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Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (*Morelia viridis*) from Indonesia

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ABSTRACT

Wildlife breeding farms have been promoted to aid biodiversity conservation by alleviating the pressure of harvest on wild populations. There is, however, growing concern that many breeding farms are being used to launder illegally caught wildlife. Surveys of wildlife traders in the Indonesian provinces of Maluku, West Papua and Papua were conducted between August 2009 and April 2011 to assess the trade of the green python (*Morelia viridis*), the species currently exported in the largest numbers from Indonesia declared as captive-bred. In total, 4227 illegally collected wild green pythons were recorded during surveys and high levels of harvest were found to have depleted and skewed the demographics of some island populations. Snakes were traced from their point of capture to breeding farms in Jakarta where they are to be exported for the pet trade, confirming the reports of wildlife laundering. Extrapolation of monthly collection estimates provided by traders revealed that at least 5337 green pythons are collected each year, suggesting that at least 80% of the green pythons exported from Indonesia annually are illegally wild-caught. The results of examination of 139 eggshells from five python species suggest that reptilian eggshells may be used as proof of provenance for each individual reptile exported. This method, in addition to the evidence that breeding farms play a significant role in the illegal exploitation of wildlife, allows conservation managers to begin to adequately monitor, regulate and determine the role of breeding farms in the conservation of wild populations.

1. Introduction

The trade in wildlife is a major contributor to biodiversity loss and has been recognised as a major conservation concern (Grieser-Johns and Thomson, 2005; Sutherland et al., 2009). Driven mainly by economics, wildlife is traded for medicines, luxury goods, food and pets and operates on local, national and international levels (Nijman, 2010). When wildlife is traded illegally, conservation efforts and sustainable harvests are seriously undermined (Schoppe, 2009; Zhou and Jiang, 2005). Few studies have attempted, or been able, to determine the scale of illegal trade (Gavin et al., 2009), the effects of illegal harvest (Schoppe, 2009; Smith et al., 2011) or the mechanisms by which it operates (but see Wutty and Simms, 2005). As the demand for wildlife increases, additional strain is placed on wild populations, and unsustainable harvesting practices can result in extensive biodiversity loss and ecosystem degradation (Broad et al., 2003; Roe, 2008). In response, the establishment of commercial breeding farms has been promoted as a means of alleviating pressure on wild populations (Jori et al., 1995; Nogueira and Nogueira-Filho, 2011; Siswomartono, 1998).

The trade of wildlife for pets, both legal and illegal, is a multi-million dollar industry, yet it has received little attention from conservation scientists (but see Auliya, 2003; Natusch and Lyons, in press; Nijman and Shepherd, 2007; Shepherd, 2006; Yuwono, 1998). South East Asian economies, particularly Indonesia, export large numbers of species as pets that are sourced from the wild each year (Nijman and Shepherd, 2009; Pernetta, 2009; Shepherd, 2006). Reptiles in particular, are heavily exploited and Indonesia exports more than 160 live reptile species destined for the pet trade (Anon., 2010a,b). Indonesia's wildlife trade is internationally regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Indonesia became a Party to CITES in 1979 and trade is monitored by the CITES Management Authority, the Directorate General of Forest Protection and Nature Conservation (PHKA). For CITES Appendix II listed species, quotas are set annually with the guidance of the CITES Scientific Authority, the Indonesian Institute of Sciences (LIPI) (Siswomartono, 1998). A small number of reptile species are protected under Indonesian legislation and these may be traded legally only if bred in captivity. In the early 1990s, in response to recommendations from the CITES Secretariat and high demands from consumer nations, the Indonesian government encouraged captive breeding of selected species for export (Siswomartono, 1998). This was intended to aid conservation: (1) by breeding foundation stocks for re-release into the

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wild, and (2) to protect species seriously threatened by commercialisation (Siswomartono, 1998).

While farming has resulted in reduced pressure on some wildlife populations (Revol, 1995), it is feared that commercial breeding may result in increased demand for wild founder stock and be used to launder illegally wild-caught animals (Bulte and Damania, 2005; Mockrin et al., 2005). For example, in Indonesia, nationally protected wildlife can be traded under permit if captive-bred, promoting the mis-declaration of animals that are in fact wild-caught (Engler and Parry-Jones, 2007). Globally, there are an increasing number of reports suggesting that for many species, this may very well be the case (Auliya, 2003; Brooks et al., 2010; Engler and Parry-Jones, 2007; Nijman and Shepherd, 2009; Vinke and Vinke, 2010).

Nijman and Shepherd (2009) found large discrepancies between the number of reptiles exported annually from Indonesia and the number of reptiles capable of being produced by Indonesian breeding farms. Their study provided strong evidence for spurious captive breeding in Indonesia (Nijman and Shepherd, 2009). The CITES-listed species exported in largest numbers from Indonesia as captive-bred is the green python (*Morelia viridis*) (CITES Trade Database, 2011). Green pythons are listed in Appendix II of CITES, which regulates international trade, and in 1999 became a fully protected species under national legislation in Indonesia (Dilindungi PP 7/1999). Green pythons are keenly sought after by reptile keepers, mainly due to their distinctive and unique colouration. Juveniles are born either yellow or red and change to green at approximately 65 cm in length. Restricted to tropical rainforests in Australia, Papua New Guinea (PNG) and the Indonesian provinces of Maluku, West Papua, and Papua (Natusch and Natusch, in press; O'Shea, 1996). Indonesia is the only range state that allows export of captive-bred green pythons for commercial purposes, but restricts such exports to the progeny of captive breeding. Reptile enthusiasts have recognised subtle differences in adult and juvenile colouration of green pythons and as such, have designated each colour morph as a specific locality type (Kivit and Wiseman, 2005; Maxwell, 2005). This has resulted in the search for new morphs and localities. There are numerous reports suggesting that illegal harvesting of green pythons is occurring and that some populations are in decline (Auliya et al., 2009). There is however, no direct evidence of the existence of an illegal trade in wild-caught specimens. A recent report submitted by LIPI for the CITES Asian Snake Trade Workshop (2011) stated that the illegal trade of snakes in Indonesia was non-existent. Most importantly, there is currently no easy method for differentiating between wild-caught or captive-bred reptiles destined for export (Auliya, 2003).

