Sustainable Management of the Trade in Reticulated Python Skins in Indonesia and Malaysia

Natusch, D.J.D., Lyons, J.A., Mumpuni, Riyanto, A., Khadiejah, S., Mustapha, N., Badiah, and Ratnaningsih, S.

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Species Survival Commission

Boa & Python Specialist Group

KERING

International Trade Centre

A REPORT UNDER THE 'PYTHON CONSERVATION PARTNERSHIP' PROGRAMME OF RESEARCH

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Cover photo: Reticulated python skins stacked at a processing facility in Central Kalimantan, Indonesia. © Jessica A. Lyons

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1 The Python Conservation Partnership is a collaboration between Kering, the International Trade Centre (ITC) and the Boa and Python Specialist Group of the International Union for Conservation of Nature (IUCN SSC Boa & Python Specialist Group). See Executive Summary for greater detail.

EXECUTIVE SUMMARY

RATIONALE AND AIMS

"*Sustainable Management of the Trade in Reticulated Python Skins in Indonesia and Malaysia*" is the second report delivered by the Python Conservation Partnership (PCP). The PCP is a collaboration between Kering, the International Trade Centre (ITC) and the International Union for Conservation of Nature (IUCN SSC Boa & Python Specialist Group) that was established in November 2013 to contribute to a robust and sustainable python skin trade and to facilitate industry-wide change. The PCP's research program focuses on developing science-based recommendations to improve sustainability of the python skin trade, and through enhanced transparency ensure benefits for local livelihoods and high standards of animal welfare.

This report describes the results of an intensive field-based research program over the last three years. We use this information to inform recommendations for the implementation of systems to facilitate sustainable management of the trade in wild pythons.

Each year, approximately 300,000 reticulated pythons (*Python reticulatus*) are harvested from the wild in Indonesia and Malaysia to supply skins for the international trade in exotic leathers. Concerns have been raised about the sustainability of such a high level of off-take, along with issues related to illegal trade and humane treatment of snakes. Specifically, reservations have been expressed that the management frameworks in these countries are insufficient to ensure international trade is not detrimental to the survival of reticulated pythons in the wild. For example, since 2002, the European Union has implemented a ban on imports of wild-sourced reticulated python skins from Peninsular Malaysia due to concerns about harvest sustainability.

To address the concern around harvest sustainability and to incentivize legal trade, the Python Conservation Partnership, members of the IUCN SSC Boa & Python Specialist Group, and scientists from Indonesia and Malaysia, undertook an intensive program of research to provide recommendations for managing and regulating harvest and trade in wild reticulated pythons. More broadly, this work aims to contribute to the design of systems to improve confidence in the sustainability of the trade for importing Parties (countries), policy makers, conservationists and other key stakeholders. Our recommendations are based on two important principles:

1) Science-based data collection and a detailed knowledge of the biological traits and trade dynamics of reticulated pythons.

2) Pragmatism to ensure rapid integration of systems and tools into the python skin value chain with minimal economic impact and effort.

The key sources of data were:

a. Interviews with stakeholders throughout the trade chain, and

b. An intensive biological research program to collect data from pythons harvested from the wild between September 2014 and May 2016, focused on nine of the largest python processing facilities in Indonesia and Malaysia.

KEY RESULTS OF THE RESEARCH PROGRAM

Conclusions are based on examination of 7,019 wild-sourced reticulated pythons harvested for trade in five regions of Indonesia and Malaysia. The biological results presented here inform and underpin the management strategies presented in this report. Specifically, these are:

- At all sites, female reticulated pythons grow longer and heavier than males.
- There are statistically significant differences in mean body sizes of pythons among locations, but the magnitude of such variation is minor (< 10%).
- Male reticulated pythons mature at smaller body sizes than females, with 99% of males in the sample being sexually mature compared to 76% of females.
- Approximately 50% of female reticulated pythons reach sexual maturity at 255 - 265 cm snout-vent length (SVL)
- Geographic differences in the relative numbers of immature snakes (of both sexes) among the sample of harvested animals reflect body size differences among sites, rather than geographic variation in sizes at maturity. Minimum sizes at sexual maturity accord strongly with previous studies on reticulated pythons in Sumatra (Shine et al. 1999).

In addition to the examination of biological characteristics, the dried and crust-tanned skins of 1,502 reticulated pythons were measured to document the relationship between skin size and the size of live snakes from which they came.

- All measurements made on dried skins exhibited strong relationships with the size of the live pythons from which they came. Therefore, skin sizes can be used to easily and effectively regulate the size of harvested snakes.

KEY FINDINGS ON THE MANAGEMENT OF WILD HARVESTS

Indonesia and Malaysia currently use quotas as a tool for regulating harvests and trade in pythons. These quotas appear to be lower than the total offtake python populations can sustain. The evidence underpinning this conclusion has revealed that, despite intensive harvesting over a 20-year period, the numbers, sex ratios, body sizes, fecundity, and size at sexual maturity of pythons have not changed. The detailed results of this research can be found here:

Natusch D.J.D., Lyons J.A., Mumpuni, Riyanto, A. & Shine R. (2016). Jungle Giants: Assessing Sustainable Harvesting in a Difficult-to-Survey species (Python reticulatus) PLoS ONE 11(7) http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0158397

This disconnect between the quota system and the sustainable offtake level has created a management situation that is inappropriate for the socio-economic context in which trade is taking place (whereby hundreds of thousands of people rely on harvesting snakes to enhance their livelihoods). Consequently, skins are harvested in excess of the quotas. This, in turn, leads to some skins entering trade illegally and creating compliance problems such as smuggling, laundering and falsification of CITES permits. A similar situation has arisen due to the European Union import ban on reticulated python skins from Peninsular Malaysia. Somewhat paradoxically, we conclude that the current system of quotas and trade bans has created problems, while at the same time conferring no apparent benefits for management of wild python harvests. Clearly, alternative management tools and approaches are urgently required. Based on the results of our research program, we provide the following specific conclusions and recommendations for sustainable management of the harvest:

Re-evaluate the quota system and identify alternative approaches: Explore novel management approaches that are more effectively linked to science-based principles for sustainable use. To assist the development of management alternatives, we provide the following specific conclusions from our study:

a. Inappropriate management frameworks based on harvest quotas are creating incentives for illegal trade.

b. Managing harvests using skin size limits, rather than quotas, will eliminate much of the incentive for illegal trade and will provide a 'precautionary approach' for managing offtake.

c. Implementing sustainable sourcing policies focused on the capture of live snakes > 240 cm SVL can support harvest sustainability and "non-detrimental" trade in wild pythons.

d. A live snake of 240 cm SVL corresponds to a dried skin with a length of approximately 280 cm and belly width of 30 cm; this may be a useful minimum size limit for dry skins entering trade.

e. Skin size limits are easily regulated using simple measurements of length, width and scale dimensions of dry skins.

Re-evaluate trade bans: Trade bans and/or unrealistic trade provisions are unlikely to reduce the number of snakes captured and may create incentives for non-compliance.

Implement ongoing monitoring and data collection: Ongoing data collection and monitoring is essential for determining trends in wild python populations and for ensuring ongoing ecological sustainability. Specific recommendations include:

a. Two forms of data collection and harvest monitoring should be undertaken: (1) compulsory data collection and annual monitoring of processing facility trade records, and (2) independent facility monitoring by trained biologists.

b. A management system for reticulated pythons should operate in an adaptive manner to allow flexible changes to be made based on the results of monitoring.

Implement holistic management systems: Effective management requires a suite of actions and approaches. In addition to implementing size limits and undertaking ongoing monitoring, elements of a successful management system should include:

a. Clear standards and capacity development in best practice for the collection and monitoring of harvest data (with verification against these standards).

b. Complimentary use of methodologies (e.g. stable isotopes) for preventing the laundering of skins by verifying their geographic origin and source (i.e., wild vs. captive-bred).

c. Traceability can form an important part of any successful management system, but needs to be logistically simple and cost-effective (commensurate with the benefits of trade).

Funding and resources: To support the implementation of improved management in the python skin trade, an independent dedicated funding mechanism needs to be created. This fund could be supported by the end-users of python skins (e.g., tanneries and/or fashion brands). Further work is needed to gather input from all stakeholders on the design, governance, and implementation of such a funding mechanism.

Consistent commitment: Industry change will not occur without a sustained commitment to sustainability by the end users of python skins that is formalized in transparent sustainable sourcing policies and actions.

Broader significance: Many of the management recommendations provided here are applicable to the trade in other reptile species and can form the basis of CITES non-detriment findings.

SPECIFIC RECOMMENDATIONS FOR STAKEHOLDERS

For Range State Authorities

1) The Indonesian Directorate General of Biodiversity Conservation (PHKA) and Department of Wildlife and National Parks of Peninsular Malaysia (PERHILITAN) are encouraged to explore alternatives to quotas for managing and regulating trade in reticulated python skins.

2) The European Union and the Malaysian CITES Management Authority should actively engage to address the compliance problems created by the ban on imports of python skins from Peninsular Malaysia.

3) Regardless of the management systems adopted for ensuring sustainable and legal trade in python skins, Range States should implement and/or continue ongoing monitoring programs.

For end-users and industry

1) Industry should promote and implement best practices for a holistic management system that enables continuous assessment of sustainability, adaptive management, legal compliance, humane treatment, and the development of capacity at all points within the supply chains.

2) Industry should commit to sustainable sourcing policies, that are clearly communicated throughout the supply chain, complement regulations, and that are enforced by purchasing practices.

3) Industry should adopt traceability systems that are simple and applicable to many stakeholders rather than technologically, logistically, and financially burdensome systems.

4) End-users of python skins should support a dedicated funding mechanism (independent of domestic levies on trade) for ongoing monitoring, enforcement, capacity development, and research to ensure sustainable trade. This fund should be created with full stakeholder input and administered through a transparent governance structure.

5) A broad spectrum of the python skin industry needs to become engaged in improving trade sustainability, communication, and collaboration with other python skin producers/consumers - particularly when deciding upon important issues such as sustainable sourcing, traceability, capacity development, and dedicated funding.

For CITES

1) CITES non-detriment findings for trade in reticulated pythons should focus on drawing conclusions about wild populations by monitoring changes in harvested snakes. This can be most simply and effectively done by collecting records from traders, together with regular and independent monitoring of python processing facilities and tanneries in Range States as well as importing countries.

1.0 INTRODUCTION

1.1 Background, rationale and aims

The reticulated python is the world's longest snake. Individuals have been reliably recorded at over 8.5 metres in length and can attain a mass of 145 kilograms (Barton and Allen, 1961; Murphy and Henderson, 1987). Unsurprisingly, giant reticulated pythons have become creatures of myth and legend, with many elaborate and often exaggerated accounts of encounters by early European explorers (Murphy and Henderson, 1987). Reticulated pythons are also well known to the peoples of Southeast Asia, where the species ranges from India in the west, across Indo-china to Viet Nam and south into the Indonesian Archipelago (McDiarmid et al. 1999). In this region, reticulated pythons have traditionally been captured and sold for their meat, skin, fat, and other body parts, to supply growing demands for protein through to traditional medicines (Groombridge and Luxmoore, 1991; Shine et al. 1999). Since the early 1900s, however, demand from European garment-makers for exotic leathers has stimulated a significant trade in reptile skins worldwide (Jenkins and Broad, 1993). This industry has grown substantially over the past half century and several reptile species are commercially harvested from the wild and exported in large numbers to supply this trade (Erdelen, 1997; Kasterine et al. 2012).

Today, approximately 300,000 to 450,000 reticulated python skins are exported from Southeast Asia each year (Kasterine et al. 2012; Ashley, 2013). These skins are sourced primarily from the wild in Indonesia and Malaysia, although closed-cycle breeding farms (particularly in Viet Nam) are producing small but growing numbers (Natusch and Lyons, 2014). International trade in reticulated pythons is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which aims to prevent overexploitation of species by trade. Nonetheless, conservationists, government authorities and industry have expressed concerns about the sustainability of the wild reticulated python harvests in Indonesia and Malaysia, owing largely to the high volumes exported annually and preconceptions about the ecological characteristics of the species (Groombridge and Luxmoore, 1991; Kasterine et al. 2012; Natusch et al. 2016).

These concerns are understandable. Intuition suggests that removing 300,000 individuals of a large-bodied apex predator from an ecosystem each year would have serious implications for the persistence of the species in the wild. Although strong evidence exists that harvesting of wild pythons is sustainable (Shine et al. 1999; Natusch et al. 2016), there remains little confidence that the management structures in place are adequate to prevent pervasive declines if negative impacts are detected. Parallel concerns about the welfare of pythons in trade, and evidence of illegal activity within the industry, have prompted governments and NGOs to question the ethics of this trade.

The current report is the result of several years of research on the biology, trade and management of reticulated pythons in Indonesia and Malaysia. The purpose of this document is to: (1) inform readers about the background and context of trade, (2) identify real rather than perceived problems, (3) suggest ways to improve management and monitoring systems for wild harvests of reticulated pythons, and (4) contribute to helping Indonesia and Malaysia develop methodologies to comply with CITES "Non-detriment Findings"[2]. To do this, the report is structured around the following questions:

1) What is the history of trade and why is improvement within the industry necessary?

2) How is trade operating now?

3) What are the results of the PCP's intensive research program and how can they inform improved management and regulation of trade?

4) What key principles are required for a successful management program?

5) What are our recommendations for improvement of this trade?

[2] See Page 13 for further information on CITES Non-detriment Findings

1.2 Methodology

Several of us have conducted research on the biology and trade of reticulated pythons over the past 20 years. We gathered much information through interviews and anecdotal accounts from people involved in the trade. In addition, between 2014 and 2016, we undertook a detailed research program on the biology of reticulated pythons by collecting data from snakes brought to processing facilities in the main trading areas in Indonesia and Malaysia. The aim of this report is to inform policy on how the trade in reticulated pythons can be better managed and regulated. For this reason, and for ease of reading, we have omitted detailed methodologies and results of statistical tests. Where necessary, we have provided the methodologies used to reach specific conclusions discussed in this report. Detailed methodologies and results will be published elsewhere within peer-reviewed scientific journal articles (e.g., see Natusch et al. 2016); some methods are already published (Shine et al. 1998 and 1999).

