Article

Valorisation of Madagascar's Wildlife Trade and Wildlife Tourism; What Are the Conservation Benefits?

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Simple Summary: Countries often experience tensions between conservation and poverty alleviation. Natural resource use can provide potential long term economic benefits if managed sustainably. This study aimed to estimate the economic benefits wildlife tourism and wildlife trade provided local communities on Madagascar. The study used data sets collated from Madagascar's Ministère du Tourisme (tourism data) and CITES (wildlife trade data) respectively for the period 2007 to 2018. Over this period, wildlife tourism, with a herpetological focus, provided over two magnitudes of difference higher income than that generated from the international live trade, which was dominated by reptilia. Little information existed from which to estimate levels of economic benefit reaching local communities adjacent to NPs from tourism. However, due to the smaller, more direct, networks involved within wildlife trade, it was possible to estimate economic benefits reaching local Malagasy. Both trade types require careful management to ensure minimal environmental impacts and long-term sustainability.

Abstract: Wildlife tourism and wildlife trade may appear juxtaposed, but are two, potentially aligning, income generators that could benefit conservation in developing countries. Utilising data sets collated from Madagascar's Ministère du Tourisme and CITES respectively for the period 2007 to 2018, this study estimated levels of income from wildlife tourism and wildlife trade for Madagascar. Between 2007-2018, tourism reported yearly incomes ranging from a low of US $1.4 million up to a high of US $15.7 million. However, it was unclear what percentage of this figure flowed to benefit local communities. Alternatively, using reported networks for the live wildlife trade, the estimated economic value reaching collectors and/or intermediaries on Madagascar was US $72,299.80 for the period 2007 to 2018. Both revenue generators operated within different geographical areas, with tourism opportunities presenting themselves to communities adjacent NPs, while wildlife trade networks were not restricted to NPs and operated sporadically across Madagascar. Hence, the economic benefits reached different Malagasy participants across the country. The management of both activities needs great care to ensure that environmental impacts and sustainability are core measures on any such activities. Whilst this study shines light on economic values and novel perspectives regarding these two trade types, it also highlighted knowledge gaps. Thus, indicating where much greater research attentions was required to allow better understanding of the specific benefits and risks from engaging with both trade types for local Malagasy people and their environments.

Keywords: Madagascar; conservation; wildlife trade; wildlife tourism; wildlife valorisation; wildlife economics; community-based conservation; resource management

1. Introduction

1.1. Socioeconomic aspects of wildlife valorisation in Madagascar

A long-standing ambition in many societies has been to seek the alignment of conservation requirements and poverty alleviation to engender mutual benefits [1,2,3,4]. The paucity of reported successful case studies highlights the complexities, juxtapositions and contested notions of justice that surround such projects [5], especially regarding efforts to improve distributive justice concerned with benefits and burden sharing [6]. One of the most persistent issues being that the poor pay disproportionately higher costs for conservation, while the rich secure most of the benefits [7,8,9].

To varying degrees, conservation benefits have been cited globally from the sustainable exploitation of wildlife resources [3,9,10,11]. Conversely, it has also been stated that unsustainable trade in wildlife was one of the major drivers causing species decline globally [11,12]. However, on Madagascar the impacts from harvesting wild flora and fauna were relatively poorly known, while both illegal [9,13,14] and unsustainable harvesting have been reported within and outside of protected areas [15]. A situation further compounded by the fact that high numbers of new species, endemic to Madagascar, were still being classified to date with others to follow [16,17,18].

Historically, National Parks (NPs) were established on Madagascar with the overriding aim to protect its unique biodiversity [19,20]. However, often local communities had little or no involvement in the establishment of NPs and other protected areas on Madagascar [21]. Yet in many cases local communities have ostensibly received varying scales of negative impact from their creation, as local communities were prevented from utilizing these areas, and the natural resources within them, for either subsistence or commerce [19,21,22,23]. Since 2003, during an expansion of almost 100 additional protected areas, the selection rationale also expanded to include cultural heritage, poverty alleviation and sustainable use of natural resources [24]. However, local communities' knowledge on the legal processes and legislation governing protected areas and/or species protection was mostly very poor [25].

1.2. Wildlife tourism revenue

An alternative to extractive approaches for valorising wildlife would be to view it in-situ; wildlife tourism. Tourism, across its varying formats, was often viewed as a panacea to resolving potential conflicts between local peoples' needs and NP protection, by bringing tourists to see the wildlife in-situ and having associated services develop around this premise [26,27]. Hence, wildlife tourism has been suggested as a non-extractive method for use on Madagascar [26,28,29]. However, it requires careful management to ensure long-term sustainability, from broad scale issues, such as operator responsibility (eg. deleterious impacts from water supply demands to waste product disposal) [30], to fine scale issues, such as negative impacts on species populations and animal welfare [31,32,33], to minimize potential negative impacts on Madagascar's environments.

Several studies have estimated the economic value of tourism to a few protected areas and more generally for Madagascar. For example, at Mantadia NP the economic values generated from tourism were estimated at US $24-65 per individual or US $0.8-2.2 million per annum [26]. At Ranomafana NP, in 2002, it was estimated that a total of US $29-31,246 was generated per annum with US $15,836 going to the local communities, while lemurs were stated by visitors to be the wildlife attraction [34]. Similarly, over 600 tourists visiting different NPs on Madagascar also stated lemurs to be the main attraction, with chameleons ranked second [35]. Revenues estimated to be received by local communities at Masoala NP ranged from US $700, in 1999, to US $500, in 2001 [28]. A national scale estimate of income generation via tourism was stated to be between US $26-29 million, with approximately 17% of tourists to Madagascar visiting national parks [35].