It is the aim of the present paper to quantify the scale of illegal trade in green pythons and evaluate the effects of current harvest levels on wild populations. The evidence for laundering of green pythons through breeding farms is examined and the role that commercial breeding plays in the conservation of wild animals is discussed. The mechanisms by which the illegal trade operates are identified and ways in which it can be reduced are suggested. Finally, a novel method for regulating the export of reptiles is proposed and it is suggested that it be trialled using green pythons.

2. Material and methods

2.1. Study region

Six sites were visited in the Indonesian provinces of Maluku, West Papua and Papua between August 2009 and April 2011 (Fig. 1). These sites were selected on the basis of known consumer demand for 'locality specific' green pythons, and therefore areas where trade of green pythons was likely to occur. Study sites were grouped into five localities based on geography (Fig. 1). In addition, markets and breeding farms that claimed to keep, breed and export green pythons were visited in the Indonesian capital, Jakarta.

2.2. Trader identification and interviews

Green python traders were identified mainly through anonymous informants, and additional traders were located using snowball (non-probability) sampling (which uses recommendations from traders to establish contact with others; Bryman, 2004). Trade data were gathered by conducting semi-structured interviews with traders at each site and included the number of snakes collected, collection trends, and trade history. The information given in interviews was ground-truthed using direct counts of individual green pythons and by crosschecking with others within the trade chain. The average numbers given by traders at each locality were combined to determine the total number of green pythons collected each month. These data were then extrapolated to estimate the total number collected annually from each locality (Table 1). Companies registered to export reptiles internationally were identified using lists provided by the Indonesian Reptile and Amphibian Trade Association.

2.3. Examination and morphometrics

2.3.1. Green pythons

A large number ($N = 701$) of green pythons in the possession of traders was measured to determine the harvest demographic for each locality. The measurements recorded were: (1) snout-to-vent length (SVL) measured with a steel measuring tape to the nearest 0.5 cm; (2) weight, to the nearest 1 g using Pesola spring scales, and (3) sex, which was determined by insertion of a blunt probe into the cloaca and recording probe depth. In addition, the colour of snakes was recorded as red, yellow or green and their condition of health was noted. Finally, each snake was given a unique scale clip so that it could be identified if relocated (Brown and Parker, 1976).

2.3.2. Pythonid eggshells

The eggshells of five python species were measured to determine whether the eggshell size could be used to identify the species. Eggshells from a number of different clutches were measured to avoid intra-clutch homogeneity and to encompass the variation in eggshell size and weight for each species. Eggshells were obtained from a breeding farm in Indonesia, and had been kept in a dry and sheltered room between 0 and 2 years. The length and width of each eggshell was determined to the nearest 0.1 mm using a dial caliper. Weight of the eggshell was measured to the nearest 0.1 g using 30 g Pesola spring scales. The eggs of pythons approximate closely to a prolate spheroid. As such, we used the following formula to calculate the volume of each egg in cm^3:

$$V = 4/3\pi a^2 b$$

where a is the width of the egg divided by 2 and b is the length of the egg divided by 2.

2.3.3. Analysis

Contingency table analysis was used to determine deviances from a null hypothesis of equal proportions between sexes, sizes and colours of green pythons harvested from each locality. Analysis of covariance was used to determine whether snakes lose condition as they progressed along the trade chain (with time since capture as factor, SVL as the covariate, and ln weight as dependent variable). All tests were conducted using Minitab 16 software.

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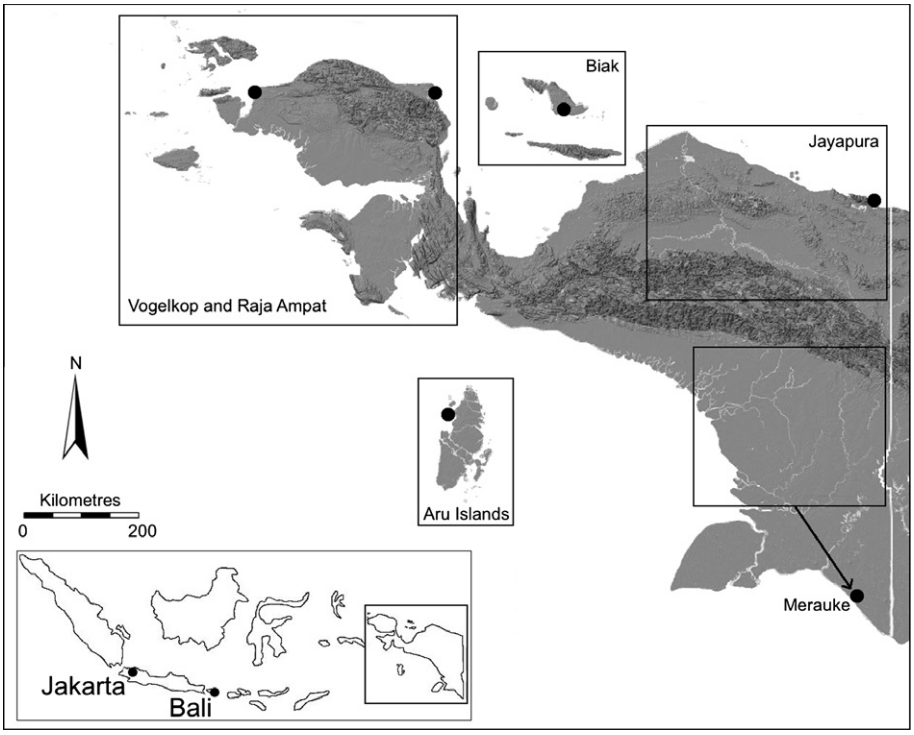

Fig. 1. Six study sites visited in Indonesia (●), and the five corresponding localities from which green pythons are sourced (enclosed in boxes).

Table 1
Trade data for green pythons collected from five localities in Indonesia.

Locality	Traders	Times visited	Snakes recorded	Collected per month	Collected per year
Aru Islands	1	2	123	67	804
Biak	1	25	3831	250	2841
Jayapura	3	15	70	40	480
Merauke	2	21	29	9	108
Vogelkop and Raja Ampat	6	31	176	92	1104
Total	13	94	4229	458	5337

3. Results

3.1. Trade dynamics

In total, 13 traders were located in the Indonesian provinces of Maluku, Papua and West Papua, and visited 94 times between August 2009 and April 2011 (Table 1). Several different individuals are involved in the trade of green pythons, and collectively they form the trade chain. Villagers working in, or in close proximity to, rainforest during the day opportunistically collect green pythons. Snakes are captured by hand and kept in a plastic bottle or bag for a variable period of time. Depending on the ease of access, snakes are sold either directly to a trader situated in a major centre, or via a local collector.

