Recent estimates of ring-tailed lemur (Lemur catta) population declines are methodologically flawed and misleading

Short title: Recent estimates of ring-tailed lemur decline misleading

Conserving and managing threatened species requires accurate population estimates. Recently, LaFleur et al. (2017) and Gould and Sauther (2016) attempted to estimate the size of the extant ring-tailed lemur (Lemur catta) population based on rapid field assessments and published counts from 32 and 34 sites, respectively, and estimated there to be fewer than 2,500 ring-tailed lemurs remaining in the wild (Gould & Sauther, 2016: 2,000-2,400 individuals; LaFleur et al., 2017: 2,200 individuals). However, both studies have likely severely underestimated the size of the extant ring-tailed lemur population due to a range of methodological problems. Specifically, i) the population status of several sites was misinterpreted from the literature, ii) population estimates for several important sites are incomplete or lacking, and iii) total population estimates are based on an incomplete sample of known populations.

Misinterpretation of Literature

Both studies depend primarily on published records; however, the data on presence and/or abundance of ring-tailed lemurs extracted from prior studies were misinterpreted or mischaracterized in several instances. For example, Gould and Sauther (2016) cite Gardner et al. (2009) to state that ring-tailed lemurs are likely extirpated from the Fiheranana-Manombo Complex (PK32 Ranobe). However, Gardner et al. (2009, p. 41) did record the species in both the Fiherenana and Manombo valleys and state: “Our failure to record [this] species elsewhere should therefore not be interpreted as implying their absence in other areas of the PA…”. Additionally, Gould and Sauther (2016) claim that there are three ring-tailed lemur groups in Nord-Ifotaka based on Semel and Ferguson (2013), although Semel and Ferguson (2013) was focused on characterizing the

use of cliffs by lemurs, and not on surveying the ring-tailed lemur population. LaFleur et al. (2017) cite Irwin at al. (2005) for evidence that ring-tailed lemurs are extirpated from Pic d'Ivohibe and Kalambatritra, yet the latter paper reports a multi-site census that i) did not include Pic d'Ivohibe, and ii) did not census the areas of Kalambatritra where ring-tailed lemurs are thought to occur. Finally, LaFleur et al. (2017) cite Moniac and Heitmann (2007) to estimate Andohahela's ring-tailed lemur population at 82 individuals: however, this publication is merely an observation of two hunted lemurs within a pit near the National Park, and we were unable to determine the origin of the figure 82.

Incomplete Sampling within Survey Sites

Of the sites included in the papers, counts/population estimates are incomplete or lacking for many important areas. For example, Gould and Sauther (2016) include no data for several protected areas with well-known populations including Isalo and Zombitse-Vohibasia National Parks. In addition both surveys consistently use count data from limited survey localities, but present these data as population estimates for entire protected areas. Thus, the figures likely represent severe underestimates of the population sizes at these sites. For example, Tsimanampesotse National Park covers over 200,000 ha, yet the population data presented are based on counts at two locations only and are not extrapolated for the whole National Park (LaFleur et al., 2017).

Incomplete Geographic Coverage of Sites Considered

The two studies' total population estimates were derived from 32 and 34 sites each, rather than systematic range-wide censuses or models, but these sites form an

incomplete and potentially unrepresentative sample of known ring-tailed lemur populations. Over 100 ring-tailed lemur populations are known historically (Goodman et al., 2006), and we are aware of at least 45 localities at which the species has been observed since 2000, but which were not included in either of the recent studies or were erroneously included as extirpated (Table 1; Appendix 1). Beyond these known populations, large areas of suitable habitat occur throughout southern Madagascar that have never been censused (Appendix 1). While LaFleur et al. (2017) acknowledge their total population estimate as being limited to surveyed sites, Gould and Sauther (2016, p. 94) state that their research "represents all known populations", and misleadingly present their estimate of 2,000-2,400 individuals as the total wild population of the species globally. Gould and Sauther (2016) also propose a new distribution map for the species, but omit vast areas of unsurveyed suitable habitat without presenting any evidence for their assumption that these areas are devoid of ring-tailed lemurs: of our 45 additional localities, about half (n=23) lie outside of their suggested distribution areas.

