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RAPTORS IN THE EAST AFRICAN TROPICS AND WESTERN INDIAN OCEAN ISLANDS: STATE OF ECOLOGICAL KNOWLEDGE AND CONSERVATION STATUS

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ABSTRACT.—From our review of articles published on diurnal and nocturnal birds of prey occurring in Africa and the western Indian Ocean islands, we found most of the information on their breeding biology comes from subtropical southern Africa. The number of published papers from the east African tropics declined after 1980 while those from subtropical southern Africa increased. Based on our Knowledge Rating Scale (KRS), only 6.3% of breeding raptors in the east African tropics and 13.6% of the raptors of the Indian Ocean islands can be considered Well Known, while the majority, 60.8% in mainland east Africa and 72.7% in the Indian Ocean islands, are rated Unknown. Human-caused habitat alteration resulting from overgrazing by livestock and impacts of cultivation are the main threats facing raptors in the east African tropics, while clearing of forests through slash-and-burn methods is most important in the Indian Ocean islands. We describe conservation recommendations, list priority species for study, and list areas of ecological understanding that need to be improved.

KEY WORDS: *Conservation; east Africa; ecology; western Indian Ocean; islands; priorities; raptors; research.*

Aves rapaces en los tropicos del este de Africa y en islas al oeste del Océano Indico: estado del conocimiento ecológico y de su conservación

RESUMEN.—De nuestra recopilación de artículos publicados sobre aves rapaces diurnas y nocturnas que se encuentran en Africa y en las islas al oeste del Océano Indico, encontramos que la mayoría de la información sobre aves rapaces residentes se origina en la región subtropical del sur de Africa. El número de publicaciones provenientes de los trópicos del este de Africa, declinó despues de 1980, mientras que aquellos del subtrópico del sur del continente aumentaron. Con base en nuestra escala de valoración del conocimiento solo el 6.3% de las especies residentes en los trópicos del este del Africa y el 13.6% de las aves rapaces de islas del Océano Indico pueden ser consideradas como Bien Conocidas, mientras que la mayoría 60.8% del este de Africa y 72.2% de las islas al oeste del Océano Indico fueron clasificadas como Desconocidas. La alteración de habitats de origen antrópico como resultado del sobrepastoreo y los impactos de la agricultura son las principales amenazas para las aves rapaces de los trópicos del este de Africa, mientras que la deforestación a partir de la quema y tala de bosques es la amenaza mas importante en las islas del Océano Indico. Describimos recomendaciones de conservación, identificamos las especies prioritarias para estudiar e identificamos las áreas de entendimiento ecológico que deben ser mejoradas.

[Traducción de César Márquez]

Raptors are an important tool to focus conservation strategies locally, regionally, and globally (Watson 1991). They can be used as "umbrella species" because their large home ranges and low nesting densities necessitate that any protected areas encompassing viable populations or complete communities protect sufficient habitat and populations of most, if not all, other species in the food web below them (Thiollay 1992). Because of their top positions in terrestrial and aquatic food webs, raptors can be used as indicators of worldwide pollution by pesticides (Newton 1979). Changes in raptor distribution or abundance can serve as a measure of our impact on landscapes, even in remote areas (Reichholf 1974). Finally, raptors are popular and charismatic and several species have become significant "flagships" for increasing public interest and support of conservation programs (Burnham et al. 1992, Thiollay 1992).

This paper combines our collective knowledge

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of raptors in the east African tropics and western Indian Ocean islands as part of a worldwide review of their conservation and ecology. We chose to combine these two regions in one paper to facilitate comparison of island with continental situations in adjacent geographic areas. The east African tropics (including all countries between the Tropics of Cancer and Capricorn and east of about 20°E, Zanzibar and Pemba islands) and the western Indian Ocean islands (comprising Madagascar, Mauritius, Seychelles, Reunion, and Comores) support roughly 23% of the world's avifauna according to species listed in Martin (1987), Langrand (1990), Perlo (1995), and Zimmerman et al. (1996). These areas contain a broad spectrum of habitats, from montane through lowland, dry, moist, and riparian forests, to open woodland, savanna, scrubland, desert, marsh, mangroves, and others. The east African tropics support 82 species of diurnal birds of prey and 23 nocturnal owls (Britton 1980, Brown et al. 1982, Fry et al. 1988). Three-quarters of these raptors, or roughly 20% of the world's raptor species, breed within this area while the rest use the region as a migratory pathway. The Indian Ocean islands support 22 endemic raptor species (15 diurnal birds of prey and seven nocturnal owls), five other breeding species, and two Palearctic migrants. Although both these areas boast a tremendous diversity of birds that attracts the attention of bird watchers worldwide, their raptors are still poorly understood in many respects, ranging from basic biology to the factors affecting distribution and abundance. Conserving raptors, or using them as a tool to achieve broader conservation goals, is impossible without a sound understanding of their ecological requirements.

