Deer Habitat in Western Costa Rica: Impacts of Changing Technology and Land Use
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Deer habitat in western Costa Rica: impacts of changing technology and land use

Lynn R. Irby and Christopher Vaughan

Abstract White-tailed deer (*Odocoileus virginianus*) numbers on the Pacific Coast of Costa Rica probably peaked in the nineteenth century as native dry tropical forest was converted to shrubland and secondary forest. Overhunting and conversion of forest to crops and exotic grasses led to declines in deer through most of the 1900s. Current population levels are low, but restoration efforts may succeed partially as a result of incursions of modern technology and land-use changes. Power lines were built along several roads in the southern end of the Nicoya Peninsula of western Costa Rica in the 1970s and 1980s. Access to electricity and economic and social changes at the national level led to land-use changes in the Nicoya Peninsula including consolidation of land holdings, diversification of agricultural operations, and reductions in the number of subsistence farms. Comparisons of topographic maps based on 1945 aerial photos with ground observations in 1989–1990 indicated that: (1) rural houses and roads in the study area did not increase between 1945 and 1990 despite population increases in Costa Rica; (2) closed-canopy tree cover may have increased as much as 4-fold; and (3) rural housing distribution changed substantially, and the change was related to power-line distribution. Availability of electric power likely influenced changes in distribution of the human population and attitudes towards wildlife; these changes resulted in an increase in habitat available to wildlife and increased tolerance for several species of wild vertebrates, neither of which would have been predicted by the environmental impact models proposed by opponents of technology.

Key words Costa Rica, land use, technology, white-tailed deer

White-tailed deer (*Odocoileus virginianus*) distribution in the western New World extends from British Columbia through Peru (Baker 1984). In Costa Rica, white-tailed deer (*O. v. chirquensis*) were abundant and routinely used for food and clothing by Indians along the Pacific coast when Spaniards began exploring the area in the early 1500s (Solís and Rodriguez 1987). European colonists began extensive clearing of the tropical dry forest for grazing in the mid 1600s. From 1700 to the early 1900s much of the land in western Costa Rica was maintained in early successional forest by constant clearing to maintain cattle pastures. Deer densities during this period were high and could have exceeded those of the six-

Radiocollared deer in riparian secondary forest, Cobano, Costa Rica.

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teenth century (Solís 1994). Export of deer hides peaked around 30,000/year in 1901-1906, and in markets, venison was cheaper than beef.

Hunting pressure and conversion of secondary forest to exotic grasses, cotton, and food crops led to declines in deer populations that continued through the late 1960s when deer were rare over most of western Costa Rica (Vaughan and Rodriguez 1991). Surveys in the Guanacaste Province of northwestern Costa Rica in 1987 (Vaughan and Rodriguez 1991) indicated high densities (>8 animals observed/hr) in a few protected areas (national parks, large ranches, and an island penal colony) and little evidence of deer in most of the province.

Despite reduced populations, white-tailed deer were one of the most important game animals in Costa Rica in the 1980s (Solís 1994). In 1987, there were 529 licensed deer hunters and an estimated 3,000-4,000 illegal hunters in a country of 51,022 km^2 with a population of 3 million people (Vaughan and Rodriguez 1991). Most permits were issued for sport hunting, but some were for subsistence and scientific collection. Density of hunters, 0.08 hunters/km^2, reflected the low density of deer. In the United States, hunter density averages about 1.7 hunters/km^2 (approx 12 million licensed white-tailed deer hunters [Stransky 1984] in states with a total area of 6.9 million km^2 [Baker 1984]).

Although hunting was officially confined to an August-November season and hunters were legally limited to a single antlered buck (Fernandez 1987), neither the Costa Rican National Park Service nor the Costa Rican Wildlife Service had the personnel or funds to enforce regulations. In 1990, deer fared best in areas where individual park staff members or private landowners protected them. The only management actions directly applied to deer were attempts to limit illegal hunting. Manipulation of vegetation for other purposes (such as burning and forest clearing) sometimes had beneficial impacts on deer by providing cover or enhancing food.

