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OF WILD FAUNA AND FLORA

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AN ASSESSMENT OF THE COMMERCIAL PRODUCTION OF CITES-LISTED SNAKE SPECIES IN VIET NAM AND CHINA

The attached information document has been submitted by the Secretariat at the request of the International Union for Conservation of Nature (IUCN) in relation to agenda item 14.1.*

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An assessment of the commercial production of CITES-listed snake species in Viet Nam and China

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PREFACE

This assessment of the commercial production of CITES-listed snake species in Viet Nam and China is the result of a directive given to the CITES Secretariat to undertake a study of production systems for Asian snakes listed in CITES Appendix II and the use of source codes; and to develop guidance to assist Parties in monitoring and controlling captive-breeding operations and other production systems, including information to assess their biological feasibility and, where possible, economic viability (i.e. whether it is financially viable for commercial facilities to produce and export specimens as permitted by national authorities) (Decision 16.102a[i]). This initiative comes following a period of concern expressed by conservationists and management authorities regarding the volume, nature and impact of the trade in Asian snake species, and a fundamental lack of the baseline information required to manage the trade in a non-detrimental manner.

Since the drafting of Decision 16.102 in 2011/2012, a number of studies have emerged that address some of the primary directives. These include (a) a draft inspection manual for reptile captive breeding facilities in Southeast Asia (TRAFFIC 2013), (b) a report on python farming in Southeast Asia by IUCN (Natusch and Lyons 2014), (c) a report on differentiating between wild and captive bred snakes (Decision 16.102a[iv]) and (d) draft guidance on the use of CITES source codes for production systems (Decision 15.52 – implementation of the Convention related to Captive Bred and Ranched specimens). Despite these reports being available, they have yet to be formally considered by the CITES Animals Committee and pertinent Working Groups. However, the reports do cover key aspects relating to guidance, production systems and source codes pertaining to Decision 16.102a(i), and as such there was considerable risk of duplication of effort during the structuring and planning for this study. In September 2014, following deliberation with CITES authorities over specific terms of reference, it was decided to focus this study towards improving baseline knowledge of production systems for all species, since this remained one of the few outstanding prerequisites for informed decision-making regarding the snake trade. As a result of the above, the specific objectives of this report are stated as follows:

a) identify the most viable aspects of, and most important knowledge gaps within, current farm management systems with particular reference to species and geographic range (i.e. identify species, compare feed inputs, growth rates, fertility rates, survival rates and profitability across regions/ecosystems)

b) define optimal biological and economic farming inputs and outputs for individual species (i.e. pooling the best available farm practices from across Asia with the latest science based knowhow to improve capacity, transparency, sustainability and compliance with CITES).

Initially the study planned to carry out fieldwork in Cambodia, Thailand, Indonesia, Viet Nam and China, but due to time and resource limitations, fieldwork was eventually restricted to two of the important producers - Viet Nam and China.

This report is intended to provide an overview of the management of production systems for all CITES-listed snake species in Viet Nam and China. However, given that the production of some CITES-listed species (i.e. pythons) has been relatively well documented compared to others, the report focuses primarily on the less well studied colubrid and elapid snakes, which are farmed mainly for their meat, and refers the reader to the following publication for comparative information on pythons: Natusch, D.J.D. and Lyons, J.A. (2014). Assessment of python breeding farms supplying the international high-end leather industry. A report under the 'Python Conservation Partnership' programme of research. Occasional Paper of the IUCN Species Survival Commission No. 50. Gland, Switzerland: IUCN. 56pp.

ABBREVIATIONS, ACRONYMS AND DEFINITIONS

CCMA	China CITES Management Authority
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DOC	Day Old Chicken. Sold as a by-product of the poultry industry.
DOD	Day Old Ducks. Sold as a by-product of the poultry industry
FAO	Food and Agricultural Organisation of the United Nations
FPD	Forest Protection Department (Viet Nam)
IUCN	International Union for Conservation of Nature
CITES MA	CITES Management Authority
MARD	Ministry of Agriculture and Rural Development (Viet Nam)
PFPD	Provincial Forest Protection Department (Viet Nam)
SA	Scientific Authority
SFA	State Forestry Commission (China)
SSC	IUCN Species Survival Commission
USD	United States Dollar
VND	Vietnamese Dong

Breeding stock: The ensemble of the animals used for reproduction in a captive-breeding operation. Under CITES the breeding stock must be established in a manner that is not detrimental to the survival of the species in the wild and in accordance with the provisions of CITES and relevant national laws
Captive breeding: Legally acquired parent stock exchange gametes (egg and sperm) in a controlled environment, without reliance on wild populations. The parents must also be maintained without the introduction of specimens from the wild and must have produced offspring of at least second generation (F2) in a controlled environment or be managed in a manner that has been demonstrated to be capable of doing so
Closed-cycle farm: The production of snakes within a controlled environment independent from introduction of specimens from the wild
Colubrid: Family of snakes to which rat snakes belong
Elapids: Family of snakes to which cobras and king cobras belong
Farming: The process of raising animals within a controlled environment. In this report "farming" is synonymous with "captive breeding" and "captive production"
Growers or growing stock: See raising stock
Hatchling: A newly or recently hatched snake
Raising stock: Animals that are raised specifically for slaughter
Ranching: Rearing in a controlled environment of animals taken as eggs or juveniles from the wild. In this report it is sometimes used synonymously with "wild harvests"
Satellite farm: A small, usually family run farm contracted to raise stock on behalf of a larger farm
Wild harvest: Sustainable exploitation of wild populations of animals
For CITES definitions see the CITES Glossary: http://www.cites.org/eng/resources/terms/glossary.php

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EXECUTIVE SUMMARY

The international trade in threatened snake species is uniquely and increasingly linked to closed-cycle production systems, which are facilities where snakes are bred in a controlled environment without introduction of animals from the wild. Within the last 10 years snake farms have come to define and dictate the most important characteristics of the snake trade. A comprehensive understanding of past, present and future closed-cycle production systems is paramount for informed decision-making regarding the control and regulation of the international snake trade.

Information within this report was obtained through consultation with CITES Management Authorities, farming associations, snake farmers and relevant government authorities. The principal data were derived from 39 interviews with snake farmers in Viet Nam and China.

Six species are relevant to this report because they are a) listed in CITES Appendix II and b) farmed extensively for their skin, meat and/or medicinal value in Viet Nam and China. These include reticulated python (*Python reticulatus*), Burmese python (*Python bivittatus*), Oriental rat snake (*Ptyas mucosus*), Chinese cobra (*Naja atra*), monocled cobra (*Naja kaouthia*) and king cobra (*Ophiophagus hannah*).This report refers to a recent report on python farming for more detailed information regarding the production of pythons[1], and focuses instead on the remaining three species.

The commercial farming of CITES-listed snake species in Viet Nam and China is currently focused on the production of two species of python for their skins, three species of elapids for their meat and traditional medicine value, and one species of colubrid for its meat. This report focuses on species farmed for meat and medicinal value.

This report provides information on how each of the species are farmed in terms of basic biology, husbandry and economic parameters. Also discussed are the wider implications of snake farming, with particular emphasis on feasibility, sustainability and conservation. Recommendations are offered with the aim of providing guidance to stakeholders and improving management standards for snake farming.

Snakes are farmed extensively throughout Viet Nam and southern China. Excluding pythons, the industry in Viet Nam consists primarily of a large number of small-scale farms holding a combined national stock of less than one million individual snakes. Snake farming in China has grown exponentially in the last ten years and comprises small scale farms as well as larger, industrial scale farms producing many thousands of individuals per annum. Vietnamese snake farmers rely heavily on live snake sales to China, but these figures are not reflected in the CITES trade database.

Methods employed to farm snakes are highly variable and appear to be evolving as the industry develops. Caging systems can be broadly grouped into individual (one snake per cage) and communal (up to several hundred snakes per cage). Individual cages allow more precise management at the level of the individual, but communal systems are the preferred choice for increasing carrying capacity and profitability. Food consists of a variety of wild harvested small vertebrates and/or waste protein from food production chains. Breeding systems are relatively uniform and similarly successful for all species. The development of a number of specialised management techniques (e.g. supplementary heating, hibernation and selective breeding) have catalysed the success of closed-cycle snake farming.

The biology and economics of the most commonly farmed snake species (i.e. those outlined in this report) are broadly similar, especially within the meat production context. All are large terrestrial snakes with a wide distribution across Asia. They are tolerant of disturbed agricultural landscapes, although king cobras are less common than the other five species. In captivity growth rates are relatively rapid and individuals take less than two years to reach market size. Maturity is reached within three years and thereafter fecundity is generally high (>20 eggs per annum) for a period of

[1] Natusch, D.J.D. and Lyons, J.A. (2014). Assessment of python breeding farms supplying the international high-end leather industry. A report under the 'Python Conservation Partnership' programme of research. Occasional Paper of the IUCN Species Survival Commission No. 50. Gland, Switzerland: IUCN. 56pp.

about four years. Rat snakes and cobras reach an optimal market weight at approximately 1.5kg, at which point they are sold for their meat for approximately US$27/kg. King cobras are sold for their meat and traditional medicinal value for US$81/kg. King cobras and cobras are highly venomous and are considered the more difficult species to farm.

Biologically snakes are relatively well suited to farming, and display a number of desirable qualities. These include classic traits such as rapid growth rates, but also involve specialised adaptations such as energy efficient physiologies. As a result they have the potential to become a cheap and environmentally friendly source of high quality protein.

Snake farming is a commercially viable enterprise in all its current forms but appears to be in a state of flux. Large-scale intensive farms hold considerably more stock (~30000 adults) and are better placed to adopt new and improved management systems which reduce costs and increase profits. Profits here can exceed US$1 million per annum per farm. Small scale farms are generally less adaptable, hold considerably less stock (~500 adults), but are still profitable (~US$10000 per annum per farm).

Snake farming has good ecological credentials. Feed sources are derived largely through sustainable harvests of a variety of locally abundant species, or from waste protein from existing food production chains (e.g. culled chickens). The ectothermic physiology of snakes infers other advantages for snake farmers, such as resilience to management perturbations, and resistance to clinically important disease outbreaks. The environmental and economic volatility forecast by climate change may actually benefit snake farmers, especially when compared to the potential impacts faced by other sectors of the food production industry.

Evidence suggests snake farming and snake conservation issues are increasingly disconnected, and the industry now preferentially operates independently from wild sourced stock. Snake farming reduces the pressure on wild snakes, but in so doing may also be missing out on an opportunity to contribute towards snake conservation through sustainable utilisation programs.

Summary of key findings relating to CITES

1) Captive breeding and closed-cycle production systems are a significant and increasingly important source of CITES-listed snake species involved in the Asian snake trade.
2) The significance of closed-cycle production systems with regards to CITES is pivotal, and likely to grow exponentially in the coming years due to growing trade volumes of snakes, diversification of products and the expansion of trade networks. Rapid improvements in production technology are increasing the number of snake species farmed, and thereby affected by trade.
3) The current regulation and control of the Asian snake trade is inadequate. A lack of transparency and suboptimal trade management systems are inadvertently leading to clandestine and illegal imports and exports.
4) The exploitation of wild populations in Viet Nam and China plays a comparatively insignificant role in the international snake trade, legal or otherwise, but wild harvests are still prevalent on a local scale to supply domestic demand.
5) In its current form closed-cycle snake production is a viable industry that generates net socioeconomic and environmental benefits. However, considerable improvements in overall capacity are required to achieve the optimal cost/benefit model, which has potential to deliver profound benefits for rural development, biodiversity conservation and food security.