Conclusion

As both LaFleur et al. (2017) and Gould and Sauther (2016) highlight, there is ample evidence that the ring-tailed lemur has suffered population declines, local extinctions and an overall range contraction in recent decades. However the species continues to occur in at least 18 protected areas (Ambatotsirongorongo, Amoron'ny Onilahy, Ankodida, Analavelona, Andohahela, Andringitra, Angavo, Behara-Tranomaro, Beza-Mahafaly, Complexe Anadabolava, Complexe Mangoky-Ihotry, Kirindy-Mite, Mikea, Nord-Ifotaka, Ranobe-PK32, Tsinjoriake, Tsimanampesotse, Zombitse-

Vohibasia) as well as community-managed and private reserves, and is protected by robust cultural norms (fady/faly) that prevent its consumption by people through much of its range. Therefore we do not believe that the species is "headed for imminent extirpation" as suggested by Gould and Sauther (2016, p. 89). Rather, we believe that both studies have likely greatly overstated the severity of the species' decline. LaFleur et al. (2017) suggest there may have been a 95% decline in the ring-tailed lemur population since 2000 by comparing their estimate to that of Sussman et al. (2006). However, both Sussman et al. (2006, p. 17) and LaFleur et al. (2017, p. 320) characterize their estimates as "preliminary". Given the numerous caveats associated with both studies and their use of very different methods, the figure of 95% decline cannot be considered valid or reliable.

The use of unreliable scientific data in conservation can lead to suboptimal decision-making and may also undermine the credibility that scientists and conservationists depend on for public confidence in our findings and actions. Recent online headlines such as "Ring-tailed lemur populations have crashed by 95%" (Platt 2017), generated by the research under discussion, are misleading and risk delegitimizing and undermining critical conservation and research efforts throughout Madagascar at a time when they are required more than ever. If population estimates are to be generated to inform the conservation of threatened primate species, then they must be based on rigorous census methods, robust density estimates (not counts of individuals), and make full use of existing knowledge of species' range to ensure accurate and reliable assessments.

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133 Table 1. Additional known locality records for ring-tailed lemur (Lemur catta) since 2000
134 that were not included in the population estimates published by Gould and Sauther (2016)
135 and LaFleur et al (2017). See Supplementary Materials for map of locations and
136 references (Appendices 1 and 2).

No.	Locality	Source	Coordinates
1	Ankotapiky (Mikea)	Ganzhorn & Randriamanalina 2004	21°52'09.3"S, 43°21'16.1"E
2	Abrahama-Jiloriaky (Mikea)	Ganzhorn & Randriamanalina 2004	22°48'1"S, 43°25'6"E
3	Middle Mangoky 1	Ravoahangy et al 2008	21°41'14"S, 44°19'45"E
4	Middle Mangoky 2	Ravoahangy et al 2008	21°48'52"S, 44°08'24"E
5	Manombo	Gardner et al 2009	22°48'16"S, 43°45'38.7"E
6	Fiherenana	Gardner et al 2009	23°10'28.2"S, 43°57'42.2"E
7	Analavelona	Ravoahangy et al. 2008	22°40'40"S, 44°11'30"E
8	Lavenombato	C. Gardner & L. Jasper pers. obs.	23°34'52.93"S, 43°49'57.24"E
9	Antafoky	Emmett et al. 2003	23° 29'12.79"S, 44°4'26.52"E
10	Manderano	Emmett et al. 2003	23° 31'46.15"S, 44°5'31.27"E
11	Sept Lacs	Emmett et al. 2003 ; C. Gardner & L. Jasper pers. Obs.	23° 31'23.79"S, 44°9'38.34"E
12	Ranomay	C. Gardner & L. Jasper	23°34'28.73"S,

