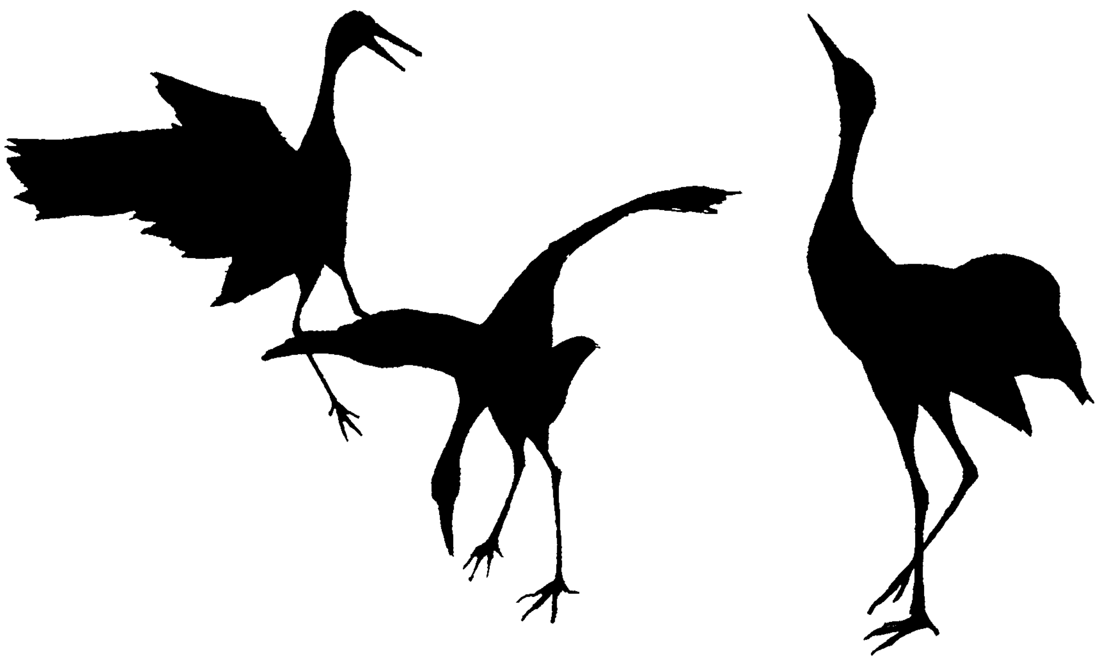
Empresa Nacional para la Protección de la Flora y la Fauna
Ministry of Agriculture, Cuba

Distribution and abundance of *Grus canadensis nesiotes* in Cuba; and,habitat use and reproduction in the population at Los Indios Ecological Reserve, Isle of Youth

Thesis presented as part of the degree of Doctor of Biological Sciences,
by Lic. Xiomara Gálvez Aguilera



Tutors: Dr. Felipe Chávez Ramírez, University of Texas, U.S.A.
Dr. Martín Acosta Cruz, University of Havana, Cuba

Havana, Cuba
2002

1. Introduction

We live at a critical juncture for the natural world. As a result of human activity, ecosystems are being degraded, many species are going extinct, and those that survive often suffer from reduction in population size and genetic variability. The majority of species extinctions have occurred during the past 150 years (Primack, 2000), especially in islands and archipelagos where 75% of the 113 avian extinctions recorded since 1660 have taken place (Groombridge, 1993, cited in Meine and Archibald, 1996a). Among birds at risk of extinction is one of the most attractive and interesting families: the cranes, which consist of 15 living species distributed across more than 110 countries on five continents (Meffe and Carroll, 1997).

Although they usually live in open wetlands, grasslands, and savannas, cranes can adjust to life in some anthropogenic habitats. This does not mean, though, that one fundamental problem that cranes face is habitat loss. Chiefly as a result of habitat loss, today cranes are one of the most threatened bird groups in the world, with seven of the 15 species included in the IUCN (International Union for the Conservation of Nature) Red Book (Meine and Archibald 1996a) (Appendix I).

For millennia people of diverse cultures have respected and admired cranes. Thus, aside from their other values (ecological, esthetic, recreational and conservation) the cultural value of cranes plays a critical role in plans to conserve them throughout the world. These plans do not only consider cranes alone but also the natural and anthropogenic ecosystems where they live. That is, cranes may act as "umbrella species", their conservation in turn protecting the wetland habitats where they typically live and the biodiversity associated with those. This conservation effort, centered on just one bird family and just one type of ecosystem (wetlands) throughout the world, is unique at present but offers possibilities highly relevant to other conservation efforts at local and global levels (Meffe and Carroll, 1997). Currently, the crane conservation effort is led by the International Crane Foundation (ICF), based in Wisconsin (USA).

In October 1994, PhD. George W. Archibald, the president and cofounder of ICF, visited Cuba. From that moment on, Cuba has had a continuous, countrywide research and conservation program for the Cuban Sandhill Crane (Gálvez and Perera, 1995). The program is sponsored by the Cuban Ministry of Agriculture with the financial support of ICF.

The Cuban subspecies of *Grus canadensis* faces the same threats as do the world's remaining cranes, especially habitat loss. Historical records as well as present-day observations suggest that the Cuban cranes have always depended on savannas and wetlands for reproduction. Apparently, though, Cuba has never had great expanses of naturally occurring savannas; originally the island was about 90% forested (Del Risco, 1995; Vales *et al.*, 1998). Today, in many provinces even the uncultivated remnants of savanna and wetland habitats have failed to escape human modification: overgrazing by cattle, artificial drainage, and subsequent effects on hydrological cycles.

Even though the Sandhill Crane is the largest bird not only for Cuba but also for any Caribbean island and is an endemic subspecies considered to be threatened (Buide *et al.*, 1974; García, 1987), its ecology and conservation have been little studied. Gundlach (1876) considered the Crane to be common in some large savannas in the east and southeast of Cuba and on the Isle of Pines. He observed cranes first-hand in Viñales, savannas to the east of Guamuta, in the Zapata Swamp, and on the Isle of Pines. By the 1970s, only four populations of sandhill cranes were known to exist and all were thought to be isolated: Isle of Pines, Pinar del Río, the Zapata Swamp, and the Lesca Savanna. Garrido and García (1975) warned that the last was in danger of disappearing. Likewise, Raffaele *et al.* (1998) and Garrido and Kirkornell (2000) list only a few localities for the species.

Given the scientific, ecological and cultural importance for Cuba of our subspecies of *Grus canadensis*, plus the scarcity of information about this threatened bird, we proposed the following.

WORKING HYPOTHESIS: The differential use of habitats, both natural and anthropogenic, and the landscape distribution of the Cuban Sandhill Crane varies among the phases of the annual reproductive cycle: incubation, raising chicks, and the non-breeding period.

From the working hypothesis we proposed the following objectives of the study.

General objective: to assess the distribution and abundance of the Cuban Sandhill Crane throughout Cuba and characterize the pattern of habitat use, plus seasonal changes in same, by the population on the Isle of Youth (formerly Isle of Pines).

Specific objectives:

1. To determine the current distribution of the Cuban subspecies of the Sandhill Crane, noting conservation problems and threats to the subspecies as a whole and to each of the populations.
2. To estimate the number of individuals in each population.

3. To investigate aspects of reproduction in the population at Los Indios Ecological Reserve, Isle of Youth.
4. To characterize the structure and species composition of the vegetation in nesting and feeding areas of the population at Los Indios Ecological Reserve.
5. To evaluate habitat use, habitat selection, and home range size for cranes within and outside of Los Indios Ecological Reserve.
6. Based on the above information, to propose realistic and sustainable management guidelines for both the Crane and the habitats it uses.

We proposed the following tasks to achieve the objectives.

- Through Cuba's local centers of the Empresa Nacional para la Protección de la Flora y Fauna (Ministry of Agriculture), to conduct interviews in local communities across the country, inquiring about locations of Crane sightings over the five preceding years.
- Through aerial reconnaissance, to explore all wetlands on the north and south coasts of all provinces where Crane sightings were reported during interviews.
- On the ground and in the field, to verify all historical accounts of Crane populations and all Crane sightings reported during interviews, then to determine the conservation status of the landscape and the potential short- and medium-term threats to those localities having cranes.
- To design and apply a standardized census technique to the populations found.
- To set up a functional classification of wet savannas based on the five years' accumulated knowledge of cranes' natural history and ecology.
- To design a method to capture ten individuals of the wild population on the Isle of Youth, and to fit them with radiotransmitters.
- To assemble the data bases necessary to using Geographic Information Systems (ArcView) (GIS) for analyzing habitat use and calculating home range size.
- To monitor all Crane nests encountered with respect to the most fundamental variables (number of eggs, number of chicks, and incubation period).
- Using each nest as a central point, to set up parcels for analyzing the surrounding vegetation, then comparing those analyses with those from parcels centered on randomly chosen points.
- Through radiotelemetry, to determine points that cranes choose for foraging and then set up vegetation parcels at those points.

Scientific importance

This study involves the following scientific advances for Cuba.

1. It is the first in Cuba to analyze habitat use by a bird species through advanced techniques such as radiotelemetry and GIS.
2. For the first time in Cuba, a bird species undergoes a simultaneous census that covers all the appropriate habitat in the country and involves local communities that share the species' habitat.
3. The investigation has revealed six new populations of cranes, changing the subspecies' conservation status in the IUCN Red Book.
4. The multi-year study is a first for Cuba and leads to an understanding of the reproductive dynamics and demography of this threatened Cuban bird.
5. The study reveals the comparative use of natural and anthropogenic habitats (savannas), which information can serve as the basis for a recovery program for the subspecies involved.

Theoretical importance

1. The study brings the complete geographic distribution of the Cuban Sandhill Crane up to date and establishes reliable figures for population size.
2. Results reveal those structural and taxonomic features of the vegetation associated with use and selection of habitats for feeding and breeding by individual cranes in the Los Indios Ecological Reserve.
3. Reproductive indices are established for the cranes of Los Indios and are evaluated with respect to key climatic factors that could influence these.
4. Analysis of home ranges leads to quantification of use and selection of the habitats making up Los Indios.
5. We proposed and tested a methodology to link crane censuses with non-formal environmental education.

