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Identifying snake species threatened by economic exploitation and international trade in China

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Abstract. It is important to identify endangered species from thousands of species and take conservation measures in time. Many researchers have reported declines and overexploitation of snake species, but it is difficult to identify the species requiring emergency concern. We tried to identify the snake species threatened by economic exploitation in mainland China through the following procedure: First, we identified 16 snake species in significant international trade through analyzing trade records; second, we chose 10 variables representing biological characteristics and economics factors. The values of these variables for each species were evaluated from 0 (minimum risk) to 3 (high risk). Three snake species protected by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) were also assessed. We then got the priority rank of these species by calculating their average scores. We found that among the species in significant international trade, except those CITES-listed ones, four snake species were at extremely high risk, while all other snake species in significant trade were endangered or vulnerable. Principal component analysis (PCA) was used to classify the species into four groups according to their different biological and economic characteristics. This study provides a possible way to identify endangered species and to rank their conservation priority. The results of this paper can also be used as a priority sequence for taking conservation action, especially trade control measures.

Introduction

Like many endangered or threatened species in the world, many snake species in China face severe exploitation pressure (Zhao 1998; Gibbons et al. 2000; Webb et al. 2002; Zhou and Jiang 2004). About 800,000 to 1,000,000 heads of snakes are harvested in northeast China each year, and 10–15 years of hunting prohibition is necessary for the wild population to recover to pre-1985 levels (Liu 2001). The quantity of snakes consumed in the markets of Guangzhou, Guangdong Province of China was about 1.4×10^7 kg each year (He 1999). From 1990 to 1995, the annual demand for wild snakes from 13 factories producing traditional Chinese medicine (TCM) was 1,656.77 kg of *Zaocys dhumnades*, 234.75 kg of *Deinagkistrodon acutus*, and 20,300 heads and 32.1 kg of *Bungarus multicinctus* (Zheng and Zhang 2000). Liu et al. (2001) estimated that about 7.57×10^6 kg of snakes were exploited in nine provinces of China each year. Ten thousand kilograms of gall bladders of snakes are consumed by a TCM factory in Guangzhou (Guo 1996). In Anhui Province of China, the consumption of snake increased from 15,170 kg in 1997 to 91,592 kg in 2000 (Gu 2001). Wan and Fan (1998) estimated that the total volume of snakes traded in China was about 7×10^6 to 9×10^6 kg. Zhou and Jiang (in press) estimated that about 3–3.5 $\times 10^6$ heads of snakes were exported from China each year in early 1990s, and they observed that China has changed from a net export country to a net import country of snake trade during the past 10 years. There is no direct data concerning the relationship between international trade and domestic trade. But comparing the estimation given above by different researchers, the export quantity accounted for about half of the total domestic exploitation in early 1990s. As China shifted to a net import country of snakes in recent years, the wild population of snakes in China may be decreasing thus unable to satisfy the domestic demand. Large scale of exploitation reminded us that high concern should be given to conservation of snake species in China.

Legislation on snake conservation is not enough. Only a few snake species are protected by CITES (Convention on international trade in endangered species of wild fauna and flora). In 2003, because of the outbreak of SARS (Severe Acute Respiratory Syndrome), eating snakes had been prohibited in China. It is more strictly controlled to transport, deal and hunt snakes (Anon. 2003). The list of national key protected terrestrial wild animals is under review. But the hunting pressure on wild snake populations could not be removed overnight. Snakes can still be used as leather, medicine and other products, and in some places, people are reverting to their habit of eating snakes as the fear of SARS is fading.

While more and more species become endangered or extinct, scientists, conservationists and governmental authorities are usually required to identify species at risk and take active measures as early as possible (Pimm et al. 1995). However, such actions are often blocked by limited resources (e.g. money, time or personnel) to survey the wild population and market demand of species (Sutherland 2000). Sometimes, conservation measures are too late to save the species concerned. There are 209 species of snakes range in China (Zhao 2000). Now we have to face following questions: Which snake species should be considered for listing in CITES Appendices or national protection lists? Which snake species should be the priority of conservation plans?