Seventy-six per cent (10/13) of traders stated that collecting wildlife was not their only source of income. On average, traders had been dealing in wildlife for about 14 years (range 4–27; 9/13). Only one trader (1/13) harvested green pythons only; the others stated that they also traded in other species. None of the traders (0/13) had attempted to breed green pythons, although 15% (2/13) expressed interest in doing so in the future. Sixty per cent (6/10) stated that they had been approached by foreigners, who had purchased green pythons from them directly. Ninety-two per cent (12/13) of traders reported that they could easily circumvented laws and regulations by paying off officials. Finally, all traders (13/13) were clearly aware that trading wild-caught green pythons was illegal.

3.2. Harvest levels

In total 4229 illegally harvested green pythons were recorded between August 2009 and April 2011. Most were collected from Biak (including both Biak and nearby Supiori Islands but together referred to hereafter as Biak), with a smaller number being collected from the four other localities (Table 1). Seventy-six per cent (10/13) of traders provided information on the average number of green pythons collected each month. These figures were corroborated by our surveys and through interviews with others along the trade chain. It should be noted that two collectors from Vogelkop and Raja Ampat and one from Jayapura did not provide information on the number of green pythons collected. Consequently, the total numbers collected from these localities are likely to be higher.

The number of green pythons that were claimed to be collected each month differed significantly between localities ($\chi^2 = 384$, df = 4, $P = <0.001$). Ground-truthing showed that the numbers provided by traders were consistent, although they did depend on the number and timing of visits. For instance, despite only two visits to the trader from the Aru Islands, large numbers of snakes were recorded on both occasions due to a backlog of unsent shipments. One trader from Biak provided us with written records of the number of green pythons collected between January and September 2010 and surveys conducted in this locality indicated that the numbers claimed were consistent with the numbers recorded (Fig. 2).

The trader from Biak indicated that during the 10 years green pythons had been collected, they had become less abundant. Similarly, collectors on the island of Kofiau (located in the Raja Ampat Archipelago) reported that green pythons had become particularly difficult to find. According to traders and local people this was due to intensive harvests driven by a high demand for green pythons from this island, which apparently retain their yellow juvenile col-

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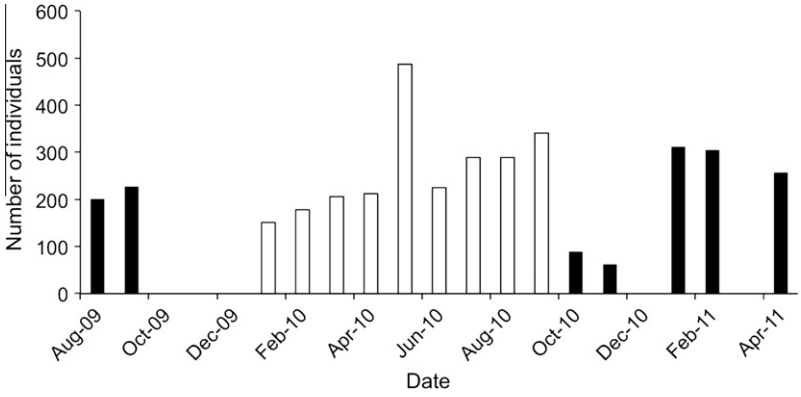

Fig. 2. Numbers of green pythons collected from Biak between August 2009 and April 2011. Black columns represent the numbers counted in this survey and white columns represent the number recorded by a single trader. Missing columns indicate months when no data were gathered.

ouration into adulthood. The single trader on Kofiau estimated that only one snake was collected per month. During our two visits we recorded five snakes on each occasion, which were apparently collected over 4-month periods. Further, one long-time trader based in Sorong on the Vogelkop Peninsula and another based in Jayapura reported declines in mainland populations.

3.3. Variation in harvest demographic among localities

There was a significant difference between the demographic composition of green pythons collected at each locality ($\chi^2 = 22.86$, df = 4, $P = 0.001$; Fig. 3). Adults significantly outnumbered juveniles at all localities except Biak (Fig. 3). In Biak, juveniles were collected more often than adults in both years surveyed (2009, $\chi^2 = 10.99$, df = 1, $P = 0.001$; 2011, $\chi^2 = 87.67$, df = 1, $P = <0.001$; Fig. 3b). The single trader on Biak indicated that when harvesting first began more than 10 years ago, a substantial number of adults were collected. More recently however, juveniles are most commonly encountered. The larger number of juveniles from Vogelkop and Raja Ampat was due primarily to the inclusion of two clutches of recently hatched snakes (Fig. 3a).

There was no significant difference between the number of red and yellow juveniles collected from all localities ($\chi^2 = 3.405$, df = 3, $P = 0.333$), or from Biak in either year surveyed (2009, $\chi^2 = 2.32$, df = 1, $P = 0.128$; 2011, $\chi^2 = 0.47$, df = 1, $P = 0.49$; Fig. 3b). No red juveniles were recorded from the Aru Islands or Merauke where this juvenile colour phase does not occur (Natusch and Lyons, unpubl. data). There was a significant change in the proportion of juvenile to adult green pythons collected from Biak between 2009 and 2011 with the proportion of adults dropping from 37% to 21%, respectively ($\chi^2 = 26.77$, df = 1, $P = <0.001$; Fig. 3b). The numbers of each sex collected at all localities were equal ($\chi^2 = 1.561$, df = 4, $P = 0.816$).

The general health of green pythons being traded was poor. We observed hundreds of snakes that were malnourished, showing symptoms of disease and/or infection, or were dead. A small number of green pythons were measured within a day of collection at villages in the Aru Islands and their weights were compared with those of snakes from the Aru Islands encountered further along the trade chain. A significant difference was observed between the weights of each ($F_{(1,24)} = 72.4$, $P = 0.001$), indicating that the stress of trade conducted in this manner adversely affects the health of green pythons (Fig. 4).

3.4. Final destination

Unique scale clips enabled green pythons to be traced as they moved through the trade chain. After leaving Papua, 60 snakes clipped by us were found again in Jakarta for sale in the Barito Market, in the possession of two middlemen and at a single breeding farm. According to the middlemen, all green pythons in their possession were destined for breeding farms. This confirmed the information given by the traders surveyed, of which 76% (10/13) reported sending green pythons, and other wildlife, to many different breeding farms in Java and/or Bali.

