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Analysis

Effects of consumer preferences for rarity on the harvest of wild populations within a species

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ABSTRACT

Economic theory predicts that exploitation of a species alone is unlikely to result in extinction because of escalating costs involved in finding increasingly rare individuals of a declining species. However, a recently proposed hypothesis, the Anthropogenic Allee Effect (AAE), proposes that if people place disproportionate value on rare species, this may result in a cycle whereby increased exploitation reduces the population size, thus increasing its value and ultimately leading to its extinction in the wild. We tested this hypothesis using data collected on wild harvests, preferences of pet keepers and sale prices of different populations of green pythons (*Morelia viridis*) and hypothesized that the AAE could occur among population within species, not just between them. The rarity of populations of green pythons was strongly positively correlated with price and negatively correlated with harvest levels. The two populations that were deemed most desirable by pet collectors exhibited abnormal coloration and were found to be suffering from the effects of over-exploitation for the pet trade. Adequate regulation and enforcement are needed to reduce the effects of demand on illegal harvesting and conservationists and government bodies should be aware of the effects of disclosing the rarity of a species and its populations.

1. Introduction

Human activities are increasingly threatening ecosystems and biodiversity (Baillie et al., 2004; Sodhi et al., 2009). One activity, the trade in wildlife, is considered to be one of the largest direct threats to species survival. This is partly due to overexploitation for medicines, food, luxury items, clothing, and pets (Broad et al., 2003; Rosser and Mainka, 2002). An increasing number of studies are showing the deleterious effects of a species' own inherent rarity, whether actual or perceived, due to increased rates of unsustainable wild harvest (Angulo and Courchamp, 2009; Brook and Sodhi, 2006; Hall et al., 2008). Traditional economic theory predicts that the exploitation of a species alone is unlikely to result in extinction because of the escalating cost involved in finding increasingly rare individuals of a declining species (Gault et al., 2008). For example, many fisheries have been significantly depleted due to overharvesting. Nevertheless, harvesting alone has not resulted in their extinction because the cost of harvesting cannot be recouped from the sale of the small numbers of fish caught (Iudicello et al., 1999). However, Courchamp et al. (2006) hypothesized that if people place disproportionate value on a rare species, this may result in a cycle whereby increased exploitation reduces the population size, which in turn increases its value and ultimately leads to its extinction in the wild — a concept termed the Anthropogenic Allee Effect (AAE). This concept is founded on two assumptions: (1) there is a positive correlation between species rarity and its value and (2) this correlation fuels sufficient demand to ensure that the market price exceeds the escalating costs of finding and harvesting a declining species (Courchamp et al., 2006). A growing number of studies have suggested that some people do place disproportionate value on species rarity (see Gault et al., 2008; Hall et al., 2008; Johnson et al., 2010; Tournant et al., 2012). However, we are aware of no studies that have shown the direct effect of consumer preferences for rarity on the harvest of a species. Understanding the response of consumers to a species' perceived rarity is vital for predicting the impact of intervention strategies that seek to minimize extinction risk (Hall et al., 2008).

The exotic pet trade is a multi-million dollar global industry. One group of wildlife that is heavily exploited for pets is reptiles (Gibbons et al., 2000; Lyons et al., 2013; Natusch and Lyons, 2012a; Nijman and Shepherd, 2011; Zhou and Jiang, 2005). Reptile species that are highly prized are often brightly colored, patterned and/or rare (Auliya, 2003). Newly described species are also highly sought after, and sometimes excessively harvested from the wild before a quota for their trade is established (Shepherd and Ibarrondo, 2005). Because many reptiles exhibit significant intraspecific variation (e.g. color forms specific to particular regions), we hypothesized that an AAE could occur not only at the species level, but also among populations of single species. We tested this hypothesis using survey questionnaires, advertisements and harvest data to determine the effect of consumer preferences for rarity on the harvest of wild populations of green pythons (*Morelia viridis*).