Biological data collection

Between September 2014 and May 2016 we visited nine processing facilities at five sites in Indonesia and Malaysia to collect data from reticulated pythons harvested for trade (Table 1). We evenly spaced our visits throughout the year and focused on areas in both countries where the highest volumes of trade were occurring and thus where most data could be gathered. At each processing facility we recorded snout-vent length (SVL) and body mass of pythons immediately after they were killed. We stretched pythons as much as physically possible before SVL was recorded. After skinning, we examined the python's carcasses to determine sex and reproductive condition (by direct inspection of the gonads). We classified males as mature if they had convoluted efferent ducts (indicating the presence of sperm). We classified females as mature if they had thickened muscular oviducts, vitellogenic ovarian follicles (classified based on size and colouration), and primary follicles larger than 8 mm in diameter and/or corpora albicantia from previous reproductive events.

Table 1. Locations of python processing facilities, timing of visits and number of pythons examined in Indonesia and Malaysia between September 2014 and November 2015.

Country	Province	# facilities visited	# pythons examined	Visitation dates
Indonesia	North Sumatra	3	1027	November, February, May, September
Indonesia	South Sumatra	3	1364	October, February, May, August
Indonesia	Central Kalimantan	1	923	November, February, May, September
Malaysia	Selangor	1	2244	June, August, November, May
Malaysia	Johor	1	1461	June, August, November, May

Relationships between sizes of live snakes and dry skins

At each site we tagged a sample of skins (1,502 in total) to determine the relationship between the SVLs of live pythons and their dried skins. We measured the length and width (at the widest point) of each skin using a steel ruler. We also measured the width of a mid-body ventral scale and an adjacent dorsal scale using digital calipers (see Fig. 7 for an example). All measurements were taken 24 hours after each snake was skinned (when the skin was completely dry).

Tannery trials

We measured dry skins before and after they had been crust-tanned[2] to determine how the tanning process changes the dimensions of python skins. To encompass variation in tanning techniques between different facilities, we obtained measurements of crust-tanned skins from tanneries in Italy, Indonesia and Thailand and took the same measurements as described above.

Interviews

We conducted a mixture of semi-structured and informal interviews with hunters, agents, processing facility owners, tanners, exporters, and provincial and national regulatory authorities. We asked questions about how the trade operates, current issues in trade, and how they believed trade could be improved (for example, see Nossal et al. 2016).

[1] Leather that has been tanned, dyed and dried, but not finished

1.3 CITES and the history of concern

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) came into force on 1 July 1975 with the aim of preventing overexploitation of species by international trade. Species that are threatened with extinction, and may be affected by trade, are listed within CITES Appendix I. Appendix II includes species not necessarily threatened with extinction, but in which international trade must be controlled in order to avoid utilization incompatible with their survival. From the outset, several reptilian groups (boas, pythons, monitor lizards, crocodilians) were included within the CITES appendices because of high levels of international trade, known population declines (e.g., the Indian python, *Python molurus molurus*), and/or the difficulty of identifying skins and other products of different species by customs officers. Today, all but one species of python are listed in CITES Appendix II[3]. This listing requires countries that are signatory to CITES (referred to as Parties) to ensure that any trade in these species will not be detrimental to wild populations, is legal, and is based on a system of permits and certificates.

Public interest in the python trade is typically prompted by concerns about the welfare of pythons, severe fluctuations in harvest volumes, or evidence of illegal trade activities (Kasterine et al. 2012). This focus has resulted in increasing pressure on range States (countries where pythons naturally occur) to meet their obligations to the CITES Convention by proving harvest sustainability. In response, many studies have been undertaken to provide recommendations on how to improve regulation of this trade (see Table 3). In some cases, this has resulted in changes to trade regulation. For example, in 1987 Indonesia implemented harvest quotas in an attempt to enhance sustainability; and in 1991, the CITES Secretariat recommended that Indonesia tag skins of several reptile species (including pythons) to improve trade transparency (Siswomartono, 1998). Despite these improvements, concerns about the sustainability of trade persist.

Reticulated pythons and CITES Non-Detriment findings

Reticulated pythons were not threatened by international trade when they were listed in CITES Appendix II in 1976[4] (and there remains little evidence that they are threatened today). Nonetheless, under Article IV of the CITES Convention, legal exports of Appendix II species require proof that trade is not detrimental to their survival in the wild before an export permit can be granted. Trade can therefore only take place when:

(1) The designated Scientific Authority of the exporting Party has advised that trade will not be *detrimental to the survival of the species in the wild*, and

(2) Once exports are underway, the Scientific Authority has monitored the actual levels of export to ensure that the species *is maintained throughout its range at a level consistent with its role in the ecosystem and well above the level at which the species might become eligible for inclusion in Appendix I*.

This proof has become known as the CITES Non-detriment Finding (NDF). NDFs can include information on population status, distribution, population trends, harvest, trade, and other biological and ecological factors of the traded species, as appropriate. The Party importing the wildlife product determines whether the NDF for a particular export sufficiently verifies "non-detriment". In many cases, reservations have been expressed that NDFs completed for harvests of reticulated pythons in Indonesia and Malaysia are not sufficient to reject detriment. Typically, this concern is driven by a lack of information about how python populations respond to harvests. The highly cryptic nature and vast geographic distribution of these snakes make determining wild population sizes virtually impossible (Natusch et al. 2016). As a result, new approaches are urgently needed for assessing sustainability and non-detriment for this species.

[3] The Indian Python (*Python molurus molurus*) is the only python species listed in CITES Appendix I.

[4] All species of python (threatened by trade or not) were listed in the Appendices of CITES under lookalike provisions.

Reticulated pythons and the review of significant trade

When significant levels of trade in a species are identified, and coincide with concerns that a Party's NDF may not be sufficient to reject detriment, the species may be selected for the Review of Significant Trade (RST) process. If a species is selected for review, the CITES Secretariat notifies range State(s), providing an explanation for the selection, and requests information relevant to the implementation of Article IV regarding NDFs. If the response of the range State(s) is deemed satisfactory, the species is eliminated from the review. Conversely, if the information is considered unsatisfactory the Secretariat (or in some cases consultants) compile information on the biology, management and trade of the species and, where necessary, engage the range State(s) or relevant experts to obtain additional information. For species deemed to be of possible concern, recommendations are formulated, and the range State(s) must report to the Secretariat on the implementation of those recommendations within a specified time period. The CITES RST is thus essentially a species-specific non-compliance response mechanism aimed at determining if current levels of harvest and export are sustainable. The reticulated python has been selected for the RST on two occasions (initiated in 1991 and reintroduced into the process in 2011). For most range States, the reticulated python has been eliminated from the review. However, under the most recent review (which is ongoing), Lao People's Democratic Republic and Malaysia are classified as "possible concern". These countries must now comply with recommendations for the implementation of Article IV.

1.4 Reticulated pythons and the European Union

The European Union (EU) is the largest importer of reticulated python skins, owing to the long-established industry of European fashion brands using exotic leathers. CITES is implemented within the EU's 28 member states through Council Regulation (EC) No. 338/97 (the Basic Regulation) and Commission Regulation (EC) No. 865/2006 (the Implementing Regulation), known more generally as the EU Wildlife Trade Regulations (European Commission, 20115). These regulations are broadly complementary to CITES (UNEP-WCMC, 2009), but are stricter in their application by allowing the EU to suspend the import of certain species from certain countries (known as the *Suspensions Regulation*; Regulation (EC) No. 338/97). Members of the CITES Scientific Authorities of the EU's member states form the European Union Scientific Review Group (SRG), which meets three times per year to evaluate trade transactions for species/country combinations and form opinions on whether imports comply with the conservation requirements of the Regulation (European Commission, 2015). Trade suspensions are usually implemented after the SRG forms a "negative opinion" on the import of a species from a particular range state and after the Party in question has been consulted. Once a negative opinion is formed, all import permit applications for that species/country combination will be rejected.

The CITES Management Authority of an individual EU Member State, under the advice of the Scientific Authority, can also form a negative opinion independent of the SRG and stop issuing import permits for that species/country combination. This decision is then reported to the Commission, who in turn inform the remaining EU Member States to refrain from issuing import permits for that species/country combination until concerns can be addressed at the next SRG meeting. At the time of writing, imports of reticulated python skins from several countries are subject to EU suspensions (Table 2). However, most of these relate to wild specimens from countries where wild populations are small or depleted (e.g., Singapore, Viet Nam). The prominent exception is the suspension on imports of wild-sourced reticulated python skins from Peninsular Malaysia, which has been in place since 2004 after a negative opinion was formed in 2002 (information on EU Decision here; Table 2). The justification for this suspension is unclear, but the impacts are far-reaching (Nossal et al. 2016; see Section 1.8 for further detail).

Table 2. Summary of European Union Scientific Review Group (SRG) opinions on the trade of reticulated pythons from different countries.

Range state	Opinion	SRG/Date of recommendation	Comments
Bangladesh	Suspension	22/12/1997	
Bangladesh	No opinion	22/02/2000	
Cambodia	Suspension	22/12/1997	
Cambodia	No Opinion	22/02/2000	
Indonesia	Negative	16th/(22/2/2000)	
Indonesia	Positive	18th(7/11/2000)	
Indonesia	No opinion	62nd/(7/12/2012)	Positive opinion removed
Indonesia	Positive	64th/(28/05/2013)	Positive opinion reinstated
Malaysia	Negative	24th/(5/9/2002)	
Malaysia	Suspension	30/04/2004	
Malaysia	Suspension	28/05/2015	Suspension confirmed
Singapore	Suspension	22/12/1997	All Wild specimens
Singapore	No opinion	55th/(11/3/2011)	Recommend suspension removal
Viet Nam	Negative	62nd (7/12/2012)	Wild specimens
Viet Nam	No opinion	8/12/2014	Wild specimens

1.5 Attempts to address concerns

The need to ensure sustainability of reticulated python harvests in the face of growing conservation concern is clear. Numerous individuals and organisations have directly addressed this issue by undertaking studies on this species and its trade (Table 3). It is important, therefore, to understand what is contained within these works, what knowledge gaps remain, and how these can be filled. The fundamental constraint for all studies on reticulated pythons is the difficulty of accurately surveying and thus quantifying wild python populations. As a result, knowledge of the impacts of harvesting is scarce, and new monitoring approaches are urgently needed to fill this gap.

Table 3. Summary of studies examining the harvest of reticulated pythons.

Reference	Year	Focus	Scope
Chairuddin et al.	1990	Indonesia	Provincial study of trade and sustainability
Groombridge & Luxmoore	1991	Global	Review of reptile skin trade
Jenkins & Broad	1994	Global	Review of reptile skin trade
Webb et al.	1995	Indonesia	Literature review and interviews
Erdelen et al.	1997	Indonesia	Overview of harvest impacts based on field studies
Abel	1998	Indonesia	Population field study
Riquier	1998	Indonesia	Population field study
Shine et al. a, b, c	1998	Indonesia	Biology of pythons harvested for trade
Shine et al.	1999	Indonesia	Review of biology and trade monitoring methods
Auliya	2006	Indonesia	Population field study
Webb et al.	2011	Global	Review of reptile skin trade
Kasterine et al.	2012	Global	Review of global trade chain
Wardhani	2012	Indonesia	Studies of habitat use and trade
Siregar	2012	Indonesia	Evaluation of livelihood impacts of trade
Khadiejah	2013	Malaysia	Biology of harvested pythons for CITES NDF
Ashley	2013	Global	Review of traceability systems for python skins
Silalahi	2014	Indonesia	Studies of habitat use and trade
Natusch & Lyons	2014	Global	Analysis of python farming
Nainggolan	2014	Indonesia	Biology of harvested pythons
Natusch et al.	2016	Indonesia	Sustainability of python harvests

1.6 What are the challenges with trade?

Harvest sustainability and animal welfare are often cited as major problems in the global trade of reticulated pythons. However, the concern underlying these issues is not based on scientific evidence or investigation. Harvests of reticulated pythons in Indonesia and Malaysia have remained high for decades (Table 5). The species' life-history traits (e.g., rapid growth, high fecundity) render it resilient to high levels of offtake (Shine et al. 1999). Furthermore, over the past 20 years the number of snakes brought to processing facilities in Sumatra (a major harvesting area) has remained constant, as have body and maturation sizes of harvested snakes (Natusch et al. 2016). Thus, there is strong evidence that a level of sustainability has been achieved.

In addition, both Indonesia and Malaysia practice humane killing methods, which rely on destruction of the brain before skinning (Swiss Federal Veterinary Office, 2013). To ensure there is a clear understanding and adherence to best practice, workshops and trainings have been underway over the last three years, particularly focused on improving the techniques used by Vietnamese industry (Natusch unpubl. data). It appears, therefore, that general assertions of population crashes and inhumane practices cannot be substantiated. Misgivings about significant levels of illegal trade, however, do have substance. Python skins appear to be illegally transported between Southeast Asian countries to circumvent national quotas or international trade bans (Kasterine et al. 2012; Table 4). In addition, misuse of CITES permits has allowed python skins sourced from the wild in some range States to be falsely re-exported using "captive-bred" source codes. Specifically, skins may never leave the country of origin, yet the false permits give the impression that legally imported skins are being re-exported (Natusch unpubl. data). Illegal trade of python skins is a problem because it: undermines the rule of law, avoids taxes, makes accurate monitoring of harvests impossible, and jeopardizes legal and sustainable python trade.

Table. 4. Examples of media articles reporting on illegal trade of reticulated python skins.

Sibon, P 2011 '**16,000 python skins destroyed**', *Borneo Post* 19 Jan. Available from: http://www.theborneopost.com/2011/01/19/16000-python-skins-destroyed/
Vijayan, KC 2005 '**Seized: 500 kg of python skins**', *The Straits Times* 30 Jul. Available from: http://www.wildsingapore.com/news/20050708/050729-3.htm
Singapore Immigration and Checkpoints Authority 2004 '**Smuggling of 31 bales of python and lizard skins**', *Case Detected at Checkpoints* 2 Nov. Available from: http://www.ica.gov.sg/news_details.aspx?nid=7268
Leow, J 2005 '**Customs officers foil attempt to smuggle python skins into Singapore**', *Channel NewsAsia* 29 Jul. Available from: http://www.customs.gov.sg/insync/Issue20/article_3.html

1.7 Why is illegal trade occurring?

If illegal activity is the major concern for trade in *P. reticulatus* skins globally, then what are the drivers? Like many illegal activities, common problems like greed and corruption play a role here. However, the major drivers are much simpler, are incentive-based, and thus can be addressed.

