Preliminary Study of the Feasibility of a Tiger Restoration Programme in Cambodia's Eastern Plains

A Report Commissioned
by World Wide Fund for Nature

Tiger *Panthera tigris* walking at night. Last camera trap taken of tiger in Mondulkiri Protected Forest of Eastern Plains Landscape, Mondulkiri Province, Cambodia. 2007.

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Table of Contents

Preface

In October 2007, a camera trap captured a tiger walking towards the Vietnamese border at O Chrouh near the Mereuch outpost in Mondulkiri Protected Forest, part of Cambodia's Eastern Plains Landscape. This is the last confirmed photograph of a wild tiger anywhere in Cambodia. Since that photograph was taken, single pugmark tracks—most recently reported in late 2010—are the only evidence that any tigers may still roam Cambodia. Recent survey levels with camera traps and scat detection dogs have been high enough to be sure that the scarcity of reports means the population must now be so low that the species is functionally extinct in the Eastern Plains Landscape. In fact, it appears likely that no breeding tiger population remains in Cambodia. Thus, the opportunity for a natural recovery of Cambodia's tiger population is extremely low.

In the Global Tiger Recovery Program 2010-2022 (GTRP 2010), Cambodia set the goal of increasing tiger numbers to 50 by 2022, noting that a translocation programme may be needed to achieve the goal. Among the country's National Tiger Recovery Priorities (GTRP 2010) is to "identify a suitable source site for eventual reintroduction of tigers and obtain a clear mandate for managing the site for tiger recovery". The source site would be the area in Cambodia to receive translocated tigers and would be managed as a source site where offspring of breeding individuals would disperse into the landscape.

In the Global Tiger Recovery Program Implementation Report 2012 (Global Tiger Initiative Secretariat 2012), Cambodia revised its numerical target to 75 tigers and set as its goal, "By 2022, to restore and conserve the Core Zone of the Mondulkiri Protection Forest as an inviolate Tiger Recovery Site within a well-defined Eastern Plains Tiger Conservation Landscape (EPL[1]) that is tiger permeable and can potentially hold at least 25 tigers." This recognizes the fact that Cambodia's tiger population is nearly or entirely extirpated. The draft Cambodia Tiger Action Plan (CTAP 2012) similarly cites the Eastern Plains as the best location to restore tigers.

WWF has been supporting conservation in the Mondulkiri Protection Forest and the Phnom Prich Wildlife Sanctuary in the Eastern Plains since 2001. To obtain advice on approaching the subject of restoring tigers in this landscape, WWF commissioned a study to examine the feasibility of a restoration programme that involves reintroduction if tigers are entirely extirpated or reinforcement if a few tigers still inhabit the area. Henceforth the term 'restoration' includes the concept of both reinforcement and reintroduction in accordance to the *IUCN Guidelines for Re-introductions and Other Conservation Translocations* (2012).

The study sought to assess whether it is both necessary and feasible to restore tigers to the Eastern Plains by answering two sets of questions.

- Is it justifiable to restore tigers in the Eastern Plains Landscape as a part of the wider global tiger recovery programme?

If the answer is, yes, then:

- What conditions in the Eastern Plains would influence successful restoration?
- What operational factors need consideration before and after restoration begins?

This report is the result of that study, conducted by its authors, and is primarily aimed at providing information to the Royal Government of Cambodia for their consideration, as well as to other tiger range country governments and interested parties.

Cambodia is not alone in facing the challenge of recovering tiger numbers from nearly zero to a viable population size; Vietnam, for instance, is also examining options for restoration. We hope the governments of Cambodia and other range countries find this document useful to draw from for a tiger restoration programme.

Michael Baltzer
WWF

[1] This is an acronym used by WWF to reference the Eastern Plains Landscape and is used is this paper as an abbreviation to reference the area.

Executive Summary

The Eastern Plains Landscape (EPL) of Cambodia has been identified as the best location to restore the heavily diminished and potentially extirpated tiger *Panthera tigris* population of Cambodia; most recently in the draft Cambodia Tiger Action Plan (CTAP 2012).

World Wide Fund for Nature (WWF) commissioned this study to seek advice on the feasibility of restoring tigers to the EPL. The group of experts convened to undertake this analysis concluded:

1. Consideration of the EPL for a focused restoration programme is justifiable and necessary for global tiger conservation.

- The EPL has a unique role to play in the recovery of the global tiger population because there is no place better suited to restoring a tiger population in the southeast of the Mekong region.
- The EPL as a whole has the potential to support a significant increase in tiger numbers therefore the area offers a major opportunity to reach the global goal of doubling the numbers of tiger worldwide. If successful restoration is achieved, Cambodia could contribute at least five percent to the global goal of doubling the number of tigers in the wild.[2]
- The EPL can provide a launch pad for recovery in Cambodia and if the human will is there, southern Vietnam and southern Laos.
- Intensive protection and management of a large landscape for tigers in the EPL will have a very significant benefit for this endangered habitat type and the many globally threatened species persisiting within it, including the world's most important population of banteng *Bos javanicus*[3].

2. Threats to the tiger population are under some control at present but if a restoration programme is considered, the management of the site would have to be elevated dramatically.

- Recent efforts have improved the situation that caused the dramatic decline of tigers in this area but original threats still remain.
- The window of opportunity is closing rapidly. Without a government-led restoration programme to prioritize land-use for tiger restoration (and other conservation targets), it is unlikely that the EPL will remain intact due to the land use aspirations from other sectors across the region. At present rates of conversion, within five years it is unlikely there will be enough habitat remaining to make tiger restoration feasible.

3. Restoration of tigers will require translocating tigers from outside Cambodia, and/or from the local captive population, if any. There are no wild breeding populations in Cambodia to source from.

- There is not a ready source of the Indochinese tiger subspecies *P. t. corbetti* from any scientifically managed or accredited zoo facility. A breeding programme would have to be developed. This will be a challenge as only a very few number of pure bred Indochinese tigers were found to be in captivity within credible institutions.
- If founders can be assembled, a scientifically-managed captive breeding programme for Indochinese tigers could be initiated. Sourcing from tiger farms or other privately owned facilities is not an option due to the breeding regimes undertaken in these facilities (See Appendix 2).
- Nearly all wild Indochinese tigers remaining, estimated to be fewer than 350 across the Greater Mekong, are found in western Thailand and, presumably adjacent Myanmar. Estimates for Thailand range from 190-250. Recovering that population is Thailand's immediate conservation goal and there is considerable habitat remaining for that population to expand; removing a small number of individuals may be an option. If it were considered possible by the Thai government, this would be the ideal source of tigers for restoration.

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[2] This percentage is based on the carrying capacity of the landscape and the numbers of tigers needed to double the global tiger population. [180 tigers (approximate carrying capacity of the landscape) is 5.6% of 3,200 (number needed to double the number of tigers)].

[3] Banteng is itself an endangered species, which will require management if restoring the ecosystem's top predator.

- There is a small population of perhaps about 16 individuals (Vongkhamheng 2011) living in one area of Laos. Recovering that small population is a national priority for Laos and, with so few tigers, none should be removed. Myanmar is in a similar situation, with a population of unknown but probably small size.
- There are no evident wild Indochinese tiger populations in China or Vietnam.

4. If neither wild nor captive Indochinese tigers are available, sourcing from other subspecies is the only remaining option.

- The closest genetic relatives to Indochinese tiger are Malayan and Amur tiger with nuclear markers placing Malayan marginally closer to Indochinese. In addition Malayan tiger, which is widely present in captivity, appears to have more genetic variation than Amur tiger. However the tropical moist forest habitat and prey assemblage is a mismatch to the open dry forests of the EPL.
- The subspecies sharing the most similar habitat and prey assemblage is the Bengal subspecies *P. t. tigris*, which is present in robust populations. India and Nepal may be the most appropriate countries to source from due to the most similar habitat and prey assemblage and their stable and, in some places, increasing population.
- Sourcing individuals of a different subspecies is considered to be acceptable in this case. It was concluded that the importance of establishing a robust population in Cambodia outweighs the extremely remote risk of mixing with wild individuals of the Indochinese subspecies in Thailand, Laos and, the unlikely remaining, individuals in Cambodia or Vietnam.
- Arrangements would need to be made between the governments of Cambodia and the sourcing country (i.e. Thailand, India, or Nepal) to support the recovery process over a sustained period.
- A follow-up study is needed to critically analyze the conservation implications of each potential source population.

5. The restoration effort should source adequate number of founders to ensure that the population persists even with a certain level of loss to unnatural causes (poaching) and emigration to other areas.

- A founder population of at least eight individuals (six females and two males) is recommended.
- Even with population loss (to poaching or emigration) of one individual every three years, such a founder population would have a 93 percent probability of persistence over 25 years.
- With additional supplementation of one tiger pair (a male and a female) every three years for the first nine years (an additional six tigers), the probability of population persistence increases to 99 percent.
- A follow-up study is needed to understand the extent in which the founder population with need to be supplemented with additional individuals to ensure genetic variability over time.