Practical importance

1. The study provides data on countrywide distribution of the Cuban Sandhill Crane and on general problems that affect prospects for its conservation.
2. The status and conservation problems of each of the Crane's principal populations are illuminated. These data provide specialists and local decision-makers with the elements necessary to reconcile local economic development and the conservation of each region's wetlands.
3. The simultaneous census across provinces and regions, undertaken every three or five years by local communities, foments pride, a feeling of "ownership", and feelings of self-esteem. The massive, participatory census effort and associated activities enhance communities' sense of responsibility for conserving local ecosystems and in general promote a conservation ethic.

Along the way, interim results of the research detailed in this thesis have enabled the author to:

- Publish 13 papers about Crane conservation in national and international journals. Some journals (such as Bird Conservation International) have "high impact".
- Publish articles included in sections or chapters of four books on ornithology or conservation.
- Participate in 23 scientific events, among these 13 international congresses or conferences in such countries as Puerto Rico, the United States (including Hawaii), Mexico, Martinique, Trinidad and Tobago, the Bahamas, St. Lucia, Belize, and Guatemala. Of these, three were world congresses (Guadalajara 1994, St. Louis, Missouri 1998 and Hilo, Hawaii 2001).
- Have been proposed, by the Crane Specialist Group of IUCN and the International Crane Foundation, for the Prince of Asturias prize that is awarded annually in Spain.

The complete thesis consists of the following sections: Introduction, Literature Survey, Materials and Methods, Results, Discussion, Conclusions, Recommendations, Literature Cited, and Appendixes.

2. Materials and methods

2.1. Evaluation of the distribution and abundance of the Sandhill Crane in Cuba

The process began by searching the literature, from the 19th century onwards, for all localities where cranes had been recorded. Based the geographic distributions of Cuba's savanna habitats as displayed in the Atlas Nacional de Cuba (Academia de Ciencias de Cuba, 1970), we mapped all regions suitable for Crane populations. In October 1995, overflights at 40-60 meters height criss-crossed the savannas of the Zapata Swamp, Isle of Youth (formerly Isle of Pines), Sancti Spíritus, and Camagüey (Cayo Romano). Later, in January 1996 we overflew Pinar del Río, Birama, and north of Matanzas.

The next step followed the methods of Lewis (1977), William (in Nesbitt, 1994), and Jacobson (1995). Throughout those regions of the north and south coasts that bordered on wet savannas, 340 persons were interviewed, between 10 and 20 per locality. Interviewees included personnel of the Empresa Nacional para la Protección de Flora y Fauna (ENPFF), forest rangers, stockmen, farmers, fishermen, and rice growers.

2.2. Censuses of four crane populations

In four regions with large expanses of savanna inhabited by cranes (North of Ciego de Ávila, Zapata Swamp, Isle of Youth and Las Guayaberas Swamp) we organized simultaneous Crane censuses with extensive participation by local people. We adapted the methodology from that used by the International Crane Foundation in Wisconsin (Meine and Archibald, 1996a) and Mississippi, USA (Hereford *et al.*, 2001). Basically, people recorded cranes during two successive days at previously selected and georeferenced census points. The Crane-counters were volunteers selected from the surrounding communities (which totaled from 300 to 500 persons per region). From these counts we calculated the following variables: frequency of census points producing where cranes were observed; total number of cranes recorded (after eliminating repeat counts); mean number of cranes per census point, with range and variation; repeatability of counts between the two days; and, numerical concordance between successive counts. In total we completed and analyzed 11 censuses (1995-2002), usually two per year per locality and usually occurring in the month of February.

2.3. Intensive study of the Crane population in Los Indios Ecological Reserve, Isle of Youth

2.3.1. Description of Los Indios Ecological Reserve

Los Indios Ecological Reserve occupies a chunk of the west-central region of the Isle of Youth (Fig. 1). Its orientation, southwest to northeast, parallels the coast, that is the reserve's western limit. The southern limit is La Siguanea highway while the eastern and northern limits are defined by a river, a local road, or an abrupt change in vegetation. Most of the reserve's 5395.47 ha consists of white-sand savannas. The management plan for Los Indios (EMPA, 1994) presents a complete, detailed description.

2.3.2. Capturing, marking, and locating cranes

Cranes (11) were captured and marked with four colored plastic rings each, for individual identification. The four rings per bird (two per leg) presented a unique combination of colors and positions above the distal joint of the tibia. On ten cranes, we placed radiotransmitters (never exceeding 2.5% of body weight) above one pair of rings. Radios were water-resistant Crane Model M-16, emission F3E and with frequencies between 142.175 and 142.475. We used two receivers, models R2000 and R2100 respectively, with Yaggi antennas. The radios had a maximum range of 12 km but the average range was 6.4 to 8 km depending on terrain. Fifteen days after the last Crane was released, we initiated simultaneous triangulations of the positions of sets of four cranes over a 24 hour period. Each day we entered in the receivers the frequencies of the cranes to be located, made visual contact with them, and recorded on field data sheets (Appendix 5) their behavior for at least five minutes. We also recorded the Crane's Lambert North and East coordinates with a GPS unit (Magellan 300). Later, the coordinates were transferred directly to the computer. At the time of the observation we also classified habitat according to the code we had developed to classify the physiognomy of the savannas. Later, we used GPS to return to the exact sites where cranes had been observed to feed, using those sites as center points of parcels to characterize vegetation structure and composition (see below). We compared vegetation data with data from parcels centered on randomly chosen points.

Just as for feeding sites, we recorded GPS coordinates of each Crane nest discovered and, after nesting, characterized vegetation in a 50 m^2 parcel centered on the nest. Over three years we investigated the vegetation surrounding 41 nests.

2.3.3. Habitat classification

We established a system for functional classification of habitats in the Itabo-Majagua-Los Indios watershed. Our system combined the classification Borhidi and Herrera (1977) proposed for Cuban savannas with our prior knowledge of crane natural history and observations on which sorts of savanna microhabitats cranes themselves appeared to distinguish. To this end we used the Shugart method (Morrison *et al.*, 1998) to quantify the physiognomy and structure of wet savannas, open pinelands, and grasslands. The habitats defined (with codes) were: lakes (LG), coastal dune vegetation (VCA), dams (CP), streams (CA), ponds (CE), beaches (CAY), pastures (SP), abandoned pastures with secondary "weeds" (SS), open pinelands (SPPA), closed pinelands (SPPC), other woodlands (SOT), closed savanna (SNC), semi-closed savanna (SSC), and open savanna (SNA).

2.3.4. Habitat selection and use by cranes

We estimated frequency of habitat use by the number of cranes recorded per habitat class over the total, grouping cranes according to reproductive status (Bishop, 1992). Reproductive statuses were: non-breeders, breeders that laid eggs but failed to produce chicks, and breeders that successfully incubated eggs and raised chicks.

We evaluated the data on frequency of habitat by means of a three-dimensional G test (Sokal and Rohlf, 1981) for the three reproductive statuses, two seasons (dry and wet), and four classes of habitats: the three most heavily used habitats (SNA, SP, and SSC), each with ≥ 10% of records for all statuses ands easons, and the other seven lumped together.

To evaluate habitat selection, we applied the general methodology of Neu (Alldridge and Ratti, 1992; Manly *et al.*, 1993) as used by Bennet (1988) for the Florida Sandhill Crane and by Almeida and Pinto (1995) for *Grus grus* in Portugal. This approach corresponds to Designs I and II in Manley *et al.* (1993).

2.3.5. Using GIS to determine home range, nesting sites, and sleeping sites of cranes

We designed these analyses using the program Arc View 3.2, on three computers equipped with Pentium IV. For interpreting the vegetation and calculating total area and home ranges, we used the most recent aerial photos available for the Isle of Youth (August 1997). To ground-truth vegetation classifications and refine the vegetation map, we used 1:10 000 scale maps from the Geodesic and Cartography Institute and four Magellan GPS units. Across the landscape we assigned each vegetation patch to one of the eleven physiognomic categories established previously, taking the Crane's point of view. To estimate home range size based on point records, we followed the Kernel method (Samuel and Fuller, 1994; Chávez-Ramírez, 2001). Based on the GIS results (types of habitats, number of patches of each type, area and perimeter of each) we calculated the following indices for the watershed as a whole and for the home range of each radioinstrumented crane (see Mladenoff 1997): richness, diversity, and equitability of habitat types.

2.3.6. Evaluating the vegetation of feeding areas

During the 300 days that radiotransmitter batteries lasted, we located each of the ten cranes twice weekly and recorded its Lambert North and East coordinates. We returned to the exact coordinates of each point where it was certain that the Crane had spent at least five minutes feeding, and delimited the vegetation parcel. We determined the standard parcel size as minimum sampling area according to Lacoste and Salanon (1978). This gave 64 m^2 for the savanna vegetation in general and 50 m^2 for open patches. We repeated the procedure for randomly chosen points.

In each parcel, we followed the method of Morrison *et al.* (1998) to determine vegetation physiognomy and structure. For each parcel we also recorded general data such as parcel number, date, coordinates, orientation, and vegetation variables. The last were compared between points with and without cranes, taking habitat class into account, by means of a bifactorial ANOVA (Zar, 1999).

2.3.7. Reproductive ecology

For studies on the reproductive ecology of Cuban sandhill cranes, we followed the methods of Thompson (1970), Layne (1981, 1982), Bennett (1988), Dwyer and Tanner (1992), Depkin *et al.* (1994), and Valentine and Hereford (1997). Between 1997 and 2002 we encountered 73 nests and monitored 44 of these through hatching, recording a total of 76 eggs. For each of the six years of the study we calculated seven reproductive indices: eggs per nest, chicks per egg, chicks per nest, chicks per successful nest, nests with eggs (%), eggs hatched (%), and successful nests (%). We compared these indices among years, running Spearman rank correlations between each index and (a) total rainfall during the three months prior to reproduction (January to March) and (b) total rainfall during the breeding season (April to July).

