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Rapid assessments and local knowledge reveal high bird diversity in mangroves of north-west Madagascar

Charlie J. Gardner[1,2*], Zo Andriamahenina[1], Aude Carro[1], Trevor G. Jones[1] and Louise D. Jasper[1]

1 Blue Ventures Conservation, Level 2 Annex, Omnibus Business Centre, 39-41 North Road, London N7 9D, UK.

[2] Durrell Institute of Conservation and Ecology (DICE), School of Anthropology and Conservation, University of Kent, Canterbury, Kent, CT2 7NR, UK.

* Corresponding author. Email cg399@kent.ac.uk

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Abstract

Although the importance of regulating and provisioning services provided by mangroves is widely recognised, our understanding of their role in the maintenance of terrestrial biodiversity is patchy globally and largely lacking for many regions, including conservation priorities such as Madagascar. We carried out the first multi-site bird inventory of mangroves in Madagascar and complemented our data with assessments of local knowledge, in order to broaden our knowledge of which species use this habitat. We directly observed 73 species across three sites in Ambanja and Ambaro Bays, while local respondents indicated the presence of 18 additional species: four observed species are globally threatened, while 37 are endemic to Madagascar or the Malagasy region. Over half the species observed are typically terrestrial, of which 22 have not previously been recorded in mangrove habitats in Madagascar. Local knowledge provided a useful complement to our observed data but we are likely to have underestimated total richness; nevertheless, our findings greatly increased our knowledge of mangrove use by Madagascar's birds. However, further research is required to investigate the functional role of mangroves in the ecology of the observed species and provide insights into the factors influencing mangrove use.

Keywords: Biodiversity; Blue Forests, Coastal environment; Conservation; Inventory; Traditional Ecological Knowledge (TEK)

Introduction

Mangroves are vegetated ecosystems growing in intertidal areas of sheltered tropical and subtropical coastlines worldwide. They are amongst the most threatened of all tropical ecosystems (Duke et al. 2007; Valiela et al. 2001) having lost approximately 20-35% of their global extent since 1980 (FAO 2007; Polidoro et al. 2010; Valiela et al. 2001) as a result of

natural and anthropogenic processes including conversion to agriculture and aquaculture, overharvesting, and altered hydrological dynamics arising from upstream land use change (Gilman et al. 2008; Gopal and Chauhan 2006; Primavera 2000, 2006; Walters et al. 2008).

Mangroves have attracted increasing attention from conservation and climate change mitigation programmes in recent years due to the valuable ecosystem services they provide, in particular carbon sequestration and storage (Lafolley and Grimsditch 2009; Nellemann et al. 2009; Ullman et al. 2012): indeed the combined above- and below-ground carbon storage of mangroves greatly exceeds that of many terrestrial tropical forest systems (Donato et al. 2011; Kauffman et al. 2011, 2014; Pendleton et al. 2012; Wang et al. 2013). In addition, mangroves play an important role in coastal protection and erosion prevention (Alongi 2008; Dahdouh-Guebas et al. 2005), and provide breeding and feeding grounds for a range of marine species (Kathiresan and Bingham 2001; Nagelkerken et al. 2008) including commercially important fish and crustaceans (Manson et al. 2005; Naylor et al. 2000). Around the world many human populations in coastal areas depend heavily on mangroves for their subsistence and household income (Glaser 2003; Rasolofo 1997; van Bochove et al. 2014).

Although the socio-economic and ecosystem regulating contributions of mangrove systems are now widely recognised, our understanding of their importance for terrestrial biodiversity remains patchy at the global scale, and even basic knowledge of the species occurring in mangroves is largely lacking for many areas (Nagelkerken et al. 2008). This knowledge gap is important because information on the distribution of biodiversity is fundamental to conservation planning (Ferrier 2002; Pressey et al. 2007). Madagascar is a global conservation priority harbouring an unparalleled combination of diversity and endemism

among its terrestrial fauna and flora, particularly at higher taxonomic levels (Brooks et al 2006; Holt et al. 2013), but is amongst the countries where mangrove use by terrestrial biodiversity remains little researched. With around 213,000 ha of mangroves in 2010, Madagascar possesses approximately 2% of their global area and is amongst the top 15 most mangrove rich countries in the world (FAO 2007; Giri and Mulhausen 2008; Giri et al. 2011), but despite this we know little about the extent to which these ecosystems are used by the island's (largely endemic) terrestrial fauna. Knowledge of bird occurrence in Madagascar's mangroves is limited to two single site inventories (Gardner et al. 2012; Razafindrajao et al. 2002), a small number of single species studies (e.g. Andrianarimisa and Razafimanjato 2012; Razafimanjato et al. 2014) and miscellaneous short reports (e.g. Appert 1970; Woolaver et al. 2004). Since the first step in understanding the use of mangroves by birds is to know which species occur in them, we seek to broaden our knowledge base with a rapid ornithological assessment of three sites in the Ambanja and Ambaro Bays mangrove in north-west Madagascar, which constitutes the largest continuous mangrove system in Madagascar (Jones et al. 2016a). Since rapid inventories may fail to detect rare or seasonal events or species (Anderson et al. 2007; van der Hoeven et al. 2004), we complement our data with an evaluation of the local ecological knowledge (LEK) of fishers and mangrove users in order to provide a more complete picture of the avian diversity of our study system.