6. Recovery to a population of at least 180 individuals is possible in the EPL with strong enforcement and continued prey recovery.

- Within one to three years prey densities in the 460 km^2 inner-core of Mondulkiri Protected Forest could increase sufficiently to support 10 tigers.
- The entire EPL protected area complex (four areas in Cambodian and one in Vietnam), under realistic prey recovery conditions and strong landscape management, could support a minimum of 180 individual tigers (Figure 1).
- From a founder population of eight individual tigers in 2017, a population size of 180 could be reached by 2050.

7. Recovery of tigers through translocation is feasible only if stringent management conditions are in place before and during the restoration programme.

- A large area of habitat needs to be protected from land conversion and other threats. The EPL offers a contiguous landscape comprising several protected areas including, in Cambodia, Lomphat Wildlife Sanctuary, Mondulkiri Protected Forest, Phnom Prich Wildlife Sanctuary, and Seima Protected Forest. Yok Don National Park in Vietnam is contiguous with Mondulkiri Protected Forest (MPF).
- The Cambodian government has already provisionally identified MPF as a target site for tiger restoration. MPF covers an area of 3,631km^2 and the government has made suggestions to designate, within 1,700km^2 of high biodiversity, an area as an inviolate 'Tiger Recovery Core Zone' (it also could be referred to as a strict protection zone, its current unofficial designation).
- The MPF is the ideal location for the centre point of the restoration programme but does not have the facilities immediately available for either a hard release or soft release of introduced animals such as animal pens and veterinary services. The necessary facilities would need to be identified in the full restoration operational plan[4].
- At present, the governance of the EPL, even from a tiger conservation perspective, is very complicated. For the restoration programme to be feasible, a streamlined and clear governance system will be required to ensure all stakeholders are aligned to the plan.
- While a considerable amount of capacity has been put in place across the EPL, the capacity to support and manage a restoration programme of this scale is currently lacking. A full commitment from the Royal Government of Cambodia and its partners to support the necessary capacity is required before the restoration programme commences.
- The local community living within the EPL and particularly the primary recovery site in MPF is actively engaged in conservation efforts and this should continue, with specific measures in the operational plan to provide effective outreach before and during the restoration programme.
- One of the essential elements for the restoration programme is effective protection against poaching in the restoration sites. There is at present a significant foundation for protection, which has successfully led to a recovery in the large animal population in the EPL and MPF. However this protection would need to be greatly increased and expanded.
- If the Royal Government of Cambodia decides to launch a restoration plan, the first step would be to create a full operational plan with a team of relevant government officials and internationally recognized experts in tiger recovery, translocation and management including protection.

The study indicates there is a very strong case for investing in the recovery of tigers in the Eastern Plains of Cambodia. There are, however, a number of barriers to overcome in the sourcing of the candidate tigers for translocation that need further consideration, consultation and agreement.

In the process of examining the feasibility of a tiger restoration programme, the technical aspects of necessary initial activities are presented here. The study stops short of prescribing a plan, but rather considers the various options for such a programme. Among the aspects considered are: founding population size, possible population growth, sourcing population, habitat and protection needs, and community participation. A full operational plan is required before the restoration programme is initiated.

The most important element for the restoration programme to be feasible is the complete commitment to the programme at the highest levels of the Royal Government of Cambodia. To be successful, the restoration programme will need strong governance and leadership so all partners are committed from the beginning to ensuring poaching and habitat fragmentation threats will be effectively managed, the plan is strictly adhered to and is sustained well beyond the initial recovery stages. Without this commitment from the beginning, the programme should not be considered further.

[4] The *IUCN Guidelines for Re-introductions and Other Conservation Translocations* (2012) details components of such a plan (see Appendix 3 for a subset of the guidelines).

Part 1 – Justification for a Tiger Restoration Programme in the Eastern Plains

Section 1. Introduction

Wild tigers *Panthera tigris* are globally threatened with extinction. An estimated 3,200 tigers, down from perhaps 100,000 in 1900, live in just seven percent of their former habitat that once stretched from Central Asia in the west, through South and Southeast Asia, to the Russian Far East and Korea (Dinerstein et al. 2007). In 2010, the leaders of the remaining 13 Tiger Range Countries committed to an ambitious Global Tiger Recovery Program 2010-2022 (GTRP 2010) with the goal of doubling the number of wild tigers by 2022.

To contribute to the global goal, Cambodia aims to reach 75 wild tigers by 2022 (Global Tiger Initiative Secretariat 2012), a number revised upward in 2012 from 50 reported in the GTRP (2010). The only way to reach this goal is through a restoration programme because wild tigers are nearly if not completely extirpated in Cambodia. The Royal Government of Cambodia recognizes this and has named the Eastern Plains Landscape (EPL) as the area with the greatest potential for a successful tiger recovery programme.

Part 1 of this study examines the evidence for why the Cambodian tiger population cannot recover naturally, the importance of tiger recovery in Cambodia to the global effort to save wild tigers and then whether restoration of tigers to the EPL is feasible. Part 2 of this study then discusses enabling conditions, obstacles to success and operational factors to be considered before and during restoration.

Section 2. Current Status of Tigers in Cambodia

In early 2010, the Cambodian Ministry of Environment and supporting NGOs were contacted by the Forest Administration's Department of Wildlife and Biodiversity (DWB) requesting all confirmed tiger records from 2005 to 2009 from all protected forests and protected areas in the Northern Plains, Cardamom Mountains, Eastern Plains and Virachey landscapes, these being the only areas in Cambodia where tigers were known to have occurred in the recent past. These data were used to update the Cambodia Tiger Status for the Global Tiger Initiative and to provide a baseline for preparing the Cambodia National Tiger Action Plan (Draft CTAP 2012).

The resulting Cambodia Profile (also published in Walston et al. 2010) concluded:

- Only a few scattered individual tigers remain in Cambodia, based on the analysis of all confirmed tiger records from all organizations in Cambodia from 2005 to 2010.
- There is no evidence of a resident breeding population anywhere in Cambodia and survey effort has been sufficient to conclude that this therefore means there is no source site for tiger recovery in the country. Moreover, there is no likelihood of recovery through immigration from adjacent countries, looking at current tiger distribution in Vietnam, Lao PDR and Thailand (Walston et al. 2010).
- The EPL is the best potential source site for tiger recovery in Cambodia, through reintroduction of wild tigers from another source.

In 2010, WWF undertook a survey of Mondulkiri Protected Forest (MPF) and Phnom Prich Wildlife Sanctuary (PPWS) in the EPL using specially trained tracker dogs ("scat dogs") to detect tiger scat. This survey found scats of leopard *Panthera pardus* and dhole *Cuon alpinus*. A number of scats first recorded as potential tiger scats proved upon genetic analysis to be from leopard (T. Gray, WWF Greater Mekong, T. Sugimato, Hokkaido University, in litt. Aug 2012). In October 2010, an experienced ranger from PPWS photographed and obtained a plaster cast of an apparent tiger footprint in the core zone of PPWS. This indicates that, if tigers do still exist in the landscape, they do so in extremely low numbers.

The EPL is contiguous with Yok Don National Park (YDNP) in Vietnam, where tigers are also nearly if not completely extirpated (Eames et al. 2004). In Laos, tigers appear to have been extirpated from all landscapes except Nam Et Phou Louey in the northeast of the country. Nam Et Phou Louey's tiger population is estimated at just 16 individuals (Vongkhamheng 2011). Apart from this small one, no breeding populations of tigers exist east of the Mekong River. The Government of Laos is committed to growing the Nam Et Phou Louey population but due to the distance and intensity of existing threats there is little chance it will be able to act as a source for the now-empty forests in the rest of Laos in the foreseeable future, let alone for Vietnam and Cambodia.

Therefore, restoration is considered to be the best option for recovering a tiger population in Cambodia. Given the dramatic decline in the global wild tiger population, efforts are required to secure the species in the wild wherever possible[5]. Any area with strong potential to support a large viable tiger population has an important role in the global recovery plan. Recovery of tigers in the EPL alone could provide an additional population of more than 180 tigers in the medium to long-term. This is nearly five percent toward achieving the global goal of doubling the number of tigers in the wild. This goal is shared by all 13 Tiger Range Countries and endorsed at the 2012 St. Petersburg International Tiger Forum on Tiger Conservation.

Tiger restoration[6] also fits the primary objective under the definition and classification of conservation translocations in accordance with the *IUCN Guidelines for Re-introductions and Other Conservation Translocations* (IUCN 2012) which state, "intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem functions or processes." This would be among the objectives of a tiger restoration programme in Cambodia.

Section 3. Reasons for the Tiger's Decline in Cambodia

While habitat loss and degradation is considered one of the main reasons for the decline of wild tigers across the range, intense hunting and poaching of both tigers and their prey (which include banteng, sambar *Rusa unicolor*, Eld's deer *Rucervus eldii*, wild pigs *Sus scrofa* and others) is largely responsible for their disappearance in Cambodia (Loucks et al. 2009).

