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Wildlife supply chains in Madagascar from local collection to global export

Janine E. Robinson[a]*

Iain M. Fraser[b,c]

Freya A.V. St. John[a,d]

J. Christian Randrianantoandro[e]

Raphali R. Andriantsimanarilafy[e]

Julie H. Razafimanahaka[e]

Richard A. Griffiths[a]

David L. Roberts[a]

[a]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, Marlowe Building, University of Kent, Canterbury, Kent, CT2 7NR, UK.

[b]School of Economics, Keynes College, University of Kent, Kent, CT2 7NR, UK.

[c]Department of Economics and Finance, La Trobe University, Melbourne, Victoria 3083, Australia.

[d]School of Environment, Natural Resources and Geography, Bangor University, UK

[e]Madagasikara Voakajy, Lot II 14 P Bis Andraisoro, B.P 5181 Antananarivo (101), Madagascar.

*Corresponding author:

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Abstract

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

1. Introduction

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

Within conservation science, there is a need for research to adopt interdisciplinary approaches to address socio-ecological challenges (Mascia et al. 2003; Milner-Gulland 2012). This is particularly important when considering wildlife trade, where an understanding of the ecological consequences of trade alone would fail to illuminate the economic and social benefits associated with ongoing business. Therefore, an understanding of socio-economic factors, including markets, is paramount. One method for understanding trade-chains is the value chain approach (VCA). The VCA is a descriptive tool and analytical instrument used to understand not only the structure, operation and profit distribution through the trade chain, but also to identify entry points for policy initiatives and value addition. It incorporates the whole range of activities and relations associated with production, exchange, transport and distribution of a commodity (Kaplinsky & Morris 2001; Jensen 2009). VCA has been used to examine markets (including financial analyses, competition, governance, entry barriers, and geographic coverage) and has contributed to the research agenda for various non-timber forest products (Avocèvou-Ayisso et al. 2009; Jensen 2009) including charcoal (Shively et al. 2010), wild meat (Boakye et al. 2016; Cowlishaw et al. 2005), fisheries (Johnson 2010) and python skins (Kasterine et al. 2012). However, there is limited research applying VCA to commercial trade in live animals.

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

To address this data gap, we explore the legal commercial trade in live animals, with particular emphasis on herpetofauna, in a biodiversity hotspot, Madagascar. Madagascar has unparalleled levels of biological diversity and endemic species (Myers et al. 2000) which are threatened by continued habitat degradation, driven by economic activities, population growth and high human poverty (Harper et al. 2007; Waeber et al. 2016). Over the last 15 years, Madagascar has emerged as a significant exporter of reptiles and amphibians to supply trade in exotic pets (Carpenter et al. 2004; Rabemananjara et al. 2008; Robinson et al. 2015). Whilst legal trade exists for many species subject to national quotas and CITES regulation, illegal trade, particularly in high value CITES Appendix I species which are prohibited in commercial trade (including several of Madagascar’s endemic tortoise species) has proliferated, having a devastating impact on their wild populations (O'Brien et al. 2003; Walker et al. 2004; Mbohoahy & Manjoazy 2016). There is insufficient information to understand the degree of crossover between the legal and illegal herpetofauna trade, although some consider it unlikely that smuggling of large quantities of low commercial value species occurs (Rabemananjara et al. 2008). Previous studies, conducted over a decade ago, explored the structure of the trade chain in Madagascar in relation to chameleons (Carpenter et al. 2004) and mantella frogs (Rabemananjara et al. 2008) and more recent research has analysed the relative importance of wildlife trade as a livelihood strategy in rural areas (Robinson et al. 2018). Here we apply VCA to understand the scale and value of the wildlife trade on a national scale, and the profit distribution and value along the chain from village to export. We also update information on the current structure and operation of the wildlife supply chain, and estimate the number of actors involved. This study expands our understanding of the conservation and socio-economic implications of wildlife trade, and contributes towards discussions concerning sustainability and management of trade in wildlife in Madagascar, and more generally.