In 2002 we examined the vegetation surrounding nests. Using the nest's coordinates as the center of the parcel, we demarcated radii 5 m long towards the four cardinal points, using a Sunto 200 compass. These radii defined four quadrants that we evaluated in clockwise fashion, recording 19 structural variables and the species of trees, palms, shrubs, and herbs. We compared these data from those obtained from identically treated parcels centered on random points at 30 m from the nest.

3. Results and Discussion

3.1. Distribution, abundance, and conservation concerns

Eight of the Crane populations we recorded in the Cuban Archipelago (Table 1, Fig. 1) occur in areas protected by the Empresa Nacional para la Protección de la Flora y la Fauna: Birama, Cayo Romano, North of Morón, Las Guayaberas Swamp, Zapata Swamp, Los Indios, Majaguillar, Júcaro, and Sabana Grande. Two more occur in areas managed by the Empresa Integral Forestal Ciénaga de Zapata. Both institutions are in the Agriculture Ministry. The populations at Guane (Pinar del Río) and Lesca (Camagüey) are administered by the Forest Ranger Corps.

We estimated population stability by interviewing local residents, through results of five years of monitoring data, or by population counts described below. Of those populations for which we have adequate data, 42% appear to be stable and 25% increasing. We lack good data for two populations, and the final population's existence has not been confirmed (Table 1). Some 53% of the populations reside in protected areas. All current Crane populations have existed in those localities for at least 30 years, except the Birama population, which may have split off from another or may simply have moved in wholesale from another site.

We found that hunting was likely to molest the Pinar del Río and Isle of Youth populations than the populations in central and eastern Cuba. The two most serious threats to the survival of Crane populations, however, were the conversion of their preferred nesting habitats (natural savannas) to sugarcane or rice cultivation, and alterations in the natural hydrological regimes of cranes' habitats, caused by the damming of rivers.

Table 1. Status of the Cuban Sandhill Crane in 2002

Province	Geographic region	Populations	Administered by	Population status
Pinar de Río	Guane	1	ENPFF / CGB	Stable
	Consolación del Sur	†	---------	Extirpated
Matanzas Zapata Swamp	Majaguillar Swamp	1	ENPFF	Unknown
	Santo Tomás	1	EFI / (AP)	Increasing
	San Lázaro	1	EFI / (AP)	Increasing
Sancti Spíritus	Las Guayaberas Swamp	1	ENPFF (AP)	Stable
Ciego de Ávila	North of Morón	1	ENPFF (AP)	Stable
	Júcaro	1	ENPFF	Stable
Camagüey	Sabana de Lesca	1	CGB	Stable
	Cayo Romano	1	ENPFF (AP)	Unknown
Granma	Birama Swamp	1	ENPFF (AP)	Not confirmed
Isle of Youth	Los Indios	1	ENPFF (AP)	Increasing
	Sabana Grande	1	ENPFF	Increasing

ENPFF = Emp. Nac. Protección de la Flora y la Fauna
EFI = Empresa Forestal Integral
CGB = Forest Ranger Corps
AP = Protected Area

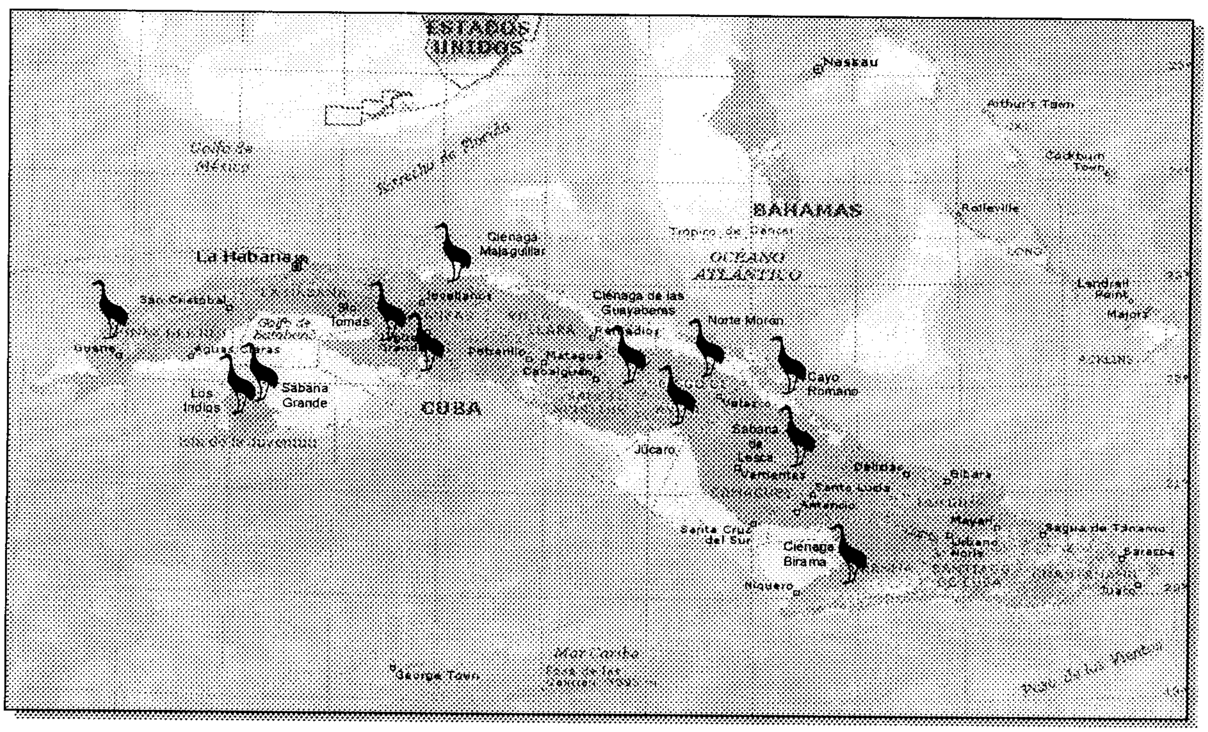


Figure 1. Locations of populations of the Cuban Sandhill Crane *(Grus canadensis nesiotes).*

3.2. Population censuses

Table 2 summarizes the results of the four two-day-long censuses in four regions inhabited by cranes. Figure 2 presents the dendrogram resulting from the similarity matrix among the data from each locality. According to these analyses, the Isle of Youth population is the most numerous, followed by the Zapata Swamp and Morón, with Las Guayaberas Swamp supporting fewer cranes. The dendrogram, based on similarity across all indices calculated, shows that by these synthetic criteria the Isle of Youth and Zapata populations are very different from those of Morón and Las Guayaberas, which by these criteria are quite similar to one another. This may be due to habitat similarities between the last two sites, in the same set of savannas of "mocarreros" on the north coast. Furthermore, the Morón and Las Guayaberas populations are spatially concentrated due to extensive agricultural activity (mostly sugarcane), which has spared only small wetland patches throughout the zone. In contrast, the savannas of the Zapata Swamp and Los Indios (Isle of Youth) have different origins, in the first case being sedimentation savannas and in the second silica sand savannas. Combining these results, it appears that the type of savanna may influence the distribution and abundance of the cranes

Table 2. Results of the massive censuses of Cuban sandhill cranes in four localities

	Localities			
	Isle of Youth	Zapata	Guayaberas	Morón
Date	11/98	02/99	02/98	02/97
No. of stations	52	26	16	40
Stations with cranes, %	61.5	73.0	50.0	42.5
Cranes/station, range	5.3	6.3	9.1	6.7
	(1-22)	(1-21)	(4-16)	(1-20)
Total count	171	120	71	102
Distribution of counts 1-5 (%)	68.7	57.1	37.5	57.1
Repeatibility +/+	20.8	34.6	31.2	15.8
Repeatibility 0/0	37.5	26.9	50.0	60.0
Total	58.3	61.5	81.2	75.8
Numerical concordance	53.1	64.4	80.0	69.2

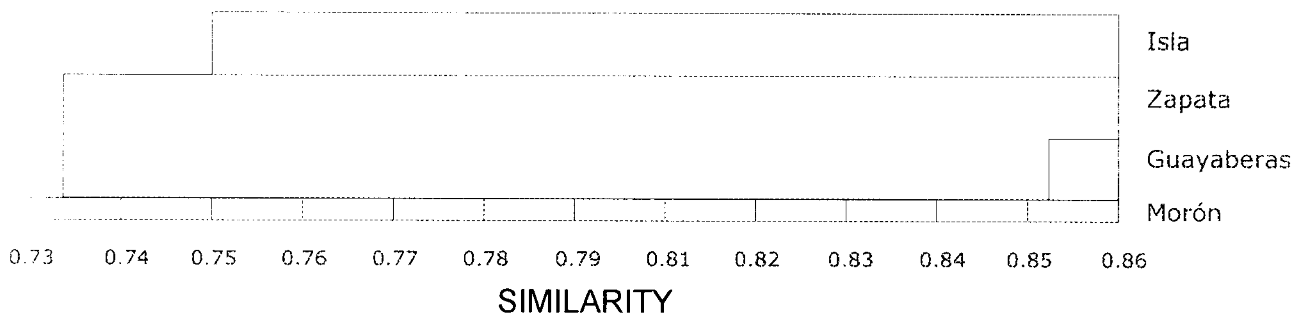


Figure 2. Dendogram relating four populations of the Cuban Sandhill Crane with respect to various population indices.

In total, these four populations include an estimated 460 individuals. If we add minimum estimates of some 30 cranes for three other well known populations (Pinar del Río, North of Ciego de Ávila, and Camagüey), then at a bare minimum the Cuban Sandhill Crane has a population of 550. This estimated population size greatly exceeds that recorded for the Mississippi subspecies (*G. canadensis pulla*), with 102 individuals (Hereford *et al.*, 2001) but would be far lower than the numbers of Florida sandhill cranes (*G. c. pratensis*), with 4000 (Nesbitt, 1994). Thus, the Cuban population is probably intermediate in abundance among the sedentary subspecies of *G. canadensis*.