We argue that three interacting variables create incentives for illegal trade in reticulated python skins: (1) poverty, (2) abundant populations of snakes, and (3) quotas and trade bans. Both Indonesia and Malaysia implement quotas to regulate the number of wild pythons harvested each year. Establishing a quota effectively complies with the CITES requirement of making non-detriment findings, and simplifies management and administration at national and provincial levels (CITES, 2015). Although quota establishment is a national decision, the quotas currently implemented by Indonesia and Malaysia are strongly influenced by input from external Parties and stakeholders (Saputra, 1998). For example, historically Indonesia has implemented quotas based on the preceding year's harvest (Webb et al. 2000). However, the quota has been methodically reduced because of external concerns about population sustainability, and a lack of effective population monitoring to prove such harvest levels can be sustained. Because local people continue to harvest pythons to improve their livelihoods, a situation has been created whereby the actual offtake of pythons exceeds the annual harvest quota.

Although a reduction in the national harvest quota may appear to be a conservation success, the reality is quite different. The critical players are large rural populations of poor people (e.g., 40% of

Indonesia's 250 million population live on less than US$2 per day; World Bank, 2015). For people living in poverty, finding a python worth up to US$40 is a significant boost to their livelihood. Cash from the sale of pythons is used for basic necessities, such as feeding and clothing family members, visiting the doctor or buying medicine, and for children's education (Nossal et al. 2016). The Indonesian Ministry of Forestry (PHKA) estimates that 190,000 people are involved in the trade in python skins in the country, mostly at the hunter level. For many of these people, participating in the python trade is not a choice, but an imperative (Hutton and Leader-Williams, 2003). Not surprisingly, every python of marketable size encountered by people is captured and killed for the trade in meat, Traditional Chinese Medicine and/or skins. As a result, more snakes are harvested each year than the quota permits. But rather than waste the excess skins produced, traders find clandestine ways to sell the skins into the market, creating compliance problems. Trade bans by importing countries (such as that imposed by the European Union on exports of *P. reticulatus* skins from Peninsular Malaysia) can exacerbate the situation. The significant loss in revenue experienced by the Malaysian industry as a result of the EU trade ban created incentives to circumvent this ban and continue trading into the EU. In effect, these restrictions on harvest and trade merely create illegality without improving the conservation situation for pythons, or indeed addressing a valid conservation problem. That situation continues to create compliance problems and blemish the image of the python trade more broadly.

1.8 Should trade bans be considered?

Opponents of the trade in python skins lobby strongly for banning trade, or preventing countries from harvesting pythons from the wild. Although imposing a ban may appear to benefit python conservation, it is important to understand the potential impact of that management option on pythons in these countries, and the people relying on them (Weber et al. 2015). Asian snakes have been traded for a variety of purposes for centuries (Natusch and Lyons, 2014; Aust et al. 2016). Banning the international trade in skins is unlikely to discourage people from harvesting snakes, which will continue to be used for the domestic leather industry, traditional medicines and food. In fact, in several parts of Southeast Asia (Sabah and parts of Kalimantan, Indonesia), reticulated pythons are not sold into the skin trade because they are more highly valued for local consumption (food) (Natusch unpubl. data). The main effect, therefore, will be a reduction in the incomes of poor rural people. Secondly, there is no conservation justification for trade bans because there is no evidence that trade is unsustainable, and several lines of enquire suggest that it is (Shine et al. 1999; Natusch et al. 2016). Trade bans will not enhance harvest sustainability if the trade is already sustainable.

The harvest and trade of reticulated python skins from Malaysia provides a noteworthy example. The European Union (EU) ban on imports of wild reticulated pythons from Peninsular Malaysia was implemented due to concerns about harvest sustainability. The goal of the ban was to remove the European market for Malaysian python skins, in the hope of decreasing demand for skins and thus enhancing conservation of wild pythons in Malaysia. In reality, however, the ban resulted in a market shift to Asia, rather than reducing the total catch of wild pythons in Malaysia (Morgan, 2002; UNEP-WCMC, 2014). The EU ban resulted in a 30% loss in value per skin due to lower prices offered by the Asian market (Kasterine et al. 2012; Nossal et al. 2016). The negative impact of such a ban on the livelihoods of people in Malaysia is clear, but it remains unknown what other adverse impacts may have arisen. For example, anecdotal evidence from Malaysia suggests that hunters harvested more snakes following the ban, in order to maintain their income (Morgan, 2002; Nossal et al. 2016).

Finally, banning the trade may also remove incentives for local people to implement best-practice industry standards in humane treatment and monitoring of traded snakes. At present, the value attributed to pythons provides end-users of skins with leverage to improve industry standards, which may not be possible if the value of trade is lost to domestic use and/or local consumption. So although the intentions of those calling for a ban on the python skin trade may be laudable, we highlight the importance of understanding the context of trade. Paradoxically, trade bans may in fact jeopardize genuine conservation, animal welfare and sustainable development goals, and restrict the uptake of industry best practices.

1.9 What is a solution?

We propose that the real drivers behind illegal trade are poverty, excessively restrictive quotas, and the opportunity presented by abundant python populations. Acknowledging which problems are real and which are merely perceived is an important first step to improving trade regulation. Rather than addressing symptoms of poor regulatory frameworks, we suggest amending those frameworks to minimise negative incentives. An important first step is to eliminate (or at least increase) the quotas currently used for regulating trade, and to augment those quotas with more effective management strategies. Removing quotas may seem counter-intuitive to conservation goals. The reality, however, is that the same number of snakes will continue being captured each year, regardless of whether quotas are implemented or not. Capture rates are driven by poverty and opportunity, not by externally-imposed regulations. Our report identifies the option of more effective management strategies.

Table 5. Reported imports of *Python reticulatus* skins from 1997 to 2013 (adapted from Ashley 2013; Source CITES-WCMC Trade Database).

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Indonesia	134090	155478	155669	155330	161738	153062	151479	152180	151425	154703	154655	154955	152997	151720	150486	157500*
Lao PDR	59*	351*	100*	2*								5000*	20000*	88000*	131400*	24003*
Malaysia	137038	170016	281972	189691	170127	72842	121270	147472	166508	113721	168787	120761	105874	128639	143193	160051
Thailand									1819	756		10	1176	1000	1005*	87*
Viet Nam	25840*	47571	28600	27299	44859	44859	35061	47957	75182	97954	93248	98854	111958	124582	46158	22855
Total	**297027**	**373416**	**466341**	**372322**	**270763**	**270763**	**307810**	**347609**	**394934**	**367134**	**416690**	**379580**	**392005**	**493941**	**472242**	**364496**

*Figure derived from export data

2.0 HOW IS TRADE OPERATING NOW?

2.1 Regional context

Although reticulated pythons are distributed in every country in Southeast Asia (McDiarmid et al. 1999), the history of international trade differs considerably among countries. At present, Indonesia and Malaysia are the largest exporters of skins from wild reticulated pythons, owing largely to the widespread and abundant populations of the snakes (Table 5). Several other countries also historically harvested the species from the wild in smaller numbers, but due to diminishing wild populations or legislative changes prohibiting wild collection, they have shifted entirely to closed-cycle captive production (principally Thailand and Viet Nam; Natusch and Lyons, 2014). Although there are anecdotal claims of captive breeding in Cambodia and Lao PDR, there is no direct evidence to substantiate these assertions (Natusch and Lyons, 2014). These claims are particularly noteworthy in the case of Lao PDR, which has exported increasing numbers of *P. reticulatus* skins (claiming a captive-bred source) over the past several years and has recently been subject to a CITES import ban (Table 6).

Singapore is also a significant player in the trade of reticulated python skins. Although the island State does not harvest and export snakes itself, Singapore is a major re-exporter of skins sourced from neighbouring countries. Concerns have been expressed that stockpiling and mixing of skins by traders in Singapore disguises illegally sourced skins, while others have reservations about Singapore monopolising and controlling the python skin market (Kasterine et al. 2012). To mitigate these concerns, in the past Malaysia has implemented regulations whereby the number of python skins exported to Singapore has been restricted to protect local industry. Below we provide detailed information about *P. reticulatus* in Indonesia and Malaysia and the ways in which trade operates and is regulated in these countries.

Table 6. Summary of countries, status, and trade of *Python reticulatus* in Southeast Asia.

Country	Production system	Wild harvest	Status of wild population	Notes
Cambodia	Captive	No	Protected; stable	Anecdotal claims of captive breeding occurring
Indonesia	Wild	175,000	Not protected; stable	Can only export crust-tanned skins
Lao PDR	?	?	?	Despite exports, no evidence of wild harvest or captive breeding occurring
Peninsular Malaysia	Wild	162,000	Protected but hunting allowed; stable	Ban on imports of skins into the European Union
Myanmar	?	?	?	Unsubstantiated reports of wild harvest occurring
Singapore	N/A	No	Protected; stable	Re-export hub, no harvest occurring
Thailand	Captive	No	Protected; stable	Captive breeding only
Viet Nam	Captive	No	Protected; depleted but stable in rural areas	Captive breeding only

2.2 Malaysia

Malaysia is the world's second largest producer of reticulated python skins (Table 5). All Malaysian skins are sourced from the wild and each year a catch-quota is established to limit the harvest of wild snakes (Table 6). Although some trade has been reported from the Malaysian state of Sabah in the past, effectively all current harvest and trade in reticulated pythons occurs in Peninsular Malaysia (Natusch unpubl. data). In 2002, the European Union's Scientific Review Group formed a negative opinion of exports of *P. reticulatus* skins from Peninsular Malaysia due to concerns over the sustainability of harvest. This resulted in a ban on imports of *P. reticulatus* skins into the EU. Malaysia has attempted to address the EU concerns to remove the ban, but these attempts have been unsatisfactory and the ban has remained in place for the past 13 years (for more information see Section 1.4).

How the trade operates

Hunters.- The people capturing wild reticulated pythons in Malaysia are generally farmers, plantation workers, or inhabitants of towns and villages. Many pythons are captured by hand, often opportunistically from the same areas in which people are working. However, pythons are also captured using nets set across small watercourses. The majority (approximately 80%) of snakes captured in Malaysia originate from oil palm plantations or secondary regrowth (previously logged primary forest; Nossal et al. 2016). Pythons captured for skins are transported alive in dry sacks to processing facilities where they are sold by the kilogram.

Processing facilities and exporters.- There are 23 registered python processing facilities in Peninsular Malaysia, 11 of which also export raw skins internationally. Although all processing facilities purchase pythons brought in by local hunters, most employ agents who travel throughout Peninsular Malaysia collecting pythons captured by local people. Processing facilities purchase pythons by the kilogram (kg). The mean price is approximately USD 3.5/kg (N = 38; SD = 0.8; range = USD 2.5–5.6/kg), depending on the skin quality. Pythons with very damaged skins receive a price of USD 1/kg or are purchased for a single price at the buyer's discretion. Large pythons (>12 kg), or pythons with particularly high quality skins can receive a "top-up" amount in addition to the per kilogram price. The size of processing facilities varies substantially, with some small households processing fewer than 10 pythons per day, while others can process up to 300 per day in the peak season. Skins are sold primarily to Asian markets such as China, Japan, Singapore, and Korea. Python meat is sold both locally or to a python meat processor for export. Python gall bladders are sold individually for the domestic trade in Traditional Chinese Medicine.

Tanneries and meat processing.- Malaysia has one python skin tannery, which processes both crust and finished skins for international markets. A single meat processing company currently purchases wet python meat from processing facilities and exports it dried to China for human consumption.

Trade regulation

Malaysia acceded to CITES in 1977. The trade in reticulated pythons is regulated by the Department of Wildlife and National Parks Peninsular Malaysia (*Jabatan Perlindungan Hidupan Liar dan Taman Negara*; PERHILITAN), which acts as the CITES Scientific Authority. Together with the Malaysian Ministry of Natural Resources and Environment (NRE), PERHILITAN also acts as the CITES Management Authority. The reticulated python is a protected species in Peninsular Malaysia, but hunting of the species is allowed by the Wildlife Conservation Act 2010 (Act 716) under the following conditions:

i. Only licensed hunters are legally permitted to catch *P. reticulatus* using nets or by hand. No shooting or destructive methods are allowed.

ii. A licence allows a hunter to capture a maximum of 50 pythons, which is valid all year. Hunting is allowed between the hours of 0700 to 1900 (Federal Government Gazette: Wildlife

Conservation (Open Season, Methods and Times of Hunting) Order 2014). A hunter can purchase many licences as they want.

iii. Hunting licenses issued by a state are only applicable for hunting activities within that respective state. For example, if a hunter collects pythons from both Selangor and Perak States, two licenses are required.

iv. Licensed traders are allowed to source their pythons from licensed hunters or other licensed traders. Every trade transaction must be recorded in a logbook provided by PERHILITAN. Transaction details include the date of transaction, number of pythons, source person (with license number), and remaining stock. Enforcement officers check this logbook regularly.

v. CITES exports are issued by CITES registered offices in Kuala Lumpur, Penang or Johor Bahru. When an application for export is submitted, the exporter is required to make the stock available for examination by officers of PERHILITAN. Officers count and record every skin destined for export, and seal and stamp the boxes with unique identifiers held by the department. When the exports are checked by customs, any skin not possessing a PERHILITAN stamp, or having a broken seal, are seized.

vi. State Government has the right to impose additional regulations via the State's Enactments, as natural resources are considered State-owned. Such an enactment has been implemented by the Sultan of Johor, who has forbidden hunting of all animals except feral pigs in the state.

