



## Wildlife supply chains in Madagascar from local collection to global export

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## 5 **Abstract**

6 International trade in wildlife is a complex multi-billion dollar industry. To supply it,  
7 many animals are extracted from the wild, sourced from biodiversity-rich, developing  
8 countries. Whilst the trade has far-reaching implications for wildlife protection, there is  
9 limited information regarding the socio-economic implications in supply countries.  
10 Consequently, a better understanding of the costs and benefits of wildlife supply  
11 chains, for both livelihoods and conservation, is required to enhance wildlife trade  
12 management and inform its regulation. Using Madagascar as a case study, we used  
13 value chain analysis to explore the operation of legal wildlife trade on a national scale;  
14 we estimate the number of actors involved, the scale, value and profit distribution  
15 along the chain, and explore management options. We find that the supply of wildlife  
16 provided economic benefits to a number of actors, from local collectors, to  
17 intermediaries, exporters and national authorities. CITES-listed reptiles and  
18 amphibians comprised a substantial proportion of the quantity and value of live animal  
19 exports with a total minimum export value of 230,795USD per year. Sales prices of  
20 reptiles and amphibians increased over 100-fold between local collectors and  
21 exporters, with exporters capturing ~92% of final export price (or 57% when their  
22 costs are deducted). However, exporters shouldered the largest costs and financial  
23 risks. Local collectors obtained ~1.4% of the final sales price, and opportunities for  
24 poverty alleviation and incentives for sustainable management from the trade appear to  
25 be limited. Promoting collective management of species harvests at the local level may  
26 enhance conservation and livelihood benefits. However, this approach requires  
27 consideration of property rights and land-tenure systems. The complex and informal  
28 nature of some wildlife supply chains make the design and implementation of policy  
29 instruments aimed at enhancing conservation and livelihoods challenging.  
30 Nevertheless, value chain analysis provides a mechanism by which management  
31 actions can be more precisely targeted.

## 32 **1. Introduction**

33 The scale of the legal and illegal global trade in wildlife is vast, with legal trade alone  
34 estimated to be worth 323 billion USD each year (TRAFFIC 2008). To supply this  
35 trade, fauna and flora are often extracted from the wild, frequently from biodiversity-  
36 rich countries experiencing high levels of poverty. Consequently, wildlife trade has  
37 implications for biodiversity conservation (Kenney et al. 1995; Garcia-Diaz et al.  
38 2015), human and environmental health (Karesh et al. 2005; Smith et al. 2009), and  
39 human development and society (Roe 2002, 2008, Duffy 2014). To enhance its  
40 management, improved understanding of the costs and benefits of wildlife trade supply  
41 chains are required. However, this is a multifaceted and complex task. For example,  
42 the dependency of people on forests and their products such as medicinal plants, wild  
43 meat, live animals, fungi and nuts, goes far beyond village boundaries, contributing to  
44 rural, urban, migrant and resident livelihoods, as well as national and global economies  
45 (Ambrose-Oji 2003; Jensen 2009; Roe et al. 2009). Therefore, threats to species and  
46 habitats are driven by economic activity and consumer demand locally and globally by  
47 economic actors far removed from the place of origin (Lenzen et al. 2012).  
48 Additionally, as well as providing livelihood benefits to local people; economic,  
49 cultural or spiritual benefits obtained by those engaged in wildlife trade may, or may  
50 not, provide incentives for conservation and sustainable management of natural  
51 resources at the local level (Hutton & Leader-Williams 2003; Jones et al. 2008;  
52 Robinson et al. 2018). In general, for trade to generate incentives for conservation,  
53 both adequate benefits, and favourable governance conditions including long-term,  
54 secure property rights, are required (Bulte et al. 2003). In addition, a number of  
55 combined factors come into play, including ‘species-level’ factors such as suitability  
56 for harvest (e.g. resilience, accessibility); wider ‘governance’ factors including policy  
57 settings; ‘supply chain’ factors including organisation and operation of the supply  
58 chain (e.g. barriers to entry, length of the chain); and ‘end-market’ factors, including  
59 market size, demand elasticity and consumer preferences (Cooney et al. 2015), all of  
60 which will vary considerably on a case-by-case basis.

