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# A rapid avifaunal survey of the Mahimborondro Protected Area, northern Madagascar

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## Abstract

Mahimborondro (officially Réserve de Ressources Naturelles de Mahimborondro) is a recently designated protected area in northern Madagascar. Until recently, the protected area had only been briefly visited by biologists and little was known about the biodiversity of the site. Here we report on the results of the first extended ornithological surveys conducted in Mahimborondro. We visited Mahimborondro over the course of two expeditions in February 2019 and November-December 2019 and made ornithological observations at four locations in the western, eastern, and southern portions of the reserve over the course of 26 days. We documented 92 bird species in Mahimborondro, including 14 species that are globally threatened or near threatened. Among these were multiple poorly known, endemic forest birds, such as Red Owl *Tyto soumagnei*, Madagascar Serpent-Eagle *Eutriorchis*

*astur*, and Red-tailed Newtonia *Newtonia fanovanae*. Montane forest in Mahimborondro extends to over 2,000 m asl and at one of our survey sites we made detailed observations of the elevational occurrence of forest birds. Our results demonstrate differences in the avifauna of Mahimborondro compared to the nearby protected area of Bemanevika and highlight the importance of Mahimborondro as a refuge for threatened forest birds.

**Keywords:** birds, biological surveys, endangered species, rapid biological assessment, IUCN

## Résumé détaillé

Mahimborondro (officiellement une Réserve de Ressources Naturelles de Mahimborondro) est une réserve naturelle qui a été récemment créée dans le nord de Madagascar. Jusqu'à récemment, cette aire protégée n'avait été visitée que brièvement par des biologistes et la connaissance de la biodiversité de la réserve était limitée. Les résultats de la première étude ornithologique exhaustive de Mahimborondro sont rapportés dans cet article.

Deux expéditions à Mahimborondro, en février 2019 et en novembre-décembre 2019 ont été réalisées. Les observations ornithologiques ont été effectuées dans les parties ouest, est, et sud de la réserve pendant 26 jours. Les relevés ont couvert quatre types d'habitats distincts de l'aire protégée, notamment les lacs et les marais d'eau douce, les prairies, la forêt primaire de montagne et la forêt de crêtes. Les détails sur chacune des localités visitées au cours des inventaires sont consignés dans l'Annexe 1. La présence de 92 espèces d'oiseaux à Mahimborondro a été documentée, parmi lesquelles 14 espèces globalement menacées ou quasi menacées. Des commentaires sur nos observations des espèces suivantes sont fournis : Canard de Meller *Anas melleri* (En Danger), Grèbe malgache *Tachybaptus pelzelni* (En Danger), Bécassine malgache *Gallinago macrodactyla* (Vulnérable), Firasabé de Madagascar *Eutriorchis astur* (En Danger), Epervier de Madagascar *Accipiter madagascariensis* (Quasi menacé), Effraie de Soumagne *Tyto soumagnei* (Vulnérable),

Brachyptérolle écaillé *Brachypteracias squamiger* (Vulnérable), Brachyptérolle de Crossley *Atelornis crossleyi* (Quasi menacé), Philépitte sp. *Neodrepanis* sp., Newtonie de Fanovana *Newtonia fanovanae* (Vulnérable), Vanga de Pollen *Xenopirostris polleni* (Quasi menacé), Jery à queue étagée *Hartertula flavoviridis* (Quasi menacé) et Fouditany à sourcils jaunes *Crossleyia xanthophrys* (Quasi menacé).

La forêt montagnarde de Mahimborondro s'élève au-dessus de 2000 m d'altitude. Dans l'un des sites d'étude, les lignes de transect ont suivi un gradient altitudinal clair, ce qui a permis de collecter des informations détaillées sur la distribution altitudinale. Pour plusieurs d'espèces, les altitudes significativement plus élevées (> 300 m) que les altitudes maximales publiées pour ces espèces sont enregistrées. Un grand nombre de ces observations concordent avec les distributions altitudinales théoriques de modèles de distribution des espèces.

L'inventaire rapide a fourni une compréhension de base de la diversité des oiseaux présents à Mahimborondro. Il a été constaté qu'il existe une différence entre l'avifaune de Mahimborondro et celle de la zone protégée voisine de Bemanevika, ce qui souligne l'importance de l'aire protégée de Mahimborondro, en particulier pour les oiseaux forestiers.

**Mots clés** : oiseaux, inventaire biologique, espèces menacées, évaluation biologique rapide, UICN

## Introduction

Mahimborondro (officially Réserve de Ressources Naturelles de Mahimborondro) is a recently designated protected area located in Madagascar's northern highlands (Goodman *et al.*, 2018). Granted protected area status (IUCN Category VI) in April 2015, Mahimborondro forms a corridor that links the protected area of Bemanevika (officially Paysage Harmonieux Protégé de Bemanevika) to the Tsaratanàna Massif (Réserve Naturelle Intégrale de Tsaratanàna) and together with these forms part of northern Madagascar's largest protected landscape (Complexe des Aires Protégées d'Ambohimirahavy-Marivorahona or CAPAM). Mahimborondro is managed by The Peregrine Fund Madagascar, which has had an active presence at Bemanevika since the early 2000s. The reserves adjacent to Mahimborondro are globally significant for bird conservation. Tsaratanàna is recognized as an Important Bird and Biodiversity Area (BirdLife International, 2020a), and Bemanevika has