2. Methods

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

2.1. Sampling

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

2.2. Semi-structured interviews

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

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

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

2.3. Data request

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

2.4. Data analysis

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

We estimated marketing margins of actor groups following Cowlishaw et al. (2005) and Avocèvou-Ayisso et al. (2009). This was 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 (Ps-Pp-Pc)/Pf-ΣPc where Pc is the estimated costs incurred by the actor group. Marketing margins were also calculated for each of the 24 species individually, and Spearman's Rank correlations used to test for relationships between species value and marketing margins received by different actor groups to explore if respondents received a greater share of export value for more valuable species.

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

3. Results

3.1. Scale and value of wildlife trade from Madagascar

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

CITES reptiles and amphibians comprised 87.9% of the trade in all animals in terms of numbers of individuals (Figure 1b). A total of 31,871 reptiles and amphibians were exported from Madagascar during the calendar year 2013 (including CITES and non-CITES species).

3.2. Structure and operation of the supply chain

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

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

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

Animal export usually occurred from September to July (exporter interviews: median=6.6 months a year, IQR=2, n=7). At the time of research one exporter interviewed had temporarily stopped exporting reptiles and amphibians, the other seven exported reptiles and amphibians and other animals such as mammals (n=6, tenrecs in all cases), invertebrates (n=4), birds (n=4, e.g. *Agapornis canus*), fish (n=2), plants (n=2) and cultivated and non-CITES coral (n=1). In all cases, respondents reported that animals were exported live (as opposed to skins or other products), and mainly supplied wholesalers, pet shops and specialised reptile outlets around the world. Ministry data indicates that the USA, Japan and Canada were the most significant importers in terms of volume (no. animals imported), importing 45%, 13% and 9% respectively of Malagasy herpetofauna in 2013.

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

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

3.3. Economics of the supply chain

3.3.1. Comparison of price information provided by actor groups

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

3.3.2. Summary of costs encountered by actor groups

Exporters had considerably higher costs than other actor groups along the chain (Table 1). These costs included facility setup and maintenance (e.g. land, staff, utility bills), transport, packing, agent/broker, collection permit (one-time fee each year), price of animals, collection fees (paid to local branch of the Ministry; set price of 80 MGA (0.04USD) per reptile and 30 MGA (0.01USD) per amphibian), informal fees to communities (varies), and various taxes. Taxes included an export tax for wild animals to the Ministry (4% of shipment value), voluntary fees to support the CITES Scientific Authority (2%), taxes to the Ministry of Commerce, veterinary certificate fees (2%), fees to GasyNet (private company that deals with import/export at airport, one exporter quoted this as 2% of total invoice per shipment). According to detailed price information provided by one exporter, costs comprised 35% of revenue generated from shipments (Table 1). Another exporter corroborated this estimating that costs comprised 30-50% of final shipment value.

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

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

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

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

Exporters estimated that ~35% of shipment value was used on expenses, therefore based on a final declared export value of 230,795USD logged with the Ministry for all exporters in 2013, this represents a profit of 149,324USD (Figure 3). According to the sensitivity analysis, we estimated that purchase prices paid by exporters for animals comprised 7.7 to 9.3% of prices they sold them for, representing a transmission of 17,708 to 21,511USD to intermediaries. Incorporating animal purchase costs paid by intermediaries (ranging from 15.5 to 47.7% of sales prices) and additional costs (0.18%, Table 1), estimates for profit received by intermediaries ranged from 9,238 to 18,144USD. Local collectors did not encounter costs of purchasing animals but based on estimated additional costs (10.6%, Table 1), this resulted in an estimate of 2,449 to 9,163USD reaching local collectors (Figure 3). However, based on the discrepancy in prices between declared export values reported in Ministry data, and the prices exporters reported during the interviews, these values may be considerably higher. For example, based on a cumulative export value of 646,226USD (sales prices reported by exporters being 2.8-times higher than prices reported to Ministry), exporters could receive a profit of 418,108USD; intermediaries from 25,866 to 50,804USD and local collectors from 6,857 to 25,658USD.

