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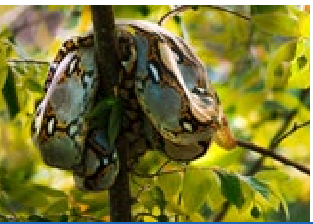
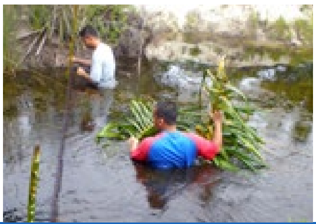
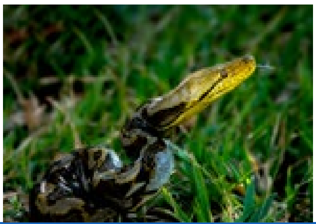

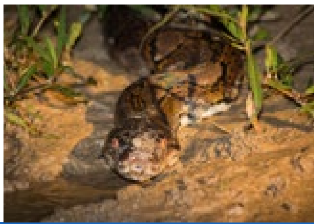

MANAGEMENT AND TRADE IN RETICULATED PYTHONS (*Malayopython reticulatus*)

IN PENINSULAR MALAYSIA

PERHILITAN

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General introduction

This management report is the second in a series concerning reptile management and trade in Malaysia. The first (Khadiejah et al. 2020) addresses harvest and trade management of Asian water monitors (Varanus salvator) in Peninsular Malaysia, which is managed in a similar way to reticulated pythons. The two reports have considerable overlap and can be read in conjunction with each other.

The reptile Family Pythonidae comprises about 35 species of pythons (0.5 - < 10.0 m in total length) that occur naturally in Africa, Asia and Oceania, and as invasive species within the Americas.

For millennia pythons have been used by local people and traded domestically throughout their range, for food, medicines and skins (Groombridge and Luxmoore 1991; Klemens and Thorbjarnarson 1995). Traditional uses were primarily centered on meat and skins, but other body parts have long been valued for decorative and medicinal purposes. Over the last 100 years, significant international trade in the skins of larger python species, for leather, has occurred (Jenkins and Broad 1994). Global trade in live pythons for exhibition, research and keeping including as pets has grown over the last 50 years. It involves a diversity of python species, with trade typically in small volumes, with sharp species-specific increases and decreases in trade volumes matching changes in demand.

As a precautionary and safeguard measure, when the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) came into force 1975, it included a generic listing of all Pythonidae spp. on its Appendices. Most species are listed on Appendix II where trade is subject to compliance with Article IV, but one subspecies (*Python molurus molurus*) is listed on Appendix I, where trade in wild-caught specimens is prohibited.

The reticulated python (*Malayopython reticulatus*) is the longest snake species on earth, with adults reaching 8 to 10 m in length and weighing more than 100 kg (Murphy and Henderson 1997; Natusch et al. 2019a). It is the most widespread of all python species, ranging from India in the west across Southeast Asia to the Philippines in the east and to western and central Indonesia in the south (Murray-Dickson et al. 2017). Most range States exported reticulated python skins historically but, today, trade in compliance with CITES is now largely restricted to Indonesia and Malaysia, and to a lesser extent Vietnam and Thailand (Kasterine et al. 2012; Natusch et al. 2016a). The IUCN Red List review (2018) of the status of the reticulated python in the wild, across its range, confirmed that it is not an endangered species (“Least Concern”) despite both harvest and trade.

The Government of Malaysia is committed to protecting and preserving its natural resources, for the benefit of all Malaysians. When Malaysia became the 38th Party to CITES in 1978, it did not lodge any reservations concerning trade in reticulated pythons and accepted its obligations to ensure ongoing international trade in this species complied with Article IV of the CITES Convention. *Malayopython reticulatus* is a ubiquitous and common vertebrate species within Peninsular Malaysia (land area: 132,339 km^2), both in rural areas and in more densely settled areas. The reticulated python’s generalist biological and ecological traits have allowed it to benefit greatly from increases

General introduction

in rodent prey abundance, and its population densities in many human-modified environments have increased rather than decreased (Shine et al. 1999; Nossal et al. 2016; Low 2018; Natusch et al. 2019a). Like many snakes, direct censusing of wild populations of reticulated pythons, to allow accurate and precise estimates of population abundance and sustainable offtake, is technically almost impossible and highly error-prone (Webb and Vardon 1998; Natusch et al. 2019a; Nafus et al. 2020), hence new approaches are required.

This report describes the management context, strategy, and program being implemented in Peninsular Malaysia to ensure wild reticulated python populations are conserved, managed, and valued. It describes the indices used for evaluating objectively the degree to which the national conservation and management goals are being achieved.

The report is structured as follows

Chapter I: Management context

- History of use
- Legal frameworks governing use and trade
- Management goals

Chapter II: Biological parameters of *Malayopython reticulatus* germane to management

- Distribution
- General biology
- Population dynamics
- Conservation status in Malaysia and Southeast Asia

Chapter III: Experimental attempts at monitoring

- Attempts at surveying wild populations
- Insights in management
- Summary of monitoring methodology

Chapter IV: Monitoring system for ensuring sustainable use

- Monitoring and adaptive management process
- Harvest and trade monitoring
- The case for sustainable utilisation

Chapter V: Trade and management controls in Peninsular Malaysia

- Harvest restrictions
- Management tools
- Technological advances
- Illegal trade and enforcement

Conclusion

CHAPTER I

Management context

1.1 History of use

Pythons have been utilized as a renewable resource by the people of Peninsular Malaysia from pre-history to the present time. Traditional and customary uses include meat for consumption, skins for various decorative and utility purposes, and fat and other products for medical purposes (Klemens and Thorbjarnarson 1995; Ashwell and Walston 2008; Nossal et al. 2016). In times the human population across the species' range was much lower than today, with much less rural and urban development.

Today, *Malayopython reticulatus* remains one of the most common large vertebrate species in Peninsular Malaysia. They are distributed throughout the country and in most habitat types, which indicates:

a) Increased availability of food (e.g., agricultural rodent pests),

b) Increased habitat (e.g., channeled water resources and agri-forestry)

c) Increased habitat connectivity (e.g., underground water and sewerage reticulation systems)

d) Reduced predation and competition from less-adaptable species (e.g., large raptors and carnivores)

The historical abundance of reticulated pythons relative to today was not quantified, but anecdotal evidence suggests they have always been common (Ridley 1899; Groombridge and Luxmoore 1991 and references therein). The possibility that human landscape changes and food subsidies have resulted in increased abundance cannot be rejected on available data. Today, *M. reticulatus* is the snake species most commonly involved in cases of human-wildlife conflict. In rural areas of Malaysia, pythons regularly kill and consume livestock (e.g., poultry) and domestic pets (e.g., cats and dogs). Reticulated pythons are common in urban areas and are feared by most people. They are regularly removed and relocated by the wildlife department.

The use of python skin for fashion leather began in the 1920s (Jenkins and Broad 1994). Demand declined during World War II but increased significantly from the 1950s onward (Jenkins and Broad 1994). To supply this demand, people in Malaysia began to harvest reticulated pythons for trade; mostly opportunistically, but also using nets set in water courses. Animals sold to processing facilities, which sell the skins, meat, and other parts domestically and internationally.

The demand for python skins is centered on larger individuals (> 2 m snout-vent length). However, skins of very large individuals (> 4 m) are typically not utilized because of declining skin quality with increasing size.

Python meat is consumed by some people in Peninsular Malaysia in low volumes, and local Aboriginal (Orang Asli) people hunt and consume pythons without selling the skins. The meat of pythons captured and brought to processing facilities for their skins is also used. It is sold domestically or exported, mainly to China and Hong Kong.

No harvesting is permitted in protected areas (22.5% of Peninsular Malaysia's land area) and pythons are rarely harvested in natural habitats (natural forest comprises 44% of land area), hence PERHILITAN considers that the species' role in the ecosystem is unlikely to have been compromised by harvest in these habitats (see Chapter IV). The habitats with the most pythons are disturbed areas (e.g., oil palm plantations; see Chapter IV). It is in those habitats where most harvesting in Peninsular Malaysia occurs, concentrated in coastal areas where the largest human populations (and thus most harvesters) are located.

1.2 International trade

1.2.1 Skins

Skins are mostly exported from Malaysia for the manufacture of leather goods, to Europe, USA, Mexico, China, throughout Asia, and the Middle East (CITES Trade Database 2020). In the early 1990s, skin exports from Malaysia were around 100,000 per year, but increased to almost 300,000 by the year 2000. Since that time, skin export volume has remained consistent around the 120-150,000 units per year depending on demand (**Fig. 1**)

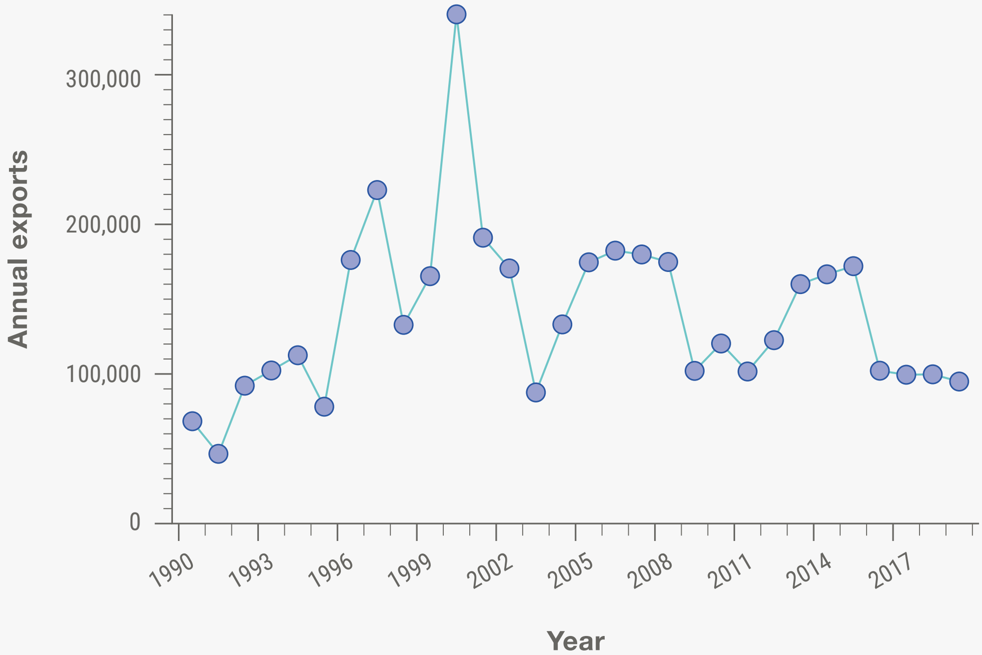


Fig. 1. Annual exports of reticulated python (*Malayopython reticulatus*) skins from Peninsular Malaysia between 1990 and 2019.

1.2.2 Meat

Malaysia has one reptile meat processing and export facility, which exports dried meat. Annual exports of *M. reticulatus* have varied over the last 20 years (1.3 – 41 tonnes/year; CITES Trade Database 2020), but since 2013 have stabilized around 20 tonnes of meat exports annually (**Fig. 2**). Based on average harvest size and processed carcass characteristics, it takes 4.5 pythons to make 1kg, suggesting that annual meat exports correspond to approximately 100,000 individual snakes (broadly commensurate with the number of skins exported annually; meat, skins and other products are taken from the same specimens). Most meat has been exported to Hong Kong, with smaller quantities imported directly by China, Taiwan and the United States.

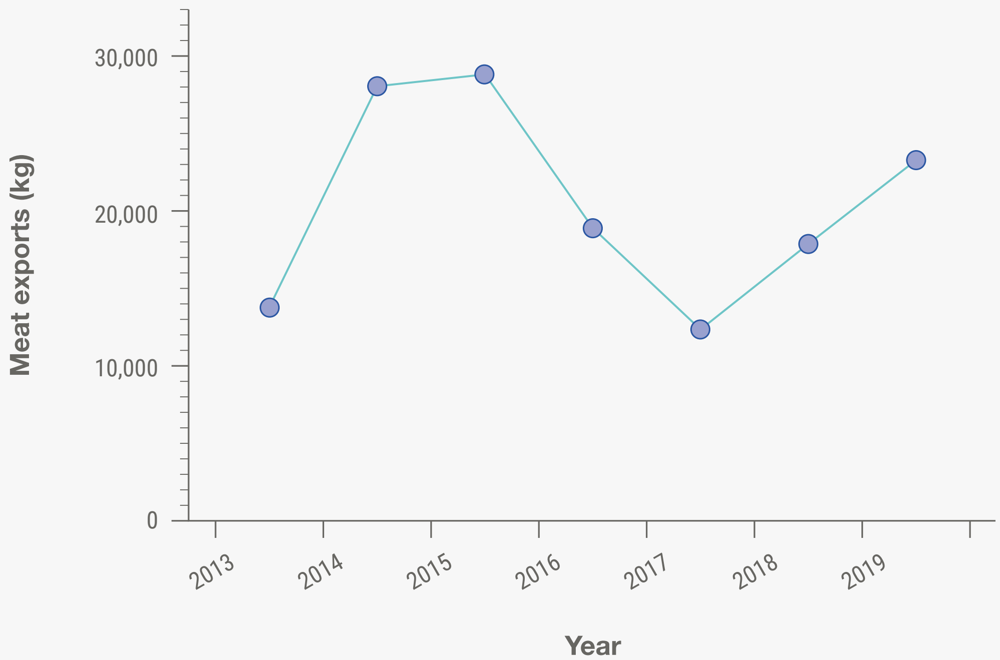


Fig. 2. Annual exports of reticulated python (*Malayopython reticulatus*) meat from Peninsular Malaysia between 2013 and 2019.

1.2.3 Live animals

Exports of approximately 100 live *M. reticulatus* per year have occurred over the past two decades for various purposes. Numbers have declined steadily, and no exports of live specimens have occurred since 2015.

1.2.4 Other products

The majority of other co-products utilized from *M. reticulatus* are tissues for traditional medicines, but these are typically sold domestically rather than exported. However, approximately 300 kg (30 – 690 kg) of dried gall bladders have been exported annually since 2011. Mean dry gall bladder mass of Malaysia's pythons is 5 g (range: 1 – 19 g; PERHILITAN 2021). Annual exports correspond to approximately 60,000 pythons. Most gall bladders are exported to Hong Kong. Exports of some finished leather goods using reticulated python skins occur each year, but the numbers are small (CITES Trade Database 2020).

1.3 Domestic utilisation and trade

Malayopython reticulatus skins are used within Peninsular Malaysia to make leather products, sold locally, but total volumes are exceptionally small (e.g., typically fewer than 100 skins/year; PERHILITAN 2021). In addition to being exported, meat from pythons is consumed domestically, mainly by local Aboriginal (Orang Asli) populations. The most common domestic use of co-products are organs (e.g., spurs, gall bladders, tongues) for traditional medicines. All are co-products of the more significant trade in meat and skins (PERHILITAN 2021).

1.4 Legal frameworks

1.4.1 International

The generic listing of all pythons by CITES, before the first Conference of the Parties, and without reference to listing criteria, species-specific trade nor status data, was a well-intentioned precautionary measure, but not one based on hard science. Malaysia was well aware of this situation and accepted the obligations to comply with Article IV in order to continue legal and sustainable trade, in a responsible manner. The primary requirements of Article IV, that all Parties to CITES address when exporting CITES-listed species on Appendix II, are embodied within Paragraph 2:

a) [Exports will not be] *detrimental to the survival of the species in the wild*, and;
b) [Exports will not be] *in contravention of the laws of that State*

However, additional requirements are in Paragraph 3:

a) [Exports will be] *limited in order to maintain that species throughout its range at a level consistent with its role in the ecosystems in which it occurs*, and;
b) [The population will be maintained] *well above the level at which that species might become eligible for inclusion in Appendix I*

As detailed in this report, all four of these conditions are satisfied for *M. reticulatus* in Malaysia, which has:

a. Introduced management of the harvest and trade at levels commensurate with the local context and risks of extinction;
b. Derived monitoring indices for the harvest, trade and status of the wild population;
c. Ensured compliance with regulations designed to ensure sustainable levels of offtake from the wild; and
d. Is undertaking targeted research to ensure assessments are science-based.

1.4.2 Domestic

Trade in *M. reticulatus* is regulated by the Department of Wildlife and National Parks (DWNP) Peninsular Malaysia (PERHILITAN), which is the Malaysian CITES Scientific Authority. Together with the Malaysian Ministry of Energy and Natural Resources (KeTSA), PERHILITAN also acts as the CITES Management Authority. *M. reticulatus* is a protected species in Peninsular Malaysia, but harvesting is permitted by the Wildlife Conservation Act 2010 (Act 716) if subject to strict regulations (see Chapter V for further information on trade controls and management).

1.5 Jurisdiction

Malaysia is divided into 13 States (and 3 federal territories). All but two States are located in Peninsular Malaysia, which forms part of mainland Asia. The other two States (Sabah and Sarawak) are located on the island of Borneo. Sabah and Sarawak are semi-autonomous States, with separate wildlife management authorities and regulations that are different to Peninsular Malaysia. For example, Sabah and Sarawak implement their own harvest quotas for *M. reticulatus* and manage those harvests differently. This report and the management system presented here relate to *M. reticulatus* in Peninsular Malaysia, implemented by PERHILITAN, and does not concern the Malaysian Borneo States of Sabah or Sarawak.

1.6 European Union import suspensions

In 2002, the European Union Scientific Review Group (SRG) made a negative opinion for imports of *M. reticulatus* skins from Peninsular Malaysia. This opinion was formed in response to a spike in skin exports from Malaysia in the year 2000 and reflected concerns about the sustainability of that level of offtake (**Fig. 1**). An EU-wide import suspension was formalized in 2004. After the suspension, exports dropped back to pre-suspension volumes (~160,000 skins) and skins continued to be exported to other markets. However, approximately 30% of the value of skins was lost (Nossal et al. 2016) and there are anecdotal reports of Malaysia skins being re-exported to the EU in shipments from neighboring countries with permits claiming an incorrect origin (Kasterine et al. 2012; Natusch et al. 2016a).

In 2016, due to the availability of more research data, the EU SRG made a No Opinion for imports of python skins from Peninsular Malaysia. Trade resumed, albeit at lower levels than in the past, and sustainability data collection continued. In 2019, Malaysia was informed that the EU SRG had made another Negative Opinion on imports of reticulated pythons from Peninsular Malaysia, despite no changes to quotas or management, effectively suspending all imports from Malaysia into the EU. The EU SRG explained to Malaysia that the Negative Opinion was formed mainly in response to disagreement about an increase in Malaysia's export quota for a different species, the Asian water monitor (*Varanus salvator*; D. Zikova, pers. comm., 17 August 2019). The EU Negative Opinion on imports of python skins remains in place at the time of writing.

1.7 Importance of sustainable use in Malaysia

PERHILITAN's primary mandate is to ensure the conservation of Malaysia's unique biodiversity for the benefit of Malaysian people. For some species and habitats considered vulnerable and in need of special measures (e.g., elephants, tigers, primary forest reserves, etc), strict prohibition of harvest and trade is implemented. However, the Malaysian Government and the public are also committed to deriving benefits from the sustainable use of wild species. This applies to species that are common and widespread and to habitat types at low risk, and it requires management interventions to ensure sustainable use. The benefits derived from sustainable use change public perceptions of species like *M. reticulatus*, to ensure that those who live alongside wildlife perceive it as an integral component of rural development and livelihood upliftment rather than a nuisance. Responsibility for implementing both protection and sustainable use is vested in PERHILITAN.

Malayopython reticulatus is a protected species, but because it is common and widespread, it can be utilized with authorization from PERHILITAN (see Chapter V). The benefits derived go mostly to lower income, rural Malaysians, particularly the local Aboriginal people (Orang Asli) who are traditional hunters and gatherers. Much like other wildlife harvests at the artisanal level, in most cases the harvest itself does not provide a sole source of livelihood (Nossal et al. 2016). However, the ability to utilize common and freely available resource provides significant food security and income resilience in times of economic and environmental volatility (Nossal et al. 2016).

The harvest and trade of *M. reticulatus* in Peninsular Malaysia is conducted in line with several biodiversity conventions and international agreements. For example:

(1) **The Convention on Biological Diversity (CBD):** *conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources*

(2) **The Addis Ababa principles and guidelines:** *the needs of indigenous and local communities who live with and are affected by the use and conservation of biological diversity, along with their contributions to its conservation and sustainable use, should be reflected in the equitable distribution of the benefits from the use of those resources, and, the costs of management and conservation of biological diversity should be internalized within the area of management and reflected in the distribution of the benefits from the use.*

(3) **UN sustainable development goals:** *....to end poverty, targeting the most vulnerable, increasing basic resources and supporting communities affected by conflict and climate related disasters... and ...action to reduce loss of natural habitats and biodiversity and support food security, climate change mitigation and adaptation....sustainable use of terrestrial ecosystems to halt and reverse land degradation.*

1.8 Management goals: sustainable trade and mitigation of wildlife conflict

PERHILITAN's management goals for a species are tailored to the social, economic and biological context within which that species exists, is being used by people, and is likely to need conservation action in the short- or long-term. *Malayopython reticulatus* is one of four common species (including: Asian water monitors *Varaus salvator*, long-tailed macaques *Macaca fascicularis*, and wild pigs *Sus scrofa*) that are considered "wildlife conflict" species, in different parts of their range, to which the public attributes negative values. Conservation management for these species in Malaysia involves both culling or removal (which reduces negative values), and sustainable use (which creates positive values).

In the case of *M. reticulatus*, this species is abundant throughout much of the country and, despite their large size, is common even in densely populated areas. In rural areas, pythons regularly consume domestic pets and household livestock (mainly ducks and chickens; Natusch et al. 2019a). Similar to many other snakes, reticulated pythons are feared by local people, whose instinct is to kill them. However, at approximately US$25-30 for an average-sized live specimen, the trade in pythons can generate significant value for many people in Malaysia, particularly in rural areas (Natusch et al. 2016a). PERHILITAN's goal is thus to ensure that in areas where commercial harvesting takes place, that python abundance does not decline to levels likely to threaten the optimum sustainable levels of offtake.

1.9 Compliance with CITES Article IV

The non-detriment provisions of CITES [Article IV. Paragraph 2(a)], are a significant safeguard for species in which excessive harvesting for trade could threaten the survival of the species, in accordance with Article II (Fundamental Principles), Paragraph 2(a): *all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival.*

In the case of *M. reticulatus*, it is assumed this was the rationale for listing (based on trade levels alone), although many species in the generic listing have never been traded in high volumes and may have been listed for "look-a-like" reasons – difficulties in identifying species in trade [Article II Paragraph 2(b)].

Regardless, evidence that trade in a common and abundant species like *M. reticulatus* is not causing extreme population declines, likely to cause extinction, needs to be resolved by range States. For Malaysia, a high harvest level has been sustained over multiple snake generations, which is consistent with harvesting for trade resulting in high and positive rates of population increase (Sinclair et al. 2006; Fitzgerald 2012; Natusch et al. 2019b) - the opposite to a situation where trade demonstrably decreases populations and may increase the risk of extinction.

PERHILITAN accepts that the sustainability of the wild harvest, over generations, and now indicated by detailed biological monitoring of the species itself, provides unequivocal evidence of compliance with Article IV Paragraph 2 (a) (*not detrimental to the survival of the species*). *Malayopython reticulatus* is not at risk of extinction in Peninsular Malaysia due to trade.

Article IV Paragraph 3(a)*(maintain … species … at a level consistent with its role in the ecosystems in which it occurs*) is ecologically challenging for many species, but the situation in Peninsular Malaysia is relatively simple. *Malayopython reticulatus* is rarely harvested in natural habitats and ecosystems, where their ecological role could be adversely affected by harvesting. Most harvesting of *M. reticulatus* occurs in disturbed and altered habitats, such as palm oil plantations, where much of their original biodiversity has been lost (e.g. Yue et al. 2015; Pardo et al. 2018), and no historical ecosystem role benefiting other native species can be re-established. Pythons play an important role as rodent predators in oil palm plantations. The removal of some pythons from this habitat may indirectly influence palm oil yield but does not significantly reduce rodent populations such that their role in the ecosystem is compromised. PERHILITAN considers that the species' role in the ecosystem is not being impacted by harvest and trade (see Chapter IV), which complies with Article IV Paragraph 3(a).