Hunting/poaching of tiger prey in the EPL is largely for local subsistence, local markets and some international trade, while poaching of tigers has fed the well-documented illegal international trade in tiger parts and products. Before 2000, there was almost no protection or other attempt to control hunting and poaching in the EPL.

Shortly after civil unrest ceased, the Cambodian government made initial commitments to conserve wildlife, including the country's remaining tigers. In 1998, the DWB (then called the Forestry Administration's Wildlife Protection Office) made the first, albeit coarse, country-wide assessment of the status and distribution of tigers and their prey. Officials interviewed 153 hunters and 156 district and provincial officials in 13 forested provinces (Weiler et al. 1998; Nowell et al. 1999). Surveys and workshops then proposed the best remaining Tiger Conservation Units (TCU) (Wikramanayake et al. 1999) were the Northern Plains, Cardamom Mountains and Eastern Plains. Three regional offices were established by the Wildlife Protection Office, which managed a network of community rangers who monitored tigers and their prey from 2000 to 2005 (CTAP 2012).

Conservation efforts started in the EPL in 2001 and were slowly increased to the extent that, by 2005, protection became a significant deterrent to poaching across much of PPWS and MPF (in total approximately 600,000ha), especially within the core areas (approximtely 200,000ha in total). This has led to a recovery of tiger prey populations (Gray et al. 2011; Gray et al. 2013 (in press)). There are now sufficient prey to support a population of tigers; and with reasonable levels of prey recovery the EPL Protected Area (PA) complex, could support 180 tigers (see Section 5). Baited snares for large cats that were commonly used in the past have not been found recently, despite regular searches in the protected areas on the Cambodian side of the EPL. This indicates poachers are no longer targeting big cats in these parts of the EPL. Similarly, leopards and other carnivores are recovering (Gray and Prum 2011). This indicates protection is working, albeit not with maximum effectiveness (The level of threat has increased in the last five years; see Section 5 for details of protection effort).

The proximity of the EPL to the porous borders of Vietnam (from which a large proportion of the demand for wild meat and parts comes) has been a key factor driving the intensity of hunting and poaching. While it is questionable whether the border is any more or less secure against poachers compared with 10 to 15 years ago, demand is likely to be increasing as the human population in Vietnam and other tiger-consuming

[5] Preparation work is underway to re-establish tigers in the Caspian region of Kazakhstan (Driscoll et al. 2012).
[6] Population Restoration is defined by the *IUCN Guidelines for Re-introductions and Other Conservation Translocations* as any conservation translocation to within indigenous range, and comprises two activities: reinforcement and reintroduction.

countries become economically stronger (TRAFFIC 2008). With improved access and transportation links, the speed to market has increased, so it can be assumed threats driven by high demand and ever-present traders looking for opportunities will remain for the foreseeable future.

The IUCN (2012) reintroduction guidelines stipulate that the factors that led to extinction must be alleviated before reintroduction or reinforcement commences. While the ecological and management conditions are presently favourable, there is only a small window of opportunity within the EPL for the recovery of tigers in Cambodia. Without a very active and determined effort to manage the expansion and locations of plantations and other economic activities in this part of Cambodia and without consistent improvement in protection and ecological monitoring, the conditions for recovery will likely disappear in the next five years[7]. A commitment to restoration and to creating the necessary pre-conditions is required immediately.

Section 4. Suitability of the Eastern Plains as a Tiger Restoration Site

The draft CTAP (2012) concludes “The Eastern Plains Landscape was identified as the best potential source site for eventual tiger reintroduction, which is of sufficient size and quality to support a breeding population embedded in a larger block of habitat that will enable tiger dispersal and repopulation of the larger landscape.”[8] The EPL was also classified as a Global Priority by Sanderson et al. (2010).

The EPL offers a contiguous landscape comprising several protected areas including, in Cambodia, MPF, PPWS, Lomphat Wildlife Sanctuary (LWS), and Seima Protected Forest (SPF). YDNP in Vietnam is contiguous with MPF (Figure 2). This landscape has the largest extent of high-quality tiger habitat left in mainland Southeast Asia and has among the highest potential carrying capacities for tigers and their prey in the region. These large expanses of deciduous dipterocarp forest with patches of semi-evergreen forest provide ideal conditions for recovery of large tiger prey populations (see Section 5). Figure 2 also shows that the EPL is also part of a much larger potential tiger conservation landscape that extends up to Southern Laos and Central Vietnam. Success here could translate, long-term, to the EPL serving as a source to re-populate other landscapes where and when the necessary conditions are in place; for example, the Cardamoms landscape in Southwest Cambodia through human-assisted movement.

MPF is a key protected area within the EPL and is globally important for the conservation of threatened forest types, wildlife communities and aquatic systems. Among the rare and highly threatened vertebrates in the MPF are gaur *Bos gaur*, banteng, wild water buffalo *Bubalus bubalis*, Eld’s deer, Asian elephant *Elaphus maximus*, sarus crane *Grus antigone*, giant ibis *Thaumatibis gigantea* and Siamese crocodile *Crocodylus siamensis*, as well as a host of other endangered species (Pollard et al. 2007, Phan et al. 2010, Gray et al. 2012-a and b). The EPL also has important economic, cultural and historical values. A high-profile tiger restoration programme in the EPL, and the activities required to support it including increased protection, will help conserve all the biological and human values of the area.

A draft zoning plan of MPF (Figure 3 and 4), developed in 2008, identifies a strict protection zone which has been the focus of joint government and NGO management efforts. Intensive protection and monitoring work has shown tiger prey populations are recovering in this zone. Therefore it is a logical place for a tiger restoration programme which will need intensive protection and monitoring measures in place. MPF covers an area of 3,631km^2 and the government has made suggestions about designating the already proposed 1,700km^2 strict protection zone within the MPF as an inviolate ‘Tiger Recovery Core Zone’ (exact name to be decided). Within the strict protection zone, the most remote and secure area with the highest prey density is 470km^2; an area which could support an estimated 10 breeding tigers.

The draft CTAP (2012) states that, “Effective on the ground law enforcement and monitoring have been established in the Eastern Plains TCL with strong long-term support by conservation NGOs. Evidence that prey species have stopped declining and are possibly increasing in eastern Cambodia is starting to emerge. The National and Provincial governments are strongly committed to conservation in this region. Conservation activities should be continued and expanded to lay the groundwork for reintroduction of Tigers.”

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[7] This timeframe is the perceived window of opportunity as put forth by the authors based on trends of present threats.

[8] During development of the CTAP, the Cardamom Mountains Landscape in Southwestern Cambodia was also considered as a source site but the EPL was determined to be the preferable site for investment.

Recent studies, detailed in Section 5, have also documented a tiger prey base (primarily banteng, red muntjac *Muntiacus muntjak*, and wild pig) as being present at a density of almost five animals per square kilometer and it is generally believed the landscape is capable of supporting even higher densities.

In conclusion, consideration of the EPL for a focused restoration programme is justifiable and necessary for global tiger conservation:

- The EPL has a unique role to play in the recovery of the global tiger population because there is no place better suited to restoring a tiger population in the southeast of the Mekong region.
- The EPL as a whole has the potential to support a significant increase in tiger numbers therefore the area offers a major opportunity towards reaching the global goal of doubling the numbers of tiger worldwide. If successful restoration is achieved Cambodia could contribute at least five percent of the goal.
- The EPL can provide a launch pad for recovery in Cambodia and possibly adjacent Vietnam and southern Laos.

Part 2 of the report examines the conditions required to make a restoration programme reality.

Part 2 – Conditions needed for a Tiger Restoration Programme

Section 5. Tiger Biology and Ecology: Implications for Recovery in the Eastern Plains Landscape

Tigers are habitat generalists, as evinced by their once-wide distribution in multiple vegetation types throughout Central, South, East and Southeast Asia (Sunquist et al. 1999). Tigers are the largest carnivores living in Asian forests (Seidensticker et al. 1999). They kill prey ranging in mass from 20kg[9] to more than 1,000kg, but selectively seek out large-bodied ungulate prey, in particular large deer (*Cervus*, *Axis*, *Rucervus*, *Rusa*), wild cattle (*Bos*, *Bubalus*) and wild pigs (*Sus*), thereby gaining access to a major percentage of potential prey biomass contributed by relatively few individuals (Eisenberg 1980, Karanth et al. 2004, Hayward et al. 2012). Tigers kill about one large prey animal per week and, in a stable system, take about 10 percent of the standing prey biomass each year (Sunquist 1981, Karanth et al. 2004). Thus, a base of approximately 500 large ungulates is needed to produce the 50 individuals a tiger kills each year. In the absence of human-induced mortality, prey density and distribution explain tiger density, not habitat/ vegetation parameters (Karanth et al. 1999, Miquelle et al. 1999, Chapron et al. 2008). Tiger prey densities vary naturally cross the different Asian forest types largely because the production and availability of food for ungulates varies in different forest types (Eisenberg and Seidensticker 1976); however, now these natural patterns are much modified by hunting pressures.

