MADAGASCAR SACRED IBIS *THRESKIORNIS BERNIERI*: CURRENT POPULATION STATUS, DISTRIBUTION, AND IMPLICATIONS FOR CONSERVATION

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KEY WORDS

Madagascar Sacred Ibis, *Threskiornis bernieri*, Madagascar, wetlands, population estimate, current status, foraging behaviour

ABSTRACT

The Madagascar Sacred Ibis, *Threskiornis bernieri*, has recently been classified as an endemic species separate from the closely related African Sacred Ibis *Threskiornis aethiopicus* based on ecology and morphological characteristics. This species is generally confined to coastal ecosystems of western Madagascar. We investigated changes in the population and distribution of the Madagascar Sacred Ibis over the last 10 years, through literature reviews and field surveys undertaken from June 2005 – February 2006. A total of 91 sites were identified and documented, 55 of which were new sites and 26 were previously documented sites. About 69% of the sites were situated within 2 km of the coastline, and only 2% were found more than 40 km inland. Average altitude was 14.9±3.81 m.a.s.l (n = 91) and ranged from 0 to 191 m.a.s.l. Coastal ecosystems were significantly more important habitats for Madagascar Sacred Ibis than inland wetlands – overall 82.8% of individuals were recorded within 2 km from the coast. Over 70% of individual birds recorded in this study were seen outside current protected areas, which included three important breeding colonies. The average number of individuals recorded at each site was 9.47±3.81 (n = 81) (mean±SE), and 74% of the sites had no more than 10 individuals per site. Over 90% of the 26 historically known sites which were revisited during the last 10 years showed drastically declining populations (z = –3.63, p < 0.0005, n = 26). We estimate the current population to be about 2,000 adult birds, and sparsely distributed along the west coast. This low population figure implies an increased conservation concern for the Madagascar Sacred Ibis especially in light of habitat loss and direct persecution.

INTRODUCTION

Originally named *Ibis bernieri* by Bonaparte (1855), the Madagascar Sacred Ibis *Threskiornis bernieri* has recently been declared a distinct species from the African Sacred Ibis *Threskiornis aethiopicus,* its closest congener on mainland Africa (BirdLife Taxonomic Working Group 2003, Morris & Hawkins 1998, Sinclair & Langrand 1998). Previous reviews have also discussed the taxonomy of the Madagascar Sacred Ibis (Dowsett & Forbes-Watson 1993, Lowe & Richards 1991, Sibley & Monroe 1990), and Roselaar (1977) recognized it as a separate species. The African Sacred Ibis has a broad distribution throughout Africa, southern and eastern Asia, and Australasia, and *Threskiornis aethiopicus bernieri* was the recognized Madagascar subspecies (Steinbacher 1979, Van Tets 1978). A detailed review based on morphological and cytological investigations concluded that the status of the "form *bernieri*" was unclear and that further study was needed (Lowe & Richards 1991). In particular, the pale-blue iris and black-tipped primaries and secondaries differentiate *Threskiornis bernieri* from *T. aethiopicus*. The Madagascar Sacred Ibis has also been considered a separate species based on ecological considerations (Morris & Hawkins 1998, Sinclair & Langrand 1998). Two races are recognised: *Threskiornis bernieri bernieri* in Madagascar and *Threskiornis bernieri abbotti* on Aldabra Island, Seychelles (BirdLife Taxonomic Working Group 2003).

Contrary to its African congener, the Madagascar Sacred Ibis is not widespread but sparsely distributed and restricted to the west coast of Madagascar. Due to its previous consideration as conspecific with the African Sacred Ibis, which is the commonest and most adapted ibis to human-modified habitats of the 32 species of Threskiornithidae in Africa (Brown *et al.* 1982), the Madagascar Sacred Ibis has no conservation measures in place. This study focused on using all previous records and recently collected data to describe the distribu-

tion and conservation status of this poorly-known species in Madagascar.

METHODS

Surveys were conducted from June–July in 2005 and February 2006 throughout the coastal zones of western Madagascar from Tsimanampetsotsa Lake in the south (24°08'S, 43°45'E) to Diego Suarez (Antsiranana) in the north (12°19'S, 49°17'E) (Fig. 1). Coastal and estuarine habitats were surveyed from a twin-outboard fibreglass boat. Potential adjacent wetland habitats were visited on foot or by local *pirogue* (dugout canoe). These natural habitat types have known to support ibises in the past (Langrand 1990, Milon *et al.* 1973). Observations were made with 10 × 50 binoculars and a Discoverer 60× spotting scope. In addition to the bird counts, general notes were taken on the characteristics of the habitats and possible waterbird threats, and several villagers were briefly interviewed about waterbird threats at each locality. Locations were recorded to the nearest 10 m using a Global Positioning System (GPS, Garmin 12 XL) and locality names were based on information from villagers and a 1:100 000 scale map.

Historical records on the Madagascar Sacred Ibis came from the "coast opposite of Nossi Be" (Rand 1936), which corresponds nowadays to Sahamalaza Bay; this area was surveyed intensively during February 2006. Sahamalaza is a peninsula in north-western Madagascar between 18°75' and 19°25'S, 44°25' and 44°50'E (Fig. 1). Mangroves, estuaries, and brackish coastal areas are the main wetland habitats in this area. In 2005, roughly 26,080 ha of the bay was formally protected in which forests, mangroves and other natural wetland habitats are part of preserved zones (Madagascar Park Service pers. com.). Each area was surveyed using dugout canoes and on foot for at least two consecutive days. Local villagers and fishermen were questioned for knowledge of Madagascar Sacred Ibis in their area and all potential leads were followed to help