Methods

Study site

The Ambanja and Ambaro Bays in northwest Madagascar are lined with mangroves totalling 45,680 ha, of which 14,015 ha in closed-canopy and 31,665 in open-canopy ecosystems (Jones et al. 2014). The climate is sub-humid tropical with a warm rainy season and frequent cyclones from November–April, and a cooler dry season in May–October (Rasolofo and

Ramilijaona 2009). The underlying geology is composed primarily of alluvial and lake deposits, and the relative abundance of rainfall and freshwater contributes to a high stature of mangrove trees compared to equivalent systems in western Madagascar (Giri and Mulhausen 2008; Jones et al. 2014). As with all of Madagascar's mangroves, the ecosystem is relatively species-poor and is composed of eight true mangrove species: *Avicennia marina* (white mangrove), *Bruguiera gymnorrhiza* (orange mangrove), *Ceriops tagal* (Indian mangrove), *Rhizophora mucronata* (red mangrove), *Sonneratia alba* (mangrove apple), *Xylocarpus granatum* (cannonball mangrove), *Lumnitzera racemosa* (black mangrove) and *Heritiera littoralis* (looking-glass mangrove). Mangroves throughout the area are the focus of extensive artisanal fishing and resource extraction activities (Rasolofo 1997) and are threatened by deforestation, having lost 20% of their area in the period 1990–2010 as a result of timber exploitation and charcoal production (Jones et al. 2014, 2016b).

We surveyed three sites (Antsahampano, Ankazomborona and Ankatafa) currently the subject of community-based mangrove management initiatives within conservation programs led by the international non-governmental organisations WWF, l'Homme et l'Environnement and Blue Ventures (Fig.1). All sites are governed under a GELOSE management transfer contract (see Pollini et al. 2014), and managed by an association of local resource users called a *Communauté Locale de Base* (CLB).

[FIGURE 1]

Bird surveys

We carried out ornithological surveys at each site towards the end of the rainy season in 2015 (Antsahampano, 11th–12th March; Ankazomborona, 18th–21st April; Ankatafa, 22nd–24th

April). At each site we attempted to sample different parts of the mangrove (seaward side, small and large channels, back mangrove) approximately equally, but were constrained by tides which restricted accessibility. In order to maximise the diversity of species recorded at each site we also visited areas said by local respondents (mangrove users and CLB members) to be rich in birds or frequented by particular species of interest (e.g. IUCN Red List species). Transects were primarily water based, using a motor boat at Antsahampano and traditional dugout pirogues (*lakana*) at the other two sites, and were largely carried out during high tides to permit entry into shallow channels. Where possible we also surveyed transects on foot along the terrestrial edge of the mangrove (back mangrove), but we did not penetrate dense mangrove stands on foot (Fig. 1; Table 1). During transects we noted all visual and auditory contacts with birds from within or above mangroves, in mangrove channels or immediately adjacent to mangroves on the seaward side (including on exposed mudflats dotted with mangrove trees, at low tide), but did not record species observed only in terrestrial habitats immediately adjacent to mangroves on the landward side (e.g. dead zones, secondary scrub, grasslands, freshwater wetlands, agriculture and native forests). We scored the relative abundance of each species using an index based on the percentage of transects in which the species was recorded (Rare = recorded in < 25% of transects; Uncommon = recorded in 25-50% of transects; Frequent = recorded in 50-75% of transects; Common = recorded in > 75% of transects).

[Table 1]

Assessment of local knowledge

The expert knowledge of local resource users who spend significant periods of time within a study system can be a reliable and cost effective complement or alternative to directly

observed data (Anderson et al. 2007; Danielsen et al. 2014; Turvey et al. 2014; van der Hoeven et al. 2004), particularly given the high costs of, and rapidly diminishing returns from, increased inventorying (Gardner et al. 2008; Grantham et al. 2008). As such, the integration of traditional and scientific knowledge systems to inform environmental management has been widely promoted (Raymond et al. 2010; Sutherland et al. 2014; Tengö et al. 2014; Thaman et al. 2013). In order to provide a fuller picture of bird occurrence in mangroves than can be provided by rapid inventories alone, we ascertained local knowledge using two methods, 'walking interviews' (also known as 'walk-in-the-woods interviews') (Thomas et al. 2007), and structured focus group interviews (Diamond 1991; Bernard 2006).

