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Wildlife supply chains in Madagascar from local collection to global export

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32 **Abstract**

33 International trade in wildlife is a complex multi-billion dollar industry. To supply it,
34 many animals are extracted from the wild, sourced from biodiversity-rich, developing
35 countries. Whilst the trade has far-reaching implications for wildlife protection, there is
36 limited information regarding the socio-economic implications in supply countries.
37 Consequently, a better understanding of the costs and benefits of wildlife supply
38 chains, for both livelihoods and conservation, is required to enhance wildlife trade
39 management and inform its regulation. Using Madagascar as a case study, we used
40 value chain analysis to explore the operation of legal wildlife trade on a national scale;
41 we estimate the number of actors involved, the scale, value and profit distribution
42 along the chain, and explore management options. We find that the supply of wildlife
43 provided economic benefits to a number of actors, from local collectors, to
44 intermediaries, exporters and national authorities. CITES-listed reptiles and
45 amphibians comprised a substantial proportion of the quantity and value of live animal
46 exports with a total minimum export value of 230,795USD per year. Sales prices of
47 reptiles and amphibians increased over 100-fold between local collectors and
48 exporters, with exporters capturing ~92% of final export price (or 57% when their
49 costs are deducted). However, exporters shouldered the largest costs and financial
50 risks. Local collectors obtained ~1.4% of the final sales price, and opportunities for
51 poverty alleviation and incentives for sustainable management from the trade appear to
52 be limited. Promoting collective management of species harvests at the local level may
53 enhance conservation and livelihood benefits. However, this approach requires
54 consideration of property rights and land-tenure systems. The complex and informal
55 nature of some wildlife supply chains make the design and implementation of policy
56 instruments aimed at enhancing conservation and livelihoods challenging.
57 Nevertheless, value chain analysis provides a mechanism by which management
58 actions can be more precisely targeted.

59 **1. Introduction**

60 The scale of the legal and illegal global trade in wildlife is vast, with legal trade alone
61 estimated to be worth 323 billion USD each year (TRAFFIC 2008). To supply this
62 trade, fauna and flora are often extracted from the wild, frequently from biodiversity-
63 rich countries experiencing high levels of poverty. Consequently, wildlife trade has
64 implications for biodiversity conservation (Kenney et al. 1995; Garcia-Diaz et al.
65 2015), human and environmental health (Karesh et al. 2005; Smith et al. 2009), and
66 human development and society (Roe 2002, 2008, Duffy 2014). To enhance its
67 management, improved understanding of the costs and benefits of wildlife trade supply
68 chains are required. However, this is a multifaceted and complex task. For example,
69 the dependency of people on forests and their products such as medicinal plants, wild
70 meat, live animals, fungi and nuts, goes far beyond village boundaries, contributing to
71 rural, urban, migrant and resident livelihoods, as well as national and global economies
72 (Ambrose-Oji 2003; Jensen 2009; Roe et al. 2009). Therefore, threats to species and
73 habitats are driven by economic activity and consumer demand locally and globally by
74 economic actors far removed from the place of origin (Lenzen et al. 2012).
75 Additionally, as well as providing livelihood benefits to local people; economic,
76 cultural or spiritual benefits obtained by those engaged in wildlife trade may, or may
77 not, provide incentives for conservation and sustainable management of natural
78 resources at the local level (Hutton & Leader-Williams 2003; Jones et al. 2008;
79 Robinson et al. 2018). In general, for trade to generate incentives for conservation,
80 both adequate benefits, and favourable governance conditions including long-term,
81 secure property rights, are required (Bulte et al. 2003). In addition, a number of
82 combined factors come into play, including ‘species-level’ factors such as suitability
83 for harvest (e.g. resilience, accessibility); wider ‘governance’ factors including policy
84 settings; ‘supply chain’ factors including organisation and operation of the supply
85 chain (e.g. barriers to entry, length of the chain); and ‘end-market’ factors, including
86 market size, demand elasticity and consumer preferences (Cooney et al. 2015), all of
87 which will vary considerably on a case-by-case basis.

88 Within conservation science, there is a need for research to adopt interdisciplinary
89 approaches to address socio-ecological challenges (Mascia et al. 2003; Milner-Gulland
90 2012). This is particularly important when considering wildlife trade, where an
91 understanding of the ecological consequences of trade alone would fail to illuminate
92 the economic and social benefits associated with ongoing business. Therefore, an
93 understanding of socio-economic factors, including markets, is paramount. One
94 method for understanding trade-chains is the value chain approach (VCA). The VCA is
95 a descriptive tool and analytical instrument used to understand not only the structure,
96 operation and profit distribution through the trade chain, but also to identify entry
97 points for policy initiatives and value addition. It incorporates the whole range of
98 activities and relations associated with production, exchange, transport and distribution
99 of a commodity (Kaplinsky & Morris 2001; Jensen 2009). VCA has been used to

100 examine markets (including financial analyses, competition, governance, entry
101 barriers, and geographic coverage) and has contributed to the research agenda for
102 various non-timber forest products (Avocèvou-Ayisso et al. 2009; Jensen 2009)
103 including charcoal (Shively et al. 2010), wild meat (Boakye et al. 2016; Cowlshaw et
104 al. 2005), fisheries (Johnson 2010) and python skins (Kasterine et al. 2012). However,
105 there is limited research applying VCA to commercial trade in live animals.

106 With increasing globalisation and awareness of the impact of international trade on
107 biodiversity (Lenzen et al. 2012), initiatives such as certification or labelling schemes
108 that require producers of goods and services to adhere to environmental and social
109 welfare production standards have become increasingly popular (Blackman & Rivera
110 2011). For example, there are an estimated 600 eco-labels worldwide, covering ~15%
111 of the global trade in bananas, 12% of wild fisheries, 10% of global forestry products
112 and 7% of global coffee (Eilperin 2010). Whilst much of the trade in live wild animals
113 does not currently fall under such schemes, there is increasing pressure from
114 environmental groups and other stakeholders to ban the trade on the grounds of
115 welfare, biodiversity loss, health and/or moral considerations (Check 2004; Huyton
116 2015). The Convention on International Trade in Endangered Species of Wild Fauna
117 and Flora (CITES) provides some means of assurance regarding ecological
118 sustainability of wildlife trade, through its requirement for trading countries to
119 determine that exports of listed-species will not be detrimental to their populations in
120 the wild (a 'non-detriment finding'). However, not all species are listed by CITES, and
121 there is limited information available regarding wider implications of the trade on
122 livelihoods and economies in supply countries. Therefore, debates concerning
123 regulation of the trade in live animals are often dominated by potential impacts on wild
124 populations and animal welfare issues, rather than incentives for conservation.
125 Consequently, there is a need for a thorough understanding of trade chains supplying
126 such animals, including information on the actors, livelihood benefits, and potential
127 conservation implications.