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2. Materials and Methods

2.1. Study Species

The green python (*M. viridis*) ranks among the top ten most heavily traded captive-bred, CITES-listed, reptile species globally (CITES Trade Database, 2012). These small (<2 m) snakes are restricted to far northern Australia and the island of New Guinea, which is politically divided between Papua New Guinea (PNG) and Indonesia (Natusch and Natusch, 2011; O'Shea, 1996). Green pythons are highly recognizable due to their distinctive coloration and pattern, with juveniles born either yellow or red, and later changing to green (Natusch and Lyons, 2012b; Wilson et al., 2007; ~~Fig. 1~~). Throughout their range, green pythons exhibit subtly different "locality specific" colors and patterns. As a result, individuals from certain localities are more desirable than others, and can demand higher prices (Maxwell, 2005). In addition, green pythons that display "abnormal" variations in color also generally obtain higher prices, and are known as "designer" snakes.

The green python is listed in Appendix II of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), which monitors and regulates its international trade. They are fully protected in Indonesia and Australia by national legislation (Dilindungi PP 7/1999 and the Queensland Nature Conservation Act 1992, respectively) permitting a zero harvest quota in these countries. The green python is not protected in PNG; however, they cannot be exported for commercial purposes. Indonesia is currently the only country that permits the commercial export of green pythons, but they must be captive-bred, meaning that offspring are produced in a controlled environment from captive-bred animals of at least second generation (F2) (CITES Resolution Conf. 10.16 (Rev.)). However, Lyons and Natusch (2011) found that the majority of green pythons exported from Indonesia are illegally harvested from the wild and laundered through breeding farms as "captive-bred". Between the years 2000 and 2009 approximately 50, 000 green pythons were exported as "captive-bred" from Indonesia (CITES Trade Database, 2012). The major importing countries over this period were the United States of America (USA) ($N = 27{,}516$), France ($N = 2639$) and Germany ($N = 2611$) (CITES Trade Database, 2012).

2.2. Harvest Data from Indonesia

We visited six sites in the Indonesian provinces of Maluku, West Papua and Papua between August 2009 and April 2011. Sites were selected upon the basis of known consumer demand for "locality specific" green pythons and therefore areas where trade was likely to occur. At each site we conducted interviews with traders who were identified through anonymous informants. Interview questions focused on the number of green pythons collected, prices, collection trends, and trade history. We ground truthed this information using direct counts of individual green pythons and by crosschecking with other actors within the trade chain (see Lyons and Natusch, 2011 for further details).

2.3. Survey Questionnaire

We created a structured survey questionnaire using an online survey site (SurveyMonkey, 2010) and made it available on twenty international reptile forums between 29 May 2010 and 26 April 2011. In addition, we identified a number of well-known green python keepers (mostly in Europe and the USA) and sent the survey questionnaire directly to them via email. Each respondent was asked to pass the questionnaire to other keepers to facilitate a wide coverage of responses. We provided the survey questionnaire in four languages (English, French, German, and Bahasa Indonesian) depending on where the survey was offered. Answering questions was not mandatory and respondents could exit the survey at any time. Each respondent's IP address was recorded to permit only one response per machine, and once the survey questionnaire was exited the respondent was not able to re-enter the survey. Although Internet surveys such as these are a relatively new means of gathering social demographic data they often provide much larger sample sizes than comparable survey methods and can be used to target specific groups (in this case herpetoculturists). Moreover, Internet surveys have been shown to be comparable to more typical methods of survey (Fleming and Bowden, 2009).

Our survey questionnaire aimed to gain responses to four basic questions: (1) did respondents keep green pythons, (2) what qualities did respondents look for in a green python, (3) from a list of "locality specific" green pythons, what did respondents think were the most common to least common in their respective countries, and (4) from the same list, what did respondents think was the most desirable "locality specific" green python.

2.4. Advertisements

We used the Internet to search for advertisements selling green pythons between May 2010 and July 2011 and obtained data from sixty reptile websites and online classifieds. Searches were conducted in English, French, German and Bahasa Indonesian and included key words such as "*M. viridis*", "green tree python", "sale" and "designer". For each advertisement the following information was gathered: (1) color of green python (yellow, red, green, or "designer"), (2) sale region, (3) price (in USD), and (4) locality.