1.3. Flora and Fauna trade revenues

In addition to their apparent lack of knowledge regarding NP and species conservation legislation [25], not all local communities were keen to engage in the live trade of wildlife for international markets (which typically omits bush meat, other derivatives, and domestic uses, such as medicinal plants) for several reasons. For example, individuals reported being repulsed by reptiles, while payment insecurity, fear of legal repercussions and traditional barriers to harvesting certain species were other reported concerns [36,37].

However, it has been argued that Malagasy communities have the right to trade in their local wildlife resources [38]. Certainly, the international, live wildlife trade appeared to be flourishing on Madagascar. For example, relatively high levels of trade in Malagasy flora and fauna have been reported in studies to meet international demands [37,39,40,41, 42,43, 44,45].

As to the value generated from the international wildlife trade in Malagasy flora and fauna, estimates vary greatly, between product types and years. For example, Waeber and Wilmé [39] reported that illegal Rosewood and Ebony timber stockpiles due for export were valued at a minimum of US $600 million, while trade conducted in 2013 alone, across all CITES listed flora and fauna, was estimated at between US $ 346,246 to US $646,226 [37]. Alternatively, various estimated values have been provided for specific taxonomic groups; such as Chameleons generating over US $14.5 million [44], amphibians traded between 2000-2006 generating up to US $906,750 [43] or just Mantella traded between 2001–2003 generating up to US $246,372 [42]. Supply chain structures on Madagascar vary [46,47], though the three-actor level chain was most commonly used with collector and intermediary positions filled by Malagasy people [37,42]. However, the wildlife trade comes with potential hazards to an already challenging situation of protecting Madagascar's wildlife, such as the potential of overharvesting, animal welfare issues, cartel formations, the possibility of introducing the amphibian disease chytridiomycosis into new locations, etc. [18,35,48].

For the first time, this study draws together national scale data sets on these two forms of income generation to investigate both the levels and dynamics of the income generated. Furthermore, it will compare across both forms and discuss the potential benefits and costs to Madagascar for local communities. Such information will greatly enhance discussions on Madagascar and internationally, which currently lack any such comparisons, regarding advancing management options and seeking the best outcomes for conservation and poverty alleviation. This paper will present: 1/numbers of tourists and levels of income generated over the period 2007 – 2018. 2/the numbers of ecotourists and income generated each year over the same period. 3/the CITES listed species of flora and fauna exported from Madagascar and the numbers exported in the period 2007-2018. 4/the income generated from the trade in wildlife exported from Madagascar. Before then comparing the dynamics and variation in income levels between wildlife trade and ecotourism, especially in relation to the potential benefits or negative impacts on conservation and local communities.

2. Materials and Methods

Tourism data were obtained by request (collated Oct. 2019) from the Ministère du Tourisme on Madagascar. The Ministry supplied data covering the period 2007-2018 that included the total number of overseas visitors (tourists) each year and estimated income from tourism for each year (Table 1). Wollenberg et.al.'s [35] value of 17% (percentage of tourists who were ecotourists) was applied to the yearly tourist numbers to provide an estimate for the number of ecotourists visiting Madagascar each year (Table 1).

To estimate the income values generated from ecotourism, the yearly number of ecotourists (Table 1b) were multiplied with published conversion values presented by both Wollenberg et al [35] and Dixon & Pagiola [26], in each case the published values were adjusted for inflation in US$ to 2019. Estimation 1 was calculated using Wollenberg et al's [35] conversion value with yearly ecotourist numbers. Estimation 2 used Dixon & Pagiola's [26] conversion values, who provided an upper and lower value. Hence there were two calculations performed and two sets of estimates, upper and lower values, presented.

CITES data were obtained from the CITES Trade database (https://trade.cites.org/). These data were collated on 23rd Dec. 2019 using the following criteria; export country = Madagascar, source = wild, purpose = commercial, terms = live. These criteria were applied while the 'Search by taxon' was left empty to collect trade data records across all

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CITES listed taxa groups, animals and plants, for the period 2007-2018. These data were downloaded in an excel format for analysis and presentation.

Flora and fauna trade prices were extracted from published literature [37,42] and adjusted for inflation, in US$, for each year over the period. For plants, there were no trade structure price data available other than a single average export price [49]. The price structure reported for animals displayed a decrease in the order of two magnitude from export to collector, hence, it has been assumed here that a similar price structure would be observed for plants. Thus, the average plant price has been reduced by two fold to provide a general indicator of price at the collector level.

Table 1. The yearly number of tourists visiting Madagascar between 2007-2018 and the levels of income generated from those tourists, in US$ as reported, in 2019, by Madagascar's Ministère du Tourisme.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
TABLE 1a												
Number of tourists arriving on Madagascar*	344348	375010	162687	19052	225055	255942	196375	222374	244321	293185	255460	291299
Tourist income generation (US$ millions)*	313	459,65	178,5	211,1	262,49	279,81	390,42	649,62	585,38	748297	668262	
TABLE 1b												
Number of ecotourists (17%; Wollenberg et al, 2011)	58539	63752	27657	3239	38259	43510	33384	37804	41535	49841	43428	49521

* denotes data source Ministère du Tourisme/PAF/ADEMA/RAVINALA AIR-PORTS/APMF (collated Oct 2019).

3. Results

3.1. Ecotourism revenue generation

The total number of tourists arriving on Madagascar for the period 2007 to 2018 was nearly 3 million people with, on average, over 240,000 people arriving each year (Table 1a). Of this number of tourists, it was estimated that the number of ecotourists visiting each year was nearly 41,000 (Table 1b). Over the total period 2007-2018, ecotourism generated a total income of nearly US $189 million using Estimate 1, nearly US $46 million using Estimate 2 upper and nearly US $17 million with Estimate 2 lower value. On average, across the period 2007-2018, a yearly income was reported ranging from a low of US$1.4 million up to a high of US$15.7 million (Figure 1).