128 To address this data gap, we explore the legal commercial trade in live animals, with
129 particular emphasis on herpetofauna, in a biodiversity hotspot, Madagascar.
130 Madagascar has unparalleled levels of biological diversity and endemic species (Myers
131 et al. 2000) which are threatened by continued habitat degradation, driven by economic
132 activities, population growth and high human poverty (Harper et al. 2007; Waeber et
133 al. 2016). Over the last 15 years, Madagascar has emerged as a significant exporter of
134 reptiles and amphibians to supply trade in exotic pets (Carpenter et al. 2004;
135 Rabemananjara et al. 2008; Robinson et al. 2015). Whilst legal trade exists for many
136 species subject to national quotas and CITES regulation, illegal trade, particularly in
137 high value CITES Appendix I species which are prohibited in commercial trade
138 (including several of Madagascar's endemic tortoise species) has proliferated, having a
139 devastating impact on their wild populations (O'Brien et al. 2003; Walker et al. 2004;
140 Mbohoahy & Manjoazy 2016). There is insufficient information to understand the
141 degree of crossover between the legal and illegal herpetofauna trade, although some
142 consider it unlikely that smuggling of large quantities of low commercial value species

143 occurs (Rabemananjara et al. 2008). Previous studies, conducted over a decade ago,
144 explored the structure of the trade chain in Madagascar in relation to chameleons
145 (Carpenter et al. 2004) and mantella frogs (Rabemananjara et al. 2008) and more
146 recent research has analysed the relative importance of wildlife trade as a livelihood
147 strategy in rural areas (Robinson et al. 2018). Here we apply VCA to understand the
148 scale and value of the wildlife trade on a national scale, and the profit distribution and
149 value along the chain from village to export. We also update information on the current
150 structure and operation of the wildlife supply chain, and estimate the number of actors
151 involved. This study expands our understanding of the conservation and socio-
152 economic implications of wildlife trade, and contributes towards discussions
153 concerning sustainability and management of trade in wildlife in Madagascar, and
154 more generally.

155 **2. Methods**

156 We carried out semi-structured interviews with a range of stakeholders involved in
157 wildlife trade in Madagascar between 22nd November 2013 and 8th June 2014. This
158 included the CITES Management Authority of Madagascar, registered wildlife
159 exporters, intermediaries and local collectors. Our research focussed on legal wildlife
160 trade (i.e. trade permitted under CITES and/or national regulations), all questions were
161 voluntary, and all respondents were made aware of this during the free prior informed
162 consent process. However, we acknowledge that there may be some cross-over with
163 illegal markets within the supply chain.

164 **2.1. Sampling**

165 To identify individuals involved at different points along the wildlife trade chain, we
166 used snowball sampling (Bryman 2015). Initially, we conducted interviews with the
167 CITES Management Authority who provided a list of registered wildlife exporters.
168 During interviews, exporters were asked to list names and locations of intermediaries
169 they worked with in order for us to obtain an estimate of the number of intermediaries,
170 and approach them for interviews. Subsequently, intermediaries were asked to provide
171 names and village locations of local collectors. Local collectors were identified
172 through systematic household sampling in identified villages and snowball sampling,
173 whereby village leaders, local guides and respondents from the household sample were
174 asked to identify local reptiles and amphibian collectors (Robinson et al. 2018).

175 **2.2. Semi-structured interviews**

176 Interviews with exporters, intermediaries and local collectors covered several topics
177 including: demographics (age, education etc.); livelihood information relating to
178 wildlife trade (time in job, working hours, income, costs, other livelihood activities);
179 wildlife groups traded and species sale/purchase prices; structure and operation of the
180 supply chain (suppliers used, procedures followed, specific instructions
181 received/provided, questions relating to supply/demand, collection practices);

182 legislation and quotas. Additionally, we asked exporters about their facilities (location,
183 date established, number of employees, job types, revenue, costs). To understand profit
184 distribution across the supply chain, we asked each respondent along the chain
185 (exporters, intermediaries, local collectors) to provide purchase and sale prices of 24
186 pre-selected reptile and amphibian species known to be traded. This was facilitated
187 using Latin, English and Malagasy names of species and photographs. Where no new
188 relevant information was emerging for particular questions, i.e. saturation had been
189 achieved (Bryman 2012), particular lines of questioning were dropped or adapted.
190 Therefore not all respondents were asked all questions. Triangulation was used to
191 verify information received from different actor groups; for example, both exporters
192 and intermediaries were asked the prices animals were exchanged for.

193 Interviews were carried out in English or in Malagasy/French and interpreted by two of
194 the authors. Exporter and intermediary interviews were recorded for verification if
195 respondents granted permission. Consent was recorded by means of a tick box on the
196 data form. Ethical approval was received from the University of Kent.

197 **2.3. Data request**

198 To determine the extent of the trade, data were requested from the General Director of
199 Forests, Ministry of Environment, Ecology and Forests (CITES Management
200 Authority of Madagascar) on the volume of animals and plants belonging to different
201 species exported from Madagascar in 2013; the individual value declared by exporters
202 for individual species; and the total value of wildlife exports. Price information was
203 converted into US dollars (USD) based on an exchange rate of 1USD=2283.11
204 Malagasy Ariary (MGA) valid at the time of the study (29.01.2014)
205 (www.coinmill.com).

206 **2.4. Data analysis**

207 Prices declared by exporters to the authorities (from data request) were compared with
208 price information provided in person during exporter interviews using a non-
209 parametric Wilcoxon Signed-Rank Test. As data were not normally distributed we
210 calculated median prices for each of the 24 pre-selected species at each stage of the
211 chain across respondents, resulting in median purchase and sales prices for each
212 species from exporters and intermediaries, and median sales prices declared by local
213 collectors. Prices provided by different actor groups were compared using a Wilcoxon
214 Signed-Rank Test. We then calculated the mean price across all 24 species and used
215 this value to calculate the mark-up of prices along the chain, marketing margins
216 (proportion of final sales price captured by different actor groups), and the value of the
217 herpetofauna trade to different actor groups.

218 We estimated marketing margins of actor groups following Cowlshaw et al. (2005)
219 and Avocèvou-Ayisso et al. (2009). This was calculated as $(P_s - P_p)/P_f$ where P_s is the
220 mean sales price, P_p is the mean purchase price (i.e. the sales price reported by the
221 previous actor in the chain) and P_f is the final sales price at the end of the chain (at

222 export). We then adjusted this figure to allow for estimated costs (transport, equipment
223 etc.) using $(P_s - P_p - P_c) / P_f - \Sigma P_c$ where P_c is the estimated costs incurred by the actor
224 group. Marketing margins were also calculated for each of the 24 species individually,
225 and Spearman's Rank correlations used to test for relationships between species value
226 and marketing margins received by different actor groups to explore if respondents
227 received a greater share of export value for more valuable species.

228 To calculate the potential value of the reptile and amphibian trade to different actor
229 groups along the chain, we calculated the proportion of the final export value declared
230 by exporters (provided in data request) that reached different actor groups. To do this
231 we used the mean sale and purchase price provided by respondents (across the 24
232 species) to calculate the proportion of the sales price comprised of the cost of
233 purchasing animals from the previous actor in the chain. This represented the value
234 being passed to the previous actor group. We then incorporated additional cost
235 information based on expenses (equipment, transport, etc.) into the calculations,
236 adjusting the profit received by each actor group accordingly. Based on this, we
237 estimated the proportion of the final declared export value that was made up of profit
238 and costs for each group. Since we obtained price data from multiple sources (for
239 comparison and triangulation), we conducted a sensitivity analysis to incorporate the
240 variation in prices given by different actor groups. For example, exporters told us the
241 prices they paid to purchase animals from intermediaries, and intermediaries told us
242 prices they charged to exporters. Therefore, the proportion of the final export value
243 made up of exporter's purchase costs could be calculated in two ways; from the
244 exporter-declared mean sale price divided by exporter-declared mean purchase price,
245 or from the exporter-declared mean sales price divided by the intermediary-declared
246 mean sales price. Therefore, we report the minimum and maximum potential values.