Walking interviews were carried out during all survey transects, which were accompanied by 1–4 members of the local CLB management committee, by systematically asking our respondents for the local names of all birds encountered either visually or aurally. We also used these interviews to ascertain the knowledge of respondents and thus their suitability as expert respondents for further enquiries. Subsequently, we carried out focus group interviews with participants selected on the basis of their knowledge of birds and their familiarity with mangrove environments; respondents (n = 3 at Antsahampano, n= 7 at Ankazomborona and n = 4 at Ankatafa) thus largely comprised CLB members and mud crab (*Scylla serrata*) fishers, who spend more time in the mangroves than fishers targeting other resources. Focus group interviews were facilitated by the use of an illustrated field guide (Sinclair and Langrand 1998) and MP3 recordings of bird calls and song (Huguet and Chappuis 2003). For each species thought to occur in the region and potentially occurring within mangroves, we showed respondents an image of the species and simultaneously played its call/song on a small loudspeaker. If respondents recognised the bird, we asked them to describe aspects of its appearance, behaviour, habitat use or life history in order to corroborate their

identification. If the bird was not initially recognised, we prompted respondents by describing aspects of its appearance, size, behaviour or other identifying characteristics (Diamond 1991), or by offering local names already ascertained from walking interviews: if respondents recognised the description, we again sought to corroborate their identification by asking them to describe additional characteristics of the species in question. For all species known to respondents, we asked for its name (specifying that we were interested in the local name rather than that from other villages or regions), and whether they had ever seen it in mangroves; when affirmative responses were provided, we further enquired about its regularity and behaviour within this environment.

Results

We recorded 73 species by direct observation across the three sites, either within or above mangroves or immediately adjacent to them on the seaward side (Table 2). An additional 18 species were not observed but were reported to occur within mangroves by respondents. Four observed species are globally Endangered (EN) or Critically Endangered (CR) (Madagascar fish-eagle *Haliaeetus vociferoides*, CR; Madagascar heron *Ardea humbloti*, EN; Madagascar pond-heron *Ardeola idae*, EN and Madagascar teal *Anas bernieri*, EN), while two additional EN species were reported by respondents (Madagascar sacred ibis *Threskiornis bernieri* and Van Dam's vanga *Xenopirostris damii*) (IUCN 2015).

[Table 2]

In terms of principal habitats utilised, over half of observed species (54.8 %) are terrestrial, i.e. inhabitants of forests, scrublands or open areas rather than seabirds, shorebirds and wetland specialists. Eighteen observed species (24.7 %) are endemic to Madagascar,

including four species belonging to endemic genera (Common jery *Neomixis tenella*, stripe-throated jery *N. striatigula*, Madagascar starling *Hartlaubius auratus* and Madagascar mannikin *Lepidopygia nana*), one belonging to an endemic subfamily (crested coua *Coua cristata*) and five belonging to the endemic family Vangidae (common newtonia *Newtonia brunneicauda*, chabert vanga *Leptopterus chabert*, hook-billed vanga *Vanga curvirostris*, white-headed vanga *Artamella viridis* and sickle-billed vanga *Falculea palliata*). Two further Vangidae and cuckoo roller *Leptosomus discolor* of the monospecific endemic family Leptosomidae were also reported by informants, as well as two additional endemic species. Nineteen observed species are endemic to the islands of the western Indian Ocean (Madagascar and the Comoros, Seychelles and Mascarene archipelagos) and two are endemic breeders to the region; when added to the strict endemics, 53.4 % of observed species are endemic to some degree.

Discussion

Our data have revealed that a higher diversity of bird species than was previously recognised utilise the mangroves of north-west Madagascar, including a large proportion of terrestrial species that were not known to occur in this habitat. In addition to the 73 species we observed, 14 further species have been recorded in mangrove inventories elsewhere in Madagascar by Razafindrajao et al. (2002) and Gardner et al. (2012) and 12 more were reported by respondents in this study, indicating that at least 99 species (38.7 % of all species regularly occurring in Madagascar, Safford and Hawkins 2014) utilise this habitat. This figure places Madagascar in the lower ranks of global mangrove range states in which bird occurrence has been researched, with a greater richness than Trinidad (84 species, Ffrench 1966) and Surinam (94 species, Haverschmidt 1965), but lower than Guinea-Bissau (125 species, Altenberg and van Spanje 1989), and Peninsular Malaysia (135 species, Nisbet