In 1987, The Regional Program in Wildlife Management at the National University in Costa Rica (PRMVS) established a community education program in conjunction with restocking white-tailed deer in the Cobano District in northwestern Costa Rica (Hernandez 1994). Deer were released on several small ranches. Local landowners formed deer reintroduction committees and encouraged people in outlying areas to support reintroductions. Extension personnel from the PRMVS developed education programs in elementary and high schools, and local families were recruited to raise fawns for release. Deer for the restocking effort were obtained from San Lucas, a prison island near the Costa Rican coast. Introduced deer survived, and numbers increased during 1988-1992 (Calvopina 1994, Irby and Calvopina 1994, Vaughan, unpubl.). Although monitoring was discontinued in 1992, deer persist in the Cobano area.

Technology, land-use changes, and deer prospects

Data from radiotelemetry studies (Calvopiña 1990, 1994; Irby and Calvopiña 1994) indicated that suitable habitat for deer was widely available in the Cobano District. Conversations with local people indicated that changes in land use, human distribution, and attitudes towards wildlife in the area were largely responsible for the success of reintroductions in 1988-1990.

Although clearing of forests and European settlements began in the 1600s, the southern end of the Nicoya Peninsula near Cobano was not heavily impacted until the Coast Rican government opened lands for settlement in the 1930s and 1940s. By the 1950s, <5% of the southern end of the peninsula maintained its original cover of dry and humid tropical forest. Large indigenous mammals were eradicated or reduced to small remnant populations during this period.

By the 1980s, land-use patterns changed again (C. Vaughan, J. Fallas, D. Hernandez, J. Mora, P. Sanchez, and H. Chaves, Univ. Nacional, Heredia, Costa Rica, unpubl. tech. rep., 1994). Small farmers abandoned uneconomical units. The remaining farmers operated larger units producing more diverse crops. Ranchers increased the sizes of their operations and diversified into forest plantations and specialty crops.

View of pasture and secondary forest along a road without power lines, Cobano, Costa Rica.

A few foreigners purchased land in the area. Tourists discovered coastal areas, and tourist facilities began to add to the economic base in the area. Some villages disappeared, and others grew larger.

The availability of electricity was a factor in new land-use practices, and its temporal association with broader social and economic trends made it a convenient index with which to assess the impacts of land-use changes on deer habitat. Costa Rica subsidizes rural electricity. Lines are built along major roads. People have to pay to connect to the lines, and cost is proportional to distance from trunk lines. Once a house is connected to the system, rates are relatively low. Monthly household bills were $10–30 in 1990. This program produced a steady increase in areas served by electricity in the Nicoya Peninsula in the 1960s through the 1980s. Electricity provided local people with more leisure time and access to television which gave them a broader view of the world. This broader view included greater environmental awareness.

Some residents in the Cobano District remembered their parents' accounts of deer hunting and began to look for ways to restore populations for sustainable harvest. Their interest eventually led to the PRMVS choosing Cobano as a site for testing community involvement as an approach to deer reintroduction (Calvopiña 1990, Hernandez 1994). In our study, we examined changes in vegetation cover and human distribution during the last half of this century, determined if changes in human distribution were correlated with availability of electrical service, and outlined the implications of land-use changes for wildlife in the Cobano area.

Study area

The Cobano District occupies the southern tip of the Nicoya Peninsula of western Costa Rica. Elevations in the study area ranged from sea level to 400 m. Precipitation averages approximately 200 cm with a pronounced wet season (May-Nov) and dry season (Dec-Apr; Coen 1983).

The original vegetation of the area was classified by Hartshorn (1983) as predominantly "tropical moist forest," a 40–50m multistrata mix of evergreen and deciduous species. At the time of this study few undisturbed patches of forest remained in the area, but successional and disturbed woodlands were common on former agricultural lands. Soils underlying the forest were a mix of thin mountain orthents on steep slopes and alluvial tropepts of moderate fertility on flatter areas (Vasquez Morera 1983).

