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NEAREST NEIGHBOR NEST DISTANCES, HOME RANGE AND TERRITORY AREA OF THE MADAGASCAR FISH-EAGLE (*HALIAEETUS VOCIFEROIDES*)

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KEY WORDS: *Madagascar Fish-Eagle;* Haliaeetus vociferoides; *carrying capacity; conservation; ecotone; endangered; spatial utilization.*

The Madagascar Fish-Eagle *(Haliaeetus vociferoides)* is endemic to Madagascar and considered endangered due to its low and declining population of only 100–120 breeding pairs (Langrand and Meyburg 1989, Collar et al. 1994, Rabarisoa et al. 1997). Little was known about the species' biology or ecology until intensive studies began in 1991 aimed at understanding its natural history, with emphasis on those ecological parameters that may influence survival and to suggest a design for a conservation recovery program (Watson 1997).

The area needed to support a breeding pair of eagles is an important ecological parameter that can determine the carrying capacity of suitable habitat (Newton 1979), and can be estimated from measurement of nesting density, nearest neighbor nest distance, home range area or territory area. In continuous suitable habitat, noncolonial nesting raptors generally space themselves by maintaining a mutually exclusive territory which pairs defend by a variety of behavioral displays and interactions (Newton 1979). Nearest neighbor distances can be used to estimate nest spacing in species that nest only along linear ecotones, such as the Madagascar Fish-Eagle which nests only along woodland to water ecotones. An estimate of pair spacing can be used to extrapolate population carrying capacity if the area of suitable habitat is known, carrying capacity being an important estimate for setting a target population size for endangered species recovery. In this report, we evaluate the relative suitability of nearest neighbor nest distance, home range and territory size as indices of the area needed to support a pair of eagles and their use in estimating the Madagascar Fish-Eagle population carrying capacity.

Table 1. Home range parameters of six adjacent Madagascar Fish Eagle pairs on three adjacent lakes in western Madagascar in 1993.

PAIR NAME (PAIR NO.)	NO. OF OBSERVATIONS	MAX. AREA (ha)	90%-PROBABILITY (ha)	50%-PROBABILITY (ha)	NOTES
Befo-2 (3)	245	266	154	9.4	
Befo-3 (4)	403	244	44	0.3	nest on island
Soam-2 (24)	396	487	292	3.2	
Soam-1 (1)	333	434	224	6.7	
Mean		350	189	8.1	
SD		118.8	49.5	1.9	

METHODS

Nearest neighbor nest distances and intra-pair alternate nests were measured during the breeding period (June–October) each year from 1992–96 at three adjacent lakes (Lakes Ankerika, Befotaka and Soamalipo) in western Madagascar. The study area was thoroughly surveyed at the start of each breeding season to find every breeding pair. Nest sites were marked on a 1:40 000 scale map from which distance measurements were made. Nearest neighbor nest distances included only those pairs that built or repaired nests within the year of measurement.

In 1993, we made behavioral observations of four adjacent nesting pairs to measure home range and territory size. Home range was defined as that area used by pair members for any activity. Territory size was defined as that area defended by the pair, either by aggressive intraspecific interactions with intruders or by prominent displays and duetting calls by the pair. Daily observations took place from dawn to midday or from midday to dusk once per week at each of the nests for the duration of the breeding period. Members of the focal pair were tracked visually for as long as possible by two mobile observers who worked together on foot or by boat to keep birds in sight. Each new position of a bird was recorded on a 1:40 000 map of the lakes overlaid with a 40 × 40 m grid. Individual birds were recognized by radio tags, leg bands and/or visits to their own nest site. Sexes were differentiated by the relatively larger size of the female and the lower pitch of her vocalizations. Territory and home range size were calculated from subsampled independent observations using Ranges IV (Biotrack, U.K.) to determine the minimum-area convex polygon size, and 90%- and 50%-probability areas (Kenward 1987).

RESULTS

Pairs used a mean of 3.5 alternate nests in the five year study period. One pair (Befo-3) moved to alternate nests each year and built a total of six nests during the study, while others (e.g., Anke-1) used the same nest for up to three successive years. Pairs moved to alternate nests in 28 of the 36 pair-years recorded, a 78% relocation rate. Because pairs moved to alternate nests, nearest neighbor nest distances changed every year.