230 1968). Australia has the highest diversity of mangrove birds including 186 species in
231 Queensland and 104 species in north-western Australia (Saenger et al. 1977). Species
232 richness at individual sites in Australia has been recorded at 54 and 70 at Darwin Harbour
233 (Noske 1996; Mohd-Azlan et al. 2012) and 47 in Cairns (Kutt 2007); however groups such as
234 migratory shorebirds, herons and aerial insectivores were not included in these studies.
235
236 However, both our observations and our assessment of local knowledge are likely to have
237 underestimated diversity for a number of reasons. First, we carried out our surveys at the end
238 of the breeding season for most species, reducing the detectability of terrestrial birds that
239 were not singing, while many migratory species, particularly shorebirds (Scolopacidae and
240 Charadriidae), would be expected to be absent when surveying was carried out (or present in
241 highly reduced numbers). In addition, although respondents were consistently able to
242 differentiate between terrestrial species on the basis of images and calls, they tended not to
243 differentiate between species in certain species-rich groups of similar looking (and less vocal)
244 species (e.g. shorebirds, terns and other seabirds) and were thus unable to estimate the full
245 richness of these groups that they have observed in mangroves. As a result, our diversity
246 estimates should be considered conservative and further investigations could be expected to
247 reveal additional species.
248
249 While the use of mangroves by many coastal and wetland species is well known, our
250 observations of 40 terrestrial species using this habitat is significant because the majority of
251 these species are endemic or regionally endemic, and over half (22 species) have not
252 previously been reported as using mangroves (Safford and Hawkins 2014). Since mangroves
253 are regularly inundated, have low plant species diversity and lower invertebrate diversity and
254 biomass than terrestrial forests (Intachat et al. 2005; Nagelkerken et al. 2008), the use of

mangroves by these species is surprising given that Madagascar's endemic bird species tend to be habitat specialists (Wilmé 1996). However, many of these are relatively common and widespread species that, while forest-dependent, are relatively tolerant of habitat degradation and edge habitats and are therefore not highly threatened (Safford and Hawkins 2014). The most important species for conservation are the six observed or reported birds listed as Endangered or Critically Endangered by the IUCN. Of these none were observed regularly, and all but one (Madagascar heron) were reported as only infrequently seen by respondents; we recorded a pair of Madagascar fish-eagle mating near the village of Andrekareka (Ankatafa), three Madagascar pond-herons roosting among squacco herons (*Ardeola ralloides*) at Antsahampano, two Madagascar herons feeding in a large channel at Ankatafa, and three Madagascar teal near the village of Ankazomborona. The call of Van Dam's vanga was recognised by all informants at Ankazomborona and the bird was said to be relatively common in mangroves there, although we cannot rule out possible confusion with white-headed vanga and hook-billed vanga because informants sometimes confused these three species in the field and during interviews. Van Dam's vanga was also recognised by all informants at Ankatafa and was said to be relatively common in the adjacent terrestrial forests, but was not thought to occur in mangroves at that site (we did not enquire about this species at Antsahampano).

Our data should be interpreted with caution when considering the importance of mangroves for Madagascar's avifauna because the simple presence of a bird within a mangrove says little about the functional role of this habitat in the ecology of the species. Some largely pelagic species (e.g. terns, frigatebirds) may perch in mangrove trees and/or forage in deeper channels but primarily feed out at sea, while many shorebirds and wetland birds may roost and forage in mangroves but also feed in coastal areas lacking mangrove vegetation.

Amongst terrestrial species some may use mangroves for breeding (e.g. grey-headed lovebird *Agapornis cana*), roosting (e.g. Madagascar mannikin) or perching to sing (e.g. Madagascar hoopoe *Upupa marginatus*) but are unlikely to feed in this habitat due to their foraging ecology, while others forage over mangroves but are probably unable to roost or breed within them (e.g. swifts and Madagascar nightjar *Caprimulgus madagascariensis*) (Safford and Hawkins 2014). The persistence of many of species using the mangroves of the region may therefore depend on the maintenance of connectivity between them and adjacent terrestrial habitats (Nagelkerken et al. 2008; Noske 1996; Wells 1999). Overall Madagascar appears to lack any mangrove-dependent species among its terrestrial avifauna, although the Madagascar teal is an obligate mangrove breeder nesting only in holes in *Avicennia marina* trees (Young 2006; Young et al. 2013), and the habitat provides a stronghold for other threatened endemic species including Madagascar fish-eagle and Madagascar sacred ibis (Andrianarimisa and Razafimanjato 2012; Razafimanjato et al. 2014.