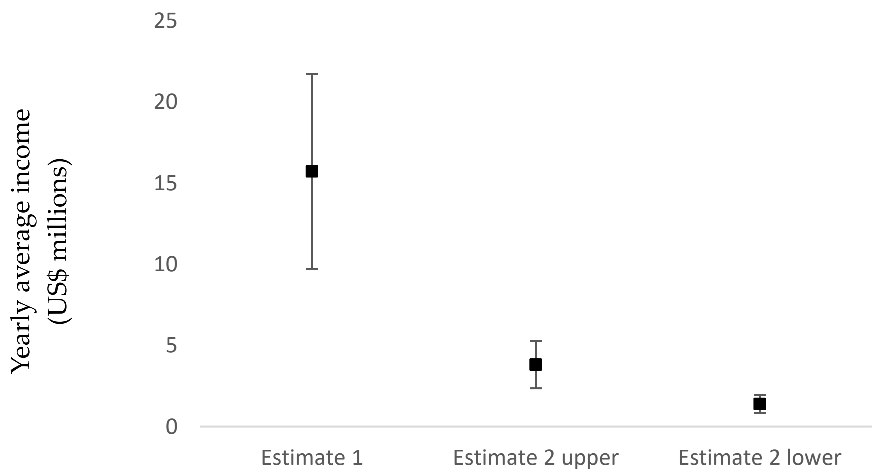

Figure 1. The average yearly level of income (+/- Std. Dev.) generated using the three calculation variations used to estimate ecotourism income, based on the original source tourist data from the Ministère du Tourisme, Madagascar.

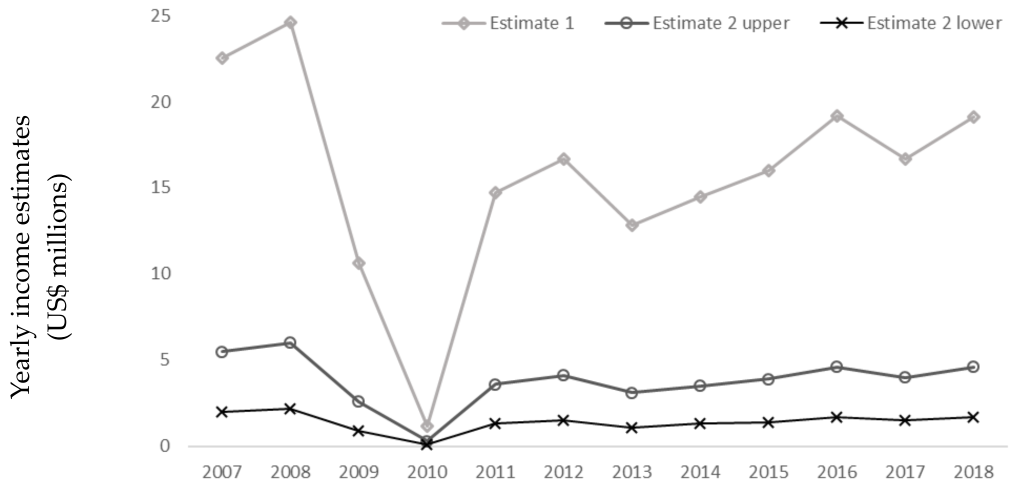

Figure 2. The trends in yearly estimated values (in US$) from ecotourism on Madagascar using the published conversion values of Wollenberg et al, [35] (Estimate 1) and Dixon and Pagiola, [26] (Estimate 2 upper and lower values). All values in US$ at 2019 rates. .

The highest level of income in any one year from tourists was in 2008 when it generated US$24.6 million, while the lowest was in 2010 when US$0.1 million was generated (Figure 2). Over 2007-2018, a linear regression records no increase in ecotourism growth over the period (y=0.0741x+15.235; R2=0.002). However, any long-term trend would be masked by the significant decrease in 2010. Applying a linear regression to a subset of the data, after the crash from 2011 to 2018, income generated from ecotourism was generally increasing (y=0.613x+13.454; R2=0.4556) back towards the high recorded in 2008 (Figure 2).

3.2. Flora and fauna trade revenues

Between 2007 and 2018. a total of 286,938 individual organisms were reported being exported from Madagascar with over 83% being animals and nearly 17% plants. The exported flora and fauna were from 52 known genera; 35 (67%) plant genera and 17 (33%) animal genera.

Of the 238,961 individual animals traded, over 70% was in Reptilia, over 29% in Amphibia with minor amounts in Aves (0.3%) and Mammalia (0.002%). Reviewing trade within the animal grouping at the genus level, the top five genera, which accounted for 97% of the trade in animals, were Mantella (29%), Phelsuma (27%), Furcifer (25%), Uroplatus (13%) and Brookesia (3%) (Figure3). Furthermore, within each genus just a handful of species accounted for the majority of its trade (Table 2). The top five species traded accounted for over 40.5% of the total number of animals exported; Mantella betsileo (n=22737, 23.5%), Mantella baroni (n=21110, 21.8%), Furcifer pardalis (n=19029, 19.7%), Phelsuma lineata (n=17939, 18.5%) and Furcifer lateralis (n=15908, 16.4%).