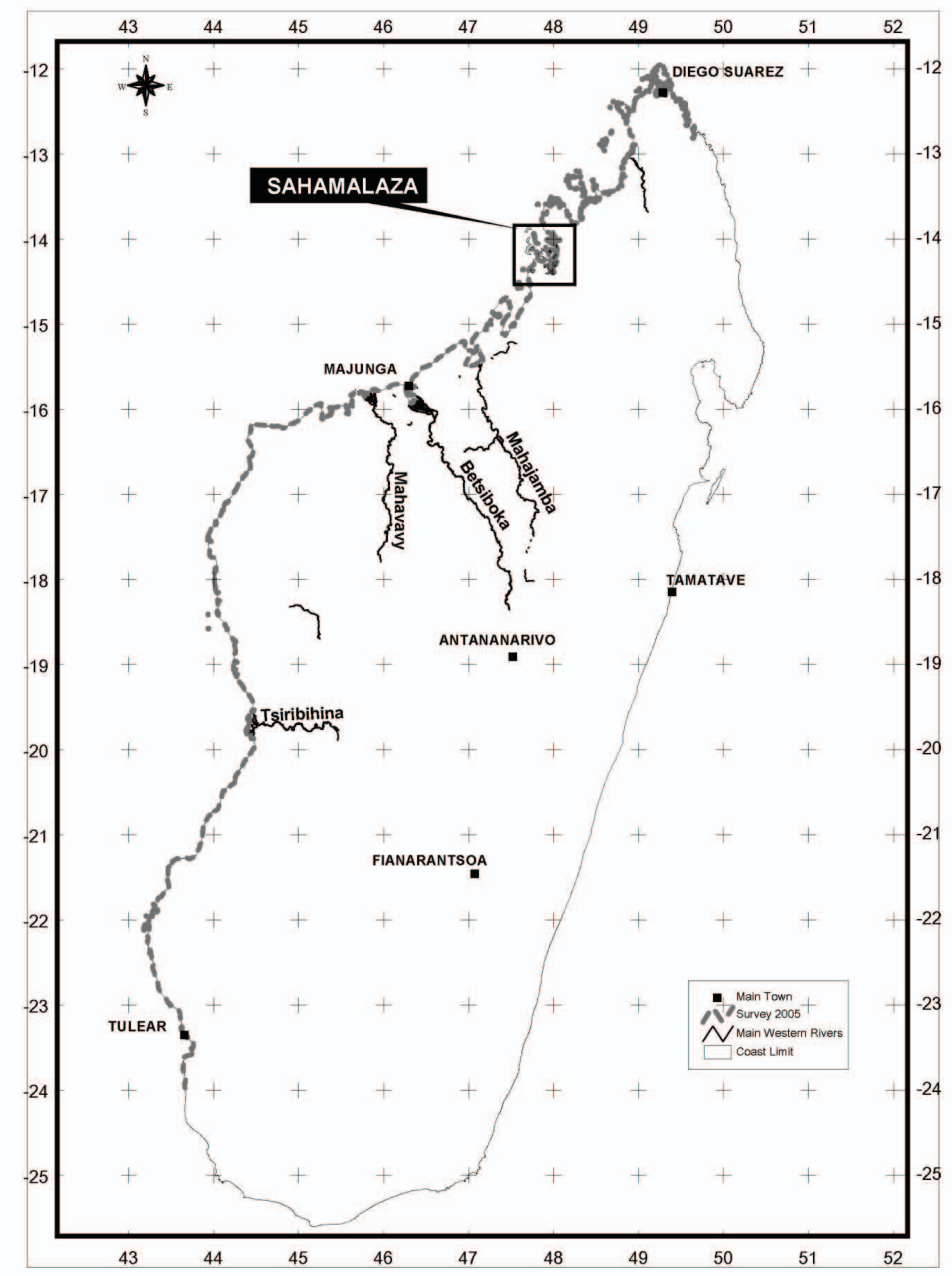

Fig. 1. The stretch of coastline surveyed for Madagacar Sacred Ibis *Threskiornis bernieri* during 2005 and 2006 in western Madagacar. The inset highlights the Sahamalaza Peninsula.

in identifying potential breeding colonies, roosting sites and feeding areas. In addition to locational data, other information recorded included: date of visit, time of day, amount of time spent at each site, individual numbers, habitat types, nesting and signs of potential threats (bones, feathers, traps etc.).

Data on behaviour were limited to the recording of feeding and resting durations. To avoid bias, only individuals seen early in the morning and not feeding were observed. Where possible, diet was recorded by direct observations and investigations of feeding areas. To avoid disturbance we did not inspect the nests during the incubation period. We tested the hypothesis that the birds would divide their time equally between feeding (supposed 50%) and resting (supposed 50%).

Comparisons of ibis counts between surveys made during the last 10 years and data collected during this study were made using a non-parametric test, the Wilcoxon Sign Ranks Test (Zar 1974). We tested the null hypothesis that there was no difference between ibis numbers in coastal ecosystems and inland wetlands habitats. Additional tests, using Mann–Whitney's U-test, were carried out to determine if abundance differed between areas inside and outside current protected areas. Except where stated, abundance is given as mean ± SE.

To estimate current populations, we used individual numbers from direct counts and any available information from the literature of sites revisited during 2005. We assumed each site to be a year-round habitat for ibises, and the population to be resident. Global positioning system data were used for GIS analysis in ArcView 3.2. We used Maximum-Entropy Techniques known as "Maxent Software" (see Hijmans *et al.* 2004, Phillips *et al.* 2004, 2006 for details) to predict distribution of the Madagascar Sacred Ibis throughout Madagascar based on available habitat types. Briefly, the idea of Maxent is to predict a species' distribution based on its presence/absence from point data and environmental variables. For the latter, altitude layers and climate layers (temperatures, precipitations, water balance, etc.) were chosen as environmental variables (see Hijmans *et al.* 2004). This software works as an algorithm iteration process based on these environmental variables in grid cells of 1 km^2. Graphically, the higher the predicted probability of occurrence, the darker the colour of the areas where the species is likely to be present.