Although our pooled observations indicate that a high diversity of bird species utilise the mangroves of Ambanja and Ambaro Bays, our data cannot be used to infer the relative value of the three sites for bird conservation or prioritise between them because we were unable to ensure comparable research effort between sites. Since our transects were primarily carried out by boat our access into mangroves was limited by tides; we therefore spent variable amounts of time in different parts of the mangrove (e.g. small channels, main channels and the seaward edge) at each site, and this during different parts of the day when birds show variable activity and detectability. As a result, we are unable to produce rarefaction curves to estimate the completeness of sampling at each site. Observed differences in species diversity may be the result of differences in mangrove habitat structure or their proximity to terrestrial forests, but may also have arisen partially as a result of methodological differences: water-

based surveying in Antsahampano was carried out in a motor boat rather than a pirogue, which greatly reduced the detectability of terrestrial species (such as parrots, pigeons and passerines) which were often observed by call. However, this site was also surveyed a month earlier than the others, with the result that several migratory wader species were recorded which may already have been absent by the time Ankazomborona and Ankatafa were surveyed.

Our assessments of local knowledge of mangrove utilisation by birds provided a complementary data source to our direct observations and enabled us to generate a more complete picture of local mangrove bird diversity than would otherwise have been possible from a rapid inventory alone. For example, local respondents reported the presence of two Endangered species (Van Dam's vanga and Madagascar sacred ibis) that we did not observe directly. In addition, data from the bird survey alone may have suggested that Ankatafa was more important than the other sites as both Madagascar fish-eagle (CR) and Madagascar heron (EN) were recorded only there, though these species in fact occur at all three sites, as revealed by LEK. The method was rapid and cheap compared to boat-based field surveys, and we are confident in the reliability of the data collected in this way because we systematically sought corroborating evidence from our informants (Diamond 1991). However, use of this approach is dependent on the use of audio recordings of bird calls as well as visual aids since many species were more readily identified by respondents by their vocalisations than by images. The relative lack of distinctive vocalisations among seabirds and shorebirds compared to terrestrial species may partly explain why the former two groups tended to be lumped and known only by generic names, while the latter tended to be individually distinguished as species; thus the method appears more valid for some species groups than for others. In addition, the method requires an excellent knowledge of local birds

on the part of the interviewer, because corroborating enquiries involving species' behaviour and other identifying characteristics are necessary to ensure correct identification and thus the viability of respondent data (Diamond 1991).

In conclusion, we have carried out the most comprehensive assessment to date of mangrove utilisation by Madagascar's birds, and revealed that a previously unrecognised diversity of species use this habitat to some extent. Although these data are preliminary and tell us little about the functional importance of mangroves for the maintenance of species populations, the records of 39 species not previously reported from mangroves demonstrates that these ecosystems may support diverse bird communities in Madagascar and provides the first indication of the potential importance of mangroves for the species in question. Further research should build on these findings to better understand the conservation importance of mangroves for the country's avifauna. This should include i) further inventories of an expanded range of sites and in different seasons; ii) ecological research to better understand the functional role of mangroves in the maintenance of species populations (focused particularly on endemics and species of conservation concern); and iii) habitat selection studies focused on mangroves and adjacent terrestrial habitats, to understand differences in the ecological traits of bird species that do and do not utilise mangrove habitats. Such research would provide valuable insights into the ecological and behavioural factors influencing mangrove use by birds in Madagascar and worldwide.

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Figure 1 Map of study sites in north-west Madagascar showing vegetation cover and transect routes followed during rapid bird inventories. Mangrove vegetation cover is derived from Jones et al. (2014), and other vegetation classes from Harper et al. (2007). The background uses a true colour Landsat 8 image from 2014, at low tide.

632 **Table 1** Summary of bird survey transects carried out at three mangrove sites in Ambanja
633 and Ambaro Bays, March-April 2015. Water-based transects were carried out in a motorised
634 vessel and Antsahampano and non-motorised vessels at Ankazomborona and Ankatafa.
635

Site	Water-based transects		Terrestrial transects	
	No. transects	Total distance	No. transects	Total distance
Antasahampano	4	42.7	2	10.6
Ankazomborona	8	28.3	0	0
Ankatafa	9	13.4	3	2.0

636

Table 2 Bird species recorded in Ambanja and Ambaro Bays mangroves during March-April 2015. Birds identified by informants during assessments of local ecological knowledge (LEK) are indicated by a Y in the relevant column. Local names used at each site are indicated by a number (1, Antsahampano; 2, Ankazomborona; 3, Ankatafa); names not recorded in Safford and Hawkins (2014) are italicised. All species observed directly are denoted by a measure of relative abundance, defined as follows: Rare = observed on < 25% of transects; Uncommon = observed on 25-50% of transects; Frequent = observed on 50-75% of transects; Common = observed on >75% of transects. Terrestrial species (i.e. not seabirds, shorebirds or wetland species) are indicated in bold, while species not recorded in mangroves in Safford and Hawkins (2014) are denoted by an asterisk. EN, Endangered; CR, Critically endangered.