247 **3. Results**

248 **3.1. Scale and value of wildlife trade from Madagascar**

249 Data provided by the CITES Management Authority indicated that the live trade in
250 wildlife from Madagascar, including both flora and fauna was worth 346,249USD in
251 2013. Reptiles and amphibians (CITES and non-CITES) accounted for 66.7% of this
252 total, with CITES reptiles accounting for a considerable proportion (50.4%) of total
253 wildlife export income (Figure 1a). The 2013 Ministry records show the total declared
254 export value of reptiles and amphibians from Madagascar amounted to 230,795USD,
255 generating 14,621USD in taxes to the Ministry of Environment and Forests. However,
256 the mean sales price provided by exporters during our interviews was 2.8 times higher
257 than declared export prices (Wilcoxon Signed-Rank $Z = -4.29$, $n = 24$, $p < 0.001$,
258 Supporting Information, Table S.4.8.1). Therefore, based on the proportional
259 difference, the total export value of reptiles and amphibians for 2013 may total
260 646,226USD.

261 CITES reptiles and amphibians comprised 87.9% of the trade in all animals in terms of
262 numbers of individuals (Figure 1b). A total of 31,871 reptiles and amphibians were

263 exported from Madagascar during the calendar year 2013 (including CITES and non-
264 CITES species).

265 **3.2. Structure and operation of the supply chain**

266 The wildlife supply chain comprised registered exporters, local collectors who trapped
267 animals in the wild and intermediaries who brought animals from local collection areas
268 to export facilities (Figure 2). In some cases, however, the distinction between actors
269 was not clear. For example, the role of local collectors and intermediaries sometimes
270 overlapped, and exporters occasionally by-passed intermediaries to obtain animals
271 directly from local collectors, sent their own staff to collection areas, or supplied other
272 exporters (particularly when exporters were located in different parts of the country).
273 We conducted in-depth interviews with eight of the 11 wildlife exporters (72.7% of
274 exporters), 12 intermediaries and 28 local collectors of reptiles and amphibians. In
275 total, 48 actors were interviewed.

276 Animal exporters were mainly situated in or around the capital Antananarivo, with one
277 in Toamasina (East) and one in Toliara (South). Exporters estimated there were
278 between 20 and 30 intermediaries in Madagascar, but provided 32 different names
279 between them. However, over the course of the study (asking exporters and other
280 actors in the chain to identify intermediaries) we were given a total of 39 names.
281 Intermediaries were identified in several locations including (amongst others)
282 Moramanga (6), Tulear (6), Tamatave (3), Fort Dauphin (2), Diego Suarez (3), Nosy
283 Be (1), Antananarivo (2), Mahajanga (1) and Sambava (2).

284 Fifty-seven percent (n=4) of exporters had other jobs often including additional
285 businesses, and they employed between one and 13 people (median=6, IQR=3.75,
286 n=8), sometimes in part-time seasonal jobs (e.g. guards, feeding animals, packing,
287 transport to airport and general assistance). Most intermediaries (82%, n=9) also had
288 other jobs (e.g. agriculture, minibus driver, shop, mechanic) and generally worked
289 alone with occasional help from family and friends to conduct tasks such as counting
290 animals. Local collectors engaged in wildlife collection as part of a diverse livelihood
291 portfolio and occasionally engaged family members or others to help. All respondents
292 had been engaged in the trade long-term (exporters: median=20 years, IQR=10, n=8;
293 intermediaries median=22 years, IQR=8.3, n=12 and local collectors median=17 years,
294 IQR=16, n=17).

295 Animal export usually occurred from September to July (exporter interviews:
296 median=6.6 months a year, IQR=2, n=7). At the time of research one exporter
297 interviewed had temporarily stopped exporting reptiles and amphibians, the other
298 seven exported reptiles and amphibians and other animals such as mammals (n=6,
299 tenrecs in all cases), invertebrates (n=4), birds (n=4, e.g. *Agapornis canus*), fish (n=2),
300 plants (n=2) and cultivated and non-CITES coral (n=1). In all cases, respondents
301 reported that animals were exported live (as opposed to skins or other products), and
302 mainly supplied wholesalers, pet shops and specialised reptile outlets around the

303 world. Ministry data indicates that the USA, Japan and Canada were the most
304 significant importers in terms of volume (no. animals imported), importing 45%, 13%
305 and 9% respectively of Malagasy herpetofauna in 2013.

306 Informal verbal contracts existed between different actor groups in the chain, and
307 intermediaries were required to carry a collection mandate obtained from the exporter
308 (in turn obtained from the Management Authority) detailing the order specifics. In
309 almost all cases animals were collected to order, with specific information on
310 number/species/sex transferred down the chain from exporter to local collector, only
311 occasionally were animals collected opportunistically. When local collectors were
312 asked: 'if you were to collect more animals, how likely is it that you could sell them',
313 the majority (82%, n=23) said 'unlikely'. When asked 'if you were paid more for each
314 animal, how would it influence the number you collect', the majority (86%, n=24)
315 stated that they would collect the same quantity with most commenting that they stick
316 to the number ordered because 'no-one will buy extra animals', or, if someone would
317 buy them, it would be for a much lower price. All nine intermediaries corroborated this
318 stating it was 'very unlikely' that if they themselves requested more animals they
319 would find a buyer.

320 Exporters were permitted by authorities to collect 10% above quotas to allow for
321 mortality, but this was not perceived economically viable for all species, depending on
322 how robust they were. Exporters kept animals for three days to one month prior to
323 export (median=7, IQR=2.5), and gave intermediaries between two days and one
324 month to supply animals (median=15 days, IQR=10.5). One exporter commented that
325 'it's not in our interest to keep them in the facility as it says 'W' (wild) on [CITES]
326 application and the animals may lose health if kept'. Local collectors reported it took
327 between one and 15 days to collect and supply animals to the intermediary
328 (median=2.5, n=24). Therefore, the total time from collection to export was between a
329 few days and two months.

330 **3.3. Economics of the supply chain**

331 **3.3.1. Comparison of price information provided by actor groups**

332 Purchase prices for 24 species provided by exporters were slightly higher (mean
333 proportional difference=1.2±0.11, n=23 taxa) than equivalent sale prices provided by
334 intermediaries, but there was no significant difference (Wilcoxon Signed Rank Z=1.15,
335 p=0.249). However, there was a significant difference between purchase prices
336 provided by intermediaries and equivalent sale prices provided by local collectors
337 (Z=3.88, p<0.001), with prices declared by intermediaries more than double sale prices
338 declared by local collectors (mean proportional difference=2.5±0.73, n=20 taxa,
339 supporting Information, Table S2).