In this paper, we first give an overview of the state of ecological knowledge and conservation status of breeding raptors in the east African tropics and the western Indian Ocean islands, based on 546 published papers and recent lists of species in jeopardy. Second, we outline the main conservation issues, contrast threats to raptors on the mainland with those on islands, summarize information on causes of threats, and cite particular examples of problems. Lastly, we discuss priorities for further studies and focus of conservation efforts.

METHODS

We reviewed the literature in peer-reviewed journals on 105 species in Africa, 79 of which breed in tropical east Africa, and 22 that are endemic to the Indian Ocean islands. The review was divided into pre-1980 and post-1980 material. Pre-1980 titles were obtained from the bibliography of Brown et al. (1982) and Fry et al. (1988). Post-1980 titles were obtained from a keyword search from 1980 through the first quarter of 1996 on the BIOSIS (Biological Abstracts Inc.) and RRTAC (Raptor Research and Technical Assistance Center, Boise, ID U.S.A) computer databases. We assumed that the material obtained represented a significant proportion of all articles published in peer-reviewed journals, and that these sources accurately reflect ecological knowledge based on scientific studies. *Ad-hoc* accounts published in newsletters or magazines can provide additional knowledge but they were not included in this review as they are difficult to find and their significance to the understanding of a species' ecology is difficult to assess.

Based on a similar review of the status and knowledge of Central and South American raptors (Bierregaard 1995), we assigned scores to each species from 1 to 5 from our Knowledge Rating Scale (KRS) where 1 = anecdotal, speculative or unstudied; 2 = 1 nest or 1 year low sample size studies; 3 = multi-year, local area studies, <5 pairs; 4 = multi-year, >5 pairs; and 5 = >10 pairs, >10 years, or regional studies. This was repeated for four subject areas, factors affecting distribution and abundance, population trends, breeding biology, and feeding ecology. Scores for each subject were summed for each species (min. 4, max. 20), and species ranked by score. Species were then grouped into four categories of knowledge based on their scores: Unknown (score 4–6), Little Known (score 7–10), Known (score 11–13), and Well Known (score 14 and above). Although these categories were subjective, they simplified our review by separating species into roughly common levels of knowledge. To compare between subject areas, we calculated a "study index" (first line of Tables 1 and 2) by summing the KRS for all species within each subject, and converting the total to a percentage of the maximum possible if all species had KRS of 5. Species' total scores were calculated by summing KRS for all species in all subject areas and expressed as a percentage of the maximum possible if all species had KRS of 5. The conservation status of each species was compiled from two sources (Collar et al 1994, Bennun and Njoroge 1996).

RESULTS AND DISCUSSION

State of Ecological Knowledge and Conservation Status. We found 251 and 295 articles in our pre-1980 and post-1980 literature searches, respectively. During the pre-1980 era, raptor research originated almost equally from countries in the east African tropics (36%) and subtropical southern Africa (39%), with 14% originating from tropical west Africa and 12% from north and central Africa. From 1980 through the first quarter of 1996, the proportion of publications originating from subtropical southern Africa increased to 55% and decreased to 25% from countries in the east African tropics, while they increased from the western Indian Ocean islands (10%) and decreased from tropical west and north Africa (each 5%). The

Table 1. Knowledge rating scores (KRS) for distribution and abundance, population biology, breeding biology, and feeding ecology of 79 raptor species breeding in the east African tropics. Species are listed in order of increasing KRS. KRS scores: 1 = anecdotal, speculative or unstudied; 2 = single nest and single year low sample size studies; 3 = multi-year local area studies; 4 = multi-year and >10 pairs; 5 = >10 pairs, >10 years or regional studies. Conservation status for species in the east African region (Bennun and Njoroge 1996): EN = Endangered, NT = Near Threatened, VU = Vulnerable, RR = Regional Responsibility. Global conservation status categories (Collar et al. 1994): EN = Endangered, NT = Near Threatened, VU = Vulnerable.