Scientific name	English name	Local name	Antsahampano		Ankazomborana		Ankatafa		Status
			Direct	LEK	Direct	LEK	Direct	LEK	
Phaethon lepturus	White-tailed tropicbird	*Samby* (3)						Y	*
Phalacrocorax africanus	Reed cormorant	*Mpangalamotimboay* (2, 3)				Y	Frequent	Y	
Anhinga rufa	African darter	*Fandalamotiboay* (1), *Mpangalamotimboay* (2)		Y[a]		Y			
Fregata minor	Great frigatebird	Bamonandry (2), *Gamonandra* (2), Monandry (1)		Y[b]	Rare[c]	Y[b]		Y[b]	*
Fragata ariel	Lesser frigatebird	Bamonandry (2), *Gamonandra* (2), *Monandry* (1)		Y[b]	Uncommon	Y[b]		Y[b]	*
Ardea cinerea	Grey heron	*Kisirano* (3), *Langaro* (2)			Frequent	Y	Frequent		
Ardea humbloti	Madagascar heron	*Kisirano* (1), *Langaro* (2), *Langaroko* (3)		Y		Y	Rare	Y	EN, Regional endemic
Ardea purpurea	Purple heron	*Kisirano* (3), *Langaro* (1, 2)	Frequent	Y		Y			
Ardea alba	Great egret	*Langaro* (1), *Langaroko* (2), *Langaroky* (2), Kilandibe (2)	Rare	Y	Common	Y	Common		
Ardea ibis	Cattle egret	Kilandy (1, 2)	Common	Y	Rare	Y			
Egretta ardesiaca	Black egret	Lombokoma (2)		Y[1]	Rare[d]	Y			
Egretta garzetta	Little egret	*Langaro* (1), *Langaroko* (2, 3), *Kilandy* (2)	Common	Y	Common	Y	Common		
Ardeola ralloides	Squacco heron	*Kilandigodra* (1)	Common	Y					

Ardeola idae	Madagascar pond heron	*Kilandigodra* (1)	Uncommon						EN, Breeding regional endemic
Butorides striata	Striated heron	Ambaramaty (1, 2)	Common	Y	Common	Y	Common		
Nycticorax nycticorax	Black-crowned night heron	*Rangoaka* (2), *Sonaka* (3), *Songake* (3), *Tambako* (3), *Tsimandrihaly* (2)	Uncommon	Y	Rare	Y			
Scopus umbretta	Hamerkop	Takatra (1)		Y[a]					*
Anastomus lamelligerus	African openbill	Famakiankora (1, 3)		Y	Rare[d]	Y			
Threskiornis bernieri	Madagascar sacred ibis	*Fitilibengy* (3), Voronosy (2)				Y[a]		Y	EN, Regional endemic
Platalea alba	African spoonbill	*Sadrosogno* (2), *Sadrovava* (2), Sotrosogny (2)			Uncommon	Y	Rare		
	Flamingo sp.	Samaky (2)		Y		Y			*
Dendrocygna viduata	White-faced whistling duck	Vivy (1, 2)		Y		Y			*
Sarkidiornis melanotos	Comb duck	Tsivongo (1, 2)		Y[1]		Y			
Anas bernieri	Madagascar teal	*Drakidrakirano* (2), Moreha (2)			Rare	Y			EN, Endemic species
Anas erythrorhyncha	Red-billed teal	*Drakidrakirano* (2)				Y			*
Milvus migrans	**Black kite**	**Papango (2, 3)**			**Frequent**	**Y**		**Y**	*****
Haliaeetus vociferoides	Madagascar fish eagle	Ankoay (1, 2)		Y[a]		Y	Frequent	Y	CR, Endemic species
Polyboroides radiatus	**Madagascar harrier-hawk**	**Fihiaka (1, 2), *Tinoro* (3)**		**Y**	**Uncommon**	**Y**		**Y**	**Endemic species**
Accipiter francesiae	**Frances's sparrowhawk**						**Rare**		**Regional endemic**
Buteo brachypterus	**Madagascar buzzard**	***Fihiaka* (3), *Tinora* (1), *Tinoro* (2)**	**Rare**	**Y**		**Y**	**Uncommon**	**Y**	*** Endemic species**
Falco newtoni	**Madagascar**	**Hitsikitsiky (2), Hitikitiky (3)**				**Y**	**Rare[e]**	**Y**	*** Regional**

