Biological Conservation 201 (2016) 293–300

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Endangered leopards: Range collapse of the Indochinese leopard (*Panthera pardus delacouri*) in Southeast Asia

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ARTICLE INFO

Article history:
Received 4 January 2016
Received in revised form 4 June 2016
Accepted 2 July 2016
Available online xxxx

Keywords:
Carnivore conservation
Distribution
IUCN status
Panthera pardus
Population size
Wildlife trade

ABSTRACT

The Indochinese leopard (*Panthera pardus delacouri*) is a genetically distinct subspecies that historically occurred throughout mainland Southeast Asia, but might have experienced recent declines in numbers and distribution. This study aimed to determine the current distribution of the Indochinese leopard, and estimate its population size, by reviewing data from camera trap and other wildlife surveys conducted during the past 20 years. Our results showed the Indochinese leopard likely now occurs only in 6.2% of its historical range, with only 2.4% of its distribution in areas of confirmed leopard presence. The leopard is extirpated in Singapore, likely extirpated in Laos and Vietnam, nearly extirpated in Cambodia and China, and has greatly reduced distributions in Malaysia, Myanmar, and Thailand. There are plausibly only two major strongholds remaining, which we consider priority sites: Peninsular Malaysia, and the Northern Tenasserim Forest Complex. We also identified a small isolated population in eastern Cambodia as a third priority site, because of its uniqueness and high conservation value. We estimate a total remaining population of 973–2503 individuals, with only 409–1051 breeding adults. Increased poaching for the illegal wildlife trade likely is the main factor causing the decline of the Indochinese leopard. Other potential contributing factors include prey declines, habitat destruction, and possibly disease. We recommend a separate IUCN assessment for the Indochinese leopard, and that this subspecies be classified as Endangered. Our findings provide important information that can help guide where conservation actions would be most effective in preventing the extinction of this subspecies.

1. Introduction

The leopard (*Panthera pardus*) has the widest distribution of any felid species, and it historically occurred throughout Africa (except Saharan desert), and in Asia from the Middle East to the Pacific Ocean (Stein and Hayssen, 2013). Its wide distribution reflects its ability to inhabit diverse habitats and consume a wide range of prey (Stein and Hayssen, 2013). Despite its adaptability, it has experienced severe declines in distribution and numbers, primarily because of habitat loss, prey declines, conflict with humans, and poaching for the wildlife trade, with the relative importance of these factors varying among regions (Henschel et al., 2008). Consequently, the leopard now occurs in mostly small and fragmented populations, especially in Asia where 5 of 8 subspecies are listed as Endangered or Critically Endangered (Henschel et al., 2008). A recent review recommended the north Chinese leopard (*Panthera pardus japonensis*) be listed as Critically Endangered because of the high risk of extinction (Laguardia et al., 2016), leaving only two subspecies in Asia with presumably high and stable

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http://dx.doi.org/10.1016/j.biocon.2016.07.001
0006-3207/

numbers: the Indian leopard (*Panthera pardus fusca*) and Indochinese leopard (*Panthera pardus delacouri*).

The Indochinese leopard is a genetically distinct subspecies (Miththapala et al., 1996; Uphyrkina et al., 2001; Sugimoto et al., 2014) that historically occurred throughout all mainland Southeast Asian countries and southeastern China (hereafter Southeast Asia). The exact historical geographical boundary of this subspecies is not clear, and for the purposes of this paper we presume it occurred from the India-Myanmar border to Vietnam, and from Singapore to southeastern China (Miththapala et al., 1996; Uphyrkina et al., 2001), as far north as the Pearl River (Laguardia et al., 2016). As of 2008, the Indochinese leopard reportedly was still extant throughout most of the region (Henschel et al., 2008). However, recent camera trap studies suggested numbers and distribution of this subspecies might have declined, similar to that reported for other species in the region. Recent deforestation rates in Southeast Asia, the highest in the world, have coincided with a recent explosion in the illegal wildlife trade fuelled by increased demand, causing serious declines in many species (Duckworth et al., 2012; Lynam, 2010), which also could have negatively impacted the leopard. Therefore, we reviewed camera trapping and other wildlife surveys to determine the current distribution and population size of the Indochinese leopard in Southeast Asia, and propose recommendations for the conservation of this subspecies.