breeding populations of 11 globally threatened species: Meller's Duck *Anas melleri* (Endangered), Madagascar Grebe *Tachybaptus pelzelinii* (Endangered), Slender-billed Flufftail *Sarothrura watersi* (Endangered), Madagascar Rail *Rallus madagascariensis* (Vulnerable), Madagascar Pond Heron *Ardeola idae* (Endangered), Madagascar Snipe *Gallinago macrodactyla* (Vulnerable), Red Owl *Tyto soumagnei* (Vulnerable), Madagascar Serpent-Eagle *Eutriorchis astur* (Endangered), Madagascar Harrier *Circus macroscelus* (Endangered), Scaly Ground-Roller *Brachypteracias squamiger* (Vulnerable), and most notably, the world's only wild population of Madagascar Pochard *Aythya innotata* (Critically Endangered) (Goodman *et al.*, 2018).

Due to this geographic location and the fact that Mahimborondro includes substantial areas of intact forest (roughly 50% of Mahimborondro's 751 km<sup>2</sup> is forested (Goodman *et al.*, 2018), this new protected area has the potential to be important for several globally threatened bird species. Additionally, Mahimborondro may support populations of threatened species that occur in Bemanevika and connect these populations to more extensive areas of forest to the east and south. The birds and other biodiversity of Madagascar face significant threats, including clearing of land and forests for agriculture, overhunting, poaching for the pet trade, timber harvesting, and mineral resource exploitation (Jones *et al.*, 2019). Protected areas of Madagascar, such as Mahimborondro and Bemanevika, are a crucial safe-guard against these threats.

Ornithological fieldwork, and biodiversity fieldwork in general, in Mahimborondro has thus far been extremely limited. Previous biodiversity surveys have been almost entirely restricted to the flora of the site, including collecting expeditions undertaken in 1908, 1923, and between 1932 and 1951 (Goodman *et al.*, 2018). In more recent times, the Missouri Botanical Garden conducted collections at Mahimborondro between 2001 and 2003. Much of the landscape is difficult to access, and knowledge of Mahimborondro's ornithological diversity comes from a few preliminary surveys of the site made during brief visits to the reserve by The Peregrine Fund research team in Bemanevika. These previous surveys were primarily focused on monitoring threatened species of waterfowl in the wetlands on the edge of the reserve, rather than studying the avifauna as a whole.

As a result of this limited survey effort, the presence of a number of threatened bird species that could potentially occur in Mahimborondro

remained unconfirmed. This was particularly true of several forest species that occur in the neighboring Bemanevika protected area, such as *Eutriorchis astur* and *Tyto soumagnei*. Conducting field studies to confirm whether these species occur in the reserve is important since Mahimborondro's forests differ from those in Bemanevika in their higher rainfall and elevation (84% of Mahimborondro is above 1,250 m asl), and thus represent different habitat opportunities for forest birds.

We conducted ornithological fieldwork in Mahimborondro over the course of two expeditions in February and November-December 2019. In February, a large team of all the authors except for AB visited Mahimborondro between 4-11 February and conducted field observations around two camps in the western part of the protected area. In November-December, AB and LARR revisited one of these camps and also conducted field observations at locations in the southern and eastern parts of the protected area between 25 November and 16 December. Over the course of these two visits, we made ornithological observations between 1,518 and 2,256 m asl in freshwater wetland habitats, open montane grasslands, primary montane forests, and elfin ridge forests within the Mahimborondro protected area. This represents the most extensive ornithological fieldwork in Mahimborondro conducted to date. Here we provide a brief overview of the sites visited during our fieldwork, present a list of species, and discuss noteworthy observations. In doing so, we provide a foundation of ornithological knowledge in this interesting protected area.

## Methods

In total we surveyed four locations within the Mahimborondro protected area (Figure 1; Appendix 1). This included two sites in February and three in November-December, one of which was a revisit to one of the February locations. Mist nets were used at one of the survey locations in February (Bekavahy) and at all survey sites in November-December (five 12 m nets and three 6 m). Nets were opened at dawn and, weather permitting, left open until dusk being checked every 30 minutes. At all sites, daily audiovisual surveys were conducted beginning shortly after dawn and continuing for 4-5 hours each morning. Field surveys made by JCM and DRW in February are archived and publicly available through eBird.org, together with photographs and sound recordings made using a Sennheiser MKH70 microphone and Marantz PMD660 recorder. We used