2.5. Analysis of Data

We used contingency table analysis to test for significant differences between what respondents look for in quality green pythons and Fisher's Exact tests to determine differences in the proportion of responses among regions. Only advertisements from North America provided detailed information on the color of green pythons and thus we restricted color analysis to this region. We used a two-way analysis of variance (ANOVA), with $\log_{10}$-price as the dependent variable and region and color as factors, to test for differences in the price of green pythons of different colors between New Guinea and North America. Repeated linear regressions were performed to determine significant relationships between the numbers of green pythons harvested, how common they are in consumer markets, and price. We $\log_{10}$-transformed and square root transformed our data in order to meet the assumptions of normality and homogeneity of variance. Similar results were obtained using both methods and thus we favored $\log_{10}$-transformed data sets to allow determination of the magnitude of the original values. Respondents from Australia and South Africa indicated that very few "locality specific" green pythons were available in trade and therefore they had difficulty ranking the commonness of the localities listed within the survey questionnaire. Thus, we included Australia and South Africa in our examination of consumer preferences, but omitted them from rarity analysis.

3. Results

3.1. Traders in Indonesia

We recorded 4229 illegally harvested green pythons in Indonesia (see Lyons and Natusch, 2011 for specific numbers and information on how data were collected). Seventy-six per cent (10/13) of traders provided information on the mean number of green pythons collected per month from each locality (Table 1).

3.2. Survey Responses and Advertisements

Overall, 410 survey responses were collected from 28 countries. We grouped respondents from each country into five geographic regions

