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

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30 **Abstract**

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

46

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

49

50 **Introduction**

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

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

58

59 Mangroves have attracted increasing attention from conservation and climate change
60 mitigation programmes in recent years due to the valuable ecosystem services they provide,
61 in particular carbon sequestration and storage (Lafolley and Grimsditch 2009; Nellemann et
62 al. 2009; Ullman et al. 2012): indeed the combined above- and below-ground carbon storage
63 of mangroves greatly exceeds that of many terrestrial tropical forest systems (Donato et al.
64 2011; Kauffman et al. 2011, 2014; Pendleton et al. 2012; Wang et al. 2013). In addition,
65 mangroves play an important role in coastal protection and erosion prevention (Alongi 2008;
66 Dahdouh-Guebas et al. 2005), and provide breeding and feeding grounds for a range of
67 marine species (Kathiresan and Bingham 2001; Nagelkerken et al. 2008) including
68 commercially important fish and crustaceans (Manson et al. 2005; Naylor et al. 2000).
69 Around the world many human populations in coastal areas depend heavily on mangroves for
70 their subsistence and household income (Glaser 2003; Rasolofo 1997; van Bochove et al.
71 2014).

72

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

80 among its terrestrial fauna and flora, particularly at higher taxonomic levels (Brooks et al
81 2006; Holt et al. 2013), but is amongst the countries where mangrove use by terrestrial
82 biodiversity remains little researched. With around 213,000 ha of mangroves in 2010,
83 Madagascar possesses approximately 2% of their global area and is amongst the top 15 most
84 mangrove rich countries in the world (FAO 2007; Giri and Mulhausen 2008; Giri et al. 2011),
85 but despite this we know little about the extent to which these ecosystems are used by the
86 island's (largely endemic) terrestrial fauna. Knowledge of bird occurrence in Madagascar's
87 mangroves is limited to two single site inventories (Gardner et al. 2012; Razafindrajao et al.
88 2002), a small number of single species studies (e.g. Andrianarimisa and Razafimanjato
89 2012; Razafimanjato et al. 2014) and miscellaneous short reports (e.g. Appert 1970;
90 Woolaver et al. 2004). Since the first step in understanding the use of mangroves by birds is
91 to know which species occur in them, we seek to broaden our knowledge base with a rapid
92 ornithological assessment of three sites in the Ambanja and Ambaro Bays mangrove in north-
93 west Madagascar, which constitutes the largest continuous mangrove system in Madagascar
94 (Jones et al. 2016a). Since rapid inventories may fail to detect rare or seasonal events or
95 species (Anderson et al. 2007; van der Hoeven et al. 2004), we complement our data with an
96 evaluation of the local ecological knowledge (LEK) of fishers and mangrove users in order to
97 provide a more complete picture of the avian diversity of our study system.

98

99 **Methods**

100 **Study site**

101 The Ambanja and Ambaro Bays in northwest Madagascar are lined with mangroves totalling
102 45,680 ha, of which 14,015 ha in closed-canopy and 31,665 in open-canopy ecosystems
103 (Jones et al. 2014). The climate is sub-humid tropical with a warm rainy season and frequent
104 cyclones from November–April, and a cooler dry season in May–October (Rasolofo and

105 Ramilijaona 2009). The underlying geology is composed primarily of alluvial and lake
106 deposits, and the relative abundance of rainfall and freshwater contributes to a high stature of
107 mangrove trees compared to equivalent systems in western Madagascar (Giri and Mulhausen
108 2008; Jones et al. 2014). As with all of Madagascar’s mangroves, the ecosystem is relatively
109 species-poor and is composed of eight true mangrove species: *Avicennia marina* (white
110 mangrove), *Bruguiera gymnorhiza* (orange mangrove), *Ceriops tagal* (Indian mangrove),
111 *Rhizophora mucronata* (red mangrove), *Sonneratia alba* (mangrove apple), *Xylocarpus*
112 *granatum* (cannonball mangrove), *Lumnitzera racemosa* (black mangrove) and *Heritiera*
113 *littoralis* (looking-glass mangrove). Mangroves throughout the area are the focus of extensive
114 artisanal fishing and resource extraction activities (Rasolofo 1997) and are threatened by
115 deforestation, having lost 20% of their area in the period 1990–2010 as a result of timber
116 exploitation and charcoal production (Jones et al. 2014, 2016b).