2.3 Indonesia

Indonesia is the world's largest producer of reticulated python skins (Table 5). All pythons are sourced from the wild and each year a catch-quota is established to limit harvests of wild pythons (Table 6). Indonesian law prevents the export of raw (air-dried) skins (*Peraturan Menteri Perdaganan* No.44/M. DAG/ PER/7/2012). Instead, all skins exported must be at least crust-tanned[5], which is a value-adding measure designed to support domestic industry and create employment opportunities. In addition to supplying the export market, Indonesia also has a small but growing domestic industry focused on the finishing, production and retail of leather goods utilizing reticulated python skins. Between 2010 and 2014 Indonesia reported the export of 163,500 reticulated python skin products (finished products rather than crust-tanned skins) (UNEP-WCMC CITES Trade Database 2015).

How the trade operates

Hunters.- The people capturing wild reticulated pythons in Indonesia are generally farmers, plantation workers, or people living in towns and villages. Pythons are captured by hand, usually opportunistically, from the same areas in which people are working. Some pythons are also caught using nets and traps, but this is not the preferred method because it can damage the skin and reduce its value. Although specialised snake hunters exist, most people capturing pythons in Indonesia also have other professions and income sources (Siregar, 2011). Captured pythons are sold live to agents or directly to processing facilities that buy based on the snout-vent length of the python. Significantly, all stages of the harvest and trade in reticulated pythons is closely linked to the capture and trade in other species of reptiles. Many collectors catch other species of reptiles (e.g. *Python brongersmai and Varanus salvator*) at different times of the year to further supplement their incomes.

[5] Leather that has been tanned, dyed and dried, but not finished

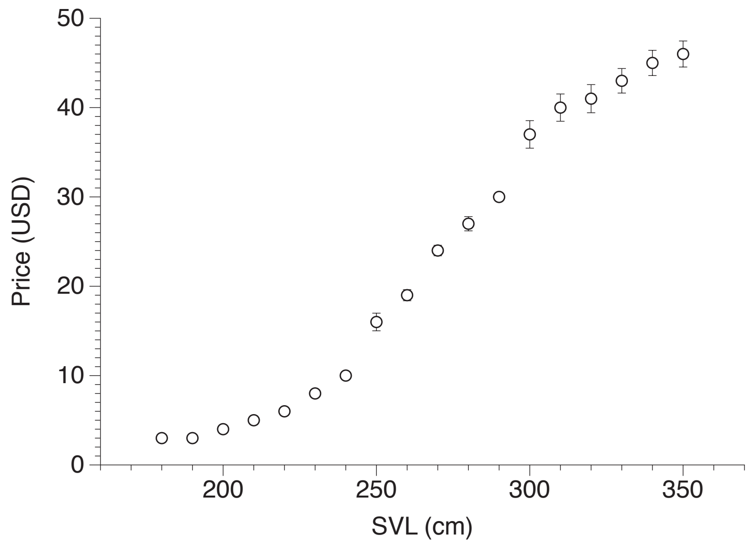

Fig. 1. Mean sale prices (and standard errors) for live reticulated pythons of different snout-to-vent lengths (SVL) destined for the skin trade in Indonesia. Information gathered from processing facility owners (n = 5) and converted into USD on 1 September 2015.

Processing facilities.- Processing facilities purchase live pythons from local people, as well as from agents who bring them from throughout the region. The price paid by processing facilities for pythons of different sizes is shown in Figure 1, although these prices vary depending on skin quality and buyer demand. Pythons are usually kept for a short period of time within individual bags prior to processing. Approximately 20 to 40 pythons are killed and skinned per day, depending on the season. Home processing of pythons is becoming more common, with an increasing number of people choosing to skin snakes themselves rather than sell them to larger processing facilities.

Tanneries and exporters.- There are 14 python skin exporters in Indonesia. These exporters also operate tanneries that process raw python skins to crust or finished leather. The tanneries purchase raw (air-dried) python skins from processing facilities throughout Indonesia and sell the crust-tanned skins to agents in Asia (usually Singapore) or Europe. Some also process through to the finished product, which is then exported under contract (usually to Asian markets).

Trade regulation

Indonesia acceded to CITES in 1978 and has been meeting its obligations since that time (Siswomartono, 1998). The Directorate General of Conservation of Natural Resources and Ecosystems (*Direktorat Jenderal Perlindungan Hutan dan Konservasi Alam*; PHKA) regulates trade in reticulated pythons at the national level and is the designated CITES Management Authority. Provincial responsibilities for trade regulation and management fall to the government's Nature Conservation Agency (*Balai Konservasi Sumber Daya Alam*; BKSDA), which is closely advised on national policy and strategy by PHKA in Jakarta. The Indonesian Institute of Sciences (*Lembaga Ilmu Pengetahuan Indonesia*; LIPI) is the designated CITES Scientific Authority, which advises the PHKA about the status and impacts of trade on wild populations of wildlife.

Reticulated pythons are not protected by national law; nevertheless, permits are required for the capture, transport, sale or export of python skins (*Undang Undang* No. 25/1990). The harvest of wild reticulated pythons is managed using a quota system, currently allowing the collection of 175,000 pythons annually. Ninety per-cent of the pythons caught under the quota (157,500) are allocated for international skin exports, while the remaining 10% (17,500) are reserved for domestic use. In January each year the total catch quota for reticulated pythons is divided among provinces, and then divided among registered python processing facilities by BKSDA. The export quota of 157,500 python skins is divided among the python skin exporters registered with PHKA. Indonesia applies a unique sticker to each python skin destined for export. That sticker contains an ID number that is recorded on the CITES export permit.

3.0 REGULATED SUSTAINABLE TRADE: A MODEL

In this section we present the results of research undertaken to inform the design of a management system for regulated sustainable trade in reticulated python skins. An example of this proposed management system successfully working in practice can be found in Natusch et al. 2015; https://cites.org/sites/default/files/eng/com/ac/28/Inf/E-AC28-Inf-03.pdf

3.1 Quotas – are they useful?

Quotas are currently used for regulating the python skin trade in both Indonesia and Malaysia. Hence it is critical to evaluate the effectiveness of the quota system as a management tool. In Section 1.7 we outline how overly restrictive quotas, in areas where snakes remain plentiful yet income opportunities sparse, can encourage non-compliance in the trade in python skins. The major benefit of quotas is administrative. For example, regulatory authorities in Indonesia allocate portions of the national capture quota among provinces and processing facilities as a means of deriving revenue based on the pro-rata use of the resource, as well as to minimise market monopolisation. Quotas should theoretically limit the number of snakes captured in each province in order to ensure harvest sustainability. In reality, however, the dynamics of trade often result in pythons captured in one province being transported and processed in another, thus reducing the intended benefits of quotas as a management tool (Natusch unpubl. data). Other limitations to the effectiveness of quotas as a management tool include:

Quotas are arbitrary unless underpinned by science.- Harvest quotas are a useful tool for regulating trade if set at sustainable levels. Sustainability can be achieved either through knowledge of vital population parameters (usually determined by field studies) or through experimentation and monitoring to ensure populations are not declining (Sutherland, 2001). However, attempting to enumerate underlying python abundances is fraught with difficulty and potential biases, making it almost impossible to determine population rates. Similarly, the difficulty in monitoring cryptic species, and the complex nature of trade, also makes setting sustainable harvest limits using trial and error problematic (Sutherland, 2001). Setting quotas too low can result in compliance problems (as has occurred with the trade in reticulated pythons); setting quotas too high may compromise harvest sustainability.

Quotas don't account for natural population fluctuations.- Populations of all species fluctuate for a variety of reasons, which quotas do not account for (Sutherland, 2001). When years are favorable and populations are high, quotas create incentives to smuggle or launder the excess through other countries, or keep skins for a bad year in order to "meet the quota". A fixed quota that is above the numbers easily produced during a bad year can also foster an increase in hunting effort and prices to "meet the quota", potentially rendering the harvest unsustainable (Copes, 1986; Sutherland, 2001).

Quotas do not discriminate vulnerable life-stages.- The sustainability of harvests is strongly influenced by the type of animals being captured for trade. For example, a harvest that focuses primarily on immature males is more likely to be sustainable than one that focuses on reproductive females (Shine et al. 1999). Restricting harvests to a specific subset of a population can thus aid sustainability; however, as is the case currently, quotas are non-discriminatory, so do not confer these benefits.

Quotas can mask real trade levels.- Even if quotas are set at sustainable levels, it is impossible to determine actual harvest levels if they are being illegally exceeded (because of the clandestine nature of illegal trade). The consequence of such data fouling is that a harvest may be unsustainable, but that knowledge is masked (Sutherland, 2001). Figure 2 depicts a scenario whereby a quota results in the observed (legal) harvest being constant each year, when in fact the total (legal and illegal) harvest has been steadily declining (which may suggest sustainability has been compromised).

Quotas cannot be easily enforced.- If illegal trade is occurring, determining whether a particular skin is "within" or "in excess of" an assigned quota is rarely possible without other measures in place. Similarly, enforcing separate harvest and export quotas (as in Indonesia) for storable commodities like python skins requires a robust chain of custody. **Quotas are only useful if collectors and traders abide by them and authorities can enforce them** (Copes, 1986).

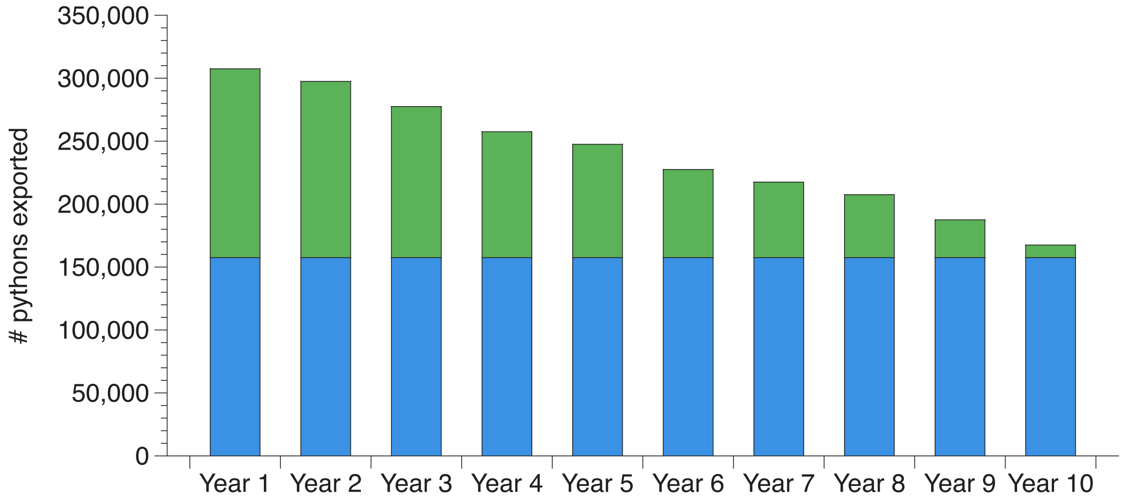

Fig. 2. A scenario where the effect of harvesting is hidden by a quota. The legal exports (blue columns) remain constant, giving the impression that sustainability has been achieved, when in reality the overall harvest has been declining as indicated by the decrease in illegal trade (green columns).

Alternatives to quotas

If a quota is not the most practical tool for regulating harvests of reticulated pythons, then what are some alternatives? Table 7 presents three common alternatives to using quotas and provides a summary of the positives and negatives of each for the trade in reticulated python skins.

Table 7. Positives and negatives of alternative harvest management tools that can be used in place of quotas for regulating harvests of reticulated pythons (modified from Natusch et al. 2015).

Method	Positives	Negatives
Size restrictions	• Can protect specific life stages. • Measurement of trade skin sizes can be used to easily enforce harvest size limits • Size of pythons at maturity is near the minimum size of pythons demanded by trade • Only a finite number of pythons are available for harvest within a given size cohort • Accounts for natural population fluctuations	• Pythons outside the allowed size ranges can be harvested and illegally exported by captive breeding facilities or other countries where size restrictions are not in place • Theoretically, regulators do not have direct control over the yield of the population (as with quotas)
Effort restrictions [6]	• Can naturally limit the number of pythons collected • May allow changes in capture per unit effort to be monitored	• Unrealistic to expect poor people not to collect snakes and therefore difficult to enforce • Does not accord with the opportunistic nature by which pythons are currently captured for trade
Season restrictions [6]	• Harvest could be restricted during important periods in a python's life cycle (e.g., breeding and incubation) • Only a finite number of pythons can be harvested in the specified period • Reduces the time and resources invested during the hunting season	• Unrealistic to expect poor people to cease harvesting during certain periods of the year • Several important periods of a python's life cycle may occur throughout the year (e.g., multiple breeding and incubation events) and therefore may render this harvest management option impractical • Difficult to enforce, with pythons captured outside hunting season being stockpiled, laundered or smuggled • May negatively affect the livelihoods of people who may need to find alternative work during periods when harvest is not permitted

[6] Effort restrictions limit the amount of effort that can be dedicated to hunting (e.g., restricting hunter numbers). Season restrictions limit the hunting season (e.g., hunting is restricted to the winter months).

3.2 Limiting the size of harvested snakes

Evaluation of different management tools suggests that applying specific harvest body-size limits is a more practical method of regulating harvests than quotas. Body-size restrictions should ideally be biologically meaningful, be practical to implement and enforce, and should improve confidence in sustainable trade with minimal economic impact. Before exploring ways to improve collection practices, we use our data to make some broad generalizations about pythons harvested for trade. We base these conclusions on the examination of biological characteristics for 7,019 reticulated pythons harvested for trade in Indonesia and Malaysia

- At all sites in Indonesia and Malaysia, female reticulated pythons grow longer and heavier than males.
- Differences in mean body sizes of pythons among locations (Table 8) are minor. For management purposes, the body sizes of pythons at all sites are remarkably similar.
- Male reticulated pythons mature at smaller body sizes than females, with 99% of males in our sample being sexually mature vs. 76% of females (Figs. 5 and 6).
- Geographic differences in the number of immature snakes of both sexes among sites reflects body size differences among sites, rather than geographic variation in sizes at maturity. Minimum sizes at sexual maturity accord strongly with previous studies on reticulated pythons in Sumatra (Shine et al. 1999).

What could a potential harvest size limit be?