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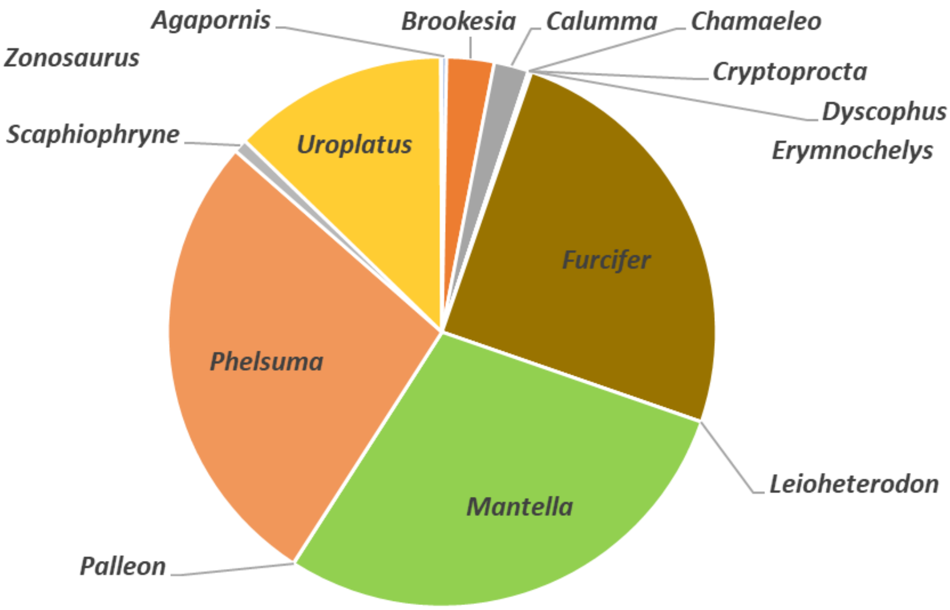

Figure 3. Each of the animal genera with species and numbers reported within the import data (two genera, *Eupleres* and *Fossa*, were reported in the import data set but with no data reported) exported from Madagascar between 2007 and 2018 (Source: CITES Database). .

Table 2. The top five traded genera within the animals grouping exported from Madagascar over the period 2007-2018, showing the total number traded within a genus and the four highest traded species within that genus and the percentage that species accounts for within the genus in trade. (Source: CITES).

Genus	Species	No.	%	Genus	Species	No.	%	Genus	Species	No.	%	Genus	Species	No.	%	Genus	Species	No.	%
Mantella		68798		*Phelsuma*		65329		*Furcifer*		59722		*Uroplatus*		30335		*Brookesia*		6686	
	Mantella betsileo	22737	33.0		*Phelsuma lineata*	17939	27.5		*Furcifer pardalis*	19029	31.9		*Uroplatus sikorae*	10059	33.2		*Brookesia superciliaris*	1927	28.8
	Mantella baroni	21110	30.7		*Phelsuma quadriocellata*	15534	23.8		*Furcifer lateralis*	15908	26.6		*Uroplatus fimbriatus*	6170	20.3		*Brookesia stumpffi*	1657	24.8
	Mantella nigricans	7306	10.6		*Phelsuma laticauda*	14124	21.6		*Furcifer oustaleti*	11268	18.9		*Uroplatus phantasticus*	5002	16.5		*Brookesia thieli*	1326	19.8
	Mantella pulchra	5969	8.7		*Phelsuma madagascariensis*	10563	16.2		*Furcifer verrucosus*	11312	18.9		*Uroplatus ebenaui*	4202	13.9		*Brookesia therezieni*	1169	17.5

Of the 47,977 individual plants traded, four genera accounted for over 84% (n=40382) of the exported plants from Madagascar with these four genera being Pachypodium, nearly 48% (n=22967), Euphorbia, over 24% (n=11608), Operculicarya, nearly 9% (n=4175) and Angraecum, over 3% (n=1632) (Figure4). Furthermore, within each genus just a handful of species accounted for most of the trade (Table 3). The top five plant species traded accounted for nearly 47% (n=22504) of the total number exported; Pachypodium spp. (n=7532, 15.7%), Pachypodium densiflorum (n=4232, 8.8%), Pachypodium brevicaule (n=4219, 8.7%), Operculicarya pachypus (n=3337, 6.9%) and Euphorbia primulifolia (n=3184, 6.6%).

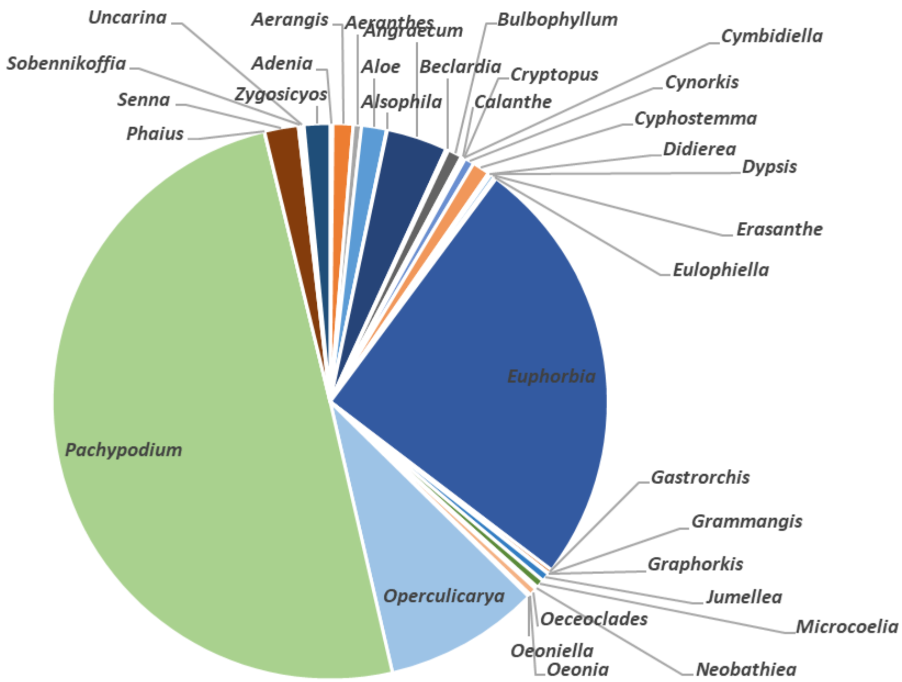

Figure 4. Each of the plant genera with species and numbers reported within the import data (one genera, *Alluaudia*, were reported in the import data set but with no data reported) exported from Madagascar between 2007 and 2018 (Source: CITES Database). **.**

Table 3. The top four traded genera within the plants grouping exported from Madagascar over the period 2007-2018, showing the total number traded within a genus and the four highest traded species within that genus and the percentage that species accounts for trade within the genus. (Source: CITES).