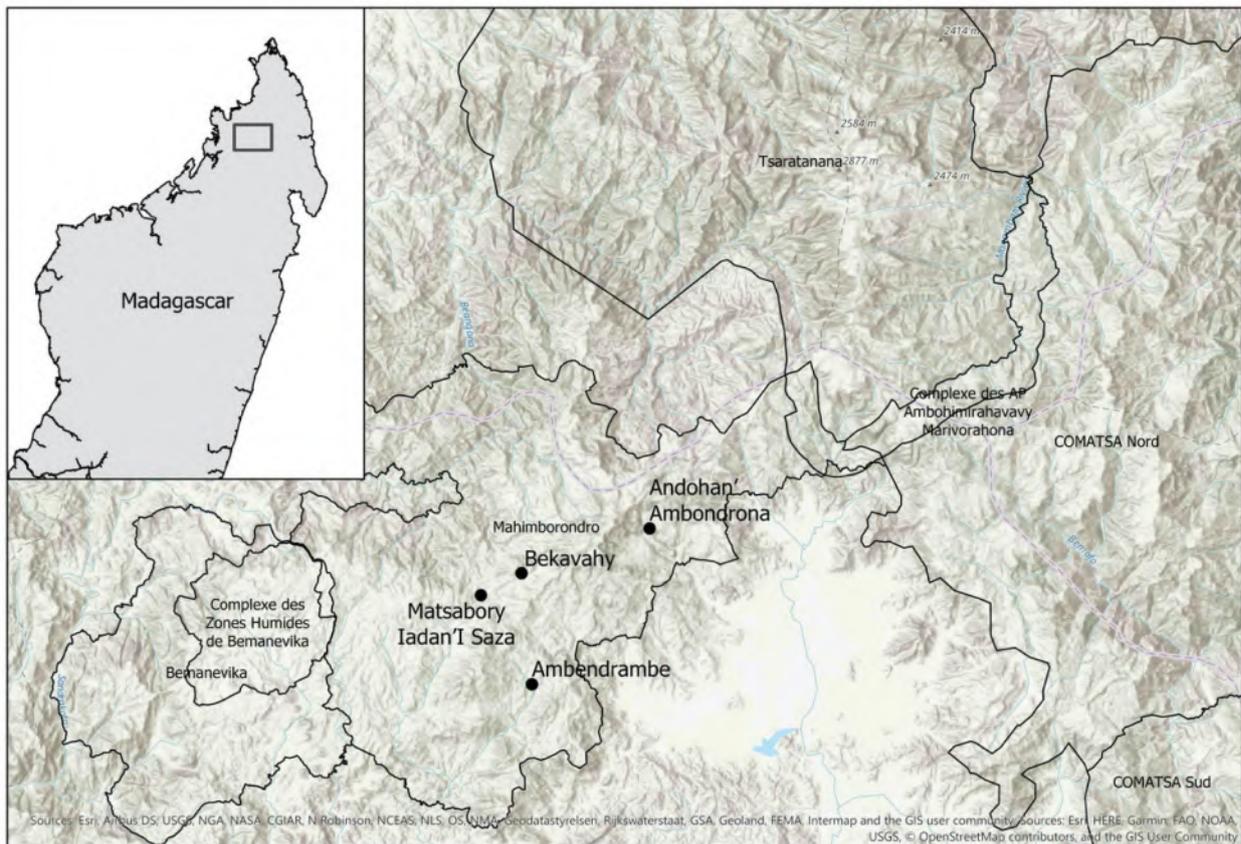
a Garmin 60CSX handheld GPS in February and a Garmin eTrex 20 in November-December to record elevation and location data.

Our surveys covered four distinct habitat types within the Mahimborondro protected area (Figure 2): freshwater lakes and marshes, open grassland, primary montane forest and elfin ridge forest. Freshwater wetland habitats were present near two of our survey sites. A large, shallow lake covering ca 21 ha was adjacent to our camp at Matsabory Iadan'l Saza and several smaller marshes without open water were located near our camp at Ambendrambe. Open grassland habitats in Mahimborondro are located on dry ground and characterized by grasses and low vegetation generally not exceeding one meter in height. Grassland habitats visited by us were primarily located at the margins of the protected area and may have been created through burning and disturbance. Primary montane forest in Mahimborondro is characterized by trees extending > 20 m in height and an understory with dense thickets of herbaceous vegetation as well as numerous drainages with steep gullies and small streams. Primary montane forest is the most widespread habitat in the protected area and occurred at all of our survey locations. Elfin ridge forest in Mahimborondro is found on well-drained ridges primarily above 1,700 m asl (though this varied by location) and was characterized by stunted forest with dense, nearly impenetrable stands of low trees growing to ca. 5 m in height. This habitat occurred at the higher elevations near our survey sites at Bekavahy and Andohan'Ambondrona. Avian taxonomy and nomenclature follow Clements *et al.* (2019).

## Results

### Species diversity

We recorded 61 species during our field surveys in February and 86 during our November-December surveys for a cumulative total of 92 species (Figure 3; Table 1). Among these were seven species that are globally threatened according to the Red List assessments of the International Union for the Conservation of Nature (BirdLife International, 2020b): *Anas melleri*, *Tachybaptus pelzelinii*, *Gallinago macrodactyla*, *Tyto soumagnei*, *Eutriorchis astur*, *Brachypteracias squamiger*, and *Newtonia fanovanae*. In addition to the globally threatened species, we recorded seven species that are considered Near Threatened: Madagascar Crested Ibis *Lophotibis cristata*, Madagascar Sparrowhawk *Accipiter madagascariensis*, Rufous-headed Ground-



**Figure 1.** Map of locations surveyed in the Mahimborondro protected area, 4-11 February 2019 and 25 November-16 December 2019.

Ground-roller *Atelornis crossleyi*, Pollen's Vanga *Xenopirostris polleni*, Wedge-tailed Jery *Hartertula flavoviridis*, Gray-crowned Tetraka *Xanthomixis cinereiceps*, and Yellow-browed Oxylabes *Crossleyia xanthophrys*. Mist-netting complimented our survey efforts, but did not add to our species list; all species caught in nets were also detected during audiovisual surveys.