RESULTS

Current population trends

In total, about 3,500 km along the west coast of Madagascar were surveyed. A total of 767 individuals of Madagascar Sacred Ibis was recorded at 55 new sites identified from this study. An overall sum of 1,311 individuals was recorded from a total of 91 sites: 10 sites from literature, 26 other re-visited sites, and 55 newly identified from the current study, based on maximum counts from each site (Table 1). Of the sites reported by Thorstrom & Rabarisoa (1998) Ankalasina River and Bom-

Table 1. Maximum individual numbers of Madagascar Sacred Ibis *Threskiornis bernieri* from published records and ibises observed during 2005 and 2006 surveys in this study. Conservation status: NP: Not protected, P: Protected area

Locality names	Coordinates	Altitude (m.a.s.l.)	No. of birds	Habitat types	Conservation status	Sources
SW of Androka	25°40'S, 44°12'E	24	1	Coastal zone	NP	Projet ZICOMA 1999
Ambakivao	19°35'S, 44°25'E	0	3	Coastal zone	NP	ZICOMA 1998a
Ambariomborona	14°20'S, 47°59'E	0	56	Coastal zone	P	This study
Ampitsopitsoka site 1	15°48'S, 46°02'E	0	4	Coastal zone	NP	This study
Ampitsopitsoka site 2	15°50'S, 46°03'E	0	8	Coastal zone	NP	This study
Ampitsopitsoka site 3	15°51'S, 46°03'E	0	2	Coastal zone	NP	This study
Ampitsopitsoka site 4	15°46'S, 45°52'E	0	6	Coastal zone	NP	This study
Ampitsopitsoka site 5	15°46'S, 45°51'E	0	20	Coastal zone	NP	This study
Ampitsopitsoka site 6	15°51'S, 46°02'E	0	6	Coastal zone	NP	This study
Ampitsopitsoka site 7	15°50'S, 46°00'E	0	9	Coastal zone	NP	This study
Ampitsopitsoka site 8	15°46'S, 45°50'E	0	2	Coastal zone	NP	This study
Ampitsopitsoka site 9	15°47'S, 45°47'E	0	14	Coastal zone	NP	This study
Ampitsopitsoka site 10	15°47'S, 45°46'E	0	10	Coastal zone	NP	This study
Ampotaka	25°04'S, 44°40'E	64	1	Coastal zone	NP	Rand 1936
Andopitaly	19°40'S, 44°25'E	0	3	Coastal zone	NP	ZICOMA 1998a
Andranokalo Lake	19°45'S, 44°31'E	1	1	Lake	NP	Appert 1996
Ankeramboalavo	14°24'S, 47°58'E	0	4	Coastal zone	NP	This study
Anorontsangana	13°54'S, 47°55'E	77	1	Coastal zone	NP	This study
Antafia-Antainambalaka	14°15'S, 48°00'E	0	86	Coastal zone	NP	This study
Antsalova	18°38'S, 44°36'E	128	1	Lake	P	This study
Antsiraka–Ankitsika	14°20'S, 47°59'E	0	4	Coastal zone	NP	This study
Baie d'Ampasindava	13°46'S, 48°03'E	191	1	Coastal zone	NP	Projet ZICOMA 1999
Baie de Baly site 1	15°57'S, 45°33'E	4	4	Coastal zone	P	This study
Baie de Baly site 2	16°01'S, 45°22'E	4	2	Coastal zone	P	This study
Baie de Baly site 3	16°00'S, 45°23'E	1	2	Coastal zone	P	This study
Baie de Baly site 4	16°01'S, 45°23'E	0	2	Coastal zone	P	This study
Baie de Baly site 5	16°01'S, 45°24'E	0	6	Coastal zone	P	This study
Baie de Baly site 6	16°07'S, 45°18'E	0	16	Coastal zone	P	This study
Baie de Baly site 7	16°07'S, 45°16'E	0	2	Coastal zone	P	This study
Baie de Baly site 8	16°05'S, 45°16'E	0	13	Coastal zone	P	This study

Table 1. Continued.