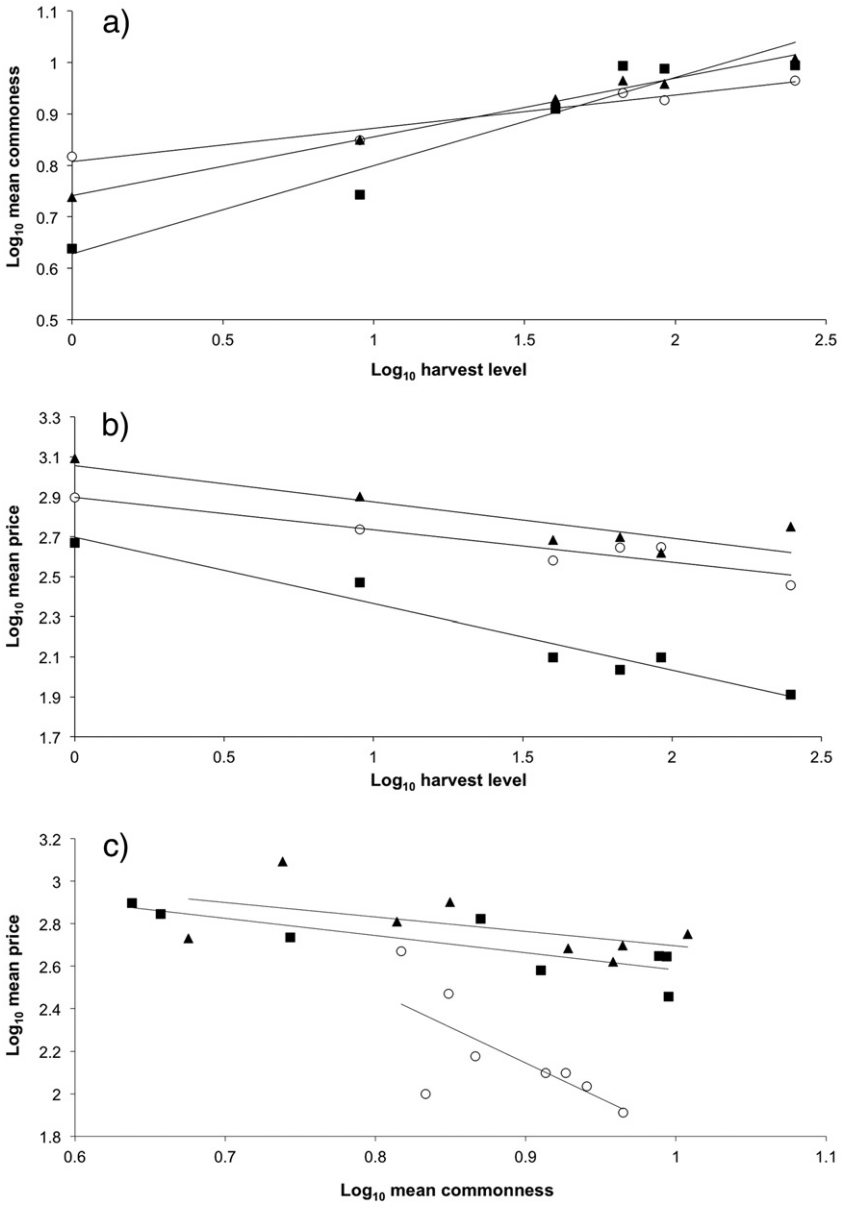

Fig. 1. Relationships between trade variables for the green python. (a) Mean commonness of green pythons from six localities as ranked by respondents vs. mean number of green pythons that traders claimed to have harvested per month from the same localities. (b) Mean commonness of green pythons from eight localities as ranked by respondents vs. mean price of green pythons from the same localities. (c) Mean price of green pythons from seven localities vs. mean number of green pythons that traders claimed to have harvested per month from the same localities. North America (○), Europe (▲), and Asia (■).

(Table 2). Although the summary data appear biased as to the geographic origin of respondents (i.e. North America and Europe), our sample fits with the popularity of reptile keeping in these regions. Furthermore, the vast majority of green pythons exported from Indonesia are imported into the USA and Europe (CITES Trade Database, 2012). Our preliminary analyses revealed no significant difference in responses to all questions between respondents that kept green pythons and those that did not (all tests $P > 0.05$), and therefore we pooled these groups together for subsequent analyses. Information obtained from advertisements selling green pythons is summarized in Table 2.

3.3. Rarity, Demand, Harvest, and Price

Not surprisingly, there was a strong positive correlation between the number of green pythons harvested from certain localities and the respondents "commonness" ranking for those same localities

Table 1
Mean number of green pythons collected per month by traders in Indonesia.

	Locality						
	Aru	Biak	Jayapura	Kofiau	Manokwari	Merauke	Sorong
Number of green pythons collected per month	67	250	40	1	10	9	82

Table 2
Summary data for survey questionnaire and advertisements.

Region	Number of respondents	Number of respondents that keep green pythons	Most desirable locality of green python	Number of advertisements examined
Asia	20	14	Kofiau	37
Australia	91	55	Australian	N/A
Europe	83	69	Biak	51
North America	194	174	Biak/Kofiau	225
Africa	22	16	Biak	N/A
Totals	410	328		313

Table 3
Summary statistics for linear regressions of trade attributes for green pythons.

Factors	Region	R^2	Parameter estimate	Std Error	F-value	*P*-value
Harvest level × mean commonness	Asia	0.95	0.065	0.007	76.2	>0.0001
	Europe	0.99	0.115	0.005	550	>0.0001
	North America	0.93	0.172	0.023	55.7	0.002
Harvest level × mean price	Asia	0.9	−0.314	0.047	43.1	0.001
	Europe	0.62	−0.162	0.056	8.22	0.035
	North America	0.88	−0.167	0.027	38.1	0.001
Mean price × mean commonness	Asia	0.5	−0.15	0.061	6.06	0.049
	Europe	0.29	−0.43	0.271	2.44	0.17
	North America	0.67	−0.83	0.236	12.3	0.013

(Table 3; Fig. 1). There was a strong negative correlation between the number of green pythons harvested from certain localities, the commonness of green pythons from those localities and their advertised price (Table 3; Fig. 1). In other words, green pythons from localities where little harvest occurred and were ranked as the least common (i.e. "rare"), also obtained the highest prices. According to respondents, the two most sought after localities of green python are from Kofiau and Biak islands (Table 2). Traders of green pythons from Kofiau Island claimed that despite snakes becoming increasingly rare, their high price meant they continue to be targeted. Interestingly, the correlation between mean price and "commonness" was not significant for Europe (Table 3).

There were significant differences among what respondents looked for in a quality green python, with coloration and pattern being the most sought after traits ($\chi^2 = 38.3$, df = 20, $P = 0.008$). Proportions of these attributes were almost identical among regions, with the exception that respondents from Europe placed less emphasis on coloration and more emphasis on the locality of green pythons than respondents from other regions (Fishers Exacts test; $Z = -3.04$, $P = 0.002$; Fig. 2).