Article IV Paragraph 3(b) requires species to be maintained at levels well above what is needed for inclusion in Appendix I. *Malayopython reticulatus* is on Appendix II because of the generic listing in 1975 – it has not been assessed objectively against present or past listing criteria. Importantly, it does not, and is unlikely to ever comply with, the listing criteria for Appendix I [Resolution Conf. 9.24 (Rev. CoP17) Annex 1]. Hence exports of *M. reticulatus* comply with Article IV paragraph 3(b).

1.10 Buy-in by industry

The sustainable use management programs implemented by PERHILITAN for *M. reticulatus* have been significant and can be difficult to understand for industry people who were in operation for decades prior to implementation of conservation-based management. Therefore, requested changes need to be "fair and reasonable", undertaken for sound reasons, respect commercial confidentiality under Malaysian law, and not engender animosity between the industry and the Department. This limits the ability to publish some data publicly (e.g., export volumes for specific identified facilities), but allows such data to be assembled and used by the regulators to better monitor trade and harvest levels.

CHAPTER II

The reticulated python

2.1 Background

The biological characteristics of *M. reticulatus* are a key suite of variables implicated in the species' resilience to harvest and are reviewed here from throughout its range and specifically within Peninsular Malaysia. Data sources include peer-reviewed scientific research and various data and results PERHILITAN researchers and others have access to, some of which is published in peer-reviewed journals and some of which is not.

2.2 Nomenclature

Johann Schneider first described *M. reticulatus* in 1801. Since that time its taxonomy has remained relatively stable in comparison to other python species. Recently, however, Hoser (2004) separated reticulated pythons from other Asian and African pythonids and offered the generic name *Broghammerus*. The name was not adopted within the scientific community because Hoser (2004) provided little evidence for his arrangement. However, recent molecular work by Rawlings et al. (2008), combined with earlier morphological work by McDowell (1975), validated a split from the genus *Python.* Reynolds et al. (2014) formed the generic name *Malayopython.* At the time of writing *M. reticulatus* continues to be referred to by CITES under the generic name, Python. Two subspecies of reticulated python have been described from Indonesia: *M. r. jampeanus* and *M. r. saputrai* (Auliya et al. 2002). The type locality for the neotype of *M. reticulatus* designated by Auliya (2002) is from Rengit (Johor) Peninsular Malaysia (the holotype is presumed lost; Auliya et al. 2002). Thus, there is little doubt that specimens from Malaysia are *M. r. reticulatus*. For sake of ease, we refer here simply to *M. reticulatus* without the subspecific epithet.

2.3 Distribution

Malayopython reticulatus is the most widely distributed species of python (Auliya 2006). It inhabits all of Southeast Asia, ranging from Ceram and Timor islands in the east and south, through to northern Viet Nam in the northeast and Bangladesh in the west (Groombridge and Luxmoore 1990; Auliya 2006). Within this distribution, *M. reticulatus* is most commonly encountered below 1500 m above sea level and is considered rare in high elevation habitats.

2.4 Distribution in Peninsular Malaysia – past and present

The land area of Peninsular Malaysia is 132,339 km^2. Reticulated pythons are common over much of this area and are distributed in all habitats within this region, including urban areas (and indeed large cities, where they are common; Devan-Song et al. 2017; Low 2018; PERHILITAN 2021). Some reports suggest that *M. reticulatus* is most common below 1,500 m, although they have been recorded regularly at this elevation on Bukit Fraser in Peninsular Malaysia (PERHILITAN 2021). Because only 0.72% of Peninsular Malaysia's land area is above 1500 m, reticulated pythons are considered to occur throughout the Peninsular (Kumaran et al. 2010).

2.5 Habitat use and spatial ecology

Malayopython reticulatus thrive in a wide range of habitats, including rainforests, swamps and riverine areas to agricultural plantations and urban areas (Auliya 2006; Kasterine et al. 2012). Although common in terrestrial settings far from water bodies, they are often found in close proximity to rivers, streams, canals and other water bodies. Large individuals are thought to be uncommon in disturbed habitats close to urban areas because of the increased chance of detection, perhaps linked to predation on livestock and pets (Shine et al. 1999; Auliya 2006; Natusch et al. 2019a). Knowledge of the spatial ecology of *M. reticulatus* is rudimentary, but radiotelemetry studies suggest they occupy relatively small home ranges for their body size, and that their movements are typical of other large pythons studied to date (D. Natusch and R. Burger pers. comm. 2020). That being said, reticulated pythons appear to have considerable dispersal ability, and were one of the first species to re-colonise the Indonesian island of Krakatau after its eruption (Rawlinson et al. 1992; Thornton 1996). Pythons typically seek refuge in caves and burrows beneath trees or within hollow logs (Auliya 2006). It is possible that this species, or at least large individuals, occupy a defined home range centered upon such retreat sites. They are also known to be arboreal, particularly when young.

2.6 Morphological characteristics

Malayopython reticulatus is unequivocally the world's longest snake. Verified reports of individuals over nine metres in length have been recorded, with individuals in excess of six metres not uncommon in several parts of the species range (Murphy and Henderson 1997; Auliya 2006; Natusch et al. 2019a). However, mean adult body size throughout most of the range is likely to be closer to 3.5 metres (Auliya 2006; Natusch et al. 2019a). Shine et al. (1999) suggested that collection of pythons from highly disturbed areas (e.g., palm oil plantations) may focus on individuals with smaller body sizes than those collected from more natural areas due to the latter having access to a wider range of prey sizes and retreat sites. However, Natusch et al. (2019a) did not find this to be the case, at least at large spatial scales. Body sizes were correlated with harvest intensity, as would be expected, with mean python body size being smaller in local sites where harvesting was more intensive (Natusch et al. 2019a). *Malayopython reticulatus* is highly sexually dimorphic (Shine et al. 1998b). From a sample of > 10,000 pythons from across their range, the largest female recorded was 7 metres long while the largest male was 4.8 metres (Natusch et al. 2019a). However, dimorphism in mean body sizes of harvested pythons is relatively low in Peninsular Malaysia (Natusch et al. 2019a).

2.7 Diet

Malayopython reticulatus is broadly generalist in its diet. They are both nocturnal ambush predators and active foragers. They will position themselves along well established animal trails or watering points in order to capture prey. In addition, they may actively seek out prey, being drawn to the scent of bat colonies and domestic chicken hutches (Auliya 2006; PERHILITAN 2021). Pythons < 3 m feed primarily on rats, while larger individuals exploit a wider range of prey (Shine et al. 1998c). Pythons inhabiting primary forest areas are likely to also feed on a broader range of prey than those in agricultural landscapes, which feed on commensal rodents (Shine et al. 1999; Natusch et al. 2019). Specific prey records for *M. reticulatus* include: rats (Muridae), shrews (Soricidae), civets (Viverridae), monitor lizards (Varanidae), pangolins (Manidae) and porcupines (Hystricidae), pigs (Suidae), primates and a suite of domestic animals such as cats, dogs and poultry (Shine et al. 1998; Auliya 2006; Natusch et al. 2019a; summarised in Corlett 2011). In Peninsular Malaysia, 95% of 107 intact prey items recovered from reticulated pythons were commensal rodents or domestic animals (chicken, cats, dogs, and goats; see Natusch et al. 2019a). Harvested individuals from Sumatra and Kalimantan also reveal high proportions of domestic livestock and commensal rodents (Shine et al. 1999; Auliya 2006; Natusch et al. 2019a).

2.8 Growth rates

Growth data available for a small sample (N = 3) of wild reticulated pythons from West Kalimantan had a mean growth rate of 6 cm SVL over 41.5 days (~1.5 mm/day; Auliya 2006). However, the small sample size involved (N = 3) and short duration between measurements (40 days) makes the result liable to error. Data from a > 2,000 pythons from Sumatra, Indonesia, suggest growth rates from hatching (~80 cm) to 130 – 150 cm SVL in six months, and to > 200 cm within a year (Shine et al. 1998b; Shine et al. 1999; Auliya

2006). Experimental growth trials on 200 captive individuals confirmed some individuals can reach a body size of > 300 cm SVL (> 15 kg) in 365 days (6 mm/day), with most reaching about 270 cm (7 kg; 5.2 mm/day); D. Natusch pers. comm. 2020). In captivity, the growth of males and females is the same within the first year of life (D. Natusch pers. comm. 2020). Using a similar approach in Peninsular Malaysia to that used by Shine et al. (1999) in Indonesia to account for seasonal growth, it is estimated that the average wild python reaching processing facilities has obtained 250 cm SVL in 2 years (2.4 mm/year; PERHILITAN 2021). Thus, despite growth rates of captive specimens being much higher than in the wild, wild individuals still exhibit remarkably rapid growth in the early part of their life (Shine et al. 1999; Auliya 2006; Natusch et al. 2019a).

2.9 Reproductive characteristics

Malayopython reticulatus grows quickly and reaches sexual maturity early in life. Males become sexually mature at a body size of around 180 cm SVL (Natusch et al. 2019a). Experimental growth trials in captivity show that this size can be reached within 6 months, but likely takes more than a year in wild specimens (D. Natusch pers. comm. 2020; PERHILITAN 2021). Females become physiologically mature around 210 cm SVL, or in their second year of life, but most likely delay reproduction until their third year when they have reached a body size of 240 – 270 cm SVL (Natusch et al. 2019a; PERHILITAN 2021). Sex ratios of reticulated pythons in Peninsular Malaysia are roughly equal (Chapter IV; Natusch et al. 2019a).

2.10 Timing of reproduction

The timing of reproduction in *M. reticulatus* also exhibits significant spatial variation across their range. In Kalimantan and southern Sumatra, the testes are smallest at the beginning of the year (January to February) and increase in size to a peak at the end of the year (October to December). In contrast, testis sizes of males from Malaysia and north Sumatra are smallest in the middle of the year (June to August) and largest in December to February (Shine et al. 1999; Natusch et al. 2019a). Female reproduction also exhibits strong seasonality and varies geographically (Table 1). In Peninsular Malaysia, female follicle sizes begin to increase at the start of the year (January), during the wet season, with fully formed oviductal eggs by March to June (Natusch et al. 2019a).

Table 1. Comparison of reproductive timing among studied populations of *Malayopython reticulatus* in Southeast Asia. The main wet season lasts from December to March at all sites. Source: Natusch et al. (2019a)

COUNTRY	REGION	LATITUDE	OVIPOSITION
Indonesia	South Sumatra	3° S	September/October
Indonesia	North Sumatra	3° N	March-May
Indonesia	Central Kalimantan	3° S	September-November
Malaysia	Peninsular	4° N	March-June

2.11 Reproductive output

Reproductive output in *M. reticulatus* is strongly correlated with maternal body size and condition (Shine et al. 1998b; Natusch et al. 2019a). Mean clutch size in harvested specimens generally is 17-30 eggs, but the largest females, in good body condition, are capable of producing more than 100 eggs in a single clutch (Natusch et al. 2019a). Mean clutch size in harvested specimens in Peninsular Malaysia is 20 eggs (Natusch et al. 2019a). Reproductive frequency is also correlated with body size. For example, approximately 50% of wild females in the 200 – 300 cm SVL size range reproduce in a given year, while only 20 – 30% of females larger than 400 cm SVL reproduce in a given year (Shine et al. 1999; Natusch et al. 2016a). There is also geographic variation. In Central Kalimantan 64% of female pythons reproduce in a given year (suggesting bi-annual reproduction) versus 18% reproducing in a given year in Peninsular Malaysia (suggesting females reproduce only every 5 years). This estimate needs to be treated cautiously because Malaysian regulations do not allow the harvesting of pregnant/gravid wildlife, and at least some hunters avoid harvesting them to promote sustainability (Nossal et al. 2016; Natusch et al. 2019a). At processing facilities, a large number of females with eggs or enlarged ova also have corpora albicantia 1-2 years of age, suggesting reproduction in successive or alternating years; (PERHILITAN 2021).

2.12 Mortality rates

There are no primary data on the age- or size-specific mortality rates of wild *M. reticulatus*. Survival rates of python eggs and hatchlings are likely greater than in many other snakes because females brood (protect) eggs, and because juvenile pythons hatch at large sizes (Natusch et al. 2016b). Juvenile pythons are preyed on by a wide range of predators, including crocodilians, birds, felids, pigs and canids (Reed and Rodda 2009). Once larger than 2 m in length, *M. reticulatus* become relatively immune to predation by all but the largest of predators. Anthropogenic activities are the greatest source of mortality for *M. reticulatus*. Collection for the skin trade and for food results in large numbers of pythons being killed throughout much of the species range. In addition, incidental mortality due to roadkill, unrelated farming activities, and people killing out of fear also result in anthropogenic mortality for this species.

2.13 Longevity

Captive individuals are known to be able to live for up to 30 years (Murphy and Henderson 1997), but in the wild longevity is likely to be significantly less, and few individuals may live for longer than 10 years (Murphy and Henderson 1997).

2.14 Population sizes and density

Despite best efforts to estimate population size over several decades, population sizes of *M. reticulatus* remain unknown for all areas within the species' range, as it does for all other Southeast Asian python species. Conventional survey methods are rendered ineffective by visibility biases linked to their cryptic colouration and secretive behaviour, and the results of all studies to date may be grossly in error. Naïve density estimates based on capture rates for West Kalimantan, Indonesia, suggests that densities are at least 5 individuals/km^2 (Auliya 2006) while those in Peninsular Malaysia suggest 10 individuals/km^2 (**See Chapter III**). All field studies carried out on this species to date have involved considerable biases that influence these results. Non-random sampling of specimens with a bias against the capture of both small juvenile and large adult specimens is common. That pythons can clearly exist in significant densities in some habitats is unequivocal. Each year > 30,000 reticulated pythons are removed from people's homes in central Bangkok, from an area of approximately 300 km^2 (~100 pythons/km^2; P. Arkarakittkul pers. comm. 2020). These captured snakes are effectively removed from the population by relocating long distances away in national parks. Yet annual capture rates in this area remain consistently high.

Experts generally agree that reticulated pythons continue to thrive in oil palm plantations, and agricultural expansion in Malaysia may have increased their abundance (Shine et al. 1999; Auliya 2006; Nossal et al. 2016; Meijaard et al. 2018; Natusch et al. 2019a). This hypothesis is supported by PERHILITAN's capture rates in oil palm vs forested habitats in Peninsular Malaysia and corroborates hunting patterns in Malaysia and traditional knowledge from local people (Nossal et al. 2016; **Chapter IV**). In addition, Auliya (2006) reports capture rates from forest habitats in Kalimantan as 0.13 snakes/day, while similar studies in an oil palm plantation in Sumatra resulted in capture rates of 0.82 pythons/day (a 6-fold increase, although methodological biases should be noted; Auliya 2006). Large female pythons typically reproduce less frequently than smaller females, because of the relatively larger amount of resources required to reach reproductive condition (Madsen and Shine 1996; Shine et al. 1998). However, the resource-rich oil palm plantations covering Malaysia, where prey density has significantly increased, may have allowed larger females (and indeed, all females) to reach reproductive condition more rapidly, increasing population recruitment. Because prey density is the most critical factor regulating python population density (Madsen and Shine 2000b), the rationale that pythons have the ability to increase population sizes and densities within oil palm habitats is well supported.

Importantly, although there is general consensus that reticulated pythons continue to thrive (and may have increased their densities) in oil palm habitats, the homogeneity and lack of dense cover in this habitat type may favour snakes with a smaller body size (< 3 m; Shine et al. 1999; Auliya 2006; Natusch et al. 2019a). Higher detectability of large snakes and a reduction in large prey may drive this result. Furthermore, while mean body sizes of snakes in oil palm plantations may be lower than in natural habitats, giant (> 5 m) specimens continue to be regularly found (PERHILITAN 2021).

2.15 Susceptibility to anthropogenic disturbance

Although robust data on historical abundance are unavailable, reticulated pythons thrive in many modified habitats, and conversion of habitat has likely increased python abundance – not reduced it (Shine et al. 1998). Human activities, most notably in the form of forest conversion for agriculture or urban development, appear not to have negatively impacted this species at the population level, despite some modifications no doubt not favouring *M. reticulatus*. The expansion of oil palm production has been particularly influential, and most hunting is now focused on this habitat type (Nossal et al. 2016; Natusch et al. 2016a; PERHILITAN 2021). In addition, pythons are commonly captured in and around local villages, and thrive in some of Asia's largest cities – including Kuala Lumpur and Singapore (Auliya 2006; Devan-Song et al. 2017; Low, 2018; PERHILITAN 2021). Given numerous research results and observational evidence, PERHILITAN does not consider habitat conversion to be a major threat to this species' long-term survival.

2.16 Conservation status

Most available information confirms that reticulated pythons continue to remain abundant throughout their range, despite intensive harvesting at some sites. Anecdotal evidence from 1996 that python populations have decreased considerably throughout the species' range (Auliya, 2006). However, no direct evidence supports this claim, and pythons continue to be common and harvested from these same sites 25 years later (D. Natusch pers. comm. 2020). All other available evidence suggests that python populations remain stable, both in Peninsular Malaysia and elsewhere (Kasterine et al. 2012; Natusch et al. 2016b; Natusch et al. 2019a; Wahab and Maulany 2020). The global reticulated python population is listed as Least Concern on the IUCN Red List, and there is no reason to believe that this classification does not apply to the population within Peninsular Malaysia. The species is protected from harvest across 37% of its range in Peninsular Malaysia, and subject to little or no harvest in another 37% of its range. *Malayopython reticulatus* are subject to intense harvest in only 27% of Peninsular Malaysia (**Chapter IV**).

2.17 Threatening processes unrelated to harvesting

2.17.1 Habitat loss

Malaopython reticulatus thrives in many habitats that have replaced natural forest (Auliya 2006). Creation of drainage canals in oil palm plantations appears to have increased the availability of suitable habitat for this species in Peninsular Malaysia (**Fig. 3**). Coupled with high prey densities in these agroforestry systems, abundance of *M. reticulatus* may be higher today relative to historical levels (see Chapter IV). In addition, pythons thrive in many other agricultural landscapes and urban areas (Auliya 2006; Devan-Song et al. 2017; Low 2018; PERHILITAN 2021). That being said, Auliya (2006) provided anecdotal reports from skin processing facility owners in Sumatra and Kalimantan of declines in python abundance in 1996 (and hence widening hunting areas). These declines were attributed to habitat changes and possibly linked to hunting pressure (Auliya 2006). However, more recent visits to the sites described by Auliya (2006) have shown that pythons continue to be harvested from modified habitats in those regions (D. Natusch pers. comm. 2020). It is unknown why these original declines were observed, and whether they simply related to modified habitats that have since recovered, or whether reticulated pythons now occur at lower densities than they did historically (D. Natusch pers. comm. 2020). It is possible that populations have indeed declined at those sites but have since stabilized (D. Natusch pers. comm. 2020). Importantly, the predominant habitat modifications in Peninsular Malaysia involve conversion to oil palm plantations, where pythons persist in abundance (Meijaard et al. 2018; PERHILITAN 2021). It is likely that some modified habitats are more suitable than others, and that microhabitat features (e.g., availability of water courses or dense cover) within those broad habitat types strongly influence the abundance (and sizes) of pythons at those sites (Natusch et al. 2019a; D. Natusch pers. comm. 2020).

2.17.2 Road kill

Malayopython reticulatus are sometimes observed as roadkill on Malaysia's roads. Based on observations made while conducting routine activities throughout Peninsular Malaysia (i.e., data not collected in a standardized way) PERHILITAN estimates that perhaps thousands of individuals are killed each year, which reflects their high abundance in many areas. The impact of roadkill on *M. reticulatus* populations is unknown, but considered benign, and not an important driver of population dynamics. Radio-telemetry studies on this species and other large pythons have shown that they move relatively infrequently and can persist beside major roadways without being killed (Fearn et al. 2005; Low 2018; Mutascio et al. 2018).

Fig. 3. The creation of drainage canals in this resource rich habitat (an oil palm plantation) appears to have increased the availability of suitable habitat for *Malayopython reticulatus* in Peninsular Malaysia. Python densities are highest in this habitat type (**see Chapter IV**).

CHAPTER III

Experimental attempts at monitoring

3.1 Introduction

Direct census of wild python populations, establishment of offtake rates considered sustainable, and then ongoing monitoring of wild populations, is an intuitive way for assessing the impact of harvesting on wild python populations. PERHILITAN's initial monitoring efforts applied these techniques to *M. reticulatus*, with the aim of using this approach as the basis for ongoing monitoring of pythons. However, after several years of research and attempted monitoring, it became clear that traditional field census techniques could not be applied to this species, and new methods for monitoring were developed. This Chapter presents the results of Malaysia's attempts at population census for *M. reticulatus* and the justification for why these methods are no longer pursued or considered appropriate for robust management of this species in Peninsular Malaysia.

3.1.1 Locations

Most harvesting in Peninsular Malaysia (80-90%; **Fig. 4**; see **Chapter IV** for greater detail) occurs in four States: Kedah, Pahang, Perak and Selangor. Therefore, PERHILITAN conducted trapping surveys for reticulated pythons in these four States, and also in Terengganu State, in 2010, 2011, 2012, and 2013 (**Fig. 5**).

These States were chosen because they are the main harvest areas for *M. reticulatus* in Peninsular Malaysia (Kedah, Pahang, Perak and Selangor), or because they represent sites with little or no harvesting against which comparisons can be made (Terengganu; PERHILITAN 2021). All sites experience a tropical equatorial climate, with high year-round temperatures and rainfall, but with a minor 'drier period' from April to October. All surveys were conducted during the drier months (May–October), and when completed at one site, the survey team moved immediately to another site, to minimize seasonal biases. Some sites were surveyed once to maximize the probability of finding snakes in different geographic areas, while other sites were surveyed over multiple years in an attempt to recapture marked specimens to better understand underlying abundance. For details of survey sites and dates see **Table 2** (below).

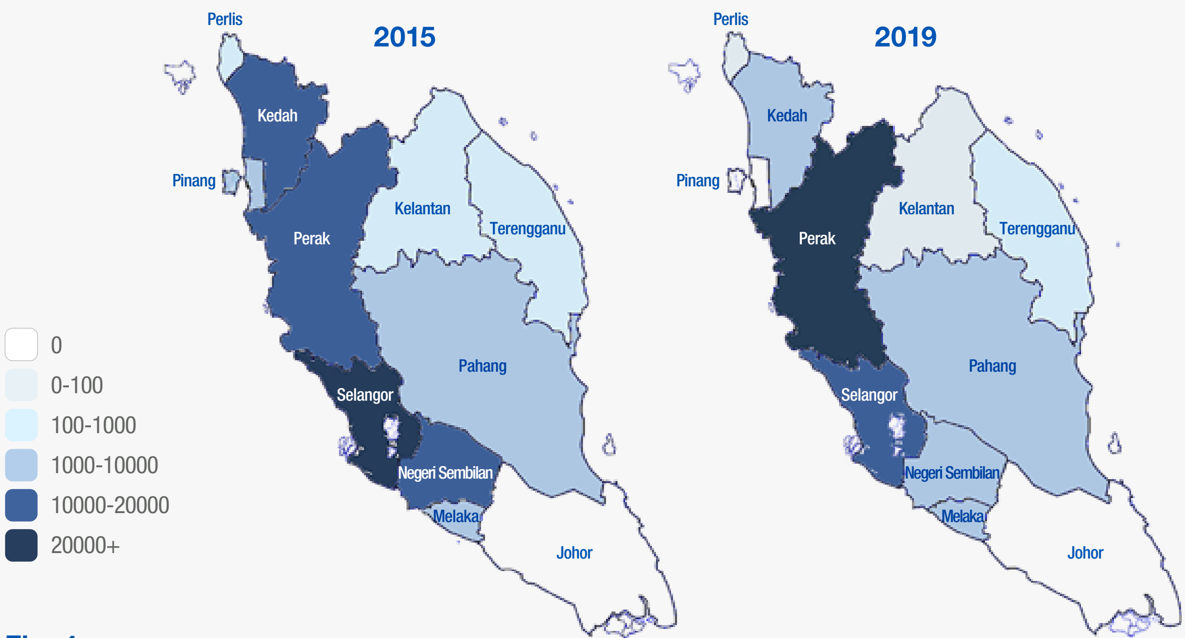


Fig. 4.
Maps of Peninsular Malaysia showing the extent of *Malayopython reticulatus* harvesting in each State. The two maps show the geographic distribution of harvests and how they have changed from 2013 (left) to 2019 (right).