Genus	Species	No.	%	Genus	Species	No.	%	Genus	Species	No.	%	Genus	Species	No.	%
Pachypodium		22967		*Euphorbia*		11608		*Operculicarya*		4175		*Angraecum*		1632	
	Pachypodium spp.	7532	32.8		*Euphorbia primulifolia*	3184	27.4		*Operculicarya pachypus*	3337	79.9		*Angraecum urschianum*	113	6.9
	Pachypodium brevicaule	4219	18.4		*Euphorbia spp.*	1222	10.5		*Operculicarya decaryi*	430	10.3		*Angraecum breve*	95	5.8
	Pachypodium densiflorum	4232	18.4		*Euphorbia itremensis*	1088	9.4		*Operculicarya hyphaenoides*	408	9.8		*Angraecum germinyanum*	95	5.8
	Pachypodium eburneum	2352	10.2		*Euphorbia guillauminiana*	1029	8.9						*Angraecum teretifolium*	89	5.5

Consequently, based on dedicated species prices extracted from the published scientific literature, adjusted for varying yearly levels of inflation, an estimated total of US$72299.80 was generated from the trade between 2007-2018 and potentially made available to people within local communities (Table 4). The animal grouping contributed the majority (US$54727.50, nearly 76%) to the total value, with the plants grouping contributing US$17572.30 (over 24%). In the year 2016, both the animal and plant groupings recorded the highest levels of income (animals = US$7944.47; plants = US$4415.60), but both decreased rapidly post 2016. Trade remained static until 2013 (animals) and 2014 (plants) after which both groupings increased rapidly in the levels of trade (Figure 5).

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Table 4. The value (US$ in 2019) of the reptile and amphibian trade to the three actor levels (Coll. = collector, Inter. = intermediary, Export. = exporter) involved with the wildlife trade on Madagascar for the period between 2007 to 2018.