Size limits are commonly used to improve harvest sustainability in fisheries management (Berekely et al. 2004). In fisheries, minimum size limits frequently correspond to the size at which 50% of females in the population have reached sexual maturity (Trippel, 1995). The rationale is that females are not removed from the population until they are given an opportunity to reproduce at least once. This is a precautionary measure used to ensure population recruitment. To determine the size at which 50% of female pythons at different sites reached maturity (hereafter SVL_{50}), we calculated and plotted the proportions of mature pythons (grouped in 10 cm length cohorts) which was best described by a two-parameter logistic function:

$$P_M = [1 + e(-a\,(L - b))]^{-1}$$

where P_M = estimated proportion of mature pythons, L = SVL of pythons (cm) and a and b = coefficients that define the shape and position of the fitted curve. We estimated SVL_{50} for each location by substituting P_M = 0.5 into the equation above and solving for L. This analysis was only conducted for female pythons because 99% of male pythons harvested were mature (Table 8).

Our analyses estimate that the size range of 255 to 265 cm SVL corresponds to the size at which approximately 50% of female reticulated pythons are reproductive at all sites (Table 9, Fig. 3). To propose an actual size limit, we took several other variables into consideration. Firstly, we know that despite pythons of all sizes currently being captured for trade, the harvest is already sustainable (Natusch et al. 2016). Secondly, our analyses rely on the more conservative measure of “already reproductive” females (e.g., the primary criterion for maturity in our study was scars from earlier reproductive events), rather than the size of females at physiological maturity. **Based on these data, we propose that 240 cm SVL is a precautionary, yet practical, size at which industry and regulatory bodies may wish to implement a minimum size limit.** We note again that applying this precautionary size limit may do little to enhance an already sustainable trade. Nevertheless, it will improve the confidence that harvesting can be continue to be sustainable in future, and provide a useful starting point for ongoing trade management.

How would restricting harvests to pythons larger than 240 cm SVL impact the economic profitability of the python skin trade at different sites? Our results suggest a minimum size limit of 240 cm SVL would reduce the harvest by only 9% (range 5 – 15%; Table 7). Perhaps serendipitously, 240 cm SVL is close to the minimum size demanded by the market for skins, and is reflected in the low price paid for snakes of smaller sizes (Fig. 1). The economic impacts of such a size limit will therefore be minimal, and would be recouped by the number of pythons that could be legally exported if quotas were removed.

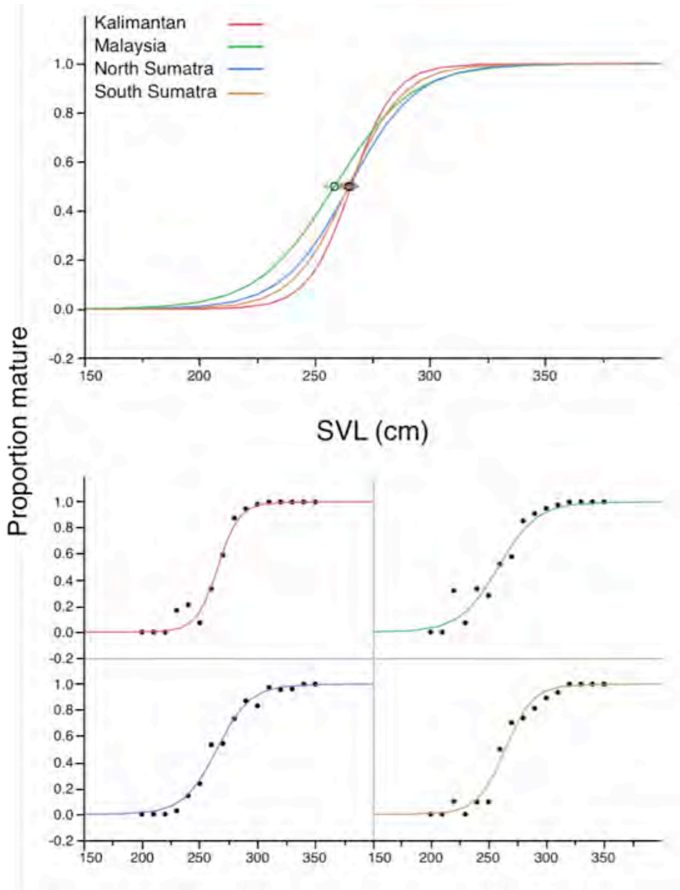

Fig. 3. Proportion of mature (P_M) reticulated pythons by 10 cm length classes harvested for trade at sites in Indonesia and Malaysia.

Table 9. Predicted snout-vent lengths (SVL), standard errors, and 95% confidence limits at which 50% of female reticulated pythons are sexually mature (reproductive) at sites in Indonesia and Malaysia.

Location	Predicted SVL	Std Error	Lower 95%	Upper 95%
Kalimantan	265.7	1.44	262.9	268.5
Malaysia	259.1	1.86	255.4	262.7
North Sumatra	264.9	1.79	261.4	268.4
South Sumatra	264.6	1.63	261.4	267.8

Many management systems also apply maximum body-size limits to protect large highly fecund females or large territorial males (Conover and Munch, 2002). In Malaysia, large reticulated pythons (> 450 cm SVL) were mostly absent from our dataset. Malaysian processing facilities usually release large live pythons or refuse to buy them from hunters (Natusch unpubl. data). Two reasons are provided for this: (1) the skins of large pythons are usually of poor quality due to scars inflicted by predators and prey, and (2) large pythons occupy considerable space in transport vehicles, which can be used for smaller, more valuable, pythons. Indonesian processing facilities confirmed similar difficulties, although some large pythons are still captured and sold for their skins.

As a precautionary measure, we should still explore whether maximum size limits worthwhile for reticulated pythons. Examination of the biological data reveals a complex situation. Larger females produce more eggs than small females, suggesting that large females have a disproportionate input on population recruitment per individual (Fig. 4a). However, large females also reproduce less frequently than small females (Fig. 4b). These data broadly suggest that despite their greater reproductive output, the infrequent reproduction of large pythons does not make them disproportionately important for population recruitment. That being said, the offspring of large individuals of many species possess traits that enhance sustainability (such as improved survivorship or rapid growth), suggesting that we should monitor maturity and mean body sizes to ensure that removal of large individuals does not negatively influence fecundity or reduce the genetic potential of the harvested population (Trippel, 1995; Conover and Munch, 2002; Milner et al. 2007). Ultimately, however, large pythons (> 450 cm SVL) comprised only a very small proportion of captured snakes at all sites (< 0.07%; 50 of 7,019). Thus, although maintaining large reticulated pythons in tropical forests may be desirable, restricting the harvest of large snakes is likely to provide few benefits to harvest sustainability.

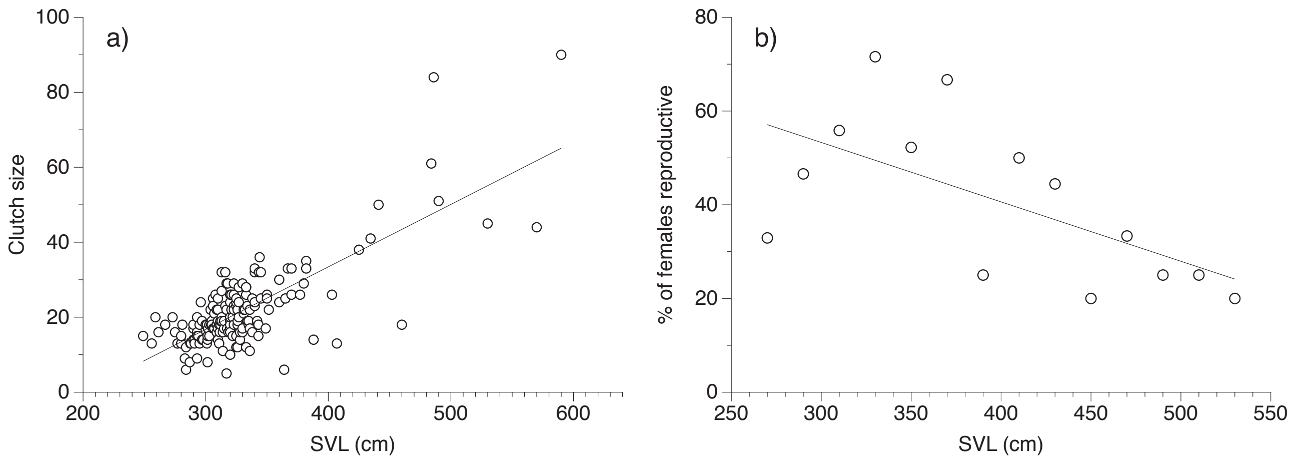

Fig. 4. The (a) number of eggs produced and (b) reproductive frequency of reticulated pythons of different body lengths (SVL) at four sites in Indonesia and Malaysia. For Figure 4a, N = 170 clutches.

How will body-size limits impact harvest volumes?

Some stakeholders may be concerned that removing quotas (in favour of size limits) will stimulate increased collection of pythons by people in Indonesia and Malaysia. But this is unlikely to be the case. Firstly, quotas are already failing to limit the numbers of snakes being collected. Secondly, most people capture snakes in their spare time rather than targeting them specifically and, thirdly, removing quotas is unlikely to affect the financial reward people receive per snake. But if prices do increase, how do harvest size restrictions limit the total number of snakes captured? This is achieved because at any one point in time, there is a finite number of pythons of a given size within any population. This creates a natural “cap” on the absolute numbers of snakes that can be harvested within that size cohort (for more information see Natusch et al. 2015). This has been illustrated in practice for harvests of yellow anacondas in Argentina (Waller et al. 2011). Historically, approximately 15,000 yellow anacondas (*Eunectes notaeus*) were harvested from Argentina each year. After implementation of a harvest size limit, trade volumes decreased from 15,000 to approximately 4,000 anacondas per year. The Argentine system is effectively regulated, because unlike merely counting “numbers of snakes”, skins sizes can be easily measured and thus enforced at any point within the supply chain. For pythons, if quotas are eliminated in favour of size limits, we might expect to see skin exports increase from Indonesia and Malaysia (where most reticulated python skins are sourced). However, we would also expect a corresponding decrease in exports from other countries (as skin exports shifted back to legal sources), and possibly a decrease in the absolute volume of global trade (assuming stockpiles do not enter the market).

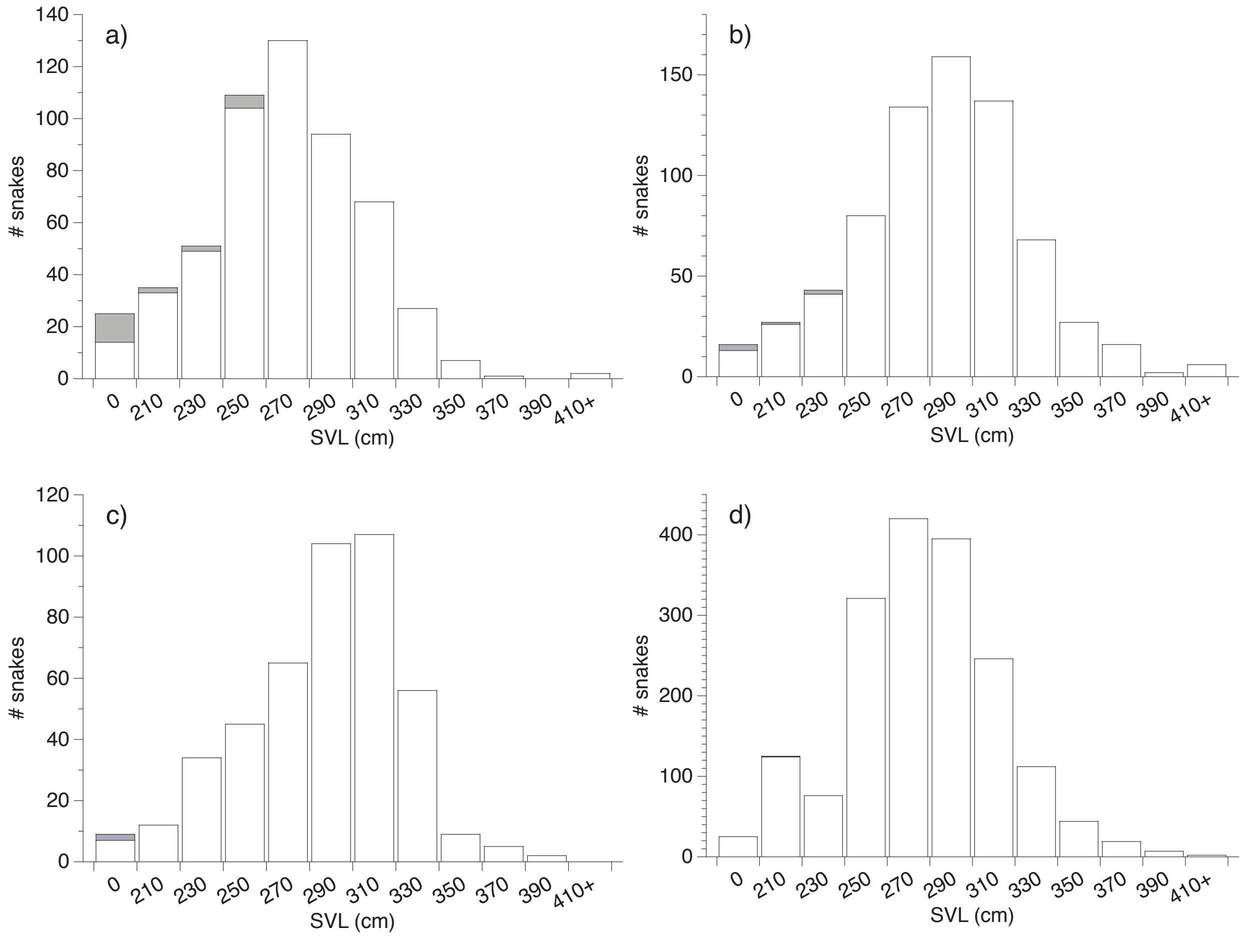

Fig. 5. Numbers of male reticulated pythons (*Python reticulatus*) within each size class brought to processing facilities in (a) north Sumatra, (b) south Sumatra, (c) Kalimantan, and (d) Malaysia. Hollow columns represent mature males while shaded areas of columns represent immature males. Criteria for determining sexual maturity are provided in text.

Table 8. Summary statistics for male and female reticulated pythons examined at processing facilities in Indonesia and Malaysia. N = number of snakes.