Considering that overexploitation stands as one of the main threats to many species (Wilson 1992; Wilcove et al. 1998; Gibbons et al. 2000), is it possible to identify species in risk at early stages using available data about exploitation? Some researchers have taken steps to solve this problem (Warren 1997; Dhar et al. 2000; Filippi et al. 2000; Reed 2002).

Different species face different biological and economical pressure. The species with larger body size are generally more sensitive to overexploitation and changed environment (Luiselli and Capizzi 1997; Koenig et al. 2001; Reed and Shine 2002). Clutch size and mature age will affect the species' endurance to exploitation (Shine et al. 1995, 1996, 1999). Similarly, the species with narrow distribution are at higher risk than those with a broad distribution. Except for these biological characteristics, economic pressure is also different for every species. Snakes are purchased as food, pets, specimens, leather, medicine and ingredient of cosmetics. According to the trade data kept by the Endangered Species Import and Export Management Office of the P.R. China, the main demands of snakes are food, leather and medicine. People prefer to eat large snakes and venomous snakes (Liu 2001). Skins of snakes are used to make bags, wallets, shoes and watch straps. Species belonging to the genus *Elaphe* are more popular in the leather trade than other snake species. Many ancient Chinese medical books described the therapeutic effects of treating rheumatism, hemiplegia, neuralgia and muscle poliomyelitis with snakes or their parts, including gall bladder and liver (Gao 1996; Chen 1999).

Based on above information, here we identify the threatened snake species by analyzing the available international trade data and their biological and economic characteristics.

Methods

International trade data

In China, snake traders are required to apply for and obtain a permit from the CITES Management Authority (the Endangered Species Import and Export Management Office of the People's Republic of China) before any exportation or importation take place. The earliest records of permits can be traced back to 1981 when China became a party of CITES. But most data about snake trade appeared since 1990, when a new trade control notification had been issued by the Ministry of Forestry of China. The CITES Management Authority recorded the information for each import or export permit, such as scientific name, quantity, unit, description of the snake in trade and the import or export countries of the snakes. Since October 2000, the prices of international trade were also documented.

Several non-CITES species in significant trade were identified by analyzing the trade volume of the categories 'live snake' and 'snake skin'. We estimated that one snake weighed about 1 kg, one piece of skin came from one snake, and 1 kg of snake skin contained five pieces of snake skin. If the total trade volume (includes import and export, 'live snake' and 'snake skin') of one species between 1990 and 2001 surpassed 4000 heads, the species were chosen for further varies analysis. The total international trade volume of snakes species being chosen accounts for $>90\%$ of the whole international trade.

For this study, we pooled and analyzed the trade of snakes between mainland China and other foreign countries or regions, including Hong Kong, Macao and Taiwan, all of which had border control with Mainland China.

Evaluation of the biological and socio-economical factors

After identifying non-CITES species in significant international trade through the above procedure, the following variables including natural history, distribution and economics pressure were selected to evaluate their risk status. Each variable was classified into four categories ranging from 0 (minimum risk) to 3 (high risk). Factors concerning natural history, distribution or other biological themes were classified based on published average adult conditions in the wild (Zhao et al. 1998; Zhao 1998; Huang et al. 1998). We used the average international trade prices of 2001 and 2002 kept by the CITES Management Authority of China as International trade prices, while the prices of the snakes in domestic food markets were cited from Liu et al. (2001), who collected and calculated the average prices of snakes as food in 10 key cities of China. Medical value was based on published references concerning list and usage of TCM. If the price data for one species was absent, we estimated its price according to that of another species of similar adult body size, medical usage, venom, skin pattern and consumption trend; such data will be marked by an asterisk. The snakes preferred as foods by domestic markets and international markets are different; the snake trade in domestic and international markets were considered separately in the analyses. Since all species concerned were under similar legal protection – neither covered by CITES nor the domestic Wild Animal Protection Law – law enforcement effort was not considered. The time a snake spends in a farm is < 10 months, which means the commercial captive breeding of snakes is far from successful (Shi 2002). Thus, captive breeding was not considered either. The variables and their category criteria are as follows:

1. Body size (BS): Average total body length of adults: $0 \leq 800$ mm; $1 = 800$–1200 mm; $2 = 1200$–1500 mm; $3 \geq 1500$ mm (Zhao et al. 1998; Zhao 1998).
2. Distribution range breadth in China (DB): $0 =$ found in more than 130 counties or cities; $1 =$ found in 90–130 counties or cities; $2 =$ found in 50–90 counties or cities; $3 =$ found in less than 50 counties or cities, based on Zhao et al. (1998).
3. Average clutch size (CS): $0 \geq 20$; $1 = 14$–19; $2 = 8$–13; $3 \leq 8$, based on Zhao et al. (1998) and Zhao (1998).
4. Dietary breadth (DB): according to the number of classes of preys appearing in the diet of the species. $0 \geq 4$; $1 = 4$; $2 = 3$; $3 = 2$ or less,

based on the information from Zhao et al. (1998); Zhao (1998), Huang et al. (1996), Mo et al. (1999), Shi and Gu (2000), and Lao (2000). But if a species also eats other kinds of serpentes in addition to lizards like reptiles, we subtract 1 from the score.

5. Altitude range (difference between the highest and lowest distribution records, in meters above sea level) (AB): 0 ≤ 2000, 1 = 1000–2000; 2 = 500–1000; 3 ≤ 500, based on Zhao et al. (1998);
6. Adaptability to altered habitat (AH): 0 = extremely adaptable (found in urban center); 1 = adaptable (found in artificial or semi-artificial area); 2 = scarcely adaptable (found in semi-artificial or low disturbed area); 3 = unadaptable (found only in undisturbed area), were based on the information from Zhao et al. (1998); Zhao (1998) and Huang et al. (1996).
7. Price in domestic market (PD): average price (USD) of live snakes in the markets investigated by Liu et al. (2001). 0 ≤ 2.5; 1 = 2.5-7; 2 = 7–12; 3 ≥ 12.
8. Price in international market (PI): according to the average price (USD) per head of live (L) or dry (D) snake in international trade from 2001 to 2002. 0 = never appear in trade since 1990; 1 ≤ 2(L) or 3(D); 2 = 2 to 6(L), or 3 to 10(D); 3 ≥ 6(L) or 10(D).
9. Leather price in international market (LP): average price (USD) per piece of skin in international trade from 2001 to 2002. 0 = never appear in trade since 1990; 1 ≤ 0.5; 2 = 0.5 to 1; 3 ≥ 1USD.
10. Perceived medical value (MV): assessed according to published reference. 0 = never cited by any medical reference; 1 = only used by rural people to cure some malaise; 2 = documented as official medicine, used to cure three or fewer kinds of diseases; 3 = documented as official medicine, used to cure more than three kinds of diseases based on the information from Gao (1999), Chen (1999); Medicinal Material Corporation of China (1994); Jiangsu New Medicine College (1979).

Three CITES listed species (*Ptyas mucosus*, *Naja atra* and *Ophiophagus hannah*) distributed in China were also scored. Mean scores of the 10 variables were used to evaluate the risk of overexploitation. Score 0 and 1 indicated minimum or moderate risk, score 2 or 3 indicated high or extremely high risk; mean scores of the chosen species were calculated, to give a rank of conservation priority.

Evaluation of scores with the principal component analysis (PCA):

PCA was applied to classify the various snake species in terms of their relative similarity to particular threats, after standard VARIMAX rotation of the data with SPSS for Windows.