61 Within conservation science, there is a need for research to adopt interdisciplinary  
62 approaches to address socio-ecological challenges (Mascia et al. 2003; Milner-Gulland  
63 2012). This is particularly important when considering wildlife trade, where an  
64 understanding of the ecological consequences of trade alone would fail to illuminate  
65 the economic and social benefits associated with ongoing business. Therefore, an  
66 understanding of socio-economic factors, including markets, is paramount. One  
67 method for understanding trade-chains is the value chain approach (VCA). The VCA is  
68 a descriptive tool and analytical instrument used to understand not only the structure,  
69 operation and profit distribution through the trade chain, but also to identify entry  
70 points for policy initiatives and value addition. It incorporates the whole range of  
71 activities and relations associated with production, exchange, transport and distribution  
72 of a commodity (Kaplinsky & Morris 2001; Jensen 2009). VCA has been used to

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

79 With increasing globalisation and awareness of the impact of international trade on  
80 biodiversity (Lenzen et al. 2012), initiatives such as certification or labelling schemes  
81 that require producers of goods and services to adhere to environmental and social  
82 welfare production standards have become increasingly popular (Blackman & Rivera  
83 2011). For example, there are an estimated 600 eco-labels worldwide, covering ~15%  
84 of the global trade in bananas, 12% of wild fisheries, 10% of global forestry products  
85 and 7% of global coffee (Eilperin 2010). Whilst much of the trade in live wild animals  
86 does not currently fall under such schemes, there is increasing pressure from  
87 environmental groups and other stakeholders to ban the trade on the grounds of  
88 welfare, biodiversity loss, health and/or moral considerations (Check 2004; Huyton  
89 2015). The Convention on International Trade in Endangered Species of Wild Fauna  
90 and Flora (CITES) provides some means of assurance regarding ecological  
91 sustainability of wildlife trade, through its requirement for trading countries to  
92 determine that exports of listed-species will not be detrimental to their populations in  
93 the wild (a 'non-detriment finding'). However, not all species are listed by CITES, and  
94 there is limited information available regarding wider implications of the trade on  
95 livelihoods and economies in supply countries. Therefore, debates concerning  
96 regulation of the trade in live animals are often dominated by potential impacts on wild  
97 populations and animal welfare issues, rather than incentives for conservation.  
98 Consequently, there is a need for a thorough understanding of trade chains supplying  
99 such animals, including information on the actors, livelihood benefits, and potential  
100 conservation implications.

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

116 occurs (Rabemananjara et al. 2008). Previous studies, conducted over a decade ago,  
117 explored the structure of the trade chain in Madagascar in relation to chameleons  
118 (Carpenter et al. 2004) and mantella frogs (Rabemananjara et al. 2008) and more  
119 recent research has analysed the relative importance of wildlife trade as a livelihood  
120 strategy in rural areas (Robinson et al. 2018). Here we apply VCA to understand the  
121 scale and value of the wildlife trade on a national scale, and the profit distribution and  
122 value along the chain from village to export. We also update information on the current  
123 structure and operation of the wildlife supply chain, and estimate the number of actors  
124 involved. This study expands our understanding of the conservation and socio-  
125 economic implications of wildlife trade, and contributes towards discussions  
126 concerning sustainability and management of trade in wildlife in Madagascar, and  
127 more generally.

## 128 **2. Methods**

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

### 137 **2.1. Sampling**

138 To identify individuals involved at different points along the wildlife trade chain, we  
139 used snowball sampling (Bryman 2015). Initially, we conducted interviews with the  
140 CITES Management Authority who provided a list of registered wildlife exporters.  
141 During interviews, exporters were asked to list names and locations of intermediaries  
142 they worked with in order for us to obtain an estimate of the number of intermediaries,  
143 and approach them for interviews. Subsequently, intermediaries were asked to provide  
144 names and village locations of local collectors. Local collectors were identified  
145 through systematic household sampling in identified villages and snowball sampling,  
146 whereby village leaders, local guides and respondents from the household sample were  
147 asked to identify local reptiles and amphibian collectors (Robinson et al. 2018).