4. Discussion

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

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

The trade consisted of well-established actors, as individuals all along the chain had mostly been in the business for long periods (~20 years). Importantly, the trade operated on the basis of informal verbal contracts between actors, based on trust. Therefore, knowledge of the supply chain participants, contacts and reputation were particularly important in coordinating activities within the chain. Animals were rarely collected opportunistically, as was sometimes the case in the past (Carpenter et al. 2005), but were collected to order, with specific details (e.g. species/sex/quantity) passed down the chain from exporters to local collectors. In the majority of cases, it was not considered economic to collect opportunistically as buyers were not available, or would pay a lower price. Only occasionally, if a desirable, evasive, or valuable specimen was encountered opportunistically, would they collect that animal. Once collected, animals were not kept in-country for long, thus minimising exporter costs. Although we did not verify health of animals in trade, with payments frequently phased (50% before and 50% on delivery), and often with no payment for poor quality animals, there are incentives for suppliers to deliver animals in good condition.

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

This research describes the economic benefits received by actors along the entire herpetofauna supply chain in Madagascar, and demonstrates that a large proportion of the benefits are obtained by exporters. However, income obtained is not straightforward to interpret. For example, a small amount of money will go further amongst local collectors, compared with intermediaries and exporters residing in towns and cities, and local collectors in rural communities may be more in need of employment no matter how small the financial benefits. Recent research in the same study area (Robinson et al. 2018) revealed that 13% of households in collection areas benefitted from local harvest of live animals for export (including some of the poorest) and it was potentially profitable. However, it also revealed the unreliable and sporadic nature of live animal collection (limited by quotas, season, opportunity cost and supply), and that incentives appear insufficient to promote conservation of species and habitats (Robinson et al. 2018). Equally, in their study of mantella frog trade in Madagascar, Rabemananjara (2008) observed that because collection permits are issued to exporters rather than local collectors - and collectors are paid low prices - the system becomes counterproductive in terms of promoting sustainable harvesting and incentives to conserve resources based on benefits received. The fact that local collectors are not in possession of permits, may promote a sense of insecurity and disconnect from regulatory processes (e.g. collectors have to trust the word of the middleman, and may have insufficient knowledge regarding measures such as quotas). In order for the trade to provide incentives to motivate pro-conservation behaviours, not only should benefits be adequate, but property rights also need to be sufficient so that local stakeholders are in a position to manage their own resources (Cooney et al. 2015). However, property rights are often poorly defined in Madagascar (Bojö et al. 2013), meaning that the collector typically does not own the resource from which the animals are being harvested, so it is unknown whether they can control management of the resource, or if the social capital exists to do so. Therefore, whilst the trade in herpetofauna from Madagascar brings some benefits to stakeholders along the chain, at the local level, both incentives for conservation, and opportunities to alleviate rural poverty appear to be limited as they currently stand.

4.1. Conclusion and options for sustainable trade

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

Certain high-value (and prohibited) reptile species, such as the ploughshare and radiated tortoise, are being illegally traded from Madagascar (Mbohoahy & Manjoazy 2016). However, the legal trade in herpetofauna is contributing to some livelihoods. Given that any move towards further trade restrictions could remove benefits and undermine management incentives, we concentrate here on exploring options with potential to enhance both conservation and livelihood benefits utilising the trade. Certification or labelling schemes aimed at improving ecological and social sustainability might allow higher prices to be realised at export, with an increase in benefits passed down the chain. However, certification schemes have large cost and bureaucratic implications, and whilst receiving limited attention in the pet trade, have been largely unsuccessful for ornamental fish (Vosseler 2015). Equally, it is unknown whether demand exists for such products amongst end-consumers. Other approaches may include promoting collective management of the resource amongst local collectors (e.g. through formation of producer associations), as well as boosting capacity. This could focus on coordinating collecting activities (e.g. sharing information on trapping requests, setting prices) and raising awareness of traded species (e.g. legislation, value, ecology, appropriate collection methods). For example, the Sustainably Harvested Devil's Claw project in Namibia, which similarly focussed on ensuring good prices, strengthening harvester bargaining power and providing general information and support, demonstrated that improved benefit sharing contributed to improved resource conservation (Stewart & Cole 2005). However, many of the villages where wildlife collectors reside are isolated and often difficult to access, making communication between local collectors difficult. Intermediaries may therefore have an important role to play within the supply chain in terms of communication (contacts, accessibility, transport) and could be incorporated into producer focussed initiatives through professionalization of middlemen networks. Greater consideration would need to be given to property rights and land tenure systems in Madagascar, to enable such management to work.Our analysis reveals that almost 32,000 reptiles and amphibians were legally exported from Madagascar in 2013, with an estimated export value of between 231,000 and 646,000USD. Local collectors obtain ~1.4% of the final sales price, and opportunities for poverty alleviation and incentives for sustainable management from the trade, appear to be limited. We also reveal the complex and informal nature of wildlife trade supply chains, and illustrate the challenges faced by practitioners attempting to enhance the trade for both livelihoods and conservation. In addition to improving understanding of the costs and benefits of the wildlife trade to different actor groups, we demonstrate the utility of value chain analysis in providing a mechanism by which management strategies to regulate wildlife trade can be more precisely targeted.