340 **3.3.2. Summary of costs encountered by actor groups**

341 Exporters had considerably higher costs than other actor groups along the chain (Table
342 1). These costs included facility setup and maintenance (e.g. land, staff, utility bills),

343 transport, packing, agent/broker, collection permit (one-time fee each year), price of
344 animals, collection fees (paid to local branch of the Ministry; set price of 80 MGA
345 (0.04USD) per reptile and 30 MGA (0.01USD) per amphibian), informal fees to
346 communities (varies), and various taxes. Taxes included an export tax for wild animals
347 to the Ministry (4% of shipment value), voluntary fees to support the CITES Scientific
348 Authority (2%), taxes to the Ministry of Commerce, veterinary certificate fees (2%),
349 fees to GasyNet (private company that deals with import/export at airport, one exporter
350 quoted this as 2% of total invoice per shipment). According to detailed price
351 information provided by one exporter, costs comprised 35% of revenue generated from
352 shipments (Table 1). Another exporter corroborated this estimating that costs
353 comprised 30-50% of final shipment value.

354 Compared to exporters, local collectors and intermediaries declared minimal costs.
355 Exporters usually covered intermediaries' costs of transport, accommodation,
356 equipment, in addition to the agreed price for animals. Some intermediaries stated they
357 paid for materials such as cages, plastic bottles, cloth bags, torches and other sundries,
358 and informal fees to communities. Local collectors' main costs included torches,
359 batteries, food and coffee, medicines, and in some cases, items for transporting animals
360 (baskets, sacks, cloth bags, bottles, and gloves).

361 **3.3.3. Price mark-up across supply chain and marketing margin**

362 Based on sale price information provided by each actor group (Supporting
363 Information, Table S2), animals were sold by intermediaries for around seven times
364 the price they were purchased for from local collectors (mean proportional
365 difference= 7.3 ± 1.32 ; $n=19$ species). The intermediary sales price increased a further
366 15 times by exporters prior to sale/export (mean proportional difference= 14.98 ± 1.8 ,
367 $n=23$ species). The sale price increased by 105 times (mean proportional
368 difference= 105.28 ± 21.2 , $n=20$ taxa) from local collector to exporter.

369 Marketing margin (at export) captured by each actor group was greatest for exporters
370 (92.3%), followed by intermediaries (6.2%) and then local collectors (1.4%) (Table 2).
371 Consideration of costs reduced the share captured by exporters to 88.5%, and increased
372 the share captured by intermediaries (9.5%) and local collectors (2.0%) (Table 2).
373 When calculated for individual species, marketing margins varied between 0.2 and
374 4.0% for local collectors, 2.8 to 31.3% for intermediaries and 67.0 to 97.3% for
375 exporters (Supporting Information, Table S3). There was no significant relationship
376 between final sales prices at export and marketing margins received by local collectors
377 ($r_s=-0.095$, $n=20$, $p=0.690$), intermediaries ($r_s=-0.371$, $n=23$, $p=0.082$) or exporters
378 ($r_s=0.335$, $n=23$, $p=0.118$), suggesting the share received by actors was not related to
379 the export value of the species.

380 Exporters estimated that ~35% of shipment value was used on expenses, therefore
381 based on a final declared export value of 230,795USD logged with the Ministry for all
382 exporters in 2013, this represents a profit of 149,324USD (Figure 3). According to the

383 sensitivity analysis, we estimated that purchase prices paid by exporters for animals
384 comprised 7.7 to 9.3% of prices they sold them for, representing a transmission of
385 17,708 to 21,511USD to intermediaries. Incorporating animal purchase costs paid by
386 intermediaries (ranging from 15.5 to 47.7% of sales prices) and additional costs
387 (0.18%, Table 1), estimates for profit received by intermediaries ranged from 9,238 to
388 18,144USD. Local collectors did not encounter costs of purchasing animals but based
389 on estimated additional costs (10.6%, Table 1), this resulted in an estimate of 2,449 to
390 9,163USD reaching local collectors (Figure 3). However, based on the discrepancy in
391 prices between declared export values reported in Ministry data, and the prices
392 exporters reported during the interviews, these values may be considerably higher. For
393 example, based on a cumulative export value of 646,226USD (sales prices reported by
394 exporters being 2.8-times higher than prices reported to Ministry), exporters could
395 receive a profit of 418,108USD; intermediaries from 25,866 to 50,804USD and local
396 collectors from 6,857 to 25,658USD.

397 **4. Discussion**

398 The export of live (particularly CITES-listed) reptiles and amphibians from
399 Madagascar clearly forms a significant component of the country's wildlife trade in
400 terms of both number of individual animals, and value. Analysis of the supply chain
401 reveals the extent and distribution of economic benefits obtained by different actors
402 along the chain. These benefits extend beyond local collection areas, to intermediaries
403 in urban areas, export businesses and their employees, to local authorities and the
404 national economy.

405 There has been a reduction in the number of animal exporters from 13 (1996-1999,
406 Carpenter et al. 2005) and 17 (2003-2004, Rabemananjara et al. 2008), to 10 active
407 exporters in the current study. Additionally, whilst in 2003-2004 intermediaries were
408 described as 'solely involved in the wildlife trade' and 'for most exporters, animal and
409 plant export is the main source of income' (Rabemananjara et al. 2008) we found few
410 people involved as their sole occupation. The flexibility of the chain, particularly the
411 overlapping roles of intermediaries and local collectors, may explain discrepancies in
412 price information received from different actors. For example, a local collector
413 subcontracted by another local collector to fulfil an order may only receive half the
414 price that the contractor receives. Other factors such as village location or collecting
415 site may also influence prices. Price differences between those exporters provided
416 during interviews and those declared to the Ministry may be explained by under-
417 declaration of prices to the Ministry, exaggeration of prices during interviews, price
418 increases since the data request, or general variation in the data.

419 The trade consisted of well-established actors, as individuals all along the chain had
420 mostly been in the business for long periods (~20 years). Importantly, the trade
421 operated on the basis of informal verbal contracts between actors, based on trust.
422 Therefore, knowledge of the supply chain participants, contacts and reputation were
423 particularly important in coordinating activities within the chain. Animals were rarely

424 collected opportunistically, as was sometimes the case in the past (Carpenter et al.
425 2005), but were collected to order, with specific details (e.g. species/sex/quantity)
426 passed down the chain from exporters to local collectors. In the majority of cases, it
427 was not considered economic to collect opportunistically as buyers were not available,
428 or would pay a lower price. Only occasionally, if a desirable, evasive, or valuable
429 specimen was encountered opportunistically, would they collect that animal. Once
430 collected, animals were not kept in-country for long, thus minimising exporter costs.
431 Although we did not verify health of animals in trade, with payments frequently
432 phased (50% before and 50% on delivery), and often with no payment for poor quality
433 animals, there are incentives for suppliers to deliver animals in good condition.