		DISTRIB. AND ABUND.	POPULAT. BIOLOGY	BREEDING BIOLOGY	FEEDING ECOLOGY	SPECIES TOTAL		
		PROPORTION OF STUDIES IN EACH SUBJECT AREA					CONSERVATION STATUS	
COMMON NAME	SCIENTIFIC NAME	11%	9%	26%	20%	13%	REGIONAL	GLOBAL
Buzzard, Mountain	*Buteo oreophilus*	1	1	1	1	4	NT	
Buzzard, Red-necked	*Buteo auguralis*	1	1	1	1	4		
Eagle, Congo Serpent	*Dryotriorchis spectabilis*	1	1	1	1	4		
Snake-eagle, Southern Banded	*Circaetus fasciolatus*	1	1	1	1	4	NT	NT
Falcon, Pygmy	*Polihierax semitorquatus*	1	1	1	1	4		
Hawk-eagle, Ayre's	*Hieraaetus ayresii*	1	1	1	1	4	VU	
Hawk-eagle, Cassin's	*Spizaetus africanus*	1	1	1	1	4		
Hawk, Long-tailed	*Urotriorchis macrourus*	1	1	1	1	4		
Kestrel, Fox	*Falco alopex*	1	1	1	1	4		
Kestrel, Grey	*Falco ardosiaceus*	1	1	1	1	4		
Kite, African Swallow-tailed	*Elanus (Chelictinia) riocourii*	1	1	1	1	4		
Kite, Black	*Milvus migrans*	1	1	1	1	4		
Owlet, Albertine	*Glaucidium albertinum*	1	1	1	1	4	VU-RR	VU
Owlet, Chestnut Barred	*Glaucidium capense castaneum*	1	1	1	1	4		
Owlet, Etchecopar's	*Glaucidium capense etchecopari*	1	1	1	1	4		
Owlet, Red-chested	*Glaucidium tephronotum*	1	1	1	1	4	VU	
Owl, Fraser's Eagle	*Bubo poensis*	1	1	1	1	4		
Owl, Congo-bay	*Phodilus prigoginei*	1	1	1	1	4		VU
Owl, Pemba Scops-	*Otus pembaensis*	1	1	1	1	4	VU-RR	NT
Owl, Usambara	*Bubo vosseleri*	1	1	1	1	4	VU-RR	VU
Secretary-bird	*Sagittarius serpentarius*	1	1	1	1	4		
Sparrowhawk, Black	*Accipiter melanoleucus*	1	1	1	1	4		
Buzzard, Augur	*Buteo augur*	2	1	1	1	5		
Buzzard, Lizard	*Kaupifalco monogrammicus*	1	1	2	1	5		
Snake-eagle, Brown	*Circaetus cinereus*	1	1	2	1	5	NT	
Eagle, Western Banded	*Circaetus cinerascens*	1	1	2	1	5	VU	
Hawk, African Cuckoo	*Aviceda cuculoides*	1	1	2	1	5	NT	
Falcon, Taita	*Falco fasciinucha*	1	1	2	1	5	VU	VU
Goshawk, Gabar	*Micronisus (Melierax) gabar*	1	1	2	1	5		
Goshawk, Little Banded (Shikra)	*Accipiter badius*	1	1	2	1	5		
Kestrel, Dickinson's	*Falco dickinsoni*	1	1	2	1	5		
Owl, Abyssinian Long-eared	*Asio abyssinicus*	1	1	1	2	5		
Owl, Pearl-spotted	*Glaucidium perlatum*	1	1	1	2	5		
Owl, Pel's Fishing	*Scotopelia peli*	1	1	2	1	5	VU	

Table 1. Continued.

COMMON NAME	SCIENTIFIC NAME	DISTRIB. AND ABUND.	POPULAT. BIOLOGY	BREEDING BIOLOGY	FEEDING ECOLOGY	SPECIES TOTAL	CONSERVATION STATUS	
		PROPORTION OF STUDIES IN EACH SUBJECT AREA						
		11%	9%	26%	20%	13%	REGIONAL	GLOBAL
Owl, Sokoke Scops-	*Otus ireneae*	1	2	1	1	5	VU-RR	VU
Owl, Spotted Eagle-	*Bubo africanus*	1	1	1	2	5		
Owl, African Wood-	*Ciccaba woodfordii*	1	1	2	1	5		
Sparrowhawk, Little	*Accipiter minullus*	1	1	2	1	5		
Vulture, Palm-nut	*Gypohierax angolensis*	1	1	1	2	5		
Vulture, White-headed	*Trigonoceps occipitalis*	1	1	2	1	5	VU	
Snake-eagle, Black-chested	*Circaetus pectoralis*	2	1	2	1	6		
Hobby, African	*Falco cuvieri*	1	1	2	2	6		
Hawk, Bat	*Macheiramphus alcinus*	1	1	2	2	6	NT	
Owl, Cape Eagle-	*Bubo capensis*	2	1	1	2	6	VU	
Owl, White-faced Scops-	*Otus leucotis*	1	1	2	2	6		
Sparrowhawk, Ovambo	*Accipiter ovampensis*	1	1	3	1	6	NT	
Vulture, Egyptian	*Neophron percnopterus*	2	2	1	1	6	NT	
Vulture, African White-backed	*Gyps africanus*	1	1	2	2	6	NT	
Hawk-eagle, African	*Hieraaetus spilogaster*	1	1	4	1	7		
Eagle, Long-crested	*Lophaetus occipitalis*	2	1	2	2	7		
Owl, Barred	*Glaucidium capense*	4	1	1	1	7		
Vulture, Hooded	*Necrosyrtes monachus*	1	1	4	1	7		
Vulture, Rüppell's Griffon	*Gyps rueppellii*	4	1	1	1	7	NT	
Falcon, Peregrine	*Falco peregrinus*	1	1	3	3	8		
Goshawk, Dark Chanting-	*Melierax metabates*	1	1	3	3	8		
Goshawk, Pale Chanting-	*Melierax canorus*	1	1	3	3	8		
Harrier-hawk, African	*Polyboroides typus*	1	1	3	3	8		
Falcon, Lanner	*Falco biarmicus*	1	2	3	3	9		
Owl, Giant Eagle	*Bubo lacteus*	4	1	2	2	9		
Falcon, Red-necked	*Falco chicquera*	1	3	3	3	10	NT	
Goshawk, African	*Accipiter tachiro*	1	3	3	3	10		
Kestrel, Rock (Common)	*Falco tinnunculus*	2	2	3	3	10		
Kite, Black-winged	*Elanus caeruleus*	1	1	4	4	10		
Owl, Barn	*Tyto alba affinus*	1	1	4	4	10		
Owl, African Grass	*Tyto capensis*	1	1	4	4	10	VU	
Owl, Scops Eurasian-	*Otus scops*	1	1	4	4	10		
Eagle, African Crowned	*Stephanoaetus coronatus*	3	3	3	3	12	VU	
Eagle, Tawny	*Aquila rapax*	3	3	3	3	12		
Eagle, Wahlberg's	*Aquila wahlbergi*	2	2	4	4	12		
Harrier, African Marsh	*Circus ranivorus*	1	3	4	4	12	NT	
Sparrowhawk, Red-breasted	*Accipiter rufiventris*	3	3	3	3	12	NT	
Eagle, Martial	*Polemaetus bellicosus*	3	3	3	4	13	VU	
Kestrel, Greater	*Falco rupicoloides*	3	3	4	3	13	NT	
Owl, African Marsh	*Asio capensis*	4	1	4	4	13	NT	
Vulture, Lappet-faced	*Torgos tracheliotus*	4	4	3	3	14	NT	
Bateleur	*Terathopius ecaudatus*	4	4	4	4	16		
Vulture, Bearded	*Gypaetus barbatus*	4	4	4	4	16	EN	