Recommendations and future research

1) ***Regulation and trade control:*** *A concerted effort to ensure the effective implementation of existing regulation and control measures is required, and where possible these should be improved to ensure transparency and legitimacy of the regional snake trade and industry as a whole.*

2) *An improved and more consistent understanding of **basic snake biology** and how this interfaces with current captive production systems would improve management in the immediate term.*
3) ***Improved feed management** through research into a) artificial feeds and b) automated food delivery systems, would reduce costs and improve industry 'green' credentials.*
4) ***Caging systems** do not fully exploit the unique biology of reptiles. Multidisciplinary research into synergies between snake biology and agricultural engineering should focus on a) carrying capacity trade-offs with vertical farming systems and b) solar driven production systems based on greenhouse technology (sustainable intensification)*
5) *Opportunities exist to integrate snake farming with snake conservation through **ranching programs**. Where and under what circumstances this can be applied has yet to be ascertained.*
6) ***Education through snake schools**: The technical skills required to farm snakes are often difficult for snake farmers to collate and interpret. Enabling existing snake farming schools in China to reach a wider audience would improve management standards.*
7) ***Tourism:** The development of snake farms as tourist attractions would help to educate the general public and bring additional benefits to those farms situated close to large cities or existing tourist destinations.*
8) ***Small scale traditional vs modern intensive**: Small-scale traditional snake farms are a valuable but economically vulnerable production model. Ensuring their intrinsic value is taken into consideration during the development of the formal snake farming industry would safeguard against the inevitable loss of less tangible benefits, such as snake farmers promoting amphibian persistence in rice fields as source of snake food.*

1. INTRODUCTION

1.1. Background

The rise of Asia's economies has been linked to the global overexploitation of wildlife, and finding solutions to the uncontrolled trade in threatened species is regarded as an important conservation objective (Nijman 2010). In the last two decades there has been an increase in the market demand for reptiles, and the trade in snakes was at one point considered one of the largest under-regulated components of the international wildlife trade (Zhou and Jiang 2004, CITES 2010).

Snakes and snake products are sought after for diverse reasons, including meat, skin, pets, cosmetics and medicines. In Asia snakes are valued primarily for their meat, which is considered both a culinary delicacy and a health tonic. They are also coveted for their skin, which is used in the making of fashion accessories and musical instruments (Zhou and Jiang 2005, Somaweera and Somaweera 2010), and as an important ingredient in Chinese Traditional Medicine (Pipeng, Weisheng et al. 2013). The trade in snakes was traditionally small and restricted to localised wild harvests, but the rise of a wealthy urban middle-class has reshaped these norms (Zhou and Jiang 2004, VAN Cao 2014). Demand from Asia's emerging cities coupled with dwindling wild stocks is fuelling the growth of a large and well organised commercial snake farming industry (Haitao, Parham et al. 2008, Pipeng, Weisheng et al. 2013).

As recently as 20 years ago the trade in reptiles was supplied largely by a combination of wild harvests and *ad hoc* ranching activities which depended on wild caught parent stock. Closed-cycle snake farming, which doesn't involve sourcing animals from the wild, is a relatively new phenomenon, made possible thanks to a number of recent breakthroughs in captive reproduction and feeding techniques. Because snake farming is relatively new, comparatively little is known about snake production systems, and conservation authorities have expressed concern over their biological and economic viability (Lyons and Natusch 2011). The lack of baseline life history information coupled with the paucity of comparative production models for snakes in other parts of the world have fuelled these concerns (Natusch and Lyons 2014). Conservation authorities worry that over-exploitation could be exacerbated by commercial production, because regulation of the industry is in its infancy, and production facilities could act as laundering operations for illegal wild harvests (Lyons and Natusch 2011, Pipeng, Weisheng et al. 2013).

For crocodilians – a now well-studied reptile taxa that faced similar conservation challenges towards the end of the last century - the controlled environment of captive production facilities resulted in a higher quality skin product compared to wild caught equivalents (Thorbjarnarson 1999). Cheaper and better quality captive bred skins undermined the economic incentives for over-exploitation of wild populations, while creating a novel livelihood opportunity for rural communities (MacGregor 2006). In some instances, crocodile farming has been integrated with sustainable utilisation programs (i.e. ranching), thereby creating a tool for rural development and a highly successful market based conservation model (Hutton and Webb 2003, MacGregor 2006, Micucci and Waller 2007).

Reptile farming is recognised as a viable enterprise for small-scale farmers in rural, periurban and urban areas (Wilson 2011). Reptile farming can increase food security, generate a steady cash flow, play an important role in poverty alleviation, contribute to the empowerment of women and children and give value to local resources not normally suitable for direct consumption by people (Wilson 2011). It can also provide a viable livelihood in areas where conditions are unsuitable for conventional livestock (Revol 1995, Eilers, Koops et al. 2001).

Farmers in China and Viet Nam have been engaged with novel wildlife production systems for decades. Reptiles are one of the more common wildlife taxa currently being farmed on a commercial scale, and the industry now includes at least 24 species from 18 genera and three orders. Included in this list are a number of CITES Appendix II listed snake species including reticulated python (*Python reticulatus*), Burmese python (*Python bivittatus*), Oriental rat snake (*Ptyas mucosus*), Chinese cobra (*Naja atra*), monocled cobra (*Naja kaouthia*) and king cobra (*Ophiophagus hannah*).

The six species above covered in this study are all listed in CITES Appendix II because of their prevalence within the international snake trade. Parties to CITES must ensure that any trade that occurs in these species must not be detrimental to wild populations (under Article IV of the CITES Convention) and is carried out in a controlled way through a system of permits and certificates to ensure that it is legal, traceable and sustainable. Party countries have designated CITES Management Authorities who are responsible for overseeing and issuing relevant permissions. Scientific Authorities determine a non-detriment finding for the species before it is exported. This report concerns closed-cycle captive breeding production systems (CITES source code "C") of snakes in both China and Viet Nam.

The particular biology of snakes and the characteristics of the associated snake farming industry mean that a comprehensive understanding of closed-cycle production systems is a cornerstone for the effective regulation and control of the international snake trade. The aim of this report is to examine the closed-cycle production systems currently employed for the captive breeding and rearing of CITES Appendix II-listed snake species in China and Viet Nam. The report summarises the biological and economic inputs and outputs of commercial snake farms and provides information on the environmental and commercial consequences of snake farming. Recommendations are provided for the improvement of production systems and future management of CITES-listed snakes entering trade.

1.2. Methodology - Farm surveys and data

A total of 39 farm surveys were carried out between 16/09/2014 and 16/1/2015. Thirty surveys were carried out in the Vietnamese provinces of Ca Mau, Ho Chi Minh City, Tay Ninh, Vinh Phuc and Phu Tho and nine surveys were carried out in the Chinese province of Guangxi. The selection of survey sites was based on the most important snake farming regions according to local expert opinion. In Viet Nam a broad spectrum of farms were randomly selected based on farmer availability at the time of the interview, whilst in China farm selection was mostly (but not always) skewed towards the larger and more technologically advanced farms, due to time constraints. The study assumes a representative sample of farms, but it is important to be cognisant of the paucity of smaller (and possibly unlicensed) farms in the data, particularly in the China set.

The survey team usually consisted of the principle investigator, one or more forestry officials, a CITES representative, a biologist/herpetologist from a relevant in-country institution and an interpreter. The survey process typically began with a tour of the farm followed by 45 minute structured interview (ethics clearance certificate: H14/11/46). Interviews were followed by a general discussion designed to explore the farm production model. This was often essential as the diversity of production systems rendered some of the structured questions redundant unless the broader context was understood. Interviews were designed to give an overview of the biological and economic parameters that define farm inputs and outputs.

Information on individual species was based on four King cobra entries[2], 25 cobra entries and 30 oriental rat snake entries. Data were also fortuitously collected on a number of other species including Burmese pythons, king rat snakes (*Elaphe carinata*), Chinese rat snakes (*Ptyas korros*), radiated rat snakes (*Coelognathus radiata*), masked water snake (*Homalopsis buccata*) and Bocourts water snake (*Enhydris bocourti*).

[2] An entry is a farmer's account of the production of a particular species.

2. SNAKE FARMING BY COUNTRY

2.1. Viet Nam

Viet Nam is considered one of the largest and most important producers of captive-bred snakes in Asia. Snake farming occurs throughout the country and involves a number of different species. Python farming occurs mainly in the south due to the tropical maritime climate. In the north of the country, where winter temperatures can drop to near freezing, there is a preference for more cold tolerant species such as elapids and colubrids. Farms producing aquatic species (e.g. *Enhydris bocourti*) are prevalent in the Mekong Delta.

The captive production of pythons in Viet Nam has been ongoing since the early 1980s and now represents a well-established and well-regulated industry (Natusch and Lyons 2014). Viet Nam is the world's largest producer of captive-bred pythons exporting over 150,000 skins in 2013 (CITES Trade Database, 2014). The situation with regards to the remainder of the snake species is less well known. At least four other CITES-listed species are farmed in large numbers on government registered farms (table 1). The industry is heavily dependent on export markets (87% of farmers rely on Chinese markets) but CITES trade statistics do not accurately reflect this. For example, in 2012, Viet Nam exported 456,000 oriental rat snakes and ~150,000 cobras, all of which are recorded as having originated from ranching operations in neighbouring Laos, rather than from within Viet Nam. Similar irregularities are evident for other species. In fact, records of Vietnamese exports of farmed elapids and colubrids are conspicuously rare in the CITES trade database. This study suggests that the numbers of farmed animals exported from Viet Nam are an order of magnitude greater than CITES trade figures suggest (table 2). The informal but well organised trade in wildlife between Viet Nam and China has a long history which could well explain some of these discrepancies (see Yiming and Dianmo 1998).

Wild populations of all farmed CITES species are listed as either Critically Endangered or Endangered in the Vietnamese Red Data Book due to habitat degradation, hunting and illegal trade (table 1). Recent evidence suggests however that populations of reticulated and Burmese pythons in U Minh Ha National Park in Viet Nam are healthy and stable (various pers. comm.)