Background

How do we know the size of the areas that tigers need (from Smith et al. 2011)?

- Breeding male and female tigers are territorial.
- Overlap among breeding female territories is low, less than seven percent.
- Male territories on average are about 3.5 times the size of those of breeding females and overlap with one or more female territories.
- A female’s territory must be large enough to support enough prey to feed her and her offspring as they grow until they disperse at 19 to 28 months of age; with older cubs the total prey requirement may be 300 percent above that of the average adult female alone (Miller 2012).
- A viable tiger habitat must also be large enough to provide the prey the resident breeding male requires. Further, it must be large enough to support the non-reproducing transients, dispersing and non-reproducing adults that may represent approximately 20 percent of the total tiger population.
- Based on energetic calculations, a female territory includes enough prey to support about three to four adult-sized tigers. Tiger density and territory size of breeding female tigers is therefore correlated with prey densities, and the territory size of a reproducing female is a base measure of the carrying capacity of tiger habitat.

Several studies, across a number of tiger range countries and vegetation types, have demonstrated a positive relationship between tiger abundance (measured as either the number of individuals per 100km^2 or mean female home-range size) and prey density. The shape of the relationship, whether linear or curvilinear, is unclear. However, at low ungulate prey densities, the limited evidence suggests a linear relationship, with female home range size (territory size) calibrating so as to provide a similar prey biomass per home range (Miquelle et al. 2010). This has been measured in the tropical dry forest of the Huai Kha Khaeng Wildlife Sanctuary as approximately 600 Prey Units (127,200kg)[10]; female territory size was 74km^2, established through radio tracking (Smith et al. 2011).

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[9] In some areas, smaller sized prey is hunted by tiger.

[10] Prey Units per km^2 are used as a measure to average out all prey species into a *single prey item equivalent*. This also allows for comparison across other tiger landscapes where the predominant prey species vary. One Prey Unit is 212 kg (Karanth and Sunquist 1995, L. J. D. Smith. person. com.)

Where tiger densities have been measured accurately, densities vary by a factor of 40: from less than 0.5/100km^2 in ever-wet rainforests in Sumatra and northern temperate forests in the Russian Far East, to more than 20/100km^2 in the prey-rich alluvial floodplains and riverine forest strips of India. The largest strictly protected reserve in the Russian Far East is 4,000km^2, yet it supports only about 30 tigers. A reserve the same size in the prey-rich riverine tall-grass savannas in India and Nepal could potentially support 800 tigers (Wikramanayake et al. 2011).

The potential productivity of large ungulates, and hence the tiger carrying capacity of a landscape, is a product of the vegetative response to soil quality, human activity (disturbance regime such as fire and livestock grazing) and rainfall. As a generalization, when proceeding from a dry thorn forest to a moist deciduous forest, the mammalian biomass increases as rainfall increases. If the forest becomes continuous and there is very little grassland area, then the forest will tend to support a very low density of ground-dwelling herbivores so that, at the extreme wet end of the vegetation gradient, the biomass of terrestrial herbivores declines. In South and Southeast Asian ungulate assemblages, mixed browsers/grazers or grazers alone—the large deer and wild cattle that tigers select as prey—contribute the greatest percentage overall to terrestrial mammalian biomass in any given habitat (Eisenberg 1980). Grasslands and the interspersion of resources (grass, shrubs and scrub, as well as low-stature trees) create the optimum habitat for a diverse and abundant ground-dwelling mammalian herbivore community (Eisenberg and Seidensticker 1976).

A distinct annual wet and dry season and periodic fires are key ecological drivers of seasonally dry tropical forests like those found in the EPL (McShea et al. 2011). An extended annual dry season with periodic fires (every 3 to 5 years) results in a deciduous forest that has a more open canopy than found, for example, in a moist evergreen forest. Increased light at the ground layer produces fast-growing shrubs, herbs and grasses with high protein content. However without periodic fires, grass is replaced by shrubs and bamboo (McShea et al. 2011), and these are less palatable to ungulates than are non-woody graminoids. The general consequence of these ecological differences between dry deciduous and moist evergreen tropical forests is that dry deciduous forests produce a much higher biomass of the large mammals upon which tigers depend (Eisenberg 1980, Seidensticker et al. 2010).

The deciduous dipterocarp forest that dominates the landscape of eastern Cambodia represents conditions that are close to the apex of the relationship between rainfall and mammalian biomass described above. The EPL therefore has the potential to support high ungulate densities due to their high primary productivity and, consequently, the potential for a large tiger population. The role of annual anthropogenic burning in promoting grass growth, and hence productivity, within Cambodian dry forests is a key area for future research (McShea et al. 2011).

While no historical information exists on tiger prey abundance or density within the EPL, based on the pioneering surveys of Charles Wharton (e.g. Wharton 1968) during the 1950s it is known that Cambodia's dry forests supported an abundant and diverse herbivore community with high densities of Eld's deer and banteng—both optimal tiger prey species given their relatively high biomass in non-hunted situations. In the 1960s, Cambodia's large game attracted international sport hunters who could shoot high numbers of gaur, banteng and wild water buffalo (Engle 1981, Cambodia Ministere De L'information 1960 as in CTAP 2012). However, current ungulate prey densities across the EPL are significantly below the landscape's carrying capacity due to hunting (Loucks et al. 2009).

Information on current ungulate densities from 460km^2 of the strict protection zone of MPF, based on distance-based line-transect sampling during the 2010/11 dry-season are given in Table 1. This area, between the Tonle Srepok and the O Rovei rivers, supports the highest tiger prey densities in the EPL. Current tiger prey densities elsewhere in the EPL (the remainder of the strict protection zone of MPF, the core zone of PPWS and the strict protection zone of SPF) are between 5 to 25 percent lower in wild pigs and red muntjacs and 60 to 80 percent lower in banteng. Banteng and wild pigs, ideal tiger prey species, make up most (almost 75 percent) of the available ungulate numbers and biomass in the core of MPF (O'Kelly and Nut 2010, Gray et al. 2011).

Densities of Eld's deer and sambar were too low to estimate based on line-transect surveys. This suggests the populations of these important tiger prey species remain severely depressed. Research would be helpful in understanding the implications for tiger recovery given that the majority of currently available biomass is provided by only one species, banteng.

Table 1. Ungulate tiger prey biomass and density in the inner core of Mondulkiri Protected Forest's core zone (460km^2 of total core zone area of 1,700km^2)(Gray et al. 2011). CI: Confidence Interval; PU: Prey Units.

	Weight (kg)	Biomass (kg per km^2) lower 95% CI in MPF core (number of individuals)	Biomass (kg per km^2) upper 95% CI in MPF core (number of individuals)
Red muntjac	20	44 (2.2)	72 (3.6)
Wild pig	50	55 (1.1)	160 (3.2)
Banteng	320	416 (1.3)	896 (2.8)
Total kg (individuals)		515 (4.5)	1128 (9.6)
	Weight (kg)	**Minimum PU (per km^2)**	**Maximum PU (per km^2)**
Prey Units (PU)	212	2.43	5.32

As noted above, breeding tiger territories in the tropical dry forest of Thailand's Huai Kha Khaeng Wildlife Sanctuary averaged 74km^2 (range 70-78), supported by a prey base of 547 Prey Units (Smith et al. 2011). Based on prey biomass within the core of MPF, the landscape could currently support female home-ranges of between approximately 113 and 247km^2 (upper and lower 95 percent Confidence Interval (CI)) i.e. the area required to support a minimum of 600 Prey Units). This is larger than the documented home ranges of a female tiger in any seasonally dry forest ecosystem in Asia but smaller than the 400km^2 or larger recorded in the ecologically highly dissimilar Russian Far East.

At this female territory size, the 460km^2 inner core of the 1,700km^2 core area for the MPF would be able to support between 1.9 and 4 breeding female tigers.

For the purposes of this feasibility study, the authors agreed that a key pre-condition for tiger restoration in the EPL is sufficient ungulate prey to support female territories of <70km^2. This is similar to documented territory size in Huai Kha Khaeng Wildlife Sanctuary (Smith et al. 2011).

At such female territory sizes, the 460km^2 inner-core of MPF could support approximately six breeding female tigers and an overall population, including males and transients, of approximately 10 individuals (approximately 2.2 individuals per 100km^2). This is similar to the founder population recommended below, that is, six females and two males (See Section 6).

Based on estimates of tiger prey requirements, such a population would require an increase in ungulate biomass of between 30 percent (upper 95 percent CI estimate) and 90 percent (lower 95 percent CI estimate).

At the intrinsic annual growth rate of large ungulates (estimated at approximately 0.3[11]; Steinmetz et al. 2010) such population increases are biologically feasible within one to three years. However, for such ungulate population growth to occur, levels of effective law enforcement and habitat protection within the core of MPF would need to be significantly strengthened.