Results

We found 17 non-CITES species in significant trade (including import and export). The variable values for 16 species were evaluated except *Homalopsis buccata* (Table 1). *H. buccata* appeared in importation but its data was deficient. These species could be ranked in order according to their mean scores from high to low: Mean score ≥ 2.0: *Elaphe moellendorffi*, *Deinagkistrodon acutus, O. hannah*; 1.7 ≤ mean score < 2.0: *El. taeniura*, *P. mucosus*, *B. fasciatus*, *N. atra*; 1.5 ≤ mean score < 1.7: *Enhydris chinensis*, *Macropisthodon rudis*, *Gloydius brevicaudus*, *El. radiata*, *P. korros*, *Z. dhumnades*, *Sinonatrix annularis*, *B. multicinctus*; 1.0 ≤ mean score < 1.5: *En. plumbea*, *El. carinata*, *Dinodon rufozonatum*, *Trimeresurus mucrosquamatus*.

All three CITES species had high mean scores, while the mean score of *O. hannah* was the highest. *Elaphe moellendorffi*, *El. taeniura*, *B. fasciatus* and *D. acutus* had scores higher than 1.7. Except for four species (*El. carinata*, *En. plumbea*, *Dinodon rufozonatum*, *Trimeresurus mucrosquamatus*), all other species assessed had scores higher than 1.5, which meant they were vulnerable species or endangered species.

According to the rotated component matrix from PCA (Table 2), component 1 was mainly associated with socio-economical factors, such as food price, perceived medical value, whereas component 2 was mainly related to natural factors, such as adaptability to altered habitat, clutch size and breadth of distribution range. The species fell into four separated groups (Figure 1). The main threat to the Group 1 (*El. taeniura*, *El. carinata*, *Z. dhumnades*, *D. rufozonatum*, *B. multicinctus*, *T. mucrosquamatus*, *G. brevicaudus*, *P. mucosus*, *N. atra*) was commercial exploitation. These species may have relatively broad distribution, diverse diets, medium or low reproductive rates and are adaptable to altered habitats. Group 2 (*El. moellendorffi*, *B. fasciatus*, *D. acutus*, *O. hannah*) was facing both serious socio-economical pressure and natural pressure (narrow distribution or low reproductive rate), all at high risk. Group 3 (*El. radiata*, *P. korros*, *En. chinensis*, *En. plumbea*, *S. annularis*) was facing median socio-economic pressure and median natural pressure. If we try to divide the species into five groups, then *El. radiata* and *P. korros* will fall into a separate group, different with the other three species. Group 4 (*M. rudis*), the members of the group had small body size, high reproductive rate but a narrow distribution range and was facing median socio-economical pressure.

Discussion

Some species were mainly threatened by habitat degradation or narrow distribution, some by low reproductive rate, while others were threatened by overexploitation. If a snake species has all above characteristics, it is at extremely high risk (Table 1 and Figure 1). Considering both the biological and economic variables, we could evaluate the threat one species is facing more

Table 1. Score of variables[a] assessed for the snake species in significant trade.