Table 1. Continued.

Common Name	Scientific Name	Distrib. and Abund.	Popul. Biology	Breeding Biology	Feeding Ecology	Species Total	Conservation Status	
		Proportion of Studies in Each Subject Area						
		11%	9%	26%	20%	13%	Regional	Global
Eagle, African Fish-	*Haliaeetus vocifer*	4	4	5	4	17		
Eagle, Black (Verreaux's)	*Aquila verreauxii*	4	4	5	5	18		

Table 2. Knowledge rating scores (KRS) for distribution and abundance, population biology, breeding biology and feeding ecology of 22 endemic raptors of the western Indian Ocean islands. Species are listed in order of increasing KRS. KRS scores: 1 = anecdotal, speculative or unstudied; 2 = single nest and single year low sample size studies; 3 = multi-year local area studies; 4 = multi-year and >10 pairs; 5 = >10 pairs, >10 years or regional studies. Global conservation status (Collar et al. 1994): CR = Critical; EN = Endangered; VU = Vulnerable; NT = Near-threatened

Common Name	Scientific Name	Distrib. and Abund.	Populat. Biology	Breeding Biology	Feeding Biology	Species Total	Conservation Status
		Proportion of Studies in Each Subject Area					
		18%	10%	16%	6%	15%	Global
Falcon, Madagascar Cuckoo-	*Aviceda madagascariensis*	1	1	1	1	4	
Goshawk, Henst's	*Accipiter henstii*	1	1	1	1	4	NT
Harrier-hawk, Madagascar	*Polyboroides radiatus*	1	1	1	1	4	
Harrier, Réunion	*Circus maillardi*	1	1	1	1	4	NT
Kestrel, Aldabra	*Falco newtoni aldabranus*	1	1	1	1	4	
Kestrel, Madagascar	*Falco newtoni*	1	1	1	1	4	
Owl, Grand Comoro Scops-	*Otus pauliani*	1	1	1	1	4	CR
Owl, Malagasy Scops-	*Otus rutilus*	1	1	1	1	4	
Owl, Seychelles Scops-	*Otus insularis*	1	1	1	1	4	CR
Owl, White-browed	*Ninox superciliaris*	1	1	1	1	4	
Sparrowhawk, Anjouan	*Accipiter francesii pusillus*	1	1	1	1	4	
Sparrowhawk, Frances's	*Accipiter francesii*	1	1	1	1	4	
Sparrowhawk, Madagascar	*Accipiter madagascariensis*	1	1	1	1	4	NT
Serpent-eagle, Madagascar	*Eutriorchis astur*	2	1	1	1	5	CR
Owl, Anjouan Scops	*Otus rutilus capnodes*	2	1	1	1	5	CR
Owl, Madagascar Long-eared	*Asio madagascariensis*	1	1	1	2	5	
Kestrel, Banded	*Falco zoniventris*	2	1	2	2	7	
Owl, Madagascar Red	*Tyto soumagnei*	2	1	2	2	7	EN
Buzzard, Madagascar	*Buteo brachypterus*	3	1	4	4	12	
Kestrel, Seychelles	*Falco araea*	4	4	4	4	16	VU
Fish-eagle, Madagascar	*Haliaeetus vociferoides*	5	4	4	4	17	CR
Kestrel, Mauritius	*Falco punctatus*	5	5	5	4	19	EN