Biannual robust distance-based line transect sampling of ungulate populations across the EPL (approximate biannual cost USD 50,000) is essential to measure ungulate densities which are a key prerequisite for reintroducing tigers into the EPL.

Based on the above ecologically realistic potential tiger densities within the landscape (i.e. 2.2 individuals per 100km^2), the core areas of the three principal protected areas of the EPL (MPF, PPWS, SPF) could support almost 90 tigers (Table 2). Assuming a lower carrying capacity (1.0 individual per 100km^2) in SPF and PPWS, due to lower current prey densities (O'Kelly and Nut 2010, Gray et al. 2011) and more representation of semi-evergreen and evergreen forest which intrinsically support lower tiger densities (Wikramanayake et al. 2011), the cores of these protected areas could support an estimated 60 tigers.

[11] An intrinsic annual growth rate of 0.3 equates to a 30% annual population increase.

Given annual tiger population growth rates of 10-15% (see Section 6 Population Viability Analysis) a founder population of eight individual tigers could reach 90 individuals within 18 to 25 years. Additional increases in prey density (above the 30-90% necessary to support 2.2 tigers per $100km^2$) in the inner-core of MPF are likely given strong enforcement in this area thus increasing the carrying capacity for tigers to at least 4.0 individuals per $100km^2$.

Table 2. Potential tiger numbers in core/strictly protected areas of Eastern Plains Landscape Protected Areas/Protected Forests

Protected Area	**Size of 'core' (km2)**	**Approx. tiger population at density 2.2 per 100km2**	**Approx. tiger population at density 1.0 per 100km2 in PPWS and SPF**
MPF	1700	37	37
PPWS	800	18	8
SPF	1550	34	16
Total	**4,050**	**89**	**61**

Assuming tiger-friendly land management across the entire protected area complex of the EPL, with prey densities sufficient to support between 0.5 and 1.0 tigers per $100km^2$ away from the core areas of MPF, PPWS and SPF, the landscape could support approximately 180 tigers (Table 3). From a founder population of 8 individuals this population size could be reached in 33 years (assuming 10% annual population increase).

Table 3. Potential tiger population sizes in protected areas of the Eastern Plains Landscape by 2050 (assuming translocation by 2017 of a minimum of 8 individuals and tiger-friendly landscape management leading to increases in prey densities approximately threefold across the landscape and strong enforcement to prevent poaching).

Protected Area	**Size (km2)**	**Potential tiger density (individuals per 100km2)**	**Potential tiger population***
MPF – inner core	460	4	19
MPF – rest of core	1230	2.2	27
MPF – buffer	2400	1	24
SPF – core	1550	2.2	34
SPF - buffer	1440	1	14
PPWS - core	800	2.2	18
PPWS – buffer	1400	1	14
O Yadao PF	1010	1	12
Lumphat WS	2510	0.5	5
Yok Don NP, Vietnam	1150	0.5	13
Total	**-**	**-**	**180**

* Population growth rates come, as stated, from minimum growth rates from the Population Viability Analysis that do include some loss due to poaching/emigration (on top of 'natural' mortality).

Section 6. Population Viability Analysis (PVA): Founder Population Requirements Necessary for Population Persistence

Population Viability Analysis (PVA) is an analytical tool for identifying the threats faced by a species and evaluating the likelihood that a species' population will persist for a given period into the future. A PVA was conducted on potential tiger founder populations in the EPL. Results predict the mean population size and probability of tiger population persistence in 25 years, based on 500 iterations in the VORTEX (Lacy 1993; Ver. 9.96), using demographic parameters obtained from studies across tiger range countries and under various founder population scenarios and threat perceptions. The models assume there are sufficient prey to support a tiger population of a maximum of 30 individuals; a population of 30 tigers would require prey densities to be at least double current levels.

The PVA indicates that with a founder population of between four and six individuals (that is, three females and one male initially and then supplemented by two additional individuals within a few years), any population loss, from poaching or emigration away from the breeding population, above natural mortality (set in the model as 10 percent per year for adults; 50 percent per year for cubs under one year of age) leads to a mean probability of population survival of 74 percent, an unacceptably low probability of population persistence over 25 years. This highlights that, when starting from such a small founder population, no losses in tiger population can be tolerated. However, in reality, it is almost impossible to ensure no tiger losses from the breeding population.

Therefore, a larger founder population of a minimum of eight individuals—six females and two males—is recommended. Even with population loss, to poaching or emigration of one individual every three years, such a founder population would have a 93 percent probability of persistence over 25 years. With supplementation of one male and one female every three years for the first nine years (an additional six tigers), probability of population persistence increases to 99 percent.[12]

Section 7. Enabling Conditions and Obstacles

Some conditions necessary for successful tiger restoration are currently below the level deemed adequate. The following were identified as pre-conditions that need to be met to ensure a high probability of success in a restoration programme.

Habitat Protection and Law Enforcement

If tigers are to recover, it is critical to have high levels of protection and law enforcement in the restoration area. A representative from the Forestry Administration is responsible for managing enforcement activities in MPF. Substantial technical and financial support has been provided by WWF to both PPWS and MPF since 2001 and 2004, respectively.

At present, habitat protection in MPF is under-resourced for the size of area to be protected. There are six ranger stations and two sub-stations in MPF. The MPF enforcement team comprises six patrol teams based out of these ranger stations. All patrol rangers follow a monthly patrolling schedule of 16 days and 10 nights. Each ranger team conducts four patrols per month, two patrols lasting five days, and two lasting three days. In addition, each team spends seven days stationed at their outpost. This system works well in practice, but the MPF team is hindered by an inadequate number of staff to address the scale of illegal activities, including illegal logging and poaching, that continue to take place within MPF.

As of mid-2012, the team had 14 rangers, but is now down to seven[13], consisting of representatives from local communities, the Provincial Police and the Forestry Administration. Under ideal conditions, it would be expected to have at least 48 rangers in a protected area of this size. This is reflected in the draft CTAP (2012), which suggested that at least 50 rangers would be needed for the Core Zone alone to ensure sufficient protection for tigers.

In March 2009, a Mobile Enforcement Unit (MEU) was established to control illegal activities outside

[12] The need to supplement the population with additional individuals over time must also be assessed for ensuring genetic viability of the population.
[13] This lower number is expected to be temporary.

the protected areas across Mondulkiri Province. Since January 2011, the MEU has been made up of a joint team of two Forestry Administration staff and two Provincial Police staff. The MEU is responsible for monitoring international border transit points, checking restaurants and local district markets for illegal wildlife, and gathering intelligence on wildlife and forest crime. It is also highly effective in responding to tip-offs of illegal wildlife trade and logging activities within the province.

The MPF patrol team conducts a monthly patrol planning meeting. Information from different sources is used for planning patrols, including reviewing patrol management blocks, previous patrol routes, etc., to ensure the entire protected forest has been patrolled over a given period of time. Under a parallel initiative, a number of public informants, most of whom are former wildlife traders or hunters, who live in villages around the forest and in the nearest towns, provide information on illegal forest activities. In 2012 the informant network was supported by 10 people actively providing regular information on illegal wildlife and timber trade. However, based on a strategic assessment of the distribution of communities across the landscape, 18-20 people would provide better coverage (WWF-Cambodia 2012).

Law Enforcement Monitoring

Within MPF, the Monitoring Information SysTem (MIST) is used to plan and evaluate patrolling (Stokes 2010). The primary function of MIST is to measure the patrol effort and effectiveness of rangers. It has a secondary function of monitoring the key species and threats to their survival. Using MIST in MPF involves dividing the protected forest into six management zones, and, in turn, each management zone is divided into patrol blocks (5km x 5km). A team of enforcement rangers monitors each of these management zones. While on patrol, rangers record the route, location, details of threats encountered and any species sightings. GPS data and descriptive information collected by rangers are entered into the MIST database to produce a report on patrol effort and patrol coverage.

Wildlife Crime Database (WCD)

The Forestry Law of Cambodia provides for three types of legal action against those who commit forest and wildlife offences: written warnings, fines and court hearings. The law also suggests that stronger legal action be applied to repeat offenders. However, records held by Forestry Administration have traditionally not been maintained in a manner that allows tracking of the legal actions taken against forest and wildlife crime offenders. To address this issue, a Wildlife Crime Database was created by the Foresty Administration in 2011 to manage information on legal action against criminal offenders in Mondulkiri Province.

Informant Monitoring Tool (IMT)

This tool is designed to store information gathered by informants and to track how effectively information is used to tackle forest and wildlife crime. The tool has details of all informants, their target areas, information received from them and incentives provided to them. This information is sensitive and therefore is not shared widely, however in the future some data will be entered into the regional database managed by TRAFFIC.

Other Monitoring Tools

In addition to the monitoring systems described above, two other databases are maintained, one to record vehicle checks, and another of photographs and camera-trap images.