Animals			2007	price	value	2008	price	value	2009	price	value	2010	price	value	2011	price	value	2012	price	value	2013	price	value	2014	price	value	2015	price	value	2016	price	value	2017	price	value	2018	price	value
	Anura		7772			7348			8076			8000			6194			6191			6815			6395			3346			6070			4140			703		
		Dyscophus		0.25	0		0.26	0		0.26	0		0.26	0		0.27	0		0.28	0		0.28	0		0.28	0		0.28	0		0.29	0	232	0.29	67.28	110	0.3	33
		Mantella*	7307	0.11	803.77	7177	0.11	789.47	7699	0.11	846.89	7698	0.11	846.78	6003	0.12	720.36	6028	0.12	723.36	6644	0.12	797.28	6347	0.12	761.64	3346	0.12	401.52	6070	0.12	728.4	3886	0.13	505.18	593	0.13	77.09
		Scaphiophryne	465	0.25	116.25	171	0.26	44.46	377	0.26	98.02	302	0.26	78.52	191	0.27	51.57	163	0.28	45.64	171	0.28	47.88	48	0.28	13.44		0.28	0		0.29	0	22	0.29	6.38		0.3	0
	Carnivora				0																													4					
		Cryptoprocta			0						0			0			0			0			0			0			0			0	4		0			0
	Psittaciformes				0																250			300												100		
		Agapornis^		0.3	0		0.31	0		0.31	0		0.31	0		0.32	0		0.33	0	250	0.33	82.5	300	0.34	102		0.34	0		0.34	0		0.35	0	100	0.36	36
	Sauria		12991		0	14995			14030			13253			16697			14812			8937			11677			14923			24873			17351			2592		
		Brookesia	267	0.25	66.75	267	0.26	69.42	396	0.26	102.96	348	0.26	90.48	564	0.27	152.28	386	0.28	108.08	298	0.28	83.44	212	0.28	59.36	922	0.28	258.16	1781	0.29	516.49	1010	0.29	292.9	235	0.3	70.5
		Calumma		0.25	0		0.26	0		0.26	0		0.26	0		0.27	0		0.28	0		0.28	0	262	0.28	73.36	1326	0.28	371.28	2103	0.29	609.87	1152	0.29	334.08	28	0.3	8.4
		Chamaeleo		0.25	0		0.26	0		0.26	0		0.26	0		0.27	0		0.28	0		0.28	0		0.28	0		0.28	0	10	0.29	2.9		0.29	0		0.3	0
		Furcifer	4079	0.25	1019.75	4794	0.26	1246.44	4046	0.26	1051.96	4549	0.26	1182.74	6116	0.27	1651.32	6638	0.28	1858.64	4259	0.28	1192.52	5410	0.28	1514.8	4997	0.28	1399.16	8364	0.29	2425.56	5512	0.29	1598.48	958	0.3	287.4
		Palleon		0.25	0		0.26	0		0.26	0		0.26	0		0.27	0		0.28	0		0.28	0		0.28	0	6	0.28	1.68	15	0.29	4.35	11	0.29	3.19		0.3	0
		Phelsuma	4273	0.25	1068.25	4830	0.26	1255.8	5577	0.26	1450.02	5203	0.26	1352.78	7776	0.27	2099.52	6383	0.28	1787.24	3556	0.28	995.68	4539	0.28	1270.92	5617	0.28	1572.76	8942	0.29	2593.18	7328	0.29	2125.12	1305	0.3	391.5
		Uroplatus	4297	0.25	1074.25	5104	0.26	1327.04	3990	0.26	1037.4	3153	0.26	819.78	2241	0.27	605.07	1405	0.28	393.4	824	0.28	230.72	1254	0.28	351.12	2055	0.28	575.4	3633	0.29	1053.57	2338	0.29	678.02	41	0.3	12.3
		Zonosaurus	75	0.25	18.75		0.26	0	21	0.26	5.46		0.26	0		0.27	0		0.28	0		0.28	0		0.28	0		0.28	0	25	0.29	7.25		0.29	0	25	0.3	7.5
	Serpentes				0	5						16																										
		Leioheterodon		0.25	0	5	0.26	1.3		0.26	0	16	0.26	4.16		0.27	0		0.28	0		0.28	0		0.28	0		0.28	0		0.29	0		0.29	0		0.3	0
	Testudines		14		0	3			10			2						16			8			15			16			10			11					
		Erymnochelys	14	0.25	3.5	3	0.26	0.78	10	0.26	2.6	2	0.26	0.52		0.27	0	16	0.28	4.48	8	0.28	2.24	15	0.28	4.2	16	0.28	4.48	10	0.29	2.9	11	0.29	3.19		0.3	0
Animal total			20777		4171.27	22351		4734.71	22116		4595.31	21271		4375.76	22891		5280.12	21019		4920.84	16010		3432.26	18387		4150.84	18285		4584.44	30953		7944.47	21506		5613.82	3395		923.69
Plants			2007	price	value	2008	price	value	2009	price	value	2010	price	value	2011	price	value	2012	price		2013	price	value	2014	price	value	2015	price	value	2016	price	value	2017	price	value			
	Arecales			32.93			34.2			34.07			34.63			35.73			36.47			37			37.6			37.64			38.12			38.93				
		Dypsis	3	0.33	0.99		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
	Caryophyllales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Alluaudia		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Didierea		0.33	0		0.34	0		0.34	0	50	0.35	17.5		0.36	0		0.37	0		0.37	0	3	0.38	1.14		0.38	0	20	0.38	7.6		0.39	0			
	Cyatheales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Alsophila	20	0.33	6.6		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
	Euphorbiales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Euphorbia	1381	0.33	455.73	1033	0.34	351.22	620	0.34	210.8	370	0.35	129.5	895	0.36	322.2	1600	0.37	592	710	0.37	262.7	1104	0.38	419.52	1411	0.38	536.18	1974	0.38	750.12	510	0.39	198.9			
	Fabales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Senna		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0	55	0.38	20.9	502	0.38	190.76	350	0.38	133		0.39	0			
	Gentianales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Pachypodium	2798	0.33	923.34	2434	0.34	827.56	530	0.34	180.2	945	0.35	330.75	1876	0.36	675.36	2598	0.37	961.26	1425	0.37	527.25	1156	0.38	439.28	3175	0.38	1206.5	5470	0.38	2078.6	560	0.39	218.4			
	Liliales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Aloe	390	0.33	128.7	130	0.34	44.2		0.34	0		0.35	0	100	0.36	36	50	0.37	18.5		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
	Orchidales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Aerangis	75	0.33	24.75	35	0.34	11.9	20	0.34	6.8		0.35	0		0.36	0		0.37	0	30	0.37	11.1		0.38	0	138	0.38	52.44	143	0.38	54.34	100	0.39	39			
		Aeranthes	30	0.33	9.9	55	0.34	18.7		0.34	0		0.35	0		0.36	0		0.37	0	20	0.37	7.4		0.38	0	51	0.38	19.38	30	0.38	11.4	38	0.39	14.82			
		Angraecum	93	0.33	30.69	185	0.34	62.9		0.34	0		0.35	0		0.36	0		0.37	0	80	0.37	29.6		0.38	0	460	0.38	174.8	558	0.38	212.04	256	0.39	99.84			
		Beclardia	13	0.33	4.29		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0	10	0.37	3.7		0.38	0	22	0.38	8.36	18	0.38	6.84	7	0.39	2.73			
		Bulbophyllum	10	0.33	3.3	40	0.34	13.6		0.34	0		0.35	0		0.36	0		0.37	0	30	0.37	11.1		0.38	0	73	0.38	27.74	143	0.38	54.34	88	0.39	34.32			
		Calanthe		0.33	0	20	0.34	6.8		0.34	0		0.35	0		0.36	0		0.37	0	10	0.37	3.7		0.38	0	15	0.38	5.7	18	0.38	6.84		0.39	0			
		Cryptopus		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0	3	0.38	1.14		0.39	0			
		Cymbidiella	11	0.33	3.63	15	0.34	5.1		0.34	0		0.35	0		0.36	0		0.37	0	5	0.37	1.85		0.38	0	4	0.38	1.52	12	0.38	4.56	1	0.39	0.39			
		Cynorkis	9	0.33	2.97	45	0.34	15.3		0.34	0		0.35	0		0.36	0		0.37	0	60	0.37	22.2		0.38	0	40	0.38	15.2	94	0.38	35.72	9	0.39	3.51			
		Erasanthe	33	0.33	10.89	30	0.34	10.2		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0	16	0.38	6.08	23	0.38	8.74	12	0.39	4.68			
		Eulophiella	3	0.33	0.99		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0	5	0.37	1.85		0.38	0	3	0.38	1.14	35	0.38	13.3	13	0.39	5.07			
		Gastrorchis	2	0.33	0.66		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0	25	0.37	9.25		0.38	0	24	0.38	9.12	36	0.38	13.68	25	0.39	9.75			
		Grammangis	9	0.33	2.97		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0	2	0.38	0.76	6	0.38	2.28	1	0.39	0.39			
		Graphorkis	2	0.33	0.66		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Jumellea	3	0.33	0.99	30	0.34	10.2		0.34	0		0.35	0		0.36	0		0.37	0	35	0.37	12.95		0.38	0	45	0.38	17.1	66	0.38	25.08	50	0.39	19.5			
		Microcoelia		0.33	0	20	0.34	6.8		0.34	0		0.35	0		0.36	0		0.37	0	60	0.37	22.2		0.38	0	40	0.38	15.2	60	0.38	22.8	45	0.39	17.55			
		Neobathiea	2	0.33	0.66		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0	36	0.38	13.68	16	0.38	6.08	11	0.39	4.29			
		Oeceoclades	150	0.33	49.5		0.34	0		0.34	0	30	0.35	10.5		0.36	0		0.37	0		0.37	0		0.38	0	3	0.38	1.14	23	0.38	8.74	4	0.39	1.56			
		Oeonia	3	0.33	0.99		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0	33	0.38	12.54	17	0.38	6.46	3	0.39	1.17			
		Oeoniella	6	0.33	1.98		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0	1	0.38	0.38		0.39	0			
		Phaius		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0	3	0.38	1.14	3	0.38	1.14	1	0.39	0.39			
		Sobennikoffia	40	0.33	13.2		0.34	0	15	0.34	5.1		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0	12	0.38	4.56	2	0.39	0.78			
		(blank)	230	0.33	75.9	103	0.34	35.02	124	0.34	42.16	204	0.35	71.4	239	0.36	86.04		0.37	0	305	0.37	112.85		0.38	0	641	0.38	243.58		0.38	0	2	0.39	0.78			
	Rhamnales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Cyphostemma		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0	33	0.37	12.21	120	0.37	44.4	21	0.38	7.98	155	0.38	58.9	125	0.38	47.5	10	0.39	3.9			
	Sapindales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Operculicarya		0.33	0		0.34	0		0.34	0	50	0.35	17.5	231	0.36	83.16	511	0.37	189.07	84	0.37	31.08	229	0.38	87.02	545	0.38	207.1	2031	0.38	771.78	494	0.39	192.66			
	Scrophulariales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Uncarina		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0	1	0.38	0.38	80	0.38	30.4		0.38	0		0.39	0			
	Violales			0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0		0.38	0		0.38	0		0.38	0		0.39	0			
		Adenia		0.33	0		0.34	0		0.34	0		0.35	0		0.36	0		0.37	0		0.37	0	1	0.38	0.38		0.38	0	70	0.38	26.6		0.39	0			
		Zygosicyos		0.33	0		0.34	0		0.34	0		0.35	0	5	0.36	1.8	20	0.37	7.4	179	0.37	66.23	45	0.38	17.1	163	0.38	61.94	263	0.38	99.94	20	0.39	7.8			
Plant total			5316		1754.28	4175		1419.5	1309		445.06	1649		577.15	3346		1204.56	4812		1780.44	3193		1181.41	2615		993.7	7680		2918.4	11620		4415.6	2262		882.18			