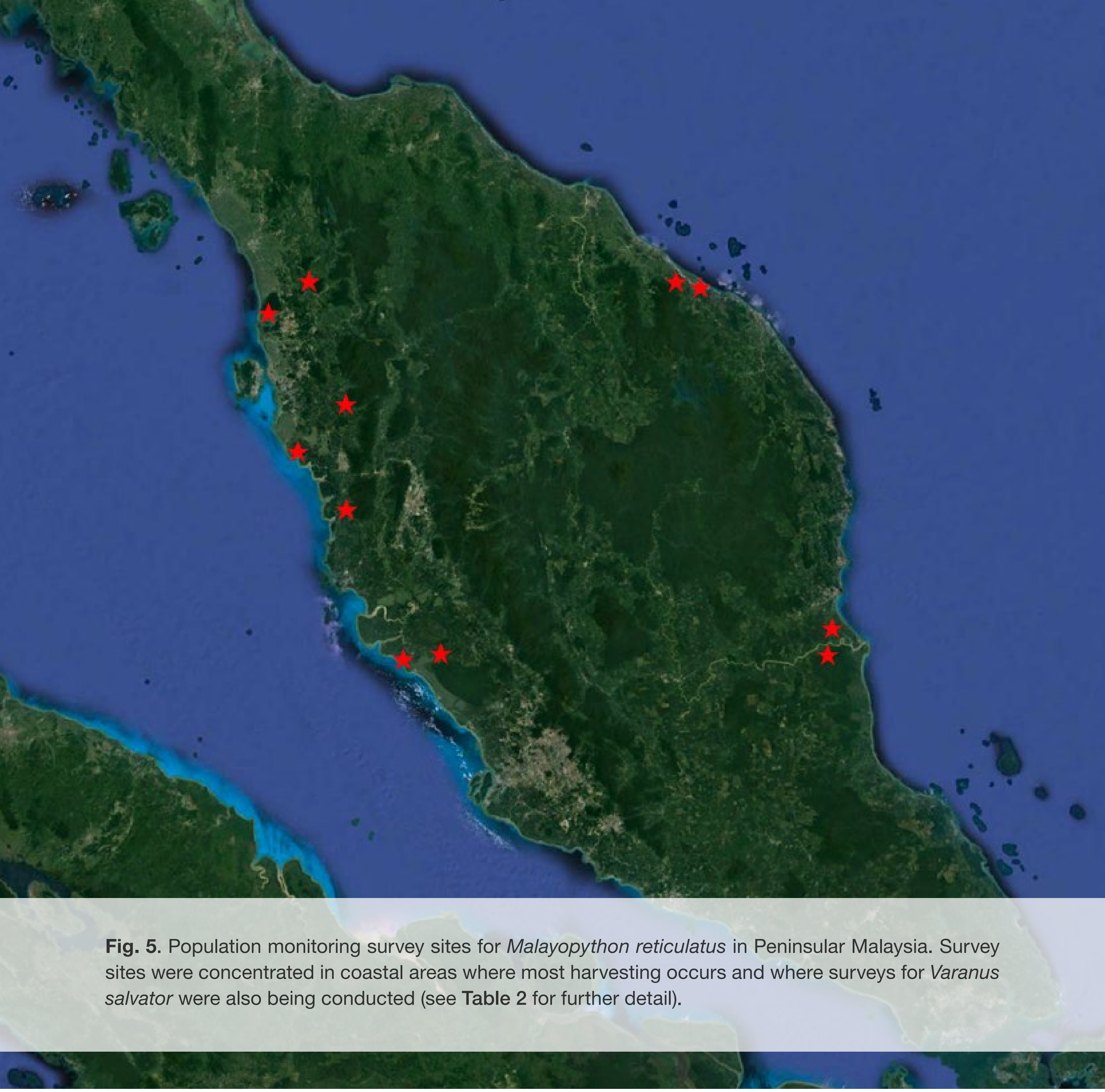


Fig. 5. Population monitoring survey sites for *Malayopython reticulatus* in Peninsular Malaysia. Survey sites were concentrated in coastal areas where most harvesting occurs and where surveys for *Varanus salvator* were also being conducted (see **Table 2** for further detail).

At each site PERHILITAN surveyed pythons in two main habitat types: oil palm plantations and secondary forest areas (**Fig. 6**). These habitat types were chosen because harvesting is focused on these habitats (according to local harvesters; Nossal et al. 2016). In addition, traps were sometimes opportunistically deployed within mangroves and rice paddies to see if pythons could be captured in these habitats, where they are known to occur there (PERHILITAN 2021). Within each State, all habitats were within 25 km of one another. Natural forest habitats were a mixture of primary and secondary vegetation and were all within protected areas, where harvesting is strictly prohibited. Although illegal hunting may occasionally take place at these sites, difficulty of access coupled with the ready availability of pythons at other locations mean harvesting pressure was relatively low. Most harvesting occurs in oil palm plantations or in the mosaic of agricultural plantations and secondary vegetation around villages. Survey sites were concentrated in coastal areas because (1) most harvesting licenses are issued to harvesters living in coastal sites with flat topography and many oil palm plantations, where most harvesting occurs, and (2) because surveys were carried out in conjunction with surveys for *Varanus salvator*, which was surveyed for in a variety of habitats (specifically, mangroves; **Fig. 5**).

Fig. 6. Examples of the two main habitat types regularly surveyed for *Malayopython reticulatus* in Peninsular Malaysia. Natural forest (left) and oil palm plantation (right).

3.1.2 Survey Protocol

Trapping protocol

At the beginning of the study, local harvesters, with experience and equipment, were an integral part of the survey team in each different area. Once PERHILITAN personnel had learned from the hunters, all future surveys were undertaken by PERHILITAN staff (**Fig. 7**). At each site we established a single trapping line (transect) in each survey habitat. On this trap line, two methods were used to capture pythons. First, we deployed fishing nets with a maximum of 3-inch mesh size across slow flowing rivers and man-made drainages (**Fig. 7**). Where possible we set nets in shaded areas, following advice from the licensed hunters who assisted us (captures of pythons are much lower if nets are set in areas of direct sunlight). No bait was used to attract the snakes. Instead, pythons are captured when they swim into the nets and become tangled in the mesh (**Fig. 7**). The second method used to capture pythons was a modified fish trap, with a trap opening of 3 feet in diameter. Branches with leaves (e.g. palm fronds) were placed on both sides of the fish trap and extended to the riverbank (to ensure that any python swimming in the canal is directed to the trap opening). We baited the traps with live ducks to attract pythons. When population surveys are planned, PERHILITAN suspends all other harvesting at survey sites.

The single transects became the trapping survey line (i.e. a single replicate per habitat type; **Table 3**). In 2010, 2011, and 2012, approximately 20 nets and 10 traps were deployed in each habitat. Due to low capture rates, in 2013 the number of nets deployed was increased to 50 per habitat type. As such, the length of each trap line varied with habitat type and logistical constraints (e.g., number of nets and traps available for deployment), but the distance between adjacent nets and traps never exceeded 300 m (mean trap line length = 7.79 ± 1.08 km; **Table 3**). Trap lines are usually non-linear due to constraints of topography. Transect lines at the same sites in multiple years also attempted to recapture marked individuals (see **Table 2**). Nets are used traditionally to capture pythons in Peninsular Malaysia (PERHILITAN 2021). Nets and traps were set in sheltered sites, within watercourses used by pythons (**Fig. 7**). The sex of pythons was determined via cloacal probing. Snout–vent length (hereafter SVL) and body mass were measured using a steel tape and spring scales, respectively (**Figs. 8**). Before release at the site of capture, a passive integrative transponder (PIT) tag was implanted in each python to identify individuals on subsequent encounters (**Fig. 9**). A set of ventral scales were also clipped in a specific pattern to allow identification (Brown and Parker 1976).

Fig. 7. PERHILITAN staff deploying a net for capturing pythons in a sheltered site in a small stream on the edge of secondary forest.

Fig. 8. PERHILITAN staff take morphometric data from a python captured in an oil palm plantation.

Fig. 9. PERHILITAN staff collect data from and implant a PIT tag (Passive Integrated Transponder) beneath the skin of a python collected in secondary forest.

3.1.3 Frequency

PERHILITAN surveyed for pythons annually for four years, from 2010 until 2013. Trap lines were operated for approximately 1 week (mean = 8.3 days; s.e. = 0.43; range 7–10; Table 2) in the first years of surveying but were increased to 10 trapping days at all sites in 2013. Surveys for pythons were discontinued in 2014 because of the significant effort involved and low capture rates.

3.1.4 Visual encounter surveys

Since population surveys in 2010, PERHILITAN staff and international experts have also tested ad hoc surveys for pythons in suitable habitat. This has involved passive or active searches during harvesting expeditions to locate snakes with local people while going about their normal activities, or independently while conducting other fieldwork. Active surveys were conducted at night, either on foot or from the back of a moving car or motorbike, with the aid of a handheld spotlight. Surveys teams varied from two to 10 people and were conducted throughout the year. These surveys were not standardized, and the distances covered were not recorded.

Table 2. Summary of survey effort and captures of *Malayopython reticulatus* in four habitats in five States in Peninsular Malaysia. *At this site, the secondary forest habitat underwent considerable disturbance between years due to an urban development.

Study area	Year of survey	Habitat	Survey dates	Survey days	Number of traps	Survey transect length (km)	Pythons captured	Pythons recaptured
Terengganu	2010	Forest	27.10.2010 - 4.11.2010	9	20 nets, 10 traps	7.5	1	0
		Oil palm	27.10.2010 - 4.11.2010	9	20 nets, 9 traps	7.25	1	0
	2011	Forest	23.5.2011 - 02.6.2011	10	20 nets, 10 traps	7.5	0	0
		Oil palm	23.5.2011 - 02.6.2011	10	20 nets, 9 traps	7.25	1	0
Selangor	2010	Forest	1.10.2010 - 9.10.2010	9	21 nets, 3 traps	6	3	0
		Oil palm	1.10.2010 - 9.10.2010	9	20 nets, 3 traps	5.75	1	0
		Rice paddy	1.10.2010 - 9.10.2010	9	4 nets, 3 traps	1.75	0	0
	2011	Forest	27.6.2011 - 6.6.2011	10	20 nets, 10 traps	7.5	4	0
		Oil palm	27.6.2011 - 6.6.2011	10	20 nets, 10 traps	7.5	3	0
	2013	Forest*	24.10.2013 - 2.10.2013	10	50 nets, 10 traps	15	0	0
		Oil palm	24.10.2013 - 2.10.2013	10	50 nets, 10 traps	15	1	0
Perak	2010	Forest	24.11.2010 - 30.11.2010	7	20 nets, 10 traps	7.5	0	0
		Oil palm	24.11.2010 - 30.11.2010	7	20 nets, 9 traps	7.25	0	0
	2011	Forest	6.10.2011 - 12.10.2011	7	20 nets, 10 traps	7.5	3	0
		Oil palm	6.10.2011 - 12.10.2011	7	20 nets, 10 traps	7.5	0	0
	2013	Forest	6.11.2013 - 16.11.2013	10	50 nets, 10 traps	15	2	0
		Oil palm	6.11.2013 - 16.11.2013	10	50 nets, 10 traps	15	4	0
Pahang	2012	Forest	14.5.2012 - 21.5.2012	8	20 nets, 13 traps	8.25	0	0
		Oil palm	13.5.2012 - 23.5.2012	11	20 nets, 12 traps	8	4	0
		Mangrove	14.5.2012 - 22.5.2012	9	2 nets	0.5	0	0
		Rice paddy	14.5.2012 - 24.5.2012	11	3 nets, 1 trap	1	0	0
Kedah	2012	Forest	11.7.2012 - 17.7.2012	7	10 nets, 13 traps	5.75	2	0
		Oil palm	11.7.2012 - 17.7.2012	7	15 nets, 7 traps	5.5	4	0
		Mangrove	11.7.2012 - 17.7.2012	7	4 nets, 5 traps	2.25	0	0
		Rice paddy	11.7.2012 - 17.7.2012	7	1 net, 5 traps	1.5	0	0
	2013	Forest	21.11.2013 - 30.11.2013	10	50 nets, 10 traps	15	2	0
		Oil palm	21.11.2013 - 30.11.2013	10	50 nets, 10 traps	15	11	1
Total				**240**		**210.5**	**44**	**1**

*At this site, the secondary forest habitat underwent considerable disturbance between years due to an urban development.

3.2 Overall survey results

Over four survey seasons, including 240 survey days and 7,679 individual trap days, we captured 44 pythons 45 times (i.e., one recapture; Table 2). Most pythons (64%) were captured in oil palm plantations; the remainder was captured in secondary forest. No pythons were captured in rice paddies or in mangroves (but note the significantly lower survey effort).

3.2.1 Population demography

The 44 pythons captured during the monitoring research program had a sex ratio of 1:1 (52% female). Snout-vent lengths of male (mean = 262 cm; SE = 93, range = 183 – 325 cm) and female (mean = 266; SE = 87; range = 143 – 352 cm) pythons were similar ($F_{1,44}$ = 0.145, P = 0.71).

The heaviest male python captured weighed 15.5 kg while the heaviest female weighed 21 kg. Body mass relative to SVL was similar between the sexes ($F_{1,44}$ = 1.24, P = 0.271). Of the pythons captured, 27% were too small to be of commercial value and would have been released by hunters (**Fig. 10**). Although more pythons were captured in oil palm plantations, those pythons were smaller overall than python captured in secondary forest (mean: 249 vs 292 cm, respectively: = $F_{1,44}$ = 12.4, P = 0.0010). This pattern is also found in harvested *Varanus salvator* populations (Khadiejah et al. 2019) and fits with other results for *M. reticulatus* in other parts of its range (Shine et al. 1999; Auliya 2006; Natusch et al. 2019a).

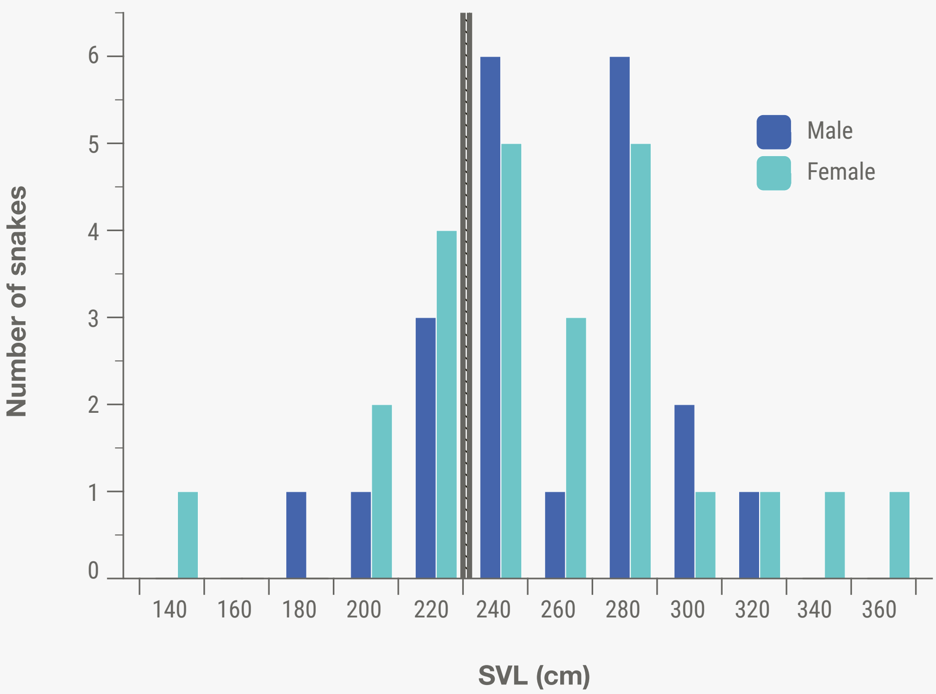


Fig. 10. Size frequency histogram of male (shaded) and female (unshaded) *Malayopython reticulatus* captured during monitoring surveys in Peninsular Malaysia. The shaded line indicates the legally binding minimum size limit, with specimens smaller than this threshold not captured for trade.

3.2.2 Visual encounter surveys

We encountered > 20 pythons during ad hoc surveys, including small hatchlings through to large specimens ~25 kg. Approximately 50% were considered too small for capture and sale. The majority of pythons located with hunters during ad hoc surveys were not captured for trade, either because they were too small or because their skins were too damaged. Independent/international experts that have conducted surveys with local hunters report similar findings, suggesting that hunters were not purposefully releasing snakes because of the presence of the wildlife department (D. Natusch, pers. comm. 2020). Surveys of python processing facilities throughout Peninsular Malaysia confirm this finding; small snakes below the legal size limit (240 cm SVL) are not captured for trade because they have no commercial value (PERHILITAN 2021).

3.3 Insights from field population monitoring

The capture of only 44 pythons over the course of our surveys does not provide a robust basis for assessing the impact of harvesting on wild populations. Nevertheless, several insights can be gathered, as follows:

- Despite similar survey effort, more pythons were captured in oil palm plantations than in secondary forests, echoing the claims of local hunters (Nossal et al. 2016; PERHILITAN 2020). This is likely an artifact of the increased prey abundance (rodents) in this habitat type. For this reason, oil palm plantations are preferentially targeted as hunting sites.

- Although more snakes were captured in oil palm plantations, they had smaller mean body sizes than snakes captured in secondary forest. This finding may be caused by a difference in availability of prey sizes for large pythons (oil palm plantations have fewer large-bodied prey than secondary forest) and/or because fewer pythons are harvested in secondary forest, allow a larger proportion of snakes to reach large sizes (Shine et al. 1999; Natusch et al. 2019a).

- Traps were more effective than nets at catching large pythons. The five largest pythons captured were all captured in traps. Unlike our experimental surveys, hunters do not use baited traps and the use of nets may naturally restrict the sizes of pythons that can be captured.

- Trap biases in the size of pythons captured in our surveys, and low recapture rates, confound estimates of the density of both small and large pythons in the populations surveyed.

- Of the catchable population, only 73% of snakes were of a commercially valuable size.

- Python capture rates were slightly higher in States with intense harvests (Kedah, Pahang, Perak, Selangor) than in Terengganu where little harvesting occurs. However, differences were minor (a few snakes only) and should not be used as a basis to draw broad conclusions.

- In most States (Selangor, Perak, Kedah) numbers of pythons captured in successive years increased, despite harvesting in the intervening period between surveys, which is not consistent with harvesting negatively impacting the wild populations. Several other factors may account for this disparity, for example: (1) the survey team became more adept at setting traps, and in the right locations, over time; (2) the month of survey was more conducive to capturing pythons; and/or (3) luck (random probabilities). Again, captured rates were too low and variable to draw firm conclusions.

- The results of ad hoc nocturnal surveys were too variable to draw meaningful conclusions about python abundance or the impacts of harvesting, but two observations may be significant:

1) Pythons were located in all locations, regardless of whether harvested or not; and,

2) Assessing quality at the site of capture is standard commercial practice. Hunters regularly locate snakes, but do not capture them when they are too small (outside the legal and commercial limit) or have obviously damaged skins.

3.4 Summary of monitoring methodology

Unlike Varanus salvator, four years of field monitoring and mark-recapture studies with *M. reticulatus* simply confirmed the difficulties in direct surveys of this species. This approach to monitoring did not allow robust conclusions to be drawn about abundance, population size-structure, or the impact of harvesting in Peninsular Malaysia. PERHILITAN suspended field surveys for *M. reticulatus* in 2014.

Malayopython reticulatus are notoriously difficult to survey in the wild, because they are well camouflaged, sedentary, and do not aggregate for reproduction or thermoregulation (Shine et al. 1999; Auliya 2006). Experimental studies on closely related species (*Python molurus bivittatus*) have shown that detection rates are sometimes lower than 1% (i.e., only 1 in 100 pythons in the environment are detected; Dorcas and Willson 2013). Use of Judas snakes (reproductive males that locate females) revealed detection probabilities of 1% (Smith et al. 2016). Experimental radiotelemetry and visual encounter surveys coupled with detection probability modelling suggested that detection probabilities for pythons varied from 0.01 – 1.46% (i.e., for every python encountered, investigators possibly walked past 10,000; Nafus et al. 2020).

These real-world difficulties encountered by PERHILITAN's research efforts confirm the findings of others. Abel (1998) and Auliya (2006) spent 5-6 months in the field undertaking trapping surveys for reticulated pythons and located only 11 and 22 pythons, respectively (Auliya 2006). Furthermore, many of these captures were not made in a standardized way. Standardized visual encounter surveys for pythons on the Kinabatangan River in Sabah, east Malaysia, resulted in the capture of 75 pythons 94 times. Compared to PERHILITAN's surveys, increased survey effort explains the larger sample from Sabah (mean 2.5 surveys/week over 3.5 years, for a total of 459 transects and 2,096 survey kilometres; R. Burger, pers. comm. 2020). Although total captures and recaptures were significantly increased, yield given survey effort was much lower than in PERHILITAN's trapping surveys in Peninsular Malaysia – despite no harvesting occurring at the site of the Sabah population. Extrapolating results from a spatially limited site to large spatial scales, for management purposes, is obviously fraught with problems (Auliya 2006; Natusch et al. 2019a).

The possibility of greatly increasing survey effort in Peninsula Malaysia always remains, but the budget required to do so, given the same problems with accuracy and precision, need to be considered carefully. The PERHILITAN surveys involved between 2-10 salaried staff, travel time, insurances, 2 x department Toyota Hilux vehicles and fuel, payments to hunters, purchase of equipment (PIT Tags, nets), staff accommodation and subsistence, and sundry other costs. Deploying these human and physical resources is difficult to justify given the limited value of the results.

Even if resources were dedicated to this task, for academic purposes, the data gathered would be of little value for assessing sustainability (Natusch et al. 2019a; Nafus et al. 2020). A study on box turtles, with a similarly low detection probability (0.03) to pythons, yielded a population abundance estimate with a 95% CI that ranged from 28 to 1,360 individuals (Refsnider et al. 2011), a range that represents vastly different management goals and challenges.

Numerous studies on reptiles with low detection probability have highlighted such difficulties (Durso and Seigel 2015; Rodda et al. 2015). For example, even after correcting for several sources of variation in a field study of lizards, Lardner et al. (2015) showed that unexplained variation in detection surpassed 4-fold the variation explained by population abundance and other explanatory covariables. For the task of estimating population abundance and harvest sustainability of reticulated pythons in Peninsular Malaysia, independent field-based surveys of wild populations are undermined by the following major considerations:

- Estimates would be available for a single spatial location and may not be applicable to other sites or States in Malaysia.
- Estimates would be available for a single habitat, despite pythons occurring in numerous habitat types in Malaysia (perhaps with different visibility biases).
- Seasonal differences in survey effort and population demographics require results to be obtained over successive years.
- Pythons are most easily captured in watercourses (PERHILITAN surveys involved setting nets or traps within canals). Because we do not know the frequency with which pythons utilise these watercourses, or their densities away from such watercourses, we may well be under or overestimating python abundance.
- Attempting to capture pythons using nets resulted in a highly skewed size demographic. No large adult or small juvenile pythons were captured during our field sampling.

Employing multiple different survey techniques in unison can yield increased capture rates (Dorcas and Willson 2009). This was experienced during targeted and *ad hoc* field surveys for reticulated pythons. However, the variability in techniques used (active search *vs* capture with traps *vs* capture with nets), distances covered, number of harvesters, time of year, variations in microhabitat, and broader spatial variations, makes standardizing the survey methods, and applying corrections to the results for known biases, a daunting challenge. Given the low quality of the data gathered, PERHILITAN cannot justify the expense involved in conducting studies on such a common species, listed as Least Concern by IUCN, considered a pest in many parts of Malaysia, and for which all available evidence suggests harvesting is sustainable (Shine et al. 1999; Natusch et al. 2016b, 2019a; **Chapter IV**).

In conclusion, the results of our efforts to apply conventional survey methods, coupled with the available literature, reveal two major findings. First, that pythons have extremely low detection probabilities. Second, that detection probabilities are not due to low abundance of pythons, but rather to other behavioral, landscape, and logistical factors (Nafus et al. 2020). Based on consideration of an extensive body of scientific literature and PERHILITAN's own survey efforts and experience, alternative methods for assessing the sustainability of harvesting have been considered and pursued.

CHAPTER IV

Annual monitoring system for reticulated pythons in Peninsular Malaysia

This Chapter summarises the methods and results of PERHILITAN's annual monitoring program for M. reticulatus. Harvest monitoring is a critical component of any wildlife harvest program. PERHILITAN synthesizes a broad range of information to provide confidence that harvesting of M. reticulatus is sustainable in Peninsular Malaysia. With secretive snakes like M. reticulatus, significant challenges exist in obtaining an accurate census of wild population sizes. Application of techniques used to estimate population sizes for other reptile or vertebrate species have proven unsuccessful for this species ***(see Chapter III)****. PERHILITAN relies instead on the more robust method of drawing inferences about the status of the wild population from harvested individuals. This assessment is augmented with strict monitoring and management protocols that allow rapid adaptive management and reduction of harvests should evidence of unsustainable levels of offtake become available*

4.1 Monitoring and management process: decision-making steps

PERHILITAN implements an adaptive management approach to establish sustainable offtake of *M. reticulatus* from Peninsular Malaysia. This approach includes four steps (**Fig. 11**):

1) Establish a harvest quota for *M. reticulatus* based on historical averages from previous harvest years.