post-1980 shift in the proportion of studies from east Africa to southern Africa may be partly due to the death in 1980 of Leslie Brown who contributed almost a quarter of all pre-1980 articles from east Africa.

Of the four subject areas reviewed, breeding biology (26%) was best studied in the African raptors, followed in descending order by feeding ecology, factors affecting distribution and abundance, and population biology (Table 1). Indian Ocean island species were mostly less well-studied than continental species, but scored higher in factors affecting distribution and abundance (18%), followed in descending order by breeding biology, population biology, and feeding ecology (Table 2). There was little difference in species' total scores between continental species (13%, Table 1) and Indian Ocean island species (15%, Table 2), both of which indicate our knowledge is substantially incomplete. Breeding biology may be the most often studied aspect of raptor ecology on mainland Africa because there are many large species, often inhabiting open landscapes, that build large conspicuous nests which are used year after year, thus facilitating observations on nesting behavior. The relatively small sizes of the Indian Ocean islands perhaps enable a better and more accurate survey of distribution and abundance of island raptors. The fact that many Indian Ocean island species are Threatened may also have contributed to an interest in distribution and abundance studies. Population trends and demographic parameters were least studied in both regions (Tables 1 and 2) possibly being the most difficult kind of studies to complete. Monitoring and understanding population changes is probably the most important kind of knowledge needed for species that are in jeopardy.

Of 79 species that breed in the east African tropics, five (6.3%) scored a total KRS > 14 and could be said to be Well Known, eight (10.1%) scored from 11–13 and might be considered Known, 18 (22.8%) were rated Unknown in at least two subject areas, and may be considered Little Known, while the majority 48 (60.8%) were rated Unknown in all four subject areas (Table 1). Well Known species were large and charismatic, or locally threatened such as the Lappet-faced Vulture (*Torgos tracheliotus*), Bearded Vulture (*Gypaetus barbatus*), Bateleur (*Terathopius ecaudatus*), African Fish-eagle (*Haliaeetus vocifer*), and Black Eagle (*Aquila verreauxii*) (Table 1).

Almost 40% of all the breeding raptors in Africa have been placed in a recently compiled east African list of birds in jeopardy (Table 1, Bennun and Njoroge 1996). This regional list, comprising species found in Kenya, Uganda, Tanzania, Rwanda, and Burundi, was compiled to give more detailed resolution of conservation priorities in these countries and to set a regional agenda for research, monitoring, and conservation. Of the 30 breeding raptors listed in jeopardy in the east African region, one species is listed as Endangered, 14 as Vulnerable, and 15 as Near Threatened (Table 1). In contrast, only seven of the 79 breeding African species were listed as globally Threatened (Table 1, Collar et al. 1994). This substantial difference is because many raptors have continental ranges which make their global (but not necessarily regional) status more secure. There may also be a regional awareness that raptor populations are declining because once-common species are not seen as frequently as they were within memory, but data are lacking. It may also reflect an inherent problem of categorizing a species' status based on standard criteria for which data are almost invariably lacking, especially on a global scale.

Species considered globally Vulnerable or Near Threatened that rated as Unknown in our KRS and, therefore, should be targeted for study included Southern Banded Snake-eagle (*Circaetus fasciolatus*), Albertine Owlet (*Glaucidium albertinum*), Congo Bay-owl (*Phodilus prigoginei*), Pemba Scops-owl (*Otus pembaensis*), Usambara Eagle-owl(*Bubo vosseleri*), and Taita Falcon (*Falco fasciinucha*) (Table 1). The Sokoke Scops-owl (*Otus ireneae*), previously listed as Endangered (Collar and Stuart 1985) but now listed as Vulnerable (Collar et al. 1994, Bennun and Njoroge 1996), was rated Unknown, but a recent study has increased our knowledge of this bird to at least Known in all four subjects (Virani 1995a).

Of 22 endemic Indian Ocean island species, only three (14%) rated as Well Known (Table 2). The majority of species (83.6%) were rated Little Known or Unknown (Species Total ≤ 10, Table 2). The Endangered Mauritius Kestrel (*Falco punctatus*) and the Vulnerable Seychelles Kestrel (*Falco araea*) were considered Well Known. The Endangered Madagascar Fish-eagle (*Haliaeetus vociferoides*) was rated Known but recent studies have raised our knowledge level to Well Known (Watson et al. 1996, Rafanomezantsoa 1997, Watson 1997, Watson et al. 1997). Half of the endemic raptors

of the Indian Ocean islands were listed at some level of global jeopardy (Collar et al. 1994). Of these, five were listed as Critically Endangered, two as Endangered, one as Vulnerable, and three as Near Threatened (Table 2).