In February, wet-season weather strongly impacted our survey efforts. Rainfall followed a predictable pattern with mornings being either clear or slightly overcast and heavy rain beginning in the early to mid-afternoon and continuing into the evening or occasionally through the night. As a result, bird surveys were primarily limited to the morning. Weather was less of limiting factor in November-December when there was only rain on seven of the 18 survey days. Furthermore, we found that vocal activity of birds was relatively low in February. Juvenile birds and recently fledged young of several species were observed, and we did not encounter any active nests nor did any of the birds caught in mist-nets have brood patches. In November-December, in contrast, vocal activity and breeding was more pronounced, as is to be expected following the usual

seasonal breeding patterns of Malagasy forest birds (Hawkins *et al.*, 2015). Given these differences it is unsurprising that the November-December surveys detected several cryptic species that were not observed in February, including *Eutriorchis astur* and Cryptic Warbler *Cryptosylvicola randrianasoloi*.

Several of our February survey transects followed a clear elevational gradient which enabled us to record detailed information on the elevational occurrence of species. Species that we observed at notably high elevations include: *Accipiter madagascariensis* (1,630 m), Madagascar Harrier-hawk *Polyboroides radiatus* (ca. 1,600 m), Crested Coua *Coua cristata* (ca. 1,600 m), Velvet Asity *Philepitta castanea* (1,830 m), Hook-billed Vanga *curvirostris* (ca. 1,700 m), Red-tailed Vanga *Calicalicus madagascariensis* (1,640 m), Nuthatch Vanga *Hypositta corallirostris* (1,630 m), Blue Vanga *Cyanolanius madagacariensis* (1,630 m), Spectacled Tetraka *Xanthomixis zosterops* (1,660 m), and Rand's Warbler *Randia pseudozosterops* (1,690 m). Our observation of a pair of *Newtonia fanovanae* at 1,640 m is significantly higher than the previously published observations of the species (Safford & Hawkins, 2013; Hawkins *et al.*, 2015) as well as



**Figure 2.** Habitats surveyed in the Mahimborondro area. Top left and right: primary montane forest near Bekavahy. Bottom left: elfin ridge forest near Bekavahy. Bottom right: freshwater wetland and open grassland at Matsabory Iadan'i Saza. (All photos by John C. Mittermeier.)

**Table 1.** Species recorded in the Mahimborondro Protected Area during surveys in 4-11 February 2019 and 25 November-16 December 2019. Columns indicate habitat types: (1) freshwater wetlands, (2) open montane grassland, (3) primary montane forest, (4) elfin ridge forest. Relative abundance for species recorded in February, following Stotz *et al.* (1996) are: (C) common, > 10 individuals per day; (F) fairly common, 4-10 individuals per day; (U) uncommon, 1-3 per day; and (R) rare, <1 per day. For species where abundance was not recorded, we note only presence (X). For globally threatened species, the Red List status following BirdLife International (2020b), is listed. Maximum elevation indicates the highest elevation at which we observed a species; for some species this data was not recorded. Taxonomy follows Clements *et al.* (2019).

	Species	Red List status	Maximum Elevation	1	2	3	4
1	White-faced Whistling Duck <i>Dendrocygna viduata</i>		-	X			
2	Meller's Duck <i>Anas melleri</i>	EN	1590	R			
3	Red-billed Duck <i>Anas erythrorhyncha</i>		1590	U			
4	Madagascar Partridge <i>Margaroperdix madagarensis</i>		-		X	X	
5	Little Grebe <i>Tachybaptus ruficollis</i>		1590	U			
6	Madagascar Grebe <i>Tachybaptus pelzelni</i>	EN	1590	U			
-	Grebe sp. <i>Tachybaptus</i> sp.		1590	F			
7	Madagascar Turtle Dove <i>Streptopelia picturata</i>		1640			R	
8	Madagascar Blue-pigeon <i>Alectroenas madagascariensis</i>		-			X	
9	Crested Coua <i>Coua cristata</i>		~1600			R	
10	Blue Coua <i>Coua caerulea</i>		1720			F	U
11	Red-fronted Coua <i>Coua reynaudii</i>		1630			U	
12	Madagascar Coucal <i>Centropus toulou</i>		1590		R		
13	Madagascar Cuckoo <i>Cuculus rochii</i>		-			X	
14	Collared Nightjar <i>Gactornis enarratus</i>		-			X	
15	Madagascar Nightjar <i>Caprimulgus madagascariensis</i>		1590		U		
16	Malagasy Spinetail <i>Zonavena grandidieri</i>		1640			U	
17	Madagascar Flufftail <i>Sarothrura insularis</i>		1630		F	U	
18	White-throated Rail <i>Dryolimnas cuvieri</i>		1630			U	
19	Red-knobbed Coot <i>Fulica cristata</i>		1590	F			
20	Madagascar Snipe <i>Gallinago macrodactyla</i>	VU	-	X			
21	Madagascar Buttonquail <i>Turnix nigricollis</i>		1600		R		
22	Cattle Egret <i>Bubulcus ibis</i>		-		X		
23	Madagascar Ibis <i>Lophotibis cristata</i>	NT	-			X	
24	Madagascar Harrier-hawk <i>Polyboroides radiatus</i>		~1600			R	
25	Madagascar Serpent-eagle <i>Eutriorchis astur</i>	EN	-			X	
26	France's Sparrowhawk <i>Accipiter francesiae</i>		-			X	
27	Madagascar Sparrowhawk <i>Accipiter madagascariensis</i>	NT	1630*			R	
28	Black Kite <i>Milvus migrans</i>		-		X		
29	Madagascar Buzzard <i>Buteo brachypterus</i>		1730			U	
30	Red Owl <i>Tyto soumagnei</i>	VU	-			X	
31	Malagasy Scops Owl <i>Otus rutilus</i>		1730			R	R
32	Madagascar Owl <i>Asio madagascariensis</i>		1630			R	
33	Cuckoo-roller <i>Leptosomus discolor</i>		>1700			U	U
34	Malagasy Kingfisher <i>Corythornis vintsioides</i>		-	X			
35	Madagascar Pygmy-kingfisher <i>Corythornis madagascariensis</i>		-			X	
36	Madagascar Bee-eater <i>Merops superciliosus</i>		-		X		
37	Broad-billed Roller <i>Eurystomus glaucurus</i>		~1700			R	
38	Scaly Ground-roller <i>Brachypteracias squamiger</i>	VU	-			X	
39	Pitta-like Ground-roller <i>Atelornis pittoides</i>		-			X	
40	Rufous-headed Ground-roller <i>Atelornis crossleyi</i>	NT	1630			R	
41	Madagascar Kestrel <i>Falco newtoni</i>		~1600		R		
42	Lesser Vasa Parrot <i>Coracopsis nigra</i>		>1700			F	F
43	Velvet Asity <i>Philepitta castanea</i>		1830			F	F
44	Common Sunbird-asity <i>Neodrepanis coruscans</i>		1690			F	F
45	Common Newtonia <i>Newtonia brunneicauda</i>		~1650			C	
46	Dark Newtonia <i>Newtonia amphichroa</i>		1720			F	
47	Red-tailed Newtonia <i>Newtonia fanovanae</i>	VU	1640*			R	
48	Tylas Vanga <i>Tylas eduardi</i>		1630			U	
49	Red-tailed Vanga <i>Calicalicus madagascariensis</i>		1640			F	
50	Nuthatch-vanga <i>Hypositta corallirostris</i>		1630			R	
51	Chabert's Vanga <i>Leptopterus chabert</i>		-			X	