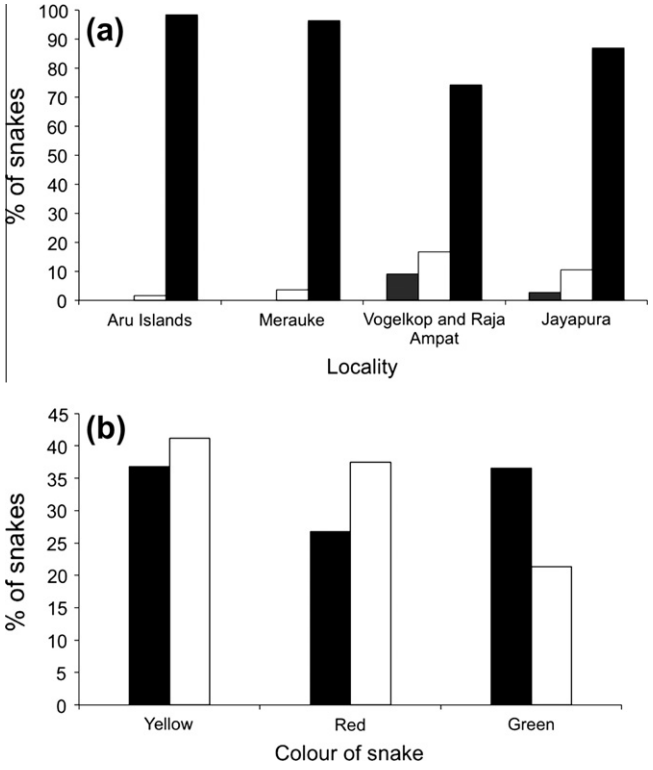

Fig. 3. Percentage of green pythons that were red (●), yellow (○) and green (●), collected from (a) the Aru Islands, Merauke, Vogelkop and Raja Ampat, and Jayapura and (b) the percentage of green pythons that were yellow, red and green, collected from Biak in 2009 (black columns) and 2011 (white columns).

3.5. Pythonid eggshells

A total of 139 eggshells from five species of python were measured (Table 2). Each species has a distinctively shaped eggshell (Fig. 5). The largest eggshells were those of the Papuan olive python (*Apodora papuana*) and Sumatran blood python (*Python curtus*). Although both eggshells are large, they differ significantly in

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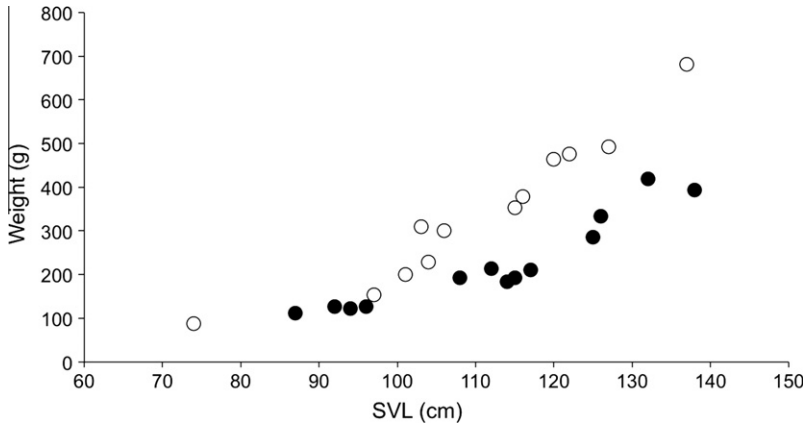

Fig. 4. Weight vs. SVL of green pythons from the Aru Islands measured the day of collection (○), compared to individuals recorded further along the trade chain (●).

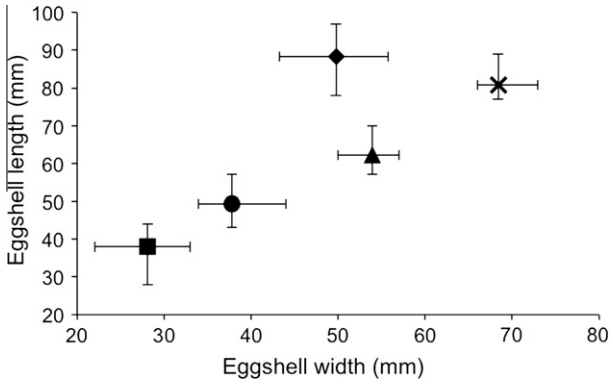

Fig. 5. Length vs. width of pythonid eggshells, showing the distinctive shape of *Morelia viridis* (■), *Morelia spilota* (●), *Apodora papuana* (♦), *Morelia tracyae* (▲), and *Python curtus* (×). Error bars indicate the extremes of length and width for each species.

their shape, weight and volume (Fig. 5; Table 2). The eggshells of the green python were the smallest and lightest of those measured (Fig. 5; Table 2).

4. Discussion

This is one of few studies to provide quantitative data relating to the illegal trade and laundering of wildlife through breeding farms. It provides evidence that there is a thriving illegal trade of wild-caught green pythons in Indonesia and documents this trade from its source to destination.

4.1. Effects of illegal harvest on wild populations of green pythons

Evaluating the extent to which harvesting threatens wild populations is important for designing adequate enforcement and management strategies. Other studies have found that harvesting techniques or selection for specific attributes have altered population demographics (Fenberg and Roy, 2008; Fitzgerald and Painter, 2000). However, the results presented herein indicate that the opportunistic nature of green python collection at most sites does not result in collection biases based on sex, size or colour. On Biak the large number of green pythons collected allowed determination of the harvested demographic at this site. The high proportion of juveniles collected from Biak suggests that over-harvesting may have skewed the age composition as has been observed in populations of other harvested snakes (Means, 2009; Sasaki et al., 2008; Webb et al., 2002), and to a lesser degree in other green python populations (Natusch and Natusch, in press). Furthermore, the proportion of adult green pythons collected from Biak decreased significantly between 2009 and 2011 (Fig. 3b) suggesting a continued decline in the reproductive potential and therefore sustainability of that population. Adding to these concerns, the green python population in Biak appears to be distinct, possibly specifically, from mainland populations (Natusch and Lyons, unpubl. data). Intensive, prolonged depredation on this population caused by exploitation may lead to earlier maturation of individuals as well as genetic changes that could increase the risk of extinction and reduce the ability of the population to recover even if this depredation is brought under control (Allendorf et al., 2008; Congdon et al., 1993).