### 148 **2.2. Semi-structured interviews**

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

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

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

### 170 **2.3. Data request**

171 To determine the extent of the trade, data were requested from the General Director of  
172 Forests, Ministry of Environment, Ecology and Forests (CITES Management  
173 Authority of Madagascar) on the volume of animals and plants belonging to different  
174 species exported from Madagascar in 2013; the individual value declared by exporters  
175 for individual species; and the total value of wildlife exports. Price information was  
176 converted into US dollars (USD) based on an exchange rate of 1USD=2283.11  
177 Malagasy Ariary (MGA) valid at the time of the study (29.01.2014)  
178 ([www.coinmill.com](http://www.coinmill.com)).

### 179 **2.4. Data analysis**

180 Prices declared by exporters to the authorities (from data request) were compared with  
181 price information provided in person during exporter interviews using a non-  
182 parametric Wilcoxon Signed-Rank Test. As data were not normally distributed we  
183 calculated median prices for each of the 24 pre-selected species at each stage of the  
184 chain across respondents, resulting in median purchase and sales prices for each  
185 species from exporters and intermediaries, and median sales prices declared by local  
186 collectors. Prices provided by different actor groups were compared using a Wilcoxon  
187 Signed-Rank Test. We then calculated the mean price across all 24 species and used  
188 this value to calculate the mark-up of prices along the chain, marketing margins  
189 (proportion of final sales price captured by different actor groups), and the value of the  
190 herpetofauna trade to different actor groups.

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

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

201 To calculate the potential value of the reptile and amphibian trade to different actor  
202 groups along the chain, we calculated the proportion of the final export value declared  
203 by exporters (provided in data request) that reached different actor groups. To do this  
204 we used the mean sale and purchase price provided by respondents (across the 24  
205 species) to calculate the proportion of the sales price comprised of the cost of  
206 purchasing animals from the previous actor in the chain. This represented the value  
207 being passed to the previous actor group. We then incorporated additional cost  
208 information based on expenses (equipment, transport, etc.) into the calculations,  
209 adjusting the profit received by each actor group accordingly. Based on this, we  
210 estimated the proportion of the final declared export value that was made up of profit  
211 and costs for each group. Since we obtained price data from multiple sources (for  
212 comparison and triangulation), we conducted a sensitivity analysis to incorporate the  
213 variation in prices given by different actor groups. For example, exporters told us the  
214 prices they paid to purchase animals from intermediaries, and intermediaries told us  
215 prices they charged to exporters. Therefore, the proportion of the final export value  
216 made up of exporter's purchase costs could be calculated in two ways; from the  
217 exporter-declared mean sale price divided by exporter-declared mean purchase price,  
218 or from the exporter-declared mean sales price divided by the intermediary-declared  
219 mean sales price. Therefore, we report the minimum and maximum potential values.

## 220 **3. Results**

### 221 **3.1. Scale and value of wildlife trade from Madagascar**

222 Data provided by the CITES Management Authority indicated that the live trade in  
223 wildlife from Madagascar, including both flora and fauna was worth 346,249USD in  
224 2013. Reptiles and amphibians (CITES and non-CITES) accounted for 66.7% of this  
225 total, with CITES reptiles accounting for a considerable proportion (50.4%) of total  
226 wildlife export income (Figure 1a). The 2013 Ministry records show the total declared  
227 export value of reptiles and amphibians from Madagascar amounted to 230,795USD,  
228 generating 14,621USD in taxes to the Ministry of Environment and Forests. However,  
229 the mean sales price provided by exporters during our interviews was 2.8 times higher  
230 than declared export prices (Wilcoxon Signed-Rank  $Z = -4.29$ ,  $n = 24$ ,  $p < 0.001$ ,  
231 Supporting Information, Table S.4.8.1). Therefore, based on the proportional  
232 difference, the total export value of reptiles and amphibians for 2013 may total  
233 646,226USD.