	Species	Red List status	Maximum Elevation	1	2	3	4
52	Crossley's Vanga <i>Mystacornis crossleyi</i>		-			X	
53	Blue Vanga <i>Cyanolanius madagascarinus</i>		1630			R	
54	Hook-billed Vanga <i>Vanga curvirostris</i>		~1700				R
55	Ward's Flycatcher <i>Pseudobias wardi</i>		1630			F	
56	White-headed Vanga <i>Artamella viridis</i>		1630			R	
57	Pollen's Vanga <i>Xenopirostris polleni</i>	NT	-			X	
58	Ashy Cuckooshrike <i>Coracina cinerea</i>		1630			F	
59	Crested Drongo <i>Dicrurus forficatus</i>		1640			F	
60	Madagascar Paradise-flycatcher <i>Terpsiphone mutata</i>		~1700			F	
61	Pied Crow <i>Corvus albus</i>		-		X	X	
62	Madagascar Lark <i>Eremopterix hova</i>		~1790		C		
63	Common Jery <i>Neomixis tenella</i>		-			X	
64	Green Jery <i>Neomixis viridis</i>		1690			F	
65	Stripe-throated Jery <i>Neomixis striatigula</i>		~1700			F	
66	Madagascar Cisticola <i>Cisticola cherina</i>		1600		F		
67	Madagascar Brush-warbler <i>Nesillas typica</i>		~1750			F	F
68	Madagascar Swamp Warbler <i>Acrocephalus newtoni</i>		-	X			
69	Gray Emutail <i>Amphispalis seebohmi</i>		-	X			
70	White-throated Oxylabes <i>Oxylabes madagascariensis</i>		1630			U	
71	Long-billed Bernieria <i>Bernieria madagascariensis</i>		-			X	
72	Cryptic Warbler <i>Cryptosylvicola randrianasoloi</i>		-			X	
73	Wedge-tailed Jery <i>Hartertula flavoviridis</i>	NT	-			X	
74	Yellow-browed Oxylabes <i>Crossleyia xanthophrys</i>	NT	1640			R	
75	Spectacled Tetraka <i>Xanthomixis zosterops</i>		1660			U	
76	Gray-crowed Tetraka <i>Xanthomixis cinereiceps</i>	NT	1660			F	
77	Rand's Warbler <i>Randia pseudozosterops</i>		1690			U	
78	Plain Martin <i>Riparia paludicola</i>		1600		C		
79	Mascarene Martin <i>Phedina borbonica</i>		-		X	X	
80	Madagascar Bulbul <i>Hypsipetes madagascariensis</i>		~1700			F	
81	Madagascar White-eye <i>Zosterops maderaspatanus</i>		1730			F	U
82	Madagascar Starling <i>Saroglossa aurata</i>		-			X	
83	Madagascar Magpie-robin <i>Copsychus albospecularis</i>		1630			U	
84	Forest Rock-thrush <i>Monticola sharpei</i>		1630			U	
85	African Stonechat <i>Saxicola torquatus</i>		1600		C		
86	Souimanga Sunbird <i>Cinnyris sovimanga</i>		1720			C	C
87	Madagascar Sunbird <i>Cinnyris notatus</i>		1640		U	U	
88	Nelicourvi Weaver <i>Ploceus nelicourvi</i>		1630			U	
89	Red Fody <i>Foudia madagascariensis</i>		1600		U		
90	Forest Fody <i>Foudia omissa</i>		1600			R	
91	Madagascar Munia <i>Lonchura nana</i>		-		X	X	
92	Madagascar Wagtail <i>Motacilla flaviventris</i>		-		X	X	

maximum-entropy (MaxEnt) model predictions for the species distribution (to 908 m asl; Goodman & Raherilalao, 2013). This is undoubtedly due to the fact that this rare and poorly known bird has few observations and published records.