434 Whilst exporters captured by far the largest proportion of the final sales price, they also
435 incurred the largest proportion of costs associated with running and licencing their
436 facilities and infrastructures. There is also risk associated with export of live
437 herpetofauna. For example, exporters must factor in mortality of animals in transit, for
438 which they may not get paid. Comparably, intermediaries and local collectors had
439 minimal costs and therefore much lower investment. However, even when taking into
440 account the estimated costs exporters' face, the proportion of final sales price received
441 by local collectors is relatively low (1.3-2.0%). Recent comparable examples are
442 scarce, but caiman hunters in Louisiana received 5-15% of export price (Moyle 2013);
443 chameleons collectors in Tanzania received ~8.3% (Roe 2002); parrots collectors in
444 Indonesia received 5.2% (Swanson 1992), and ornamental fish collectors in Brazil
445 received 10%-19% (Baquero 1999, Watson & Roberts 2015). Carpenter et al. (2005)
446 noted that local collectors and intermediaries in Madagascar suffered
447 disproportionately greater price reductions than exporters following trade restrictions,
448 in particular the Experimental Management Program (EMP) implemented in 1999. The
449 EMP was a national initiative, in compliance with exporters, to address CITES
450 concerns. It initially restricted trade, with the aim of increasing the number of species
451 permitted based on good management, but was essentially dominated by a cartel of
452 powerful exporters and resulted in a ~100-fold differential between prices paid to
453 exporters and local collectors (Carpenter et al. 2005). This price differential still
454 appears to be the case today despite the collapse of the EMP.

455 This research describes the economic benefits received by actors along the entire
456 herpetofauna supply chain in Madagascar, and demonstrates that a large proportion of
457 the benefits are obtained by exporters. However, income obtained is not
458 straightforward to interpret. For example, a small amount of money will go further
459 amongst local collectors, compared with intermediaries and exporters residing in towns
460 and cities, and local collectors in rural communities may be more in need of
461 employment no matter how small the financial benefits. Recent research in the same
462 study area (Robinson et al. 2018) revealed that 13% of households in collection areas
463 benefitted from local harvest of live animals for export (including some of the poorest)
464 and it was potentially profitable. However, it also revealed the unreliable and sporadic
465 nature of live animal collection (limited by quotas, season, opportunity cost and
466 supply), and that incentives appear insufficient to promote conservation of species and

467 habitats (Robinson et al. 2018). Equally, in their study of mantella frog trade in
468 Madagascar, Rabemananjara (2008) observed that because collection permits are
469 issued to exporters rather than local collectors - and collectors are paid low prices - the
470 system becomes counterproductive in terms of promoting sustainable harvesting and
471 incentives to conserve resources based on benefits received. The fact that local
472 collectors are not in possession of permits, may promote a sense of insecurity and
473 disconnect from regulatory processes (e.g. collectors have to trust the word of the
474 middleman, and may have insufficient knowledge regarding measures such as quotas).
475 In order for the trade to provide incentives to motivate pro-conservation behaviours,
476 not only should benefits be adequate, but property rights also need to be sufficient so
477 that local stakeholders are in a position to manage their own resources (Cooney et al.
478 2015). However, property rights are often poorly defined in Madagascar (Bojö et al.
479 2013), meaning that the collector typically does not own the resource from which the
480 animals are being harvested, so it is unknown whether they can control management of
481 the resource, or if the social capital exists to do so. Therefore, whilst the trade in
482 herpetofauna from Madagascar brings some benefits to stakeholders along the chain, at
483 the local level, both incentives for conservation, and opportunities to alleviate rural
484 poverty appear to be limited as they currently stand.

485 **4.1. Conclusion and options for sustainable trade**

486 Madagascar is a top global conservation priority (Myers et al. 2000), but with 77.8%
487 of its population living below the poverty line of \$1.90 a day (UNDP, 2018); pressures
488 on natural resources are high. Habitats are severely threatened by slash and burn
489 agriculture, cutting fuelwood, charcoal production, cattle raising, mining, bushmeat
490 and over-harvesting of resources (Cardiff & Andriamanalina 2007, Harper et al. 2007,
491 Razafimanahaka et al., 2012). Political instability (2009-2014) saw donor funding
492 suspended and a proliferation of illegal activities, including logging of valuable
493 hardwoods in protected areas (Innes 2010; Waeber & Wilmé 2013). Despite hundreds
494 of millions of US dollars invested in environmental projects and an expanded protected
495 area network, efforts to deliver progress towards poverty reduction and reducing
496 deforestation rates have failed (Gardener et al. 2018, Waeber et al. 2018).
497 Consequently, finding solutions where livelihood and conservation benefits can be
498 reconciled are essential.

499 Certain high-value (and prohibited) reptile species, such as the ploughshare and
500 radiated tortoise, are being illegally traded from Madagascar (Mbohoahy & Manjoazy
501 2016). However, the legal trade in herpetofauna is contributing to some livelihoods.
502 Given that any move towards further trade restrictions could remove benefits and
503 undermine management incentives, we concentrate here on exploring options with
504 potential to enhance both conservation and livelihood benefits utilising the trade.
505 Certification or labelling schemes aimed at improving ecological and social
506 sustainability might allow higher prices to be realised at export, with an increase in
507 benefits passed down the chain. However, certification schemes have large cost and
508 bureaucratic implications, and whilst receiving limited attention in the pet trade, have

509 been largely unsuccessful for ornamental fish (Vosseler 2015). Equally, it is unknown
510 whether demand exists for such products amongst end-consumers. Other approaches
511 may include promoting collective management of the resource amongst local
512 collectors (e.g. through formation of producer associations), as well as boosting
513 capacity. This could focus on coordinating collecting activities (e.g. sharing
514 information on trapping requests, setting prices) and raising awareness of traded
515 species (e.g. legislation, value, ecology, appropriate collection methods). For example,
516 the Sustainably Harvested Devil's Claw project in Namibia, which similarly focussed
517 on ensuring good prices, strengthening harvester bargaining power and providing
518 general information and support, demonstrated that improved benefit sharing
519 contributed to improved resource conservation (Stewart & Cole 2005). However, many
520 of the villages where wildlife collectors reside are isolated and often difficult to access,
521 making communication between local collectors difficult. Intermediaries may therefore
522 have an important role to play within the supply chain in terms of communication
523 (contacts, accessibility, transport) and could be incorporated into producer focussed
524 initiatives through professionalization of middlemen networks. Greater consideration
525 would need to be given to property rights and land tenure systems in Madagascar, to
526 enable such management to work. Our analysis reveals that almost 32,000 reptiles and
527 amphibians were legally exported from Madagascar in 2013, with an estimated export
528 value of between 231,000 and 646,000USD. Local collectors obtain ~1.4% of the final
529 sales price, and opportunities for poverty alleviation and incentives for sustainable
530 management from the trade, appear to be limited. We also reveal the complex and
531 informal nature of wildlife trade supply chains, and illustrate the challenges faced by
532 practitioners attempting to enhance the trade for both livelihoods and conservation. In
533 addition to improving understanding of the costs and benefits of the wildlife trade to
534 different actor groups, we demonstrate the utility of value chain analysis in providing a
535 mechanism by which management strategies to regulate wildlife trade can be more
536 precisely targeted.