3.3. Reproductive ecology

3.3.1. Temporal changes in reproductive variables

Raw values for reproductive data were converted into reproductive indices, as shown in Figures 3 and 4. In general, all indices increased from 1997 through 1999, then a decrease in 2000 and 2001, followed by a slight recovery in 2002.

Statistical analyses showed that the changes among years in percentage of nests with two eggs, and in percentage of successful nests, were not statistically significant ($G = 3.89$, $P > 0.05$ and $G = 9.59$, $P > 0.05$, respectively), in contrast to changes in percentage of hatching ($G = 19.05$, $P < 0.01$). These patterns could possibly be due to combinations of factors, for example rainfall before (January to March) and during (April to July) the breeding season of Florida Sandhill Crane. Nevertheless, Spearman r_s (rank coefficient of correlation) for correlations between either rainfall variable and each reproductive index reached values of possible biological significance (set at > 0.40) only for two cases (Figs. 3, 4): chicks per successful nest versus rainfall before the breeding season ($r_s = 0.60$), and percent of successful nests versus rainfall during the breeding season ($r_s = -0.59$).

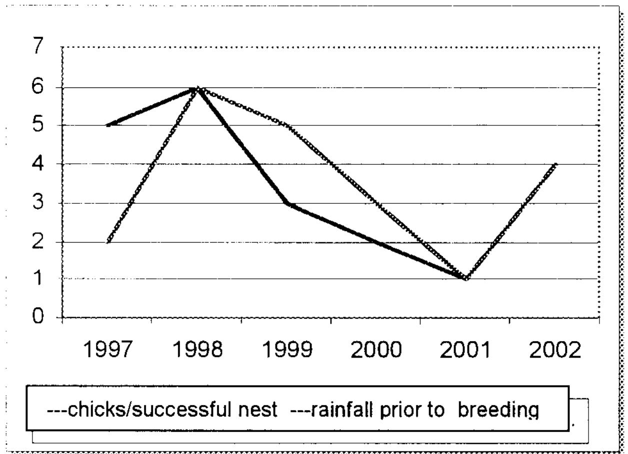


Figure 3. Correlation between nestings per successful nest and total rainfall January-March in Los Indios Reserve, Isle of Youth.

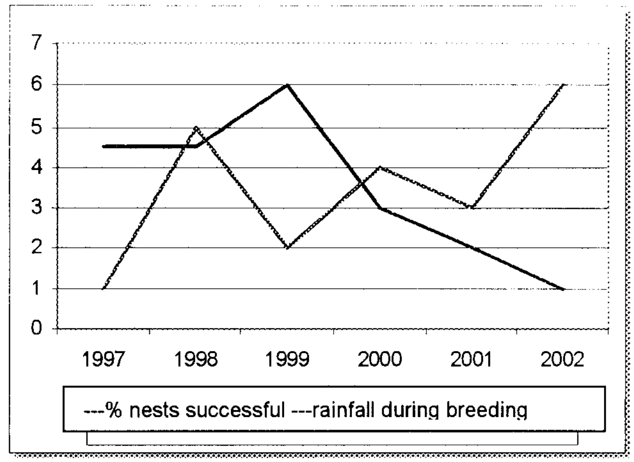


Figure 4. Correlation between the percentage of nests that were successful and rainfall during the reproductive season, in Los Indios Reserve, Isle of Youth.

That is, the number of chicks per successful nest basically paralleled total rainfall prior to breeding season (Fig. 3), while the percent of successful nests tended to fall in breeding seasons with higher rainfall (Fig. 4). Analysis of monthly rainfall indicated that heavy June rainfalls coincided with the greatest loss of nests and chicks. These results resemble those of Layne (1983), Bennet and Bennet (1990a), and Dwyer (1990), who proposed that rains during the "dry" season preceding reproduction led to increased food availability for cranes just as energy needed to be expended for reproduction -thus enhancing reproductive output- whereas torrential rains during breeding season could lead to nest flooding and loss of chicks to pneumonia. Nesbitt (1988) added nest abandonment, which we also recorded, to the latter list.

Not only January-March rainfall, as presented in Fig. 3, but also October-November rainfall appeared to enhance reproductive success in the next breeding season. Heavy October-November rains kept intermittent streams flowing through the breeding season, lowering exposure of chicks to predation in open areas.

Table 3 presents overall values (over the six years of the study) of reproductive indices.

Table 3. Mean (X) and standard deviation (s), or average frequency, of reproductive indices over six years (1997-2002), for the Cuban Sandhill Crane in Los Indios Ecological Reserve, Isle of Youth.

Variables on interval scale	X	s
Eggs per nest	1.72	0.12
Chicks per egg	0.51	0.20
Chicks per nest	0.84	0.44
Chicks per successful nest	1.52	0.36
Variables on nominal scale	**%**	
Nests with eggs	71.1	
Nests with eclosing eggs	84.1	
Successful nests	54.5	

3.3.2. Structure and taxonomic composition of vegetation at nesting sites.

In comparisons between vegetation surrounding the nest and vegetation at randomly selected points at 30 m distance (Table 4), the Mann-Whitney U tests revealed statistically significant differences in only four characteristics: diameter breast height (DBH) of trees within the parcel; percent of soil covered by leaf litter (HOJ); visual obstruction to the south (OS); and number of shrubs in the plot (NAFB). All presented higher values near the nest than away from the nest (Table 4). The role of DBH, HOJ and NAFB can be explained by a tendency among cranes to seek sites with greater cover in terms of shrub density and tree canopy (positively related to DBH), both of which would result in greater leaf production (HOJ). The variable OS is probably related to the southern orientation of the watershed, leading to denser and taller vegetation to the south. A logistic regression applied to all variables ($X^2 = 38.5$, $P < 0.05$) implied that an overall significant difference existed between the vegetation near to and away from nests. The discriminant variables that contributed most to this result were NAFB, OS, and DBH, in that order.

Table 4. Means (X) and standard deviations (s) of 19 structural variables of the vegetation, and two distance variables, for Sandhill Crane nests and paired random points, in Los Indios Ecological Reserve.

Variables	Codes	At nests		At random paired points	
		X	S	X	S
Number of trees	NAR	2.95	2.94	2.30	2.6
Coefficient of variation, distance/tree (%)	CVD	20.39	22	18.94	23.43
Diameter (cm) breast height (1.4 m)	DBH*	0.16	2	0.11	0.14
Number of tree species	NSA	1.19	0.83	0.98	0.91
Number of palms	NP	1.85	3.3	2.30	3.36
Coverage of sand (%)	ARL	32.31	21.65	31.19	23.81
Coverage of leaf litter (%)	HOJ*	14.66	18.41	12.33	22.46
Coverage of seedlings (%)	PLA	8.01	11.3	10.88	14.64
Coverage of herbs (%)	HIE	42.86	27.82	45.24	29.91
Visual obstruction, north (%)	ON	49.04	30.5	49.05	33.84
Visual obstruction, south (%)	OS*	56.19	33.05	46.43	31.68
Visual obstruction, east (%)	OE	46.9	31.55	46.67	33.17
Visual obstruction, west (%)	OW	53.57	38.43	51.90	33.65
Number of herbaceous species	NSH	2.9	1.35	2.97	1.33
Height of herbs 0-25 cm	ALT25	1.18	1.11	1.51	1.57
Height of herbs 25-50 cm	ALT50	1.82	2.63	1.96	2.69
Number of shrub species	NSAR	0.95	0.88	1.02	0.96
Number of shrubs	NARB*	48.39	92.71	25.55	71.94
Shrub height (m)	ALT	0.47	0.6	0.45	0.83
Distance to water (m)	DAG	101.16	110.03	100.38	108.02
Distance to the galery forest (m)	DVE	73.4	65.41	79.21	67.93

Variables with asterisk differed between the two groups, U tests, P< 0.05

With respect to species composition of the vegetation, one species in particular differed in frequency of occurrence between nest plots and paired random plots: nest plots had much higher occurrences of *Tabebuia lepidophylla*, both in the shrub stratum and as a tree, than random plots (G = 194.7, P < .001).

Likewise, Bennet (1998) found that plant density was an important component of nest site selection by sandhill cranes in Minnesota, but proposed that cranes avoided vegetation whose density or height impeded their movements. Both Walkinshaw (1949, 1973) and Bennet (1988) proposed that species composition of wetland vegetation had minor effects, compared to vegetation structure, on nest site selection. These proposals coincide with our results.

The proportion of total eggs lost (n = 65 eggs) fluctuated between 14.3% (1999) and 84.6% (2001). The major factors responsible were infertility (19.6% of total), abandonment (19.4%), and predation by the caracara (*Caracara plancus*). Chick losses during the first 15 days post-hatching were related to heavy June rains in years when nesting had been delayed by drought prior to the breeding season. Rains kept intermittent watercourses flowing rapidly instead of shrinking into standing ponds, so that to reach permanent lakes in order to drink the chicks had to cross open zones where they were exposed to predation by crocodiles (*Crocodylus acutus* and *Caiman sclerop*) and the red-tailed hawk (*Buteo jamaicensis*).

On average, exterior diameter of nests was 66.8 cm and interior diameter 60.4 cm, with the rim reaching 3.6 cm height. Rim height varied significantly among years. Average distances between nests active at the same time varied between 2.86 and 4.86 km. Egg shell thickness was lowest in 1998 (0.33 mm) compared with 0.42 mm in 1997 and 0.40 mm in 1990. These differences were statistically significant.

3.4. Habitat use and selection

3.4.1. Habitat use

Independent of season or Crane reproductive status, in general the open habitats SNA, SSC, and SP were used in considerably greater proportion than other habitats. Other habitats used extensively under certain conditions were SPPA April-July and SOT August-October, by non-breeders, and SS April-July by incubating breeders only. The first case resulted from two highly mobile juvenile cranes, 114 and 073, who concentrated on the SPPA and SOT habitats respectively. The second case resulted from a general tendency, among those cranes that incubated but did not raise young, to use SS along with SNA, SSC, and SP in high proportions. With these exceptions, other habitats were used at frequencies lower than 6%.