† denotes dedicated chameleon prices extracted from Carpenter *et al*. (47) adjusted for inflation in US$.; * denotes dedicated *Mantella* prices extracted from Rabemananjara *et al*. (42) adjusted for inflation in Malagasy Ariary before conversion to US$

All remaining prices were extracted from Robinson *et al*. [37] adjusted for yearly inflation levels in US$

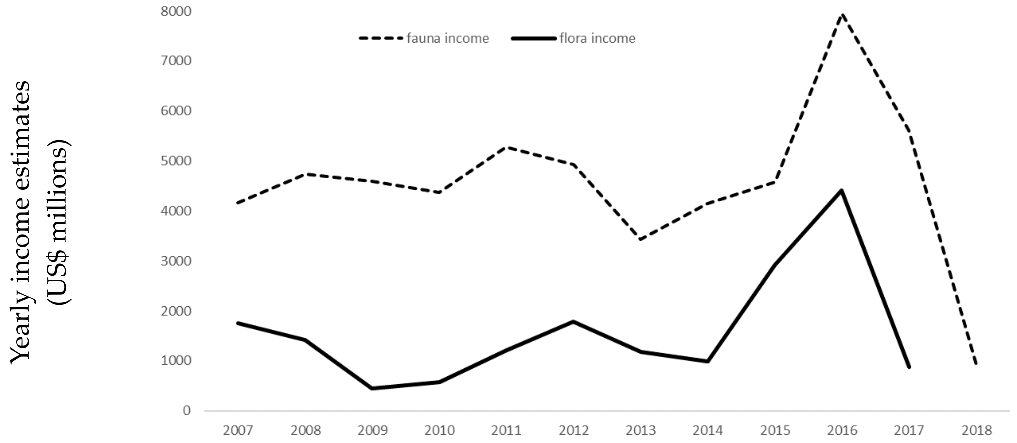

Figure 5. Yearly income estimates from the live trade in CITES listed animals and plants exported from Madagascar between 2007 and 2018 (Source: CITES Database). .

Comparing the estimated levels of income generated from both ecotourism and wildlife trade on Madagascar, a much greater level of income generation was garnered from wildlife tourism (Figure 6). Wildlife tourism reported yearly income estimated in the millions of US dollars, while estimates of income generation from the wildlife trade was recorded in thousands of US dollars (Figure 6). However, the wildlife trade displayed a positive increase in trade (y=305.23x + 4657.4, R^2=0.224) (excluding 20018; as it has been reported that observed drops in trade in the latest year of reporting were more likely due to an artifact of countries failure to meet CITES reporting timelines than a true drop in any trade – see [46].