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

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

### 238 **3.2. Structure and operation of the supply chain**

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

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

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

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

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

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

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

### 303 **3.3. Economics of the supply chain**

#### 304 *3.3.1. Comparison of price information provided by actor groups*

305 Purchase prices for 24 species provided by exporters were slightly higher (mean  
306 proportional difference=1.2±0.11, n=23 taxa) than equivalent sale prices provided by  
307 intermediaries, but there was no significant difference (Wilcoxon Signed Rank Z=1.15,  
308 p=0.249). However, there was a significant difference between purchase prices  
309 provided by intermediaries and equivalent sale prices provided by local collectors  
310 (Z=3.88, p<0.001), with prices declared by intermediaries more than double sale prices  
311 declared by local collectors (mean proportional difference=2.5±0.73, n=20 taxa,  
312 supporting Information, Table S2).

#### 313 *3.3.2. Summary of costs encountered by actor groups*

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

316 transport, packing, agent/broker, collection permit (one-time fee each year), price of  
317 animals, collection fees (paid to local branch of the Ministry; set price of 80 MGA  
318 (0.04USD) per reptile and 30 MGA (0.01USD) per amphibian), informal fees to  
319 communities (varies), and various taxes. Taxes included an export tax for wild animals  
320 to the Ministry (4% of shipment value), voluntary fees to support the CITES Scientific  
321 Authority (2%), taxes to the Ministry of Commerce, veterinary certificate fees (2%),  
322 fees to GasyNet (private company that deals with import/export at airport, one exporter  
323 quoted this as 2% of total invoice per shipment). According to detailed price  
324 information provided by one exporter, costs comprised 35% of revenue generated from  
325 shipments (Table 1). Another exporter corroborated this estimating that costs  
326 comprised 30-50% of final shipment value.

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

### 334 **3.3.3. Price mark-up across supply chain and marketing margin**

335 Based on sale price information provided by each actor group (Supporting  
336 Information, Table S2), animals were sold by intermediaries for around seven times  
337 the price they were purchased for from local collectors (mean proportional  
338 difference= $7.3 \pm 1.32$ ;  $n=19$  species). The intermediary sales price increased a further  
339 15 times by exporters prior to sale/export (mean proportional difference= $14.98 \pm 1.8$ ,  
340  $n=23$  species). The sale price increased by 105 times (mean proportional  
341 difference= $105.28 \pm 21.2$ ,  $n=20$  taxa) from local collector to exporter.

342 Marketing margin (at export) captured by each actor group was greatest for exporters  
343 (92.3%), followed by intermediaries (6.2%) and then local collectors (1.4%) (Table 2).  
344 Consideration of costs reduced the share captured by exporters to 88.5%, and increased  
345 the share captured by intermediaries (9.5%) and local collectors (2.0%) (Table 2).  
346 When calculated for individual species, marketing margins varied between 0.2 and  
347 4.0% for local collectors, 2.8 to 31.3% for intermediaries and 67.0 to 97.3% for  
348 exporters (Supporting Information, Table S3). There was no significant relationship  
349 between final sales prices at export and marketing margins received by local collectors  
350 ( $r_s=-0.095$ ,  $n=20$ ,  $p=0.690$ ), intermediaries ( $r_s=-0.371$ ,  $n=23$ ,  $p=0.082$ ) or exporters  
351 ( $r_s=0.335$ ,  $n=23$ ,  $p=0.118$ ), suggesting the share received by actors was not related to  
352 the export value of the species.

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

356 sensitivity analysis, we estimated that purchase prices paid by exporters for animals  
357 comprised 7.7 to 9.3% of prices they sold them for, representing a transmission of  
358 17,708 to 21,511USD to intermediaries. Incorporating animal purchase costs paid by  
359 intermediaries (ranging from 15.5 to 47.7% of sales prices) and additional costs  
360 (0.18%, Table 1), estimates for profit received by intermediaries ranged from 9,238 to  
361 18,144USD. Local collectors did not encounter costs of purchasing animals but based  
362 on estimated additional costs (10.6%, Table 1), this resulted in an estimate of 2,449 to  
363 9,163USD reaching local collectors (Figure 3). However, based on the discrepancy in  
364 prices between declared export values reported in Ministry data, and the prices  
365 exporters reported during the interviews, these values may be considerably higher. For  
366 example, based on a cumulative export value of 646,226USD (sales prices reported by  
367 exporters being 2.8-times higher than prices reported to Ministry), exporters could  
368 receive a profit of 418,108USD; intermediaries from 25,866 to 50,804USD and local  
369 collectors from 6,857 to 25,658USD.