In 1989–1990, cattle ranching and annual food-crop production were the dominant land uses. Use of land for orchards and tree plantations was increasing. Cattle raising and conventional annual crop production were decreasing (N. Quiroz and J. Mendoza, Cobano Reintroduction Comm, pers. commun.). A few thousand hectares of land were preserved in public nature preserves or on private ranches primarily for environmental reasons.

Methods

During November 1989–February 1990, we collected information on vegetation characteristics and human land use at random points for comparison with radio relocations for marked deer in the area. Random points were selected by identifying blocks (4–8 km^2) surrounding the home ranges of each of 8 radiocollared deer, selecting random numbers from a table to identify 20 points/km^2 within each block, and transferring the points to 1:25,000 topographic maps (Inst. Geogr. 1957). The map series was prepared from aerial photographs taken in 1945.

We visited each block and located random points as accurately as possible based on terrain configuration and distance from known land marks. Twenty to 60 points were visited in the blocks associated with each deer. At each point, we recorded cover type and distances to houses and roads. We also estimated the percentage of cover types in a 3.14-ha area around the random point to determine the influence of variations in cover type designation due to arbitrary point placement (we did not have access to Global Positioning Units). All estimates were rounded to the nearest 5%, and all cover types were given a minimum value of 5% if they occurred in the plot.

A comparable approach was taken for each point as it was located on topographic maps. Map area was determined by centering a circle scaled to 3.1 ha over the point and estimating cover types using the same system that we employed on the ground. We limited the cover types identified on topographic maps to forest, nonforest, buildings, and roads. We consolidated cover-type categories recorded during site visits (Irby and Calvopiña 1994) to produce categories analogous to the 4 noted for map locations. Successional woodland was counted as forest only if canopy coverage was >50%, and understory vegetation appeared to be influenced by tree canopy. Tree plantations were counted as forest but orchards were not.

Analyses were based on comparisons of map points with site visits. Use of the same database for both data sets would have been optimal, but we were unable to obtain 1945 aerial photographs for the study area, and the most recent available photo set was made in 1981. We were able to check the accuracy of human artifacts noted on the topographic map by examining the 1981 photo set to determine if houses and roads were identifiable and by visiting 8 sites where buildings were indicated in 1945 but not apparent in 1989-1990. We found an abandoned house or evidence of past occupation by humans at each site we examined.

Change in cover-type availability between 1945 and 1989-1990 was assessed by comparing the distribution of point locations among 4 cover types during the 2 periods using a 2 x 4 contingency analysis (Steel and Torrie 1960). To test for sensitivity to small variation in locations of points, we conducted a similar test on the distribution of cover classes in 3.14-ha plots at all points. The chi-square values for point locations were based on numbers of points summed across all random sites. The chi-square values for areas were based on the number of hectares of each type estimated for all random sites. Power was estimated using a computer package developed by Borenstein and Cohen (1988).

The distance from random points to roads and occupied houses was used as an index to distribution of roads and houses. In 1989-1990, we attempted to identify all occupied home sites outside of villages in the areas where we selected random points. On topographic maps, we assumed all building clusters noted on the map were, or had recently been, occupied by humans. The roads category included cart tracks, seasonally accessible tertiary roads, and all-weather gravel roads. There were no paved roads in the study area. Data from 1945 were compared with those from 1989 to 1990 using paired *t*-tests. The influence of electric lines on house and road distribution was assessed by dividing houses into 3 distance categories (0-300 m, 301-999 m, and >999 m from the nearest electric trunk line in 1990) and examining differences between 1945 and 1989-1990 data sets using paired *t*-tests. Power was estimated using techniques in Borenstein and Cohen (1988).