Trade was also found to occur at other sites, with small numbers of snakes being taken from the islands of Numfor and Yapen and the central highlands. In addition, traders reported that they occasionally obtained snakes from neighbouring Papua New Guinea, as had been found with the cross-border trade of other wildlife and its products (Georges et al., 2006; Hitchcock, 2006). The scale of trade from these areas was not assessed in the present study, but due to the relatively small numbers of snakes encountered in the trade cycle, it is suspected that the distance of these areas from major trading hubs, combined with the small numbers actually collected, has resulted in minimal impact on those populations.

It is widely known that a large number of animals suffer and die in the pet trade every year (Bulte and Damania, 2005; Herbig, 2010). The results presented herein confirm that the husbandry skills of traders are very poor and snakes lose condition as they

Table 2
Means and standard deviations (in parenthesis) of eggshell measurements of the fives species of python in our study. *n* = sample size.

Common name	Scientific name	*n*	Length (mm)		Width (mm)		Weight (g)		Volume (cm^3)	
			Mean (SD)	Extremes	Mean (SD)	Extremes	Mean (SD)	Extremes	Mean (SD)	Extremes
Green python	*Morelia viridis*	81	38.0 (3.1)	28–44	28.1 (2.2)	22–33	0.5 (0.1)	0.35–0.8	15.8 (2.8)	8.6–22.8
Carpet python	*Morelia spilota*	22	49.3 (3.5)	43–57	37.8 (2.6)	34–44	1.1 (0.1)	1–1.25	37.0 (5.1)	27.6–46.9
Halmahera scrub python	*Morelia tracyae*	13	62.2 (3.5)	57–70	53.9 (2.6)	50–57	2.5 (0.1)	2.25–2.6	95.0 (11.7)	77.2–108.9
Papuan olive python	*Apodora papuana*	14	88.3 (5.3)	78–96.9	53.5 (3.3)	47–59.5	4.5 (0.1)	4.2–4.75	132.5 (15.6)	109.3–157.6
Sumatran blood python	*Python curtus*	9	80.8 (3.6)	77–89	68.4 (2.8)	66–73	7.5 (0.2)	7.25–7.7	198.1 (18.3)	175.6–231.6

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are transported from their collection location (Fig. 4). Based on the present work it is estimated that up to 50% of the green pythons collected at some of the localities will die before they are transported to Jakarta. Captive-bred specimens are often more attractive for the hobbyist market as they are more resistant to health complications and hence easier to keep than wild-caught animals (Auliya, 2003). As such, the finding that many of the green pythons traded were in poor health suggests that trade based on wild-caught individuals is economically counter-productive because traders must carry the cost of being unable to sell sick or dead individuals.

4.2. The threat of breeding farms

The finding that most of the green pythons harvested are destined for breeding farms confirms previously held suspicions that most of the green pythons exported annually as captive-bred are in fact wild-caught. The number of companies in Indonesia registered to breed reptiles for export to supply the pet trade increased from 11 in 2006 to 19 in 2008 (Nijman and Shepherd, 2009). Similarly, the number of green pythons exported annually as captive-bred has increased dramatically since the year 2000 (Fig. 6).

Because visits were irregular the number of green pythons collected per unit time could not be determined. However, the large number of snakes recorded during surveys and the extrapolation of numbers reported by traders each month (Table 1) is similar to the annual number of green pythons exported (Fig. 6). This indicates that wild-caught green pythons could make up at least 80% of the annual export of this species from Indonesia. It is also possible that traders have underestimated the numbers claimed to be collected each month because they are aware that such collection is illegal. This, in addition to the lack of monthly harvest data from three traders means that the number collected annually may far exceed the 5337 estimated (Table 1).

Nijman and Shepherd (2009) found that many Indonesian breeding operators do not have the knowledge to successfully breed many reptile species. Surveys by TRAFFIC discovered that some facilities do not have parent stock and others do not even have premises from which to run a successful breeding operation (C.R. Shepherd, pers. comm.).

For breeding farms to be successful they should provide a cheaper, more acceptable product to the consumer than wild-caught individuals (Bulte and Damania, 2005). Not-surprisingly, however, breeding, raising and feeding large numbers of many species over successive years reduces profit margins and is more time consuming than directly selling wild-caught animals. This was confirmed by one farm owner who stated that all other farms launder wild-caught green pythons, so that to remain competitive he had to do the same thing. As well as citing economic motivation, this farm owner stated that the high year-round demand for pets meant that snakes could not be bred fast enough to meet demand, a common Achilles heel of species that have relatively long reproductive cycles (Mockrin et al., 2005; Vinke and Vinke, 2010). For this reason, it may be that breeding and selling many Indonesian reptile species is not economically viable given that many are slow to mature and have long reproductive cycles.

We were told that foreigners who wanted to select green pythons personally had approached the majority of traders surveyed. Traders reported that the snakes chosen were then sent to breeding farms where they are claimed to be captive-bred, given CITES export permits, and shipped to the individual concerned in the importing country. Interestingly, traders we interviewed said they had not collected green pythons prior to the time foreign dealers had approached them offering to pay for snakes.

Finally, a small number of traders claimed that they currently had orders from foreign clients. Because reptile enthusiasts seem to prefer captive-bred over wild-caught animals (Auliya, 2003; Lyons and Natusch, unpubl. data) we assume that many who purchase green pythons are not aware of the provenance of that individual. Indeed, there are a number of dealers who knowingly import wild-caught green pythons and other species and sell them as captive-bred, relying on the difficulty of differentiating between the two in order to mislead unsuspecting buyers and enforcement authorities in both Indonesia and the importing countries. It is also likely that other dealers are unaware they are receiving wild-caught green pythons, relying on the word of the Indonesian exporter that they are captive-bred.

4.3. Management implications

It is well known that Indonesia is faced with several challenges that limit effective conservation of biodiversity. These include, but are not limited too poor natural resource governance, lack of conservation funding, indifference to environmental sustainability, as well as corruption (Laurance, 2004; Posa et al., 2008; Sodhi et al., 2004). The present study has enabled identification of the key factors that facilitate illegal trade of green pythons. As a result, we recommend the following initiatives to reduce the laundering of wildlife through breeding farms.

