 (2)	4,921 (14)
Public	918 (25)	107 (3)	150 (4)	661 (18)
Forest industry	1,312 (19)	264 (4)	124 (2)	924 (14)
Other corp.[f]	812 (21)	206 (5)	89 (2)	517 (14)
Farmer	1,451 (19)	291 (4)	105 (1)	1,055 (14)
Other private	2,348 (21)	329 (3)	257 (2)	1,763 (14)

[a] Timberland (land with ≥10% tree crown cover [and land temporarily with <10% tree crown cover that was not developed for other uses], ≥0.4 ha, ≥37 m wide, capable of producing industrial wood ≥1.4 $m^3 \cdot ha^{-1} \cdot yr^{-1}$, and not reserved from timber production) having no direct human interference.
[b] Rows and columns may not sum to totals due to rounding errors.
[c] Conifer, oak-pine, and upland hardwoods.
[d] 4-wheel drive, truck operable or better.
[e] Timberland part of contiguous forests ≥1,000 ha.
[f] Corporations not primarily concerned with wood production.
[g] Timberland ≥0.8 km from urban or built-up land (Anderson et al. 1976) and ≥0.8 km from 2-wheel drive, all-weather roads.

may constrain gene flow among disjunct areas of occupied range. The approach enabled analysis of 77 million ha of forestland in 12 states, largely from existing field-based forest inventories, highlighted spatial association of classifications, and helped narrow the investigation toward locations needing finer-scaled measures.

Remote Forests

Habitat area larger than existing reserves is needed to conserve large carnivore species with broad home ranges. Forested reserves throughout the southern United States were small and scattered. Nonreserved forests, chiefly timberland, were abundant. Remote timberland represented a fourth of all timberland. Remote and nonremote timberland differed in composition by forest type, stand diameter, and ownership class. In Alabama (Rudis 1991*a*) and the south-central U.S. bottomland hardwoods (Rudis 1993) remote timberland is declining. Expanding human influences will likely further reduce remote forests and alter their composition.

Black Bears

Given that optimal black bear habitat is limited among black bear occupied range, we hypothesize that there are 5 distinct black bear provinces: (1) Florida-western Alabama-southeastern Mississippi, (2) Arkansas-Louisiana-Mississippi Delta, (3) western Arkansas, (4) central Appalachian Mountains (east. Tenn.-west. N.C.-west. Va.), and (5) coastal North Carolina. Genetic studies of black bears in these hypothesized provinces could provide evidence of prior association.

There are few high-density optimal habitat links among disjunct areas of black bear occupied range. We interpreted this scarcity as a constraint on gene flow among populations and a reason why high-density optimal habitats were unoccupied. If a single black bear metapopulation is a conservation goal, linkages among disjunct areas of black bear occupied range should be increased by converting cropland to bottomland hardwood forests along river systems and promoting remote forest conditions when managing forests (e.g., minimizing forest fragmentation, limiting road development). If conserving subpopulations is a goal, detailed monitoring of existing reserved and remote timberland in occupied range and finer-scaled mapping of subpopulations is needed to ensure that minimum area needed for a viable population is met in each of the 5 provinces.

Unoccupied counties with high-density optimal habitat are potential repopulation areas, and our model suggested 3 locations for reintroduction disjunct from existing black bear occupied range (see Results). For each location,

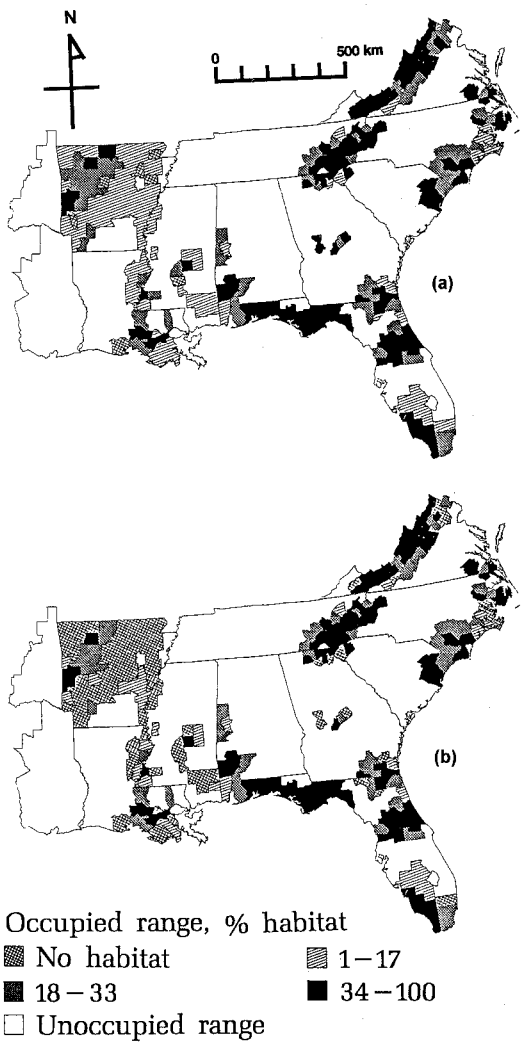


Fig. 6. Black bear unoccupied range and percent (a) suitable habitat (≥0.5% land area in reserved timberland, woodland, and remote timberland) and (b) optimal habitat (suitable habitat [excluding xeric woodland] with ≥5,000-ha bottomland hardwood and ≥16,000 ha in reserved timberland, hydric woodland, and remote timberland) by county in occupied range, southern United States, 1984–90 inventories.