Locality names	Coordinates	Altitude (m.a.s.l.)	No. of birds	Habitat types	Conservation status	Sources
Baie de Bombetoka	15°55'S, 46°17'E	0	50	Coastal zone	NP	Thorstrom & Rabarisoa 1998
Baie de Loza	14°35'S, 47°52'E	8	2	Coastal zone	NP	This study
Baie de Marambitsy site 1	15°52'S, 45°36'E	0	2	Coastal zone	NP	This study
Baie de Marambitsy site 2	15°53'S, 45°37'E	0	6	Coastal zone	NP	This study
Baie de Marambitsy site 3	15°53'S, 45°37'E	0	2	Coastal zone	NP	This study
Baie de Marambitsy site 4	15°54'S, 45°37'E	0	14	Coastal zone	NP	This study
Baie de Marambitsy site 5	15°55'S, 45°37'E	0	1	Coastal zone	NP	This study
Baie de Marambitsy site 6	15°57'S, 45°36'E	0	43	Coastal zone	NP	This study
Baie de Marambitsy site 7	15°58'S, 45°36'E	0	1	Coastal zone	NP	This study
Baie de Marambitsy site 8	15°59'S, 45°36'E	0	23	Coastal zone	NP	This study
Befotaka Lake	19°01'S, 44°24'E	10	15	Lake	P	Tingay & Gilbert 1999
Bekopaka	19°08'S, 44°49'E	55	1	Lake	P	This study
Bemelaky, Tongay	17°45'S, 44°04'E	21	13	Coastal zone	NP	ZICOMA 1998c
Bemoramba, 9 km SW	17°33'S, 44°00'E	7	90	Coastal zone	NP	ZICOMA 1998d
Berevo, 30 miles S	19°58'S, 44°49'E	90	1	Coastal zone	NP	Bang 1918
Berohitra	14°23'S, 47°59'E	0	10	Coastal zone	NP	This study
Betsiboka site 1	15°52'S, 46°22'E	0	2	Coastal zone	NP	This study
Betsiboka site 2	15°52'S, 46°21'E	0	3	Coastal zone	NP	This study
Betsiboka site 3	15°52'S, 46°21'E	0	5	Coastal zone	NP	This study
Betsiboka site 4	15°52'S, 46°20'E	0	11	Coastal zone	NP	This study
Betsiboka site 5	15°53'S, 46°21'E	0	2	Coastal zone	NP	This study
Betsiboka site 6	15°53'S, 46°21'E	0	3	Coastal zone	NP	This study
Betsimipoaka site 7	14°20'S, 47°59'E	0	5	Coastal zone	NP	This study
Bombetoka and Marovoay	15°55'S, 46°31'E	21	1	Coastal zone	NP	Projet ZICOMA 1999
Cap Saint André	16°18'S, 44°43'E	41	28	Coastal zone	NP	ZICOMA 1998b
Ihotry Lake	21°55'S, 43°36'E	69	1	Lake	P	Rand 1936
Kaday Borongeny	19°47'S, 44°27'E	2	5	Coastal zone	NP	ZICOMA 1998a
Mahajamba	15°19'S, 47°07'E	0	2	Coastal zone	NP	This study
Mahajanga	15°43'S, 46°18'E	0	1	Coastal zone	NP	This study
Maintirano	18°04'S, 44°01'E	9	1	Coastal zone	NP	This study
Manambaho, Tongay	17°42'S, 44°01'E	2	1	Coastal zone	NP	ZICOMA 1998c
Mouth of the Ankalasira River	15°48'S, 45°50'E	14	500	Coastal zone	NP	Thorstrom & Rabarisoa 1998
Namoroka	16°25'S, 45°21'E	128	1	Coastal zone	P	This study
Nossi-Be, coast opposite site no. 1	13°34'S, 48°24'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 2	13°19'S, 48°14'E?	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 3	13°19'S, 48°13'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 4	13°18'S, 48°13'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 5	13°17'S, 48°11'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 6	13°16'S, 48°15'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 7	13°17'S, 48°13'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 8	13°21'S, 48°18'E	7	1	Coastal zone	P	Rand 1936
Nossi-Be, coast opposite site no. 9	13°20'S, 48°14'E	7	1	Coastal zone	P	Rand 1936
Nosy Namoko site 1	13°36'S, 48°20'E	0	6	Coastal zone	NP	This study
Nosy Namoko site 2	13°36'S, 48°05'E	0	4	Coastal zone	NP	This study
Rive de la Menarandra	25°04'S, 44°34'E	135	1	Coastal zone	NP	ZICOMA 1998b
Sahamalaza Baie site 1	14°07'S, 47°57'E	0	13	Coastal zone	P	This study
Sahamalaza Baie site 2	14°18'S, 47°57'E	11	16	Coastal zone	P	This study
Sahamalaza Baie site 3	14°20'S, 47°59'E	0	13	Coastal zone	P	This study
Sahamalaza Baie site 4	14°19'S, 47°59'E	0	9	Coastal zone	P	This study
Sahamalaza Baie site 5	14°15'S, 48°00'E	6	13	Coastal zone	P	This study
Sahamalaza Baie site 6	14°13'S, 47°59'E	0	13	Coastal zone	P	This study
Sahamalaza Baie site 7	14°10'S, 48°01'E	0	9	Coastal zone	P	This study
Soalala	16°04'S, 45°19'E	0	1	Coastal zone	P	Delacour 1932
South of Ankavandra	18°49'S, 45°16'E	144	1	Lake	NP	Delacour 1930
Tanjona Amparafara	16°03'S, 45°16'E	0	9	Coastal zone	NP	This study
Unknown locality name no. 1	12°33'S, 48°52'E	0	10	Coastal zone	P	This study
Unknown locality name no. 2	15°49'S, 46°09'E	22	5	Coastal zone	NP	This study
Vario Betsimipoaka	14°19'S, 47°58'E	0	5	Coastal zone	NP	This study
Vavan'I Berondra	14°03'S, 48°02'E	0	25	Coastal zone	NP	This study
Vavan'I Maromandia	14°24'S, 47°56'E	0	12	Coastal zone	NP	This study
West of Beroboka	19°56'S, 44°33'E	0	1	Coastal zone	NP	Appert 1996

Table 2. Ibis sites revisited during the last ten years with the individual number of Madagascar Sacred Ibises from published records and from 2005 and 2006 surveys during this study in western Madagascar.

Locality names	Coordinates	Previous counts	Counts during this study	Conservation status	Source
SW of Androka	25°40'S, 44°12'E	1	3	NP	Projet ZICOMA 1999
Ambakivao	19°35'S, 44°25'E	3	0	NP	ZICOMA 1998a
Ampotaka	25°04'S, 44°40'E	1	0	NP	Rand 1936 and this study 2005–2006
Andopitaly	19°40'S, 44°25'E	3	2	NP	ZICOMA 1998a
Andranokalo Lake	19°45'S, 44°31'E	1	0	NP	Appert 1996
Anorontsangana	13°54'S, 47°55'E	1	4	NP	This study 2005–2006
Antsalova	18°38'S, 44°36'E	1	0	P	This study 2005–2006
Baie d'Ampasindava	13°46'S, 48°03'E	1	0	NP	Projet ZICOMA 1999
Baie de Bombetoka	15°55'S, 46°17'E	50	26	NP	Thorstrom & Rabarisoa 1998
Befotaka Lake	19°01'S, 44°24'E	15	4	P	Tingay & Gilbert 1999
Bekopaka	19°08'S, 44°49'E	1	0	P	This study 2005–2006
Bemelaky, Tongay	17°45'S, 44°04'E	13	0	NP	ZICOMA 1998c
Bemoramba, 9 km SW	17°33'S, 44°00'E	90	24	NP	ZICOMA 1998d
Berevo, 30 miles S	19°58'S, 44°49'E	1	0	NP	Bang 1918
Bombetoka and Marovoay	15°55'S, 46°31'E	1	0	NP	Projet ZICOMA 1999
Cap Saint André	16°18'S, 44°43'E	28	4	NP	ZICOMA 1998b
Ihotry Lake	21°55'S, 43°36'E	1	0	P	Rand 1936 and this study 2005–2006
Mahajanga	15°43'S, 46°18'E	1	0	NP	This study 2005–2006
Maintirano	18°04'S, 44°01'E	1	0	NP	This study 2005–2006
Manambaho, Tongay	17°42'S, 44°01'E	1	0	NP	ZICOMA 1998c
Mouth of the Ankalasira River	15°48'S, 45°50'E	500	123	NP	Thorstrom & Rabarisoa 1998
Namoroka	16°25'S, 45°21'E	1	0	P	This study 2005–2006
Rive de la Menarandra	25°04'S, 44°34'E	1	0	NP	ZICOMA 1998b
Soalala	16°04'S, 45°19'E	1	0	P	Delacour 1932 and this study 2005–2006
South of Ankavandra	18°49'S, 45°16'E	1	0	NP	Delacour 1930 and this study 2005–2006
West of Beroboka	19°56'S, 44°33'E	1	0	NP	Appert 1996 and this study 2005–2006