(1) *Adequate monitoring*: Currently, breeding farms are inadequately monitored. Regular inspections by individuals trained in the identification of species of interest should be undertaken. Disincentives are needed for farm owners who

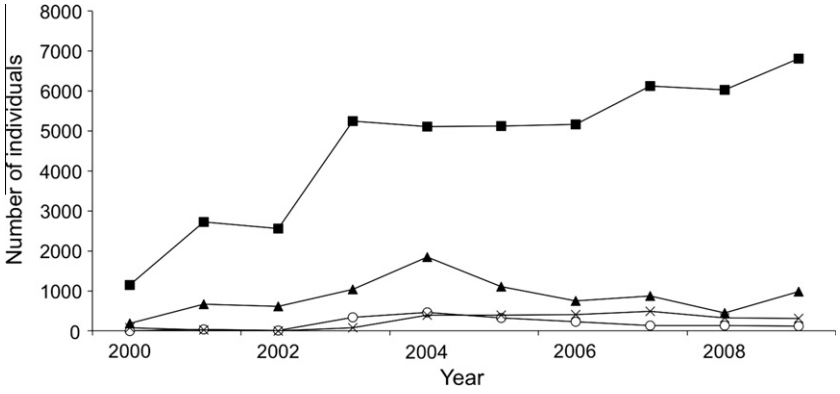

Fig. 6. Four reptile species exported from Indonesia in the highest numbers as captive-bred between the year 2000 and 2009 (UNEP-CITES Trade Database). *Morelia viridis* (■), *Varanus timorensis* (▲), *Varanus prasinus* (×), *Varanus indicus* (○).

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illegally trade in wildlife, that are appropriate to the scale of illegal trade involved. Registrations should be revoked if farm owners are found to not be complying with national laws (Keane et al., 2008; Wellsmith, 2011).

(2) *Allowing legal harvest*: Legalising the harvest of green pythons under a quota system may help to improve trade monitoring and provide economic benefit to a wider range of people and communities. However, it is currently unknown what level of harvest different populations of green pythons can sustain and would require strict enforcement by Indonesian authorities to ensure harvest quotas are not over-stepped.

(3) *Husbandry training*: The present study found that at least two traders wanted to breed green pythons, but did not have the knowledge or capacity to do so. Assistance and training in the methods required to adequately breed this, and other species, may offer economic incentive to those at the bottom of the trade chain to not trade in wild-caught animals.

(4) *Determination of economic viability*: To provide incentives for farm owners not to trade in illegal wildlife, the economic viability of farming should be determined based primarily on the biology of the species involved in the trade (Mockrin et al., 2005). Specifically, account should be taken of the receptiveness of a species to farming, rather than based primarily on consumer demand.

(5) *Educating the consumer market*: One would assume that with so many green pythons in foreign collections, there would be a large population of healthy, captive-bred animals. It may be, however, that the difficulty of keeping wild-caught green pythons, many of which were in poor health when purchased, has resulted in the mortality of many individuals within a short period after reaching their destination. Educating consumers and showcasing the issue of illegal wildlife trade may help to reinforce the need to know the provenance of any animal purchased. This may in turn reduce the number of dealers and consumers knowingly or unknowingly buying animals that may be wild-caught.

(6) The finding that green pythons were present in Jakarta's Barito Market raises the need for further research into Indonesia's growing domestic pet trade. Regardless of whether the laundering of green pythons for the international trade is stopped, demand from the Indonesian domestic market may continue to place stress on wild populations and prove to be much harder to regulate (Pires and Moreto, 2011).

4.4. Proving provenance

Despite the best efforts of Indonesian authorities, determining whether an individual is wild-caught or captive-bred is difficult. We suggest breeding farms should be required to keep eggshells from the reptiles that are bred and to export them with each individual reptile as evidence of their provenance. Like all pythons, green pythons are oviviporous, with adult females producing up to one clutch of eggs each year (Maxwell, 2005). The eggs are characteristically small, white and leathery. After hatchlings leave the egg, the leathery texture of the shell begins to harden and compress, but retains its overall shape.

Our results show that green python eggshells are considerably smaller and lighter, in terms of length, width, weight and volume, by comparison with the four other python species examined in this study (Table 2). A single extreme measurement of length overlapped slightly with that of a single egg of the closely related carpet python (*Morelia spilota*). However, in all other respects the measurements of this eggshell matched those for other green pythons. This species has the smallest egg of all commercially bred python species in Indonesia. We conclude that, with a little knowledge and the aid of reference guide, identifying the eggs of green pythons would be a relatively simple task.

There are a number of other python species exported in small numbers by Indonesian breeding farms. These include the black python (*Morelia boeleni*), water python (*Liasis fuscus*), New Guinea scrub python (*Morelia amethistina*) and the white-lipped python (*Leiopython albertisii*). Although we have a small number of average egg measurements for these species (Barker and Barker, 1994; Charles et al., 1985; Flagle and Stoops, 2009), we lack data sets that encompass the variation between individual hatched egg cases. Without this information, differentiating between the egg cases would be difficult. As a result, although further studies could turn this limitation around, at present the eggshell method can only confidently be used to monitor trade in the green python.

4.4.1. Potential loopholes

There are several ways in which breeding farms might try to circumvent the proposed eggshell identification method. However, in each case there are ways to minimise the risks of corrupt behaviour.

4.4.1.1. Using the egg shells of other species. On a few occasions measurement ranges for the different python species examined overlapped. However, never more did a single measurement do so (Table 2 and Fig. 5) and, when used in conjunction with eggshell weights and volume each species has unique eggshell metrics. Python eggs are roughly spherical or oval in shape and closely approximate a prolate spheroid. The eggs of other snake families such as Elapidae and Colubridae are generally smaller and more elongate. Consequently, confusion between families is unlikely. Further, Indonesia does not harvest or breed large enough numbers of suitably sized elapids or colubrids to substitute these shells for those of green pythons. Also, given the complexity and cost of production, it is unlikely that surrogate eggshells could be produced by artificial means.