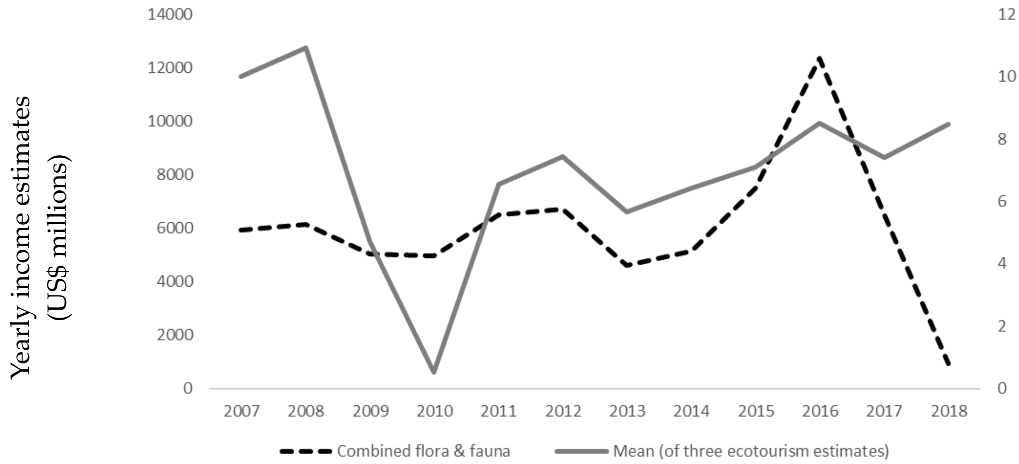

Figure 6. Yearly income estimates from both the combined live trade in CITES listed animals and plants exported from Madagascar and the mean estimated income from ecotourism to Madagascar between 2007 and 2018.

4. Discussion

Over the whole time period for which data exists (2007–2018), the international live trade in Malagasy herpetofauna generated revenues estimated at a total of US$401,470 reaching local Malagasy people. Taking just the upper estimate, for the reptile and amphibian focused wildlife tourism, it was valued at over US$51 million while the general figure was estimated at US$17-46 million. However, both these revenue estimates were greater than the estimated revenue generated from the wildlife trade, though actually how much flows to reach the local people is unknown. For comparison however, in just 2018, Madagascar's top revenue generators ranged from; firstly, coffee, tea and spices (valued at US$1 billion; on its own vanilla was worth US$855.4 million and cloves US$149 million) to tenth place, mineral fuels, including oil (valued at US$51.5 million) [50].

Whilst tourism with a herpetological focus was over two magnitudes of difference higher than that generated from the international live trade, the revenue was focused towards NPs with communities located adjacent benefiting. Conversely, those involved with the live trade were more geographically dispersed and, potentially, with no association to a national park. Hence, the two sources of revenue generation were possibly complementary to each other in that they could potentially engage with different sets of local people. Therefore, they should not be seen as alternatives, but rather can operate side by side, as long as it is sustainably conducted. Thus, both avenues to valorisation of wildlife raise not only the levels of revenue generated but also the opportunities to engage in revenue generation for a wide spectrum of local communities. However, one has to be careful of the wider dynamics involved. For example, one hotel Northeast of Mahajunga, Anjajavy, sort to train individuals from the adjacent, remote, village to work in the hotel (author, pers obs.). However, due to the multiple juxtapositions between the individuals and the western facing hotel, the training of local people to work within the hotel and, thus, provide local benefits had very mixed results. This resulted in the hotel recruiting individuals with more western 'standards' exposure from major towns and importing them to work at the hotel but lived in the local village. These new recruits were from different tribes with very different social/behavioural mannerisms, outlooks and more western experiences. Yet they were expected to be both located within the local village and welcomed by those living their. The impacts were extremely wide ranging and both negative and positive.

Despite the short-term economic benefits, the long-term conservation impact resulting from the current scope and scale of the consumptive use of wildlife was being increasingly brought into question [1,11]. However, the potential negative impacts of unsustainable exploitation are not limited to extractive use of Madagascar's herpetofauna alone. For example, broad scale issues can arise from ecotourism operators' environmental responsibility, such as deleterious impacts from the demand for water supplies or waste product disposal [30]. Alternatively, at a finer scale, irresponsible ecotourism can also bring net negative impacts on both the conservation and welfare of wild animals, including reptiles [32,33]. For example, regular, close proximity of tourists with free-ranging wildlife can negatively impact an array of animal behaviors, such as breeding [51] or foraging [52]. Direct physical contact with wild caught wildlife can also lead to the unintentional transfer of zoonotic diseases [35], the death of individual animals or to species, potentially threatened species, being brought into captivity to show-off to tourists. Often these types of negative impacts are difficult to detect, especially by tourists themselves [32], while different attitudes and societal expectations further complicate such decision-making [33].

No previous study has sought to estimate and compare such complex scenarios, especially for a country that has such a high conservation profile and in need of such evidence upon which to make robust management decisions for the national good. Ultimately, there are positives and negatives associated with both the live trade and wildlife tourism. However, it will be the long-term sustainability with minimum environmental impacts that follow both activities which managers will need to ensure going forward. These will be multi-dimensional, ranging across species and ecosystems to human dimensions, and spanning both temporal and spatial scales. Hence, balancing social demands with environmental capacity to minimise impacts and maintain sustainability should be the goal of government and managers alike.

5. Conclusions

There have been no comprehensive reviews undertaken previously on the value of these two sectors for the potential conservation benefits they offer. This study was the first that sought to contrast and compare the extent of each trade type on Madagascar. It provides a comprehensive baseline from which to further investigate these areas, but also highlights the vast differences in income generated from both. However, it also highlights the need to better understand the flow of these revenue streams to better improve their benefits to both poverty alleviation and conservation. Certainly, without a much improved understanding of the flow and divisions of income, from country level down to the local family, study's such as this one, lack the detail and nuances to best advise on the changes required. This study has highlighted the levels of incomes involved, detailed the trade networks involved, highlighted the wild flora and fauna being traded and highlighted broadscale issues. It is now incumbent on others to take the fundamentals reported in this study and add to the detail to allow sensitive, adaptive management proposals that benefit both poverty alleviation and conservation equally.

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