With respect to seasonal patterns (Fig. 5), in general cranes used grassland habitats (SP) more and the various savanna habitats less as the breeding season (April-July) yielded to the non-breeding season (August-October, November-January). This shift may have resulted from the need to obtain food more efficiently, possible in grassland and pasture, and from water availability. Savanna habitats provided protection for nests and chicks during the breeding season.

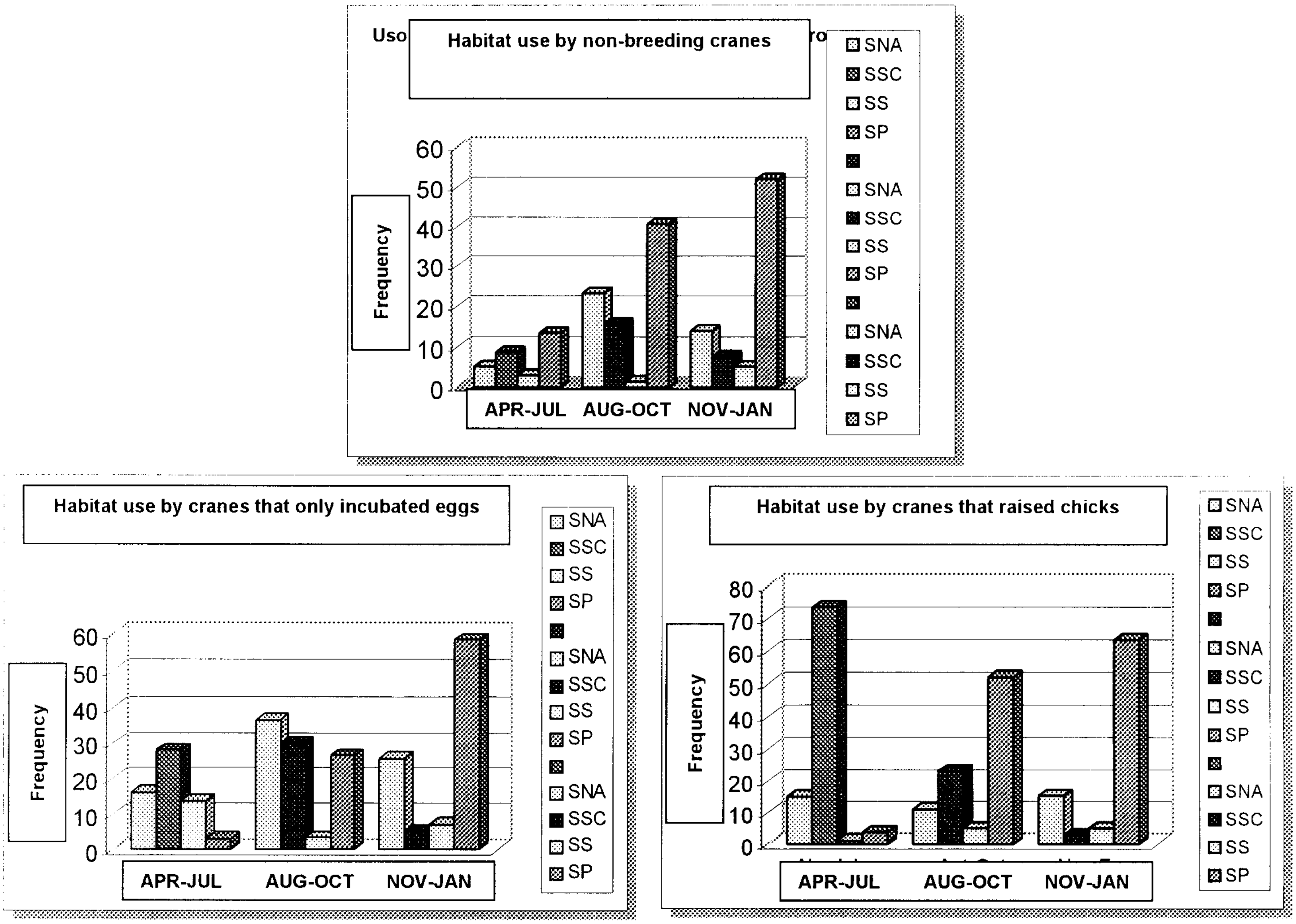


Figure 5. Habitat use (%) according to season and crane reproductive statns, in Los Indios Ecological Reserve.

As Fig. 5 indicates, cranes of each reproductive status used different proportions of the different savanna habitats during April-July. Non-breeders used SNA frequently, incubators used SSC and SS in frequencies that combined greatly exceeded their use of SP, and breeders with chicks used SSC at the greatest frequency of any recorded (73.6%). Clearly, the SSC habitat is vital to breeding cranes whether or not they have produced chicks.

Results of G tests revealed a highly significant relationship between reproductive status and habitat use ($G = 149.15$, $P < 0.001$), but this relationship was conditioned on season ($G = 151.12$, $P < 0.01$). In short, statistically speaking Crane's habitat use is related to both factors, reproductive status and season, which in turn have a strong statistical interaction effect with one another.

During the non-breeding season (August-October and November-March), all cranes, regardless of their past breeding status, used SP, especially in November-January when use varied between 50% and 60%. In second place were SNA, SSC, and SS. Those cranes that had not brought eggs to hatching the previous season used SP particularly often (63.4%), the highest single value of any for this season.

With respect to habitat selectivity *per se*, habitats we had designated as most important during the non-breeding season (SNA, SP, and SS) had selectivity indices significantly greater than 1; that is, they were selected in greater proportion than expected by their abundance. Only LG was selected in proportion to its abundance, and other habitats were selected less than expected by their abundance. This pattern changed somewhat in the breeding season. Although cranes continued to strongly select SNA and SS, SP was selected only in proportion to its abundance while SSC was selected out of proportion to its abundance. Other habitats, except SNC, were underselected. Overall, results suggest that cranes not only use SNA, SP, SS, and SSC habitats more than others but also that they select these habitats out of proportion to their abundance in the environment.

These findings generally resemble those for cranes in general (Cruz, 1996) and for North American populations of *Grus canadensis* (McIvor and Conover, 1994), especially the Florida subspecies, for which Littlefield (1981) recorded marked seasonal changes in habitat use.

3.4.2. Use and selection of microhabitats and sleeping sites

Some vegetation variables of the microhabitats in which cranes foraged differed significantly from those at randomly selected points, and in some cases the nature of these differences changed between the more general classes of habitat. Variables that differed between feeding sites and random sites were: number of trees, sand coverage, leaf litter coverage, mean abundance of grasses at 0 - 25 and 25 - 50 cm height, and visual obstruction in all four directions. Cranes slept in only three of the eleven habitat classes: CAY, SS, and SNA.

3.5. Home range and nesting sites as determined with GIS.

Figure 6 presents the vegetation map, based on the 11 habitat classes we defined, of the study area: the watershed of the Itabo, La Majagua, and Los Indios rivers on the Isle of Youth. The 33 500 ha study area includes the 12 946.48 ha of the protected area, Los Indios Ecological Reserve (henceforth labeled PA). All analyses refer to this map as the base. Figure 7 presents georeferenced, visual records of feeding for the ten radioinstrumented cranes throughout the study. About 50% of these points are outside the limits of the PA. Subadult cranes 114 and 073 spent relatively little time in the PA, and indeed their home ranges extended beyond the limits of the watershed making up the study area. Most likely this wandering decreases their chances for survival. Indeed, Figure 7 presents graphic evidence for the need to increase Crane protection throughout the ecoregion, not just in the PA. As Meffe and Carroll (2000) and Berovides (2001) state, by failing to extend to natural boundaries (such as watershed boundaries), many protected areas fail to conserve large-bodied animal species.

Table 5 presents home range sizes for 9 of the 10 radioinstrumented cranes within the watershed studied, provided by the Kernel method using 95% probability. For clarity, in the following text Table 5's values in hectares are converted to values in km^2. These values vary greatly, from 1.13 km^2 (Crane 063) to 16.08 km^2 (Crane 073). The home range of subadult Crane 073 was four times the norm for adults, as Nesbitt (1994) found for Florida sandhill cranes.