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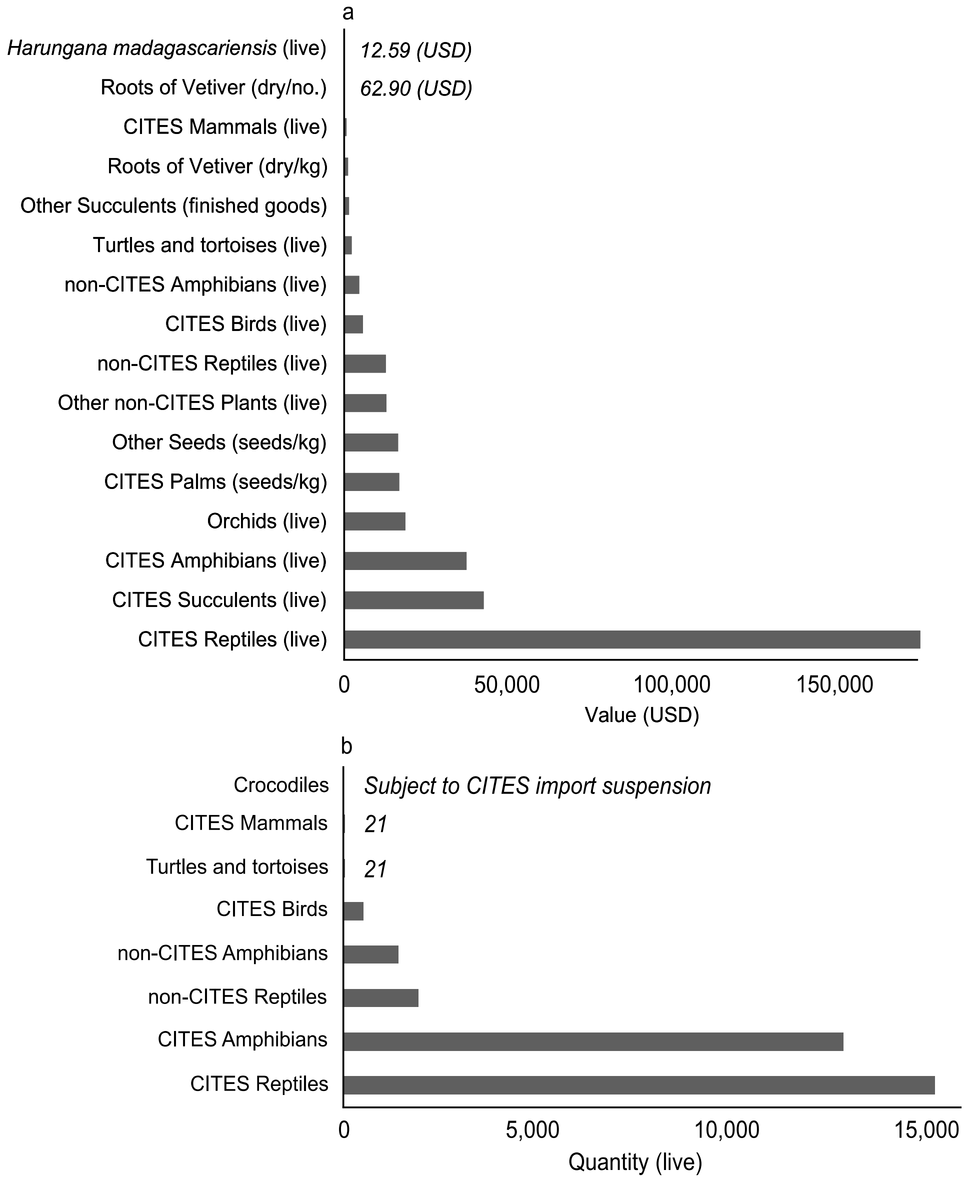