4.4.1.2. The transfer of eggshells. Individual breeding farms may produce only small numbers of green pythons each year. The snakes that are bred may produce eggs but not a juvenile animal of export quality. This potentially could enable its shell to be dishonestly attributed to what is in fact a wild-caught individual. Data compiled from captive breeding records of 109 breeding pairs of green pythons in Indonesia in the years 2009 and 2010 showed that females produced an average of 17 eggs. On average, four snakes in each clutch died, leaving about 450 empty eggshells over the 2-year period. It is possible that these eggshells could be kept and dishonestly attributed to wild-caught individuals intended for export. However, this represents only a small percentage of the green pythons currently exported from Indonesia each year; hence this dishonest behaviour would have a relatively small impact.

5. Conclusions

Despite being illegal, collection of wild green pythons is occurring. This study indicates that harvesting is threatening some populations, and, in particular, those on isolated islands. Of most concern is that green pythons from Biak, which may prove to be a distinct species, are experiencing the highest levels of population depletion. Further, the results indicate that most of the green pythons exported from Indonesia each year are actually wild-caught and laundered through breeding farms under the guise of being captive-bred. The suitability and in fact feasibility of breeding farms for producing wildlife to alleviate harvest of wild animals needs to be re-evaluated. It appears that breeding green pythons is currently not a cheaper alternative to laundering wild-caught

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animals and is therefore not fulfilling the conservation objectives that led to the establishment of farms in the first place. Adequate monitoring and serious disincentives for illegal activity by farm owners should be introduced and enforced. Despite the growth of wildlife farms and their promotion by governments in South East Asia, a thorough assessment of the economic and, more importantly, biological viability of reptile farming throughout Indonesia is needed.

Our results suggest that the eggshell method could be very effective in reducing the laundering and export of wild-caught green pythons through Indonesian breeding farms. We suggest that this method be trialed in relation to green pythons, with the onus falling upon both the exporting and the importing countries to monitor eggshells.

Although green pythons are still relatively common in most of the areas in which they occur, noticeable declines have occurred in islands and, to a lesser degree, some mainland populations. It is hoped that by quantifying the level and impacts of illegal trade, identifying the mechanisms by which it operates and publishing this information, international and Indonesian national regulation agencies will focus on enforcing laws already in place that were intended to control this debilitating activity.

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References

Allendorf, F., England, P.R., Luikart, G., Richie, P.A., Ryman, N., 2008. Genetic effects of harvest on wild animal populations. Trends in Ecology & Evolution 23, 327–337.

Anon., 2010a. Kuota ekspor tumbuhan alam dan satwa liar yang termasuk Appendix CITES untuk periode tahun 2010. Keputusan Direktur Jenderal Perlindungan Hutan Dan Konservasi Alam.

Anon., 2010b. Kuota ekspor tumbuhan alam dan satwa liar yang termasuk Non-Appendix CITES untuk periode tahun 2010. Keputusan Direktur Jenderal Perlindungan Hutan Dan Konservasi Alam.

Auliya, M., 2003. Hot Trade in Cool Creatures: A Review of the Live Reptile Trade in the European Union in the 1990s with a Focus on Germany. TRAFFIC Europe, Brussels, Belgium.

Auliya, M., Shine R.A., Allison, A., 2009. *Morelia viridis*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org> (accessed March 2011).

Barker, D.G., Barker, T.M., 1994. Pythons of the World: Australia, vol. 1. Advanced Vivarium Systems, Escondido, California.

Broad, S., Mulliken, T., Roe, D., 2003. The nature and extent of legal and illegal trade in wildlife. In: Oldfield, S. (Ed.), The Trade in Wildlife: Regulation for Conservation. Earthscan Publications, UK, pp. 3–22.

Brooks, E., Roberton, S., Bell, D., 2010. The conservation impact of commercial wildlife farming of porcupines in Vietnam. Biological Conservation 143, 2808–2814.

Brown, W., Parker, W., 1976. A ventral scale clipping system for permanently marking snakes (Reptilia, Serpentes). Journal of Herpetology 10, 247–249.

Bryman, A., 2004. Social Research Methods, second ed. Oxford University Press, New York.

Bulte, E.H., Damania, R., 2005. An economic assessment of wildlife farming and conservation. Conservation Biology 19, 1222–1233.

Charles, N., Field, R., Shine, R., 1985. Notes on the reproductive biology of Australian pythons, genera *Aspidites*, *Liasis* and *Morelia*. Herpetological Review 16, 45–48.

CITES Asian Snake Trade Workshop, 2011. Guangzhou, China, 11–14 April.

CITES Trade Database, 2011. CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK. <http://www.unep-wcmc-apps.org/citestrade/trade.cfm> (accessed June 2011).

Congdon, J.D., Durnham, A.D., Van Loben Sels, R.C., 1993. Delayed sexual maturity and demographics of Blandings turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology 7, 826–833.

Engler, M., Parry-Jones, R., 2007. Opportunity or Threat: The Role of the European Union in Global Wildlife Trade. TRAFFIC Europe, Brussels, Belgium.

Fenberg, P.B., Roy, K., 2008. Ecological and evolutionary consequences of size-selective harvesting: how much do we know? Molecular Ecology 17, 209–220.

Fitzgerald, L.A., Painter, C.W., 2000. Rattlesnake commercialization: Long-term trends, issues, and implications for conservation. Wildlife Society Bulletin 28, 235–253.

Flagle, A., Stoops, E., 2009. Black Python: *Morelia boeleni*. Chimaira Buchhandelsgesellschaft, Germany.

Gavin, M.C., Solomon, J.N., Blank, S.G., 2009. Measuring and monitoring illegal use of natural resources. Conservation Biology 24, 89–100.

Georges, A., Guarino, F., Bito, B., 2006. Freshwater turtles of the TransFly region of Papua New Guinea: Notes on diversity, distribution, reproduction, harvest and trade. Wildlife Research 33, 373–384.

Grieser-Johns, A., Thomson, J., 2005. Going, Going, Gone: The Illegal Trade in Wildlife in East and Southeast Asia. World Bank, Washington, DC.

Herbig, J., 2010. The illegal reptile trade as a form of conservation crime: a South African criminological investigation. In: White, S. (Ed.), Global Environmental Harm: Criminological Perspectives. Willan Publishing, UK, pp. 110–131.

Hitchcock, G., 2006. Cross-border trade in Saratoga fingerlings from the Bensbach River, south-west Papua New Guinea. Pacific Conservation Biology 12, 218–228.

Jori, F., Mensah, G.A., Adjanohoun, E., 1995. Grasscutter (*Trynonomys swinderianus*) production: An example of rational exploitation of wildlife. Biodiversity and Conservation 4, 257–265.