Variable	Kalimantan (n = 923)		Malaysia (n = 3705)		North Sumatra (n = 1027)		South Sumatra (n = 1364)	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Sex ratio	49%	51%	52%	48%	54%	46%	53%	47%
Adult sex ratio	53%	47%	60%	40%	64%	36%	58%	42%
Mean SVL (cm)	295	308	283	292	276	289	294	319
Mean body mass (kg)	8.7	9	8.1	8.6	7.4	8.3	9.2	11.1
Maximum SVL (cm)	402	617	483	580	460	615	472	590
Maximum mass (kg)	20.1	98.1	24.4	59.4	35.8	56.3	38.5	99.1
Proportion sexually mature (%)	99	84	99	72	96	65	99	80
Smallest mature snake (cm)	191	234	183	210	171	239	188	224
Largest immature snake (cm)	200	341	213	315	204	330	210	340
Total sample < 240 cm SVL (%)	5%		11%		15%		7%	

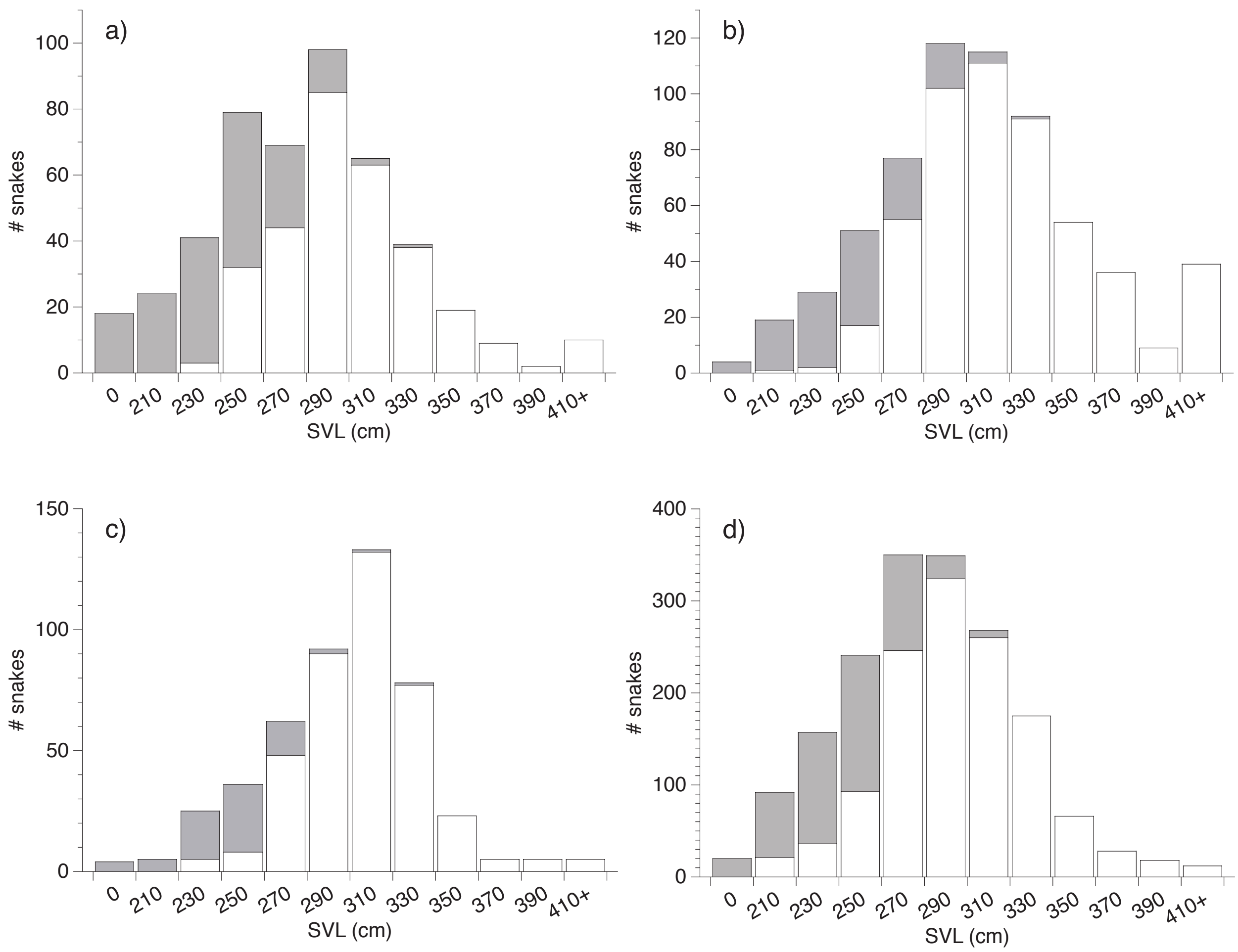

Fig. 6. Numbers of female reticulated pythons (*Python reticulatus*) within each size class brought to processing facilities in (a) north Sumatra, (b) south Sumatra, (c) Kalimantan, and (d) Malaysia. Hollow columns represent mature females while shaded areas of columns represent immature females. Criteria for determining sexual maturity are provided in text.

3.3 Regulating and enforcing size limits

Skin sizes can be measured, unlike quotas and other management tools that rely on counting numbers of skins and trying to link them to specific restrictions on absolute numbers. Measurements of skins are strongly correlated with the size of live snakes, allowing management and enforcement agencies to determine the length of a live snake from measurements made on its dry skin (Table 10; Fig. 7,8).

Results and application of skin size limits

We measured 1502 dry reticulated python skins in Indonesia and Malaysia. We measured the mass, length, width, ventral scale (VS), and dorsal scale next to ventral scale (DVS) to determine their relationship to the snout-vent length (SVL) of a live python (see the Section 1.2 and Fig. 7. for further details). Skin measurements varied significantly among processing facilities, reflecting small differences in skinning technique (unpubl. analyses). However, these differences were small (several centimetres, reflective of our large sample sizes) and are unlikely to influence the applicability of skin size limits. Differences in skinning methods between Indonesia and Malaysia generated much greater variation. We thus pooled skin measurements taken at different processing facilities within each country, but analysed skins measurements from Indonesia and Malaysia independently.

Table 10. R^2 values for relationships between the snout-to-vent length (SVL) of live reticulated pythons (*Python reticulatus*) and a range of measures made on dry skins. Higher R^2 values depict a stronger relationship. L = skin length; W = skin width; VS = ventral scale width; DVS = dorsal scale next to ventral scale width.

Predictor variable	Country	SVL (cm)	L (cm)	W (cm)	VS (mm)	DVS (mm)
SVL (cm)	Indonesia	1				
	Malaysia	1				
L (cm)	Indonesia	0.93	1			
	Malaysia	0.94	1			
W (cm)	Indonesia	0.71	0.75	1		
	Malaysia	0.81	0.81	1		
VS (mm)	Indonesia	0.84	0.83	0.64	1	
	Malaysia	0.86	0.89	0.83	1	
DVS (mm)	Indonesia	0.75	0.76	0.58	0.83	1
	Malaysia	0.85	0.86	0.82	0.88	1

Dry skin measurements in Indonesia and Malaysia were strongly correlated with the SVL of live pythons (Table 10; Fig. 8). On average, dry skins measured between 15 – 25% longer than the SVL of a live snake. The skins of the two countries differed most significantly in skin length and width (Fig. 8). For pythons of the same size, Indonesian processing facilities stretched the skin length more than in Malaysia. Conversely, Malaysian skins are shorter, but significantly wider than Indonesian skins. Unsurprisingly, less labile measurements (e.g., VS and DVS) showed the smallest differences between countries (Fig. 8). Specific scale measurements are useful for skins not traded whole. Measuring single scales, which comprise a very small piece of a full skin, can provide an indication of the size of the live snakes from which the skin piece was derived. The regression relationships provided in Table 10 indicate the strength of relationships between different measurements and thus which are most useful for predicting the measure of interest.

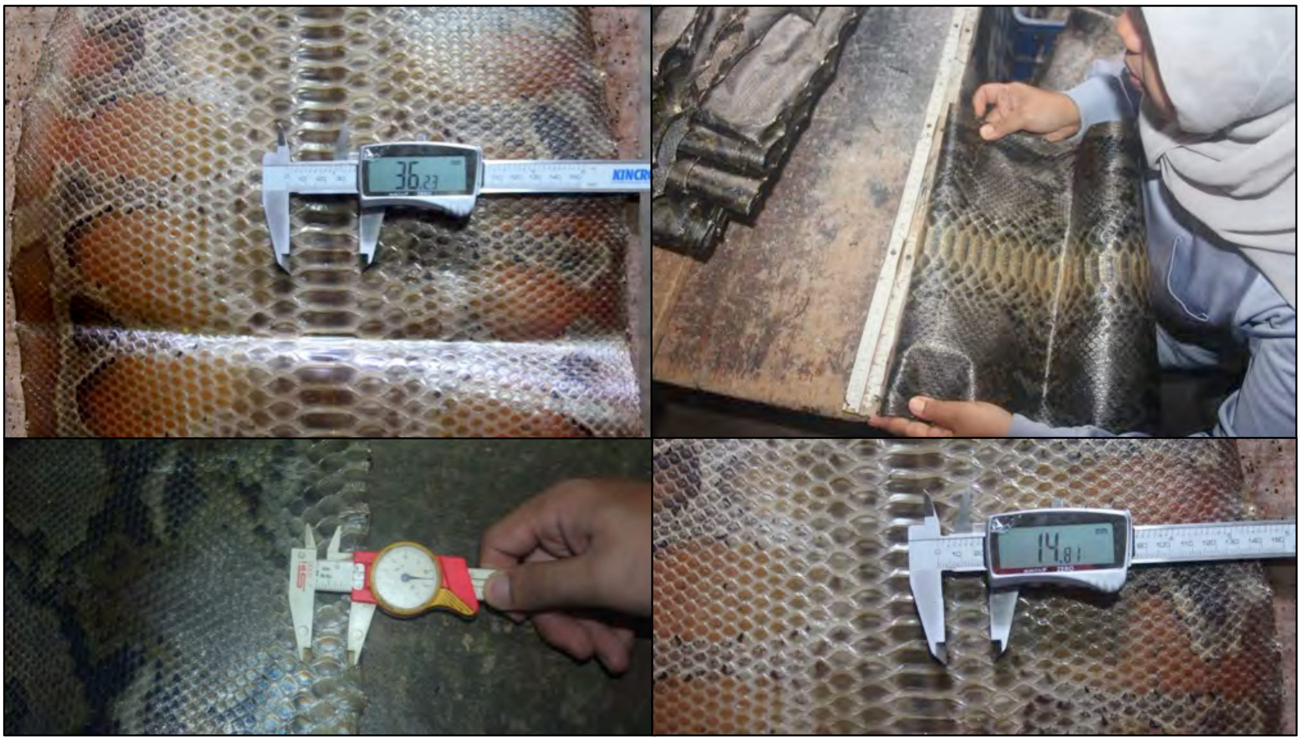

Fig. 7. Measurements taken on dry reticulated python (*Python reticulatus*; top right, bottom left) and short-tailed python (*Python brongersmai*; top left, bottom right) skins. Clockwise from the top left: ventral scale width (VS), skin width (W), dorsal scale next to ventral scale (DVS) on a “belly cut”, and dorsal scale next to ventral scale (DVS) on a “back cut”.

To facilitate regulation by authorities, Table 11 provides formulae to predict the SVL of live pythons from their dry skin measurements. Multiple measurements can be compared for improving confidence that skins of interest are indeed from live pythons of a defined size. Using the harvest size limit for live pythons of 240 cm SVL described in Section 3.2, the corresponding skin has an approximate length 280 cm and belly width of 30 cm.

Because some reticulated python skins are also traded as crust-tanned, we measured dry skins before and after they had been through the tanning process. Table 12 provides values for the mean distortion between the measurements after tanning. For example, dry skins lost an average of 11% of their total length after crust tanning, whereas the ventral scale (VS) width of dry skins increased by approximately 8% after this process.

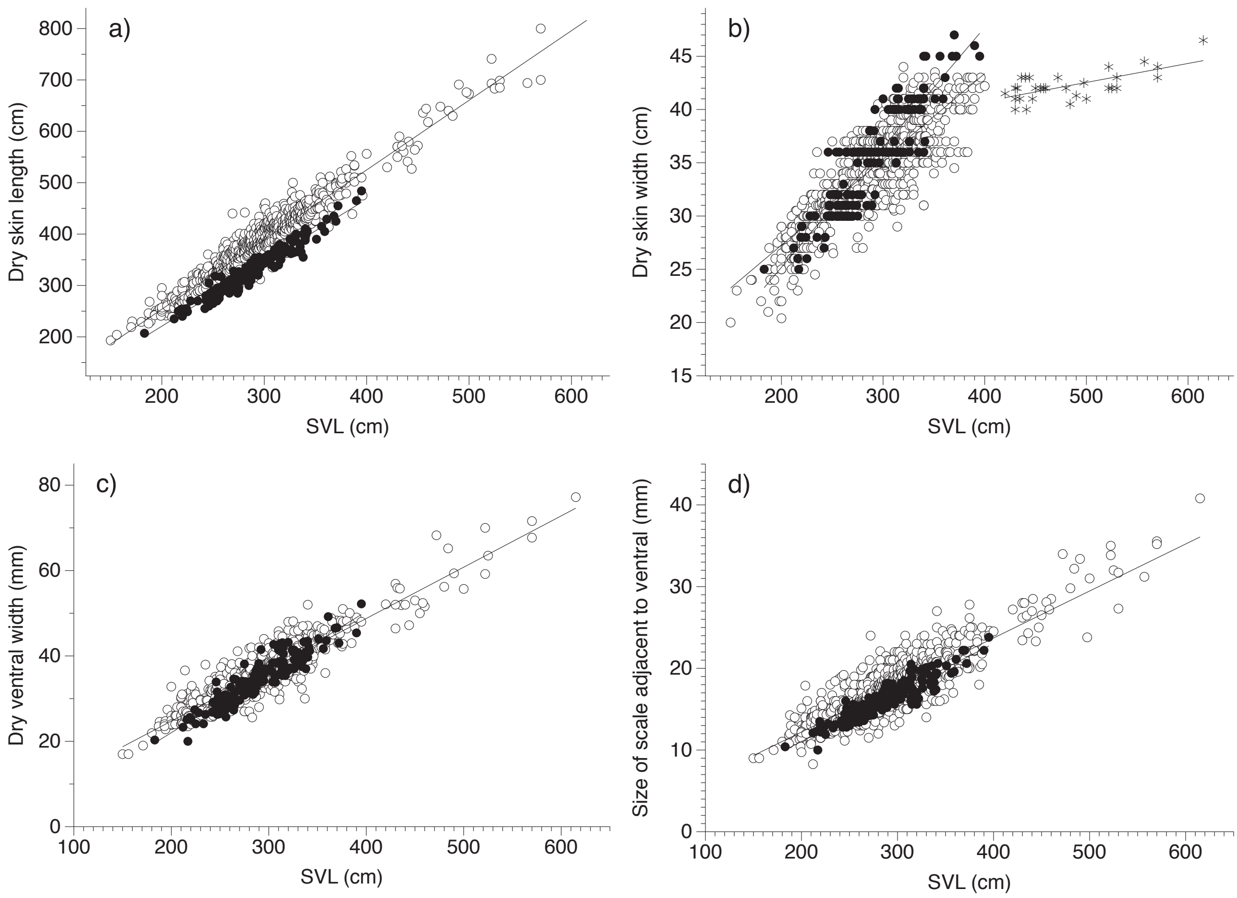

Fig. 8. Relationships between the snout-to-vent length (SVL) of reticulated pythons and (a) dry skin length, (b) dry skin width, (c) dry skin ventral scale width, and (d) dry skin dorsal scale next to ventral scale width. Hollow points represent snakes from Indonesia while solid circles represent snakes from Malaysia. Asterisks' in plate (b) represent large pythons (> 4 m) whose skins were not stretched for width.