	kestrel								**endemic**
Dryolimnas cuvieri	White-throated rail	Droviky (1, 2, 3)	Frequent	Y	Frequent	Y		Y	Regional endemic
Rostratula benghalensis	Greater painted-snipe	*Takoko* (1)		Y[a]					*
Dromas ardeola	Crab plover	Tsikiranta (1)	Rare	Y				Y	
Himantopus himantopus	Black-winged stilt	Tsikiranta (2)				Y			*
Pluvialis squatarola	Grey plover		Frequent		Frequent				
Charadrius marginatus	White-fronted plover	*Keliarivo* (2 – also generic small shorebirds)	Rare			Y			
Numenius phaeopus	Whimbrel	*Lakilosindrano* (2), Mantavazana (1, 3)	Common	Y	Common	Y	Common	Y	
Xenus cinereus	Terek sandpiper				Frequent				
Actitis hypoleucos	Common sandpiper	*Kitroitroy* (1)	Uncommon	Y			Rare		
Tringa nebularia	Common greenshank		Rare						
Arenaria interpres	Ruddy turnstone	*Kitroitroy* (1), *Lakilosindrano* (3 – also generic small shorebirds)	Frequent		Frequent		Uncommon		
Calidris ferruginea	Curlew sandpiper		Rare						
Thalasseus bengalensis	Lesser crested tern	Samby (1, 2, 3)	Common	Y[b]	Common	Y[b]	Common	Y[b]	*
Thalasseus bergii	Greater crested tern	Samby (1, 2, 3)	Common	Y[b]	Common	Y[b]	Frequent	Y[b]	
Sterna dougallii	Roseate tern	*Samby* (2)			Uncommon[c]	Y[b]			*
Sterna hirundo	Common tern	*Samby* (2)			Frequent	Y[b]			*
Nesoenas picturata	**Madagascar turtle dove**	**Domohina (2), *Domoy* (1, 2, 3)**	**Frequent**	**Y**	**Common**	**Y**	**Common**	**Y**	**Regional endemic**

Oena capensis	**Namaqua dove**	**Katoto (2)**	**Rare**	**Y**	**Uncommon**	**Y**			*****
Treron australis	**Madagascar green pigeon**	**Voronadabo (1, 2, 3)**		**Y**		**Y**		**Y**	**Regional endemic**
Agapornis cana	**Grey-headed lovebird**	**Karaoka (1, 2), Karaoko (2, 3)**		**Y**	**Common**	**Y**	**Common**	**Y**	*** Endemic species**
Coracopsis vasa	**Greater vasa parrot**	***Koera* (1, 2, 3)**		**Y**	**Rare**	**Y[b]**		**Y[b]**	*** Regional endemic**
Coracopsis nigra	**Lesser vasa parrot**	**Boeza (1), Koera (2, 3)**		**Y**	**Uncommon**	**Y[b]**		**Y[b]**	**Regional endemic**
Centropus toulou	**Madagascar coucal**	**Toloho (2, 3)**			**Rare**	**Y**	**Rare[6]**	**Y**	**Regional endemic**
Coua cristata	**Crested coua**	**Tivoky (3), Tivoka (3)**					**Uncommon**	**Y**	*** Endemic subfamily**
Cuculus rochii	**Madagascar cuckoo**	***Batankonko* (3), Taotaokafa (1), Tontonkafa (2)**	**Frequent**	**Y**	**Frequent**	**Y**	**Rare**	**Y**	*** Breeding endemic**
Otus rutilus	**Madagascar scops owl**	**Tontoroko (2, 3)**		**Y**	**Uncommon**	**Y**	**Rare**	**Y**	*** Endemic species**
Caprimulgus madagascariensis	**Madagascar nightjar**	***Dandara* (1, 2, 3)**	**Uncommon**	**Y**	**Uncommon**	**Y**	**Uncommon**	**Y**	*** Regional endemic**
Cypsiurus parvus	**African palm swift**	***Fitilidimaka* (1, 3)**					**Frequent**	**Y[b]**	*****
Tachymarptis melba	**Alpine swift**	***Fitilidimaka* (1)**			**Frequent**				*****
Apus barbatus	**African black swift**	***Fitilidimaka* (1, 3)**	**Rare**	**Y[b]**	**Rare**	**Y[b]**			*****
Corythornis vintsioides	Madagascar malachite kingfisher	*Bintsy* (1, 2), Vintsy (2)	Rare	Y	Common		Common		Regional endemic
Merops superciliosus	**Olive bee-eater**	**Tsikiriokirio (1), Tsikirikirigne (2, 3)**	**Frequent**	**Y**	**Common**	**Y**	**Common**	**Y**	*****
Eurystomus glaucurus	**Broad-billed roller**	***Jararaoko* (2, 3)**				**Y**		**Y**	*****
Leptosomus	**Cuckoo-roller**	**Kirombo (2, 3), Korombo (2)**				**Y[7]**		**Y[7]**	*** Endemic family**