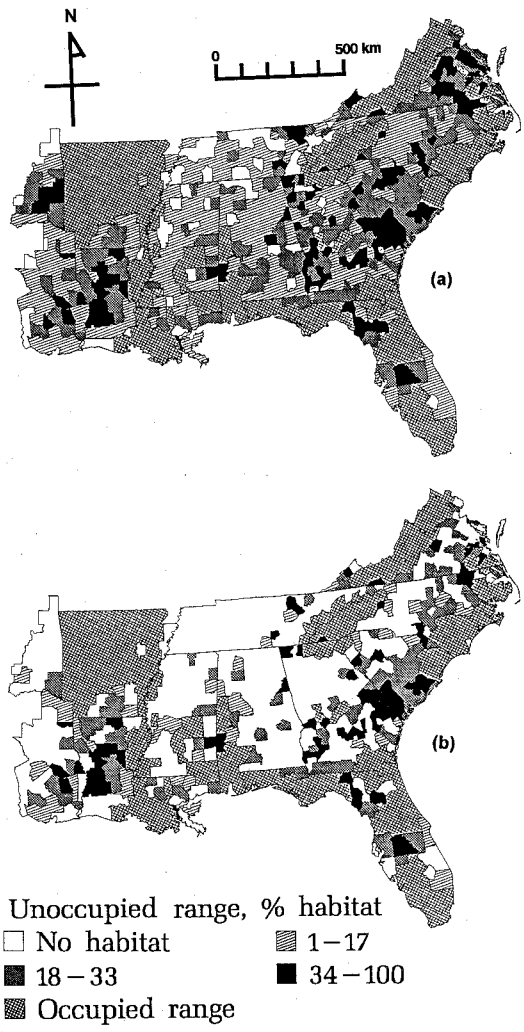


Fig. 7. Black bear occupied range and percent (a) suitable habitat (≥0.5% land area in reserved timberland, woodland, and remote timberland) and (b) optimal habitat (suitable habitat [excluding xeric woodland] with ≥5,000-ha bottomland hardwood and ≥16,000 ha in reserved timberland, hydric woodland, and remote timberland) by county in unoccupied range, southern United States, 1984–90 inventories.

we recommend mapping forests, biophysical and social community characteristics, and human influences at finer scales of resolution. Public education is necessary in any reintroduction effort.

The poor fit with optimal habitat criteria for northwestern and east-central Arkansas suggests within-region differences in either black bear behavior, populations, sightings, habitat, or indices used to estimate them. Forests with abundant mast and potential dens (trees and caves), rather than bottomland hardwood area, may be a better criterion for this largely upland portion of the bear's occupied range.

Forest Inventories

Our model, and any other effort to assess potential habitat for species with broad home ranges, requires an extensive area inventory. Knowledge of seasonal concentration areas, unusually

productive habitats, and restricted or limiting habitat features is important (Juday 1983). Clark et al. (1993) employed an effective black bear habitat assessment using forest stand inventory data, satellite imagery, a digitized road network, and ownership information with a geographic information system.

Because we could not afford to conduct such studies across the southern United States solely for this purpose, we relied on available remote forest measures designed to address other needs. A weakness in the approach was that parameter selection was opportunistic. Measures more likely important in distinguishing black bear behavior would include forest fragment size with nonforest boundaries >60 m wide (Weaver et al. 1990), road density, and vehicular traffic within forested blocks (Hellgren et al. 1991). A strength was that we could associate potential habitat with forest resource and owner attributes across an extensive area.

The approach did not incorporate within-county patterns in remote timberland (Rudis 1986), differences in wildlife management, human activity and attitudes toward black bears, and quality of potential foods. Incorporation of such detail in mapped form might have resolved some misclassifications. In this regard, mast-bearing tree species' basal area, density of potential tree dens, and selected anthropogenic uses could be prepared from FIA data (Rudis 1988*b*, 1991*b*). However, detailed habitat model development was questionable, given the quality of animal range measures (i.e., qualitative occurrence observations, limited standardization, and no animal density measures) within counties and across 12 states.

Despite the above drawbacks, we believe our approach provides a useful coarse-scaled assessment of potential black bear habitat. We anticipate improvements in procedures could be achieved with geostatistical analysis, black bear density data, and standardized remote forest estimates across the region. We suggest that multi-county and larger forest resource assessments be expanded to (1) address large carnivore mammal habitat and broad home ranges of other species that may conflict with humans or domestic animals, (2) include field inventories of woodland and reserved areas, (3) use standard measures to assess remote forests, and (4) organize available data in a geographic information system.

MANAGEMENT IMPLICATIONS

Because the black bear is a top carnivore and because only broad habitat requirements are included, key elements of its habitat include remote forests that are likely suitable for other large carnivores, associated ecological processes, and primitive (i.e., wild land) recreational opportunities. Our approach can supplement GAP (i.e., geo-referenced analysis of protected areas and diverse multispecies biological communities commonly conducted within individual states) analysis (Scott et al. 1991) by drawing attention to composition, ownership, density, and location of remote forests and large carnivores' spatial habitat needs across state boundaries.

A lower frequency of individually owned timberland was remote when compared with corporate-owned timberland, suggesting more emphasis be placed on programs and policies to mitigate fragmentation among individually owned land. Examples include public purchase of private nonforest development rights, owner coordination to augment continuous forest cover among adjacent properties, regional land management that minimizes the need for a dense road network, and zoning that restricts nonforest development in optimal black bear habitat.

Our model suggests that the best black bear conservation opportunities involve (1) retaining extensive areas of remote forests, (2) restoring optimal habitat by increasing reserved timberland and reforestation of bottomland hardwood timberland, and (3) increasing optimal habitat connections between occupied and potential habitat blocks. Conservation of remote forest areas also would help maintain within-region ecological processes (e.g., gene flow, mortality agents) and primitive recreational opportunities but could shift more intensive land uses to other areas.

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