117
118 We surveyed three sites (Antsampano, Ankazomborona and Ankatafa) currently the
119 subject of community-based mangrove management initiatives within conservation programs
120 led by the international non-governmental organisations WWF, l’Homme et l’Environnement
121 and Blue Ventures (Fig.1). All sites are governed under a GELOSE management transfer
122 contract (see Pollini et al. 2014), and managed by an association of local resource users called
123 a *Communauté Locale de Base* (CLB).

124

125 [FIGURE 1]

126

127 **Bird surveys**

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

130 April). At each site we attempted to sample different parts of the mangrove (seaward side,
131 small and large channels, back mangrove) approximately equally, but were constrained by
132 tides which restricted accessibility. In order to maximise the diversity of species recorded at
133 each site we also visited areas said by local respondents (mangrove users and CLB members)
134 to be rich in birds or frequented by particular species of interest (e.g. IUCN Red List species).
135 Transects were primarily water based, using a motor boat at Antsahampano and traditional
136 dugout pirogues (*lakana*) at the other two sites, and were largely carried out during high tides
137 to permit entry into shallow channels. Where possible we also surveyed transects on foot
138 along the terrestrial edge of the mangrove (back mangrove), but we did not penetrate dense
139 mangrove stands on foot (Fig. 1; Table 1). During transects we noted all visual and auditory
140 contacts with birds from within or above mangroves, in mangrove channels or immediately
141 adjacent to mangroves on the seaward side (including on exposed mudflats dotted with
142 mangrove trees, at low tide), but did not record species observed only in terrestrial habitats
143 immediately adjacent to mangroves on the landward side (e.g. dead zones, secondary scrub,
144 grasslands, freshwater wetlands, agriculture and native forests). We scored the relative
145 abundance of each species using an index based on the percentage of transects in which the
146 species was recorded (Rare = recorded in < 25% of transects; Uncommon = recorded in 25-
147 50% of transects; Frequent = recorded in 50-75% of transects; Common = recorded in > 75%
148 of transects).

149

150 [Table 1]

151

152 **Assessment of local knowledge**

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

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

164

165 Walking interviews were carried out during all survey transects, which were accompanied by
166 1–4 members of the local CLB management committee, by systematically asking our
167 respondents for the local names of all birds encountered either visually or aurally. We also
168 used these interviews to ascertain the knowledge of respondents and thus their suitability as
169 expert respondents for further enquiries. Subsequently, we carried out focus group interviews
170 with participants selected on the basis of their knowledge of birds and their familiarity with
171 mangrove environments; respondents (n = 3 at Antsahampano, n= 7 at Ankazomborona and n
172 = 4 at Ankatafa) thus largely comprised CLB members and mud crab (*Scylla serrata*) fishers,
173 who spend more time in the mangroves than fishers targeting other resources. Focus group
174 interviews were facilitated by the use of an illustrated field guide (Sinclair and Langrand
175 1998) and MP3 recordings of bird calls and song (Huguet and Chappuis 2003). For each
176 species thought to occur in the region and potentially occurring within mangroves, we
177 showed respondents an image of the species and simultaneously played its call/song on a
178 small loudspeaker. If respondents recognised the bird, we asked them to describe aspects of
179 its appearance, behaviour, habitat use or life history in order to corroborate their

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

189

190 **Results**

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

199

200 [Table 2]

201

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

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

217

218 **Discussion**

219 Our data have revealed that a higher diversity of bird species than was previously recognised
220 utilise the mangroves of north-west Madagascar, including a large proportion of terrestrial
221 species that were not known to occur in this habitat. In addition to the 73 species we
222 observed, 14 further species have been recorded in mangrove inventories elsewhere in
223 Madagascar by Razafindrajao et al. (2002) and Gardner et al. (2012) and 12 more were
224 reported by respondents in this study, indicating that at least 99 species (38.7 % of all species
225 regularly occurring in Madagascar, Safford and Hawkins 2014) utilise this habitat. This
226 figure places Madagascar in the lower ranks of global mangrove range states in which bird
227 occurrence has been researched, with a greater richness than Trinidad (84 species, French
228 1966) and Surinam (94 species, Haverschmidt 1965), but lower than Guinea-Bissau (125
229 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

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

273

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

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

293

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

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

311

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

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

333

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

350

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357

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627 **Figure 1** Map of study sites in north-west Madagascar showing vegetation cover and transect
628 routes followed during rapid bird inventories. Mangrove vegetation cover is derived from
629 Jones et al. (2014), and other vegetation classes from Harper et al. (2007). The background
630 uses a true colour Landsat 8 image from 2014, at low tide.
631

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

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

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

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

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

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