betoka Bay were the most important (the *Ankalasina River* is a misspelling of Ankalasira River (15°48'S, 45°50'E) on the Mahavavy Delta based on FTM map Namakia J39 cited by Thorstrom & Rabarisoa (2008), (R. Rabarisoa pers. comm.). These authors recorded about 500 Madagascar Sacred Ibis on 22 June1995 and another 50 individuals at Bombetoka Bay (15°55'S, 46°31'E). These two sites were revisited on 28 June and 4 July 2005; 123 and 26 ibises were recorded respectively. At 24 of the 26 sites that were revisited, the numbers of ibises had decreased significantly during the last ten years (Wilcoxon Sign Rank test: $z = -3.63$, $p < 0.0005$, $n = 26$). The two remaining sites were Androka (25°04'S, 44°E) and Anorontsangana (13°54'S, 47°55'E) (Table 2). Fewer than ten individuals, on average, were recorded from most (74%) of the surveyed sites (mean 9.47±3.81, n = 81, range 0–123 individuals).

Distribution

Of the 91 ibis sites, 69.2% were situated less than 2-km from the coastline; only two observations (south of Ankavandra with 1 individual and Bekopaka also 1 individual) were made more than 40 km from the coastline (Fig. 2). Most (99%) individuals were recorded below 50 m above sea level.

Coastal zones between Baie de Baly (16°19'S, 46°04'E) and

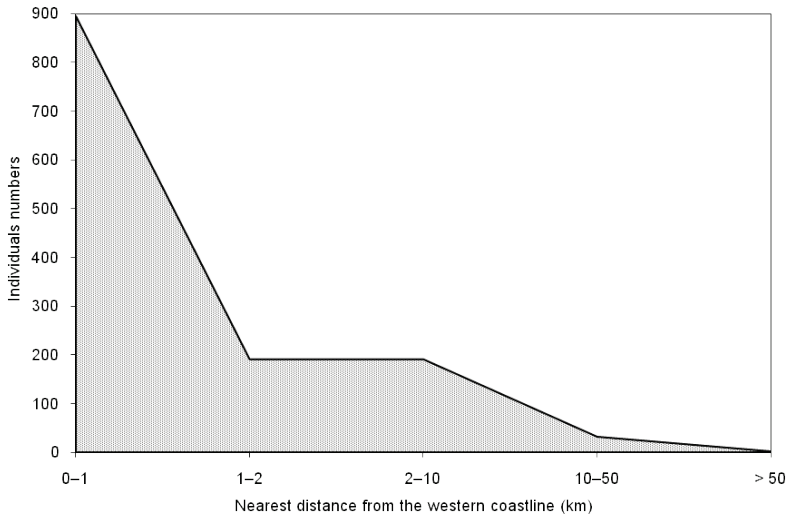

Fig. 2. Individual Madagascar Sacred Ibis *Threskiornis bernieri* numbers compared to distance (km) from the western Madagascar coastline.

Sahamalaza Bay (14°01'S, 48°04'E) hold more than 80% of overall ibises records (75 of 91 data points). Based on "Maxent" predicted distribution results these coastal areas had the higher occurrence probability (exceeding 50%, see Fig. 3). Compared with the current distribution (Fig. 4) the predicted range is narrower than the inland distance from the coastline and less extended in the southern parts.

Population estimate

Overall, 75% of the 91 sites where Madagascar Sacred Ibis were recorded had no more than 10 individuals; maximum numbers per site: 14.46±5.63, $n = 91$, range 1–500). Assuming ibis sites to have a maximum of 20 mature individuals, based on the mean maximum (20.09 individuals),the total population