Among the Unknown species that should be targeted for study were the Endangered Grand Comoro Scops-owl (*Otus pauliani*), Seychelles Scops-owl (*Otus insularis*), Anjouan Scops-owl (*Otus capnodes*), and Anjouan Sparrowhawk (*Accipiter francesii pusillus*) (Table 2). Two notable recent rediscoveries, the Madagascar Serpent-eagle (*Eutriorchis astur*) and Madagascar Red Owl (*Tyto soumagnei*), have changed the species' status from possibly extinct to extant (Halleax and Goodman 1994, Thorstrom et al. 1995); they were listed as Critically Endangered and Endangered, respectively (Collar et al. 1994). Studies on the Madagascar Red Owl in 1994–95 provided first data on breeding and diet (Thorstrom et al. 1997, Thorstrom and René de Roland 1997) so that the species could be rated as Known in two subject areas.

Threats to Raptors. The main threats facing raptors in the east African tropics can be summarized as rapidly changing land-use patterns resulting from an increase in human population size (Sorley and Andersen 1994). The precise impacts of changing land uses on breeding and migrant raptors are species specific. In general, anthropogenic habitat alteration can influence raptor distribution and abundance through direct changes in habitat characteristics, such as availability of suitable nesting and perching sites (Enderson 1964, Marion and Ryder 1975, Stahlecker 1978, Janes 1984), or indirectly through changes in prey abundance and availability (Baker and Brooks 1981). In east Africa, we believe that four main factors affect raptor density and diversity as a result of changes in habitat that accompany human land-use pressures: (1) overgrazing by domestic livestock resulting in the alteration of original vegetative cover that affects prey abundance and distribution (Sorley and Anderson 1994); (2) impact of cultivation that completely replaces native vegetation and involves the use of pesticides and fertilizers potentially toxic to raptors and other vertebrates (Sorley and Anderson 1994); (3) human hunting pressure that diminishes prey populations (Sorley and Anderson 1994); and (4) direct human persecution (Keran 1981) with resulting changes in behavior (Knight et al. 1989), species abundance and diversity (Craighead and Mindell 1981), and indirect persecution through secondary poisoning as in Kenya (Thomsett pers. comm.).

Threats to raptors on the Indian Ocean islands are similarly related to increasing human populations but they tend to be more extreme because of the limited area of islands, limited potential for dispersion of both humans and raptors, and high degree of endemism among island raptor species. Threats to raptors depend on the human colonization history, the faunal community, and the set of conservation problems that are unique to each island. For these reasons we will describe the conservation issues in some detail for each island separately.

Madagascar, the largest of the Indian Ocean islands (587 000 km^2), supports 22 species of diurnal and nocturnal birds of prey. All except two of these breed on Madagascar. Eleven species, 10 of which are found in forest habitats and one in wetlands and coastal areas, are endemic to the island. Subfossil remains indicate that two *Aquila* species existed on Madagascar during the Quaternary (Goodman and Rakotozafy 1995) and a *Stephanoaetus* species has been identified from the Holocene (Goodman 1994), but neither genus now survives on Madagascar. The island was relatively recently colonized by humans who are known to have been present since 1890 ± 90 B.P. (MacPhee and Burney 1991). With a current human population of about 14 million, a population growth rate of 3.1% per year and per capita income around $230 per year (World Bank 1992), the major threats to raptors, their habitats, and most other biota are driven by the subsistence needs of the human population. The greatest single threat to extant endemic raptors is from human induced habitat modification that renders forest or wetland habitat unsuitable for them. Clearing of eastern rainforest by slash-and-burn agriculture was estimated to occur at an average rate of 111 000 ha/year from 1950–85 when 3.8 million ha (34% of original forest cover) remained (Green and Sussman 1990). Most of the western dry deciduous forests have been replaced by relatively sterile savanna, but deforestation continues in the west when deliberate grassland fires escape into forest areas. Loss of wetlands due to drainage and modification for production of rice continues and protection of remaining wetlands is unpopular because of the need to put new areas into production. Only one significant wetland exists within a protected area

(Lake Tsimanampetsotsa, Langrand and Goodman 1995).

Habitat conservation is the single most important priority in Madagascar, with greater emphasis on wetlands than has been achieved to date. Management of wild populations of certain species, like the Madagascar Fish-eagle (Watson 1997), may also be needed in the near future, and captive breeding may be required not long after that. In the long term, however, sustainable agriculture and agroforestry to provide local inhabitants with needed food, fuel and fiber, accompanied by a reduction of population growth, are among the prerequisites for effective conservation. Addressing social and economic needs of local peoples are needed if conservation is to succeed. For example, ways to enhance local traditional rules and taboos are being explored to achieve conservation of habitats in the absence of protected areas (Razandrizanakanirina and Watson 1997).