The mean distance between alternate nests for all pairs over all years was 0.54 ± 0.49 km (±SD). Although the center of activity of pairs tended to remain more or less constant, two pairs moved to alternate nests 1.9 and 2.3 km from their previous nests and made large changes in center of activity. Although these figures reflected distances between alternate nests used in successive years, Madagascar Fish-Eagles were observed to construct or reconstruct more than one nest during the prebreeding season, eventually settling on one for the year's breeding attempt.

The mean nearest neighbor nest distance for each year was: 1.55 ± 0.30 km in 1992 (N = 10), 1.80 ± 0.35 km in 1993 (N = 9), 1.58 ± 0.56 km in 1994 (N = 11), 1.55 ± 0.56 km in 1995 (N = 10) and 1.94 ± 1.13 km in 1996 (N = 9). The mean nearest neighbor nest distance for all years was 1.68 ± 0.66 km (N = 49). Although most nearest neighbors were at fairly consistent distances from each other, one pair, Befo-2, moved its nest site 2.3 km to another small lake in 1996, where its nearest neighbor was on Lake Befotaka nearly 5 km away.

Maximum home ranges for four adjacent fish eagle pairs on Lakes Befotaka and Soamalipo in 1993 ranged from 244–487 ha, with a mean of 350 ha ± 119 ha (Table 1). The mean 90%-probability range was 189 ha indicating that about 54% of the maximum range was created by infrequent visits by fish eagles to distant points in the range. The 90%- or 50%-probability ranges were therefore more useful figures for making comparisons of range size between pairs, years or seasons One pair, Befo-3, had a substantially smaller range size, especially when comparing the 90%- and 50%-probability ranges between pairs (Table 1). This was most likely because Befo-3 nested on an island which offered more abundant access to aquatic and shoreline habitats. The difference was still apparent, but not so great, even when considering the maximum home range size which included occasional long forays across the lake to opposite shores.

Territory size varied considerably from 24–273 ha with a mean of 116 ± 80.6 ha (Table 2), the smallest

Table 2. Territory size of four adjacent Madagascar Fish Eagle pairs on Lakes Befotaka and Soamalipo in 1993.

Pair Name (Pair No.)	No. of Observations	Max. Area (ha)	90%-Probability Area (ha)	50%-Probability Area (ha)	Notes
Befo-2 (3)	21	59	19	4.7	
Befo-3 (4)	71	24	2.7	0.2	nested on island
Soam-2 (24)	65	273	203	1.2	
Soam-1 (1)	74	173	117	4.9	
Mean		116	68	4.8	
SD		80.6	69.3	0.14	

territory being that of the island nesting pair. The large variation in territory size between these four pairs remained evident even when comparing 90%- and 50%-probability areas (Table 2), suggesting that territory size was consistent within each pair. We speculated that differences in territory size reflected differences between the visibility of interlopers and/or the audibility of territorial vocalizations, both associated with the physical characteristics of the territory (e.g., relative proportions of forest to open water). We saw no physical interactions between neighboring pairs. Intraspecific interactions were recorded only between resident birds and conspecifics that came from outside the study area and were not recognized as neighbors. It appeared that territories were recognized by neighbors and were maintained without physical interaction by calling and perching in a prominent location.

DISCUSSION

The Madagascar Fish-Eagle's maximum home range varied by nearly 100% and even the mean 90%-probability range varied by a factor of six times (from 44–292 ha). In any case, home range was a poor measure of carrying capacity because of the likelihood of shared foraging areas with neighboring pairs. Territory size was likely not a useful parameter for extrapolations of carrying capacity either. In the case of the Madagascar Fish-Eagle, where territory was maintained largely by visual and audible displays that carried over a large distance, measurements based on the residents' location was probably not an accurate reflection of actual territory size.

We concluded that nearest neighbor nest distances were the best source of estimation. In the case of the Madagascar Fish-Eagle, they were much less variable and consistent with the linear nature of suitable nesting habitat (i.e., woodland to water ecotones). Thus, they offered a direct way of estimating overall carrying capacity in areas of known suitable habitat.