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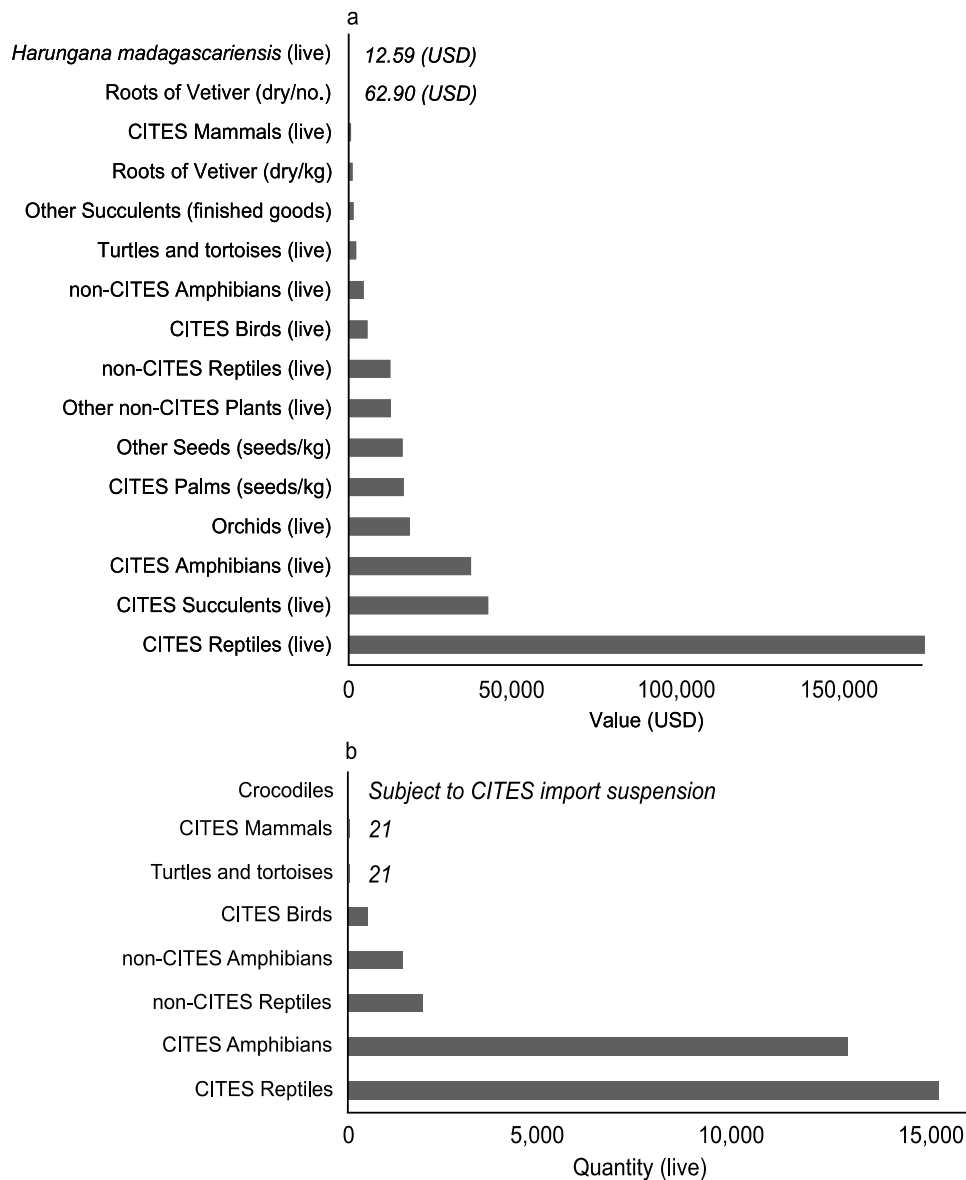


Figure 1 (a) Value in USD of wildlife exports (including both flora and fauna) from Madagascar in 2013, as provided by the CITES Management Authority of Madagascar. Data were missing for non-CITES palms, shells, and Apanga (*Pteridium aquilinum*). Additionally, whilst data were provided for ‘other succulents: finished goods’ they were missing for ‘other succulents: tubes’ and ‘other succulents: number’. Data were converted from Malagasy Ariary (MGA) to US dollars (USD) based on an exchange rate of 1USD=2283.11 MGA valid 29/01/2014 (www.coinmill.com). **(b)** Quantity of live fauna exported from Madagascar in 2013, as provided by the CITES Management Authority of Madagascar. Flora are excluded from this figure as some are exported by weight (e.g. kilograms of seed) rather than as whole plants and are therefore not directly comparable. No data were provided for non-CITES mammals or birds and we have been unable to verify whether this is because there is no trade in these groups or just no data.

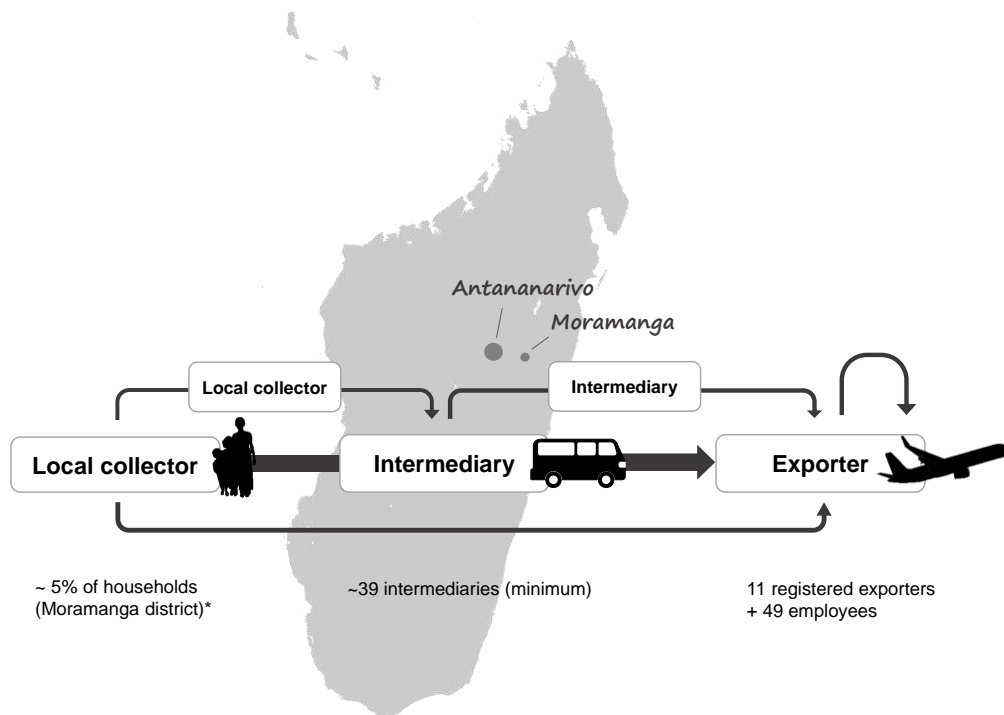


Figure 2 Structure of the wildlife trade supply chain in Madagascar and approximate numbers of people belonging to different actor groups. The supply chain comprised local collectors who trapped animals in the wild, intermediaries who brought animals from local collection areas to export facilities and registered wildlife exporters. *5.4% of randomly selected households in trapping villages in the Moramanga district of Madagascar trapped reptiles and amphibians for trade (See Robinson et al. 2018).