Future Needs and Challenges

There is a clear need for more, and better trained, boots on ground. In MPF alone, ranger numbers dropped from 30 in 2007 to the current amount of seven; who cover an area of almost 3,700km^2. With so few field rangers it is difficult to monitor each and every forest management block all the time; this situation is significantly undermining the ability to provide effective enforcement.

While rangers receive on-the-job training, a standardized training course is not required to qualify as a ranger which means the level of training and the level of commitment of rangers are variable. This is compounded by regular staff turnover. Difficulties with retaining trained staff in the landscape are present for several reasons, including, government permissions required to place Forestry Administration and police staff in forest areas in Mondulkiri, willingness of government staff to be located in the provinces and low financial benefits.

It is also clear the level of detection of illegal activity inside MPF is low, as evinced by the number of illegal cases encountered by the MEU both inside and on the outskirts of MPF. Even if people are detained, successful prosecution rates are low. The law itself, plus its weak application, does not offer the possibility of imposing strong sanctions on law breakers. Therefore there is little to no deterrent for those who choose to poach wildlife or cut timber illegally (WWF-Cambodia 2012).

Apart from the rangers whose remit is forest protection, military police and army are stationed along the border with Vietnam. An agreement has been reached with these groups to support the enforcement effort, particularly in controlling the illegal trade with Vietnam, but there is little evidence that joint actions are undertaken or that cross-border trade has been addressed.

In order to achieve the optimal enforcement level in MPF, the Royal Government of Cambodia needs to allocate an adequate number of protection staff, strengthen the trans-boundary collaboration with government agencies in Vietnam and amend the existing penalties of the current Forestry Law with regard to tiger-related offences.

Governance

Clearly defined roles and responsibilities for government agencies and partners will be critical for a successful tiger restoration programme. MPF was created by Prime Ministerial sub-decree 75 ANK-BK of The Royal Government of Cambodia on July 30, 2002 with the aim of protecting genetic resources and wildlife conservation. Its management falls under the Ministry of Agriculture, Forestry and Fisheries, specifically under the Forestry Administration's Department of Wildlife and Biodiversity (DWB). The management structure for Protected Forests under the Forestry Administration and DWB is not yet approved; therefore the role and reporting responsibilities between the assigned manager of MPF and provincial and national departments can be unclear, resulting in the loss of management authority by DWB.

A Management Plan for MPF (2008-2012) was developed in October 2007 but is still awaiting formal government approval. The result of this five year delay is that neither the boundaries nor the proposed zones within the forest (i.e. strictly protected or core zone, regulated use zone, community use zone or ecotourism zone) are adequately recognized or properly enforced. This makes controlling the movement of local communities, as well as economic and social concessions, very difficult. Approval of the management plan, which is now likely to require updating, is a top priority before a tiger restoration programme can begin.

Outside the core zone but within the protected forest, there is scope under Cambodian law for the development of Community Conservation Forests (CCFs) under Community Forests (CFs). Management responsibility for these falls to the communities who also patrol to prevent any illegal activity. As of mid-2012, no CCFs have been approved in MPF, but three are going through the approval process. Nationally, the Government has committed to approve 150 CFs in 2013 (TWG-JMI)[14].

Cambodia's draft CTAP (2012) must also receive formal approval from the government.

Transboundary Cooperation

MPF in Cambodia and YDNP in Vietnam share a long common border. This means there is a strong possibility tigers and tiger prey in MPF will, at some stage, cross into Vietnam. It is highly beneficial that the same levels of protection, as well as commitment to maintaining tiger numbers, exist in Vietnam as will be required in Cambodia. YDNP is smaller than MPF with an area of 1,155km^2. Park officials report that tigers are still present; but unless strong, peer-reviewed evidence of this is forthcoming, it should be viewed as highly unlikely that tigers persist in YDNP, and that the species is extinct within the landscape.

There has been limited collaboration between MPF and YDNP. Discussions have taken place between MPF rangers, border police, Forestry Administration Cantonment and the provincial Deputy Governor of Mondulkiri on strengthening border cooperation, and a coordination meeting was organized on 16 August 2011. Recent plans for a delegation from YDNP to visit MPF were cancelled. However, a MoU was signed

[14] Technical Working Group – Joint Monitoring Indicators: The JMIs for Forest and Environment have been approved and should be publically released shortly.

between Forestry Administration of Cambodia and Forest Protection Department of Vietnam. These early, modest steps may provide a platform to build on. Within Vietnam's National Tiger Recovery Priorities, there is a pledge to, "Initiate dialogue with Laos and Cambodia on the establishment of transboundary tiger sanctuaries specifically Yok Don, Mondulkiri Protected Forest, Bu Gia Map, Seima Biodiversity Conservation Area, Chu Mom Ray, Virachay, and Dong Ampham." (GTRP 2010). Moreover, among Vietnam's priorities in 2012 to 2013 is to conduct a detailed assessment of YDNP and another protected areas to select a site for tiger restoration (GTI Secretariat 2012).

Although there are eight police outposts on the border with Vietnam and the adjacent YDNP, the open forest habitat makes it difficult to control illegal activities. The open porous vegetation, which does not provide much of a natural boundary makes human access easier. Enforcement teams have confiscated more than 1,000m^3 of luxury timber (*Dalbergia bariensis*, *Pterocarpus indicus*, and *Afzelia xylocarpa*) since 2010 in Mondulkiri Province (WWF-Cambodia 2012, Forestry Administration Cantonment Mondulkiri pers. com.). A better understanding of wildlife and timber trade dynamics is needed for long-term biodiversity conservation in MPF; in the short-term there is a simple need for a greater on-the-ground law enforcement presence and better intelligence gathering.

Habitat Integrity

With increased accessibility to the EPL and the increased presence of large-scale agro-industrial plantations, mining explorations and other economic development concessions, large expanses of habitat have been converted (though mostly outside protected areas). The prevalence of plantations across the landscape seriously threatens the landscape integrity in the longer term, if it is not actively managed and planned with protected area connectivity in mind. Despite increased pressure, large connected expanses of natural habitat remain. The land changes taking place will need to be planned to maintain connectivity between remaining forest expanses by keeping conversion activities outside protected areas and identified corridors.

Community Outreach

Tigers are top predators and promoting their recovery in an area where people live and rear livestock will involve careful handling and require full community support. Approximately 25,000 people live on or close to the borders of MPF. Many of these are ethnic Bunong people with historical ties to the land. There is also a growing influx of people from other parts of the country, coupled with high levels of land speculation and investment in land conversion (for rubber and cassava plantations), often by non-Cambodian companies. To date there has been little direct engagement with the in-coming migrants or with the plantation companies even though these will be key shareholders in moving forward.

WWF has worked closely with many communities surrounding MPF, giving support to development of CCFs, alternative livelihoods and sustainable use of non-timber forest products (NTFPs). The Forestry Administration also works with communities to support these enterprises.

There is little human-wildlife conflict at present—but this may change if tiger numbers recover. It will take considerable effort to change currently negative attitudes toward tigers to positive ones. Carter et al. (2012) suggest that education highlighting potential benefits such as ecotourism revenue may be key to overcoming negative perceptions.

Facilities and Veterinary Capacity

The MPF is the ideal location for the centre point of the restoration programme but does not have the facilities immediately available for either a hard release or soft release of introduced animals such as animal pens or veterinary services. The necessary facilities would need to be identified in the full recovery operational plan.

It is important a wildlife veterinarian be available to the resoration programme to ensure the health of translocated tigers is maintained and that any capture–release activities are done in a way to minimize stress for the animals involved. There is some veterinary expertise at Phnom Tamao Zoological Garden and Wildlife Rescue Centre; this facility is supported by Wildlife Alliance to care for animals rescued from the wildlife trade. Forestry Administration staff have been trained in animal care including handling and basic veterinarian skills, and there is a laboratory facility at the Centre. Centre staff has undertaken soft-release of small animals (leopard cats *Prionailurus bengalensis*, macaques *Macaca*) and a gibbon *Nomascus* and *Hylobates* rehabilitation and release programme is on-going.

Commitment

The Royal Government of Cambodia must be fully committed to the programme at the highest levels. To be successful, the restoration programme will need strong governance and leadership so all partners are committed from the beginning to ensuring poaching and land conversion threats will be mitigated, the plan is strictly adhered to and the programme is sustained well beyond the initial restoration stages.

A long-term commitment of sufficient funding for the restoration programme is also essential.

Key Actions Needed

- Working towards the declaration of the Core Zone of MPF as an inviolate Tiger Recovery Core Zone by the Royal Government of Cambodia.
- MAFF and FA approval of a MPF management plan.
- Physical demarcation of MPF boundaries to support actions to address the issues of land conversion, both formal and informal.
- Regular inspections of vehicles coming into and out of MPF to increase detection and apprehension of poachers.
- Creation of disincentives for poachers and illegal loggers by increasing the conviction rate of offenders.
- Working with Yok Don National Park authorities to control illegal timber trade.
- Working with border security forces along the MPF–Yok Don/Vietnam border.
- Increasing MPF ranger force to at least 48 rangers (eight for each management zone) for more effective monitoring and patrolling.
- Taining rangers on intelligence gathering, filing court cases and crime scene investigation.
- Developing informant networks around crucial trade points such as Busra, Keo Seima, Dak Dam, Kohnheak and Lumphat.