Species	Chinese red list grade[b]	BS	DB	CS	FB	AB	AH	PD	PI	LP	MV	Average
Elaphe taeniura	Vulnerable	3	0	3	2	0	1	3	2	3	2	1.9
El. carinata	Vulnerable	3	0	2	0	0	1	3	2	1	1	1.3
El. moellendorffi	Endangered	3	3	2	1	3	2	3	2	2	3	2.4
El. radiata	Endangered	1	3	2	1	1	1	2	2	1	1	1.5
Ptyas korros	Endangered	1	2	2	1	1	1	2	2	1	2	1.5
Zaocys dhumnades	Least concern	2	0	1	1	1	1	3	2	*1	3	1.5
Enhydris chinensis	Least concern	0	2	2	3	3	1	1	2	1	1	1.6
En. plumbea	Least concern	0	2	2	3	2	1	2	1	0	1	1.4
Sinonatrix annularis		0	2	2	3	2	1	2	2	1	0	1.5
Dinodon rufozonatum		1	0	2	0	1	1	2	2	1	2	1.2
Bungarus fasciatus	Endangered	1	3	2	0	2	2	3	2	1	2	1.8
B. multicinctus	Vulnerable	1	1	3	0	1	1	3	1	1	3	1. 5
Trimeresurus mucrosquamatus		1	0	2	0	0	1	3	2	*1	2	1.2
Macropisthodon rudis		1	3	0	2	2	3	2	2	*1	0	1.6
Gloydius brevicaudus	Vulnerable	0	0	3	1	1	1	3	3	1	3	1.6
Deinagkistrodon acutus	Endangered	2	2	2	1	1	2	3	3	1	3	2
Ophiophagus hannah	Critically endangered	3	3	0	1	1	2	3	*3	*1	3	2
P. mucosus	Endangered	3	2	2	1	0	1	3	3	2	2	1.9
Naja atra	Vulnerable	2	1	2	0	1	1	3	3	1	3	1.7
Average		1.474	1.526	1.895	1.105	1.211	1.316	2.579	2.158	1.158	1.947	1.637

[a]BS, Body size; DB, Distribution breadth in China; CS, Average clutch size; FB, Dietary breadth; AB, Distribution altitude breadth; AH, Adaptable to altered habitat; PD, Food price in domestic market; PI, Food price in international market; LP, Leather price in international market; MV, Perceived medical value. Data estimated by the authors are marked with asterisks.

[b]Chinese red list grade: assessed by Chinese scientists in 2000 (Zhao 2000), different from the IUCN criteria.

[c]The price data marked by '*' is estimated by the author according to that of another species with similar adult body size, medical usage, venom, skin pattern and consumption trend.

Table 2. Rotated component matrix of variables*.

Variable	Component 1	Component 2
PD	0.877	−0.116
BS	0.825	0.193
MV	0.711	−0.152
FB	−0.674	0.225
AB	−0.595	0.509
PI	0.583	0.251
LP	0.518	−5.752E−02
AH	0.122	0.883
DB	−0.240	0.813
CS	−9.106E−03	−0.790

The Eigenvalue of Component 1 is 3.639, that of Component 2 is 2.319; 36.386% of the variation explained by Component 1, and 23.195% of the variation explained by Component 2.
*Extraction method – principal component analysis; Rotation Method – Varimax with Kaiser Normalization. Rotation converged in three iterations.