Table 1. *Registered species, number of farms and total number of individuals held by farms in 2014 (source: CITES Management Authority, Viet Nam) Also included are conservation status (national and international) and CITES listing for each species. IUCN = IUCN Red List, VNRD= Viet Nam Red Data Book, CITES= CITES Appendix, CE=Critically Endangered, E=Endangered, V=Vulnerable, LC=Least Concern, NA=Not Assessed, NL=Not Listed*

Common name	Scientific name	Individuals	Farms	IUCN	VNRD	CITES
Chinese, monocled cobra	*Naja atra & N. kaouthia*	406,987	1,461	V	E	II
King cobra	*Ophiophagus hannah*	7,432	11	V	CE	II
Oriental rat snake	*Ptyas mucosus*	210,685	1,141	NA	E	II
Radiated rat snake	*Elaphe radiate*	16,784	52	NA	V	NL
Burmese python	*Python bivittatus*	47,623	500	V	CE	II
Reticulated python	*Python reticulatus*	3,418	29	NA	CE	II
Rainbow water snake	*Enhydris enhydris*	4,580	6	LC	NL	NL
Common mock viper	*Psammodynastes pulverulentus*	100	1	NA	NL	NL
Speckled bellied keelback	*Rhabdophis chrysagus*	2,900	1	LC	NL	NL
Maclellands coral snake	*Calliophis macclellandi*	12	1	NA	NL	NL
Yellow spotted keelback	*Xenochrophis flavipunctatus*	320	2	LC	NL	NL
Chinese rat snake	*Ptyas korros*	76,247	109	NA	E	NL
Puff faced water snake	*Homalopis buccata*	17,852	30	LC	NL	NL
Bocourts water snake	*Enhydris bocourti*	79,544	174	LC	NL	NL

Table 2. *Simple analysis based on biological, economic and trade data collected during this study used to estimate theoretical export quotas for three species of CITES Appendix II listed snakes in Viet Nam. An assumed 40% of recruitment is lost due to mortalities or local sales in Viet Nam.*

Species	adult females/farm	eggs/year	recruitment minus 40%	no. registered farms	theoretical export quota
Naja spp.	254	23	2,340	1461	**3,418,232**
O. hannah	146	27	1,579	11	**17,369**
P. mucosus	331	37	4,895	1,141	**5,585,309**

2.2. Peoples Republic of China

The trade in snakes and snake products has a long and well documented history in China. At least 20 different species have been variously exploited for food, traditional medicine and musical instruments for up to 2,000 years (Pipeng, Weisheng et al. 2013). By the end of the 1990s, an estimated 9 million kilograms of snakes were traded on an annual basis, and the majority of these animals were of wild origin (Pipeng, Weisheng et al. 2013). By 2000, local demand had outstripped supply, and by 2004 an estimated 1.5 million snakes were imported into China. During this time, minimal distinction was made between wild or captive origin; wild harvested snakes entered the markets relatively freely, and conservationists became concerned about the impact the trade was having on wild populations (Zhou and Jiang 2004).

In 2003, the National Wildlife Management Authority (NWMA) in China introduced a range of measures to suppress the trade in snakes, including a ban on all imports and legislative controls placed on food businesses. The 2002 to 2004 SARS (Severe Acute Respirator Syndrome) outbreak resulted in further reductions in the number of people eating wild animals. These factors led to a drastic decline in the snake meat industry in China (Jiang, Zhou et al. 2013).

In 2006, due to increasing demand for snake products and the introduction of a government policy supporting the sustainable utilisation of wildlife, the State Forestry Association (SFA) introduced a ten year pilot program to actively promote snake farming (Pipeng pers. comm.). Starting with the licencing of four farms in Guangdong, Guangxi and Hainan provinces, the program focuses on promoting scientific research as a way of improving production techniques, ending uncontrolled wild harvests, developing legislature and regulatory frameworks for both farms and snake products and introducing monitoring and conservation programs, including the reintroduction of captive bred stock into the wild (Jiang, Zhou et al. 2013). The program is widely regarded as a success and is expected to be met with favourable reviews when it comes to an end in mid-2015. There have been fundamental improvements to closed cycle farming techniques since the start of the program, several restocking programs have taken place, illegal wild harvests have been drastically reduced and all CITES-listed species are now formally protected by a combination of national and provincial laws (e.g. List of Wild Animals under National Key Protection and the List of National Protected Terrestrial Wild Animals with Important Ecological, Economic and Scientific Values)(Pipeng, Weisheng et al. 2013). According to Jiang et al. (2013), a combination of domestic and CITES controls is effectively controlling the international snake trade in China (Jiang, Zhou et al. 2013). In Guangxi province alone there are over 280 registered closed cycle snake farms holding an estimated 5 million individual snakes, most of which are listed in CITES Appendix II (Guangxi Forestry Administration, unpublished data and pers. comm.).

Lingshan County in Guangxi province is regarded as the home of snake farming in China. Here the county government regards snake farming as one of the most important rural industries, and accordingly provides considerable policy and economic support to snake farmers. The Lingshan County Snake Farming Association was founded in 2011 and now has approximately 850 members. The association represents 90 registered farms that collectively support an estimated 6,800 households throughout the county. The association hosts an annual snake meat cooking competition, a ‘biggest snake’ competition and a best photograph competition and they have published a

comprehensive manual on snake farming (in Chinese only). Lingshan County hosted the 2013 National Snake Farming Technologies Meeting, where it was formally recognised as the national leader in snake farming technology (Lingshan County Forestry Administration, Lingshan Wenqian snake farming school, unpublished data and pers. comm.).

There are thirteen CITES-listed snake species in China. These include the oriental rat snake (Appendix II), Chinese cobra (Appendix II), monocled cobra (Appendix II), king cobra (Appendix II) Burmese python (Appendix II), Indian cobra (*Naja naja*) (Appendix II), Orsinis viper (*Vipera ursine)* (Appendix I), Mangshan pit viper (*Trimeresurus magshanensis*) (Appendix II), Russell's viper (*Daboia russelii*) (Appendix III), Asiatic water snake (*Xenochrophis piscator*) (Appendix III), Asiatic rock python (*Python molurus*) (Appendix II),Tartary sand boa (*Eryx tataricus*) (Appendix II) and Desert sand boa (*Eryx miliaris*) (Appendix II). The majority of the latter eight species are traded in relatively small numbers and are listed by CITES due to their restricted range, threatened population status, overharvesting for the pet trade and/or similarity to species which are traded in large numbers (CITES 2014). Asiatic rock pythons and Indian cobras may be present in small numbers in snake farms but otherwise these species are not farmed and are not discussed in detail in this report.

According to the CITES trade database (2014), China is regularly involved in the import and/or export of several indigenous and non-indigenous CITES-listed snake species for a variety of purposes. Much of the export trade involves the re-export of derivatives of animals suggesting China is an important processor of snakes and snake products.

3. HOW ARE SNAKES FARMED

This chapter provides a summary of the bulk of data collected during farm surveys. It describes the functional characteristics of the industry, as well as the key biological and economic criteria concerning each of the main species farmed for meat and medicinal value. Commercial snake farming is a relatively new industry and as such it is characterized by a high degree of variation both between and within production systems. Many farmers shift focus from one species to another or change management protocols depending on prevailing economic or environmental conditions. The rapidly evolving nature of the industry demands a high degree of flexibility and adaptability from farmers, and it is against this dynamic backdrop that these findings should be interpreted.

3.1. Production systems

In Viet Nam, most of the snake farms are independent, self-contained operations that breed and raise all their own stock. Only occasionally do they sell eggs or hatchlings, usually to farmers starting up new snake farms. Natusch and Lyons (2014) describe a more complex production system employed by the python farming industry which involves satellite farms contracted to larger breeding operations. There was some evidence to suggest that similar production systems exist within the snake meat industry, but the limited sample size prevented us from exploring this further.

In China there are essentially two kinds of production systems. Larger farms breed and rear snakes and small farms focus solely on rearing snakes. Large farms breed surplus animals, some of which are sold to smaller farms and some of which are raised on site. The smaller farms raise snakes to market size and then sell them either directly to local markets, or back to the larger farms. Large farms generally only sell snakes to the larger markets such as those in Guangzhou.

3.2. Farms

In Viet Nam, snake farms are generally small and compact operations (fig. 2). Average farm size is 1,329m2 with those in rural areas being generally larger than their urban counterparts. Snake farming can represent a primary livelihood activity or in can be carried out in parallel to one or more other farm activities. Often other species of reptiles are farmed such as turtles or monitor lizards. Snake facilities are typically close to, or integrated within the main dwelling area. The structures housing the snakes usually consist of large purpose built buildings fitted with smaller housing units. The security risk is considerable and anti-theft measures, including closed circuit cameras, are commonplace. The

number of snake species produced at any given farm varies from 1 to 6 but most have more than one species (mean=2.3).

In China, modern intensive farms average 4,505m2 in size and typically consist of rows of elongated buildings that are made up of numerous purpose built snake rooms (fig 2). Large farms generally have designated buildings for different species and age groups, as well as for food storage, administration etc. and are not unlike a modern intensive poultry or pig farm in appearance. Snake farming is usually the sole business, although diversification exists in the form of value added products (e.g. snake schools, snake wine). Farms employ a range of security measures and are usually surrounded by substantial perimeter walls.

3.3. Enclosures

Enclosure types are extremely variable in China and Viet Nam, and traditional mud-walled pits persist alongside state-of-the-art climate controlled cages constructed from synthetic materials (fig.3). Enclosure design appears to be changing in step with development of the industry and experimental enclosure types are common.

3.3.1 Snake pits

Several farms have large enclosed areas encompassing several hundred square meters in which they house large numbers of snakes under semi-natural conditions. Perimeter walls were up to three meters high and in some cases included a wire mesh overhang. Typically snake pits house more than one species and a range of sizes/age groups. Species farmed in this manner included rat snakes, pythons and water snakes. It is the opinion of the author that snake pits were traditionally used as a holding facility for wild harvested animals, and by default functioned as an ad hoc ranching facility.

3.3.2 Individual underground cages

The original individual caging consists of rows of small (~0.5m2) underground cages accessed via a trapdoor (fig.3). These cages require a custom built room where the entire floor is made up of cages. Cages are typically constructed from a combination of brick, clay and wood. The semi-natural design apparently allows for superior humidity control which in turn leads to overall healthier snakes. Underground cages were only used for cobras and king cobras.

3.3.3 Individual stacked cages

Stacked cages were developed relatively recently in an effort to increased carrying capacity (fig. 3). Stacked cages consist of rows of vertically aligned cages made from a variety of materials ranging from aluminium sheeting to wood and mud plaster. Although superficially similar to underground cages, stacked cages are often associated with increased veterinary issues due to inferior temperature and humidity control, and increased stress through exposure to general maintenance activities. Stacked individual cages are used for rat snakes, cobras and king cobras.

3.3.4 Communal cages

Purpose-built cages housing several dozen individuals are common with smaller scale farmers (fig.3). Cages vary from 1m2 to 3m2 and are typically constructed of wood, clay or ceramic bricks with a wire or plastic mesh frontage. Communal cages are popular with newly established small-scale farms. They are used for rat snakes, juvenile snakes and occasionally cobras.

3.3.5 Communal snake rooms

Many farms use purpose built rooms (~3mx3mx2m) in which they house several hundred individuals (fig. 3). Within rooms the snakes are accommodated within ‘tower blocks’ of stacked wooden pallets. These tower bocks are up to a metre high and covered with blankets and/or plastic sheets to insulate and retain humidity. The tower block system enables vertical farming (farming on the vertical as well as horizontal plane) and stocking rates of up to 63kgs of live snakes (~50 adult rat snakes) per m3. Some farmers incorporate an outdoor section to rooms, where snakes can bask in natural light. Snake rooms are the preferred choice for rat snakes and cobras at the majority of the larger, more progressive farms.

3.3.6 *Other caging*

Numerous other forms of caging and cage design exist. There are all manner of variations of the above, as well as a wide range of experimental designs using novel materials, particularly modern synthetics like cheap polythene mesh.