Of the four habitat types we visited, primary montane forest was by far the most diverse (70 species). Elfin forest along ridges, by comparison, was relatively depauperate (10 species) and the birds found at this higher elevation were a subset of those present at lower elevations.

The freshwater lake that we visited at Matsabory ladan'i Saza lacked a well-developed reedbed

margin and had a lower diversity of water birds than the wetlands in the neighboring Bemanevika Protected Area (6 species). Nevertheless, this habitat was home to two endemic and globally endangered species, *Anas melleri* and *Tachybaptus pelzelinii*, with evidence of *A. melleri* breeding on the lake. Grasslands around the lake were more diverse than the short, burnt grasslands that occupy large areas of degraded land around the reserve, but still depauperate compared to the forest communities (13 species observed in grasslands). Comments on selected species of interest are described below.



**Figure 3.** Notable bird species occurring in Mahimborondro. Top left: *Tachybaptus pelzelii* (photographed at Bemanevika). Top right: *Anas melleri* (photographed at Bemanevika). Middle left: *Eutriorchis astur* (photographed at Bemanevika). Middle right: *Tyto soumagnei* (photographed at Bemanevika). Bottom left: *Neodrepanis coruscans* (photographed at Bekavahy, Mahimborondro). Bottom right: *Newtonia fanovanae* (photographed at Bekavahy, Mahimborondro). (*Newtonia fanovanae* photo by Dale R. Wright, all others by John C. Mittermeier.)

## Selected species accounts

### ***Meller's Duck* *Anas melleri* (Endangered)**

Like many of Madagascar's endemic wetland bird species, *A. melleri* is threatened by habitat loss and hunting pressure. We recorded *A. melleri* on the lake at Matsabory ladan'I Saza in both February and December 2019. On 5 February, LARR observed an adult with eight ducklings on the lake confirming that this Endangered species breeds in Mahimborondro.

### **Madagascar Grebe *Tachybaptus pelzelinii* (Endangered)**

Similar to *Anas melleri*, *T. pelzelinii* is threatened by habitat loss and hunting pressure. Additionally, hybridization with the widespread Little Grebe *T. ruficollis* has been proposed as a potential threat to *T. pelzelinii* (Langrand, 1995). On freshwater lakes around Bemanevika, *T. pelzelinii* significantly outnumber *T. ruficollis*. We recorded *T. pelzelinii* at Matsabory ladan'I Saza on 5-6 February and on 13 December. In February, at least 10-20 *Tachybaptus* grebes were present on the lake, including a pair on an active nest. While most individuals were too distant to identify (including the nesting pair), we observed at least two *T. pelzelinii* and 3-4 *T. ruficollis*. Though our sample was small, this pattern of *T. ruficollis* outnumbering *T. pelzelinii*, if true, is the opposite of what occurs on lakes at Bemanevika. If hybridization between the two species is a problem, then this small population of *T. pelzelinii* could be at risk.

### **Madagascar Snipe *Gallinago macrodactyla* (Vulnerable)**

Another wetland species threatened by habitat loss and hunting, *G. macrodactyla* is found in the marsh habitats around Bemanevika. On 3 December, AB and LARR observed two individuals in the marshes near Ambendrambe indicating that this species also occurs in Mahimborondro where there is suitable habitat.

### **Madagascar Serpent-eagle *Eutriorchis astur* (Endangered)**

This forest raptor is notoriously elusive and difficult to detect and spent much of the 20th century going virtually unrecorded (Langrand, 1990). Given this, it is unsurprising that we failed to observe the species in February, when the adults would not have been vocalizing. On 7 December, AB and LARR heard a single *E. astur* vocalizing near Ambendrambe in the

eastern part of Mahimborondro. This observation confirms the occurrence of this species in Mahimborondro and, given that a territorial bird was calling, suggests that *E. astur* likely breeds in the protected area.

### **Madagascar Sparrowhawk *Accipiter madagascariensis* (Near Threatened)**

Though widespread across Madagascar, this species is considered Near Threatened due to the fact that the forest habitats it depends on are becoming increasingly fragmented and degraded (BirdLife International, 2020b). Previous assessments indicate that this species usually occurs in forests below 1,000 m (Hawkins *et al.*, 2015) or below 1,500 m (Langrand, 1990), though Safford & Hawkins (2013) note that there are occasional occurrences above these usual limits. This distribution would imply that Mahimborondro is largely unsuitable for the species due to its elevation. On 10 February we observed an *A. madagascariensis* for nearly half an hour in the canopy of Bekavahy at 1,630 m asl. The presence of this species here suggests that a population occurs in the montane forest at Mahimborondro at slightly higher elevations than elsewhere in Madagascar.