		pers. obs.	44°19'41.53"E
13	Vombositse	Ralison 2008	24°11'3"S, 43°45'9"E
14	Antabore (Itampolo)	Ralison 2008; Raselimanana et al. 2005	24°23'9"S, 43°50'8"E
15	Tongaenoro (Itampolo)	Ralison 2008; Raselimanana et al. 2005	24°44'2"S, 44°01'8"E
16	Vohindefo	L. Jasper pers. obs.	25° 10'15.07"S, 44°32'8.32"E
17	Ankirikiriky Village (Marolinta)	B. Ferguson pers. obs.	25° 5'56.38"S, 44°37'3.07"E
18	Ankirikiriky Sacred Forest (Marolinta)	B. Ferguson pers. obs.	25° 5'11.88"S, 44°37'15.40"E
19	Main Road near Tsimilofo (Beloha)	B. Ferguson pers. obs.	24°57'7.18"S, 45°10'15.67"E
20	Vohipary (Andalatanosy)	B. Ferguson pers. obs. Sterman (2012)	24°36'8.14"S, 45°33'17.81"E
21	Vohitrosy, Elonty (Dadabe Matory)	B. Ferguson pers. obs.	24° 5'39.35"S, 46°10'20.54"E
22	Besakoa Ambany (Mahaly)	B. Ferguson pers. obs.	24°13'9.71"S, 46°14'16.52"E
23	Vohidava North (Anadabolava)	B. Ferguson pers. obs.	24°13'30.11"S, 46°16'18.63"E
24	Anadabolava 1	Ravoahangy et al 2008	24°12'38"S, 46°18'02"E
25	Anadabolava 2	Ravoahangy et al 2008	24°21'20"S, 46°10'51"E