Electric lines were not present anywhere in the study area in 1945, but all of the major roads which eventually served as routes for electric powerlines were present, and no new major roads in the blocks we sampled were added between 1945 and 1990. The status of some roads changed between 1945 and 1990. The kinds of changes included: upgrading a cart track to a tertiary road passable by motor vehicles in the dry season, adding a gravel base to a stretch of road to make it passable in the wet season, and downgrading a major cart track to a minor cart track as houses were abandoned.

Results

Comparisons between 1945 and 1989-1990 were based on 366 random points (or 1,149 ha in plots surrounding points) in 49 1-km^2 blocks in the Cobano District. Distribution of points among 4 cover categories was similar to distribution of area of plots centered on points (Table 1). If cover types delineated on the topographic map series were valid, the landscape changed significantly over the 45-year period (point chi-square = 59.88, $P < 0.001$; plot chi-square = 137.2, $P < 0.001$; estimated Power for both approaches >0.99). Forest cover increased from 6% to 26% of the landscape. Buildings and roads in rural areas may have increased slightly. If the number of people/household remained relatively constant, human density outside of villages was roughly the same in 1945 and 1989-1990.

The mean distance from a random point to a road was 209 m in 1945 and 363 m in 1989-1990. Mean distances from random points to houses were 344 and 485 in 1945 and 1989-1990, respectively. Distances to roads and distances to houses from random points were positively correlated in 1945 ($r = 0.62$, $P < 0.01$, Power >0.99) and 1989-1990 ($r = 0.30$, $P < 0.01$, Power > 0.99). This was expected since many roads were established to provide access to houses. Although the strength of the association between roads and houses may have weakened between 1945 and 1989-1990, the basic pattern remained.

Random points were significantly closer to roads ($t = 7.78$, $P < 0.001$, Power > 0.99) and houses ($t = 10.00$, $P < 0.001$, Power > 0.99) in 1945 than in 1989-1990. Because we measured the distance to the nearest house, this change could indicate a decrease in house and road density or a shift in distri-

Table 1. Distribution of 366 random points and 366 plots (3.14 ha) centered on random points in the Cobano District, Costa Rica, among 4 cover classes in 1945 and 1989–1990.

	Occurrence (%)	
Cover class	**1945**	**1989–1990**
Points (n = 366)		
Forest	6	26
Nonforest	92	70
Houses	0	1
Roads	2	3
Plots (n = 1,149 ha)		
Forest	6	23
Nonforest	91	74
Houses	1	1
Roads	2	2

Table 2. Distances between random points and buildings in 3 distance classes relative to electric power lines in the Cobano District, Costa Rica. Comparisons are between buildings identified on topographic maps based on 1945 aerial photos versus occupied buildings observed in 1989–1990. Electric power distribution is based on observations in 1989–1990.

Distance of random points from powerlines in 1990	Mean (SD) distance (meters) from random points to buildings		
	n	1945	1989–1990
0–300 m	117	299 (189)	271 (178)
301–999 m	131	342 (205)[1]	523 (236)
1,000–3,090 m	118	390 (244)[1]	656 (355)

[1] Means are significantly different ($P < 0.05$).

bution. The mean distance to houses from random points within 300 m of roads paralleling electric lines (Table 2) decreased slightly between 1945 and 1989-1990 but not significantly ($t = 1.28$, $P = 0.20$, Power = 0.22). Random points at 301-999 m from electric lines were 181 m closer to houses in 1945 than in 1989-1990 ($t = 6.57$, $P < 0.001$, Power > 0.99), and points at distances >999 m were an average of 266 m closer to houses in 1945 than in 1989-1990 ($t = 7.15$, $P < 0.001$, Power > 0.99). The distribution of houses shifted significantly, and the shift was towards areas where electricity was available.

Discussion

In the Cobano area of Costa Rica, the arrival of modern technology had beneficial consequences for deer (Calvopiña 1994, Hernandez 1994). Human artifacts were more concentrated in 1990 than in 1945, and the concentrations occurred along a few major road corridors where people moved to take advantage of electric trunk lines. Concentration of the human population opened more space for wild animals, decreased some aspects of habitat fragmentation, and opened corridors between relatively undisturbed forest patches.