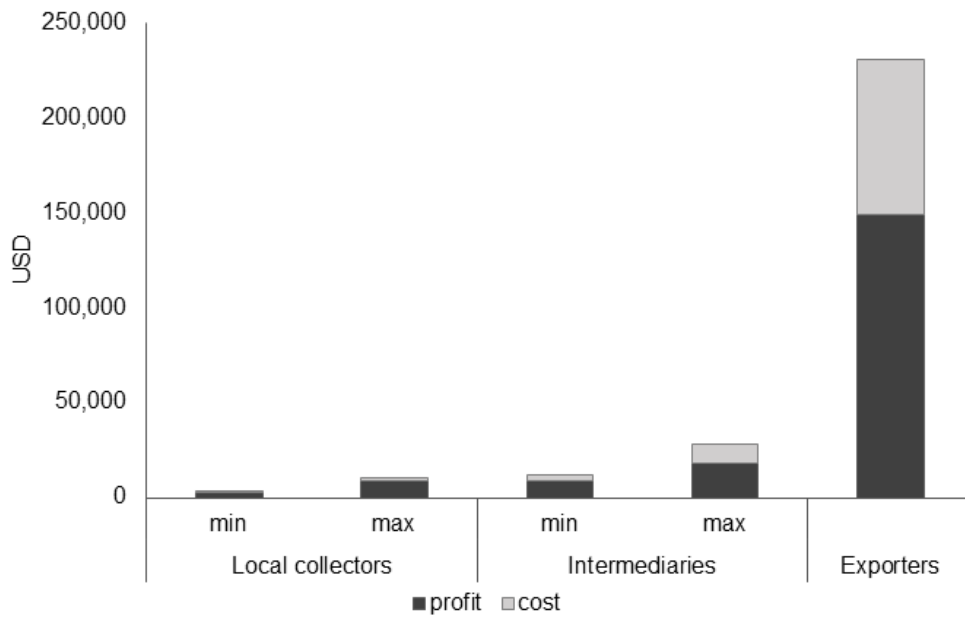


Figure 3. Minimum and maximum estimated profit and costs received by local collectors, intermediaries and exporters engaged in the commercial reptile and amphibian trade in Madagascar. Mean sales price per individual is estimated across 24 different traded species are displayed below the x axis. Individual sales prices for each of the 24 species are provided in Supporting Information, Table S2.

Table 1. Median income and cost information provided by exporters, intermediaries and local collectors during interviews for the 2012-2013 collection season (~September to July). Percentage costs were calculated based on median revenue and median cost information across respondents, with the exception of exporters (because only one exporter gave a monetary value for costs, the percentage cost was calculated from that individuals declared revenue, rather than the median revenue across all four exporters). IQR=interquartile range.

	n	Median (USD)	IQR (USD)	% costs
Exporters net revenue	4	24,381	40,278	-
Exporter costs	1	13,500		35.3 ^a
Intermediary income	8	325	1105	-
Intermediary costs	4	0.66	25	0.18
Local collector income per season	20	114	133	-
Local collector costs per season	25	12	54	10.6

^aAnother exporter did not give detailed cost information but estimated that 30-50% of the value of one shipment will go on expenses.

Table 2. Marketing margins of the different actor groups involved in the live reptile and amphibian trade in Madagascar. Marketing margins were calculated as $(P_s - P_p)/P_f$ where P_s is the mean sales price, P_p is the mean purchase price (i.e. the sales price reported by the previous actor in the chain) and P_f is the final sales price at the end of the chain (at export). We then adjusted this figure to allow for estimated costs (transport, equipment etc.) using $(P_s - P_p - P_c)/(P_f - \Sigma P_c)$ where P_c is the estimated costs incurred by the actor group.

Category of actor	Mean selling price ¹ (USD)	Costs ² (USD)	Local collectors marketing margin		Intermediaries marketing margin		Exporters marketing margin	
			P_s/P_f (%)	with costs $P_s - P_c / P_f - \Sigma P_c$ (%)	$P_{s_i} - P_p / P_f$ (%)	with costs $P_{s_i} - P_p - P_{c_i} / P_f - \Sigma P_c$ (%)	$P_f - P_{p_i} / P_f$ (%)	with costs $P_f - P_{p_i} - P_{c_{ii}} / P_f - \Sigma P_c$ (%)
Local collector	0.28 (P_s/P_p)	0.03 (P_c)	1.44	2.00				
Intermediary	1.49 (P_{s_i}/P_{p_i})	0.02 (P_{c_i})			6.23	9.51		
Exporter	19.42 (P_f)	6.86 ($P_{c_{ii}}$)					92.33	88.48

¹Mean selling price is calculated by taking the median selling price across respondents for each species, and then taking the mean price across the 24 species. Selling prices declared by each actor group (exporter, intermediary and local collector) are used.

²Costs refer to all additional expenses such as transport, packaging etc. but do not include purchase of animals. Values are calculated using the percent costs information provided in Table 1.

Supporting Information

Table S1. Median \pm interquartile range (IQR) prices for 24 species, provided by exporters during interviews ^(a) and as declared according to data received from by the General Directorate for Forests, Ministry of Environment and Forests (CITES Management Authority of Madagascar) for 2013 ^(b).

Species	Interview data (USD) ^a			Declared price (USD) ^b			Proportional difference (^a / ^b)
	median	IQR	n (exporters)	median	IQR	n	
Brookesia stumpffi	29.63	14.81	4	8.00	6.96	180	3.70
Brookesia superciliaris	22.78	8.09	4	8.00	8.00	194	2.85
Brookesia therezieni	22.78	8.09	4	6.50	7.50	95	3.50
Brookesia thieli	22.78	8.09	4	6.50	6.50	89	3.50
Furcifer campani	29.50	29.50	4	14.00	30.00	217	2.11
Furcifer lateralis	20.00	25.00	5	10.00	9.92	1797	2.00
Furcifer oustaleti	11.00	1.00	5	9.00	7.25	1660	1.22
Furcifer pardalis	80.00	32.50	5	25.00	35.00	1793	3.20
Furcifer verrucosus	12.00	9.00	5	8.00	5.38	1558	1.50
Mantella aurantiaca	8.22	5.50	5	2.00	2.00	490	4.11
Mantella baroni	5.00	2.74	4	2.00	0.38	5628	2.50
Mantella betsileo	4.00	1.37	4	2.00	0.00	4294	2.00
Mantella nigricans	4.00	6.00	5	2.00	1.00	1716	2.00
Mantella pulchra	6.11	4.54	4	2.00	1.00	351	3.06
Paroedura masobe	22.50	24.25	3	11.12	1.12	2	2.02
Phelsuma laticauda	12.00	5.00	5	4.00	3.00	569	3.00
Phelsuma lineata	9.00	4.10	3	3.00	4.00	2656	3.00
Phelsuma madagascariensis	18.00	10.00	5	6.00	5.75	799	3.00
Phelsuma quadriocellata	11.00	5.00	5	3.00	5.75	1667	3.67
Scaphiophryne gottlebei	16.00	24.00	5	3.00	3.50	184	5.33
Uroplatus eburni	20.28	8.29	4	10.00	11.75	75	2.03
Uroplatus fimbriatus	36.55	18.08	4	10.00	10.00	433	3.66
Uroplatus phantasticus	20.28	8.29	4	10.00	13.00	56	2.03
Uroplatus sikorae	22.78	10.59	4	10.00	10.00	760	2.28
Mean difference between price estimates:							2.80

Table S2. Median purchase and sale prices (USD) for 24 traded species as declared by exporters, intermediaries and local collectors during interviews.