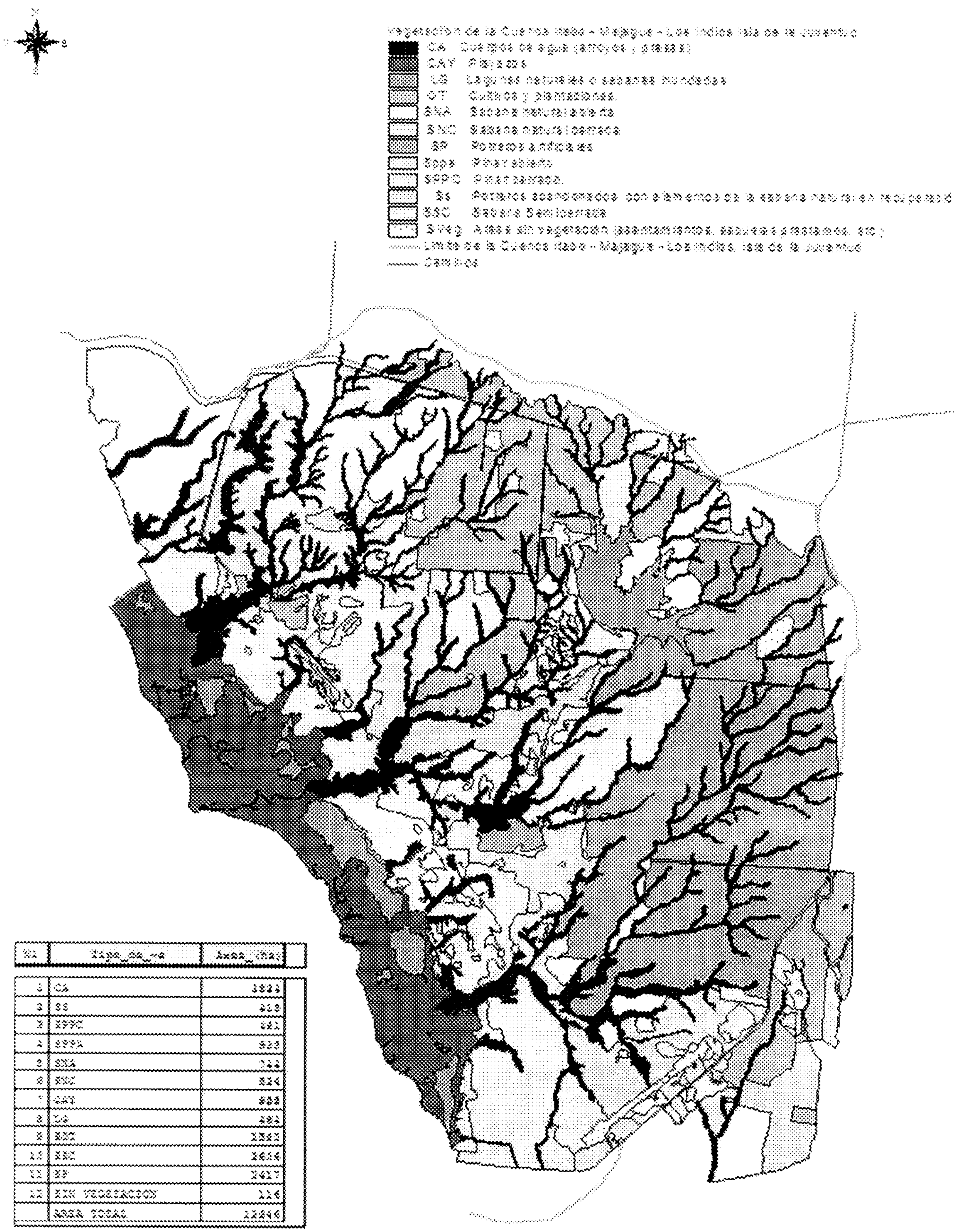


Figure. 6. Vegetation map according to the habitat classification used in the study of the Cuban Sandhill Crane in the Itabo - Majagua - Los Indios watershed on the Isle of Youth, Cuba.

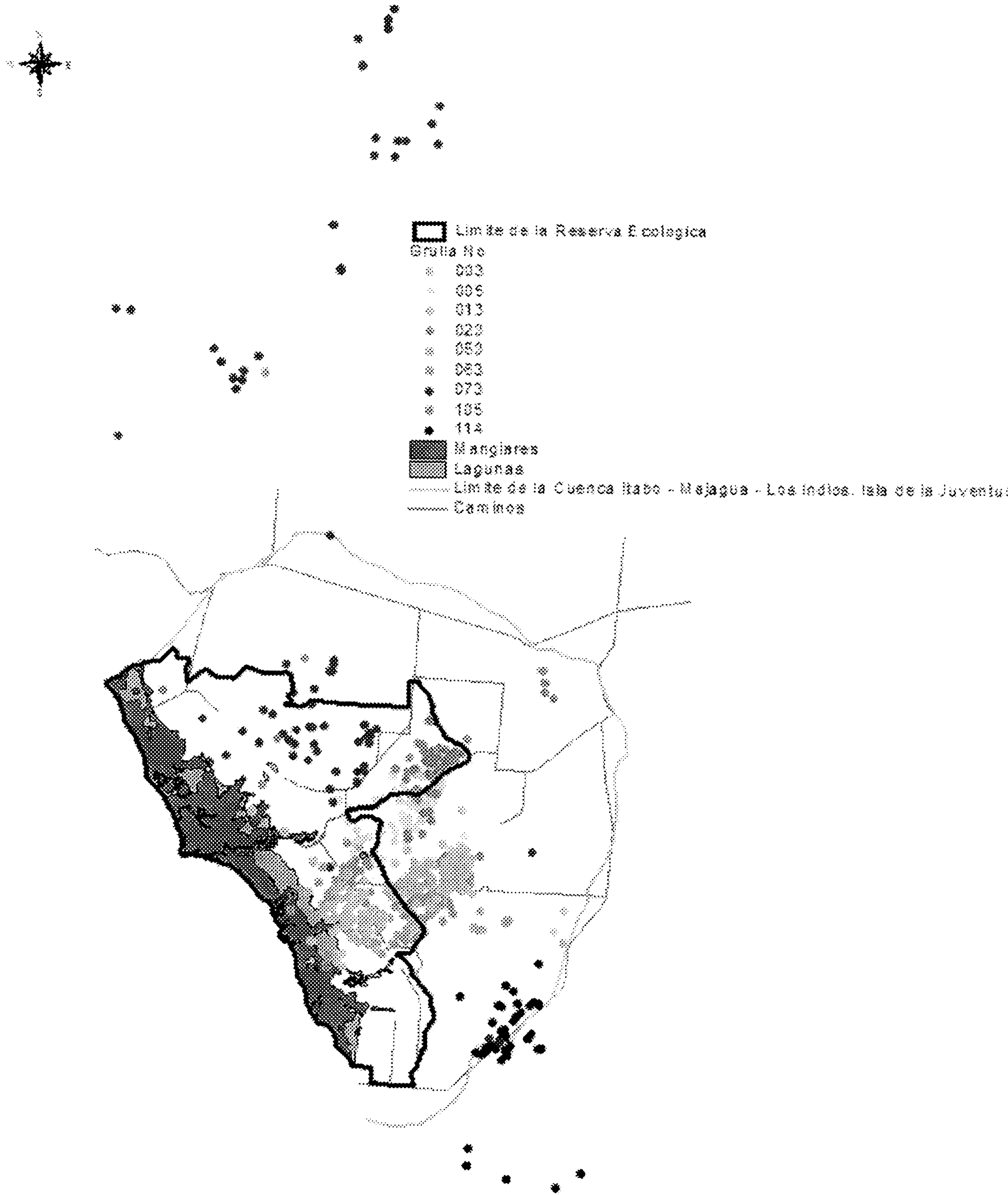


Fig. 7. Georeferenced sites where ten radiocollared cranes were observed to feed, relative to the study area, the Itabo - Majagua - Los Indios watershed on the Isle of Youth, Cuba.

Tabla 5. Home range size (ha) for nine radioinstrumented Cuban sandhill cranes in Los Indios Ecological Reserve, Isle of Youth

Age/Reproductive Status	Crane	Home range size (ha)
Subadult	073	1608.29
	114	119.38
Non-breeding	003	259.26
Breeding, incubating only	105	410.19
	063	113.58
	053	489.23
	013	319.31
Breeding, raising chicks	005	208.43
	023	247.53
Mean (± standard error), (only the 6 breeding adults)		298.04 ± 137.25 (CV = 46.05 %)

Considering only breeding adults, the relative variation in home range size is reduced to 46.1% around a mean size of 2.98 km^2. This mean figure and the range of values for breeding adults, 1.1 - 4.8 km^2, resemble figures estimated by Nesbitt (1994) of between 2.1 and 9.4 km^2 for the Florida Sandhill Crane and those of Duan *et al.* (1997) of 2 to 4 km^2 for the subspecies *Grus c. tabida*.

Proportions of the various habitat classes included within each home range were averaged and compared with the proportions of habitats across the watershed as a whole (Table 6), as a measure of the degree of habitat selectivity at the scale of the home range. The selectivity index calculated from these values indicated that only SS, SNC, and SP were represented in home ranges out of proportion to their occurrence in the watershed. The mean proportion occupied by other habitats in home ranges resembled proportions in the watershed as a whole, excepted for cultivated zones (OT), underrepresented in home ranges. This result was the same considering all radioinstrumented cranes or only that subset of breeding adults.

Taking into account the patches of different habitat classes, the indices explained in Methods and Materials were calculated for each home range. The values obtained were compared to values calculated for the PA as a whole and that part of the study area outside the PA as a whole.

Results show an interesting pattern (Table 7). Mean values of the habitat diversity indices for Crane home ranges better resemble indices for the region outside the PA than those for the PA itself, in particular with respect to the mean number of habitat patches and the diversity and equitability of patch types.

Table 6. Percentage of total area occupied by each class of habitat within the entire Itabo – La Majagua – Los Indios watershed and within the home ranges of 9 radiocollared cranes, on the Isle of Youth

Habitat class	Percentage of watershed (D)	Average percentage per home range (U)	S = U/D
SSC	18.9	21.1	1.1
SP	16.5	22.8	1.4 +
CA	16.3	14.6	0.9
OT	10.7	4.4	0.4 -
SNA	8.9	6.1	0.7
CAY	7.7	5.8	0.7
SPPA	6.8	4.0	0.6
SNC	4.6	7.4	1.6 +
SS	3.7	8.6	2.3 +
LG	3.4	3.2	0.9
SPPC	2.4	1.8	0.7

S = selectivity index

+/- = Overrepresented or underrepresented in home ranges with respect to watershed as a whole

Table 7. "Patchiness" variables and habitat diversity indices for habitat patches within and outside of the Los Indios Ecological Reserve, Isle of Youth, and for Crane home ranges

Variables	Region		Crane´s Home Range
	Inside	Outside	
Number of different habitat types	10	10	10
Total number of habitat patches	252	219	189
Average number of patches per habitat type	25.2	21.9	18.4
(Coefficient of variation, %)	(71.4)	(66.2)	(79.4)
Patch (habitat) diversity (H') (all vegetation)	1.41	1.82	1.95
Equitability of patch (E) (all vegetation)	0.67	0.87	0.85
Diversity of patches (H') (vegetation suitable for nesting)	0.65	1.32	------
Equitability of patches (E) (vegetation suitable for nesting))	0.47	0.95	------

Figure 8 displays the area having the greatest concentration of radiolocations and visual records of feeding. This concentration may result from various causes, such as insect and snail abundance, proximity to nesting sites, sources of fresh water, and history of fires (which promote the growth of low herbaceous vegetation).

Within the PA, some 87% of nests were detected over seven years (Fig. 9). A notable relationship exists between nest sites and the network of streams associated with the three rivers that define the watershed. Of 11 habitat classes present in the watershed, cranes only nested in SNA, SPPA, SS, and SSC, at similar levels of selectivity (Fig. 9). It appears that selection of nesting habitats depends not only on habitat availability but also on the proximity of water sources.