3.4. Insulation and heating

A total of 41% of farmers interviewed supply supplementary heating and all of these farms are located in the cooler northern regions of Viet Nam and China. Supplementary heating is provided in the form of incandescent light bulbs, piped hot water or modified electric blankets. Winter heating increases growth rates and improves hatchling survival rates. Most of the larger farms and all the farms in China make use of electronic thermostats to control maximum and minimum temperatures. Thermostats were set within the ranges of 28°C to 31°C. Most farmers employ some form of insulation which is used to keep snakes warm in the winter and/or cool in the summer. Some farms in the south of Viet Nam, where temperatures are often very high during the summer months, have modified irrigation systems to keep rooms cool. Only a few farmers made use of solar energy (irradiance) as a direct or indirect means of controlling temperatures, which is surprising given the potential cost-saving benefits. Greenhouses and energy efficient solar technologies play an important role in the farming of the physiologically similar crocodilians (pers. obs.).

3.5. Water and Humidity

Clean drinking water is made available at all times or at least offered on a regular basis using a variety of means. Some cages have custom fitted drinking troughs which can be removed, cleaned and refilled without opening the enclosures. Most farms use small ceramic bowls or auto-refill drinkers made for the poultry industry. Humidity is maintained through the use of natural building materials, mounds of damp sand within rooms, artificial sprinkler systems or polythene covers over a portion of the cage. Many of the larger king cobras displayed signs of incomplete sloughing, possibly the result of suboptimal humidity.

3.6. Cleaning and hygiene

Given the high density of animals and the relatively confined spaces, farms are generally odourless with only traces of ammonia or other sewer gasses present. Snake enclosures are cleaned about once a week (mean=6.7days, SD=6.8). The weekly cleaning is typically restricted to the removal of bulk waste matter only (whole faeces, sloughed skins) whilst the substrate (usually sand or clay) is replaced much less frequently. Snakes may or may not be removed from the enclosure during cleaning. Detergents and disinfectants are rarely, if ever, used. Only a few farms use water to clean and rinse enclosures. Several farms make use of extractor fans (sometimes attached to thermostats); one farm uses bio-carpets mixed with odour suppressants and another farm uses ozone machines to chemically remove sewer gasses (oxidise ammonia). Most of the larger farms in China have sterilising foot baths at the entrance to buildings. The total waste material emanating from snake farms is remarkably low, and farmers make few concessions for its management.

3.7. Feeding

Food and feed presentation are two of the most important aspects of the snake farming industry yet they remain relatively crude and under-developed components of production management. Developing alternative and less costly feed management systems is considered a key focus point for further research and development within the industry (Lingshan Snake Farming Association).

There is a widely held belief that food intake rate affects long term survival and fecundity. Overfeeding and underfeeding both lead to increased morbidity and/or decreased fecundity, especially over the longer term. In cases where snakes are raised solely for meat, they are generally fed 10% more food per unit time (or ad lib) compared to snakes raised for breeding purposes. In cases where farmers don't distinguish between breeders and growers, feed rates average 10% of body weight per feeding event for adult snakes. Hatchlings and juveniles are fed more frequently, usually daily.

The primary feed inputs for snake farms can be divided into three broad categories: wild-harvested natural food, waste protein from existing industries and formulated diets. The geographic variation in food availability and price plays a significant role in feed choices (table 3).

3.7.1 Wild-harvested food

The preferred feed choice for most of the small scale farmers is natural prey (fig.4). This is particularly so in the case of hatchling snakes which require specific stimuli to initiate healthy feeding behaviour. Rodents are trapped in large numbers during the autumn season whilst toads and frogs are collected by hand during the summer months. In the North of Vietnam a number of species of water snakes are harvest for king cobras. Harvesting is often carried out by a third party. Wild-harvested food is an important input for small scale farmers in remote areas. Some farmers breed frogs and water snakes for meat and/or snake food.

3.7.2 Waste protein

The poultry and pork industry produces substantial volumes of waste protein which provides an ideal food source for snake farms in Viet Nam and China (fig.4). Stillborn piglets, natural mortalities and culled stock from poultry farms, livestock offal and catfish skins are fed whole or processed before being fed to snakes. Day old ducks and chickens (DOD & DOC) are usually de-feathered and occasionally de-skinned. Some python farms grind up various forms of waste protein and make sausages. In China the Lingshan snake farming association has successfully developed an extruded pellet made from fish and poultry waste.

3.7.3 Formulated diets

One python farm recently started adding commercial catfish grower pellets to pork-based sausages at a rate of 20% per weight (fig.4). Formulated diets provide essential micronutrients, improve the protein to water ratio and early indications suggest they improve growth rates.

Table 3. Cost of major feed types used in the snake farming industry. Prices vary considerably depending on locality (e.g. proximity to feed source) and time of year (e.g. amphibians cheaper in monsoon season, rodents cheaper in harvest season)

Feed type	price/kg min (US$)	price/kg max (US$)
Rodents	1.4	3.3
Frogs	1.9	2.9
Toads	0.96	2.9
DOC/DOD	0.48	1.4
fish waste	0.48	0.71
poultry waste	0.48	0.71
Processed waste protein	0.29	0.29

3.8. Breeding

3.8.1 Breeding systems

Breeding systems are similar between all species (fig. 1). Most farmers keep more females than males to maximise outputs while minimising management costs. In Viet Nam there is no differentiation between grower stock (animals raised specifically for slaughter) and breeding stock. All animals are allowed to breed during the growing process, and all animals are slaughtered once they reach the optimum sale weight, irrespective of reproductive status. Optimum sale weight corresponds with market demands, which require a body size of between 1 to 4kg. Market demand is highly variable and this results in a variable number of growers/breeders/eggs present at any one time. In China farmers differentiate between breeders and growers, and typically have up to twice as many growers compared to breeders. Breeders are allowed to hibernate (enter a cooling period with no food) for an average of 2.3 months whilst growers are retained at optimal temperature through artificial heating and are fed throughout the year.

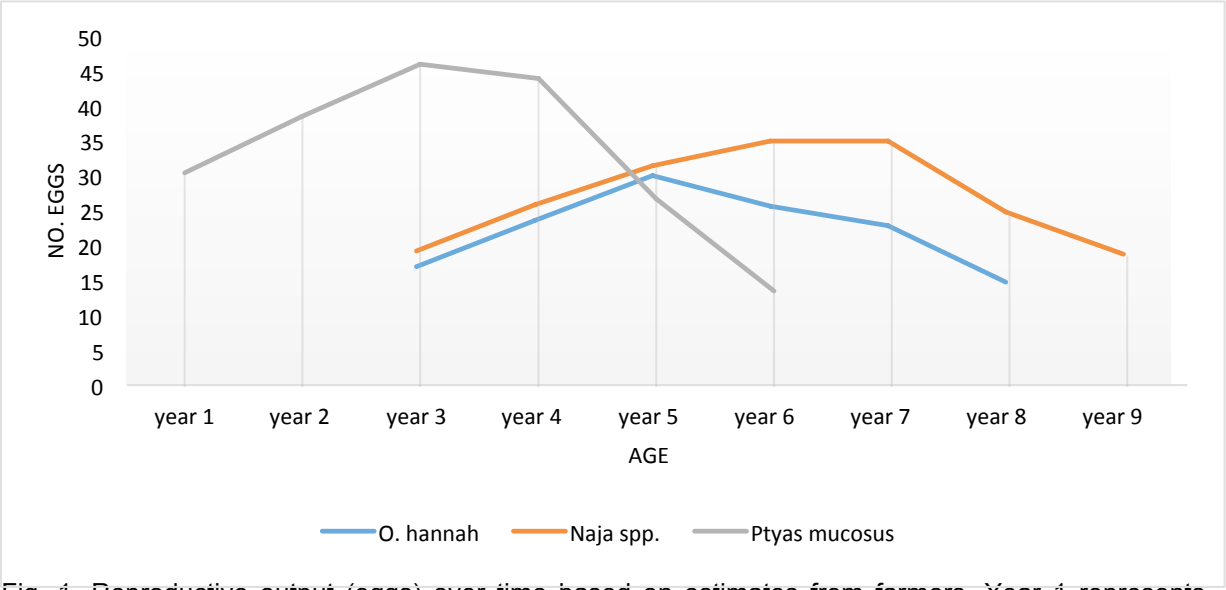

Fig. 1. Reproductive output (eggs) over time based on estimates from farmers. Year 1 represents hatch date for all species. Rat snake totals are the sum of up to three clutches per year. Trend line endpoints are a function of harvest and do not necessarily represent senescence.

3.8.2 Inbreeding

Farmers regularly exchange animals between farms to avoid inbreeding depression. Typically a small number of adult males are exchanged on an annual basis with one or more farms within the local area. There is no evidence of stud book use although at least some farmers have a good knowledge of breeding history at the level of the individual.

3.8.3 Selective breeding

Farmers are acutely aware of the benefits of selective breeding for desirable traits (fig.7). In the case of pythons, skin characteristics (colour and pattern) are considered alongside growth, survival and fecundity rates, whereas healthy feeding behaviour and juvenile survival rates and size are the most important criteria for other species. Repeatedly throughout the study the author witnessed both juvenile and adult snakes consuming unusual food items (e.g. chopped chicken pieces, extruded pellets), and it was suggested that this feeding behaviour was the result of selective breeding.

3.8.4 Incubation

All six CITES-listed species mentioned in this report lay eggs. The specialised incubation methods used for pythons are discussed in detail in Natusch et al. (2014) and will not be discussed here. Incubation methods for remaining species vary between farms but not between species. Virtually all farmers (97%) use fine sand or soil as the incubation medium which is usually contained in some form of insulated receptacle (fig. 7). Receptacles include clay pots, polystyrene boxes, plastic drums or concrete pits. Humidity is retained by either covering the eggs with a layer of moist sand or by covering the receptacle. A remarkable 54% of Vietnamese farmers interviewed claimed that they made no effort NOT to turn eggs when placing them in incubators. When questioned, these farmers were not aware that turning snake eggs during the incubation process could lead to the fatal drowning of the embryo. Despite this, egg mortality rates were relatively low and similar between all species (mean=14% SD=13%)

3.8.5 Hatchlings

Hatchling and juvenile animals are often kept within the same type and sized enclosures as the adults. Other hatchling enclosures recorded include polystyrene boxes and polyethylene mesh ‘tents’ (fig. 4). Hatchlings and juveniles of all species are housed communally (~100 individuals per cage) for the first few months after hatching. In Viet Nam, cobras and king cobras are typically moved to individual cages when they approach maturity (~1 to 2 years).

3.9. Disease and veterinary care

In general there is a low prevalence of disease among snake farms in Viet Nam and China despite the stress of captivity coupled with high densities of animals. High mortality rates amongst juveniles are accepted by farmers and the relatively rapid turnover of the adult population negates much of the concern for veterinary issues. None of the Chinese farmers interviewed use veterinary medicines whilst virtually all Vietnamese farmers (93%) said they use medicine and/or prophylactic food supplements. These include antibiotics, vitamin and mineral supplements, probiotics and paraciticides. Adult snake survivorship was not recorded. A wide range of snake-specific veterinary products are available in Viet Nam. The most commonly cited veterinary issues were respiratory infections in pythons and rat snakes and skin disease in cobras. Nose-rub – a condition whereby the rostral scale is injured through the action of the snake constantly trying to escape – was evident on some of the snakes housed in cages that incorporated wire mesh. During the study there appeared to be a correlation between general cleanliness/appearance of the farm and incidence of diseases and other veterinary issues. On average, in the author's opinion, the physical condition and general welfare of animals is exemplary.