#### 370 **4. Discussion**

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

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

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

397 collected opportunistically, as was sometimes the case in the past (Carpenter et al.  
398 2005), but were collected to order, with specific details (e.g. species/sex/quantity)  
399 passed down the chain from exporters to local collectors. In the majority of cases, it  
400 was not considered economic to collect opportunistically as buyers were not available,  
401 or would pay a lower price. Only occasionally, if a desirable, evasive, or valuable  
402 specimen was encountered opportunistically, would they collect that animal. Once  
403 collected, animals were not kept in-country for long, thus minimising exporter costs.  
404 Although we did not verify health of animals in trade, with payments frequently  
405 phased (50% before and 50% on delivery), and often with no payment for poor quality  
406 animals, there are incentives for suppliers to deliver animals in good condition.

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

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

440 habitats (Robinson et al. 2018). Equally, in their study of mantella frog trade in  
441 Madagascar, Rabemananjara (2008) observed that because collection permits are  
442 issued to exporters rather than local collectors - and collectors are paid low prices - the  
443 system becomes counterproductive in terms of promoting sustainable harvesting and  
444 incentives to conserve resources based on benefits received. The fact that local  
445 collectors are not in possession of permits, may promote a sense of insecurity and  
446 disconnect from regulatory processes (e.g. collectors have to trust the word of the  
447 middleman, and may have insufficient knowledge regarding measures such as quotas).  
448 In order for the trade to provide incentives to motivate pro-conservation behaviours,  
449 not only should benefits be adequate, but property rights also need to be sufficient so  
450 that local stakeholders are in a position to manage their own resources (Cooney et al.  
451 2015). However, property rights are often poorly defined in Madagascar (Bojö et al.  
452 2013), meaning that the collector typically does not own the resource from which the  
453 animals are being harvested, so it is unknown whether they can control management of  
454 the resource, or if the social capital exists to do so. Therefore, whilst the trade in  
455 herpetofauna from Madagascar brings some benefits to stakeholders along the chain, at  
456 the local level, both incentives for conservation, and opportunities to alleviate rural  
457 poverty appear to be limited as they currently stand.

#### 458 **4.1. Conclusion and options for sustainable trade**

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

472 Certain high-value (and prohibited) reptile species, such as the ploughshare and  
473 radiated tortoise, are being illegally traded from Madagascar (Mbohoahy & Manjoazy  
474 2016). However, the legal trade in herpetofauna is contributing to some people's  
475 livelihoods. Given that any move towards further trade restrictions could remove  
476 benefits and undermine management incentives, we concentrate here on exploring  
477 options with potential to enhance both conservation and livelihood benefits utilising  
478 the trade. Certification or labelling schemes aimed at improving ecological and social  
479 sustainability might allow higher prices to be realised at export, with an increase in  
480 benefits passed down the chain. However, certification schemes have large cost and  
481 bureaucratic implications, and whilst receiving limited attention in the pet trade, have