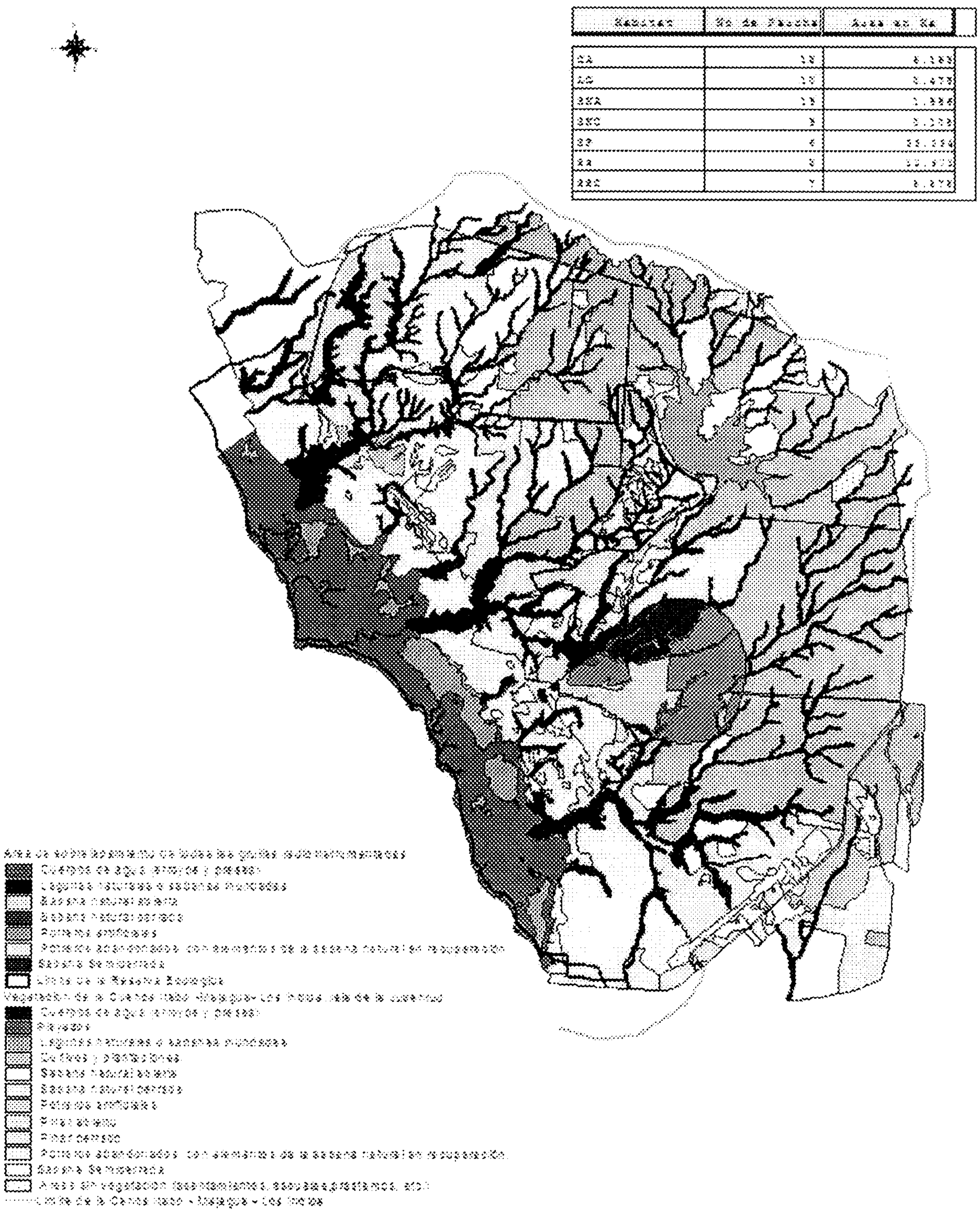


Fig. 8. Area of overlap of home ranges of the 10 radiocollared cranes, and its relation to habitat type and the stream network of the Itabo - Majagua - Los Indios watershed.

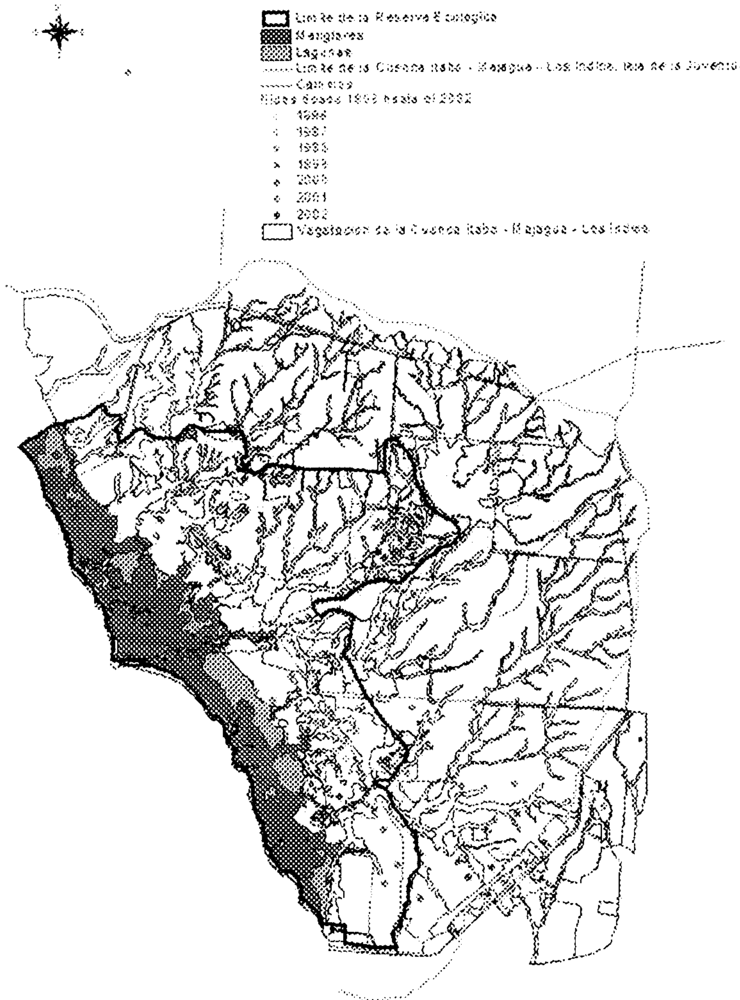


Fig. 9. Geographical coordinates of the nests of the Cuban Sandhill Crane and their spatial relationship with the Itabo – Majagua – Los Indios watershed, Isle of Youth.

3.6. Implications of this study for the management of the Cuban Sandhill Crane *(Grus canadensis nesiotes)*.

Following the results of this study, we propose immediate action to expand the current limits of the PA by some 670 ha (Fig. 10) so as to include additional patches of habitat types SSC, SNA, SS, and SPPA. These are the four habitat classes selected by nesting cranes within the macrohabitat of natural savannas. Once these additional patches are protected, they should be intensively managed as follows: provision of artificial ponds of standing water; manual clearing of perimeters of savannas that have become closed; restrictions on transit; management of cattle during the cranes' breeding season; controlled burning; modification of livestock fences to permit cranes to pass through; and control of systematic disturbances.

High intensity fires, such as those that occurred in the watershed in 1994, 1995, and 1996, destroyed so much accumulated fuel that subsequent fires in the same zones have been only of moderate or light intensity, at intervals of one or two years. Low or moderate intensity fires do not wreak havoc either on cranes or on ecosystem dynamics. On the contrary, they favor the growth of fire-resistant plants such as *Tabebuia* and *Hypericum* species that define the SSC habitat where cranes nest and breed offspring. Indeed, nests and feeding sites tend to occur in areas that recently experienced small fires (Fig. 11).