3.10. Product, market and trade

Snake meat is variously described as being similar to fish, chicken, frog's legs and crocodile. The flesh is light in colour, firm in texture and low in fat and cholesterol (Hoffman 2008). It is cooked and served in an almost endless variety of ways, although snake soup is probably the most common. Snake meat is most valuable when it is fresh (preferably live) and complete with intact skin. Frozen snakes and skinned snakes fetch lower prices. The meat by-product from the python skin industry is considered a relatively cheap meat (~2-5USD/kg), and in Viet Nam is commonly served as an affordable main course at larger gatherings such as weddings. The main market demand is for whole live snakes averaging between one and two kilograms. These animals are considered the ideal size for typical corporate and family gatherings.

Snakes are supple, shed their skin and contain paralysing venoms, and as such they are highly regarded by traditional Chinese healers in the treatment of stiffness (e.g. arthiritis), skin diseases such as acne and carbuncles, and the treatment of convulsions including epilepsy and paralysis (Dharmananda 1997). Snake bile is consumed as a general tonic, and the bile, blood and meat is said to have a warming effect (yang) which combats the cooling 'yin' of winter. Snake wine is taken as a health tonic (Dharmananda 1997, Somaweera and Somaweera 2010), particularly by the elderly to combat the cooling 'yin' of old age (Van Ngo, pers. comm.)

Only pythons are regularly slaughtered on site at farm facilities. The remainder of snake species are sold live in mesh bags. Snake eggs are usually sold in sand-filled polystyrene boxes. In the past Vietnamese farmers occasionally slaughtered animals for their skins when prices were very low, but since 2007 prices for live snakes have remained high. When snakes are slaughtered for food, the animal is restrained around the neck and decapitated using a chopping knife or a large pair of scissors.

When asked if the live snake market was increasing or decreasing, 72% of Vietnamese farmers responded that the market was increasing. The concerns of those who gave negative responses included the development of industrial-scale snake farming systems in China, and increased trade restrictions between Viet Nam and China. In China, all respondents stated that the live snake market was stable or increasing but prices were decreasing due to an increase in the number of snake farms. Throughout the study farmers were given the opportunity to ask questions at the end of the interview, and one of the most common questions was 'are there any ways we can process snakes in order to expand the market?'

The current growth in the snake farming industry is being driving by demand from China, but there is also evidence of growth in the Vietnamese market. In Viet Nam most snakes are sold to middlemen (72%) who in turn sell the snakes to local restaurants and buyers in China. Six of the farmers interviewed in Viet Nam sell direct to Chinese markets. In southern China most of the smaller farms

sell to larger farms or to local food markets. Lager farms sell to centralised snake markets located in the larger cities. Guangzhou is home to the largest snake market in China.

3.11. Miscellaneous

3.11.1 Seasonality

In Viet Nam, much of the food for snake farms is harvested from the surrounding environment and fed fresh. As such, feed inputs can be highly variable and are often seasonal in nature. Some farmers vary their management regime and synchronise feed input with feed availability, whilst others use large refrigeration units to ensure a constant year round feed supply.

Many of the farms in China and in the north of Viet Nam cool their snakes to the point of inactivity during winter (~hibernate). During this time virtually all management activities (feeding, cleaning) are halted or drastically reduced. The cooling period is not strictly linked to seasonal patterns, and there is some variation in duration and timing (mean=4.85 months, SD=1).

3.11.2 Snake Schools

Snake schools are a unique Chinese phenomenon. Leicun Snake Farm was established in 1980 specifically to carry out research on snake farming techniques and the development of snake bite treatment. The facility derives an income through hosting training courses for which prospective snake farmers pay a fee. The facility claims to have trained several thousand villagers from all over China. The farm is also responsible for the manufacture of one of the most popular snake bite treatments in China (Pipeng pers. comm.). There are several other training schools in China, usually run as side-line businesses by the larger snake farms. One school offers residential courses which run for approximately 18 days. The course costs approximately US$480 and participants are expected to spend half their time working on the farm to gain practical experience (Leicun, Qinzhou Yuanhong and Lingshan Wenqian snake farms, pers. comm. and unpublished data).

3.11.3 Handling and snake bite

In general farmers tend to avoid free-handling animals wherever possible and have developed specialised management systems to facilitate this. Nevertheless, they are competent snake handlers and demonstrate expert skill in handling venomous snakes. Handling equipment includes snake tongs, hooks and nooses. Despite their skill, bites are common and several of the people interviewed bore scars from snakebites. The preferred treatment for snakebite is traditional Chinese medicine (see 3.11.2 above), which comes in the form of a tourniquet and a course of pills which are administered orally. Fatalities are rare but are not unheard of.

3.11.4 Other species

In addition to the species mentioned in this report, a number of other reptiles are farmed in Viet Nam and China. These species are relevant because they often have similar management requirements to snakes, face similar conservation threats and are often farmed and traded in a similar fashion. Table 1 represents the official list of snake species farmed in Viet Nam. Many of these were observed during this study. Other reptiles recorded included turtles, tortoises, lizards, monitor lizards and geckos.

Fig. 2. *a) Oriental rat snakes are a large non-venomous colubrid. b) Like many snakes, they like to aggregate in high densities. c) Juvenile rat snakes.*

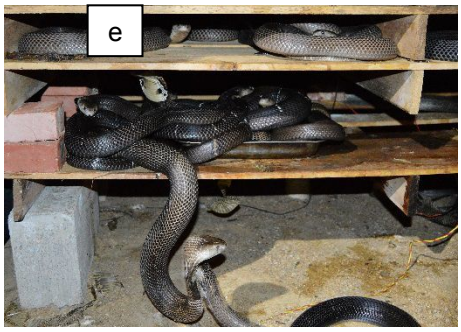

Fig. 2. *d) Captive Chinese cobra. e) Despite cannibalistic tendencies, cobras can be successfully housed in communal set-ups, provided they are well fed. f) Juvenile Chinese cobra.*

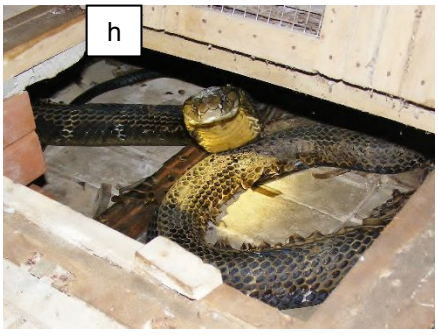

Fig. 2. *g) King cobras are the largest venomous snake in the world. h) They are housed individually from the age of four months due to their cannibalistic tendencies. i) Juvenile king cobras are more brightly coloured than adults.*

Fig. 3. *The size and style of snake farms is highly variable, ranging from traditional small scale farms to modern industrial operations. a) Small scale farm, where snake cages are integrated with living quarters (kitchen on the left, snakes on the right). b) & c) Traditional palm thatched buildings housing a few hundred individuals. d) & e) Larger commercial operations consisting of purpose build snake rooms fitted with specialised basking areas for thermoregulation. f) Modern industrial scale farm producing tens of thousands of snakes per annum.*

Fig. 4. *Enclosures used to house snakes. a) Individual underground cages. b) Individual stacked cages. c) Communal enclosures. d) & e) Snake rooms with stacked 'tower blocks'. f) Large walk in enclosures made from nylon netting. Synthetic materials are cheap, easy to work with and increasingly popular.*

Fig. 5. *Feed is the single biggest base cost in snake farming and comes in a variety of forms. a) Toads are harvested during the summer months. b) Frogs are bred on farms or harvested from the wild. c) A roadside stall selling wild harvested rodents to snake farmers. d) & e) Waste protein from the poultry and pork industries (in this case skinned DOCs and piglets). f) Processed waste protein is increasingly being used to develop cheaper snake foods.*

Fig. 6. *Feed presentation is a labour intensive and a vital skill. a) De-beaking and chopping up DOCs for hatchling snakes. b) Chopped frog offered to juvenile cobras. c) Slices of water snake skin offered to juvenile king cobras. d) Trays of skinned DOCs offered to adult rat snakes. e) Frozen thawed snakes (Xenochrophis piscator) offered to king cobras. f) Burmese python voluntarily feeding on a 'snake sausage'.*

Fig. 7. *Temperature and humidity control during incubation are ingeniously achieved using a variety of improvised incubators (a, b, c & d). e) Collecting hatchling rat snakes from a homemade incubator. f) Farmers follow vigorous selective breeding programs to improve the quality of captive stock. g) Grading takes place throughout the course of an individual's life.*

Fig. 8. *Primary products of the snake farming industry. a) Python skin is highly sought after by the high end fashion industry and for the manufacture of traditional Chinese musical instruments. b) Snake wine is a popular health tonic in Viet Nam and China. c) Snake meat is light in colour and firm in texture, and is invariably prepared whole with the skin intact. d) Python meat is sold as a by-product of the skin industry, and is relatively cheap because it lacks the tasty skin. e) A road side stall in Viet Nam selling wild harvested live snakes. f) Snake farms hold inherent curiosity value which could be developed as a novel tourism product.*

4. SPECIES ACCOUNTS

A total of six CITES II listed snake species are farmed in Viet Nam and China: Ophiophagus hannah, Naja atra, Naja kaouthia, Ptyas mucosus, Python bivittatus and Python reticulatus.

An assessment of the commercial production of the two python species was recently reported by Natusch and Lyons (2014) and will therefore not be discussed here. N. atra and N. kaouthia are biologically very similar, farmed under identical conditions and for the purpose of this report are regarded as a single species. In fact, the taxonomy of captive snake populations in Asia may be somewhat muddied, as hybridisation may well be occurring on a regular basis. In general, N. atra are farmed in China and northern Viet Nam and N. kaouthia are farmed in southern Viet Nam.

4.1. King cobra (*Ophiophagus hannah*)

The king cobra is the largest venomous snake in the world (fig. 2). It grows to over 4 meters in length and can weigh in excess of 10kg. It occurs across much of South, East and South East Asia in a diverse range of wooded habitats ranging from coastal tropical forest to the fringe of high altitude temperate forest. It can tolerate some degree of habitat alteration, and is known to persist in agricultural landscapes (RAO 2011). It is predominantly terrestrial but climbs well and often seeks refuge underground. It is not common anywhere and populations are thought to be declining due to habitat loss, over harvesting and persecution. It is listed as Vulnerable in the IUCN Red List of Threatened Species (Stuart, Wogan et al. 2012). In the wild it preys almost exclusively on other snakes. The taxonomy of the king cobra is in a state of flux, and it is likely that the species will be split into several regionally distinct taxa in the future.

King cobras are traded throughout much of their range for their meat, medicinal value, skin and as pets (Stuart, Wogan et al. 2012). In China and Viet Nam they are farmed almost exclusively for their medicinal and food value. The meat and organs are purported to have a wide range of medicinal uses, but one of the most significant contemporary values is in the treatment of cancer (Van Ngo pers. comm.).

In Viet Nam king cobra farming is carried out mainly in the north of the country in traditional snake farming villages. During this study we interviewed four king cobra farmers. One farmer stated that his family had been farming king cobras for over 300 years. King cobra farmers have been operating for an average of 25.2 years, considerably longer than the 10.8 year average for Vietnamese snake farmers in general. All farmers stated that king cobras were the most difficult species to raise. The skill required to handle these dangerous snakes together with their demanding husbandry requirements limit the number and distribution of king cobra farms.