Besides habitat loss, raptors are persecuted, especially in the west where we know nestlings of Madagascar Fish-eagle have been taken for food or as pets and adults have been killed. Given the low population size and low productivity of this species (Watson et al. 1997), the loss of just a few nestlings and adults each year has a significant impact on the species' survival (Watson 1997). Much persecution occurs out of ignorance about the value and rarity of species so increased public awareness is urgent.

The Seychelles comprise three large islands, the largest of which is Mahé (145 km^2), and numerous others. It supports two endemic raptors, the forest dwelling Seychelles Kestrel with a world population of about 420 pairs on Mahé, Silhouette and through reintroduction on Praslin, as well as some satellite islands (Watson 1989), and Seychelles Scops-owl with a population of perhaps 80 pairs all in highland forests on Mahé. Threats to the kestrel were loss of suitable habitat on Praslin in the 19th and early 20th centuries, and human persecution. Public awareness, enforcement of bird protection laws, and banning of private ownership of firearms has inhibited illegal shooting (Watson 1981), while habitat recovery on Praslin has allowed the reintroduction of the species to this island. Much of the present day highland forest habitat (secondary growth) of the Seychelles Scops-owl is incorporated in the Morne Seychellois National Park. A better understanding of the species' food and nesting requirements is needed to assess the effects of logging outside the protected area. Monitoring of small island populations is clearly desirable because of their susceptibility to extinction from random catastrophic events as well as human induced change.

Four volcanic islands form the Comoro archipelago (Ngazidja or Grand Comoro, Ndzuani or Anjouan, Mwali or Moheli, and Maore or Mayotte). Each island supports its own, mainly forest dwelling avifauna (Louette and Stevens 1992). Humans arrived perhaps 1000 years ago and deforestation on lowland coastal areas is complete. Most endemic species remain only in higher altitude forest and tree-heath on top of Mt. Karthala on Ngazidja and on Mwali. Little to no forest remains, even at high altitudes, on Ndzuani and Maore. The only remaining endemic raptor species are the Grand Comores Scops-owl (Karthala Scops-owl) and Anjouan Scops-owl. The latter was rediscovered on Ndzuani in 1992 having not been recorded with certainty since about 1886 (Safford 1993). It is found only in a few remaining patches of upland forest (above 800 m) where the population is estimated as probably 100–200 pairs. The species is endangered by forest clearance and capture for food by people. Safford (1993) recommended an investigation of the feasibility and consequences of the species' introduction to neighboring island of Mwali, as this may be the species' only hope for survival. The Grand Comores Scops-owl is confined to forest (virgin through degraded and small patches) between 1000–1900 m on Mt. Karthala on Ngazidja (Herremans et al. 1991). A 1989 study estimated that there was perhaps more than 1000 pairs on the island assuming 10 000 ha of suitable habitat and a territory size of about 5 ha for each owl pair. Although encouraging, the data are tenuous and there remains the long-term threat of habitat loss through forest fragmentation from fires, logging, and clearing for pasture. The spread of the introduced Indian Myna (*Acridotheres tristis*) as forest is opened is also a threat to endemic species from competition and other interspecific interactions.

Various subspecies of Frances's Sparrowhawk (*A. francesii*) are found on the Mascarene islands. *A. francesii francesii* occurs on Madagascar, but on Comores it is represented by three subspecies, none of which are present on Mwali. *A. francesii griveaudi* is found on Ngazidja but is not common (del Hoyo et al. 1994), *A. francesii pusillus* on Ndzuani was once common but is now probably close to extinc-

tion due to hunting (Louette and Stevens 1992), and *A. francesii brutus* on Maore is common on the moist west side (del Hoyo et al. 1994). Rainforest protection wherever it occurs is the highest conservation priority on the Comores. Remaining forest is modified by firewood collecting, timber extraction, understory clearing for vegetables and crops, and cattle grazing. The creation of a forest reserve on Mt. Karthala would protect habitat for four endemic birds (Louette and Stevens 1992) and similar habitat protection may be feasible on Mwali where the human population is still low. There is little hope for establishing a reserve on Ndzuani due to population pressure. Control of hunting which may affect raptors, control of animal introduction, and public education are also high priorities (Louette and Stevens 1992), as are investigations into introduction of the Anjouan Scops-owl to Moheli and protection of specific nest sites on Ndzuani.