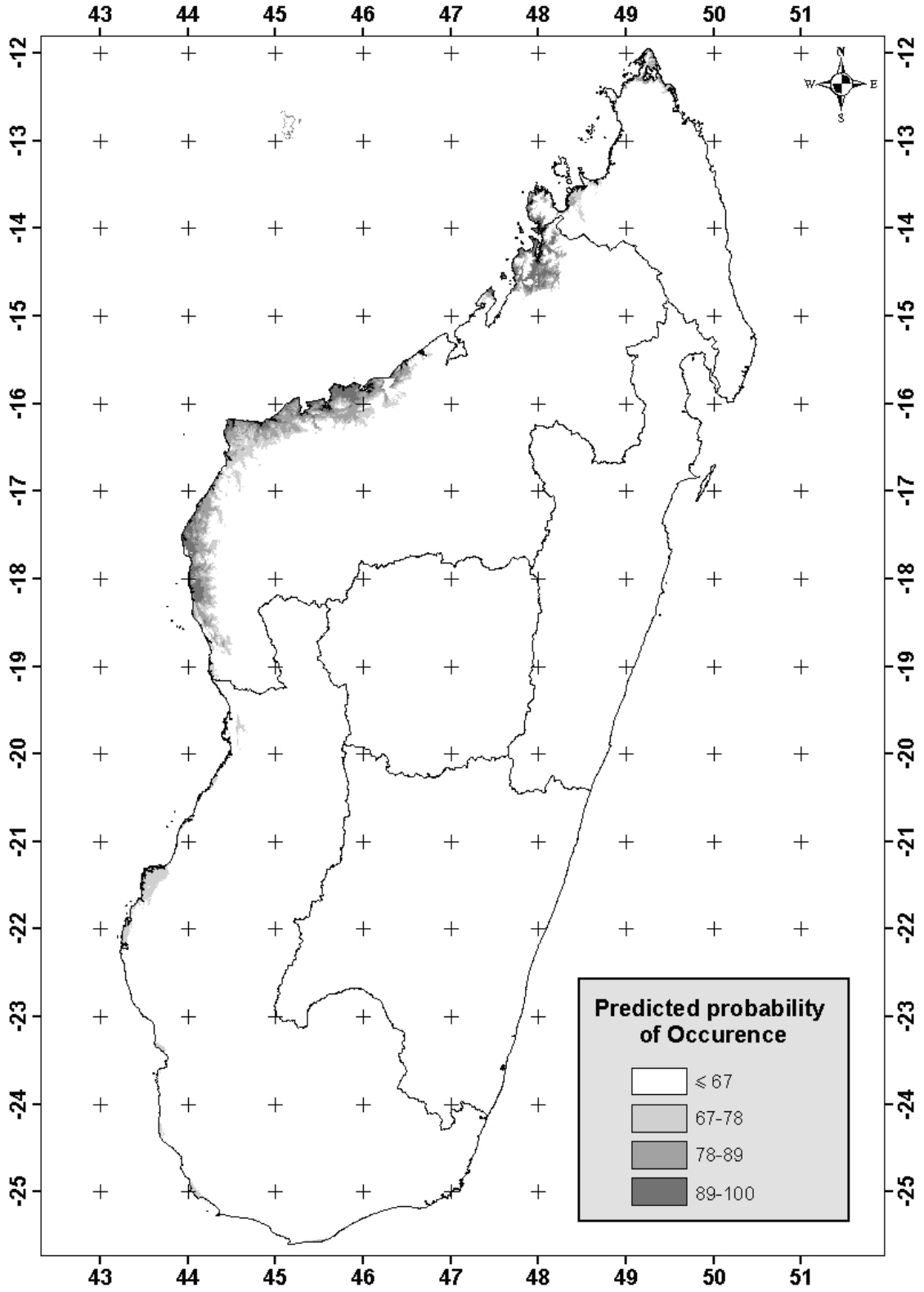

Fig. 3. Predicted probability of occurrence of Madagascar Sacred Ibis Threskiornis bernieri based on Maxent analysis (see text for details).

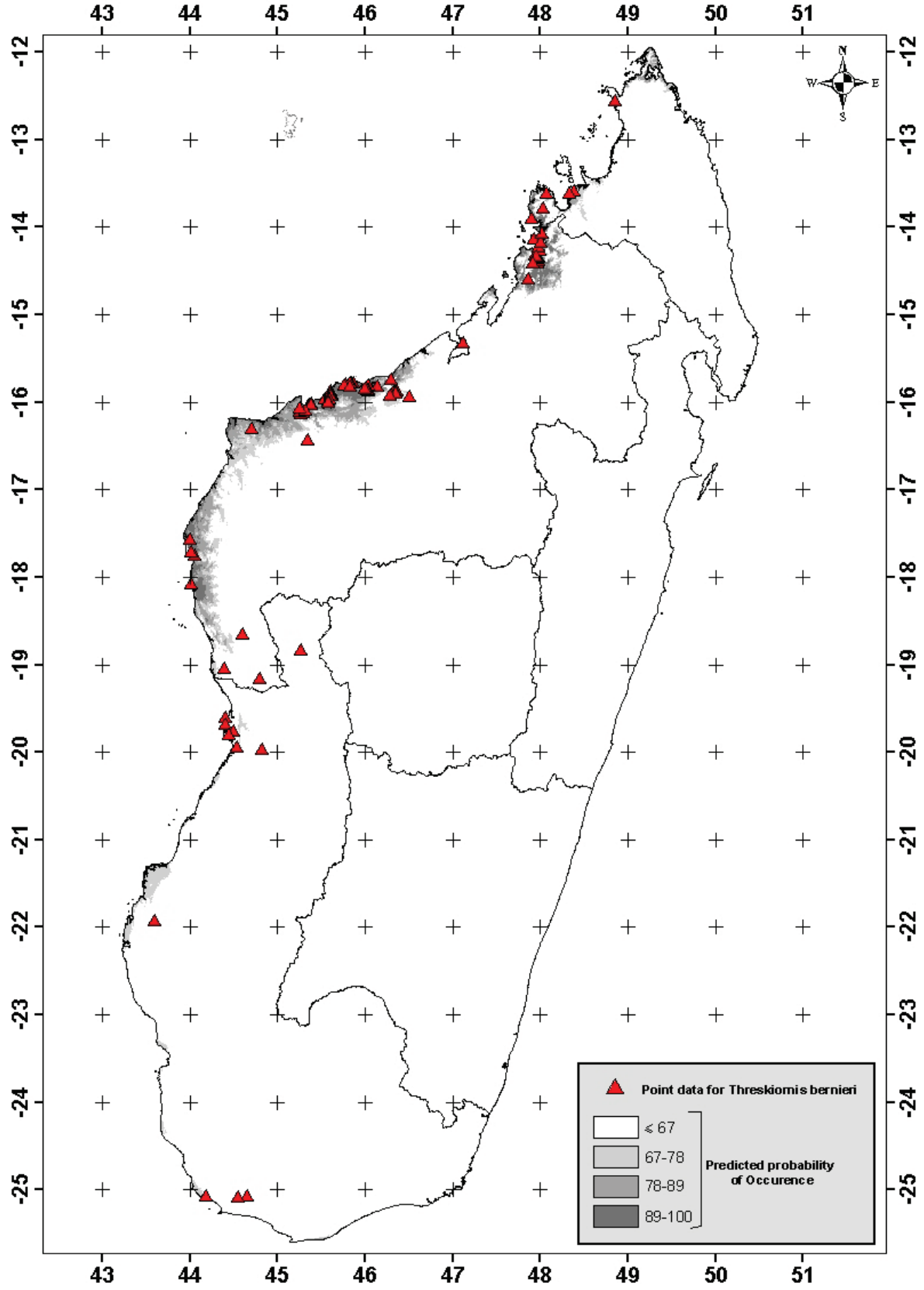

Fig. 4. Probability of occurrence and observations of Madagascar Sacred Ibis *Threskiornis bernieri* from 2005 and 2006, and showing their stronghold area between Baie de Baly and Sahamalaza in western Madagascar.

estimate would be around 1,820 mature birds. Consequently, no more than 2,000 mature birds may currently exist in the wild, and they are sparsely distributed and under intense human pressure. However, there are some mangroves and estuaries between Soalala (16°19'S, 46°04'E) and Sahamalaza Bay (14°01'S, 48°04'E) where higher concentrations of resident breeding populations have been recorded.

Behaviour

From 9 to 21 February 2006, eight adult Madagascar Sacred Ibis were followed in Sahamalaza Bay for a total of 1,567 minutes. Most (*mean* = 82.7±3.8%) of the time was spent foraging. Chi-square testing gives us a highly significant variation between feeding time and resting time ($\chi^2 = 426.34$, $df = 7$, $p < 0.000$).