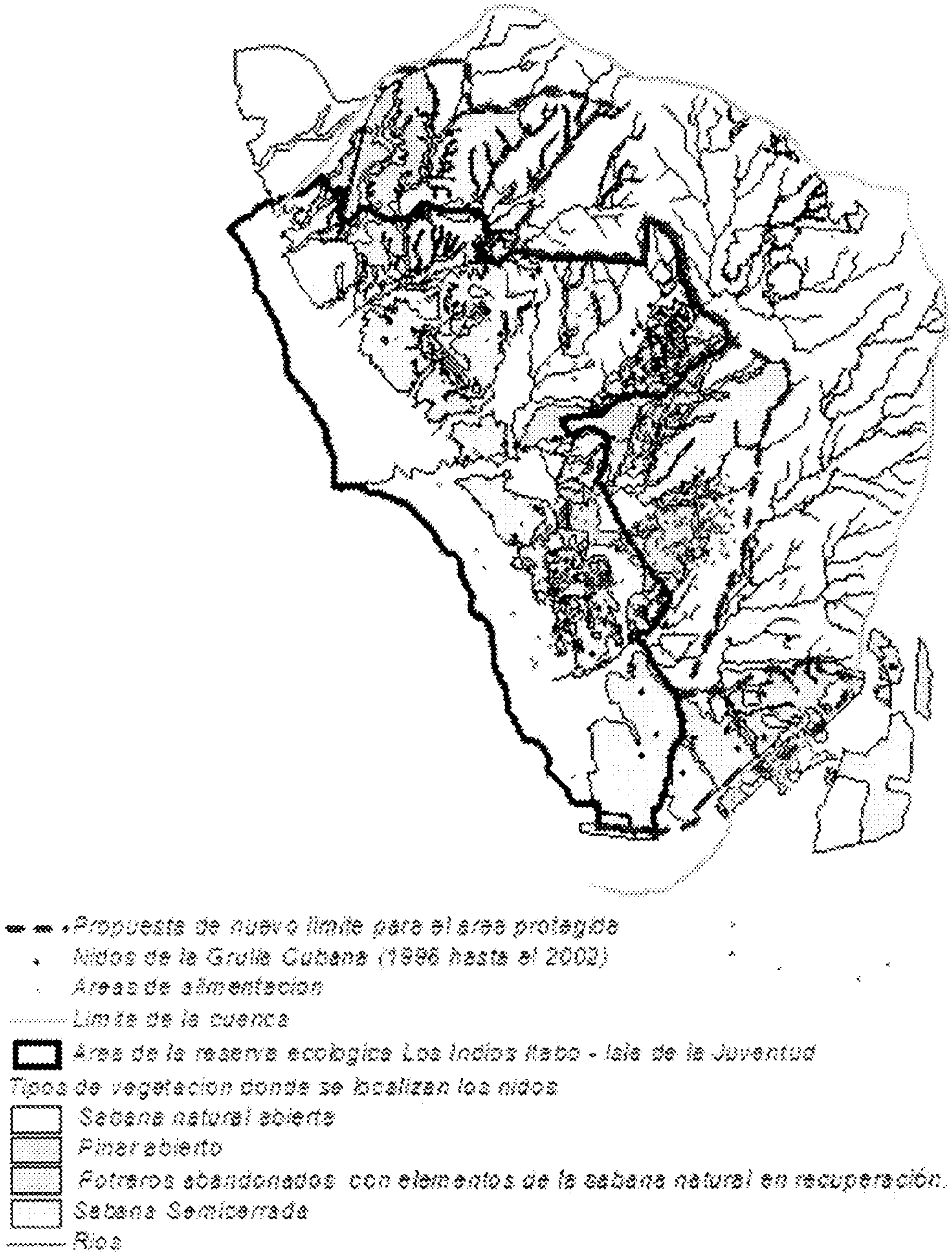


Fig. 10. Proposal of expanded limits for Los Indios Ecological Reserve, within the Itabo – Majagua – Los Indios watershed, Isle of Youth.

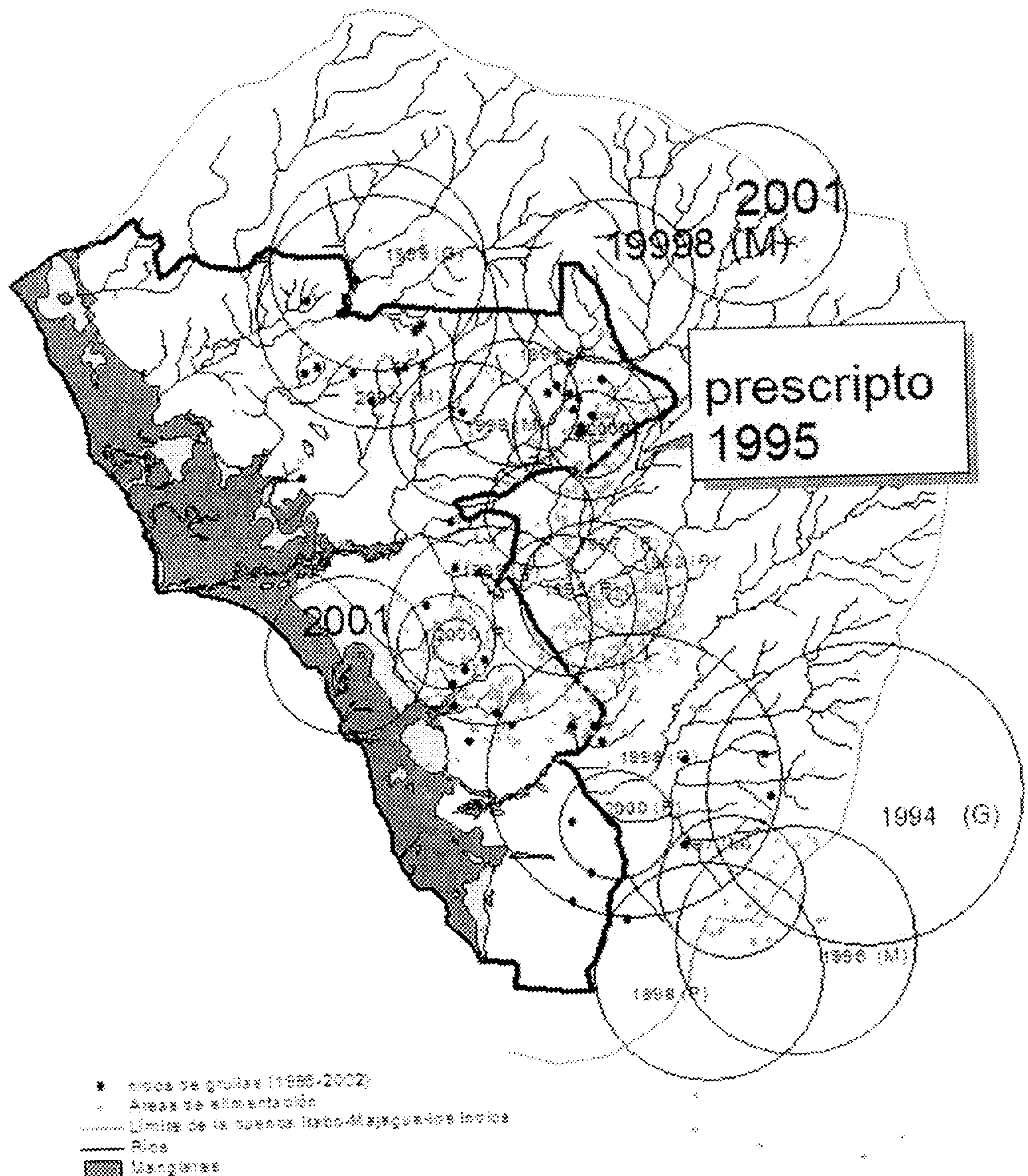


Fig.11. Relationship of nesting and feeding sites of Cuban sandhill cranes with areas experiencing fires during the past 8 years, in the Itabo – Majagua – Los Indios watershed, Isle of Youth

Conclusions:

1. We detected 13 geographic areas having one to two crane populations One population (Consolación del Sur) has been extirpated. According to simultaneous counts in which local communities participated, usually in February, the population on the Isle of Youth was the most numerous (171 cranes), followed by the Zapata Swamp (120), Morón North (102), and Las Guayaberas Swamp (71).
2. The estimated total numbers for the Cuban Sandhill Crane, for the four populations censused, is around 460 individuals. When less precise estimates for other populations are included, the absolute minimum count for the subspecies would be 550 cranes.
3. Two fundamental factors threaten the survival of Crane populations: reduction in breeding habitat (natural savannas), resulting from increases in land under sugarcane and rice cultivation, and damming of rivers, which alters natural hydrological regimes and therefore the wetlands where cranes live.
4. In Los Indios Ecological Reserve on the Isle of Youth, reproductive indices (% of eggs hatching, % of nests successful, chicks per egg, and chicks per nest) increased in 1998 and 1999 and decreased in 2000 and 2001, probably due to rainfall before (positive effect) and after (negative effect) the breeding period.
5. Reproductive variables monitored for cranes at Los Indios averaged as follows: mean clutch size 1.72; chicks per pair per year, between 1.0 and 1.4; mean outside diameter of nests 66.8 cm; mean inside diameter 60.4 cm; height of nest rim, between 2.2 and 4.8 cm, varying among years; average distance between simultaneously active nests, between 1.5 and 4.2 km depending on the year; egg shell thickness from 0.34 to 0.42 mm, depending on the year.
6. Nesting sites that cranes selected differed significantly from points chosen at random, with respect to vegetation structure and to species richness of trees, shrubs, and palms (lower at nesting sites than at random points).
7. All classes of habitats in the study area except for pine woodlands were used by cranes. The proportions in which each was used, though, varied with the reproductive status of the Crane (non-breeding, incubation only, incubation and care of chicks) and with season (breeding and non-breeding).
8. During breeding season (April-June), cranes with different reproductive status tended to prefer different habitats for feeding. Non-breeders used open natural savanna. Breeders used semi-closed savanna with great frequency. During the non-breeding season

(August-January), all cranes, regardless of previous reproductive status, used fields most commonly.

9. At the macrohabitat level, cranes selected open savannas, fields, secondary savannas, and semi-closed savannas out of proportion to the abundance of these habitats in the region. The exact pattern depended on reproductive status and season (breeding, non-breeding). At the microhabitat level, sites chosen for feeding were different from randomly chosen points in six variables of vegetation structure.
10. Cranes fed outside Los Indios Ecological Reserve just as much as inside it. In contrast, 90% of nesting sites were with in the reserve, associated with permanent streams and with patches of habitat classes SSC, SNA, SS, and SPPA, the habitats selected for nesting. This finding suggests an urgent need to expand the limits of the protected area.
11. Home range size varied widely among cranes, with one subadult having a range of over 16 km^2. Home range size for adults varied between 1.1 and 4.8 km^2.
12. All home ranges overlapped in the central zone of the watershed studied. This zone combined features such as year-round availability of water, and open habitat with low herbaceous vegetation or grasses, which probably increased the availability of insects.

Recommendations:

1. To discuss the proposal for expanding the limits of Los Indios Ecological Reserve with the stakeholders involved (stockmen, tourism officials, Empresa Forestal, and Poder Popular). Once the idea is accepted, to apply the intensive management that has been proposed above.
2. To initiate a similar study, within the framework of the conservation project run by the Empresa Nacional para la Protección de la Flora y la Fauna, on Crane populations that inhabit savannas of "mocarreros", which differ from white-sand savannas. To suggest that the National System of Protected Areas include areas inhabited by those Crane populations that aren't protected at present
3. To continue to use the GIS data bases already created for the Isle of Youth, for purposes of analyzing more completely all aspects of habitat use and behavior, especially during the non-breeding system, over a span of at least five years.
4. To initiate a pilot plan for integrating themes about this endangered Cuban species into the formal system of primary education on the Isle of Youth.

5. To use the results of this study for proposing guidelines for habitat management, primarily in areas for nesting and raising chicks, such guidelines to be applied to white sand savanna ecosystems throughout the Isle of Youth.
6. To continue with simultaneous censuses, involving local communities, every three years in order to evaluate the results of applying management guidelines.