Diet and feeding

King cobra hatchlings are fed a combination of live hatchling water snakes and thin strips of adult water snake skin. Hatchlings are offered food daily. Adult king cobras are fed whole adult snakes once every 4 to 5 days, which are fed dead, either fresh or freshly thawed. Two species of food snakes were recorded during this study; Enhydris plumbea and Xenochrophis piscator. Two of the farmers interviewed fed rats and DOC when snakes were in short supply, and both stated that their animals willingly accepted the less-preferred options if they were hungry. The average feed conversion ratio is 1 to 5 (5kg of feed input to produce 1kg of king cobra).

Breeding

Farmers keep more females than males (mean ratio 1 to 1.75). Maturity is reached at an average age of 2.2 years and an average weight of 2.5kg. Males mature a year earlier than females. Sex determination is based on tail morphology – males have longer tails with thicker bases. Towards the end of February males and females are placed in a large purpose-built enclosure to encourage copulation. If successful the female lays an average of 27 eggs about 35 days later (fig 1). Incubation ranges from 55 to 60 days. Juvenile mortality rates are high in the first year (mean=37%, SD=0.04). On average females are kept for four breeding seasons before being sold.

Economics

Farms which keep king cobras hold an average of 204 adult king cobras (SD=88). King cobras are sold at an average weight of 2.55kg for an average price of US$81/kg. Demand is greatest in the 1kg-4.2kg size range and there is a multi-tiered size based price structure within this range which varies over time. There is limited demand for large animals, but there is a demand for very large animals (>10kg) in excellent condition and these command a premium of up to US$1000 per individual. These trophy animals are used in the making of high-end bottles of snake wine. Eggs sell for an average of US$9 each and hatchlings for US$13 per individual. All king cobra farmers said that demand for king cobras was increasing.

4.2. Cobras (*Naja atra* & *Naja kaouthia*)

The Chinese (fig. 2) and monocled cobra occur over a wide range of habitats and adapt well to modified agricultural landscapes. They are predominantly nocturnal and terrestrial but spend much of their time underground down rodent burrows. Both species are highly venomous and responsible for a significant number of snake bite fatalities. The Chinese cobra can 'spit' venom, although not nearly as effectively as true spitting cobras (pers. obs). The diet of both species is highly variable and includes amphibians, rodents, birds, eggs, other reptiles and occasionally fish. Their aggressive feeding response and varied diet was a major factor in them being the first species to be successfully produced in closed-cycle farms in China (Pipeng pers comm.).

Cobras are harvested throughout much of their range and populations of both species are believed to be decreasing. The monocled cobras is listed as Least Concern and the Chinese cobra is listed as Vulnerable in the IUCN Red List of Threatened Species (Ji and Li 2014). In Viet Nam and China cobras are farmed in large numbers primarily for their meat, and to a lesser extent medicinal value. Occasionally they are traded for their skins or as pets.

Diet and Feeding

For the first four months juvenile cobras are fed small pieces of chopped frog or DOC. Thereafter they are fed on a variety of food depending on availability and cost. Toads and DOC are the most common items, followed by DOD, frogs and lastly rats. Juveniles are fed daily whilst adults are fed on average once every 4.2 days. The average feed conversion ratio is 5.6 to 1.

Breeding

Farmers keep more females than males (mean ratio 1 to 1.47). Maturity is reached at an average age of 1.8 years and an average weight of 1.6kg. Males grow faster and mature earlier than females, reaching a weight of up to 1.5kg in their first year compared to the females 0.9kg. Sex determination is based on tail morphology – males have proportionately longer tails with thicker bases. Towards the end of March males are placed in the female's cage to encourage copulation. The females lay an average of 22 eggs (SD=6.7) in May (fig 1). Incubation ranges from 50 to 55 days. Egg mortality rate is 12% and juvenile mortality rate is 13%. In Viet Nam females are retained for an average of 2.8 breeding seasons before being sold.

Economics

Vietnamese cobra farms hold an average of 347 adults and Chinese farms hold an average of 17,500 adults. Cobras are sold at an average weight of 1.7kg (~18 to 24 months) and for an average price of US$31/kg in Viet Nam and US$25/kg in China. Eggs sell for US$2.5 each in Viet Nam and US$4.2 each in China. Many of the larger cobra farms in China make and sell snake wine as a secondary business.

4.3. Oriental rat snake (*Ptyas mucosus*)

The oriental rat snake is a large, non-venomous colubrid found throughout much of Asia (fig. 2). It occurs in a diverse range of habitats with a preference open terrain adjacent forested areas. It does well in agricultural landscapes, particularly rice fields. It is terrestrial but will climb trees in pursuit of prey and to rest in at night. It is an active diurnal predator and preys on a wide range of small

vertebrates including frogs, toads, rodents, birds and lizards. In suitable habitat it can be abundant and a valuable aid in controlling commensal rodents. Historically it was harvested extensively throughout much of its range but trade volumes have reduced in recent years due to various conservation measures coming into force and possibly declining numbers (Auliya 2010). They have not been assessed for IUCN Red List status.

Rat snakes are farmed solely for their meat and are the most commonly farmed snake (numerically and by farms) due to the relatively low start-up costs and ease with which this species can be produced in large quantities. All farmers interviewed said that rat snakes were the easiest species to breed and raise.

Diet and Feeding

Rat snakes are fed a wide variety of prey depending on locality, availability and price. Toads, frogs, rats, DOC, DOD and rodents are all readily consumed by adults. Hatchlings are fed small live frogs, chopped pieces of frogs or chopped pieces of DOC. Farmers feed young snakes daily and adult rat snakes once every 3 days. The average feed conversion ratio is 6 to 1.

Breeding

Rat snake farmers keep more females than males (mean ratio 1 to 2.3). Maturity is reached at an average age of 10.7 months (SD = 2.6) and an average weight of 1.3kg (SD=0.2). Sex determination is based on tail morphology – males have longer tails with thicker bases. Copulation occurs in September or June. Approximately 35 days after copulation the females lay an average of 16 eggs (SD=3). Incubation time is approximately 75 days. Females occasionally lay up to three clutches per year (usually two) giving an average annual total of 37 eggs per female (SD=12.6) (fig. 1). Egg and hatchling mortality rates are 17% and 21% respectively. On average snakes are retained for 2.8 (SD=0.8) years before being sold. Compared to the other species, rat snake fecundity is not a limiting factor, and farmers occasionally discard surplus eggs.

Economics

Vietnamese farms keep an average of 393 adult rat snakes and Chinese farms kept an average of 16,350 adults. Rat snakes are sold at an average weight of 1.6kg (~1.5 years old) and for an average price of US$28/kg in Viet Nam and US$27/kg in China. There is a multi-tiered size-based price structure which varies over time. For example, one farmer said there was US$4.8 increase in price per kg for snakes over 1kg in weight, and a further US$4.8 increase per kg for snakes over 1.5kg. Eggs and hatchlings sell for less than US$5 each in Viet Nam whilst in China eggs fetch up to US$6 each. Rat snake farmers expressed the most concern over the future of the industry. Two Vietnamese farms visited had given up rat snake farming in recent years due to increasing numbers of snake farms leading to falling prices.

5. THE BIO-ECONOMIC FEASIBILITY OF SNAKE FARMING

This section examines snake farms in terms of the interactions between snake biology and agricultural economics. Natusch and Lyons 2014 recently highlighted the feasibility of python farming and demonstrated how in the case where large snakes are farmed to supply the high end fashion industry with an exclusive product (skin), snake farming can be a lucrative and beneficial enterprise. Here we intend to follow a similar rational to explore the feasibility of smaller snake species farmed for their comparatively less valuable meat and medicinal worth.

This exercise is important for two reasons. First, conventional logic states that energy efficiency, and therefore production efficiency, decreases the further up the tropic pyramid one farms. Snakes are apex predators and obligate carnivores requiring valuable and expensive protein as a feed input – an absurdity in conventional livestock circles. Second, many species are directly threatened with over-exploitation and snake farms offer a laundering conduit for illegally harvested wild animals. A clearer understanding of the bio-economics of snake farming will help to resolve both these issues by a) providing basic commercial guidelines for farmers and future investors and b) allowing inferences to be made about the cost/ benefit implications for conservation and wider environmental sustainability.

5.1. Biological feasibility

Biologically, many reptiles may be considered of interest to modern agriculture because they are large terrestrial ectothermic organisms specializing in energy efficiency – a potentially cheap and environmentally friendly source of high quality animal protein. Their efficiency of biomass production can exceed that of birds and mammals by as much as 90% (Pough 1980). This feat is achieved through a combination of specialised biological adaptations including ultra-efficient digestive physiologies (Bedford and Christian 2000), largely sedentary lifestyles and the ability to harness solar energy to fuel metabolic processes (Seigel, Collins et al. 1993).

Within the conventional agricultural context, snakes display a number of desirable life history traits. They have rapid growth rates, mature quickly and have a high reproductive output. Behaviourally, they are inclined to aggregate and are therefore amicable to the high density stocking rates required by intensive agriculture. They are uniquely adapted to exploit a three dimensional spatial landscape, with many species displaying duel terrestrial and arboreal tendencies. Farming on the vertical plane can radically increase livestock productivity per unit area (in this study up to 63kg/m^3). In terms of animal welfare standards, farmed snakes suffer from few of social and behavioural issues associated with the intensive farming of higher order vertebrates like pigs and chickens.

Snakes display exceptional food conversion ratios. Pythons have one of the most powerful digestive systems in the animal kingdom, with a gastric pH of 1.5 (Secor 2003), and are able to digest and assimilate a wide range of food stuffs, including dense connective tissue (Bedford and Christian 2000). This study found an average of 5.75kg of whole fresh vertebrate prey was required to produce 1kg of snake. Converted to a dry feed ratio, this translates to 1.72kg feed to 1kg of snake – a competitive figure by conventional livestock standards.

The main limitation of snakes is that they are highly specialised obligate carnivores with complex feeding behaviours. Nutritionally, they require high quality animal protein as a primary food source and have evolved specialised adaptions to do this. Feeding behaviour is governed by a combination of cues, including, but not limited to, visual, olfactory and gustatory, which together determine a potential prey item's suitability. Prey items thus have a unique 'fingerprint' which triggers the snakes feeding behaviour. In captivity, soliciting the 'strike and swallow' feed response of a particular snake species requires either feeding the natural prey species, or mimicking its unique fingerprint (fig. 5). King cobras are notorious for their highly specialised fingerprint, sometimes only preying on a few select species of snakes. Selective breeding can dampen this effect, but it is not uncommon for captive snakes to starve in the absence of live, natural prey items.

In high densities, snakes are prone to feeding conflict. Feeding conflict arises when two animals pursue the same prey item or one animal is mistaken for the prey item. It usually arises when animals are in an excited state of feeding behaviour, such as when they are very hungry or during optimal weather conditions (warm, low pressure following cool, high pressure), and it can result in serious injury or death. It is uncommon on snake farms due to individual caging and/or gluttonous feeding regimes.