2) Undertake monitoring of harvested pythons at python processing facilities and monitoring hunter activities throughout Peninsular Malaysia.

3) Monitor key trade data such as harvest locations, habitats, harvest statistics, and demand, to ensure no major biases might occur in the indicators of sustainability.

4) Review results of monitoring activities and, if necessary, adapt harvest and trade regulations (permit numbers, harvesting areas, size limits, quotas) to ensure sustainable levels of offtake.

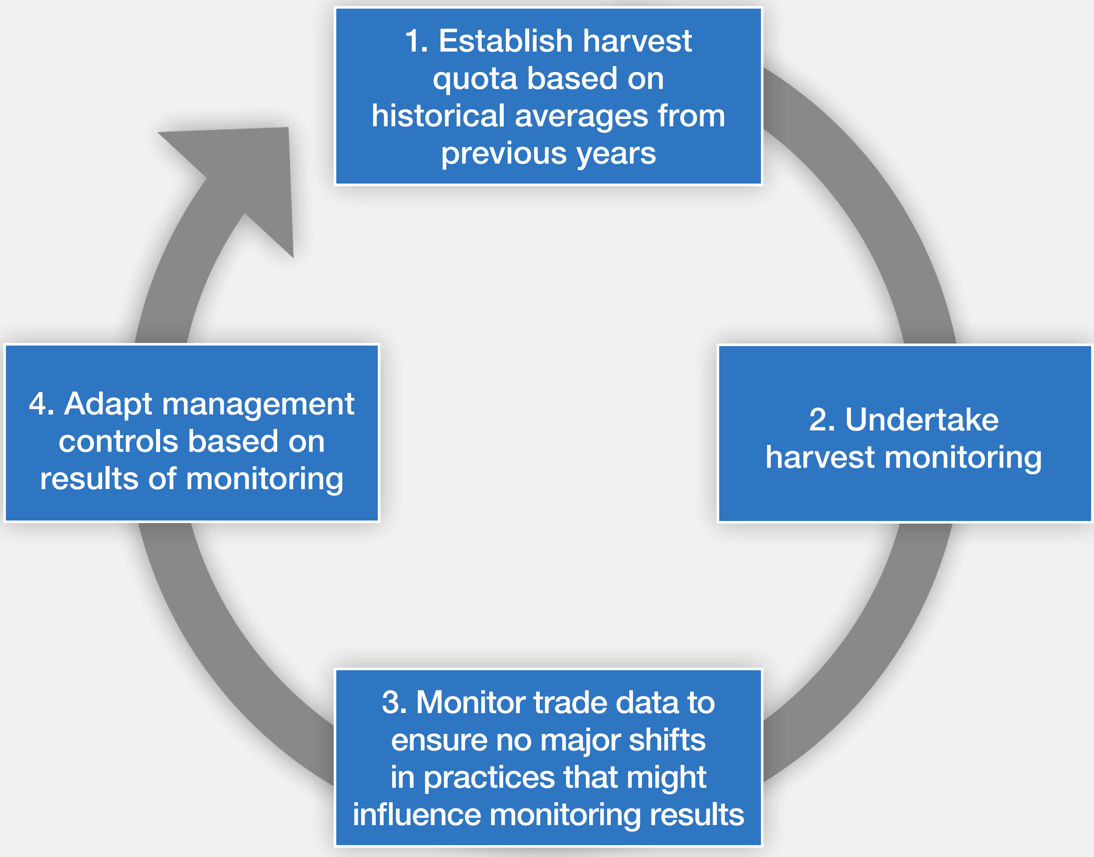


Fig. 11. Adaptive management steps taken by PERHILITAN to inform decision-making for sustainable harvesting of *Malayopython reticulatus* in Peninsular Malaysia.

4.2 Monitoring harvested animals

After four years of field-based monitoring surveys it was clear that alternative methods were needed to assess the impacts of harvesting on Peninsular Malaysia's *M. reticulatus* population. In 2012, PERHILITAN began complementing field surveys with data collection from pythons brought to processing facilities. Today, harvest monitoring forms the basis of PERHILITAN's annual monitoring system. The methodologies and results of this monitoring program are described below, together with a discussion of its applicability to ensuring sustainable offtake of *M. reticulatus* in Peninsular Malaysia.

4.2.1 Location

Each year, data are collected from facilities that harvest and trade the largest number of pythons in Peninsular Malaysia (**Fig. 12**). Because of fluctuations in demand, the facilities visited (mostly in the States of Johor, Selangor and Perak) vary from year to year, but account for around 90% of annual harvest and trade. Data are collected from multiple sites each year. In some years, data are also collected from smaller facilities to test if the harvested population demographics are similar across all facilities.

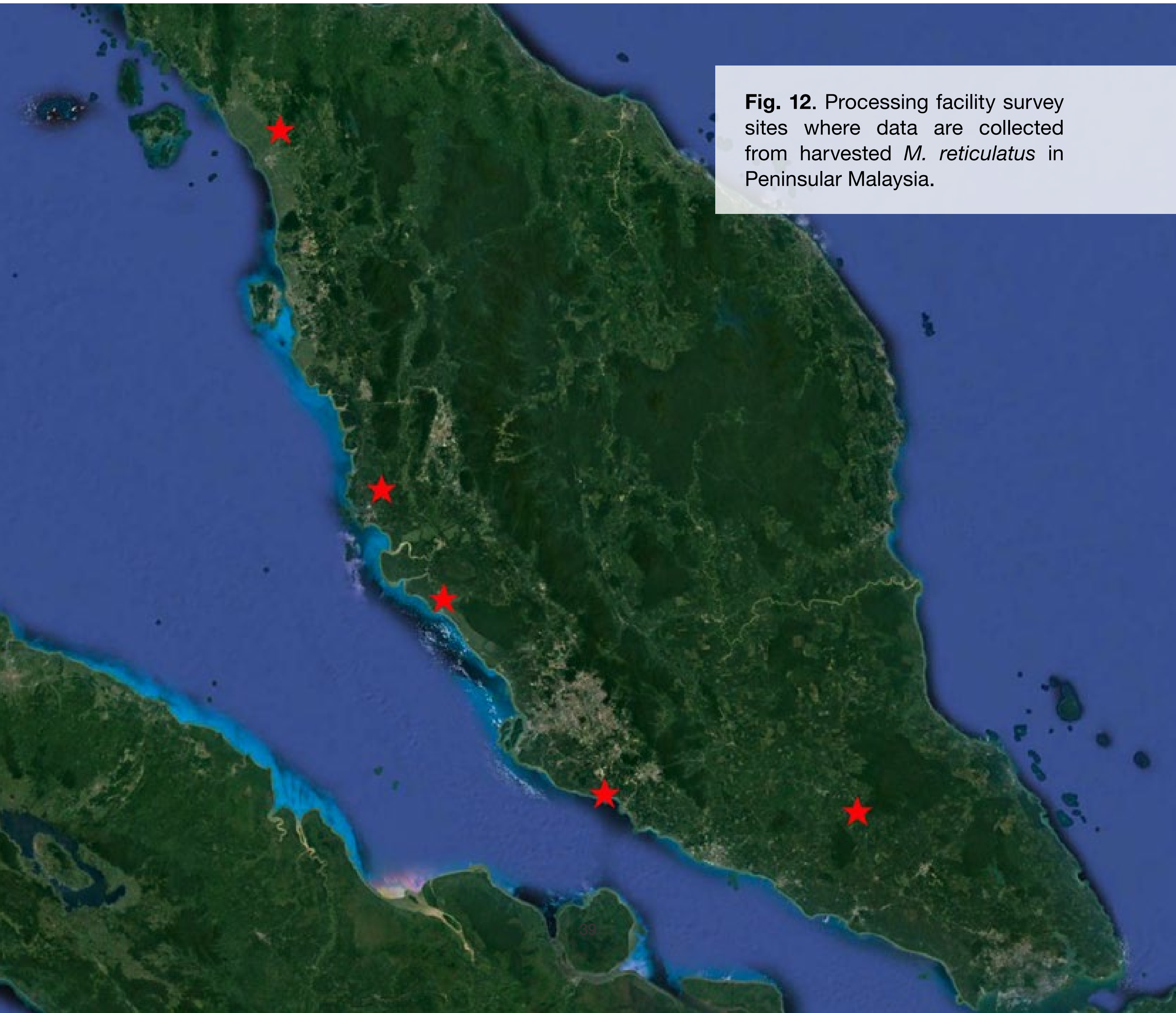


Fig. 12. Processing facility survey sites where data are collected from harvested *M. reticulatus* in Peninsular Malaysia.

4.2.2 Protocol

At each facility PERHILITAN staff examine samples of freshly killed pythons before and after skinning (**Fig. 13**). Snout–vent length and body mass are recorded (using a steel measuring tape and electronic scales, respectively), and then the pythons' carcass is examined to determine sex and reproductive condition (by visual inspection of gonads). Females are considered to be mature if they possess either thickened, muscular oviducts, primary ovarian follicles > 8 mm, vitellogenic secondary follicles, oviducal eggs, or corpora albicantia indicative of previous reproductive events (*sensu* Shine et al. 1998b; Natusch et al. 2019b). Clutch size is determined by counting eggs within the oviducts of gravid females. Males are considered to be mature if they possess thick turgid testes and convoluted efferent ducts indicating the presence of sperm.

Fig. 13. PERHILITAN rangers collecting biological data from specimens of *Malayopython reticulatus* brought to a processing facility in Peninsular Malaysia

4.2.3 Frequency

Some monitoring takes place throughout the year to quantify seasonal variation in biological attributes linked to population dynamics, but most occur once annually – either during the period when pythons possess oviducal eggs (March-May) or during the peak harvest period (November-December). The end result is that large amounts of data have been collected on the biology and life history of reticulated pythons.

4.2.4 Biological insights from the processing facilities

Overall, 9,129 pythons have been examined from across Peninsular Malaysia over eight years (2012, 2013, 2014, 2015, 2016, 2018, 2019, 2020). The data collected are summarized below and additional information are available in Natusch et al. (2019a).

Demographic of harvested pythons:

Mean SVL of males (mean = 283) and females (mean = 292) was similar, but because of large sample sizes is statistically different (**Fig. 14**). Females (mean 8.6 kg) are slightly and significantly heavier than males (mean 8.1 kg). The largest male and female snakes brought to processing facilities were 483 cm SVL and 580 cm SVL, respectively. The snakes brought to processing facilities were significantly larger than those specimens captured in the wild ($F_{1,9045} = 22.5$, $P < 0.0001$). When this analysis was restricted to wild specimens considered to be of commercial size, this was no longer the case – corroborating that small snakes do not have commercial value and are not being captured and brought to processing facilities ($F_{1,9035} = 3.03$, $P = 0.08$). Nearly all male pythons (99%) brought to processing facilities are sexually mature, while 72% of females are reproductive (possibly mature, but no signs of reproductive activity at the time of examination).

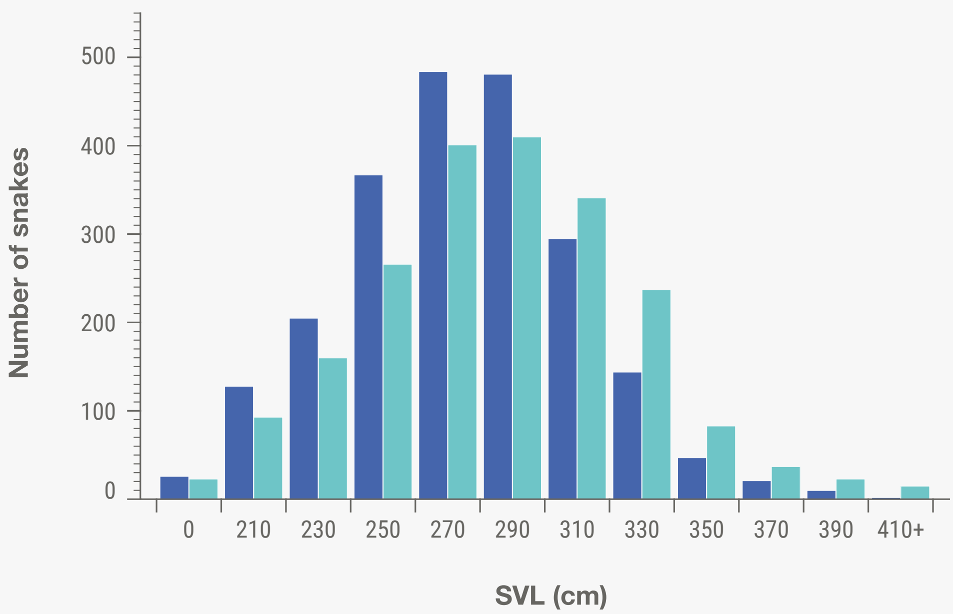


Fig. 14. Mean snout-vent length (cm) of male and female *Malayopython reticulatus* brought to processing facilities.

Sex ratios

The sex ratio of *M. reticulatus* brought to processing facilities was slightly biased towards males (51% males).

Reproductive biology

In Peninsular Malaysia, the smallest mature male recorded was 183 cm SVL while the smallest reproductive female was 210 cm SVL. Based on dissections, only 18% of females are reproductive in a given year. Given knowledge of this species in other parts of its range, this may be an artifact of harvesters identifying and avoiding harvest of gravid pythons. Testes volumes of wild male pythons in Malaysia begin to increase in November, with mating mainly taking place in December and January each year (**Fig. 15**). At that time, female follicles in the ovary begin increasing in size, with ovulation and egg formation taking place between March and June when females with oviducal eggs are most commonly encountered (**Fig. 16**). Based on the presence of oviducal eggs scars, oviposition occurs from April through to July (**Fig. 16**). Clutch sizes are significantly correlated with maternal body size and average 20 eggs per clutch (**Fig. 17**)

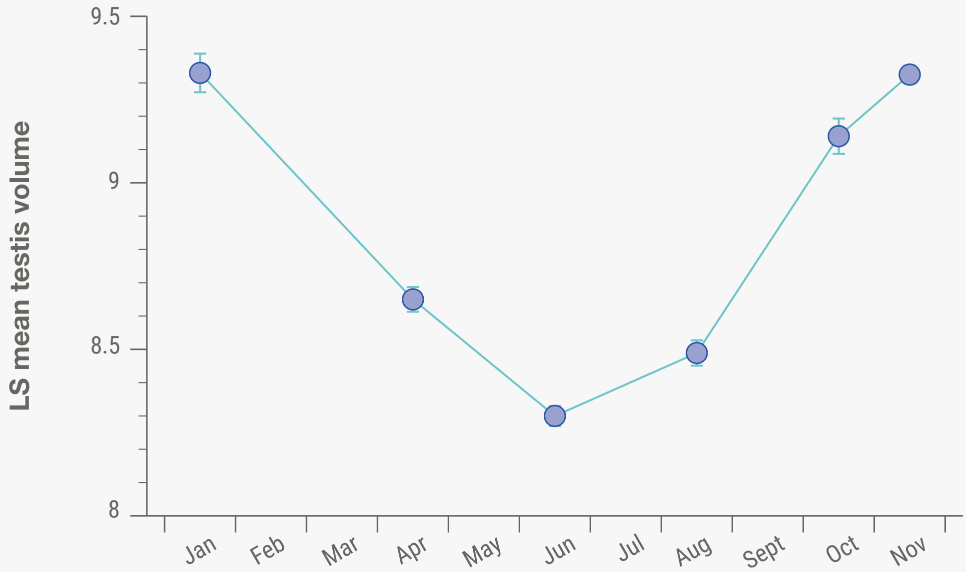


Fig. 15. Leastsquare mean values for testes volume of male *Malayopython reticulatus* throughout the year. Least-square means are used because they keep body size (SVL) constant.

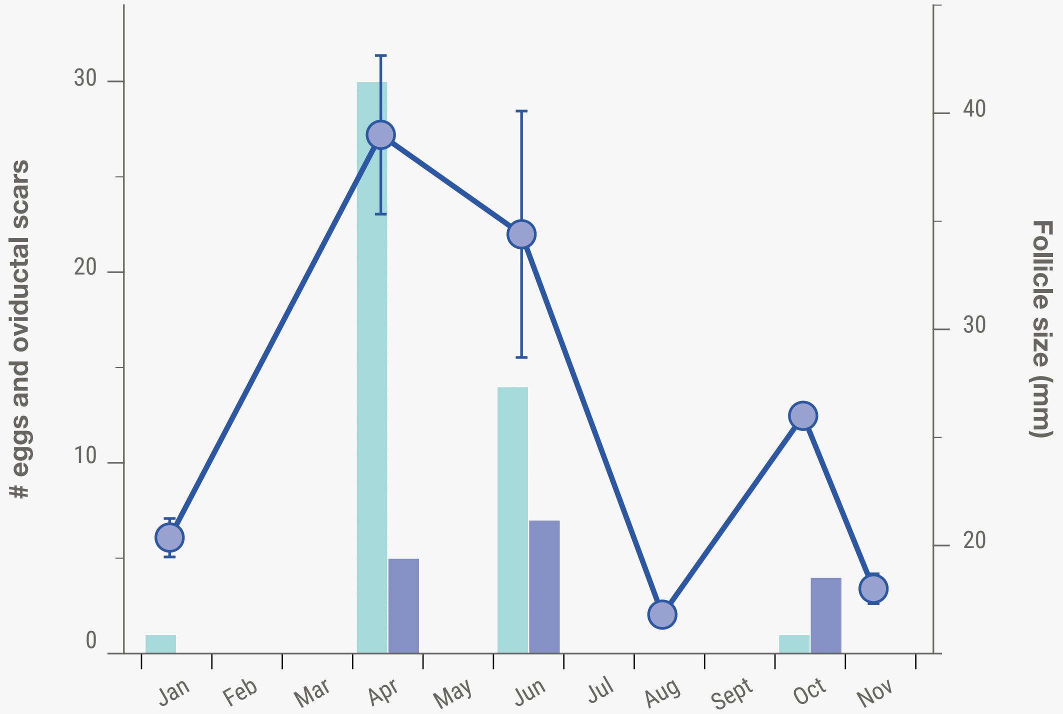


Fig. 16. Variation by month in the number of oviducal eggs (hatched columns) and scars, indicating egg-laying has occurred, (open columns), and the mean size (and standard error) of vitellogenic secondary follicles (open circles connected by line) in female *Malayopython reticulatus* from Peninsular Malaysia.

Fig. 17. Relationship between snout-vent length (SVL) and clutch size in female *Malayopython reticulatus* from Peninsular Malaysia.

Diet

The diet of harvested *M. reticulatus* consists mainly (> 95% of 107 items recovered) of commensal rodents and domesticated species (chickens, dogs, cats, goats). Other prey items include Common Water Monitors (*Varanus salvator*) and unidentified birds.

4.2.5 Insights into management

The data from processing facilities:

1) Allow independent corroboration and cross-checks of harvest data provided by traders;

2) Offer insights into biologically informed management interventions to help increase confidence in sustainable harvesting;

3) Provide definitive information on population parameters, and variation within them annually and over time, that have direct application to harvest sustainability (e.g., mean body size, mass, sex ratios and sizes at sexual maturity).

At this stage, data have been collected from processing facilities in eight survey seasons over nine years. They establish definitive status reference points for predicting future trends, and conclude:

1) Comparison of the demographic of harvest pythons with those caught in the field corroborates that small snakes, although available to harvesters in the field, are not being captured and brought to processing facilities.

2) The remarkably low proportion of reproductive females brought to processing facilities compared to harvests in other parts of the species' range is consistent with the claim that hunters do not take obviously gravid pythons (Nossal et al. 2016; Natusch et al. 2019a).

3) The sizes at which 50% of female pythons reach sexual maturity has been used to impose a legally binding minimum size limit of 240 cm SVL.

4) Data on the disproportionate contribution of large females to population recruitment has been used to impose a legally binding maximum size limit of 500 cm SVL.

4.2.6 Insights into sustainability

In the period 2012 to 2019, the harvest data confirm key biological indices of sustainability have remained stable:

1) Sex ratios of capture snakes have remained close to parity since 2012 (**Fig. 18**), but more females were collected than males in 2020. There is no immediate explanation for this. Sex ratios continue to be monitored annually.

2) Mean body sizes of harvested pythons have increased since 2012 rather than decreased (as would be expected if the harvest was negatively affecting recruitment; Natusch et al. 2019a). The increase in mean body sizes of pythons after 2016 reflects the imposition of a minimum size limit of 240 cm SVL (**Fig. 19**).

3) Although analysis of sexual maturity has only been in place since 2015, data gathered to date on SVL_{50} (the size at which 50% of female pythons reach sexual maturity) do not present cause for concern. Although SVL_{50} decreased in 2018, in this year the pythons collected were larger than usual, resulting in a smaller sample sizes of pythons in the smaller python size classes - thus skewing the logistic model used for this analysis and creating large confidence limits around the mean (very large sample sizes are required to accurately calculate this metric). SVL_{50} recovered in 2019 and continues to be closely monitored (**Fig. 20**).

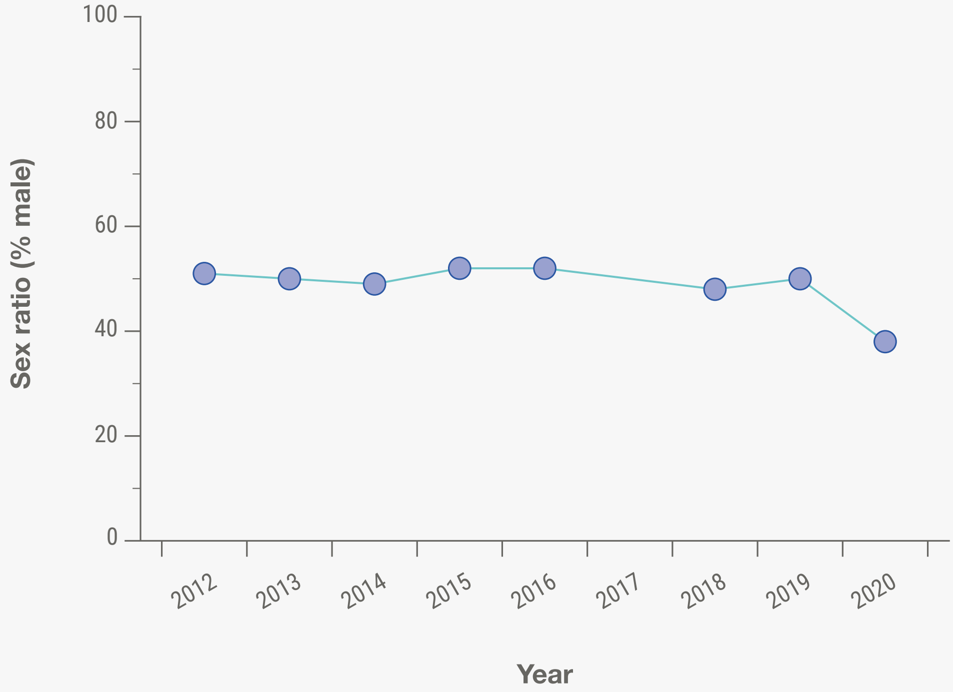


Fig. 18. Stable trend in sex ratios of reticulated pythons harvested in Peninsular Malaysia since 2012. No data were collected in 2017. If harvests were unsustainable, we would expect to see sex ratios slowly skew towards one sex.