Of 47 observations, Madagascar Sacred Ibises spent most (76.6%) of the time foraging alone; the remainder (23.4%) foraged in pairs or groups of three. There were only two records of birds feeding in rice fields; the other 45 were of birds foraging on mud in tidal areas.

On 12 February 2006, four active nests were recorded in the colony of Ambariomborona at Sahamalaza Bay (14°20'S, 47°59'E). Of these, three had two fully-grown nestlings and one was still in the incubation phase. Two of the four nests were located 1–3 meters apart and all were situated within mangrove trees (Avicennia sp. and Rhizophora sp.). Madagascar Sacred Ibises nested in a mixed colony together with more than 100 Cattle Egret (*Bubulcus ibis*) and 50 Dimorphic Egret (*Egretta dimorpha*) pairs. Nests were built about 15 m above the ground in the middle of the mangroves. Two fallen nests not beyond one week old, probably caused by poachers, had diameters of 25.6 cm and 24.8 cm. The nests were constructed of twigs and sticks collected from trees near the colony.

Threats and conservation measures

Of the 81 ibis sites located during this study, 73.5% (n = 58) were outside current protected areas. Furthermore, the known strongholds of the breeding populations, except for the Baie de Baly and part of Sahamalaza Bay, are outside of legally protected areas. Despite these facts, no statistically significant difference was detected between the number of birds outside and inside protected zones ($p = 0.46$; Mann–Whitney's *U*-test). Of 37 local villagers interviewed in Sahamalaza Bay during February 2006, 35 admitted eating Madagascar Sacred Ibis during special events at least once during the past five years, and also collected eggs and raised nestlings at home. A minimum of 15 traps were observed on 11 February in the mangrove section of Ambariomborona (14°20'S, 47°59'E) and within the newly protected Sahamalaza Complex. Bones of at least two individuals were observed in garbage dumps near Anorombato (13°54'S, 47°55'E), a fishing village on the coast of the Sahamalaza Peninsula. At least 2 of 10 fishermen at this village admitted raising chicks of Madagascar Sacred Ibis taken in January 2005 from nests at Antafia-Antainambalaka (14°15'S, 48°00'E), the largest breeding colony on the Sahamalaza Peninsula with a minimum of 40 nesting pairs, 15 km south of the village.

DISCUSSION

The Madagascar Sacred Ibis *Threskiornis bernieri* is rare, sparsely distributed, and somewhat more confined to the coastline region of western Madagascar than previously thought (Bangs 1918, Langrand 1990, Milon 1948, Milon *et al.* 1973**,** Morris & Hawkins 1998, Projet ZICOMA 1999, Rand 1936, Salvan 1970, Young 2003). Estuaries between Baie de Baly and Sahamalaza Bay appear to be its current stronghold. Despite numerous surveys of wetlands and coastal zones since the 1990s (Andrianarimisa *et al.* in prep., Projet ZICOMA 1999, Thorstrom & Rabarisoa 1998, Young & Razafindrajao 2006), none recorded larger numbers of Madagascar Sacred Ibis; in addition no observations were made far from saline and brackish coastal zones. These data emphasize that Madagascar Sacred Ibises are restricted to western Madagascar and confined to saline, coastal zones.

Long believed to be a conspecific of the African Sacred Ibis *Threskiornis aethiopicus*, (Dowsett & Forbes-Watson 1993, Langrand 1990, Lowe & Richards 1991, Sibley & Monroe 1990), the Madagascar Sacred Ibis was considered to be widespread and adapted to varying wetland habitats in Madagascar including freshwater, river mouths, seashore, and mangrove (Langrand 1990). However, in view of recent information (Hawkins & Goodman 2003, Morris & Hawkins 1998, Sinclair & Langrand 1998, Young 2003), this rare bird is more prevalent in estuaries and mangroves than in freshwater habitats. While there are some records from inland freshwater habitats, such as Befotaka Lake in the Manambolomaty Lakes Complex (Tingay & Gilbert 1999), Ihotry Lake (Rand 1936), and a lake west of Beroboka (Appert 1996), this species appears more frequently in saline areas. All of these lakes are close to brackish areas, and therefore they are slightly alkaline. Young & Razafindrajao (2006) concluded that the lake west of Beroboka cited by Appert (1996) is Lake Bedo (44°32'E; 19°55'S), which is slightly saline. Goodman & Rakotozafy (1997) divided the lakes along the west coast into four distinct types and allocated Ihotry Lake to the brackish category. Rasamoelina (2000) found that Befotaka Lake has been receiving sea water from the Manambolomaty River during certain times of the year, and which explains the more brackish fish community in the lake.

Regarding habitat availability, Cook *et al.* (2003) estimated that up to 98% of mangroves in Madagascar are located on the west coast, and 95% of them are distributed between the Mangoky Delta (21°S) and the Mahavavy estuaries (13°S). In addition, tidal saltwater penetration, acidity, and strongly mineralised rivers that support higher micro-organism diversity in western Madagascar (Cook *et al.* 2003) provide suitable habitats for the Madagascar Sacred Ibis. This explains why most of the Madagascar Sacred Ibis records are from the Mangoky, Betsiboka, Mahajamba and Mahavavy estuaries, where large areas, up to 20,000 ha, of this habitat occurs (Cook *et al.* 2003). Predicted distributions based on environmental features linked with Madagascar Sacred Ibis (climate, forest cover, etc.) highlight the importance of these areas for the species. Studies of the impact of pollution on mangroves and coral reefs, mainly along the south-west coast south of Tsiribihina (CNRE/CNRO/CNRIT 1999, Rakotoarinjanahary *et al.* 1994)

and sedimentation on Madagascar coastal ecosystems (Cockroft & Young 1998, CNRE/CNRIT/IHSM 2000, Vasseur 1988, Vasseur *et al.* 1988) concluded that there is a significant impact on the occurrence of crustaceans, snails, worms, insects and fish etc.). In addition, alluvial sands are encroaching in some areas, changing mudflats to sandy dunes which are unsuitable for many organisms, in particular those which probe for food in the mud, like the Madagascar Sacred Ibis (Kopij *et al.* 1996). This was evident in the Fiherenana and Onilahy Basins (Cook *et al.* 2003), and was also seen elsewhere from the Morondava coast up to Cap Sainte André during our surveys. It seems possible that the paucity of Madagascar Sacred Ibis records in its known southern range are linked with these impacts on coastal ecosystems.