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

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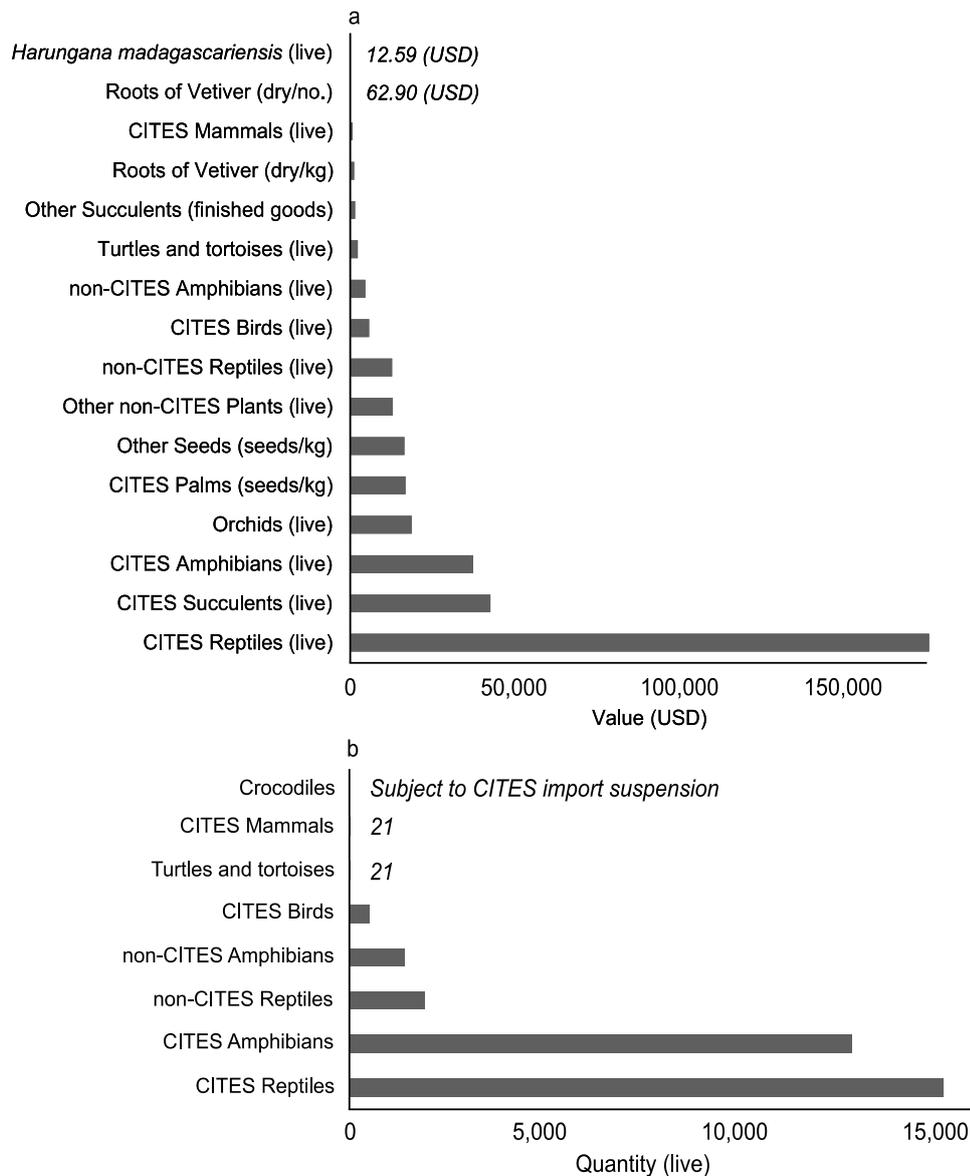
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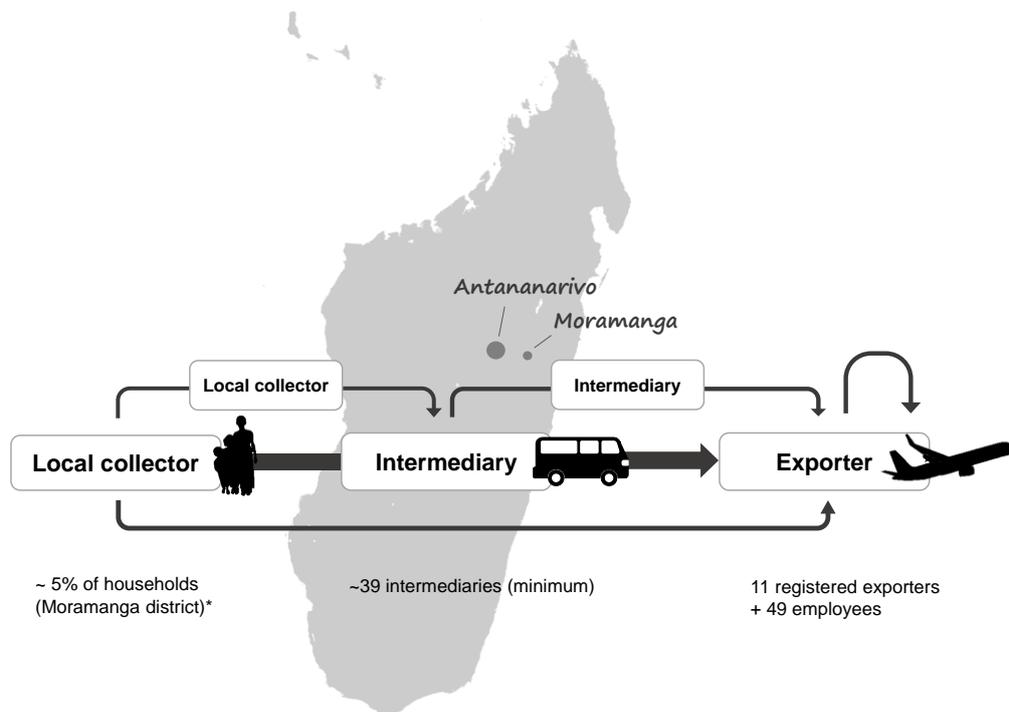
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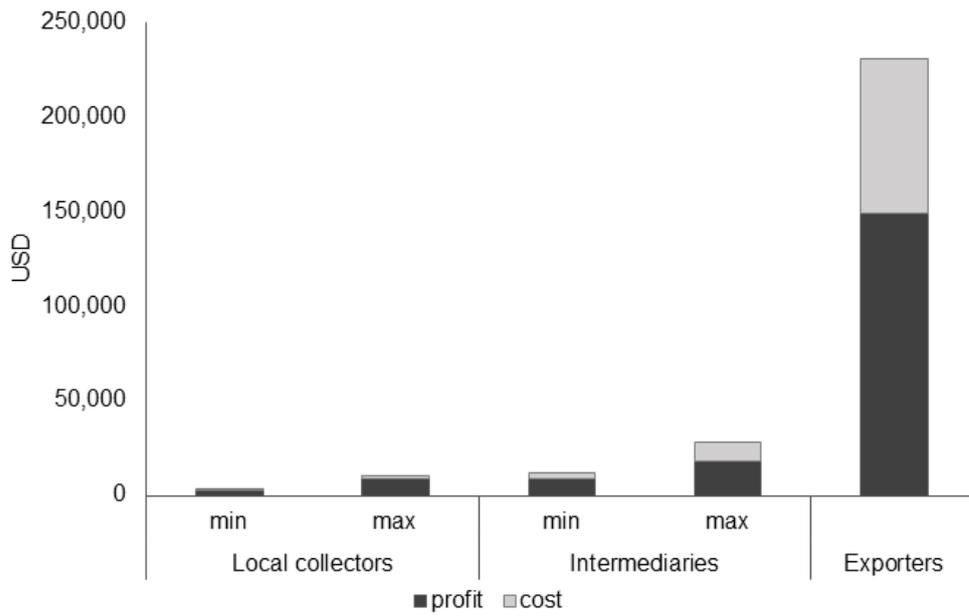
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**Figure 1 (a)** Value in USD of wildlife exports (including both flora and fauna) from Madagascar in 2013, as provided by the CITES Management Authority of Madagascar. Data were missing for non-CITES palms, shells, and Apanga (*Pteridium aquilinum*). 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](http://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 individual's declared revenue, rather than the median revenue across all four exporters). IQR=interquartile range.

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

<sup>a</sup>Another 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 <sup>1</sup> (USD)	Costs <sup>2</sup> (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 $P_{s_i} - P_p - P_{c_i} / P_f - \Sigma P_c$ (%)	$P_f - P_p / P_f$ (%)	with costs $P_f - P_p - P_{c_{ii}} / P_f - \Sigma P_c$ (%)
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

<sup>1</sup>Mean 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.

<sup>2</sup>Costs 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.