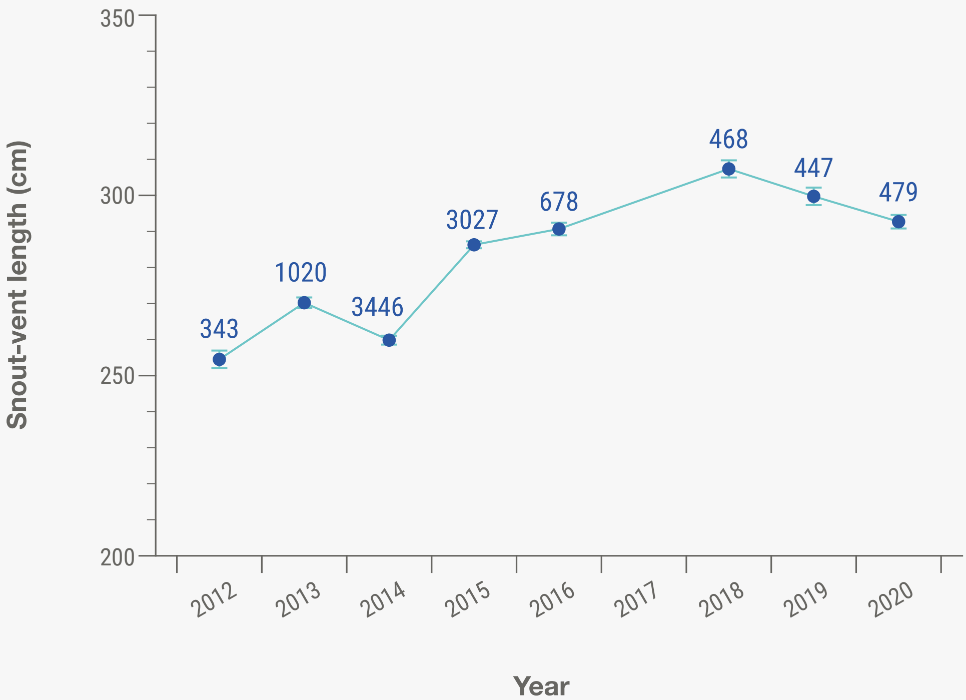


Fig. 19. Variation in mean snout-vent length of reticulated pythons harvested in Peninsular Malaysia since 2012 confirming a significant increase in mean snake size over time, which is consistent with sustainable harvest. Standard errors are present but too small to see because of large sample sizes. No data were collected in 2017.

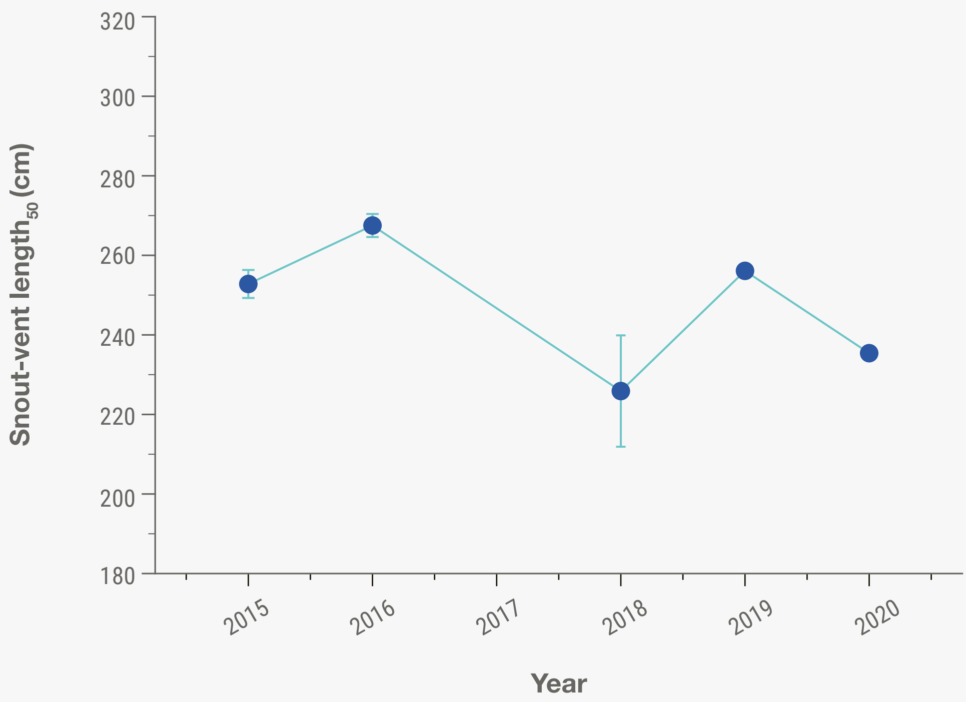


Fig. 20. Mean snout-vent length (plus standard errors) at sexual maturity for 50% of female reticulated pythons in Peninsular Malaysia as a function of year since 2015. No data were collected in 2017. Sample sizes in the smaller python size ranges were small in 2018, which resulted in the logistic model not functioning optimally. Data from 2018 are presented, nonetheless.

4.3 Trader monitoring

The third tier of monitoring by PERHILITAN examines trader information. Data gathered from the trade itself provide some insights into sustainability (e.g., changes in catch per unit effort), but also provide information that may help to explain changes observed in the biological data collected by PERHILITAN scientists.

In addition, PERHILITAN assists and encourages Malaysian industry to design and implement their own verification systems. Data from any systems developed are used by PERHILITAN to monitor and cross-check against the department's own systems to gather important data for monitoring and ensure compliance.

4.3.1 Protocol

Harvesters capturing and selling *M. reticulatus* are required to purchase a license from local PERHILITAN offices, provided on demand. Traders and processing facility operators are required to maintain logbooks (provided by PERHILITAN) and in future will be required to engage in online reporting (see **Chapter V**).

4.3.2 Locations and extent of harvest

Analysis of the number of harvesting licenses and where they were issued provides important information on the intensity of the harvest of *M. reticulatus* in Peninsular Malaysia. At present, the main harvesting areas of Kedah, Pahang, Perak, and Selangor (and, in some years, Negeri Sembilan) provide 95% of the harvest, and have been consistent from year to year (**Fig. 29**). Little harvesting occurs in other States (<~5%), and none in Johor (**Table 3; Fig. 29**).

Notably, the number of pythons harvested has decreased in Selangor State since 2016. One of Malaysia's largest python skin exporters, Sky Pacify Reptile, located in Selangor, began wrapping up his business in 2016 due to declining demand from China. He has since ceased trading. No corresponding increase in harvests in other States, to compensate for the decreased harvest in Selangor, has been observed.

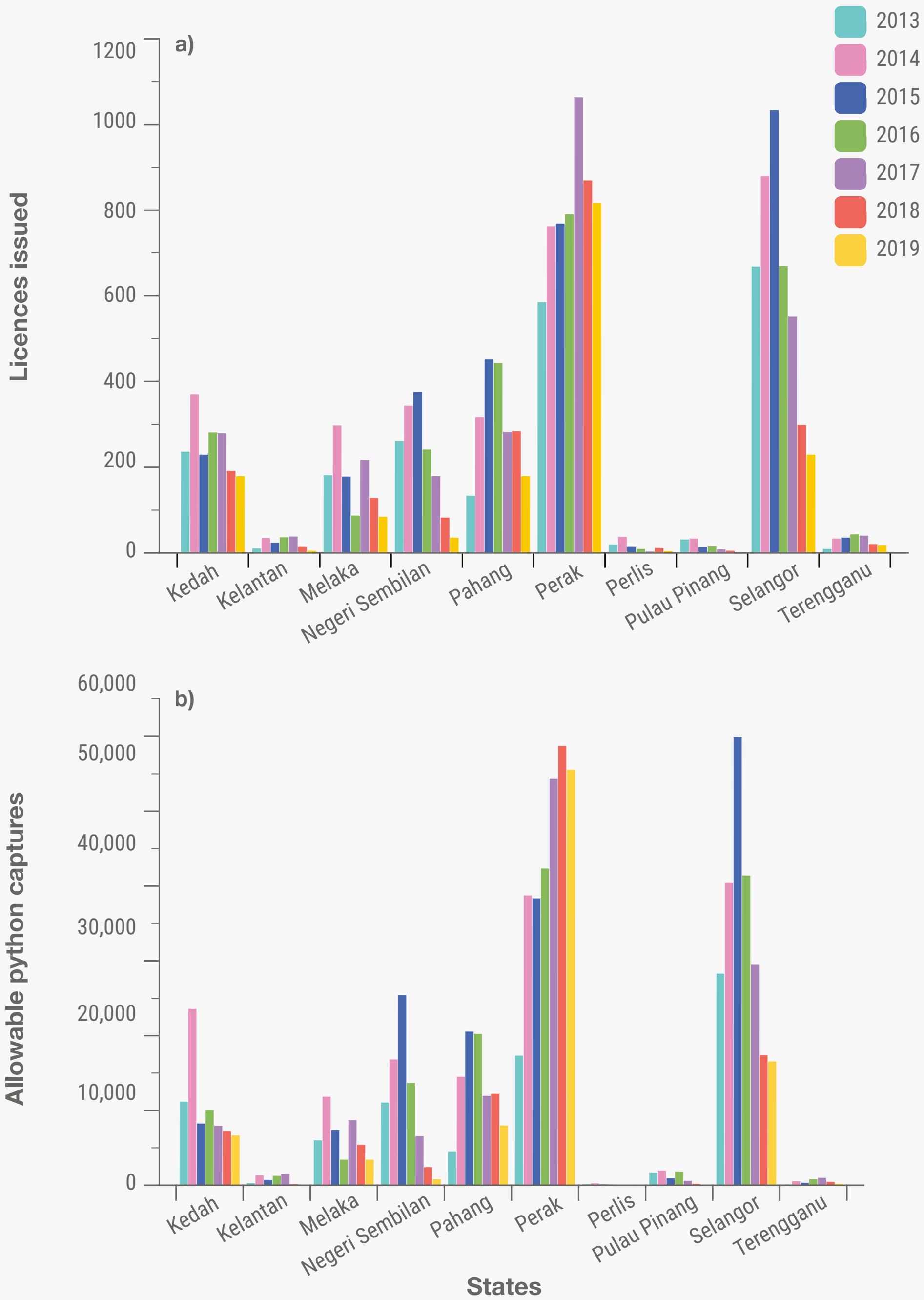


Fig. 21. The number of **a)** harvesting licenses issued and **b)** *Malayopython reticulatus* captured in each State in Malaysia from 2013 until 2019. The States with the most harvesting all continue to sustain a high abundance of pythons.

Table 3. Number of licenses issued and *Malayopython reticulatus* captured in each State in Peninsular Malaysia from 2013 until 2019.

STATES	2013		2014		2015		2016		2017		2018		2019	
	Licences	Pythons	Licences	Pythons	Licences	Pythons	Licences	Pythons	Licences	Pythons	Licences	Pythons	Licences	Pythons
Kedah	237	11217	371	23600	230	8278	282	10123	280	7979	192	7295	180	6697
Kelantan	11	307	35	1355	24	746	37	1311	39	1540	15	202	6	8
Melaka	182	6035	298	11877	179	7429	88	3465	218	8744	129	5447	85	3464
Negeri Sembilan	261	11080	344	16854	376	25438	242	13715	180	6604	83	2443	36	838
Pahang	134	4555	318	14525	452	20576	443	20255	283	11986	285	12272	180	8032
Perak	586	17368	763	38780	769	38388	791	42379	1064	54351	870	58757	817	55581
Perlis	20	157	38	285	15	145	10	123	4	6	12	12	5	5
Pulau Pinang	32	1722	34	1982	14	965	16	1846	9	627	6	224	0	0
Selangor	669	28323	880	40468	1034	59929	670	41444	552	29581	299	17435	230	16586
Terengganu	10	131	34	578	36	349	44	839	41	1032	21	479	18	239
Totals	**2142**	**80895**	**3115**	**150304**	**3129**	**162243**	**2623**	**135500**	**2669**	**122450**	**1912**	**104566**	**1556**	**91450**

4.3.3 Harvest dynamics

a. Yield

Yield is defined as the number of *M. reticulatus* taken within a particular harvesting context. A range of environmental, social and economic factors alter yield from any given population annually, and from States as a whole (**Table 3**), hence it is not a direct measure of population abundance although correlated with it to some extent.

b. Catch Per Unit Effort (CPUE)

An index of CPUE is the number of *M. reticulatus* caught per license issued. At the national level, yield and effort are highly correlated (N = 69; r^2 = 0.95, P < 0.0001; **Fig. 22**), supporting the idea that the take per license is a good measure of CPUE. CPUE is potentially able to detect any changes in the harvest due to population status, although it is also driven by changes in demand.

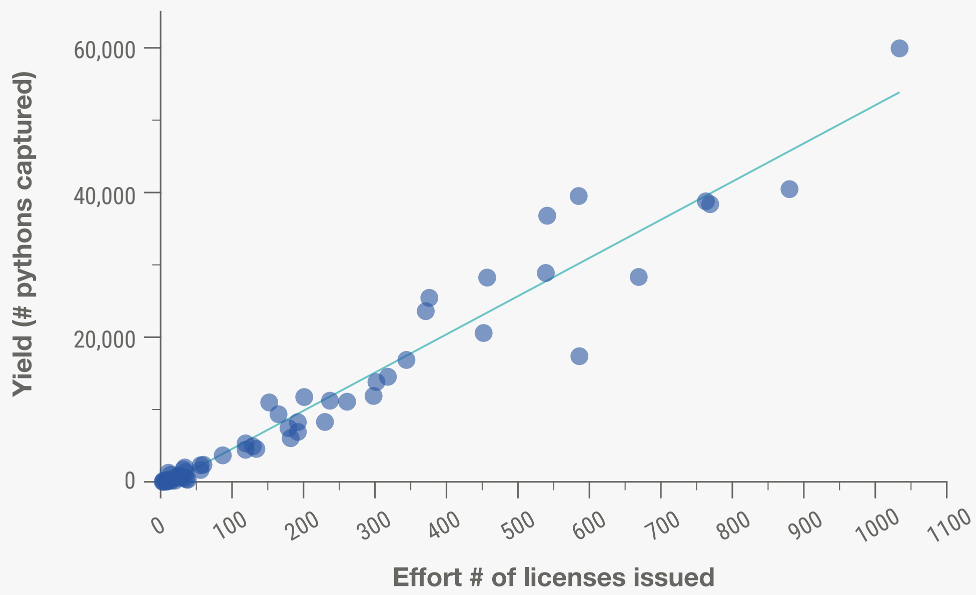


Fig. 22. Relationship between State effort (number of licenses issued) and State yield (number of pythons captured) in Peninsular Malaysia (2013-2019).

c. Analysis and interpretation

Examination of CPUE (pythons captured per license issued) revealed only a weak correlation between CPUE and effort (r^2 = 0.16, P = 0.0006; **Fig. 23a**). Generally, as the number of licenses increase, so do the number of animals caught per license. CPUE also remained stable or increased slightly in 2018 and 2019 (**Fig. 23b**). Nevertheless, it is probable that CPUE is influenced as much by economic factors (price and demand) as it is by population abundance.

Furthermore, the CPUE data presented here may not indicate the true situation on the ground because of the way most pythons are captured. Unlike other reptiles traded in Peninsular Malaysia (e.g., *Varanus salvator*; Khadiejah et al. 2019), pythons are rarely captured in a systematic way (Nossal et al. 2016). Often, pythons are captured opportunistically while people are going about their everyday tasks (Shine et al. 1999; Natusch et al. 2019a). Because encounter and capture of pythons is sometimes serendipitous, some people do not obtain licenses and instead, they sell their catch to a licensed harvester. Thus, although some harvesters do undertake their own targeted searches for pythons, in this system the CPUE figures reported here are unlikely to be a true reflection of effort. This is corroborated by inspection of the raw data. For example, outliers in **Figure 23a** reveal that some hunters capture more than 100 snakes per license, which can be issued to the same hunter several times per year. Although perhaps not impossible with great effort, the likelihood is low that all snakes were collected by those individual harvesters.

To test the hypothesis that some harvesters consistently capture more python than others, we applied a linear mixed model to the CPUE data. The model results with a Tukey's post-hoc test confirmed that CPUE was higher in 2018 and 2019 than in other years (2013-2017; $F_{6,4194}$ = 48.6, P < 0.0001), but the very significant extent of variation explained by harvester ID (P < 0.0001) confirmed the hypothesis: some harvesters consistently capture more pythons than others and exert a stronger influence on mean CPUE.

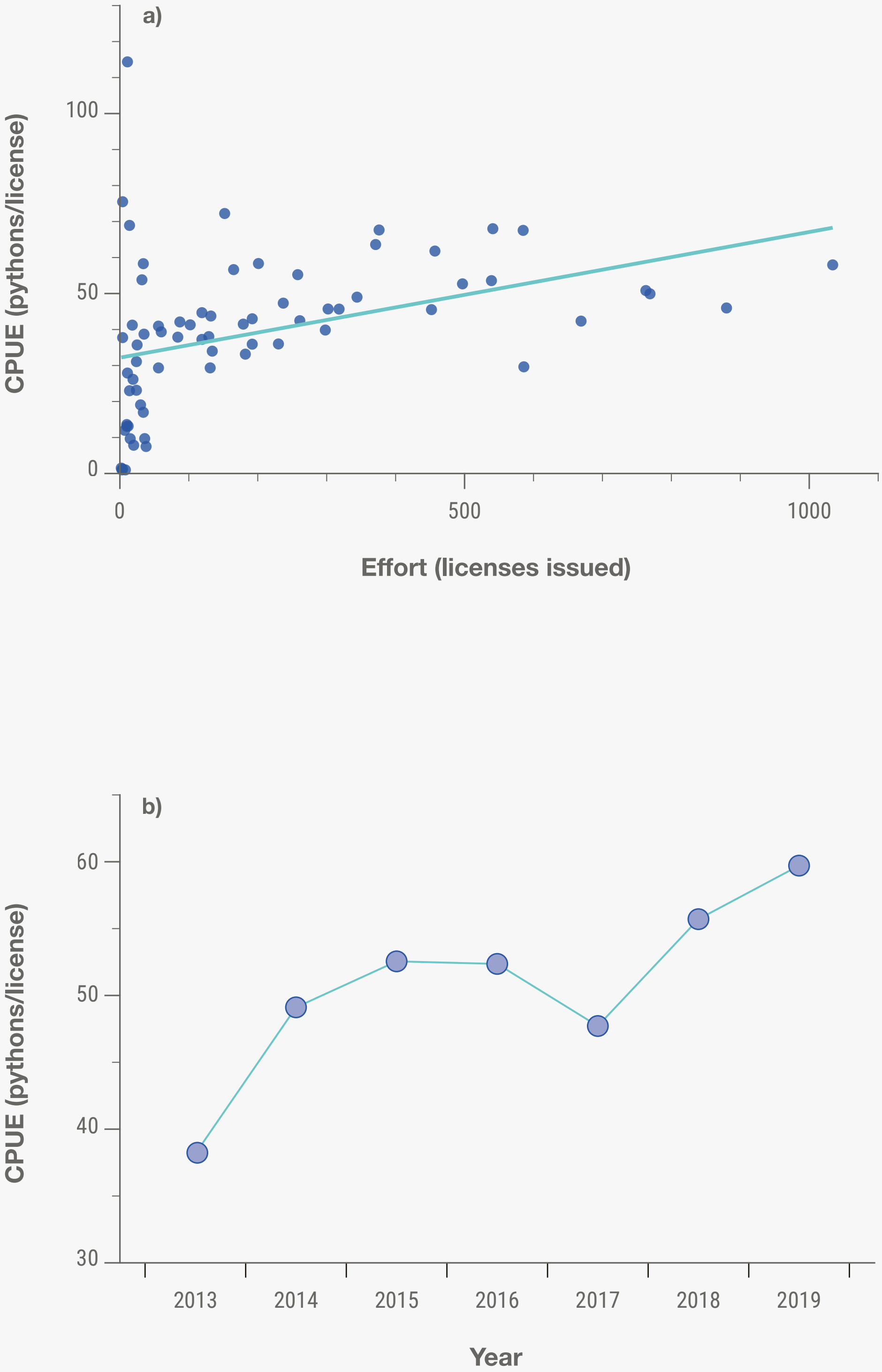


Fig. 23. Relationship between **a)** catch per unit effort (CPUE; pythons caught per license) and effort (# licenses issued) and **b)** year on year changes in catch per unit effort for *Malayopython reticulatus* at the national level.

4.4 The case for sustainable utilization

Since 1992, > 4 million *M. reticulatus* have been harvested from the wild in Peninsular Malaysia. This equates to an average offtake of ~146,000 individual pythons each year. Despite this, pythons remain common and abundant wherever surveys are undertaken. There is no evidence to suggest that python populations are declining due to trade. The consistency in offtake from several heavily harvested States, the ability to continually capture pythons during short-term field censuses, and the constancy in biological attributes over time, are all consistent with sustainability being achieved.

Auliya (2006) considered the monitoring and collection of data from skin processing facilities as "*the most promising method for collecting biological and ecological traits correlated with the specific sex*" and numerous other experts agree (Fitzgerald 1994; Webb and Vardon, 1998; Shine et al. 1998a; Shine et al. 1999; Mieres and Fitzgerald 2006; Natusch et al. 2016a; Natusch et al. 2016b; Natusch et al. 2019a; G Rodda in litt. 2020). Although analyses of harvest trends are indirect, they represent a more robust methodology for assessing population health, with fewer assumptions needed, than direct population census at spatially limited sites. Although trends like offtake rates are influenced (and thus confounded) by factors other than harvest impacts (e.g., demand, and capture effort), biological measures such as mean body sizes, sex ratios, fecundity, and minimum sizes at sexual maturity are largely insensitive to market forces. Because of the sample sizes involved, even small changes in harvest attributes can be detected (*sensu* Natusch et al. 2020a) and management tools adapted accordingly (e.g., quotas and size limits). Attempting to obtain similar sample sizes from field-caught specimens, to undertake analyses with sufficient statistical power, to avoid making Type I and Type II errors in analysis, is likely impossible – and indeed, would be impossible for studies on most species of snakes (Natusch et al. 2016b). On the other hand, by using a harvest monitoring approach obtaining such large samples for robust analyses is possible.

The applicability of an adaptive management approach to the issue of non-detriment findings for CITES-listed taxa has been discussed at length by the Parties to CITES and in the scientific literature. It is a recognized method for responsibly managing wild animal populations – especially those that are challenging to accurately census. Nevertheless, application of this methodological approach necessarily results in sustainability being determined in hindsight, rather than being precisely estimated before harvesting occurs. Here, further justification is provided to help reassure the Malaysian public and other stakeholders that current levels of offtake for this species in Peninsular Malaysia are within sustainable limits.

4.5 Additional considerations about sustainability

4.5.1 Extent of harvested habitats

Peninsular Malaysia has a land area of 132,339 km^2. The largest single land cover type in Peninsular Malaysia is natural forest (44%; **Table 4; Fig. 24**). Of this natural forest area, 83% is protected within national parks or State forest reserve. Regardless of formal protection, little harvesting takes place within forested areas of any State, which provides vast areas of safeguard refuges, buffering the species from extinction. Most harvesting is concentrated in agricultural habitats (e.g., oil palm) and in the vicinity of urban areas. This is corroborated by harvesters, who claim to undertake most hunting in these habitat types (Nossal et al. 2016), a claim independently corroborated by the stomach contents of harvested individuals: most (95%) contain commensal rodents or domestic livestock. A wider assemblage of prey should be expected if pythons were being harvested from natural forests (Natusch et al. 2019a). A similar situation has been observed in other part of the species' range, where most prey records from harvested pythons comprise domesticated or commensal species (Shine et al. 1999; Auliya 2006; Natusch et al. 2019a).

In addition to sites where no collection occurs, *M. reticulatus* is subject to negligible levels of harvest in other areas of Peninsular Malaysia. Depending on the year, 85-95% of the harvest is restricted to four States (Kedah, Pahang, Perak, Selangor and, in some years, Negeri Sembilan; Fig. 4 & Fig. 21). These four States occupy 57% of Peninsular Malaysia, but 42% of their land area is under strict protection. That no harvesting occurs in Johor State (due to State Enactment, see **Chapter V**) is a further safeguard. Thus, only **~24%** of Peninsular Malaysia's land mass is subject to the commercial harvest, with 74% protected from harvesting, or harvested at very low levels.