Changes in land use in the Cobano area also improved habitat for wild animals. The diversification in agriculture between 1945 and 1990 was driven by economic forces outside the community rather than any internal or external desire to improve habitat. However, the emigration of marginal farmers who could not sustain crop loss to vertebrates, consolidation of land into larger parcels that limited human disturbance, and conversion of annual-crop fields to structurally complex shrubby pastures, orchards, or tree plantations benefited deer and probably many other native vertebrates.

The situation in Cobano was opposite to that often reported when modern technology enters rural areas in unindustrialized countries (Dahlberg 1987, McNeely 1987, Vaughan 1990) and is analogous to the improvements in wildlife habitat that accompanied land-use changes in eastern forests and the Great Plains of the United States in the 1930s and 1940s (Barber 1981, Severson 1981). The positive effects of "modernization" in the United States and in Cobano should make us cautiously consider, rather than automatically oppose, proposed introductions of Western technology in undeveloped areas.

When ecologists realized that people who had lived on land continuously for centuries had developed land-use patterns that fit the land where they live (Altieri et al. 1987, LaFour 1990, Bennett 1992), ecological wisdom as evidenced in nontechnical societies became a part of the international conservation paradigm. Traditional, low-tech land uses are often automatically considered to be better for the environment than high-tech land uses. This attitude is just as dangerous as ignoring the ecological wisdom of indigenous people.

Reliance on traditional ecological wisdom has 2 drawbacks. First, people tend to lack objectivity when viewing their tribal history. The "golden era" view of history is typical and distorts the truth. Ecological and social mistakes are forgotten. Second, even if a traditional land use were optimal for traditional circumstances, the world is changing, and tradition may not allow the flexibility needed to meet change. People most likely to be hurt by extreme attitudes about ancestral environmental wisdom are those people living on and earning a living from the land. If we are going to sustain biodiversity, we need to learn how modern technology changes land use and to identify opportunities associated with such changes.

Three other points emerged from Cobano: (1) cattle ranchers actively supported recovery of large wild vertebrates and, through their efforts to diversify for economic reasons, promoted habitat changes that benefited many wild species; (2) the people most opposed to reintroduction of deer and least tolerant of wildlife in general were small scale farmers who produced beans, rice, and corn; and (3) the driving force which initially led local people to organize wildlife restoration efforts was a desire to recreate sport hunting opportunities their parents had known.

As noted by McNeely (1987), situations involving development must be considered individually. The modernization of the Cobano District is not equivalent to building roads in roadless areas of Amazonia. A wave of development washed over the Nicoya Peninsula long ago leaving only remnants of the original plant and animal communities. The question in Cobano is how to retain the largest portion of the remnants. Janzen (1986) outlined a strategy for restoring dry tropical forests in Guanacaste National Park, Costa Rica, based on giving local people benefits from restoration and nurturing normal successional trends. Electricity and associated changes in lifestyles in Cobano have inadvertently done this but at the expense of other areas being flooded to create the hydropower projects that produced the electricity.

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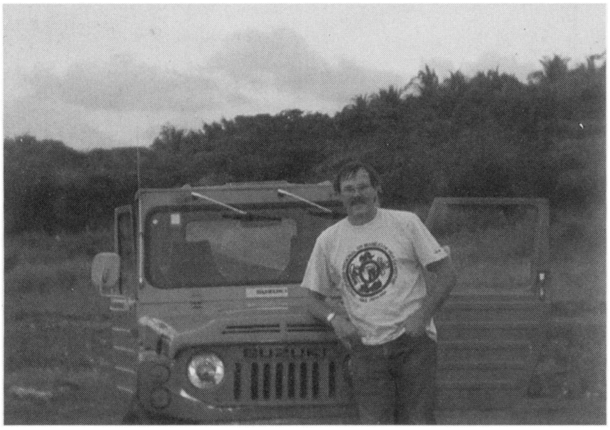

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