Keane, A., Jones, J.P.G., Edwards-Jones, G., Milner-Gulland, E.J., 2008. The sleeping policeman: Understanding issues of enforcement and compliance in conservation. Animal Conservation 11, 75–82.

Kivit, R., Wiseman, S., 2005. The Green Tree Python and Emerald Tree Boa: Care, Breeding and Natural History. Kirschner and Seufer Verlag, Germany.

Laurance, W.F., 2004. The perils of payoff: Corruption as a threat to global biodiversity. Trends in Ecology & Evolution 19, 399–401.

Maxwell, G., 2005. The More Complete Chondro. ECO Publishing, China.

Means, D., 2009. Effects of rattlesnake roundups on the eastern diamondback rattlesnake (*Crotalus adamanteus*). Herpetological Conservation and Biology 4 (2), 132–141.

Ministry of Forestry, Directorate General of Forest Protection and Nature Conservation, Directorate of Biodiversity Conservation (PHKA), 2011. Country Report of Indonesia: Snake Trade and Conservation. Jakarta. <www.cites.org/eng/com/ac/25/Snake/Indonesia.pdf> (accessed March 2011).

Mockrin, M., Bennett, E.L., LaBruna, D.T., 2005. Wildlife Farming: A Viable Alternative to Hunting in Tropical Forests? WCS Working Paper No. 23. Wildlife Conservation Society, New York.

Natusch, D.J.D., Lyons, J.A., in press. The harvest of *Antaresia maculosa* from West Papua, Indonesia. Herpetological Review.

Natusch, D.J.D., Natusch, D.F.S., in press. Distribution, abundance and demography of green pythons (*Morelia viridis*) in Cape York Peninsula, Australia. Australian Journal of Zoology.

Nijman, V., 2010. An overview of international wildlife trade from Southeast Asia. Biodiversity and Conservation 19, 1101–1114.

Nijman, V., Shepherd, C.R., 2007. Trade in non-native, CITES-listed, wildlife in Asia, as exemplified by the trade in freshwater turtles and tortoises (Chelonidae) in Thailand. Contributions to Zoology 76, 207–212.

Nijman, V., Shepherd, C.R., 2009. Wildlife Trade from ASEAN to the EU: Issues with the Trade in Captive-bred Reptiles from INDONESIA. TRAFFIC Europe Report for the European Commission, Brussels, Belgium.

Nogueira, S.S.C., Nogueira-Filho, S.L.G., 2011. Wildlife farming: an alternative to unsustainable hunting and deforestation in Neotropical forests? Biodiversity Conservation 20, 1385–1397.

O'Shea, M., 1996. A Guide to the Snakes of Papua New Guinea. Independent Publishing, Port Moresby.

Pernetta, A.P., 2009. Monitoring the trade: Using the CITES database to examine the global trade in live monitor lizards (*Varanus* spp.). Biawak 3 (2), 37–45.

Pires, S.F., Moreto, W.D., 2011. Preventing wildlife crimes: Solutions that can overcome the 'Tragedy of the Commons'. European Journal on Criminal Policy and Research 17, 101–123.

Posa, M., Diesmos, A., Sodhi, N., Brooks, T., 2008. Hope for threatened tropical biodiversity: lessons from the Philippines. BioScience 58, 231–240.

Revol, B., 1995. Crocodile farming and conservation, the example of Zimbabwe. Biodiversity and Conservation 4, 299–305.

Roe, D., 2008. Trading Nature: A Report, with Case Studies, on the Contribution of Wildlife Trade Management to Sustainable Livelihoods and the Millennium Development Goals. TRAFFIC International and WWF International.

Sasaki, K., Fox, S., Duvall, D., 2008. Rapid evolution in the wild: Changes in body size, life-history traits, and behavior in hunted populations of the Japanese Mamushi snake. Conservation Biology 23, 93–102.

Schoppe, S., 2009. Status, Trade Dynamics and Management of the Southeast Asian Box Turtle in Indonesia. TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia.

Shepherd, C.R., 2006. The bird trade in Medan, north Sumatra: An overview. Birding ASIA 5, 16–24.

Siswomartono, D., 1998. Review of the policy and activities of wildlife utilization in Indonesia. Mertensiella 9, 27–31.

Please cite this article in press as: Lyons, J.A., Natusch, D.J.D. Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (*Morelia viridis*) from Indonesia. Biol. Conserv. (2011), doi:10.1016/j.biocon.2011.10.002

Smith, M.J., Benitez-Diaz, H., Clemente-Munoz, M.A., Donaldson, J., Hutton, J.M., Mcgough, H.N., Medellin, R.A., Morgan, D.H.W., O'Criodain, C., Oldfield, T.E.E., Schippmann, U., Williams, R.J., 2011. Assessing the impacts of international trade on CITES-listed species: Current practices and opportunities for scientific research. Biological Conservation 144, 82–91.

Sodhi, N., Koh, L., Brook, B., Ng, P., 2004. Southeast Asian biodiversity: An impending disaster. Trends in Ecology & Evolution 19, 654–660.

Sutherland, W.J. et al., 2009. One hundred questions of importance to the conservation of global biological diversity. Conservation Biology 23, 557–567.

Vinke, T., Vinke, S., 2010. Do breeding facilities for chelonians threaten their stability in the wild? Schildkröten im Fokus online. Bergheim 1, 1–18.

Webb, J., Brook, B., Shine, R., 2002. Collectors endanger Australia's most threatened snake the broad-headed snake *Hoplicephalus bungaroides*. Oryx 36, 170–181.

Wellsmith, M., 2011. Wildlife crime: The problems of enforcement. European Journal on Criminal Policy and Research 17, 125–148.

Wutty, C., Simms, A., 2005. Intelligence-led Investigation into Illegal Wildlife Hunting and Trade in Southwest Cambodia. Conservation International, Natural Resource Protection Group and Fauna and Flora International.

Yuwono, F.B., 1998. The trade of live reptiles in Indonesia. Mertensiella 9, 9–15.

Zhou, Z., Jiang, Z., 2005. Identifying snake species threatened by economic exploitation and international trade in China. Biodiversity and Conservation 14, 3525–3536.

Please cite this article in press as: Lyons, J.A., Natusch, D.J.D. Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (*Morelia viridis*) from Indonesia. Biol. Conserv. (2011), doi:10.1016/j.biocon.2011.10.002