5.2. Economic feasibility

Attempting to build a clear and concise understanding of the economic mechanics behind the snake farming industry is difficult. This is due to a number of interconnected factors. First, the relatively small, disjointed and rapidly evolving industry simultaneously supports several competing business models (table 4). Second, market forces are highly variable. Cost of inputs (feed) and prices paid for product are volatile and spatially and temporally variable. Last, snake farming operations are often integrated within household activities and other farming operations. It is difficult to disentangle proportionate costs, particularly where activities overlap or have similar inputs.

Table 4. *Summary statistics highlighting the diversity of viable economic models within the snake farming industry.*

Farm criteria	**average**	**std. dev.**	**maximum**	**minimum**
Viet Nam adult snakes per farm	550	527	2,100	30
Viet Nam annual profit/farm (USD)	$12,476	$13,714	$47,619	$1,428
China adult snakes per farm	27,288	42,065	130,000	400
China annual profit/farm (USD)	$350,716	$619,403	$1,968,000	$7,392

Summarised in Box 1 & 2 are two case studies highlighting both ends of the business model spectrum.

Box 1

Case study 1: Small holding farm in Northern Viet Nam

- One large building for snakes (100m^2) constructed out of local materials
- Farmer makes and repairs all his own cages (mostly underground type)
- Snake farming only source of income
- Started farming snakes in 2005
- Only farms cobras
- Hibernates all his snakes for 4 months
- Minimal management and no food during hibernation
- No staff, farm owner and his wife do all the work
- No artificially heating
- Current stock 150 adult cobras and 100 juveniles
- Produces ~3,000 eggs per year
- Food accounts for over 90% of base costs

Sales and income for 2013	**Operational costs for 2013**
100 adult cobras X **2**kg average weight at sale X **700000** VND/kg = **140 mill** VND	**300**kg food/month X average price **40000** VND/kg X **8** months = **96 mill VND**
2500 eggs x **50000** VND/egg = **125 mill** VND	**1 mill** electricity/month X **8** months = **8 mill** VND
Income = 265 mill VND	**Costs = 104 mill VND**

Net profit in 2013 = 161 million VND (~$7,667 USD)

- This calculated estimate is approximately 50% higher than the farmer's personal estimate of 100 million. Discrepancy probably arises from unrecorded costs (e.g. administrative/regulatory related costs)
- Translates into a monthly living wage of 6.7 million VND per person, which is nearly 2 million more than the average farm workers wage (~4 million VND/month)

Box 2

Case study 2: Large commercial snake farm in Guangxi province, Southern China

- Started farming in 2006
- Total area of snake rooms 2400m^2
- Main species include cobras and rat snakes (50:50 mix)
- Also experimenting with *E. carinata* and running snake school
- All snakes housed in rooms with 'tower block' set up
- Artificial heating via electric blankets
- Breeders undergo 1.5 months cooling/hibernation
- Only feeds skinned DOC
- Current stock includes 4,000 breeders, 8,500 growers, 8200 juveniles
- Produces 20,000 cobra eggs/year and 40,000 rat snake eggs/year

Sales and income for 2013	**Operational costs for 2013**
3000 adult rat snakes X **2**kg average weight at sale X **170** RMB/kg = **1020000** RMB	**30000** kg food/month X **6** RMB average price/kg X **11** months = 1980000
12000 rat snake eggs X **40** RMB/egg = **480000** RMB	**20** staff X **1200** RMB/month X **12** = **288000** RMB
5000 adult cobras X **1.5**kg average weight at sale X **175** RMB/kg = **1312500** RMB	**40000** average electricity/month X **12** = **480000** RMB
10000 cobra eggs X **20** RMB/egg = **200000** RMB	
Income = 3012500 RMB	**Costs = 2748000 RMB**

Net profit in 2013 = 264500 RMB (~$42,320 USD)

- Estimate given by farmer based on cost of raising 1 snake to 1.7kg was 130000 RMB profit per year. Discrepancy probably arises from unrecorded costs (e.g. taxes, administrative/regulatory related costs)
- Not included in above calculations is profit derived from *E. carinata* and snake school

The management cost of raising rat snakes and cobras is considered to be fairly similar. One Vietnamese farmer said the total cost of raising a cobra to a market size of 2kg is approximately US$19. In China the average cost of raising both rat snakes and cobras to an average size of 1.7 kg is US$23 (SD=US$6). Feed constitutes at least 50% of base costs, irrespective of how many staff are employed and whether or not farms provide supplementary heating.

5.3. Ecological feasibility

The Vietnamese landscape is dominated by a patchwork mosaic of rice fields and small homesteads. The farming methods employed remain largely low-tech and traditional, and rice, for example, is still harvested by hand. This highly modified but fertile environment is well suited to a small number of agriculturally adapted wild species. These species are often highly fecund and resilient to high levels harvest. Classic examples are frogs, toads and commensal rodents (Lawler 2001, Gray, Smith et al. 2004, Brown, Tuan et al. 2006) - important food inputs for the snake farming industry.

This study made minimal attempt to classify wild harvested food species or record relative abundance in harvested habitats. Wild harvested food species are assumed to be species of least conservation concern, and harvest levels are assumed to be sustainable.

Snake farms not only offer small scale farmers a cheap and easy to access livelihood, they also offer flexibility in the face of volatile economic and environmental conditions. Many snake species are capable of shutting down their metabolic processes during unfavourable conditions. In this study, 55% of farms surveyed hibernate their animals for an average of 4.9 months per year (SD=0.96). During hibernation or aestivation, snakes expend little energy due to drastically reduced metabolic rates. The majority of farmers interviewed (74%) said they vary feed inputs according to availability and price, and when asked how long their animals could survive with no inputs (e.g. during an economic catastrophe or extreme weather events), without affecting long term production, the response was an average of 4.3 months (SD=3.7). The on/off physiology of snakes gives farmers the freedom to stagger feed inputs and synchronise productivity with trends in local resources. For example, some farmers rely on amphibians during the wet season and rodent pests during the rice harvest season to provide the bulk of their annual feed inputs. In this regard, snake farming is unique because it gives farmers an incentive to conserve the unpredictable energy fabric of biodiverse ecosystems. It may also give small scale farmers a better chance of weathering the hostile extremes forecast by climate change.

The majority of feed inputs for the larger snake farms are made up of by-products from existing food production chains. Snake farms essentially recycle low value waste protein from the poultry, pork and fish industries and repackage it into a high value form of protein.

Throughout Asia the bulk of animal protein produced by farmers is skewed towards a handful of closely related taxa with similar endothermic physiologies to humans (e.g. pigs, poultry and cattle). In recent years, Avian influenza (H5N1), sever acute respiratory syndrome (SARS) and Swine flu (H1N1) have resulted in catastrophic agricultural losses (Jones, Patel et al. 2008). It is interesting to note that snakes were not linked to any of these endotherm-centric outbreaks. Expanding the biodiversity of the livestock industry decreases the impact of veterinary epidemics and lowers the incidence of medically important cross species infections.

Much of the Mekong Delta is made up of saline soils which are considered unsuitable for commercial agriculture. This problem has been compounded in recent years due to the ‘boom and bust’ of the shrimp farming industry, and the associated long term saline contamination of formerly fertile rice fields (Joffre and Schmitt 2010). One farmer interviewed during this study had purchased one such derelict rice farm and was successfully farming water snakes (*Enhydris bocourti)* in modified fish ponds.

6. SNAKE CONSERVATION AND SNAKE FARMING

6.1 The current status and role of wild harvests

The relatively high value of snakes compared to the average earnings of rural livelihoods suggests the fortuitous harvest of wild snakes is pervasive throughout much of Viet Nam and China. However, it seems unlikely that these wild harvested animals play a significant role in the functioning of the commercial snake trade. Roadside 'snake stalls' selling small numbers of live snakes (<100 individuals per stall) are an occasional informal livelihood in Viet Nam (pers.obs.). The vast majority of these snakes are locally caught wild animals, as is made evident by the diversity of species and age groups on offer. With the exception of *O. hannah* and *P. reticulatus*, all CITES-listed species were recorded in roadside stalls, but always in low numbers compared to other species (e.g. *Xenopeltis unicolour).* There is no evidence of significant national or international trade in wild caught snakes. The informal scale and intensity of the wild harvest supplying food for local consumption suggests the overall conservation implications of wild harvests are minimal. Furthermore, the majority of the species on offer are well adapted to agricultural landscapes, and even the largest snake species are biologically resilient to over-exploitation (Shine and Harlow 1999). It is worth noting that during the course of 2015 the author recorded evidence of wild pythons and king cobras persisting in relatively small refuges surrounded by snake farming communities.

The harvest of water snakes as the primary feed input for king cobra farms may have a detrimental effect on some populations of snakes. The unsustainable exploitation of water snakes is a conservation concern in neighbouring Cambodia (Brooks, Allison et al. 2007). It takes up to 150 water snakes to raise a single king cobra to market weight. However, given the small number of king cobra farms (11 in Viet Nam) and the relative abundance of water snakes in the wetland rich landscape of Viet Nam, current harvest levels seem likely to be sustainable. Nevertheless, assuming no artificial diet can be found and the market for king cobras continues to grow, it would be hard to argue that the uncontrolled exploitation of water snakes wouldn't have negative consequences.

Snake farms place an imperative on selective breeding, especially with regards to feeding behaviour and survivability of hatchlings. The fear of contaminating carefully selected genetics with wild type genes provides at least some motivation for farmers to actively prevent wild snakes from entering the commercial farm environment. Wild snakes also present the more obvious risk of introducing parasites and infectious diseases.

6.2 Do farms reduce the demand for wild caught animals and thereby help prevent over exploitation?

Yes. It is the opinion of the author that the scale and capabilities of snake farms are reducing the demand for wild caught snakes, at least at the formal market level. Wild caught snakes rarely adapt well to captive environments and their quality and condition deteriorate rapidly post capture. Captive raised snakes are more relaxed around people, and therefore retain their value between farm and market. Professional snake catchers are finding it increasingly difficult to compete with cheap, high quality farm snakes, hostile legislation for wild capture of snakes and improved law enforcement preventing wild capture (various pers. comm.) Around U Minh Ha National Park in the Mekong Delta of Viet Nam, the use of trained sniffer dogs was once a popular means of hunting wild pythons, but this traditional livelihood has declined sharply in recent years due to the above reasons rather than through direct snake population declines (various pers. comm.)

6.3 Is there scope to incorporate snake farms into a market-based conservation model?

The sustainable ranching or harvesting of animals from a wild population for profit can have considerable conservation benefits because it places a direct financial value on conserving the species within its natural habitat. In West Africa, female royal pythons (*Python regius*) are sustainably harvested prior to the egg laying season and retained in captivity until they lay their eggs (Gorzula,

Nsiah et al. 1997). In Argentina, a proportion of yellow anacondas (*Eunectes notaeus*) are harvested for their skins under a formal program that benefits wetland ecosystems and rural communities (Waller and Micucci 2008). In India, several species of venomous snakes are sustainably harvested for their venom, once again with considerable social and environmental benefits (Whitaker and Andrews 1995).

The benefits of closed-cycle snake farming vs ranching or wild harvesting remain to be understood. Snake farming infers increased conservation benefits because it reduces the exploitation of wild populations, but snake farming invariably results in independence from wild populations and a fundamental disconnect with any potential conservation benefits. Ranching or wild harvest retain vested interests in species conservation (by locals wanting to ensure a steady supply of wild animals to harvest) and thus infer greater longer term conservation benefits for wild populations.