Traders in Indonesian New Guinea sold yellow, red and green snakes for the same price (Fig. 3). Similarly, the price of yellow, red, and green snakes were similar in North America (Fig. 3). However, the mean price of "designer" green pythons in both New Guinea and North America was significantly greater than those that exhibited normal coloration (two-way ANOVA; $F_{3,113} = 80.5$, $P = 0.001$; Fig. 3).

4. Discussion and Conclusions

There has been relatively little research conducted on the AAE and consumers' preferences for species in the pet trade, and fewer studies have related these preferences back to the actual harvest of a species from the wild. Herein, we present an example of how consumers place disproportionate value on rare populations within a

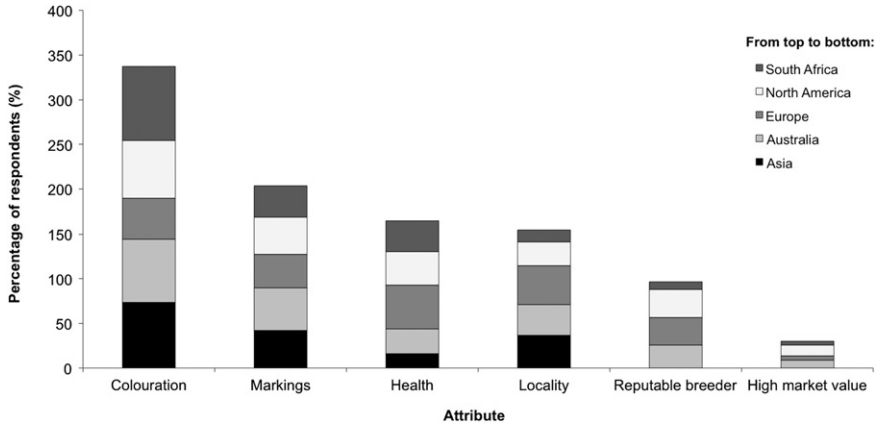

Fig. 2. Percentage of responses given for attributes looked for in a quality green python by respondents from five regions. Note: percentages may sum to more than one hundred because respondents were allowed to select more than one attribute.

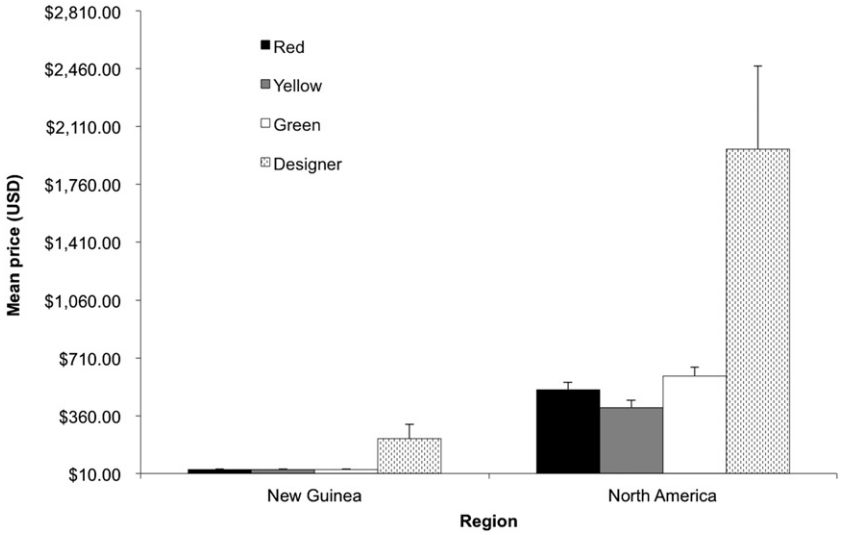

Fig. 3. Mean price of green pythons of different colors sold in New Guinea and advertised in North America.

species. Those populations perceived to be rare may be exploited at a higher rate, which may precipitate their extinction if harvesting is left unchecked.