RESUMEN.—Los estudios de comportamiento fueron conducidos desde 1992–96 para medir la variación en la utilizacion espacial de la amenazada aguila pescadora de Madagascar. Los resultados mostraron que la media de la distancia del nido vecino mas cercano fue de 1.68 ± 0.66 km (±SD), la media de la distancia al nido alterno fue de 0.54 ± 0.49 km y el centro de actividad de las parejas fue mas o menos constante. El rango del hogar máximo de 4 parejas oscilo entre 244–487 ha, con una media de 350 ± 119 ha. La media 90% de probabilidad de rango de hogar fue de 189 ha. El tamaño del territorio varió considerablemente de 24–273 ha con una media de 116 ± 80.6 ha. El rango y territorio de una pareja anidando en el interior de la isla fue substancialmente mas pequeño que el de otras. Los estimativos del tamaño del territorio fueron muy variables para ser utilizados y poder estimar la capacidad de carga de habitats convenientes. La distancia del nido vecino mas cercano fue mucho menos variable, dado que es una medida linear consistente con la naturaleza del habitat de anidación consistente para el águila pescadora (i.e., ecotonos de bosques y acuáticos) decidimos considerar esta como el mejor parametro para estimar la capacidad de carga en habitats convenientes.

[Traducción de César Márquez]

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DUMPS FOR DEAD LIVESTOCK AND THE CONSERVATION OF WINTERING RED KITES (*MILVUS MILVUS*)

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KEY WORDS: *conservation; diet;* Milvus milvus; *dead livestock; wintering populations.*

The main European population of Red Kites (*Milvus milvus*) winters in Spain (Viñuela 1996), where management of this species is critical for its conservation. Red Kites usually feed on carrion (Cramp 1980) and refuse and carrion disposal sites may be important winter feeding areas (García et al. 1998). In this paper, I evaluate the importance of livestock carcass disposal sites for kites in the Ebro Valley, which, together with the northern plateau, is one of the most important wintering areas in Spain (De Juana et al. 1988, Sunyer and Viñuela 1996).

STUDY AREA AND METHODS

The study area was in the semiarid Mediterranean basin that is crossed by the Ebro River in northeastern Spain (Zaragoza and Huesca Provinces, 41°39′N, 00°54′W). Diet composition was studied by analysis of pellets collected in communal roosts that were used by most of the wintering population. This kind of analysis allowed me to infer indirectly the foraging habits of the birds, avoiding more costly techniques such as radiotracking.

I visited three of the most important roosts situated in the two main landscape types in this area: roosts Almudévar and Leciñena were in dry lands (nonirrigated crops) and roost Luceni was in irrigated land near the Ebro River. In 1993, the number of Red Kites roosting at these three locations were 60, 75 and 90, respectively (SEO-Aragón 1994), remaining roughly constant during the study period. At the Almudévar roost, pellets were collected at the end of February 1996 and reflected the winter diet. Leciñena and Luceni roosts were visited in November 1997 and reflected the autumn diet. Pellets were collected in the morning, when all the kites had left the roosts to avoid disturbance. Prey analyses were made according to Blanco et al. (1990), assuming that one kite consumed 95 g of food and regurgitated one pellet per day. When the weight of one prey item in a pellet was heavier than this amount (e.g., a rabbit), we assumed that 95 g of prey had been consumed. When a pellet was composed of prey of lesser biomass, their partial contributions were added. When a pellet was composed of both prey over 95 g and prey of lesser biomass, we subtracted the weights of small prey from 95 g and added this amount to the heavier one. This method has been shown to accurately estimate diet composition in kites (Blanco et al. 1990). All prey weights were obtained from the literature. Prey were grouped in the following six categories: domestic animals (poultry, domestic rabbits and sheep), wild rabbits (*Oryctolagus cuniculus*) and hares (*Lepus granatensis*), small rodents, wild birds, reptiles and insects.

RESULTS

A total of 1892 food items were identified among the 262 pellets analyzed (Table 1). The most important food item in terms of biomass was carrion of domestic animals Poultry and domestic rabbits made up >80% of the domestic-prey biomass, although other types of prey, such as small rodents and wild rabbits, were also important Carrion of domestic animals and small rodents made up at least 60% of the biomass at the three roosts. On the Spanish northern plateau, carrion of small domestic animals has also been reported to be the main food of Red Kites but fluctuations in diet composition occur with cyclic fluctuations in numbers of common voles (*Microtus arvalis*) (Sunyer and Viñuela 1994, García et al. 1998). The high numerical importance of small rodents in my study could have also been related to the temporary abundance of voles (*Pitymys duodecimcostatus*), which made up 62% of the rodents consumed. High numbers of insects in the diet in autumn were probably associated with the massive emergence of flying ants which reached 85% of the total insect prey.