Species	Exporter sale price (median) ^a			Exporter purchase price			Intermediary sale price (median) ^c			Intermediary purchase price			Local collector sale price			Comparison of exporter ^(b) vs intermediary ^(c) declared prices ^(b/c)	Comparison of intermediary ^(d) vs local collector ^(e) declared prices ^(d/e)
	min-max	n		min-max	n		min-max	n		min-max	n		min-max	n			
Brookesia stumpffi	29.63	7-40	4	1.75	1.31-4.38	5				0.22		1	0.07	0.04-0.22	3		3.14
Brookesia superciliaris	22.78	7-30	4	1.53	1.31-2.63	5	1.10	0.31-1.76	5	0.50	0.22-0.88	6	0.22	0.07-1.31	10	1.39	2.25
Brookesia therezieni	22.78	7-30	4	1.75	1.31-2.63	5	1.10	0.31-1.76	4	0.55	0.22-0.88	5	0.22	0.09-0.44	9	1.59	2.50
Brookesia thieli	22.78	7-30	4	1.53	1.31-2.63	4	1.10	0.31-1.76	4	0.55	0.22-0.88	5	0.22	0.09-0.44	10	1.39	2.50
Furcifer campani	29.50	10-80	4	2.19	2.19-2.63	3	1.43	1.21-2.20	3	0.88	0.66-1.32	3				1.53	
Furcifer lateralis	20.00	14-40	5	1.53	0.66-2.19	6	0.88	0.13-1.32	4	0.48	0.04-0.79	3	0.15	0.09-0.22	2	1.74	3.23
Furcifer oustaleti	11.00	10-20	5	1.09	0.44-2.19	5	1.32	0.44-2.11	6	0.88	0.09-1.32	4	0.30	0.09-0.88	4	0.83	2.93
Furcifer pardalis	80.00	35-342.50	5	6.49	3.5-17.52	6	2.20	1.32-7.04	4	1.32	0.88-3.52	4				2.95	
Furcifer verrucosus	12.00	10-20	5	1.86	1.09-2.19	6	2.20	1.98-2.20	3	0.88	0.88-1.32	2				0.85	
Mantella aurantiaca	8.22	3-10	5	0.54	0.31-2.19	6	0.46	0.13-0.88	2	0.29	0.09-0.40	3	0.10	0.04-0.22	4	1.18	2.86
Mantella baroni	5.00	2.5-6	4	0.44	0.31-0.44	5	0.44	0.22-3.30	5	0.23	0.09-1.10	5	0.07	0.03-0.22	9	1.00	3.30
Mantella betsileo	4.00	2.5-6	4	0.44	0.31-0.66	5	0.79	0.70-1.32	3	0.44	0.26-0.44	3	0.16		1	0.55	2.75
Mantella nigricans	4.00	4-10	5	1.39	0.31-2.19	6	1.32		1	0.88		1	0.07		1	1.05	12.57
Mantella pulchra	6.11	3-9	4	0.39	0.44-0.88	6	0.66	0.22-1.32	5	0.40	0.09-0.55	6	0.05	0.04-0.26	9	0.60	7.92
paroedura masobe	22.50	20-50	3	6.68	5.26-8.76	4	4.40	2.64-8.80	4	2.31	0.44-4.40	5	0.88	0.07-2.19	9	1.52	2.63
Phelsuma laticauda	12.00	6-15	5	1.09	0.44-2.19	6	0.73	0.66-0.79	2	0.34	0.24-0.44	2				1.51	
Phelsuma lineata	9.00	5-10	3	0.44	0.35-0.44	4	0.33	0.13-1.10	4	0.18	0.09-0.44	3	0.04	0.00-0.15	11	1.33	4.40
Phelsuma madagascariensis	18.00	8-30	5	1.75	0.44-2.19	5	1.20	0.44-2.20	4	0.55	0.22-0.88	4	0.66	0.44-0.88	2	1.46	0.83
Phelsuma quadriocellata	11.00	6-15	5	0.66	0.44-2.19	6	0.40	0.18-1.10	5	0.24	0.09-0.44	4	0.09	0.03-0.18	11	1.66	2.69
Scaphiophryne gottlebei	16.00	5-25	5	1.12	0.31-0.66	6	1.76	1.32-2.20	2	0.88	0.66-0.88	2	0.07	0.04-0.22	4	0.64	12.57

Uroplatus eburnei	20.28	12-50	4	1.75	0.79-2.63	5	1.98	0.70-4.18	5	0.88	0.35-2.09	6	0.28	0.07-1.10	9	0.88	3.14
Uroplatus fimbriatus	36.55	14-60	4	3.50	2.63-6.57	5	4.40	2.20-5.28	4	1.32	0.48-4.40	5	1.04	0.66-2.63	12	0.80	1.27
Uroplatus phantasticus	20.28	12-50	4	1.75	0.79-3.07	5	2.42	1.32-3.52	5	1.10	0.66-1.76	6	0.44	0.04-1.10	12	0.72	2.50
Uroplatus sikorae	22.78	10-50	4	1.75	0.88-2.19	5	1.54	0.88-2.20	5	0.66	0.22-1.32	6	0.37	0.09-1.10	14	1.14	1.78
Mean	19.42			1.81			1.49			0.71			0.28		7.30	1.23	2.53

Table S3. Marketing margins of the different actor groups (local collectors, intermediaries and exporters) involved in the reptile and amphibian trade in Madagascar, calculated for 24 individual species.

Species	Marketing margin		
	Local collector	Intermediary	Exporter
<i>Brookesia stumpffi</i>	0.24	-	-
<i>Brookesia superciliaris</i>	0.97	3.86	95.17
<i>Brookesia therezieni</i>	0.97	3.86	95.17
<i>Brookesia thieli</i>	0.97	3.86	95.17
<i>Furcifer campani</i>	-	4.85	95.15
<i>Furcifer lateralis</i>	0.75	3.65	95.60
<i>Furcifer oustaleti</i>	2.73	9.27	88.00
<i>Furcifer pardalis</i>	-	2.75	97.25
<i>Furcifer verrucosus</i>	-	18.33	81.67
<i>Mantella aurantiaca</i>	1.22	4.40	94.38
<i>Mantella baroni</i>	1.40	7.40	91.20
<i>Mantella betsileo</i>	4.00	15.80	80.20
<i>Mantella nigricans</i>	1.75	31.25	67.00
<i>Mantella pulchra</i>	0.82	9.98	89.20
<i>Paroedura masobe</i>	3.91	15.64	80.44
<i>Phelsuma laticauda</i>	-	6.05	93.95
<i>Phelsuma lineata</i>	0.44	3.22	96.33
<i>Phelsuma madagascariensis</i>	3.67	2.99	93.34
<i>Phelsuma quadriocellata</i>	0.82	2.78	96.40
<i>Scaphiophryne gottlebei</i>	0.44	10.56	89.00
<i>Uroplatus ebenau</i>	1.38	8.38	90.23
<i>Uroplatus fimbriatus</i>	2.85	9.19	87.96
<i>Uroplatus phantasticus</i>	2.17	9.77	88.06
<i>Uroplatus sikorae</i>	1.62	5.14	93.24

*Marketing margins were calculated using price information in Table S2, according to the following formula: $(P_s - P_p)/P_f$, where P_s is the mean sales price, P_p is the mean purchase price (i.e. the sales price the previous actor in the chain) and P_f is the final sales price at the end of the chain (at export).