4.1. Rarity and Consumer Preferences

Green pythons from localities with the lowest harvest levels were ranked as least common by respondents from all regions (i.e. these localities were perceived to be the rarest), and therefore obtained the highest prices on their respective markets. The two most desirable green python localities were Biak and Kofiau, despite green pythons from Biak being relatively common and inexpensive in trade (Table 2). Both of these localities are oceanic islands where individual anomalies in color and the timing of ontogenetic color change in green python are present (Natusch and Lyons, 2012b). We suggest that these color anomalies have resulted in sustained consumer demand and thus harvest of these populations for international pet markets. This result suggests that "rarity" is not exclusively related to "abundance", but also to other attributes that confer the perception of rarity (such as color or time since scientific description). This is further corroborated by consumer demands for "designer" green pythons and those that are colorful and well patterned (Fig. 2). The demand for "designer" green pythons and color morphs of other reptiles has recently skyrocketed in the international pet trade and many keepers breed solely for this purpose (Bartlett and Bartlett, 2002; Maxwell, 2005). Indeed, traders in Indonesia showed us photographs depicting green pythons from popular literature (Maxwell, 2005). It was claimed that, if harvested, these snakes fetched the highest price and were therefore most sought after by traders. Green python populations from both Biak and Kofiau exhibit signs of over-exploitation by the pet trade and traders claimed that collection at these localities was becoming increasingly difficult (Lyons and Natusch, 2011). As with many reptile species, there is little data on the population biology and demographics of green pythons in the wild. Populations suffering from an AAE may exhibit negative growth rates at low densities, which drive them to lower densities and ultimately to extinction (Courchamp et al., 2006).

4.2. Implications and Recommendations for Conservation

The AAE hypothesizes that if consumers' value rarity there may be no economic constraint to the exploitation of a species (or population) at low density (Courchamp et al., 2006). Currently, 50% of Indonesia's population lives on less than USD 2 per day (World Bank, 2011). The costs associated with harvesting a declining wildlife population would often be a meager amount compared to the final market price for increasingly rare individuals - thus providing incentive for sustained harvesting. Island populations of many animal species frequently occur at lower densities than their mainland conspecifics (Boback, 2005; Purvis et al., 2000) and may be particularly vulnerable to the effects of over-exploitation (Dodd, 1993). Indonesia is the world's largest archipelago and many endemic, insular, reptiles and other animal species have been described from the islands in recent years. The isolation and inherent rarity of these island endemics make them prized and vulnerable targets for exploitation by the pet trade, which has already resulted in declines (Natusch and Lyons, 2012a; Shepherd and Ibarrondo, 2005). The particular threat that the AAE poses for rare species is sufficiently disturbing for scientists to use caution when disclosing rarity, both within the scientific community and to the general public. Disclosure of locality information for the endangered snake, *Hoplocephalus bungaroides*, on the Internet and in popular herpetolocultural magazines, resulted in the illegal collection and associated declines of that species in the wild (Webb et al., 2002).

Because of the sensitivity surrounding illegal trade, we aimed to maximize the anonymity of survey respondents. However, our study would have benefited from a representative test of the population sample of respondents (age, education level, income), thus providing valuable information on the socio-economic correlates of consumer demands for green pythons. Because environmental monitoring and enforcement in countries like Indonesia is poor, gauging how different types of consumer perceive a species (i.e. whether rare or common and/or attractive to collectors) is vital and should be factored into conservation plans. Conservationists and environmental managers should consider monitoring early warning indicators for species becoming popular in trade. This includes having greater awareness of the species (and populations) whose numbers, price and popularity are increasing within the pet trade and might present a potential AAE. Additional studies should be carried out on the links between awareness-raising in consumer countries and actual changes in the attitudes and behavior of consumers. In the case of green pythons, educating consumers and raising awareness about how purchasing preferences can directly affect this trade are needed. Conservationists should consider engaging popular media to highlight these issues. As a concluding point, high consumer demands for rare species or populations may not be all bad. Consumers, and the public in general, may be more willing to financially support programs aimed to protect rare species or populations than common ones. Thus, rare species (and populations)

can be promoted as flagships for their own conservation, as well as sympatric species and habitats (Angulo et al., 2009).

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