discolour									
Upupa marginata	**Madagascar hoopoe**	**Birao (2), Biron (1, 2), Bron (3)**		**Y**		**Y**	**Rare**	**Y**	*** Endemic species**
Coracina cinerea	**Madagascar cuckoo-shrike**	**Kekemavo (1, 2, 3)**	**Rare**	**Y**	**Common**	**Y**	**Common**	**Y**	**Endemic species**
Hypsipetes madagascariensis	**Madagascar bulbul**	***Jokoreva* (1, 2, 3)**		**Y**	**Frequent**	**Y**	**Frequent**	**Y**	**Regional endemic**
Copsychus albospecularis	**Madagascar magpie-robin**	**Antodiana (1, 2, 3)**		**Y**	**Frequent**	**Y**	**Rare**	**Y**	*** Endemic species**
Terpsiphone mutate	**Madagascar paradise flycatcher**	**Siketry (1, 2), Sikitry (2)**		**Y**	**Common**	**Y**	**Common**		**Regional endemic**
Neomixis tenella	**Common jery**	***Sabero* (2)**		**Y**	**?**	**Y**	**Rare**		**Endemic genus**
Neomixis striatigula	**Stripe-throated jery**						**Uncommon**	**Y**	*** Endemic genus**
Cisticola cherina	**Madagascar Cisticola**						**Rare[f]**		*** Regional endemic**
Nesillas typical	**Madagascar brush warbler**	***Tretreky* (1, 2, 3)**				**Y**		**Y**	*** Regional endemic**
Acrocephalus newtoni	Madagascar swamp warbler	*Borediky* (1), Vorombararata (2, 3)		Y		Y		Y	* Endemic species
Nectarinia notata	**Madagascar green sunbird**	**Soimanga (2,3), Soy (2)**		**Y[b]**	**Rare**	**Y**		**Y**	**Regional endemic**
Nectarinia souimanga	**Souimanga sunbird**	***Soibery* (2), Soy (1, 2, 3)**	**Frequent**	**Y[b]**	**Common**	**Y**	**Common**		**Regional endemic**
Zosterops maderaspatanus	**Madagascar white-eye**	***Sabero* (1, 2, 3)**	**Rare**	**Y**	**Rare**	**Y**	**Rare**	**Y**	**Regional endemic**
Newtonia brunneicauda	**Common newtonia**	**Tretreky (1), *Sabero* (2)**	**Frequent**	**Y**	**Common**	**Y**	**Common**	**Y**	**Endemic family**
Cyanolanius madagascarinus	**Blue Vanga**					Y			**Endemic family**
Leptopterus chabert	**Chabert vanga**	***Maritsaramaso* (3), Tsaramaso (1, 2)**		**Y**		**Y**	**Rare[d]**	**Y**	**Endemic family**

Vanga curvirostris	**Hook-billed vanga**	***Vanga* (1, 2, 3)**	**Rare**	**Y**	**Uncommon**	**Y**	**Frequent**		**Endemic family**
Xenopirostris damii	**Van Dam's vanga**	***Vanga* (2), *Trotro* (2, 3)**				**Y**			**EN, Endemic family**
Artamella viridis	**White-headed vanga**	***Trotro* (2, 3)**	**Rare**	**Y**	**Common**	**Y**	**Common**		**Endemic family**
Falculea palliata	**Sickle-billed vanga**	***Voronzaza* (2, 3)**				**Y**	**Uncommon**	**Y**	**Endemic family**
Dicrurus forficatus	**Crested drongo**	***Lairovy* (3), *Lerovy* (2), Railovy (1, 2, 3), Relovy (3)**	**Rare**	**Y**	**Common**	**Y**	**Common**	**Y**	*** Regional endemic**
Corvus albus	**Pied crow**	**Goaka (1, 2, 3)**		**Y**		**Y**[g]		**Y**	*****
Hartlaubius auratus	**Madagascar starling**				**Rare**				*** Endemic genus**
Acridotheres tristis	**Common myna**	**Martin (1, 2, 3)**	**Frequent**	**Y**	**Frequent**		**Frequent**	**Y**	**Introduced**
Foudia madagascariensis	**Madagascar fody**	**Fodilahimena (2, 3), Fodimena (2), Fody (1, 2, 3)**	**Uncommon**	**Y**	**Frequent**	**Y**	**Common**	**Y**	*** Regional endemic**
Lepidopygia nana	**Madagascar manikin**	**Tsiporitaka (3), Tsiporitiky (2), Tsipority (2)**	**Rare**	**Y**		**Y**		**Y**	*** Endemic genus**
Observed species richness			**36**		**50**		**44**		

[a] Reported as being rare
[b] Respondents did not differentiate between species
[c] Recorded in bay on seaward side of mangroves and not directly interacting with mangrove systems
[d] Recorded flying over mangroves but not directly interacting with mangrove systems
[e] Recorded on narrow (<100 m wide) island (planted with mature coconut palms) within extensive mangrove
[f] Recorded in mangrove trees in transitional mangrove/secondary scrub at high tide
[g] Reported as passing through or over mangroves, but not directly using them