The commercial characteristics of the snake meat industry (including the imperative of artificial selection and the shear volumes required by the market) bode poorly for the potential of a ranching program. However, linking the existing snake farming industry with sustainable harvest of wild populations of snakes may be possible, particularly with regards to more specialised products such as those required by the skin industry, pet trade or Chinese traditional medicine. Here the market focuses on comparatively smaller quantities of animals and a wider range of species (Zhou and Jiang 2005, Somaweera and Somaweera 2010). Examples of potential species that could be sustainably wild harvested include *Python* spp*., Deinagkistrodon acutus, Bungarus multicinctus Protobothrops mangshanensis, Gloydius shedaoensis, Azemiops faea, Zaocys* spp. and *Dinodon* spp. Indeed, a ranching program may well be the optimal conservation model for many of these specialised species threated with habitat loss. Further research would be essential to evaluate the longer-term viability of a market based conservation model for Asian snake species.

6.4 The role of farms in ex-situ conservation

The conservation value of farms as genetic repositories for species is limited. Most farmers show little regard for preserving taxonomic integrity, and it seems likely that at least two regionally distinct variants of king cobra (Thai and Chinese) and two species of cobra (*N. atra* & *N. kaouthia*) are interbred on a regular basis. In this regard a possible future conservation concern may be the impact of hybrid escapees. It necessarily follows that the role of farms in reintroduction programs (as in the case of China) also requires careful scrutiny and the development of a rigorous reintroduction protocol that incorporates genetic screening.

7. CONCLUSION

The international trade in threatened snake species is uniquely and increasingly linked to closed-cycle production systems. Within the last 10 years, snake farms have come to define and dictate the most important characteristics of the snake trade. A comprehensive understanding of past, present and future closed-cycle production systems is paramount for informed decision-making regarding the control and regulation of the international snake trade.

The commercial farming of CITES-listed snake species in Viet Nam and China is currently focused on the production of two species of python for their skins, three species of elapids for their meat and traditional medicine value, and one species of colubrid for its meat. This report focuses on species farmed for meat and medicinal value.

Snake farming is characterised by a high degree of variability and dynamism. The industry as a whole is evolving rapidly, as are most of its individual components. Measures exist to regulate the industry in China and Viet Nam according to CITES requirements, although a disparity in export and import figures and source codes is cause for concern. In Viet Nam snake farming is mostly carried out at the small scale using low-tech, traditional methods. The largest and most technologically advanced farms

are located in China, where modern intensive farming techniques have been applied. Rat snake and cobra farming dominate the industry due to the comparatively high demand for snake meat. The biology and husbandry requirements are broadly similar for all species farmed for meat, although management systems do vary according to species requirements and region. Based on the research carried out for this report, closed-cycle captive breeding facilities are well established commercial entities capable of meeting all current and future market demands. The basic biology of snakes is generally well suited to agriculture. Snake farming is a viable industry with potential socio-economic and environmental benefits.

7.1 Summary of key findings relating to CITES

1) Captive breeding in closed-cycle production systems are a significant and increasingly important source of CITES Appendix II listed snake species involved in the international snake trade.
2) The significance of closed-cycle production systems for snakes with regards to CITES is pivotal and is likely to grow exponentially in the coming years due to growing trade volumes, diversification of products and the expansion of trade networks. Rapid improvements in production technology are increasing the number of snake species farmed, and thereby affected by trade.
3) The current regulation and control of the Asian snake trade is inadequate. A lack of transparency and suboptimal trade management systems are inadvertently leading to clandestine and illegal imports and exports, particularly between Viet Nam and neighboring countries. Nevertheless, the implications for snake conservation are most likely negligible.
4) The exploitation of wild populations of snakes in Viet Nam and China plays a comparatively insignificant role in the international snake trade, legal or otherwise, but wild harvests are still prevalent on a local scale.
5) In its current form closed-cycle production is a viable industry that generates net socioeconomic and environmental benefits. However, considerable improvements in overall capacity are required to achieve the optimal cost/benefit model, which has potential to deliver profound benefits for rural development, biodiversity conservation and food security.

7.2 Recommendations and future research

1) Regulation and trade controls

The basic framework for the effective regulation and control of the snake farming industry already exists in Viet Nam and in China, and authorities in both countries are acutely aware of the growing need for good governance in wildlife-based industries. Trade control mechanisms are also well established in both countries, although it would appear that application has been slow to catch up with recent developments in close-cycle snake farming. It is important to point out that this is probably due to the entrenched legacy of illegal wildlife trade routes between and within Southeast Asia and Southern China, rather than to subversive efforts to mask an existing trade in wild caught snakes.

- The effective implementation of existing management structures is a fundamental prerequisite to establishing transparency within the snake trade. This is particularly so in the near-term to ensure rapidly evolving developments within the industry don't include unintentional or undesirable outcomes (e.g. attract bad press).
- The import and re-export of snakes to and from Viet Nam requires closer scrutiny, as does the sourcing of animals within other Southeast Asian countries (e.g. Lao, Cambodia, Thailand).
- National permitting procedures for closed-cycle production facilities (registration, vetting and licencing) need to act in concert and collectively as the primary guarantor for legitimate captive bred animals and associated CITES source codes. Improving the quality and performance of existing protocols (e.g. adoption of TRAFFIC 2013) and implementing a

standardised system for all producer countries would help to consolidate and synergise national (government legislation) and international (CITES) control mechanisms and thereby eliminate unwarranted trade discrepancies.

- It is likely that the number of species subjected to close cycle farming and high levels of trade will increase, and this will no doubt bring new conservation challenges. A bold adaptive management approach tempered within a precautionary principle methodology should benefit the majority of parties involved. For example, governments could encourage snake farms to explore the production potential of other snake species (including issuing permits to harvest wild stock), but these actions should be accompanied by robust monitoring programs.
- Ongoing institutional support from CITES, conservation NGOs and the wider development community will be essential to coordinate and develop local capacity within a multinational context. Some of the findings of this report can be extrapolated to other Asian countries, and the establishment of an umbrella organisation, such as an 'Asian Snake Producers Association', may be a useful means of providing proportionate, cost-effective and timely support.

2) Welfare

To ensure the ethical treatment of snakes throughout the production chain, further research is required on methods employed to transport eggs, hatchlings and adult snakes. Similarly, developing globally acceptable guidelines for the humane slaughter of snakes is an essential aspect for development within the industry, particularly at the international level.

3) Basic snake biology

There are inconsistencies in the level of understanding of the basic biology of snakes amongst farmers. Important gaps in general knowledge include: ectothermic physiology and the effects of temperature on reptile metabolic functions; basic reproductive biology (management of breeding stock, incubation and hatchlings); and the nutritional requirements of snakes. Ironically, the science surrounding many of these subjects is rudimentary compared to conventional livestock, and the needs of the snake farming industry may well present an opportunity to answer some of these fundamental research questions.

4) Feed management

Current feed management systems can be considered the most important component of the snake farming industry given their cost, yet both remain relatively crude and under-developed. Developing scientifically formulated, nutritionally balanced artificial diets and less labour intensive automated feed systems could radically improve management systems. The crocodile farming industry was completely reformed with the advent of artificial vegetable based diets (see Mazuri 2012, Dzirutwe 2014). The unique mechanics of snake feeding behaviour (swallowing prey whole) combined with an automated feed system may well present opportunities to bypass the costly feed palatability criteria that governs most conventional livestock feeds. This would allow farmers to consider a much wider range of feed sources. It would also allow farmers to bypass prey fingerprint issues (see Biological Feasibility) and explore the agricultural potential of a wider range of snake species.

5) Caging

Enclosure design is evolving rapidly but could still benefit greatly from a more systematic approach, based on fundamental, multidisciplinary knowledge. Snake farming is still largely practiced within the classical livestock framework (i.e. modified pig/poultry systems) and few farmers have fully explored the novel opportunities offered by the unique biology and behaviour of snakes. Their arboreal and high density aggregation behaviour suggests there is considerable potential for vertical farming and urban agriculture, and their serpentine, low-impact morphology lends them to sustainable intensification/permaculture/polyculture type applications. Excellent synergies exist between reptilian thermoregulation (e.g. basking) and greenhouse technology, which could open new pathways to a cheap and environmentally friendly source of 'solar powered' animal protein.

6) Conservation

Some snake species display the biological and economic prerequisites required for wild harvest or ranching programs, and could benefit from the development of a market-based conservation model.

Adding a commercial value to small fragmented habitats and threated snake species therein may provide local incentives for biodiversity conservation in unlikely places. Of particular interest are the buffer zones around protected areas in Viet Nam and the limestone cast outcrops in Quangxi province; areas which are of limited interest to agriculture or megafauna conservation but which present perfectly suitable habitat for snakes (fig. 9). Basic biological and ecological research and a precautionary principle approach would be essential first steps.

Fig 9. *This isolated outcrop in Viet Nam retains inaccessible fragments of indigenous forest but is otherwise surrounded by intensive agriculture (including snake farms). A recent herpetological expedition to the area confirmed the persistence of a population of king cobras (Ngo pers. comm.). Situations like these offer potential for a market based conservation model for threatened snake species.*

7) Education

Promoting the development of existing snake schools in China and widening their influence could improve the management of snake production systems as well as provide a much needed dissemination conduit for new developments within the industry. Translation of the subject material into multiple languages (e.g. Vietnamese, Mandarin, Indonesian, Khmer) could be complimented with the creation of multimedia platforms, such as online courses (e.g. youtube 'how to' clips). The existing commercial model already employed by the schools could make this a largely auto generative process (fig. 10).

Fig. 10. *A working electronics model provides a simple, low cost and effective means of teaching farmers how to control temperature in snake farms (Leicun Snake Farming School). This model could easily be explained in a 5 minute youtube clip.*

8) Tourism

Snake farming and the products that result from snake farming have inherent curiosity value and represent an excellent means of educating the general public about snakes and snake farming (Fig 8). Vin Son Village in Viet Nam has already gained a place on the national tourist map, despite minimal effort on behalf of snake farmers and a conspicuous lack of suitable tourist facilities (e.g. safe viewing areas). Many of the farmers interviewed expressed an interest in diversifying and developing new markets, and the creation of a 'snake farm attraction' may be one way of doing this. Those snake farms located close to large cities or existing tourist hubs in particular, may benefit from exploring this option.

9) Small-scale traditional vs modern industrial

As the snake farming industry becomes more established, and international trade becomes more structured, there is a strong possibility that economic forces will encourage vertical and/or horizontal integration. This means that small-scale traditional farms are likely to consolidate into fewer larger farms, and secondary sector stakeholders may invest in primary production facilities. This future scenario was suggested by several snake farmers in Viet Nam who experienced a similar phenomenon with the crocodile farming industry several years ago – an event corroborated and explained by MacGregor (2006).

The costs and benefits of snake farming are complex and not fully understood, but early indications suggest that small-scale farming has merit in terms of sustainable, environment friendly agriculture and rural development. Presenting a strong commercial argument for its persistence may not be easy, but it would be unwise to lose the traditional small-scale model in favour of the modern intensive production system before the relevant criteria have been properly assess. For example, small-scale snake farming exploits a diversity of underutilised small animals and local resources, which indirectly promotes community-based biodiversity conservation and sustainable intensification. Due consideration is recommended in issues relating to policy, government support and trade controls.

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