Figure 1 (a) Value in USD of wildlife exports (including both flora and fauna) from Madagascar in 2013, as provided by the CITES Management Authority of Madagascar. Data were missing for non-CITES palms, shells, and Apanga (*Pteridium aquilinum*). Additionally, whilst data were provided for 'other succulents: 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.

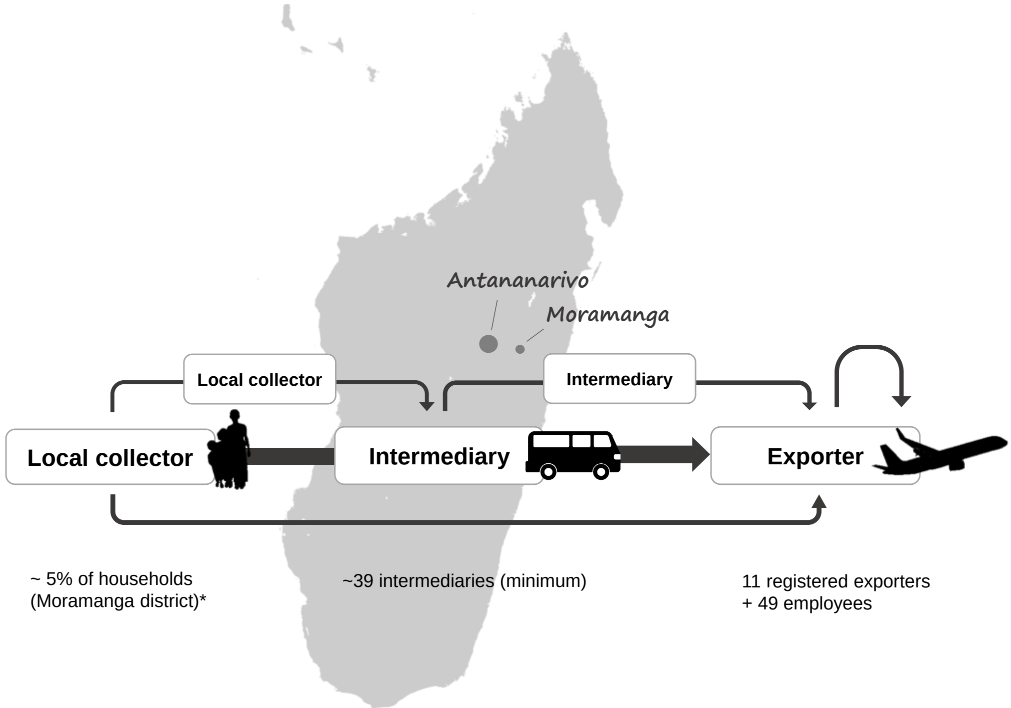

Figure 2 Structure of the wildlife trade supply chain in Madagascar and approximate numbers of people belonging to different actor groups. The supply chain comprised local collectors who trapped animals in the wild, intermediaries who brought animals from local collection areas to export facilities and 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).