2. Materials and methods

2.1. Distribution

We conducted a literature search on Google Scholar and Web of Science for publications during the last 20 years (1995–2015) on the leopard in Southeast Asia, using the search terms "*Panthera pardus*" and each country of Southeast Asia. In Laos, we also included surveys from the early 1990s, because numerous initial wildlife surveys occurred during this period just after the country was opened to foreign researchers. Because this database might not have included all documents, we also searched gray literature, especially those by local organizations operating in Southeast Asia that might have conducted wildlife surveys. When necessary, we contacted the authors for additional information. In addition, we directly contacted organizations that conducted wildlife surveys in Southeast Asia seeking unpublished data on presence/absence of leopard. Most data used in our review came from camera-trap surveys conducted within protected areas (PAs), thus notional presence or absence could be determined. Other data came from wildlife sign surveys, including direct sightings, tracks, and scats. We used all records to produce an updated map of the distribution of the Indochinese leopard. Areas were considered "confirmed" if leopard was detected in wildlife surveys from 2000 to 2015, whereas areas were considered "potential" if leopard records were from 1995 to 1999. An exception was Myanmar, where we considered "potential" records from 1995 to 2001, given that only older records were available, and these might not represent the current distribution of leopard due to increases in poaching during the last decade. Also in Myanmar, several PAs listed leopard on their fauna lists (Instituto Oikos and BANCA, 2011) but without confirmed records, so these were classified as potential, unless camera trapping surveys failed to detect leopard there. For all countries, we also considered areas "potential" if satellite imagery showed forests contiguous with confirmed sites, especially those between different confirmed areas. Although the leopard is a habitat generalist, due to poaching this species is now primarily restricted to forest patches in Southeast Asia. Areas were classified as "absent" if camera trapping surveys with ≥500 trap days or other extensive wildlife surveys failed to detect leopard. Also, if leopard was initially detected at a site, but subsequent surveys failed to detect it, then we assumed leopard had become extirpated and we considered these areas as "absent". Because leopard, especially in small populations, might have been present in some areas but was not detected in surveys for various reasons (e.g., short length of study, small area covered), we also used expert opinion with local knowledge to confirm if our results adequately reflected the current status of leopard in the area.

2.2. Population estimate

To calculate total population size for each country, we multiplied the area of distribution (confirmed and potential) by an inferred density range. The density ranges were based on results from wildlife surveys and levels of enforcement of each country. We assumed 60% occupancy for all sites with confirmed and potential distribution because leopard does not occupy sites uniformly when factors such as tiger densities, prey densities, habitat, and human disturbance are considered (Carter et al., 2015; Steinmetz et al., 2013). We chose 60% occupancy because previous camera trap studies in Asia showed leopard had occupancy ranging between 31 and 62% (Carter et al., 2015; Steinmetz et al., 2013; S. Rostro-García and WWF Cambodia, unpubl. data), thus using the approximate upper value would help ensure that leopard numbers were not underestimated.

For Cambodia, China, and Myanmar, we assumed a low density range of 0.5–1.5 leopard/100 km^2, based on similarly high levels of poaching and low levels of effective enforcement across the countries, and considering a study in Cambodia that estimated a density of about 1 leopard/100 km^2 in 2014 (S. Rostro-García and WWF Cambodia, unpubl. data). For Malaysia, we assumed a medium density range of 1.0–3.0 leopard/100 km^2, based on relatively higher levels of effective enforcement and a recent study which estimated a density of 3.0 leopard/100 km^2 (Hedges et al., 2015). We assumed this was the maximum density for leopard in the country, because this population lived under optimal conditions (e.g., low tiger numbers, high prey numbers, suitable habitat). We chose a density of 1.0 leopard/100 km^2 as the minimum, assuming other areas were less optimal for leopard, similar to the density reported in Cambodia. In Thailand, we assumed a high density range of 2.5–5.0 leopard/100 km^2, given relatively higher levels of effective enforcement (Duangchantrasiri et al., 2016) and that previous leopard densities from several PAs were within that range (Simcharoen and Duangchantrasiri, 2008; Steinmetz et al., 2009). Because PAs in Thailand are part of large PA complexes, we used the total area of the complexes, either as confirmed or potential, if leopard was detected in at least one PA within them. However, a PA was excluded from the total area of a complex if surveys failed to detect leopard in that particular PA. Another exception was the Hala-Bala Complex, because leopard was detected only in one PA within the complex (Hala Bala Wildlife Sanctuary [WS]), thus only the size of that PA was used in the calculation.

The total population size (N) includes adults and subadults that are not part of the breeding population and which might never produce offspring. Therefore, we also estimated effective population size (N_e), an estimate of the genetic size of the population, which determines the number of reproductively viable mature individuals that contribute offspring which themselves reproduce (hereafter breeding adults). We estimated N_e for the remaining Indochinese leopard populations using a N_e:N ratio of 0.42, which was used previously for leopard in Africa (Spong et al., 2000). Although this ratio might not be appropriate for all leopard populations in Southeast Asia, we assumed it to be similar to that of leopard from Africa given that data on N_e were not available for leopard in Asia. Also, the estimation of N_e can later help with the IUCN assessment of this subspecies, as estimation of total mature individuals is needed to help determine classification. Finally, to evaluate the sensitivity of our estimated results, we calculated N and Ne using extreme values of leopard occupancy (10% and 90%).

3. Results

We reviewed 146 wildlife surveys from 109 sites from 6 countries within the historic range of the Indochinese leopard (Appendix A), in addition to using previous reviews for southeastern China (Laguardia et al., 2016) and Singapore (Corlett, 1992). The Indochinese leopard