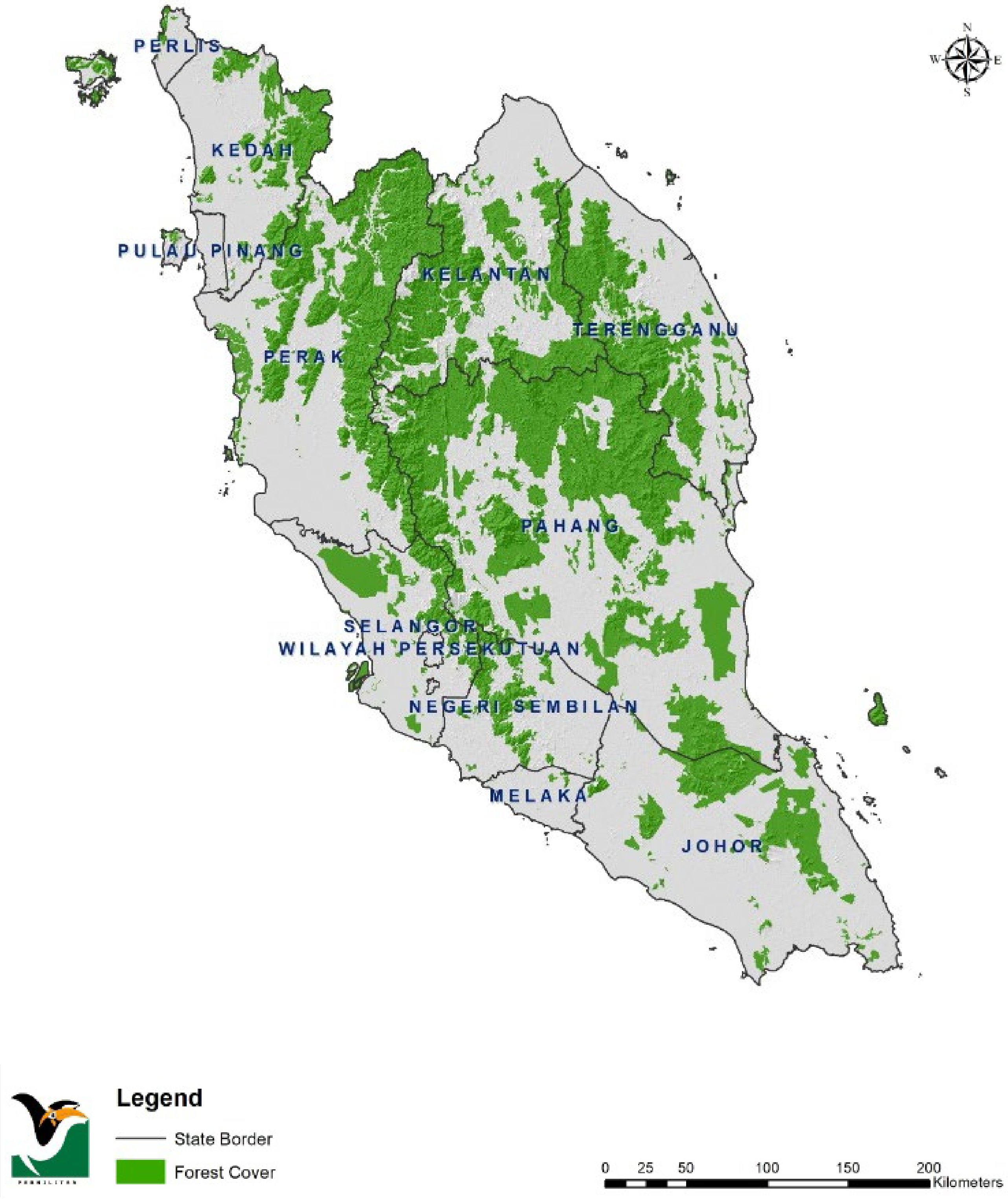
'No-take' zones in marine and other terrestrial systems can significantly increase the resilience of the harvested populations generally, by creating source populations that replenish neighboring harvested areas, and increasing harvest sustainability within adjacent sites (Navaro et al. 2000; Roberts et al. 2001). This same situation may also be functioning in Peninsular Malaysia.

Table 4. Land use cover (in km^2) for each State in Peninsular Malaysia (Malaysian Ministry of Forestry).

Study area	Natural forest	Mangroves/ swamps	Oil palm	Rice	Other agriculture[1]	Urban areas	Other[2]	Total
Johor	5613	835	6368	11.6	5820	398	163	19210
Kedah	3608	330	1032	1387	2900	229	12	9500
Kelantan	7912	103	1190	508	5291	86.7	6.3	15099
Melaka	199	16	404	17.4	867	150	8.6	1664
Negeri sembilan	2107	23	1982	11.2	2286	178	97	6686
Pahang	18958	1812	8596	28.1	6375	113	254	36137
Perak	11576	1142	4842	527	1910	351	685	21035
Perlis	74	1.72	57.8	288	368	27.6	1.91	821
Pulau Pinang	143	57	217	171	166	288	3.9	1048
Selangor	2085	1224	2059	246	1164	975	349	8104
Terengganu	7190	664	2304	146	2148	101	479	13035
Wilayah Persekutuan	11.7	1.73	1.01	0	45.2	227	5.23	292
Peninsular	59469	6212	29054	3345	29299	2897	2059	132339

[1]"Other agriculture" category includes rubber, mixed fruits, livestock, and unknown
[2]"Other" category includes water bodies, scrubland and sparse vegetation
https://www.forestry.gov.my/en/component/flippingbook/book/49/1?page=98&Itemid=1188

Fig. 24. Location of natural forest habitat within Peninsular Malaysia. Primary forest covers 44% of Peninsular Malaysia's land area (**Table 4**). Eighty-three percent of that forest is under formal protection from harvesting and habitat clearance (national parks, etc).



4.5.2 The influence of oil palm

Oil palm plantations have expanded considerably across Peninsular Malaysia over the last 30 years and today cover ~22% of its land surface (**Table 4**). These Agri-forestry habitats are the main harvest sites for a variety of wildlife, including pythons (Nossal et. al. 2016; Natusch et al. 2016a; **Chapter IV**). Thus, a central question for harvest sustainability is how the ecological changes wrought by oil palm plantations affects the abundance and demography of pythons. The available data, summarized below, suggests a positive impact: that is, oil palm plantations increase the availability of prey and reduce the densities of predators and competitors, resulting in python populations that are able to sustain even the most intense commercial harvests. Below, we review the evidence for that inference.

In naturally forested areas, prey abundance for pythons is limited by forest productivity, and by competition with other animals for limited resources. However, in oil palm plantations, tightly packed rows of palm trees provide a dramatically higher supply of energy-packed fruits (palm kernels). Common to many highly nutritious agricultural crops is the increasing density of animals that feed upon them (Tristiani and Murakami 2003; Puan et al. 2011). The chief beneficiaries of oil palm's expansion in Southeast Asia are several species of rodents that are often associated with humans (e.g., the Malaysian Field Rat *Rattus tiomanicus*, the Malaysian House Rat *Rattus rattus diardii* and the Rice-field Rat *Rattus argentiventer*). These particular species can reach extraordinarily high population densities in oil palm plantations (> 400 individuals/ha; Stuebing and Gassis 1989; Puan et al. 2011).

Snake population size and density are strongly linked to the abundance of their prey (McCauley et al. 2006; Shine and Madsen 1997; Madsen and Shine 2000b). In habitats with high rodent density, pythons have been shown to attain remarkable densities (Shine and Madsen 1997; Madesn et al. 2006). The year-round availability of palm-fruits dampens the boom-and-bust cycles typically experienced by rodent populations and ensures a steady supply of prey for pythons throughout the year, smoothing seasonal reductions in growth (Ujvari et al. 2011). Coupled with the loss of a significant amount of biodiversity in oil palm plantations, there is less interspecific competition for resident pythons (Yue et al. 2015). Increasing abundance of generalist snake species (like reticulated pythons) in oil palm plantations has been observed in Africa, Latin America, and in other parts of Asia (Shine et al. 1999; Auliya 2006 Akani et al. 2008; Lynch 2015; Meijaard et al. 2018). Likewise, enhanced availability of rodent prey in other types of agricultural plantations (such as macadamia orchards) sustain very high densities of other species of large pythons in other parts of the world (e.g., Shine and Fitzgerald 1996).

In addition to increasing density, python populations occurring in oil palm can likely sustain higher rates of offtake than pythons from other habitat types. An extensive literature documents faster growth rates of snakes with increased food intake (Ford and Seigel 1989; Taylor et al. 2005), and increased prey abundance drives increased growth rates in wild pythons (Madsen and Shine 2000a; Ujvari et al. 2011). Furthermore, high rodent density shortens the time it takes for female pythons to reach reproductive condition and increases the proportion of reproductive females within the population, resulting in more frequent reproduction and hence faster population recruitment (Shine and Madsen 1997; Madsen and Shine 2000a; Ujvari et al. 2011). Finally, pythons inhabiting oil palm plantations may experience lower mortality due to the relative absence of large predators in this Agri system (Yue et al. 2015). In summary, because Malaysia's trade focuses on snakes < 3 m in length taken primarily from oil palm plantations, harvesters are essentially cropping the top off of a large and hyper-productive python population capable of rapid recovery. Although additional research is required to test whether reticulated python populations respond to prey abundance in the same way as other pythons, the sustained offtake of snakes from palm plantations strongly suggests these same forces are at play.

4.6 Safeguards: Decision-making and adaptive management

Implicit within the current management system is the ability to reduce harvests should evidence derived from monitoring indicate sustainability is in doubt. No evidence to date suggests harvesting is causing long-tern declines in the abundance of *M. reticulatus.* Section 4.1 of **Chapter IV** describes the management steps undertaken by PERHILITAN to ensure sustainable use of *M. reticulatus* in Peninsular Malaysia. **Figure 25** below describes this process using information generated through PERHILITAN's monitoring protocols.

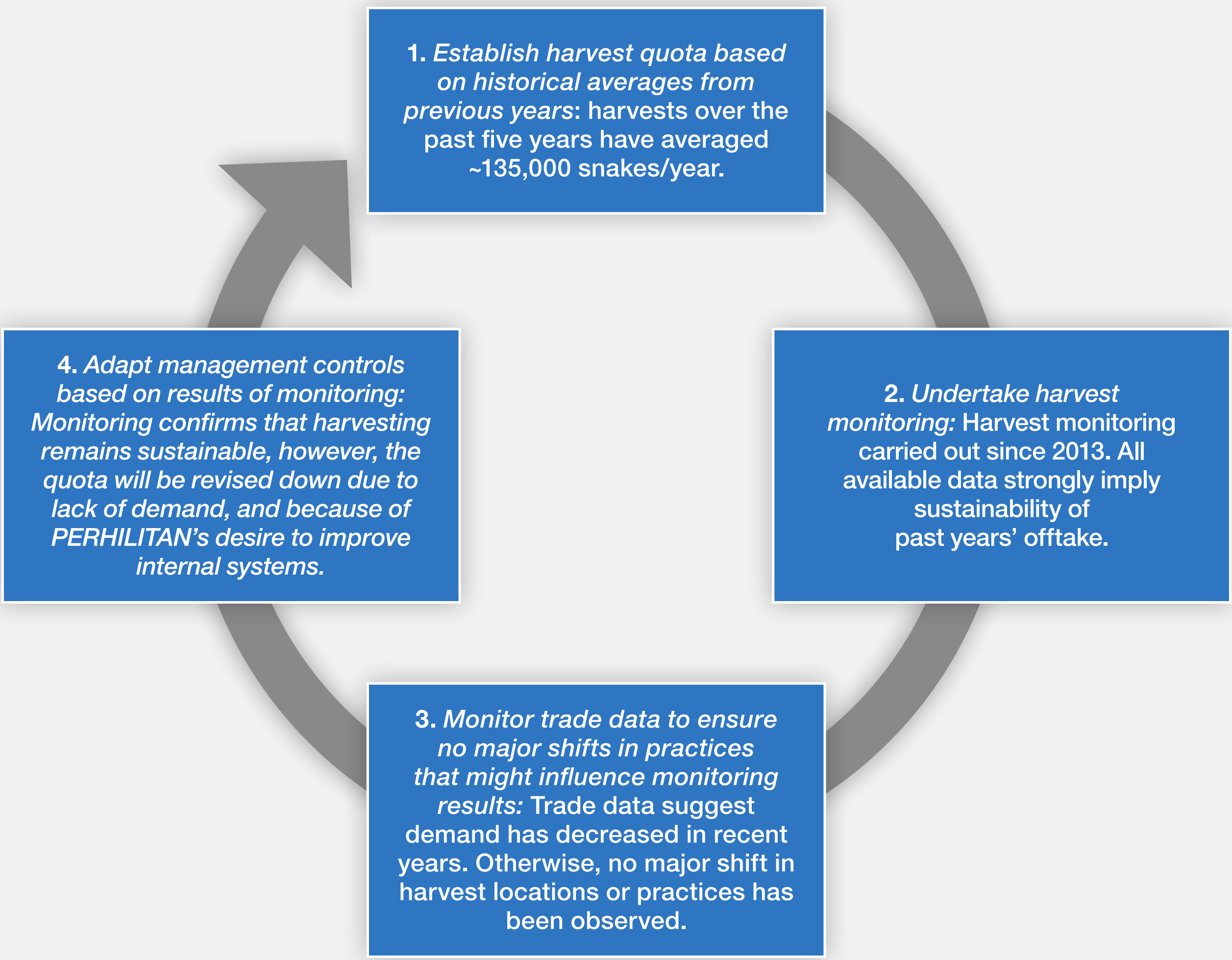


Fig. 25. Decision-making process for annual management of *Malayopython reticulatus* harvest and trade in Peninsular Malaysia, based on information gathered from monitoring systems. Conclusions presented in the figure are elaborated in **Chapter IV** of this report.

4.6.1 Summary of decision on reticulated pythons

Harvests of *M. reticulatus* from Peninsular Malaysia have averaged ~146,000 snakes for the past three decades. Since intensive monitoring began in 2013, average annual offtake has been ~121,000 pythons/year (range: 80,895 – 162,243). The results of that intensive monitoring program offer no evidence that harvests of reticulated pythons in Peninsular Malaysia are unsustainable. Based on the results of this program, Malaysia considers 121,000 skins/ year to be a demonstrably sustainable level of offtake.

In 2021, as a precautionary measure, Malaysia will reduce its harvest quota to 90,000 skins. The justification for this reduction in quota, despite data indicating harvest sustainability is not in doubt, is:

1) Exports in 2018 and 2019 have been lower than in earlier years, suggesting a drop in demand.

2) As a result of decreasing demand, one major Malaysian exporter and several smaller exporters have ceased or significantly reduced trading.

3) In January 2020, the European Union Scientific Review Group formed a negative opinion on imports of *M. reticulatus* skins from Peninsular Malaysia based on concerns about sustainability.

4) Coupled with the loss of business from the COVID-19 pandemic, Malaysia does not anticipate a recovery of trade back to pre-pandemic levels in the near future.

5) Malaysia is in the process of implementing additional management measures (e.g., maximum harvest size limits and data collection systems; see Chapter V), and lower levels of overall harvest and trade will simplify this process.

After 2021 (from 2022 onward), if the 2022 quota has been met and there is evidence of sufficient demand for python skins, Malaysia will reinstate the quota (i.e., 121,000 skins) at the rate of harvest demonstrated to be sustainable based on existing data and such new data that may be obtained.

4.6.2 Trade into the future and adaptive management

Python populations and the harvest metrics will continue to be monitored on an annual basis. At the same time, PERHILITAN will continue to conduct research on pythons and implement improvements in overall management processes, including improved traceability. As stated, data from Malaysia have demonstrated that reticulated pythons can withstand an offtake of 121,000 snakes annually. In many years, however, levels of offtake have exceeded this number of specimens, with no apparent adverse impacts. Therefore, if demand for python skins continues to increase, and if the results of monitoring suggest no adverse impacts of harvesting on population viability, then Malaysia will incrementally increase the harvest quota by small margins each year (e.g., 122,000 snakes in 2023, 123,000 snakes in 2024, etc). Harvests will continue to be monitored annually, and such increases can be revised down as needed. This is the essence of an adaptive management approach.

4.6.3 Compliance with CITES

Malaysia's key tasks for ensuring harvests and subsequent exports of reticulated python parts and/or derivatives are in compliance with Article IV of CITES include:

1. [Exports will not be] *detrimental to the survival of the species in wild,*

2. [Exports will not be] *in contravention of the laws of that State*

3. [Exports will be] *limited in order to maintain that*

species throughout its range at a level consistent with its role in the ecosystems in which it occurs, and;

4. [The population will be maintained] *well above the level at which that species might become eligible for inclusion in Appendix I*

The case made above provides robust evidence for compliance with Point 1 – harvests are geographically limited resulting in full protection for over half of Malaysia's python population. Harvesting and exports are legal, ensuring compliance with Point 2. The continuing abundance of pythons in all surveyed landscapes, and in particular those most intensively harvested, confirm that this species continues to fulfil its role in the ecosystem. Moreover, most pythons are harvested from modified habitats, where the species' role has been be altered significantly. *Malayopython reticulatus* in Malaysia clearly does not meet the criteria (CITES Res. Conf. 9.24):

A species is considered to be threatened with extinction if it meets, or is likely to meet, at least one of the following criteria.

A. *The wild population is small, and is characterized by at least one of the following:*

i. *an observed, inferred or projected decline in the number of individuals or the area and quality of habitat;*
ii. *each subpopulation being very small;*
iii. *a majority of individuals being concentrated geographically during one or more life-history phases;*
iv. *large short-term fluctuations in population size; or*
v. *a high vulnerability to either intrinsic or extrinsic factors.*

B. *The wild population has a restricted area of distribution and is characterized by at least one of the following:*

I. *fragmentation or occurrence at very few locations;*
II. *large fluctuations in the area of distribution or the number of subpopulations;*
III. *a high vulnerability to either intrinsic or extrinsic factors; or*
IV. *an observed, inferred or projected decrease in any one of the following:*

- the area of distribution;
- the area of habitat;
- the number of subpopulations;
- the number of individuals;
- the quality of habitat; or
- the recruitment.

C. *A marked decline in the population size in the wild, which has been either:*

i. *observed as ongoing or as having occurred in the past (but with a potential to resume); or*
ii. *inferred or projected on the basis of any one of the following:*

- a decrease in area of habitat;
- a decrease in quality of habitat;
- levels or patterns of exploitation;
- a high vulnerability to either intrinsic or extrinsic factors; or
- a decreasing recruitment.

Ample evidence has been presented demonstrating unequivocally that reticulated pythons in Peninsular Malaysia do not meet any of the criteria for inclusion in Appendix I. Exports of this species, at current and historical levels, meet all the conditions necessary for Appendix II and Malaysia has indicated both capacity and intent to comply with Article IV of the CITES Convention.

CHAPTER V

Trade controls and management

5 Background

The ability to monitor and ensure trade remains within sustainable levels depends on sound management practices and trade controls, which within Malaysia are becoming increasingly more effective. The management tools PERHILITAN uses to effectively monitor harvesting and trade, to exert and adapt controls on harvesting and trade, and provide safeguards, are described below.

5.1 Quotas

5.1.1 Annual quotas

Malaysia imposes annual harvest and export quotas on the number of *M. reticulatus* that can be legally captured and exported from Peninsular Malaysia. This quota system was established in 2002 in response to the need to set species-specific quotas that matched annual levels of harvest (**Table 5**). Since then, new biological data on *M. reticulatus*, and the results of periodic population monitoring, has revealed a high level of biological capacity to withstanding harvest offtake at the level occurring in Malaysia.

Separate harvest and export quotas are used in Peninsular Malaysia. The annual harvest quota is reflected by the number of pythons that can be taken from the wild each year and is regulated via the issuance of harvesting licenses. The annual export quota corresponds to the number of python skins that can be exported each year. In previous years, the annual export quota was not monitored closely. More recently, annual harvest quotas and annual export quotas have been aligned. Since 2013 the annual harvest quota has been around ~162,000 skins[1]. In 2016, the annual export quota was linked to this (**Table 5**). In January 2020, the European Union Scientific Review Group formed a "negative opinion" on skin imports, which has impacted Malaysian trade. Partly in response to this loss of confidence in Malaysia's program, Malaysia will reduce the 2021 harvest AND export quota to 90,000 snakes/skins. If demand for skins after 2021 is sufficient and monitoring data support an increase, Malaysia will raise the quota to the demonstrably sustainable level of 121,000 from 2022 (see justification in **Chapter IV**).

5.1.2 Annual quotas, demand, and the probability of detriment to the wild population

Malaysia applies an adaptive management approach to determining annual export quotas (see **Chapter IV**). Harvests and exports from Malaysia have remained consistently around ~146,000 specimens/year for three decades. Although harvests have decreased slightly since 2013 (to ~121,000 specimens/year), analysis of monitoring data suggests that current offtake rates are not detrimental to the species survival in the wild. However, in the last few years, demand has decreased to 90,000 - 100,000 skins/year. The proposed harvest of 90,000 brings harvests and exports into line with demand, and is a conservative precautionary, and safe level of offtake (see details within **Chapter IV**). The annual harvest quota is based on a 'first come, first serve' basis, and is divided into two 6-month slots (50% released at the beginning of the year, and 50% released halfway through the year). The quota is verified in several ways, described below in Sections 4.2 – 4.5 on harvest and trade licenses, CITES permits, and inspection and verification. If a portion of the quota remains unused in one year, it will not be carried forward into the next year.

1 In 2013, the Malaysian recording keeping management system changed. Harvest licenses and quota data collection and reporting protocols changed.

Table 5. Harvest quota and numbers of *Malayopython reticulatus* skins exported from Peninsular Malaysia from 2011 until 2020. The proposed 2022 quota of 120,000 skins is also included.

Year	Quota	Exports
2011	162,000	128,639
2012	162,000	143,193
2013	162,000	160,051
2014	162,000	166,599
2015	162,000	172,052
2016	162,000	102,163
2017	162,000	99,477
2018	155,000	99,749
2019	155,000	94,938
2020	145,000	21,286
2021	90,000	?
2022	121,000	?

5.2 e-license system

PERHILITAN uses an e-license system to regulate the capture and harvest of *M. reticulatus* in Peninsular Malaysia. Under the Malaysian Wildlife Conservation Act 2010 (Act 716) only licensed harvesters are legally permitted to catch *M. reticulatus* using traps or by hand. No shooting or destructive capture methods are permitted. Harvesting licenses are valid all year (Federal Government Gazette: Wildlife Conservation (Open Season, Methods and Times of Hunting) Order 2014). Harvesting licenses issued by a State are only applicable for hunting activities within that respective State. A harvester catching *M. reticulatus* from Selangor and Perak States requires two licenses. Licenses are issued by the relevant PERHILITAN field office, in each State, and can only be issued by the licensing officer in charge. The location of wildlife offices issuing harvesting permits in each State can accessed at www.wildlife.gov.my/index.php/bahagian/69-perlesenan.

Licenses are issued for the capture and sale of a set number of pythons (typically 50 – 200 specimens; mean = 52.5 ± 0.6; Range = 1 – 1,000; N = 8470). One harvester can apply for multiple licenses each year (and regularly do). The cost of each license is dependent on the quantity of pythons to be captured, at RM2 ($US0.5)/snake (or RM 200 for 100 snakes, etc). Each license is fitted with a unique QR code and since 2013, data for each license issued is uploaded by the relevant permitting officer into a national database accessible by State offices but administered by PERHILITAN Headquarters in Kuala Lumpur. As the harvest reaches the national quota allocated for the year, PERHILITAN Headquarters contacts the relevant State wildlife offices and informs the permitting officers of the exact number of pythons that can be harvested before all harvesting is ceased for the year.

A drawback of the license system is that although issuance is electronic, returns of operation on the actual numbers of pythons captured are paper based. Although bag limits are established upon issuance of the license, the entire bag limit may sometimes not be used. This cannot be determined without the paper returns. This has created inefficiencies in the system and lost returns, which appear to have resulted in minor inconsistencies in harvest data. Although harvester bag limits can be reconciled through inspection of trader logbooks (see **Section 4.3** below), PERHILITAN officers inspecting trader logbooks focus efforts on reconciling records of live snake stocks, skins, and exports, rather than information from individual hunters. This has resulted in harvester license data rarely being reconciled against the logbook system. To improve this process, PERHILITAN is exploring a more efficient online data collection system linked to the issuance of tags (see **Section 4.7** below).

5.3 Trade licenses

Licensed traders are allowed to source *M. reticulatus* from licensed harvesters or other licensed traders only. Every trade transaction is recorded in a logbook provided by PERHILITAN. Date of transaction, number of snakes, source person (with license number), and remaining stock are all recorded. Enforcement officers check logbooks regularly. Trading licenses are issued to processing facilities and exporters. A separate license is required to buy live pythons, trade in skins, and trade in meat, each of which costs RM 300. Therefore, each processing facility in Peninsular Malaysia pays an annual fee of RM 900 ($US 225) to operate under Malaysian law.

5.4 Harvest size limits

Restrictions are imposed on the size of pythons that can be legally harvested for trade, and the size of skins that can be sold. Since 2016, PERHILITAN has imposed a minimum harvest size limit of 240 cm SVL and in 2021 will impose a maximum limit of 500 cm SVL for capture of live pythons. The minimum size of live pythons corresponds to a minimum processed skin size of approximately 280 cm in length (**Fig. 26**). Smaller skins cannot be sold. Lives snakes of 500 cm SVL produce skins of 590 cm (**Fig. 26**). Skins larger than this cannot be sold into trade.