As pre-conditions are being met, preparation of a detailed action plan for restoration can begin. Plans in development to reintroduce tigers to Kazakhstan (see below) could provide input, as could experience from the reintroduction of tigers to India’s Panna Tiger Reserve (Appendix 1).

Section 8. Sourcing Tigers for Restoration in Cambodia

This study concludes that it is important to recover wild tigers in Cambodia and feasible to do so in MPF. There is a good chance of success if certain conditions are met, the most critical being increased protection and wildlife law enforcement. The next question is where tigers for restoration might come from.

Figure 5 shows a decision tree that leads to options for sourcing tigers for translocation into Cambodia. Table 4 details the barriers, benefits, and feasibility of the options at each decision point in the tree.

Table 4. Benefits, barriers, and feasibility of the sourcing options presented in Figure 3.

Sourcing Option	Barriers to this Option	Benefits to this Option	Assessed Feasibility
Viable Wild Population in Cambodia	This is the population to be restored, and a viable population within Cambodia stable enough to source individuals is not present	Translocation of these individuals would be easiest, and would lack the need to coordinate across borders	Not feasible due to the barriers listed
Viable Wild Population in Indochina	Populations of wild Indochinese tiger throughout its range are not stable enough to source tigers from: 1. Lao PDR: population not large enough 2. Viet Nam: population not large enough 3. Western Forest Complex, Thailand: Rebuilding tiger population with current success 4. Myanmar: population not large enough	Translocating wild tigers is preferred to releasing captively bred individuals into the wild	Options are limited as wild population numbers are low elsewhere. Agreements with Thailand for select wild individuals would be the only possibility under this sourcing option
Captive Bred [pure] Indochinese Tiger	More challenging than translocating wild individuals due to the release needs and possible requirement of a breeding program. Individuals must learn how to kill and guard prey. Must not be habituated to humans. Option has its challenges, but has been successfully done	Same subspecies and would provide an opportunity to create the first scientifically managed and accredited captive breeding program for this sub species	Dependent on the availability of pure bred Indochinese tigers in accredited breeding programs
Other Wild Subspecies	One subspecies (the Bengal tiger) has been identified as the most appropriate due to variations in ecotype of the other subspecies (i.e. Amur, Sumatran, Malayan). This option will require collaboration between participating countries	The subspecies identified as appropriate has large potential due to source population size, and willingness of source countries' to support global tiger work. Translocating wild tigers is preferred to habituating captively bred individuals for success in the wild	Dependent on agreements between participating countries and decision regarding subspecies
Other Captive Bred Subspecies	Translocating wild tigers is preferred to habituating captively bred individuals for success in the wild. There may not be enough of one subspecies in captivity to use as a sourcing population	Ecotype may not be an issue as captive individuals may not be habituated to any one type of environment	Dependent on availability of captive source populations and decision regarding subspecies

According to the IUCN SSC reintroduction guidelines (IUCN 2012), a population restoration programme should aim to source animals that are of the same subspecies. In this case, it would be the Indochinese subspecies. However, if none is available, the animals should be sourced from the subspecies closest genetically and geographically. This is the best way to closely match the morphological and genetic adaptations to environmental conditions as well as avoid unanticipated issues that may come with importing animals whose ecotype or adaptations do not match the local environmental conditions. The guidelines also indicate it is desirable to source animals from wild populations. A recent study shows carnivore reintroduction programmes are more successful if wild animals are the source as wild carnivores have higher survival rates in reintroductions than captive-born individuals (Jule et al. 2008).

However, options for wild and captive Indochinese tigers are quite limited. Nearly all remaining wild Indochinese tigers, estimated to be as few as 190-350 individuals, are in western Thailand (Thailand Tiger Action Plan 2010, WWF Greater Mekong Programme 2010). Recovering that population is the immediate conservation goal of Thailand and there is considerable habitat remaining for population growth. Thailand would at best be able to assist a tiger restoration programme in Cambodia. The populations in Laos and Myanmar are too small to consider removing individuals for translocation, and recovering these small populations is a national priority for both countries. There are no known wild Indochinese tiger breeding populations in China or Vietnam and nor is there any serious likelihood that hitherto undiscovered such populations exist.

Turning to captive animals as the next best option, there is no source of Indochinese tigers from scientifically managed zoo populations. There may be a small number of individuals believed to be Indochinese tigers scattered among zoos in Southeast Asia (see Appendix 2). If a small group of founders could be assembled, a large enough source population needs to be built and maintained first. Several breeding pairs reliably producing cubs are needed before releasing any for population restoration. At the earliest, cubs from the first mating could be kept with the prospect of releasing a few individuals from their litter, which would have been reared in habitat enclosures (See Appendix 2 for a detailed discussion).

Assembling pure-bred Indochinese stock and organizing the necessary consent and logistics would take a significant amount of time, which would then necessarily be followed by some years of captive management. Ultimately, the time frame depends on the numbers and ages and genetic relatedness of the source population. With those data in hand, modelling could better inform a breeding and release plan. If restoration is postponed for the time likely needed[15], the window of opportunity for restoration in the EPL will probably close as the site needs an earlier investment to secure against growing threats. Additionally, it would be hard to justify such a large-scale investment over a long time period before restoration can even begin.

Despite the barriers for breeding captive-born Indochinese individuals for restoration, a programme for managed captive breeding should be seriously considered for this subspecies. One does not yet exist even though they do for other subspecies.

The next sourcing options are from populations of wild tigers of a different subspecies, specifically from Malaysia (Malayan tiger *P. t. jacksoni*) or India and Nepal (Bengal tiger *P. t. tigris*). Although Malayan tigers are genetically closer, they are adapted to rainforest whereas many populations of Bengal tigers are adapted to dry forest habitats like those of the EPL and hunt a similar prey assemblage. If the respective governments agree to provide tigers for restoration, the best match would be tigers from India and/or Nepal. Orphaned tigers or those removed from the wild could provide the founder population needed. (See Appendix 1, which describes the successful reintroduction of orphaned tigers to Panna Tiger Reserve in India.). This is a unique situation that warrants further discussion on subspecies issues (see below).

Sourcing tigers for restoration in Cambodia from scientifically managed captive breeding programmes in India, Nepal, Malaysia, or the United States is considered a far more expensive and time-consuming effort and less likely to be successful than sourcing wild tigers from India or Nepal.

[15] Wild to wild translocation may also take a significant amount of time depending on determining factors.

The Subspecies Issue

Two centuries ago, the tiger had a nearly contiguous distribution that extended from the Russian Far East and Korea, through eastern and southern China, the Indian Subcontinent and southeast Asia into the Indus River Valley in Pakistan, with disjunct populations living around the southern reaches of the Caspian Sea and associated river valleys and on the Indonesian islands of Sumatra, Java and Bali. Today the distribution covers, as widely quoted, less than 10% of this historic distribution (Walston et a. 2010).

Recent genetic studies provide strong evidence for the classification of tiger into six extant taxonomic units or subspecies:

1. Bengal tiger *Panthera tigris tigris*
2. South China tiger *P. t. amoyensis*
3. Indochinese tiger *P. t. corbetti*
4. Malayan tiger *P. t. jacksoni*
5. Sumatran tiger *P. t. sumatrae*
6. Amur tiger *P. t. altaica* [recent genetic studies indicate this is the same subspecies as 'Caspian tiger' and thus the name *P. t. virgata* has nomencultural precedence for this form; Driscoll et al. 2009].

Luo et al. (2004), in a paper co-authored by many of the major figures in tiger conservation and genetics, demonstrated that these six subspecies are clearly differentiated on the basis of three separate genetic markers, including nuclear-DNA. The classification was based on advanced genetic analysis of 134 voucher specimens from known geographic locations. The authors concluded that a combination of population expansions, reduced gene flow, and genetic drift following the last genetic diminution led to the distinct genetic partitions observed. However overall population genetic variation within tiger is relatively small when compared to other cat species such as leopard *P. pardus*, Geoffroy's cat *Oncifelis geoffroyi*, Pampas cat *O. colocolo*, or tigrina *Leopardus tigrinus*; Luo et al. 2004).

The exact historical distribution of Indochinese tiger, and the boundaries between the subspecies and South China and Bengal tiger, are unclear. However Indochinese tiger was unquestionably the form which historically occurred within the deciduous dipterocarp forests of the lower Mekong. The historical barrier to dispersal between Indochinese and Malayan tiger is hypothesized to be the Isthmus of Kra, the narrow land bridge that connects the Malay Peninsula and mainland Asia (Luo et al. 2010). This barrier is widely recognized within biogeography and represents the boundary between predominantly Sundaic and mainland South-east Asian flora and fauna.