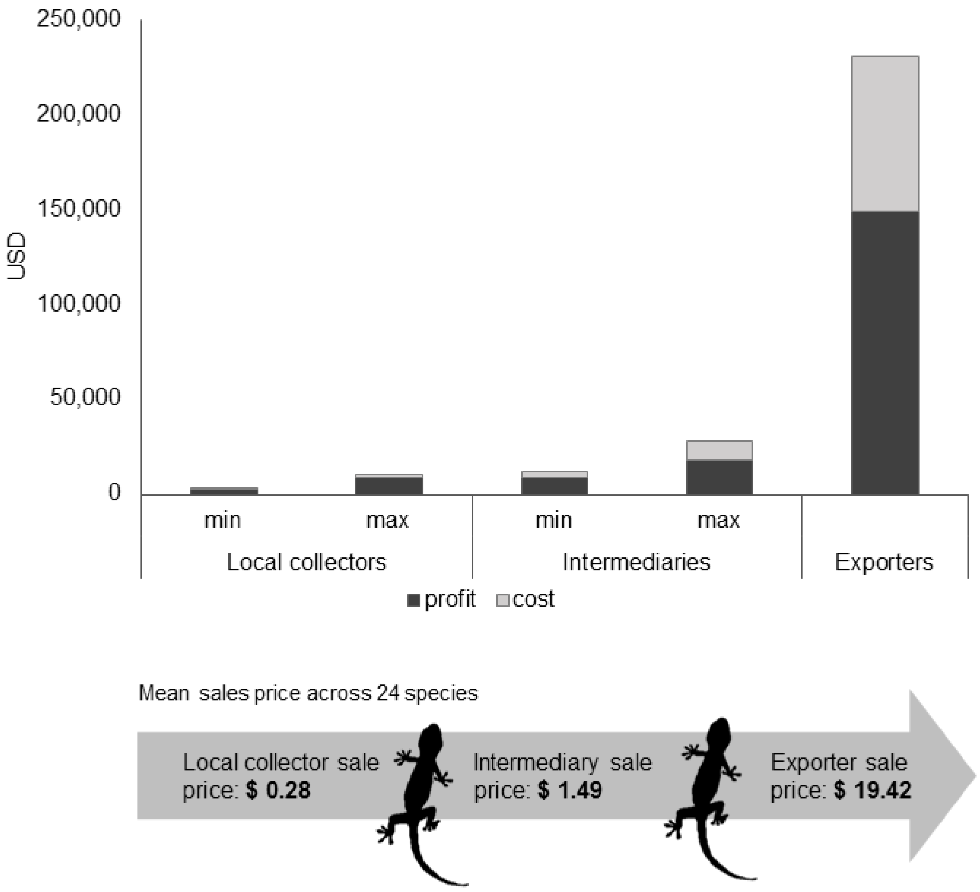

Figure 3. Minimum and maximum estimated profit and costs received by local collectors, intermediaries and exporters engaged in the commercial reptile and amphibian trade in Madagascar. Mean sales price per individual is estimated across 24 different traded species are displayed below the x axis. Individual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

[a]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 (Ps - Pp)/Pf where Ps is the mean sales price, Pp is the mean purchase price (i.e. the sales price reported by the previous actor in the chain) and Pf 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 (Ps-Pp-Pc)/(Pf-ΣPc) where Pc 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	
			Ps/Pf (%)	with costs Ps-Pc/ Pf-ΣPc (%)	Ps_i-Pp/ Pf (%)	with costs Ps_i-Pp-Pc_i/ Pf-ΣPc (%)	Pf-Pp_i/ Pf (%)	with costs Pf-Pp_i-Pc_{ii}/ Pf-ΣPc (%)
Local collector	0.28 (Ps/Pp)	0.03 (Pc)	1.44	2.00				
Intermediary	1.49 (Ps_i/Pp_i)	0.02 (Pc_i)			6.23	9.51		
Exporter	19.42 (Pf)	6.86 (Pc_{ii})					92.33	88.48

[1]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.

[2]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.

Supporting Information

Table S1. Median ± 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**
	median	**IQR**	***n* (exporters)**	**median**	**IQR**	***n***	**([a] / [b])**
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 ebenaui	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]	min-max	*n*	Exporter purchase price	min-max	*n*	Intermediary sale price (median)[c]	min-max	*n*	Intermediary purchase price	min-max	*n*	Local collector sale price	min-max	*n*	Comparison of exporter ([b]) vs intermediary ([c]) declared prices ([b]/[c])	Comparison of intermediary ([d]) vs local collector ([e]) declared prices ([d]/[e])
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 ebenaui	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.

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

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