Extensive research into the relationship between the size of live snakes and their skins allows PERHILTIAN to measure multiple parts of a skin to verify the size of the live specimens from which it came (**Figs. 25 and 26**). This prevents traders from cutting skins, because the original skin sizes can be determined based on either length, width, or the size of single scales on the skin (**Fig. 25**; Natusch et al. 2020b).

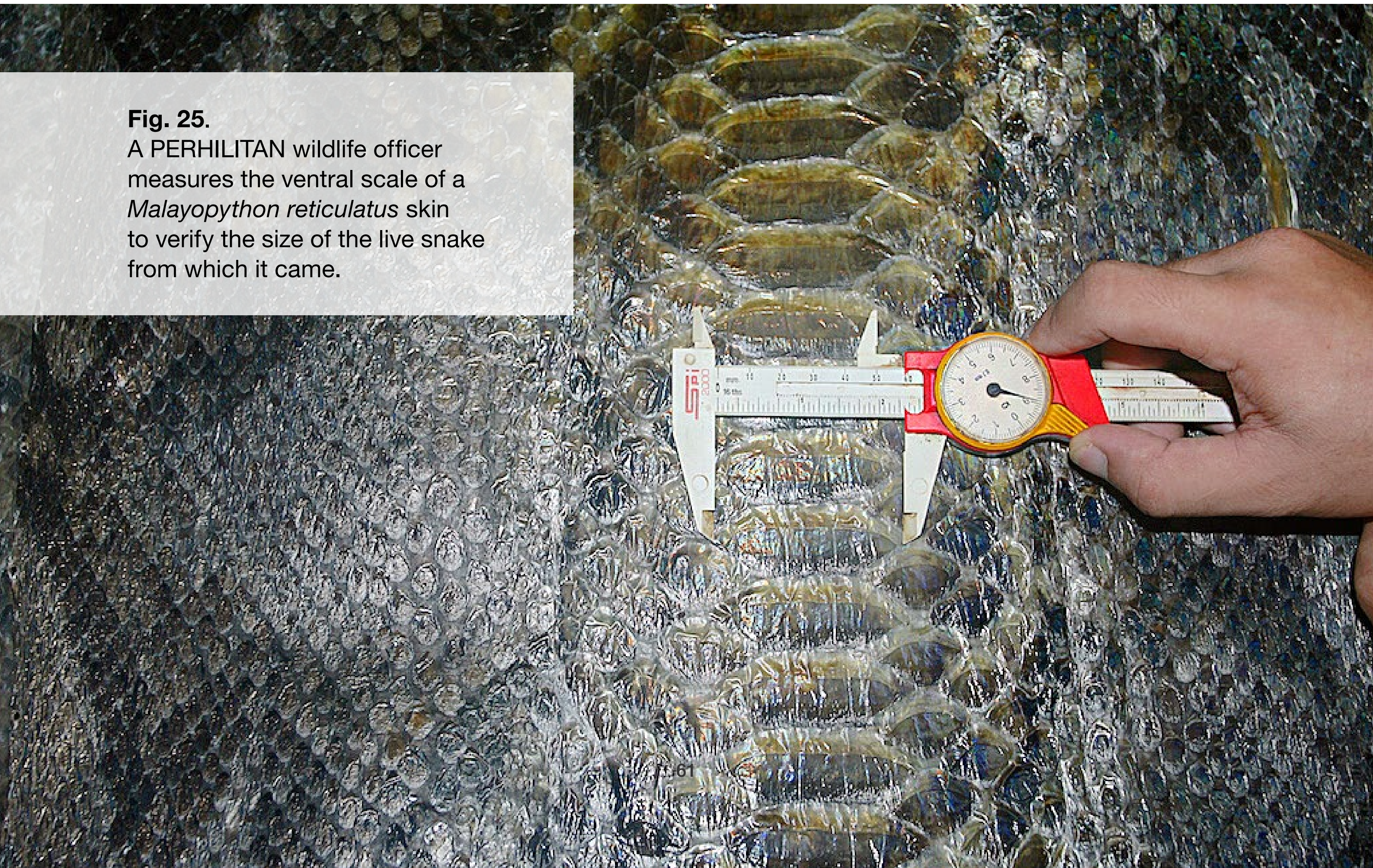


Fig. 25.
A PERHILITAN wildlife officer measures the ventral scale of a *Malayopython reticulatus* skin to verify the size of the live snake from which it came.

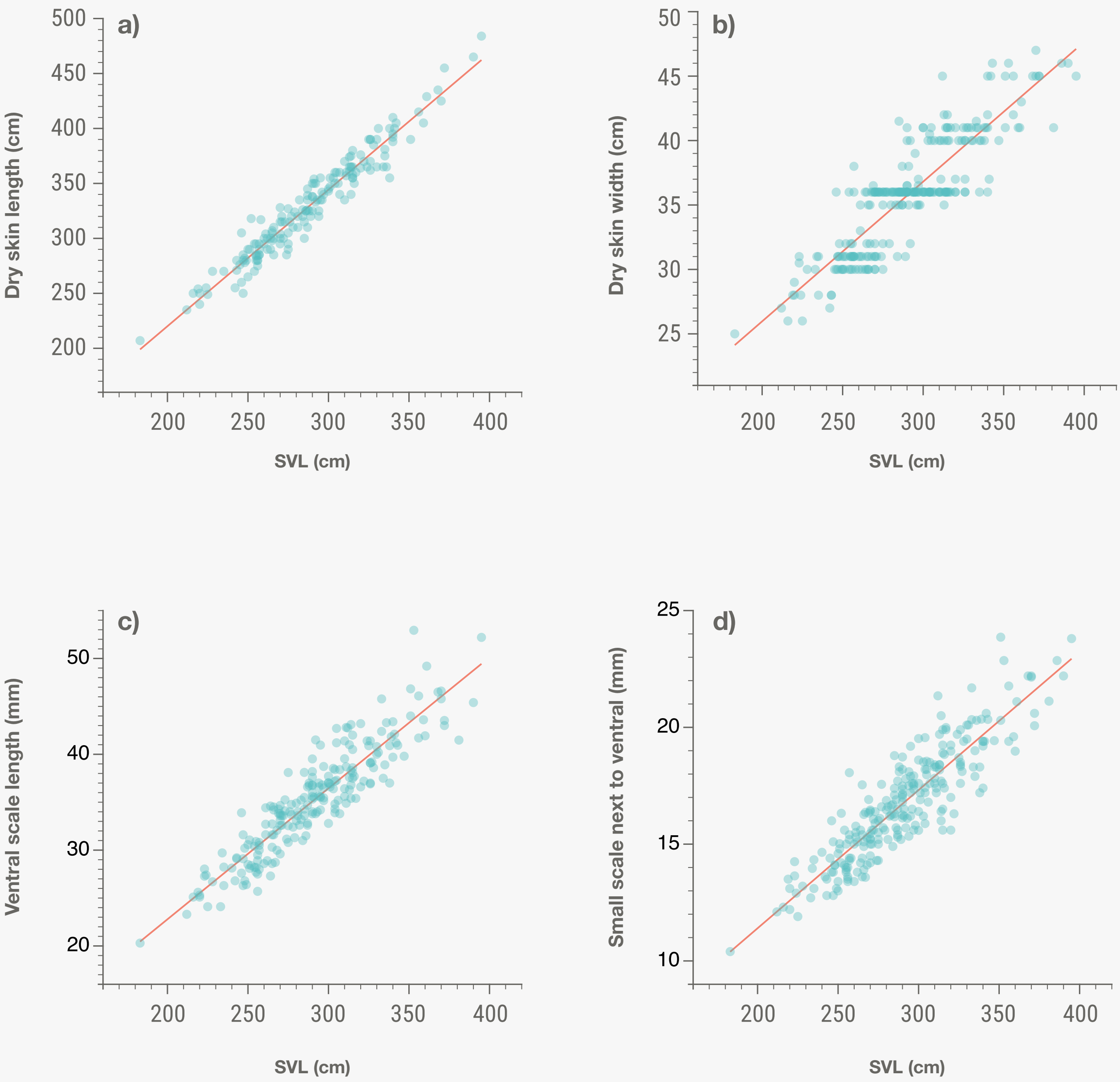


Fig. 26. Relationships between the snout-to-vent length (SVL) of *Malayopython reticulatus* and **a)** dry skin length, **b)** dry skin width, **c)** dry skin ventral scale width, and **d)** dry skin dorsal scale next to ventral scale width. Regression formulae are provided in Natusch et al. (2020b).

The size limits imposed in Malaysia act like a quota, safeguarding a significant proportion of the population from harvesting (**Fig. 27**). Unlike a quota, however, harvest size limits on pythons have the added advantage of being biologically meaningful. In Peninsular Malaysia, minimum size limits protect a significant proportion of the immature or non-reproductive population, giving them an opportunity to reproduce before harvesting takes place (**Fig. 27**). In addition, because clutch size is positively correlated with maternal body size (Shine et al. 1998b), the maximum size limit will protect the largest fecund snakes and skew the harvest towards males, which rarely grow larger than 5 meters and contribute less to rates of reproduction; **Fig. 36**; Natusch et al. 2019a; Natusch et al. 2020b).

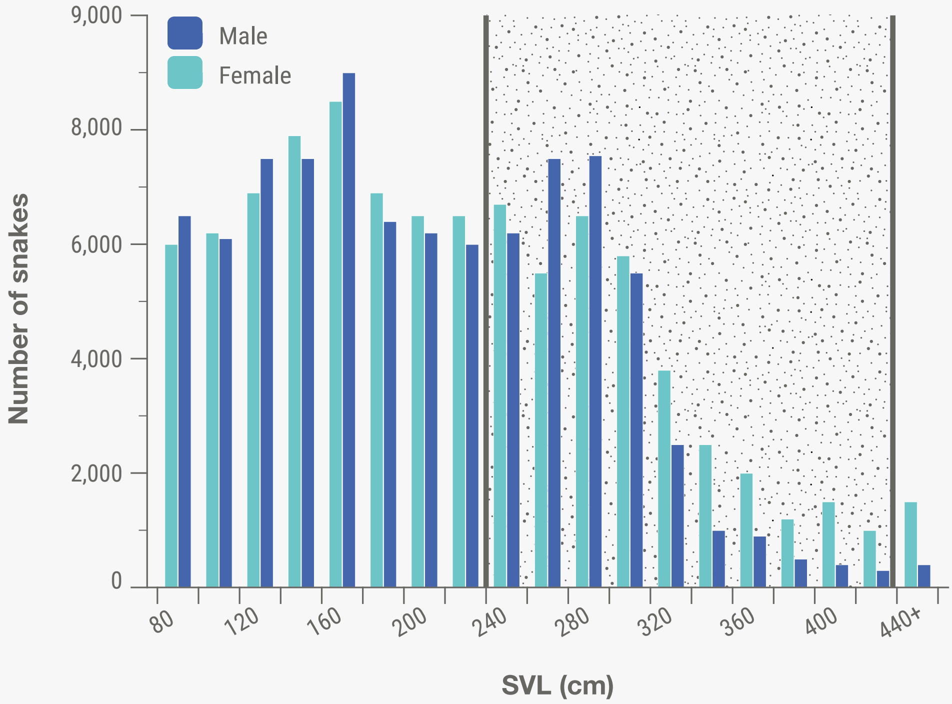


Fig. 27. Body size (snout vent length, SVL) distribution in a hypothetical *Malayopython reticulatus* population. The harvest size limits (hatched area) exclude the smallest and the largest specimens. Hatchlings and juveniles are together more abundant than adults in wild populations, but hatchlings also experience the highest natural mortality rates.

5.5 CITES export permits and traceability verification process

CITES export permits 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 PERHILITAN inspection officers. Officers travel to the processing facility and count and record every skin destined for export. The skins are boxed with the PERHILITAN inspection officer present who seals and stamps the export boxes with unique identifiers held by the department. Traders are then allowed to transport the skins to the designated ports where they are inspected once more by PERHILITAN officers at Malaysian borders. If the seal provided by PERHILITAN is tampered with or broken, the shipment is seized by PERHILITAN, customs, MAQIS or aviation security officers, and investigated. Numbers of *M. reticulatus* purchased and skins sold or kept in stock are balanced and verified by PERHILITAN enforcement officers during regular inspections and logbook reconciliation.

5.6 Stockpiling

In some years, the allowable number of pythons that can be captured is lower than the number exported, whereas in other years the reverse occurs. PERHILITAN accepts that traders need to stockpile skins from one year to the next. Such stockpiling has been raised as a regulatory challenge for reptile trade many times (e.g., Kasterine et al. 2012), but it is a normal and acceptable part of any animal production industry. For example, a census of python skin stockpiles at the beginning of Malaysia's intensive sustainability monitoring program confirmed that 69,569 python skins were held in stock by Malaysian traders and exporters. Through its systems of annual balances and checks (harvesting licenses, transaction logbooks, and tagging and traceability systems), PERHILITAN is sufficiently confident that stocks of skins of *M. reticulatus* are being adequately monitored and managed.

5.7 Online data collection for monitoring

PERHILITAN has collaborated with industry to develop and pilot an online data collection application to aid data gathering from *M. reticulatus* brought to processing facilities. The application is downloadable from the Google and Apple store onto both Apple and Android tablets and mobile phones. The Application is called *ReptileTradeMonitor* and has two main purposes:

1) To streamline self-collection and allow instant online upload of key data from harvesters and processing facilities trading in *M. reticulatus*, and
2) To simplify data collection for PERHILITAN scientists and allow instantaneous download of data for statistical analysis.

For trader monitoring, each trader is registered to use the application as a facility user by PERHILITAN staff. Each trader is given a unique identifier, so data collected is linked to their permit and business registration numbers (**Fig. 28**). The application and trader details are managed through an administrative platform accessible only by PERHILITAN staff.

Data collected and submitted by the traders includes the following:

- Name, address and permit details of harvesters selling pythons
- Sale date
- Number of pythons sold
- State and specific location of capture
- Habitat of capture
- Snout-vent length of captured pythons
- Mass of captured pythons

These data are entered manually by the processing facility owners and are uploaded to the online database, where they are viewable at PERHILITAN's administrative dashboard (**Fig. 29**). The data can be downloaded in csv. file format and can be imported into a statistical analysis program for rapid analysis and reporting. Importantly, the information gathered allows PERHILITAN to crosscheck against other available information and ensure compliance in real-time. PERHILITAN is currently working with partners to pilot-test the application in *M. reticulatus* processing facilities.

In addition to trader self-reporting, PERHILITAN scientists use this same application to collect data while surveying registered facilities trading *M. reticulatus*. The system works in the same way, except that PERHILITAN scientists are registered as science-users and are taken to a separate science portal when they sign-in to the application. From there, scientists can collect data on basic specimen details, harvest locations, morphometrics, and reproductive attributes (**Fig. 30**). Data are instantaneously uploaded to an online database accessible by PERHILITAN. The application is available in English, Indonesian and Malaysian.

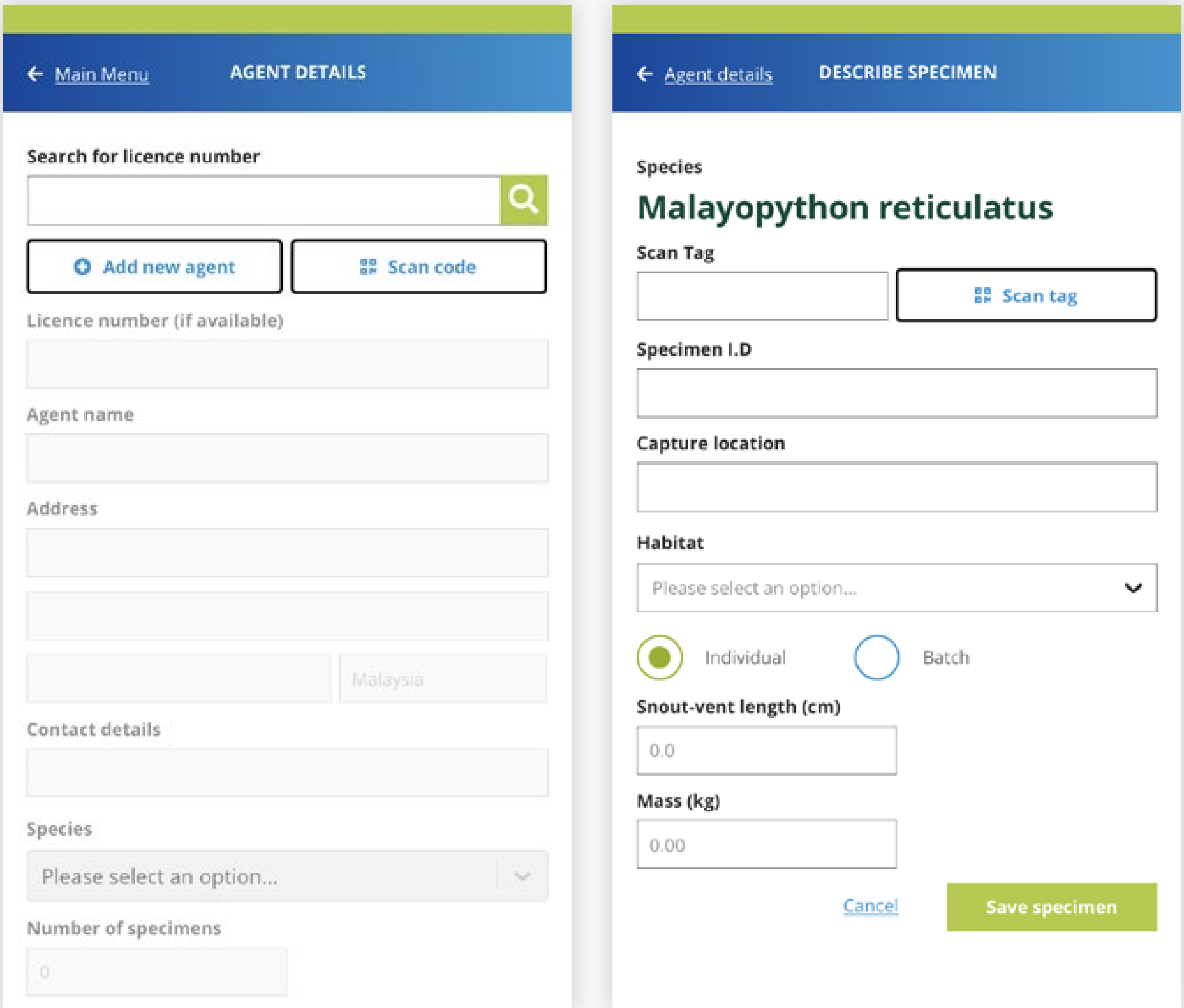


Fig. 28. Data collection application and information self-recorded by traders collecting *Malayopython reticulatus*.

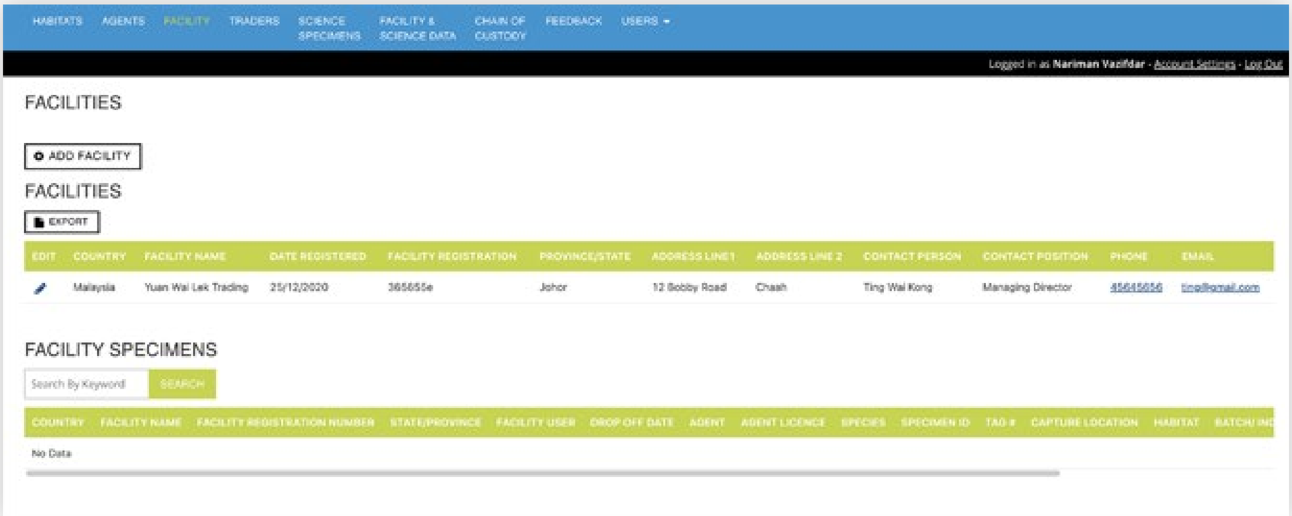


Fig. 29. The online dashboard accessible by PERHILITAN from which data collected from traders and science teams can be viewed and downloaded.

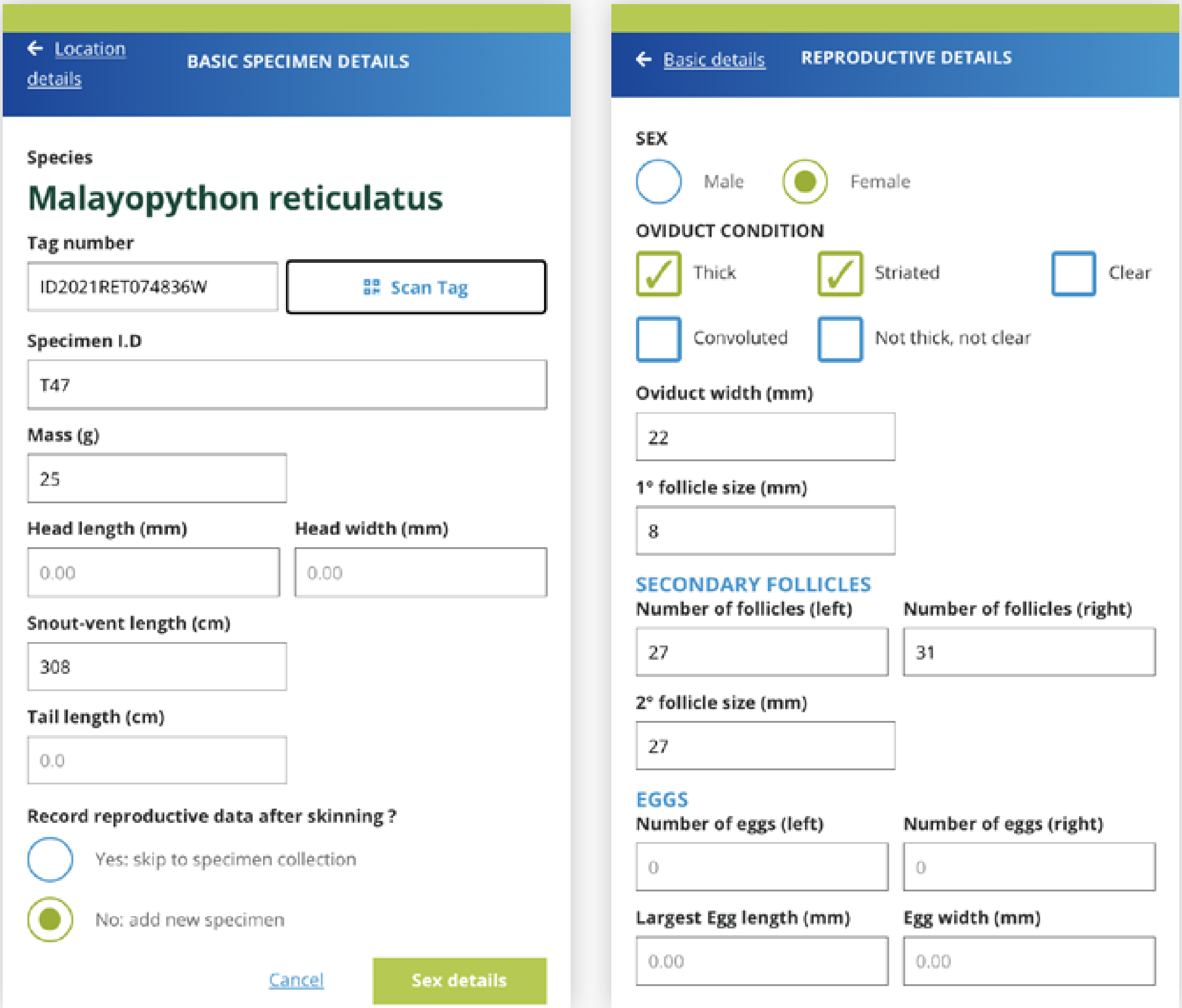


Fig. 30. Data collection application and information recorded by PERHILITAN science teams collecting data on *Malayopython reticulatus* harvested for trade.