The island of Mauritius (1843 km^2) was covered with native forest when Europeans first began to settle on it near the end of the 17th century (Vaughan and Wiehe 1937), but destruction for lumber, firewood, and agricultural land was massive. Habitat loss, hunting, and introduced species probably contributed to the demise of the Mauritian Owl (*Scops commersoni)* along with the Dodo (*Raphus cucullatus*) and other fauna during the 18th century (Diamond 1987). Today only small, highly degraded vestiges of forest remain on rugged uplands, principally Black River Gorges (Cheke 1987, Jones and Owadally 1988). Loss of native forest, use of organochlorine pesticides, and predation by introduced species undoubtedly contributed to the decline of the Mauritius Kestrel which, in 1974, was reduced to just four wild birds confined to about 4000 ha of native forest (Cade and Jones 1993). Captive breeding and management in the wild has returned the population size to 56–68 breeding pairs and 222–286 individuals (end of 1993–94 breeding season) and there is reason to hope that the population may rise to 200–250 pairs occupying degraded or even exotic forest-like habitats (Jones et al. 1994).

Réunion is a volcanic island of 2510 km^2 that lies 800 km east of Madagascar and 200 km west of Mauritius. Colonized and still run as a Department by the French, some endemic fauna are known to have become extinct from hunting and the effects of introduced species. The history of human destruction of native vegetation parallels that of Mauritius, but was somewhat constrained by the very rugged topography. A proportionately larger area of native forest remains uncut, but nearly all of it is over 500 m and most over 1000 m elevation (Diamond 1987). Currently 35% of the land surface is forest and woodland, 26% agricultural, and the remaining is listed as "other." The only raptor known to breed is the Réunion Harrier (*Circus maillardi*) that is also found on Madagascar and Comores. Today, the species persists in exotic vegetation. It suffered a severe post-war decline but has increased since banning DDT. Introduction of special protection in 1966 to reduce persecution seems ineffective (Thiollay pers. comm.). There is compelling evidence of a yet undescribed Scops Owl in the forests (Bretagnolle and Attié 1996) that needs investigation.

Conservation and Study Recommendations. Conservation needs of island fauna and flora are generally more urgent than continental species, except where limited distributions on continents mimic the island situation (e.g., Sokoke Scops-owl, Virani 1995a, 1995b). Conservation needs for raptors on the Indian Ocean islands are variable depending on the island, but they have the following priorities in common: conservation of native habitats, prevention of exotic species introduction and control of existing introduced exotics, and prevention of direct exploitation, persecution, and interference. Conservation needs for raptors in the east African tropics include protection of habitat especially where species' distributions are limited to small habitat patches, such as the Sokoke Scops-owl, control of environmental contaminants, and control of persecution through public education and awareness. In particular, because raptors typically need very large ranges in which to forage and survive, current national parks may not be sufficient to maintain viable raptor populations. It is important, therefore, to develop a "living with wildlife" ethic among people that will allow coexistence of raptors on land shared with people. Where conservation organizations and individual expertise are absent or poorly developed, such as in Madagascar and Comores, we recommend development of local capacity through training at technician through doctoral level, technical advising, and provision of material and financial resources (Watson and Lewis 1994).

For raptors rated as Little Known and at least Threatened (Tables 1 and 2), priority should be given to studies that collect the information need-

ed to determine the best course of action to reduce the probability of the species' extinction. Such studies include, but are not limited to, the following: (1) measuring the species' population size and distribution (e.g., Sokoke Scops-owl [Virani 1995a, 1995b]) to include genetic distribution if subpopulations exist that are small and disjunct; (2) understanding the species' nesting and foraging habitat needs (e.g., Madagascar Fish-eagle [Berkelman 1997] and Madagascar Red Owl); (3) monitoring population trends, productivity, survival to maturity and adult survival (e.g., Madagascar Fish-eagle [Watson et al. 1997]); (4) understanding breeding and other behaviors that may affect the species' ability to recover from low population size (e.g., Madagascar Fish-eagle [Watson et al. 1997]); (5) understanding movements including migration and natal dispersal (e.g., Madagascar Fish-eagle [Rafanomezantsoa 1997]); and (6) understanding the effects of human persecution and other anthropogenic effects (e.g., Madagascar Fish-eagle [Watson 1997]. In addition to study of Little Known Threatened species, in a few cases that are Known, such as the Madagascar Fish-eagle, Grand Comores Scops-owl, or Anjouan Scops-owl, we endorse urgent protection of key breeding sites, and, as needed, preliminary use of wild population management to increase the population size and reduce the risk of extinction (Louette and Stevens 1992, Safford 1993, Watson et al. 1996, Watson 1997). Wetlands and the water-forest ecotone in Madagascar need focused conservation efforts if they are to survive (Watson 1997). Efforts to protect significant blocks of remaining rainforest in Madagascar (e.g., Projet Masoala 1995, which used the area estimated for a viable population of Madagascar Serpent-eagles to help justify the size of protected area) are important for the survival of the Madagascar Serpent-eagle, Madagascar Red Owl, and other forest species and should be encouraged and duplicated wherever possible.

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