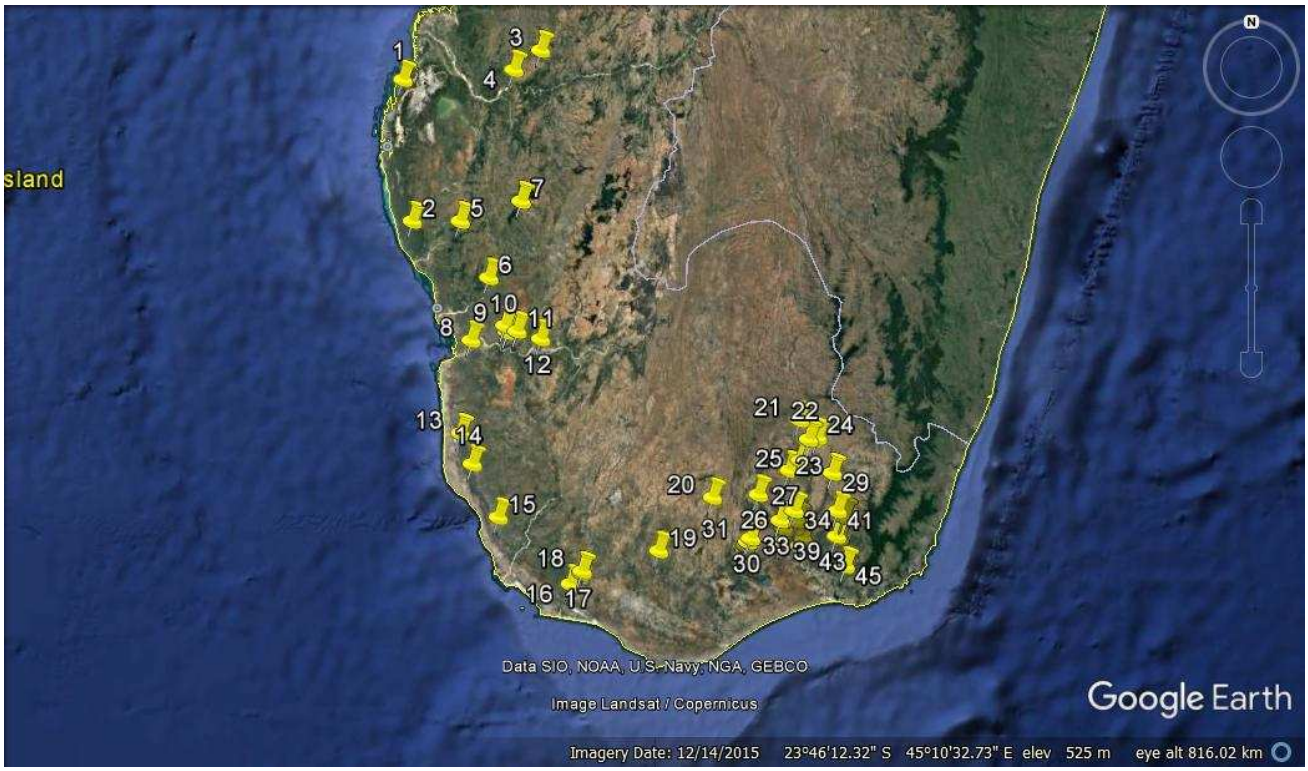
26	Mitakeba Village (Imanombo)	B. Ferguson pers. obs.	24°34'52.07"S, 45°52'58.05"E
27	Vohitsiombe West (Kapila)	B. Ferguson pers. obs. Sass (2011)	24°25'22.18"S, 46° 6'9.87"E
28	Vohitsiombe East (Ebelo)	B. Ferguson pers. obs.	24°25'16.22"S, 46° 7'16.95"E
29	Betenina Andranobe (Tranomaro)	B. Ferguson pers. obs.	24°26'11.69"S, 46°24'42.26"E
30	Angavo East (Antanimora)	Rowland et al (2011)	24°52'1.60"S, 45°49'50.23"E
31	Angavo South West 1 (Antanimora)	Rowland et al (2011)	24°53'24.13"S, 45°48'38.93"E
32	Angavo South West 2 (Antanimora)	Rowland et al (2011)	24°54'44.02"S, 45°47'41.96"E
33	Kobokara (Ifotaka)	B. Ferguson pers. obs. Scherz et al (2012)	24°44'58.75"S, 46° 2'33.16"E
34	Ankazonampingaratse (Mahabo)	B. Ferguson pers. obs.	24°41'9.10"S, 46° 8'29.33"E
35	Befinenetse (Ifotaka)	B. Ferguson pers. obs.	24°45'5.60"S, 46° 9'40.79"E
36	Anjatsikolo Vohimamy (Ifotaka)	B. Ferguson pers. obs.	24°45'39.86"S, 46°10'16.39"E
37	Zanavo (Ifotaka)	B. Ferguson pers. obs.	24°48'25.29"S, 46° 4'22.15"E

38	Ambolihena (Ifotaka)	B. Ferguson pers. obs.	24°47'42.77"S, 46° 8'31.59"E
39	Betamboro (Ifotaka SW)	King et al (2011)	24°53'15.52"S, 46° 3'55.70"E
40	Behira (Bebarimo)	B. Ferguson pers. obs.	24°51'46.68"S, 46°12'22.07"E
41	Vohondava (Tranomaro)	Ralison 2008; Raselimanana et al. 2005	24°41'2"S, 46°27'2"E
42	Ampiaky Tsilamaha (Tranomaro)	B. Ferguson pers. obs.	24°43'14.57"S, 46°29'56.44"E
43	Bevia Gallery Forest (Behara)	Denton 2003	24°50'56.32"S, 46°26'52.70"E
44	Bevia Spiny Forest (Behara)	Denton 2003	24°51'26.24"S, 46°27'58.60"E
45	Ankodida (Amboasary Sud)	Gardner et al. 2008; B. Ferguson pers. obs.	25° 2'37.60"S, 46°30'51.71"E

137

138

Appendix 1. Google Earth image of southern Madagascar showing 45 localities at which ring-tailed lemurs (Lemur catta) have been recorded since 2000, but which were not included in the population estimates of LaFleur et al (2017) or Gould and Sauther (2016), or where the species was erroneously stated to be extirpated.



Appendix 2. References for location records in Table 1.

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