5.8 Malaysian industry tagging and traceability system

In addition to the national tagging system being trialed, PERHILITAN has encouraged and assisted one Malaysian business to invest in the development of their own tagging and traceability system. This system was piloted with *Varanus salvator* in 2015, and was implemented for pythons in 2019. The ban on the import of python skins into the EU in 2020 resulted in the exporter discontinuing the use of this system in 2020, because the loss of the European market meant the cost of tag purchase and administration could not be justified. Nevertheless, we describe this system here for comparative purposes with the broader PERHILITAN system. The Malaysian trader has implemented a tagging system in their supply chain based on the use of RFID technology.

The traceability system adopted includes the following elements:

1) Harvesting occurs in three States: Kedah, Pahang and Perak (**Fig. 31**).

2) Licensed harvesters are assigned plastic cable ties containing unique information about the license issued by PERHILITAN (**Fig. 32**).

3) Pythons are captured alive and placed into breathable mesh bags. The tag is attached to the top of the mesh bag containing the live python (**Fig. 32**).

4) Agents registered with PERHILITAN are allowed to collect the pythons from the harvesters. Collection occurs daily, either on the same day the pythons are captured or the day after. Bagged pythons are kept cool within plastic crates and are provided with water by gently spraying on a regular basis.

5) Live animals are transported to a single processing facility where key information is transferred using RFID technology (**Fig. 32**).

6) After cooling to 16°C, the live pythons are humanely euthanized and processed.

7) Skins are then dried and exported to Europe. The RFID tags remain on the skins until the point of tanning in Europe.

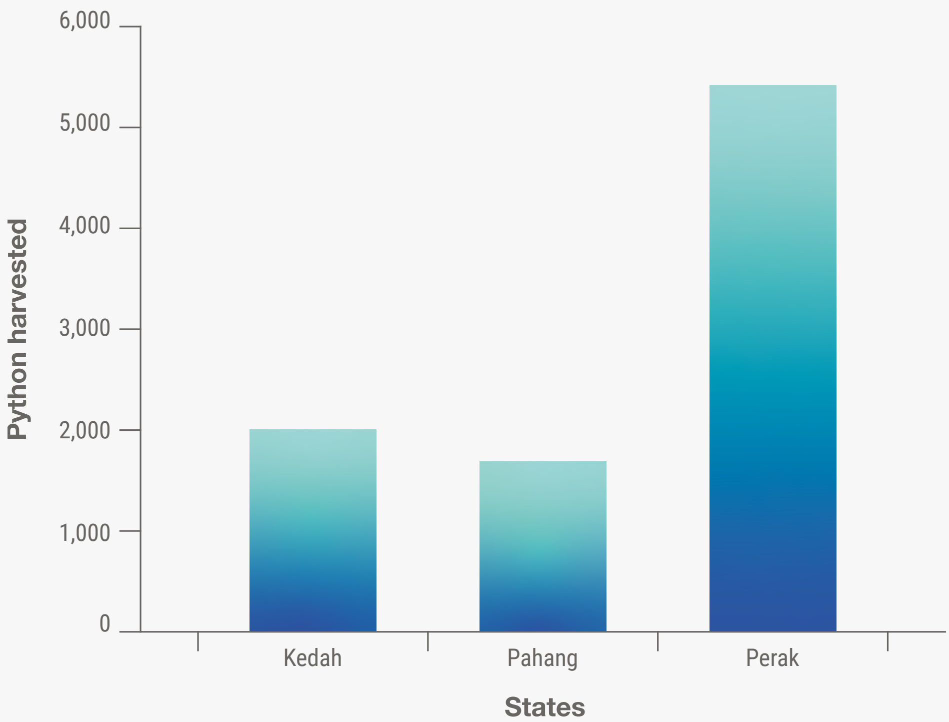


Fig. 31.
Sourcing location based on data from industry RFID traceability system in 2019. Data show that pythons tagged as part of this initiative are coming from the main harvest locations – as presented in **Figure 29.**

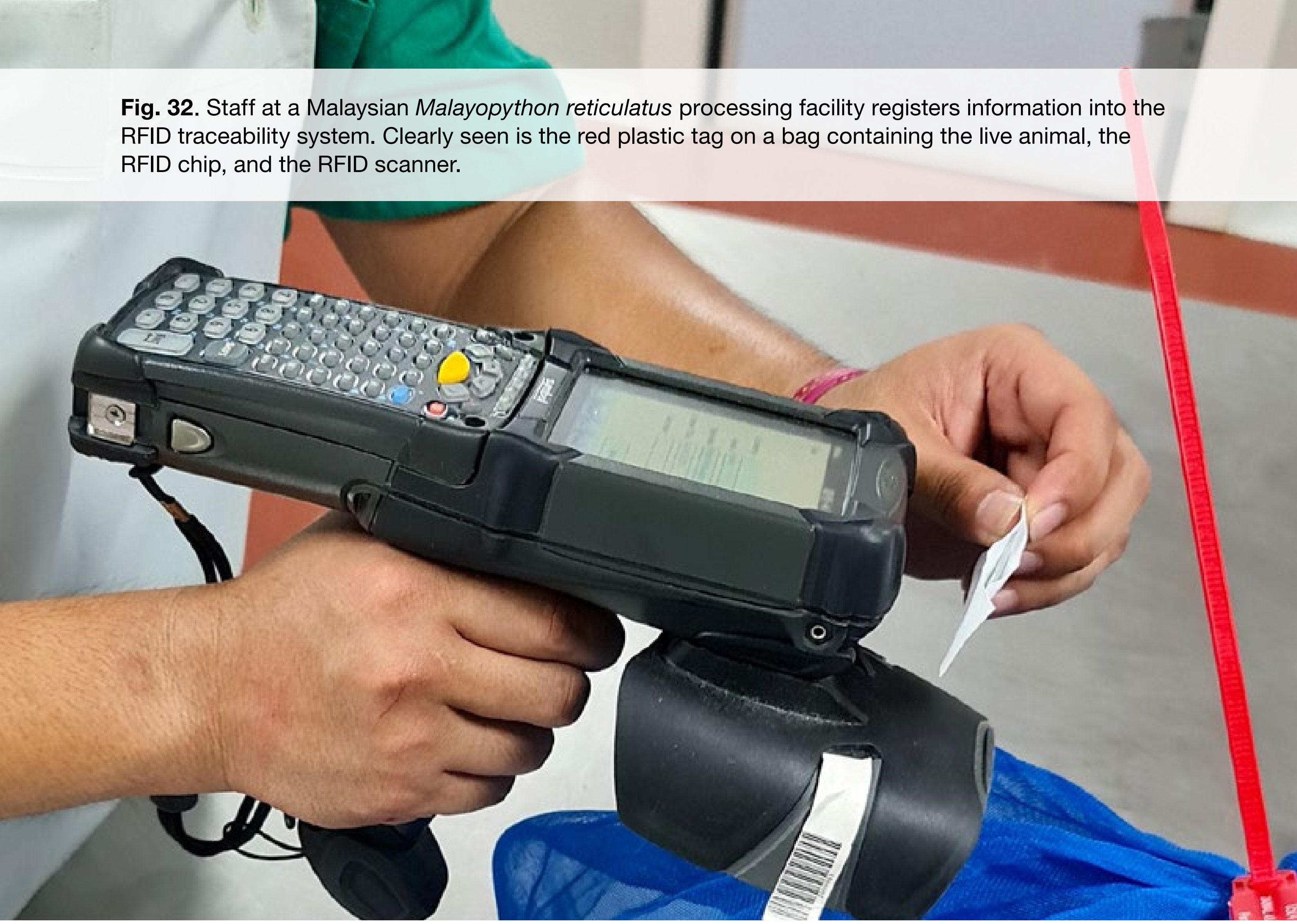


Fig. 32. Staff at a Malaysian *Malayopython reticulatus* processing facility registers information into the RFID traceability system. Clearly seen is the red plastic tag on a bag containing the live animal, the RFID chip, and the RFID scanner.

Data collected from the traceability system includes:

- Tag number
- Origin country
- Species
- CITES source code
- Capture area
- Capture date
- Harvester name
- Plastic tag colour
- Harvester license number
- Date of sale to collector
- Collector license number
- Date of sale to processing facility
- Processing facility license number
- Skinning date
- Dry skin length
- Dry skin width

5.9 State regulations

In Malaysia, natural resources are legally State-owned, and State governments have the right to impose additional regulations via State Enactments. Such an enactment has been implemented by the Sultan of Johor, who has forbidden harvesting of all animals except feral pigs (*Sus scrofa*) in the State of Johor. Hence, this State remains a refuge for *M. reticulatus* with no harvesting.

5.10 Harvesting areas and tenure

The vast majority of harvesting that occurs in Peninsular Malaysia occurs on State- or privately-owned lands. Oil palm plantations and secondary forest areas around urban development are the main target areas for harvesters, because python densities are said to be highest in these sites (see Chapter II; Nossal et al. 2016). Harvesting by aboriginal people (Orang Asli) often occurs in land granted as reservation, which may include a variety of land use types. Most private landowners allow harvesters on their land to capture pythons and other species, and support reducing densities of species such as feral pigs, monitor lizards and pythons. Some plantation owners recognize the value of large reptiles in rodent control, and do not allow harvesting on their estates (PERHILITAN 2020). In other cases, plantation owners recognize the value of these animals, but allow harvesting to keep favour with local communities (who are the mainstay of labour in these plantations). Engagement with harvesters suggests that hunting without permission is rare, because of the availability of sufficient harvesting areas (PERHILITAN 2020).

5.11 Protected areas

Much of Peninsular Malaysia's land area is protected from harvesting of *M. reticulatus*. Data from harvesting licenses and from the tagging and traceability system confirm that 85-95% of harvesting occurs within only 4-5 States (Kedah, Negeri Sembilan, Pahang, Perak, Selangor; **Fig. 2; Table 3**). This effectively safeguards populations in the remainder of the country from harvest.

In terms of formally gazetted protected areas, 22.5% of Peninsular Malaysia's land area is under formal protection (National Parks, State Parks, etc), which prohibits harvesting and land clearing. Critically, 4.8 million hectares of protected land in Peninsular Malaysia is primary rainforest. These are habitats and reserves that protect large vertebrates, such as tigers, elephants, bears and tapir. They are subject to continuous anti-poaching patrols and high levels of political will and enforcement are focused on these sites. For the benefit of *M. reticulatus*, the State of Johor is also protected from harvesting through State Enactment.

5.12 Illegal trade

Despite illegal trade in various reptile skins within Southeast Asia (Kasterine et al. 2012; Natusch et al. 2016a), there is little evidence available to PERHILITAN indicating significant illegal trade in the meat or skins of *M. reticulatus* from Malaysia is taking place. Malaysian customs and enforcement authorities are well-briefed on the importance of wildlife crime and have been involved in numerous high-profile seizures of pangolin scales, elephant ivory, and other illicit wildlife products. There are incidents where Malaysian customs have seized illegal shipments of python entering Malaysia (including in 2020; e.g., https://www.bernama.com/en/region/news.php?id=1814311), but traders indicate these skins were destined for Singapore and were in transit through Malaysia. Importantly, illegal trade that is detected invariably involves python skins entering Malaysia from Indonesia and thus is not influencing the sustainability of offtake from Malaysia's python population.

Nevertheless, the opportunity for illegal trade exists within the harvesting program, such as harvesters capturing *M. reticulatus* without a license, harvesting where harvest is prohibited, or manipulating permits etc., but PERHILITAN has not detected any significant abuse, partly because legal trade is so readily available and accessible, even for those with minimal resources.

5.13 Penalties for non-compliance

The Malaysian Wildlife Conservation Act 2010 (Act 716) has specific sections to ensure trade of *M. reticulatus*, which is a protected species under this Act, is regulated properly:

37(1) A licensed dealer shall keep and maintain a record consisting of the following particulars:

*(**a**) the number and species of wildlife (live or dead), the number of parts or derivatives of wildlife and the number of articles manufactured from any wildlife or part or derivative of any*

wildlife, which were purchased, acquired or sold;
(b) *the name, address and license number, of the person from whom the wildlife, parts or derivatives of wildlife or articles were purchased or acquired;*
(c) *the name, address and license number, if any, of the person to whom the wildlife, parts or derivatives of wildlife or articles were sold;*
(d) *the receipt number issued for any sale or purchase; and*
(e) *the date of any purchase, acquisition or sale.*

(2) Any licensed dealer who contravenes subsection (1) commits an offence and shall, on conviction, be liable to a fine not exceeding ten thousand ringgit or to imprisonment for a term not exceeding six months or to both.

40(1) A licensed hunter shall sell protected wildlife hunted or taken by him only to a licensed dealer or licensed taxidermist.

(2) Any licensed hunter who contravenes subsection (1) commits an offence and shall, on conviction, be liable to a fine not exceeding twenty thousand ringgit or to imprisonment for a term not exceeding one year or to both

44(1) A licensed dealer, licensed taxidermist or birds' nest collector shall, at the time of each sale, issue a receipt of sale to the purchaser.

(2) Any licensed dealer, licensed taxidermist or birds' nest collector who contravenes subsection (1) commits an offence and shall, on conviction, be liable to a fine not exceeding ten thousand ringgit or to imprisonment for a term not exceeding six months or to both.

60(1) Any person who –
(a) *hunts or keeps any protected wildlife (other than immature or female), or*
(b) *takes or keeps any part or derivative of any protected wildlife, without a license commits an offence and shall, on conviction, be liable to a fine not exceeding fifty thousand ringgit or to imprisonment for a term not exceeding two years or to both.*

61. Any person who hunts or keeps an immature protected wildlife without a license commits an offence and shall, on conviction, be liable to a fine not exceeding one hundred thousand ringgit or to imprisonment not exceeding five years or to both.

62. Any person who hunts or keeps the female of a protected wildlife without a license commits an offence and shall, on conviction, be liable to a fine not exceeding one hundred thousand ringgit or to imprisonment for a term not exceeding five years or to both.

63. Any person who carries out business of dealing or taxidermy business without a license commits an offence and shall, on conviction, be liable to a fine not exceeding fifty thousand ringgit or to imprisonment for a term not exceeding two years or to both.

65. Any person who imports, exports or re-exports any protected wildlife or any part or derivative of a protected wildlife without a license commits an offence and shall, on conviction, be liable to a fine of not less than twenty thousand ringgit and not more than fifty thousand ringgit and to imprisonment for a term not exceeding one year.

International trade in M. reticulatus is also regulated under the Malaysian International Trade In Endangered Species Act 2008 (Act 686). M. reticulatus is classified as an Appendix II species in Schedule Three of this Act.

10. Any person who imports or exports any scheduled species without a permit commits an offence and shall, on conviction, be liable –
(a) *where such person is an individual, to a fine not exceeding one hundred thousand ringgit for each animal, plant, or readily recognizable part or derivative of the animal or plant, of the scheduled species but such fine shall not exceed*

in the aggregate of one million ringgit, or to imprisonment for a term not exceeding seven years or to both;
(b) *where such person is a body corporate, to a fine not exceeding two hundred thousand ringgit for each animal plant, or readily recognizable part or derivative of the animal or plant, of the scheduled species but such fine shall not exceed in the aggregate of two million ringgit*

As an example of the enforcement of this law, in 2017 the staff of a large-scale, legally operating python export facility accidentally included an additional package of python skins (an additional 20 skins) in a legal shipment of 2,000 monitor lizard skins and 500 python skins. Upon inspection, the shipment was found to contain 520 python skins. The Malaysian court prosecuted and fined the exporter 100,000 Malaysian Ringgit (US$ ~25,000), or 10 months imprisonment if he failed to pay the fine. This single event caused the trader's business to close.

At the time of writing, PERHILITAN is in the midst of amending the Wildlife Conservation Act 2010 (Act 716). Within the scope of this amendment is increasing fines and imprisonment terms for offences to act as a deterrent for non-compliance. Once gazetted, any person who imports, exports or re-exports any protected wildlife without a license will be fined not less than 50,000 Malaysian Ringgit and/or be imprisoned for a period not exceeding 15 years.

5.14 Capacity development

In collaboration with industry stakeholders, PERHILITAN undertakes regular capacity development exercises with *M. reticulatus* harvesters, processing facility owners and exporters. PERHILITAN staff visits processing facilities every month to ensure compliance with national regulations.

Fig. 33. Examples of workshops on humane treatment of reptiles (including *M. reticulatus*) conducted with trade participants in Peninsular Malaysia.

In addition, PERHILITAN has undertaken several rounds of training workshops to improve animal welfare outcomes for pythons and other reptile species traded for meat and skins (**Fig. 33**). For example, in 2017 PERHILITAN visited all reptile-processing facilities to ensure humane methods of handling, restraint, holding and killing were being implemented. Hands-on training was undertaken for all processing facility owners and their staff. In 2019, PERHILITAN held several workshops where hundreds of harvesters, agents, and processing facility staff were instructed and trained in correct techniques (**Fig. 33**). During both workshop series, three key resource documents were disseminated to reptile trade stakeholders in order to improve capacity related to animal welfare. All of these documents were disseminated in the local Malay language and provide science-based assessment of current knowledge related to reptile welfare from the point of capture to humane killing.

5.15 Assurance of animal welfare

PERHILITAN keeps abreast of developments in the understanding of animal welfare for reptiles. As noted above, PERHILITAN has carried-out trainings for industry stakeholders to improve capacity in animal welfare based on recently published guidance from the World Organisation for Animal Health (OIE). All facilities processing *M. reticulatus* are implementing humane methods of euthanasia based on OIE guidelines. Under Section 86 of the Wildlife Conservation Act 2010 (Act 716), it is an offence to treat wildlife inhumanely. This provision states that any person who –

> ***(a)*** *Beats, kicks, infuriates, terrifies, tortures, declaws or defangs any wildlife;*
>
> ***(b)*** *Neglects to supply sufficient food or water to any wildlife which he houses, confines or breeds;*
>
> ***(c)*** *Keeps, houses, confines or breeds any wildlife in such manner so as to cause it unnecessary pain or suffering including the housing, confining or breeding of any wildlife in any premises which is not suitable for or conducive to the comfort or health of the wildlife;*
>
> ***(d)*** *Uses any wildlife for performing or assisting in the performance of any work or labour which by reason of any infirmity, wound, disease or any other incapacity it is unfit to perform;*
>
> ***(e)*** *Uses, provokes or infuriates any wildlife for the purpose of baiting it or for fighting with any other wildlife or animal, or manages any premises or place for any of these purposes; or*
>
> ***(f)*** *Willfully does or willfully omits to do anything which causes any unnecessary suffering, pain or discomfort to any wildlife,*

Has committed an offence and shall, on conviction, be liable to a fine of not less than five thousand ringgit and not more than fifty thousand ringgit or to imprisonment for a term not exceeding one year or to both.

PERHILITAN strongly encourages the improvement of infrastructure designed to advance welfare outcomes of pythons in trade. Two processing facilities are state-of the art establishments designed to maximize animal welfare. Data from the RFID tagging and traceability systems reveals that, on average, it takes 48 hours from the time of capture to the time of euthanasia (range ~24-78 hours). During this period in confinement, pythons are provided water, and transportation occurs within specialized climate-controlled transport vehicles. Although not all facilities employ the same standards of infrastructure, transport and handling times are shortened as a commercial imperative. For the other facilities, active engagement and improvements are ongoing. Finally, together with industry, PERHILITAN is providing expertise and assistance in the development of third-Party certification to independently verify animal welfare within Malaysian *M. reticulatus* supply chains.

5.16 Levies and funding for ongoing trade management

Ensuring monitoring and management procedures are themselves sustainable requires a dedicated source of funding. Each year, approximately MYR 140,000 is spent directly monitoring the sustainability of trade in *M. reticulatus* and *Varanus salvator* in Peninsular Malaysia. In addition, a minimum of MYR 45,000 is spent each year by local Malaysian industry on the RFID tagging and traceability from which PERHILITAN gathers important information to monitor trade. The figures displayed above are hard, direct, costs. Intangible or in-kind costs and salaries of PERHILITAN staff engaged in wildlife management issues, logbook purchases, vehicle and equipment use, and sundry other tasks, are not estimated. Levies derived from the trade of python skins are presented in **Table 9.**

Table 6. Breakdown of government revenue obtained from the trade in *Malayopython reticulatus*. This estimate does not include customs goods taxes (dependent on value and quantity of export).

Levy	Cost per unit (RM)	Units	Total revenue (RM)	Notes
Harvesting licenses	2	121,000 skins	242,000	Mean python captures annually
Trading license	300	15	4500	5 facilities, with 3 trading licenses each
CITES export permit	50 per permit + 5 per skin	97,749 skins; 211 permits	499,295	Based on skins exported and number of shipments from 2018 (211 shipments)
MAQIS Export permit	5 per permit	211	1,055	Malaysian Quarantine and Inspection Services (Fees and Charges) Regulations 2013. For permit issuance; 211 shipments per year.
Total			**(746,850) US$185,700**	

5.17 Further research

As is typical of biological and wildlife management studies, the data collected during PERHILITAN's extensive research and monitoring program has raised many questions and opportunities for further research. Important questions to be answered to better improve our knowledge of harvest sustainability include:

- More accurate determination of exact harvest locations and habitats. These data will begin to be gathered through implementation of PERHILITAN's tagging and online data recording system.

- Detailed interviews with python harvesters to determine spatial changes in harvesting patterns over time.

- Determination of densities for spatially limited sites within oil palm plantation (the most heavily harvested habitat type).

Although intensive mark-recapture studies at spatially limit sites would typically be employed to answer these questions with other species, attempts at doing so have proven challenging in Peninsular Malaysia. PERHILITAN is exploring methodologies and options to undertake this work in a cost-effective manner. The determination of non-detriment is not dependent on obtaining results from the research suggested above. Although the studies above will be of significant interest, and will help to clarify some aspects of *M. reticulatus* population characteristics, they will be unlikely to help in answering the broad question about whether harvesting is sustainable or not. Long-term trend analysis from ongoing monitoring of wild populations, harvested pythons, and harvest metrics, will achieve this.

Conclusion

Conclusion

Despite the decades-long (and ongoing) harvesting and trade of *M. reticulatus* in Peninsular Malaysia, these animals remain common in even the most intensively harvested sites. Data on the attributes of harvested pythons directly related to sustainability have remained stable over long periods of time. In some countries, *M. reticulatus* are viewed as iconic, exotic animals, living in pristine environments, in far-off lands. In the Malaysian context, they are analogous to feral cats, urban foxes, and other ubiquitously common animals in many western countries. Expansion of human-modified habitats, coupled with the ecological flexibility of *M. reticulatus*, appears to have benefitted this species. In particular, although historical data are not available, data from natural versus human-modified sites and from hunting patterns strongly suggests that land use changes to oil palm plantations (with high densities of prey species and channeled water resources) has increased the habitat available for pythons in Malaysia.

The available evidence thus suggests that constant high levels of harvesting over the last decade have been sustainable. Based on all the evidence available, Malaysia is confident that an offtake of 121,000 individual per annum is sustainable and may be implemented from 2022. In 2021, harvest and export quotas have been reduced to 90,000 skins while additional management measures are established. In addition to the available evidence supporting a sustainable harvest, *M. reticulatus* harvests in Peninsular Malaysia are concentrated in 4-5 States. Coupled with protected areas where no harvesting occurs: 74% of Peninsular Malaysia's land areas is not subject to harvest, or is harvested at very low levels.

Finally, Malaysia's monitoring and management systems are evolving and becoming more sophisticated. They currently provide sufficient failsafe provisions to both detect and reverse declines should indications of unsustainable harvesting due to trade emerge. Nevertheless, Malaysia's management system for *M. reticulatus* is not perfect. The difficulty of systematically surveying wild python populations has precluded robust estimation of habitat and State-specific densities. Research and monitoring is continuing, and management protocols will be refined and adapted as more and better information becomes available.

At the time of writing, PERHILITAN is confident that sufficient information is available to conclude that harvests of *M. reticulatus* in Peninsular Malaysia are sustainable and that adequate management, monitoring, and safegaurds are in place to ensure the sustainability of offtake into the future.

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IN PENINSULAR MALAYSIA





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