### **Red Owl *Tyto soumagnei* (Vulnerable)**

Like *Eutriorchis astur*, this elusive forest owl spent much of the 20th century undetected and until recently was extremely poorly known. Bemanevika is a well-known breeding location for this species. In November-December, LARR and AB heard at least two *T. soumagnei* calling at each of their three survey sites and on 5 February LK found an owl feather on the forest edge south of Matsabory ladan'I Saza (ca. S14.329°, E48.721°) that based on color and pattern (warm rufous with one or two small black speckles) likely belonged to *T. soumagnei*. Given this evidence, it seems likely that *T. soumagnei* is widespread in forest habitats in Mahimborondro and undoubtedly breeds there.

### **Scaly Ground-roller *Brachypteracias squamiger* (Vulnerable)**

This species is considered globally Vulnerable due to projected population declines as a result of the loss of forest habitat (BirdLife International, 2020b). LARR and AB observed a single *G. squamiger* at Andohan' Ambondrona on 27 November and at Ambendrambe on 5 December. At both locations, the vocalizations

and territorial behavior suggested that the birds were likely nesting in the vicinity.

**Rufous-headed Ground-roller *Atelornis crossleyi* (Near Threatened)**

This species occurs in humid montane forests of eastern Madagascar and is considered Near Threatened due to habitat loss. Unlike the other terrestrial rainforest ground-roller species, Pitta-like Ground-roller *A. pittoides* and *Brachypteracias squamiger*, this species has not been recorded at Bemanevika and apparently does not occur there. This may be due to the forests around Bemanevika being drier than what this species prefers. We observed *A. crossleyi* on multiple occasions around Bekavahy in Mahimborondro. On 8 February JCM and DW photographed a juvenile bird, indicating that breeding had occurred in this area earlier in the year. Given these observations and the extensive areas of suitable habitat, it seems likely that Mahimborondro holds a significant population of this species.

**Sunbird-Asities *Neodrepanis* sp.**

In other parts of Madagascar, Common Sunbird-osity *Neodrepanis coruscans* and the related Yellow-bellied Sunbird-osity *N. hypoxantha* are elevational replacements with *N. hypoxantha* occurring most commonly around 1,600 m asl. Given the elevation of our survey sites in Mahimborondro, we anticipated that *N. hypoxantha* would be present. Somewhat surprisingly, all the sunbird-asities that we observed were *N. coruscans*, which were fairly common in the primary montane forest up to nearly 1,700 m at our survey sites (Figure 3, bottom left). The absence of the ecologically similar *N. hypoxantha* could potentially lead to *N. coruscans* occurring up to higher elevations in Mahimborondro than in other parts of Madagascar.

**Red-tailed *Newtonia* *Newtonia fanovanae* (Vulnerable)**

Another poorly known species, *N. fanovanae* is one of four Madagascar endemic birds that had fewer than four confirmed records for the majority of the 20th century (Langrand, 1990) and went unrecorded from its discovery in 1931 until 1989. It is now known from a number of sites across eastern Madagascar (BirdLife International, 2020b) and was recently recorded from Bemanevika (L.-A. Rene de Roland, pers. com.). On 9 February, JCM and DRW encountered two newtonias in primary montane

forest in the vicinity of a mixed feeding party at 1,640 m (S14.29334° E48.76163°). These birds differed from Common *Newtonia* *N. brunneicauda* and Dark *Newtonia* *N. amphichroa* in having a dark iris, buffy wash to the breast, hint of a white eye-ring, and reddish-brown tones in the wings and tail. They stayed in the forest mid-story in primary montane forest, unlike *N. amphichroa* which we usually observed in the understory associated with dense patches of undergrowth. The two birds were observed and photographed at close range over the course of 2-3 minutes (Figure 3, bottom right; additional photos archived on eBird.org). After reviewing the images, we concluded that these were a pair of *N. fanovanae* on the basis of their plumage and behavior. Along with the record from Bemanevika, this observation is at significantly higher elevation than the previous known localities for *N. fanovanae* and it is exciting to discover that this poorly known and threatened species occurs in Mahimborondro.

**Pollen's *Vanga* *Xenopirostris polleni* (Near Threatened)**

This species is considered globally Near Threatened due to projected population declines as a result of loss of forest habitat (BirdLife International, 2020b). Most records of *X. polleni* are from the southern and central portions of Madagascar's eastern rainforest. One individual was recorded by LARR and AB on 28 November at Andohan'Ambondrona and another individual was seen on 5 December at Ambendrambe. These observations represent some of the only records of this species in the tropical forests north of the Antongil Bay (Goodman & Raherilalao, 2013) and thus confirm an important range extension for this species.

**Wedge-tailed *Jery* *Hartertula flavoviridis* (Near Threatened)**

This species is considered globally Near Threatened due to projected population declines as a result of loss of forest habitat (BirdLife International, 2020b). Two birds were observed on one occasion by LARR and AB at Andohan'Ambondrona on 27 November and on two occasions at Ambendrambe on 3 and 6 December.