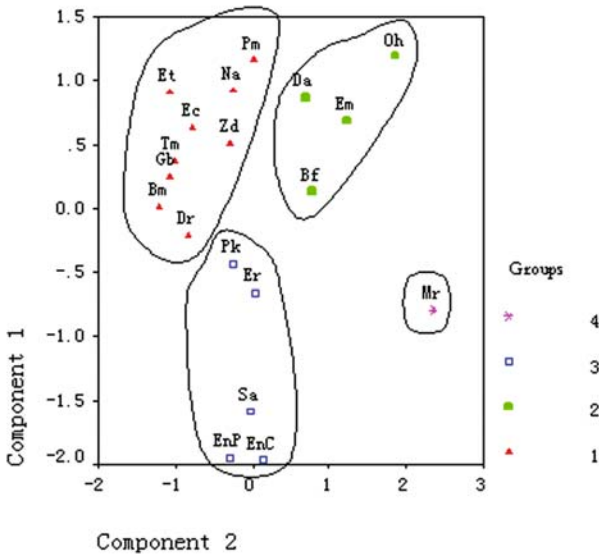

Figure 1. Grouping status of 19 snake species. This is a two-dimensional plot of scores for individual species on components 1 and 2 using a VARIMAX rotation model PCA, showing four separated groups of species. Component 1 mainly related to PD (Food price in domestic market), BS (Body size, which often related to price as food), MV (Perceived medical value), it is a synthesized factor mainly reflects the socio-economical characteristic of one species, while Component 2 mainly related to AH (Adaptable to altered habitat), DB (Distribution area), and CS (Average clutch size), it is a synthesized factor mainly related to the biological characteristics. Abbreviations of scientific names: Et: *Elaphe taeniura*, Ec: *El. carinata*, Em: *El. moellendorffi*, Er: *El. radiata*, Pk: *Ptyas korro*, Zd: *Zaocys dhumnades*, EnC: *Enhydris chinensis*, EnP: *En. plumbea*, Sa: *Sinonatrix annularis*, Dr: *Dinodon rufozonatum*, Bf: *Bungarus fasciatus*, Bm: *B. multicinctus*, Tm: *Trimeresurus mucrosquamatus*, Mr: *Macropisthodon rudis*, Gb: *Gloydius brevicaudus*, Da: *Deinagkistrodon acutus*, Oh: *Ophiophagus hannah*, Pm: *P. mucosus*, Na: *Naja atra*.

accurately than by only considering biological information. For example, some species in Group 1 got a high score, although they have broad distribution and are adaptable to altered habitat, because they still face threats from economic exploitation.

The method of score calculation although artificial, but still gives comparable results to evaluate the relative risk of different species. For example, the three CITES species have very high mean scores, while the mean score of *O. hannah* is the highest. *El. moellendorff* and *B. fasciatus*, which have narrow distribution and large scale exploitation, are more endangered than others. The results also matched with snake species listed in the China Red Data Book for Amphibians and Reptiles (Table 1, [Zhao 1998]), but we also found some species more threatened. The most significant explanation is that we considered not only the biological characteristics, but also the pressure of economic exploitation.

Price reflects the comprehensive effects of supply and demand. In other words, it represents the available snake catch and economic pressure. A high price will motivate hunters to exploit that species, and any decrease in the wild population of the species will further drive the price higher. Thus, price was a good index of the species risk, which reflects the combined effect of supply and demand. To monitor the market prices of wildlife and their products will help us to know the decline of a species as early as possible. However, a species trading at a high price may already be endangered or in low population density, or due to difficulty in capture and handling, or the high demand in the market.

Some parameters (e.g., survivorship of juveniles, mature age, or population density) are important for species risk assessment, but data is not available for many species since they haven't been studied yet. Such a deficiency might affect the results. For example, high mortality of juveniles will counteract the large clutch size, thus the risk of species will be underestimated. Broad distribution will also be counteracted by low population density. This problem was alleviated because we collected the information of 10 variables instead of four or five. Assessing more variables will further improve the results. To further evaluate the status of snake species, more biological research and market surveys are necessary.

Reed (2002) analyzed the status of *Elaphid* snakes in Australia mainly based on their biological characteristics. Filippi et al. (2000) evaluated the threats of 19 Italian snake species by scoring ten independent variables related to natural-history, ecological traits, adaptation and non-natural factors. But they only considered one non-natural factor – the illegal trade. This factor is difficult to evaluate since we have limited information about illegal trade and some species may have legal but unsustainable trade. The three economic variables we chose could represent the main threats to snakes. We combined the trade data, analyzing with both biological and economical factors assessment. There are eight families and 209 species of snakes in China and 52 of them are endemic, and only a few species which appeared in trade have been ever studied in detail

(Huang et al.1998; Zhao et al. 1998; Zhao 1998, 2000). Therefore, our results could be used to identify and filter species of conservation priority, especially those in significant trade and that could benefit by trade control measures. Considering that some species were similar in appearance with others in significant trade, we should also protect those species (Keogh et al. 2001).

According to our results, the non-CITES species with highest scores in this study should be the priorities for CITES listing proposals, and others should be listed as the national key protected wild animals in China. The result of this paper can also be used as a priority sequence for taking conservation activities, especially trade control measures.

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