Table 11. Formulae for predicting snout-to-vent length (SVL) of live reticulated pythons (*Python reticulatus*) and measurements of their dry skins. Formulae are shown separately for Indonesia and Malaysia. L = skin length; W = skin width; VS = ventral scale width; DVS = dorsal scale next to ventral scale width[7].

Predictor variable	Country	SVL (cm)	L (cm)	W (cm)	VS (mm)	DVS (mm)
SVL (cm)	Indonesia		-17.14 + 1.35(SVL) ± 17.8	11.16 + 0.08(SVL) ± 2.05	0.5 + 0.12(SVL) ± 2.87	0.69 + 0.05(SVL) ± 1.63
	Malaysia		-26.53 + 1.25 (SVL) ± 11.5	2.26 + 0.11(SVL) ± 2.04	-6.3 +0.14(SVL) ± 2.21	-0.95 + 0.06(SVL) ± 0.94
L (cm)	Indonesia	31.6 + 0.68(L) ± 12.7		12.58 + 0.06(L) ± 1.9	3.73 +0.08 (L) ± 2.95	1.84 + 0.04 (SVL) ± 1.62
	Malaysia	37.3 + 0.76(L) ± 9.06		6.03 + 0.09(L) ± 2.0	-2.07 + 0.11(L) ± 1.96	0.95 + 0.05(L) ± 0.9
W (cm)	Indonesia	-14.16 + 8.82(W) ± 21.5	-68.32 + 12.87(W) ± 28.2		-5.33 + 1.19(W) ± 3.53	1.21 + 0.54(W) ± 1.74
	Malaysia	35.03 + 7.21(W) ±16.3	-7.62 + 9.17(W) ± 20.7		-5.04 + 1.1(W) ± 2.5	-0.18 +0.47(W) ± 1.04
VS (mm)	Indonesia	43.94 + 6.94(VS) ± 21.8	27.76 + 9.74(VS) ± 31.5	15.23 + 0.53(VS) ± 2.36		1.19 + 0.45(VS) ± 1.43
	Malaysia	78.52 + 6.07(VS) ± 14.5	54.28 + 7.97(VS) ± 16.7	9.72 + 0.74(VS) ± 2.0		2.68 + 0.4(VS) ± 0.86
DVS (mm)	Indonesia	65.34 + 13(DVS) ± 24.6	59.57 + 18.27(DVS) ± 34.0	15.79 + 1.08(DVS) ± 2.47	3.79 + 1.84(DVS) ± 2.88	
	Malaysia	55.88 + 14.23(DVS) ± 14.4	29.74 + 18.37(DVS) ± 17.9	6.65 + 1.74(DVS) ± 2.0	-1.91 + 2.2(DVS) ± 2.04	

Table 12. Mean percentage change of measurements on dry reticulated python (*Python reticulatus*) skins after crust tanning. SD = one standard deviation.

Measurement	Mean change (%)	SD (%)
Length	-11	8
Width	-4	8
Ventral scale	+8	10
Dorsal scale next to ventral scale	+6	10

Where and how to regulate size limits?

Skin size limits are a powerful tool for management and regulatory authorities because they can be monitored and regulated at any point within the trade chain, from the hunter to export/import. Once export has occurred, Customs authorities of the importing country can also regulate size limits. Most importantly, the end buyers of skins can enforce skin size limits. By only buying legally sized animals, fashion brands can provide serious disincentives for capture and sale of pythons outside specified size limits.

Inspections and enforcement of skin sizes would not require measurement of all skins. Doing this for shipments containing thousands of individual skins is impractical and would require significant time and resources. But because the general size of python skins is easily determined (by their width and size of scales), inspectors can simply visually identify skins that are outside the size restriction, and focus measurements on these. For example, the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN) visits python processing facilities whenever an application for export is made. All skins in the proposed shipment are counted and recorded before being packaged. It would thus be a relatively simple task to separate and measure a number of the smaller skins, depending on the size limits imposed. This system is successfully implemented for regulation of the trade of yellow anacondas in Argentina, where harvest size limits are in place (Micucci and Waller, 2007).

[7] These data are "ready to use" by anyone wishing to estimate skin measurements based on actual measures of skin dimensions.

One potential problem of using harvest size limits is that traders may overstretch skins in order to "meet" the minimum size. Such a problem was experienced during the early stages of the Argentinian Yellow Anaconda Management Program, which also implements harvest size restrictions (T. Waller, pers. comm.). Overstretching of skins is a problem for buyers because it can reduce the quality of the leather, and also results in snakes below the legal size limit entering trade. A simple way to address this is for buyers to demand a specific formula for the length and width of dried skins. Because overstretching for length reduces the absolute width of the skin (and *vice versa*), requiring specific skin dimensions (e.g., 280 long by 30 cm wide) can prevent this problem.

Will size limits prevent smuggling and laundering?

There is evidence that smuggling and laundering of python skins among countries is occurring (see Section 1.6). We argue that implementing size restrictions, but removing restrictions on the number of pythons capable of being harvested, will eliminate incentives for illegal trade and implement a system that can be regulated at all levels of the supply chain. Fashion brands and other buyers can contribute to sustainability management by implementing sustainable sourcing policies, whereby only skins within agreed size limits are purchased.

Skins outside the range of legal size limits may be smuggled to other countries or exported using CITES permits, claiming a captive-bred source where no size limits are applied. As a back-up for monitoring and enforcing legal trade, application of forensic techniques for differentiating wild from captive-bred python skins (e.g., stable isotopes) could be used to ensure skins from small wild snakes are not laundered as captive-bred animals. In addition, countries could explore the use of specific skin-cutting patterns, which indicate the country of origin or the year of harvest. This system is already in use for the trade of yellow anacondas (*Eunectes notaeus*) from Argentina (Waller et al. 2011). Python skins are specifically cut to maintain a typically unused portion of skin (e.g., the head or tail) on the rest of the python skin (Fig. 9). Assigning specific cutting patterns to different countries (e.g., Indonesia vs. Viet Nam) or a period of time (e.g., year to year) offers a simple way to visually determine origin. Some cutting patterns are already used by many python processing facilities in Southeast Asia, but are cut-off the dried skin before export to make the skin more presentable to the buyer (Fig. 9). Encouraging processing facilities to maintain these cutting patterns on exported skins may be a simple method of determining origin, and serve the dual purpose of tag application as part of a traceability system.

Fig. 9. Examples of cutting patterns on the tail section of reticulated python (*Python reticulatus*) skins. Several alternatives exist, such as retaining an area of skin around the head (see Waller et al. 2011 or Ashley, 2013 for more information).

What do traders say?

While working in both Indonesia and Malaysia, we interviewed python traders to better understand their views on the applicability of a management system based on size limits. Significantly, all traders interviewed claimed that implementation of a system based upon size limits would improve regulation. In Indonesia, several traders suggested such a system would be “fairer” than using quotas, because they believed that quotas were distributed preferentially to some traders. Several traders were concerned they would lose money by not being allowed to trade smaller skins, and claimed there is little preventing small skins being exported by other countries without size restrictions. However, all traders agreed that if the end-users of skins consistently implemented size restrictions on the skins purchased, then they would be obliged to abide by them. Undoubtedly, strong commitment to the use of size limits by industry (from producers to consumers) and national regulatory bodies would greatly improve the applicability of a size-based system.

3.4 Monitoring trade

A strong regulatory system can provide the framework to manage python populations in a sustainable way. But knowing if wild populations continue to be managed in a sustainable way requires ongoing monitoring, which allows management authorities to respond to change and adapt regulatory frameworks to maximise sustainable management. Traditional field population surveys have proven to be poor indicators of the population status of many snakes (Fitzgerald, 2012; see Section 1.5). This is due primarily to the sedentary and highly cryptic nature of many snake species, which presents detection difficulties and thus provides unreliable population estimates (Kasterine et al. 2012; Natusch et al. 2015).

In the absence of population demographic data (such as age-specific survival, growth, and longevity), management authorities should focus their efforts on monitoring the harvest. By utilising trade bottlenecks, such as python processing facilities and tanneries, the considerable logistical impediments involved in surveying wild populations can be overcome, and enormous datasets can be gathered on the numbers of pythons harvested, their size, sex, and maturity status. Collection of this information over several years can reveal important trends in the status of wild populations, with two major benefits:

1) Potentially deleterious changes in snake populations can be revealed, allowing management authorities to adapt harvests to minimise the impact of those changes, and

2) Evidence of robust monitoring can be used to allay concerns about sustainability by importing countries and/or markets and improve stakeholder confidence about harvest levels.

A two-pronged monitoring system

Based on the information we collected, we recommend harvest monitoring take place at the level of the regional processing facility and the exporter (in some cases these are the same). Two forms of simple harvest monitoring can be undertaken: (1) record keeping by owners of python processing facilities, and (2) data gathered from pythons harvested for trade. These harvest-monitoring methods are described below and in Table 13.

Record monitoring.- Simple record keeping by owners of python processing facilities can provide powerful information on trends in the numbers and demographic attributes of pythons collected at different times and sites. The information is not a burden to collect and is already being gathered by many python processing facilities in Southeast Asia. The types of data to be collected include the date of sale, name of the seller, approximate collection location, size classes of pythons or skins sold, and the number of pythons in each size class (Fig. 10).

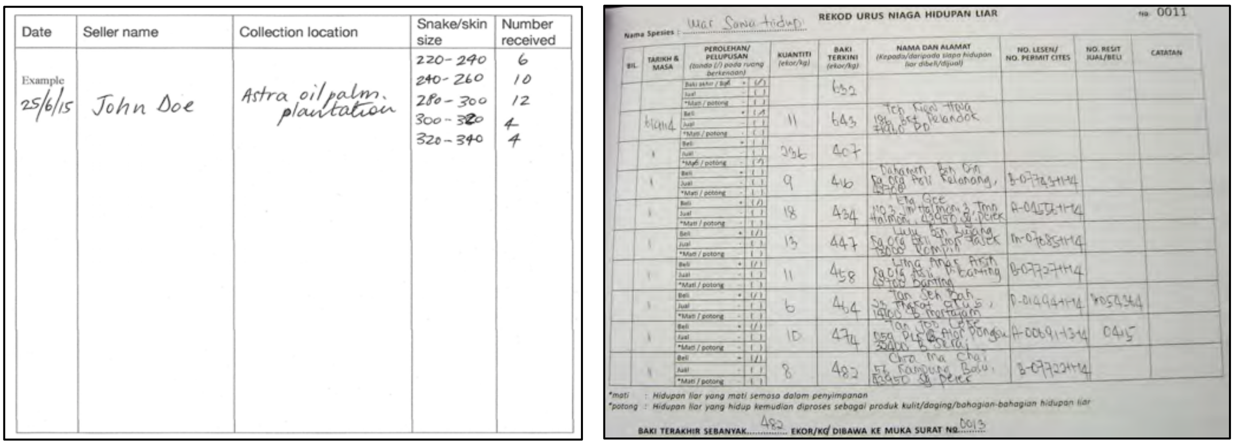

Fig. 10. Example record monitoring forms for reticulated pythons (*Python reticulatus*): (a) a hypothetical form including the basic information required for monitoring of trends, and (b) processing facility record books provided by PERHILITAN for monitoring numbers of snakes purchased from hunters, numbers processed, and remaining stocks.

Facility monitoring.- To complement record monitoring, we need to include methods independent of information provided by owners of python processing facilities. The nature of the commercial python trade (i.e., large numbers of pythons brought to central python processing facilities) makes the system ideally suited to such monitoring. Annual, biennial or triennial visits to python processing facilities by management authorities provide a simple and cost-effective method for independently monitoring the numbers and demographic attributes of harvested pythons, as has been done in the present study (and see Shine et al. 1999; Natusch et al. 2016). Skin buyers could again help enforce this monitoring by making it a mandatory requirement for the facilities from which they source.

Table 13. Key attributes of two different forms of monitoring recommended for ongoing collection of information on harvests of reticulated pythons in Indonesia and Malaysia.

Record monitoring	**Facility monitoring**
Collected annually	Collected annually, biennially or triennially
Collected from all registered python processing and export facilities	Collected from a representative sample of processing facilities
Must be submitted before registration is renewed	Collected from the same places each time
Should collect information on numbers, sizes, location of captured pythons, and hunter details	Collected using the same techniques
Data from both methods should be digitalised for ease of use and regular analysis	

Interpreting monitoring data

Harvest monitoring aims to understand changes over time and does so by examining trends in the medium (3 – 5 years) to long term (>5 years). When a database of knowledge about a harvested population has been consistently and rigorously gathered, ongoing monitoring can reveal changes in that population, which may be a direct result of harvesting pressure. Thus any wildlife monitoring program, regardless of which point in the trade is being monitored, is interested in trends or changes over time.