**Yellow-browed *Oxylabes* *Crossleyia xanthophrys* (Near Threatened)**

This species is widespread in montane forests of eastern Madagascar but is thought to have

a relatively small population and is therefore considered Near Threatened. It has been recorded in protected areas adjacent to Mahimborondro (e.g. Tsaratanàna, Bemanevika) and is expected to occur in Mahimborondro based on habitat. We observed it on two occasions; an individual seen by Eugène Ladoany on 5 February near Bekavahy and two birds seen and sound recorded by JCM and DRW in the understory of montane forest on 6 February near Bekavahy (1640 m asl; S14.30514° E48.74312°).

## Discussion

Our rapid avifaunal survey provides a baseline understanding of the bird diversity present in Mahimborondro and helps us to gain insight into the elevational distribution of birds throughout Madagascar. We found that Mahimborondro has small populations of three threatened species of wetland birds: *Anas melleri*, *Tachybaptus pelzelinii*, and *Gallinago macrodactyla*. Though we only confirmed breeding activity for *A. melleri*, it is likely that all three species breed in the protected area. Mahimborondro is clearly most important for forest species, however, and we confirmed the presence of four globally threatened (Endangered and Vulnerable) and a further seven globally Near Threatened forest birds in the protected area. Many of these species are threatened due to loss of habitat and some of them, such as *Xenopirostris polleni* and *Newtonia fanovanae*, have been previously considered to occur only in tropical wet forests further south. Our discovery that these species occur in Mahimborondro in northern Madagascar extends their known range and highlights a new area of habitat for these threatened species.

Though we were unable to confirm breeding for all the threatened species that we encountered, it is likely that all of the threatened forest birds we recorded breed within the protected area. Specific surveys focused on collecting breeding and abundance data for these species in Mahimborondro could be used to review the site against the IUCN Key Biodiversity Area (KBA) Criteria (IUCN, 2016). From a conservation perspective, it is notable that Mahimborondro has important differences from the nearby Bemanevika protected area. Bemanevika is more important for wetland species, most notably *Aythya innotata*, which we did not observe in Mahimborondro. Meanwhile Mahimborondro has some forest species, such as *Atelornis crossleyi*, which have not been recorded at Bemanevika. Furthermore, given the extent of forest habitat that Mahimborondro contains, it is likely home

to larger populations of the forest species that occur in both protected areas. These differences highlight the importance of a protected area strategy which considers both of these reserves, together with Tsaratanàna and the other protected areas of the CAPAM landscape.

With primary forest in the reserve continuing to above 2,000 m, Mahimborondro offers an excellent opportunity to study some of the higher elevation bird communities in Madagascar. In other regions of the island with lower mountains, the maximum recorded elevation of species may be an artefact of the available land area rather than true elevational limits. We recorded several species at significantly higher elevations than the elevations they are usually observed at in other parts of Madagascar (Hawkins *et al.*, 2015). Interestingly, existing records of these species at comparable elevations are primarily from nearby Tsaratanàna (Safford & Hawkins, 2013) suggesting that there may be localized increases in elevational tolerance for some species in this part of northern Madagascar. From a conservation perspective, the presence of species at these higher elevations results in Mahimborondro being home to a more diverse avifauna than might otherwise be predicted.

The differences between our surveys in February and in November-December emphasize the importance of seasonal timing when conducting ornithological field surveys in Malagasy forests. In February, many bird species were quiet, weather conditions made it challenging to conduct surveys, and we failed to detect several cryptic species. However, combining these two surveys at different times of the year provides a more thorough picture of Mahimborondro's avifauna. Future surveys can improve upon our efforts by expanding to visit other parts of the protected area such as the northeast section of Mahimborondro, which is drier than other parts of the reserve.

Though much of the habitat around Mahimborondro has been very heavily degraded, the sites we visited still maintain significant areas of primary forest. They appear to be rarely visited by people and we saw limited evidence of human activity near our camps. The only evidence of human activity we found in the forest were very old signs of bark harvesting. Lemurs, specifically Common Brown Lemur *Eulemur fulvus*, were relatively common in the areas around our camps and were not shy, suggesting that they have not experienced high hunting pressure. The largest threat to Mahimborondro seems to be

infringement of the forest by burning during the dry season. Burning grassland in the dry season to create fodder for cattle is a common practice in this region, and if not managed, continued burning will reduce the remaining forest habitat on which virtually all of Mahimborondro's bird species rely.

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**Appendix 1.** Localities surveyed in the Mahimborondro Protected Area, northern Madagascar, 4-11 February and 25 November-16 December 2019.

Locality	Coordinates	Survey dates	Description
<b>Matsabory ladan'I Saza</b>	14.316°S 48.724°E	4-5, 11 February	Shallow, freshwater lake surrounded by open grassland and forest edge in the western part of the protected area. Visited by all authors except BA (elevation: 1,590 m).
<b>Bekavahy</b>	14.300°S 48.752°E	6-10 February, 11-16 December	Primary montane forest and elfin ridge forest 3.3 km east of Matsabory ladan'I Saza in the western part of the protected area. Visited by all authors in both February and December (elevation: 1,600-2,000 m).
<b>Andohan' Ambondrona</b>	14.270°S 48.839°E	25-30 November	Primary montane forest and elfin ridge forest in the eastern part of the protected area. Visited by LARR and BA (elevation: 1,532-2,256 m).
<b>Ambendrambe</b>	14.377°S 48.759°E	3-8 December	Primary montane forest with nearby marshes in the southern part of the protected area. Visited by LARR and BA (elevation: 1,518-1,750 m).