In contrast, in some generally pristine areas such as the managed forested Ramsar site in the Manambolomaty Lakes Complex and the nearby Maintirano and Soahany estuaries, which support resident breeding populations (Rand 1936, Tingay & Gilbert 1999, this study), the decline of Madagascar Sacred Ibises is probably due to direct human persecution. The biannual waterbird surveys around the Antsalova region made by The Peregrine Fund team since 1995 have shown declines linked with egg harvesting and nest raiding (Rabarisoa 1999, Razafimanjato *et al.* 2007). Tingay & Gilbert (1999) and Andrianarimisa *et al.* (in prep) suggest the decline of large breeding colonies of waterbirds like Madagascar Herons (*Ardea humbloti*) and Madagascar Sacred Ibis in this region are a result of hunting and harvesting of eggs at their nests. The same practices exist in Sahamalaza Bay, and the people even raise Madagascar Sacred Ibis nestlings to serve as food for seasonal events (e.g. New Year's celebrations) pers. obs.

In the Free State province in South Africa, the decline of breeding populations of the African Spoonbill *Platalea alba* was occasionally attributed to the increase of the African Sacred Ibis (Kopij 1997). Investigations on food items of the two species in this area concluded that the main food items of both species chicks were the frogs *Rana angolensis* and *Xenopus laevis* (Kopij 1997, 1999, Kopij *et al.* 1996). Further studies are needed in Madagascar to determine whether or not this is the case for the Madagascar Sacred Ibis. In addition, insecticide contamination linked with consumption of man-made refuse, which is known to be responsible for African Sacred Ibis mortalities in southern Africa (Clark 1979), does not seem to be a factor in the decline of the Madagascar Sacred Ibis. In fact, we do not know of any observations of Madagascar Sacred Ibis foraging on or near man-made refuse. If this is true, the rarity of Madagascar Sacred Ibis and its current decline throughout its range would be attributed primarily to both direct persecution of breeding colonies and man-induced changes of natural ecosystems. Given that the species is sparsely distributed, restricted to coastal ecosystems, and seriously suffering from the destruction of nesting colonies throughout its range, the estimate of 2000 Madagascar Sacred Ibises appears, if anything, high. Being a gregarious bird, unwary while feeding and apparently passive at nest sites facilitates their capture by hand by local villagers.

Little is known about the behaviour and food habits of Madagascar Sacred Ibis (Morris & Hawkins 1998, Sinclair & Langrand 1998). Knowledge is limited to data collected before the species was split from its African conspecific (Dowsett & Forbes-Watson 1993, Langrand 1990, Rand 1936, Sibley & Monroe 1990). Madagascar Sacred Ibises are considered to be ecologically different from the African Sacred Ibis (BirdLife 2004, Hawkins & Goodman 2003, Morris & Hawkins 1998, Sinclair & Langrand 1998). Diet (Clark & Clark 1979), daily and seasonal movements (Clark 1977, 1979, Evans *et al.* 1982), breeding performance in both natural and man-modified habitats (Kopij 1999, Kopij *et al*. 1996) of African Sacred Ibises were extensively studied in Southern and Eastern Africa. These studies confirmed African Sacred Ibises remain the most widespread, the commonest, and well-adapted to man-modified habitats among the 11 species of the family *Threskiornithidae* which exist in Africa (del Hoyo *et al.* 1992, Hancock *et al*. 1992, Kopij 1999). During observations made in Sahamalaza, Madagascar Sacred Ibises spent long hours each day probing their bills into the mud searching for food before returning to their roost sites. Investigation of the substrate in their feeding areas showed that worms, small crustaceans, snails, and insects were among potential food items. The African Sacred Ibis was often seen eating detritus from human activities (Benson & Penny 1971, Brelsford 1943, Clark & Clark 1979, Evans *et al.* 1982). However, such behaviour by Madagascar Sacred Ibises was never observed during our surveys and no other sources have reported this in Madagascar. Hence, African Sacred Ibis appear to be ecologically different from Madagascar Sacred Ibis with regards to food habits (BirdLife 2004, Hawkins & Goodman 2003, Morris & Hawkins 1998, Sinclair & Langrand 1998). However, our foraging observations are limited to one locality, Sahamalaza Bay, which prevents us from drawing definitive conclusions. Further detailed investigations from other localities are required to substantiate these findings.

Conservation implications

Extensive annual forest and grassland slash-and-burn cultivation, locally known as "*tavy*", affects most of Madagascar's land surface, and results in the erosion of vast quantities of topsoil to the coast. Cook *et al.* (2003) estimated that sedimentation is perhaps the single greatest aspect of human impact on Madagascar's marine and coastal ecosystems. Wherever sedimentation occurs, Madagascar Sacred Ibises are recorded less frequently, especially in its southern distribution. This species, which is becoming rarer within its range and even within its last known stronghold, is now declining drastically. Compared with some previous data the current population size, for example in the Ankalasira River (15°48'S, 45°50'E, Thorstrom & Rabarisoa 2008), declined by more than 90% in some areas. This exceeds the natural population decline criterion of IUCN estimated at 30–49% for the waterbirds species that have the IUCN status Endangered (Delany & Scott 2002).

Furthermore, the weakness and ineffectiveness of current Malagasy legislation on hunting expose this species to the threat of imminent extinction if measures to protect and preserve it are not taken quickly. The situation is more drastic for the Madagascar Sacred Ibis since more than 70% of its population is currently outside protected areas and coastal ecosystems are still generally neglected in Madagascar's reserve network. Given the estimate of fewer than 2000 remaining mature birds, and the lack of effective conservation measures, the population status of the Madagascar Sacred Ibis should be reviewed regularly by national legislators and by the IUCN to improve

its protection status. Preserving suitable habitat throughout its range should be the highest priority for conservation of this species. Educating local people about colonial birds and their preservation in general as well as species-based conservation programmes are critical for not only the survival of the Madagascar Sacred Ibis, but also for other large wetland bird species and associated biodiversity.

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