A variety of indices can be used to assess harvest sustainability (Weinbaum, 2013). The simplest yet most robust indicators of population change in monitored reticulated python populations include: (1) the mean body size and maturity status, and (2) the number of snakes collected over time.

Mean body size and maturity status: These measures enable the manager to examine changes in mean body size (ideally length) and size at maturity over time.

Number of snakes collected: This measure reveals any trends in the numbers of pythons harvested over time. If survey coverage is robust and encompasses variability within the trade chain, then trends in absolute numbers of pythons harvested over time are perhaps the most powerful indicator for overall harvest sustainability (Caughley and Sinclair, 1994). Used in conjunction with changes in sex ratios, body sizes, sizes at maturity and/or catch per unit effort, managers can be confident they can detect harvest-related changes.

Natusch et al. (2016) present and interpret monitoring results for reticulated pythons based on two monitoring periods 20 years apart. Ideally, however, data collected continuously over several years will allow for more detailed time series analyses and more robust conclusions about population changes. Detailed guidance on other types of information to be gathered on harvest and how they can be interpreted can be found in the CITES Non-detriment Findings guidelines document for snakes (Natusch et al. 2015: https://cites.org/sites/default/files/eng/com/ac/28/E-AC28-14-01_Annex2.pdf).

Adaptive management

Successful management of wildlife populations must accept the reality that perfect knowledge of all variables impacting populations will never be available (especially for a cryptic species like the reticulated python, impossible to survey in the wild). Thus, effective management requires the flexibility to amend protocols when potentially adverse changes become apparent (Walters, 1986). Adaptive management is a common strategy in wildlife harvests, essentially treating management decisions as large-scale experiments. Hence, an optimal management system is achieved via a constant process of experimentation and monitoring that is used to inform modifications fed back into the management system. Adaptive management is particularly important for snakes, whose populations are inherently difficult to survey in the field with accuracy (Natusch et al. 2015).

This approach should be promoted as part of any management system for the harvest of reticulated pythons. It should follow a simple cycle, namely: (1) a regulatory system based on skin size limits, (2) regular monitoring of harvested populations, (3) assessment of monitoring information, and (4) modification of management practices if change is detected (Fig. 11).

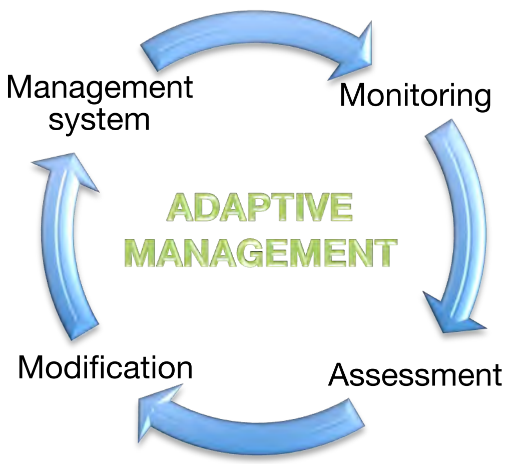

Fig. 11. A simple cycle of adaptive management, whereby a management system can be modified based on results of monitoring and assessment.

4.0 KEY PRINCIPLES FOR SUCCESSFUL MANAGEMENT

Sustainable, legal and transparent international trade in reticulated python skins will require serious commitment from the entire industry involved in this trade, from the producer to the buyer. Ensuring sustainability is critically important for two reasons: (1) sustainable trade meets the conservation goals of maintaining healthy wild reticulated python populations in Southeast Asia, and (2) sustainable trade allows rural communities and industry to continue to meet their livelihood aspirations and business goals. The wild harvest of reticulated pythons forms an integral part of this trade – and alongside captive breeding – utilises an important renewable resource for sustainable economic development. Successful management of reticulated python harvests will be enhanced by adhering to the following principles:

4.1 Commitment to sustainable sourcing

A strong and consistent commitment to sustainable sourcing by industry stakeholders throughout the trade chain is critical to the success of a robust, legal and sustainable trade in python skins. The key elements of this are:

Size limits: Buyers of pythons and python skins, from domestic processing facilities and tanneries to international fashion brands, should collaborate to agree upon and enforce limits for the size of python skins purchased from Indonesia and Malaysia. As discussed in Section 3.3, skins with a minimum length of 280 cm and minimum belly width of 30 cm may be a good starting point.

Direct sourcing: End buyers (e.g., EU-based tanneries and international fashion brands) of skins should establish more direct sourcing policies, to support transparency and enhance collaboration with producers in Indonesia and Malaysia. In this way, end users will be able to ensure appropriate standards and best practice at key points in the value chain, thus leading to greater transparency and confidence in the trade.

Clarity on standards for best practice: End-users need to be clear on acceptable sustainability standards with stakeholders in the value chain. These standards should include a requirement for processing facilities to collect data that are provided to regulatory authorities in order to monitor the ongoing sustainability of harvests.

4.2 Simple traceability

Knowing the origin and source of raw materials can be a vital part of a well-managed supply chain. Such knowledge can help ensure the legality and sustainability of a product, and increases consumer confidence in a brand's chain of custody. "Traceability" has therefore been proposed to address concerns relating to sustainability, illegal trade and animal welfare in the python skin trade, and for generally improving the transparency of the industry. However, implementing a traceability system for the trade in reticulated pythons requires a thorough understanding of the context of the trade and the incentives that encourage people to circumvent current trade regulations. Without addressing these incentives, the usefulness of any traceability tool (e.g., tags, barcodes, chips, or any other methodology) is questionable. Furthermore, traceability tools that are overly expensive, technological, or logistically difficult create additional incentives to circumvent the system. We stress that addressing the incentives for illegal trade (see Sections 1.6 and 1.7), and implementing simple tagging technologies (such as those used for tagging crocodilian skins and yellow anacondas), may be the most cost-effective method for tracing python skins through trade.

4.3 Ongoing monitoring

Long-term monitoring is the best way to reveal positive and negative trends in wild populations, because the annual variability and unpredictability of population abundance (in response to environmental stochasticity: Fitzgerald, 2012) invalidates any shorter-term measures. Studies conducted in a single year can yield important information on population features (e.g., number of snakes, their sizes and sex); however, their limited duration only provides a temporal “snapshot” and thus cannot be used to determine longer-term population trends, status or health (Natusch et al. 2016). Hence, resolving whether an observed population trend is normal for a species, or the result of potentially detrimental declines due to harvesting, often is impossible without long-term monitoring (Fitzgerald, 2012; Natusch et al. 2015). Establishing baseline knowledge of what a dynamic natural population looks like can help us recognize unnatural and potentially detrimental changes, and facilitate management interventions to ensure that trade is sustainable in the future.

4.4 Capacity Development

Support for the development of capacity is an essential building block for enhancing research, management, enforcement, compliance, trade monitoring, and conservation education (Ashley, 2013). In particular, training for scientists and wildlife managers in monitoring, analysing and interpreting sustainability data is critical for completing CITES NDFs and making informed management decisions. We recommend that Parties and industry focus resources on the education and capacity development of industry stakeholders (including producers, buyers, and regulatory agencies), and through this disseminate best practices for wild harvest operations and monitoring systems.

4.5 Government policy and practice

We have identified a management system based on size limits as the most appropriate tool for regulating harvests of reticulated pythons in Indonesia and Malaysia. The success of this approach relies primarily on its ability to reposition the incentive structure toward legal trade, which is dependent on the broader regulatory and policy environment in Indonesia and Malaysia. There is a need to harmonize regulations across the two countries to prevent exploitation of trade regulations for illegal trade activities. For example, differences in size limits between the countries may allow skins below the legal size limit to be smuggled to countries where they are of legal size. Fortunately, the data we have presented herein demonstrate that Indonesian and Malaysian reticulated pythons are remarkably similarly in their biological traits, simplifying uniformity of harvest size limits. Finally, with this regulation in place, the “market” (i.e., buyers) can reinforce the implementation of skin size limits through their sourcing policies and strategies.

4.6 Dedicated funding

Dedicated funding is critical for the success of any ongoing management system. This is particularly true in python skin supply chains, where effective management systems are still in the early stages of development and implementation. Funding is a priority for ensuring monitoring can continue and thus provide confidence about harvest sustainability. It is clearly in the interests of industry and end-users to actively support ongoing management of the trade, not only because ecological sustainability will ensure long term access to the resource, but because the industry (particularly end-users such as fashion companies) are committed to the highest standards of practice, legality and transparency. The structure of a funding mechanism needs to be urgently considered by key stakeholders in the trade. One model that is used in other reptile supply chains is that of a “levy” per skin, which is paid by the industry to support ongoing monitoring and management. By way of example, $US 1 per python skin purchased could be paid by end-users (i.e., fashion brands and/or tanneries) into a managed fund with a formal governance structure. Transparency within the funding and management structure would ensure that the cost is not transferred down the supply chain and is paid by those using and consuming the skins. The funds could be used based on an agreed annual strategy and would be allocated across a range of activities such as continuous monitoring, traceability and tagging, research, and capacity development activities. This type of funding would be different and separate (but complimentary) to funding for national management programs supported by levies at the national level.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Participation in the trade in reticulated python skins is an imperative for hundreds of thousands of people living in Southeast Asia. Ensuring sustainable use is therefore important for maintaining healthy populations of pythons and for continuing benefits for local livelihoods. However, current regulatory frameworks create incentives for conducting trade in a way that does not enhance sustainability, encourages illegal trade, and jeopardizes the livelihoods of people utilising this resource within Indonesia and Malaysia. These issues need to be urgently addressed. Below we provide conclusions and recommendations to support this process:

Re-evaluate the quota system and identify alternative approaches: Explore novel management approaches that are more effectively linked to science-based principles for sustainable use. To assist the development of management alternatives, we provide the following specific conclusions from our study:

a. Inappropriate management frameworks based on harvest quotas are creating incentives for illegal trade.

b. Managing harvests using skin size limits, rather than quotas, will eliminate much of the incentive for illegal trade and will provide a ‘precautionary approach’ for managing offtake.

c. Implementing sustainable sourcing policies focused on the capture of live snakes > 240 cm SVL can support harvest sustainability and “non-detrimental” trade in wild pythons.

d. A live snake of 240 cm SVL corresponds to a dried skin with a length of approximately 280 cm and belly width of 30 cm; this may be a useful minimum size limit for dry skins entering trade.

e. Skin size limits are easily regulated using simple measurements of length, width and scale dimensions of dry skins.

Re-evaluate trade bans: Trade bans and/or unrealistic trade provisions are unlikely to reduce the number of snakes captured and may create incentives for non-compliance.

Implement ongoing monitoring and data collection: Ongoing data collection and monitoring is essential for determining trends in wild python populations and for ensuring ongoing ecological sustainability. Specific recommendations include:

a. Two forms of data collection and harvest monitoring should be undertaken: (1) compulsory data collection and annual monitoring of processing facility trade records, and (2) independent facility monitoring by trained biologists.

b. A management system for reticulated pythons should operate in an adaptive manner to allow flexible changes to be made based on the results of monitoring.

Implement holistic management systems: Effective management requires a suite of actions and approaches. In addition to implementing size limits and undertaking ongoing monitoring, elements of a successful management system should include:

a. Clear standards and capacity development in best practice for the collection and monitoring of harvest data (with verification against these standards).

b. Complimentary use of methodologies (e.g. stable isotopes) for preventing the laundering of skins by verifying their geographic origin and source (i.e., wild vs. captive-bred).

c. Traceability can form an important part of any successful management system, but needs to be logistically simple and cost-effective (commensurate with the benefits of trade).

Funding and resources: To support the implementation of improved management in the python skin trade, an independent dedicated funding mechanism needs to be created. This fund could be supported by the end-users of python skins (e.g., tanneries and/or fashion brands). Further work is needed to gather input from all stakeholders on the design, governance, and implementation of such a funding mechanism.

Consistent commitment: Industry change will not occur without a sustained commitment to sustainability by the end users of python skins that is formalized in transparent sustainable sourcing policies and actions.

Broader significance: Many of the management recommendations provided here are applicable to the trade in other reptile species and can form the basis of CITES non-detriment findings.

SPECIFIC RECOMMENDATIONS FOR STAKEHOLDERS

For Range State Authorities

1) The Indonesian Directorate General of Biodiversity Conservation (PHKA) and Department of Wildlife and National Parks of Peninsular Malaysia (PERHILITAN) are encouraged to explore alternatives to quotas for managing and regulating trade in reticulated python skins.

2) The European Union and the Malaysian CITES Management Authority should actively engage to address the compliance problems created by the ban on imports of python skins from Peninsular Malaysia.

3) Regardless of the management systems adopted for ensuring sustainable and legal trade in python skins, Range States should implement and/or continue ongoing monitoring programs.

For end-users and industry

1) Industry should promote and implement best practices for a holistic management system that enables continuous assessment of sustainability, adaptive management, legal compliance, humane treatment, and the development of capacity at all points within the supply chains.

2) Industry should commit to sustainable sourcing policies, that are clearly communicated throughout the supply chain, complement regulations, and that are enforced by purchasing practices.

3) Industry should adopt traceability systems that are simple and applicable to many stakeholders rather than technologically, logistically, and financially burdensome systems.

4) End-users of python skins should support a dedicated funding mechanism (independent of domestic levies on trade) for ongoing monitoring, enforcement, capacity development, and research to ensure sustainable trade. This fund should be created with full stakeholder input and administered through a transparent governance structure.

5) A broad spectrum of the python skin industry needs to become engaged in improving trade sustainability, communication, and collaboration with other python skin producers/consumers - particularly when deciding upon important issues such as sustainable sourcing, traceability, capacity building, and dedicated funding.

For CITES

1) CITES non-detriment findings for trade in reticulated pythons should focus on drawing conclusions about wild populations by monitoring changes in harvested snakes. This can be most simply and effectively done by collecting records from traders, together with regular and independent monitoring of python processing facilities and tanneries in Range States as well as importing countries.

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