Genetic studies have indicated that Indochinese tiger was the most genetically diverse subspecies although the majority of this genetic diversity is likely to have already been lost (Luo et al. 2004). Phylogenetic relationships also suggest that both Malayan and 'Amur' tigers diverged from Indochinese tigers some time prior to 10,000 – 12,000 years ago (Luo et al. 2010, Driscoll 2011). These two subspecies remain the closest genetically to Indochinese with nuclear markers placing Malayan and Indochinese tigers marginally closer to each other.

It is therefore valid, under the standards of traditional vertebrate taxonomy, to separate tiger into six extant subspecies i.e. groups of actually or potentially interbreeding populations phylogenetically distinguishable from, but reproductively compatible with, other such groups and which have unique geographical ranges, a number of phylogenetically concordant characters and specific evolutionary and natural histories (Avise 1990, O'Brien and Mayr 1991).

Whilst earlier studies, based largely on morphological traits and the perceived lack of barriers to genetic dispersal, concluded that mainland tigers were not different subspecies and merely showed continuous variation across their range (e.g. Kitchener and Dugmore 2000, Mazak 2010) this approach is now no longer widely supported. Based on the genetic studies detailed above the IUCN, and the majority of the global tiger conservation community, acknowledge six extant subspecies of tiger and recommend that they are managed as evolutionary signification units for conservation (Luo et al. 2008, Luo et al. 2010).

Therefore any tigers reintroduced into the Eastern Plains of Cambodia should, ideally, be pure Indochinese tiger. However as highlighted in table 4 and section 8 (above) we believe there is neither:

a) a wild population of Indochinese tiger from which individuals could be removed without comprising the conservation value of the source population.

or

b) Enough individuals of pure Indochinese tiger within appropriately managed or accredited zoos or facilities to establish a founder population.

We therefore conclude that sourcing individuals of a different subspecies is considered to be acceptable in this case. We suggest that the importance of establishing a robust population in Cambodia outweighs the extremely remote risk of mixing with wild individuals of the Indochinese subspecies in Thailand, Laos and, the unlikely remaining, individuals in Cambodia or Vietnam.

Genetic differences, although real, are unlikely to compromise the success of a reintroduction project. From a pragmatic point of view, the choice appears to be stark: if a source of Indochinese tigers are not available, either restore wild tigers to the EPL through translocation of Malayan or Bengal tigers and contribute to global tiger recovery and to protecting this unique landscape; or face a Cambodia with no wild tigers and, probably, vanishing habitat in a heavily degraded landscape.

Other Proposed Tiger Restoration Programmes

Although Caspian tigers are extinct, analysis of genetic material harvested from museum specimens show no significant genetic differences between the Amur and Caspian tigers. Driscoll et al. (2012) thus argue that Amur tigers could be reintroduced to the former range of the Caspian tiger. The science-based management of captive Amur tigers is strong (Traylor-Holzer 2010) and the captive-managed population of Amur tigers has more genetic diversity today than the wild population has (Russello et al. 2004), offering a ready source of founders for a reintroduction. The Government of Kazakhstan intends to reintroduce Amur tigers, has designated a site in the Caspian region and, with support from WWF, are preparing a full-scale project proposal (Jungius, 2010; Global Tiger Initiative Secretariat 2012).

There are no known wild South China tigers. A small scientifically managed captive population is purported to be the South China subspecies but genetic analysis of that population revealed they are admixed (Luo et al. 2010). There are about 10 “rewilded” “South China tigers” in South Africa. While this rewilding programme has been highly controversial on several grounds, it has provided another example[16] where captive-born (in this case both young and older adult tigers) have been shown what and how to hunt to a point where they can survive without human assistance (Sanderson et al. 2011).[17] China has set re-establishing wild tigers in southern China as one of its tiger conservation priority actions (GTRP 2010) and considers the rewilded tigers in South Africa candidates for that programme. China is in the process of establishing a rewilding base (Global Tiger Initiative Secretariat 2012).

Section 9. Conclusion

Restoring tigers to the EPL would make a very significant contribution to tiger conservation and to the conservation of the unique and rich biodiversity of this landscape. This study concludes it is feasible to restore tigers in the EPL with a high probability of success if certain pre-conditions are met, the first being stronger protection so prey numbers can increase sufficiently to support the founders and a then increasing number of tigers. Should the Royal Government of Cambodia commit to undertaking a restoration programme in the EPL, the study recommends that WWF provide support. In order to draw from the best practice models being demonstrated elsewhere, those involved in a tiger restoration programme should seek administrative and technical support from others; such as, from the Government of India where the only translocation of tigers has occurred.

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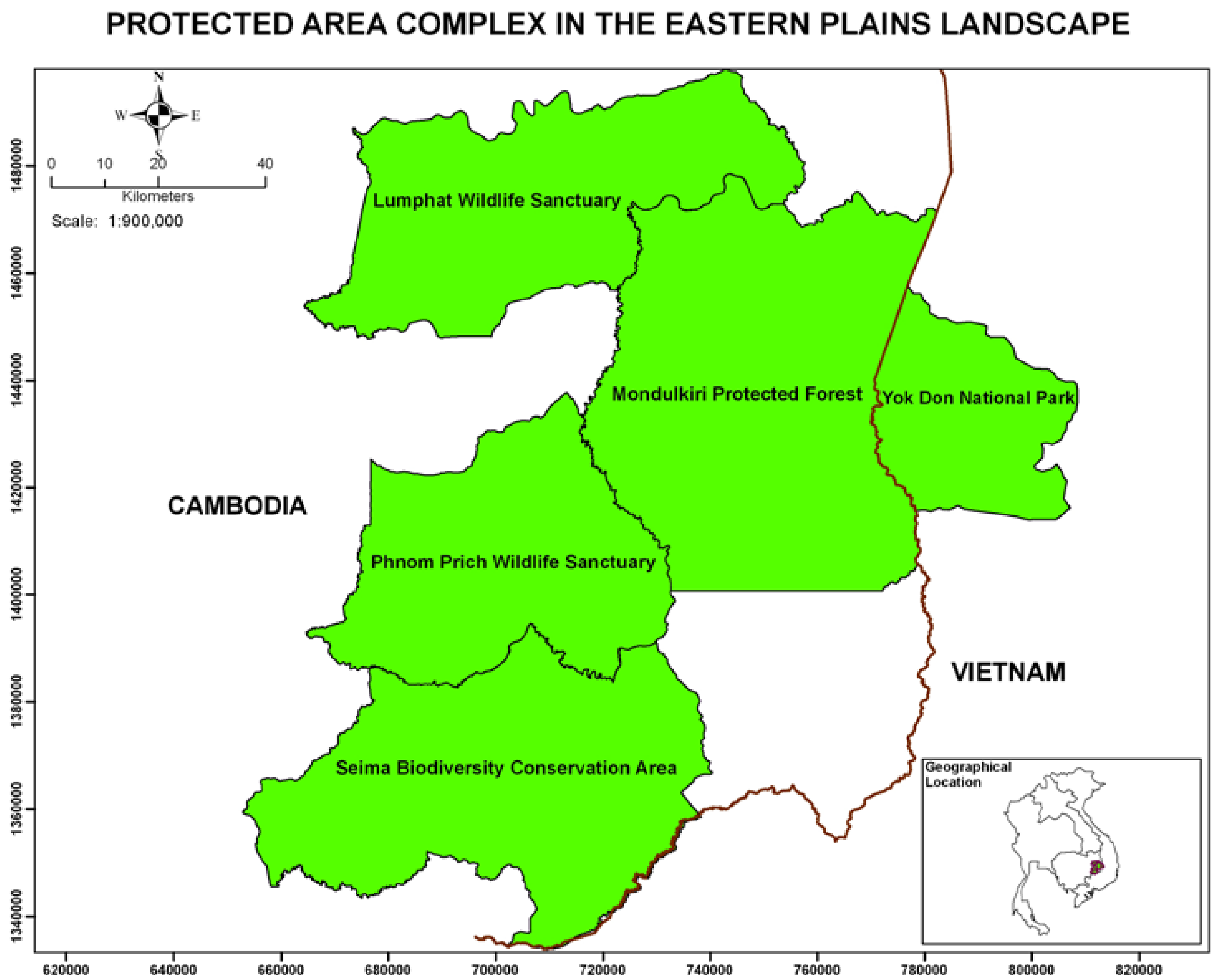
[16] There are several examples of captive-born big cats learning through human assistance to kill prey and survive in the wild. Classic examples include the Florida populations of puma, and more recently, the tigers released in Panna Tiger Reserve in India.
[17] However, there are other related challenges when releasing captive felids into the wild; these include, lacking social behaviors needed for survival in the wild and lacking ability to hunt strategically at a large scale (for instance, being able to tactfully find prey in a given landscape).



Source: WCS/WWF/FA/MoE

Figure 1. Protected Area Complex in the Eastern Plains Landscape (EPL).

Source: WWF Tigers Alive Initiative

Figure 2. Larger Tiger Landscape, inclusive of the Eastern Plains Landscape (EPL).

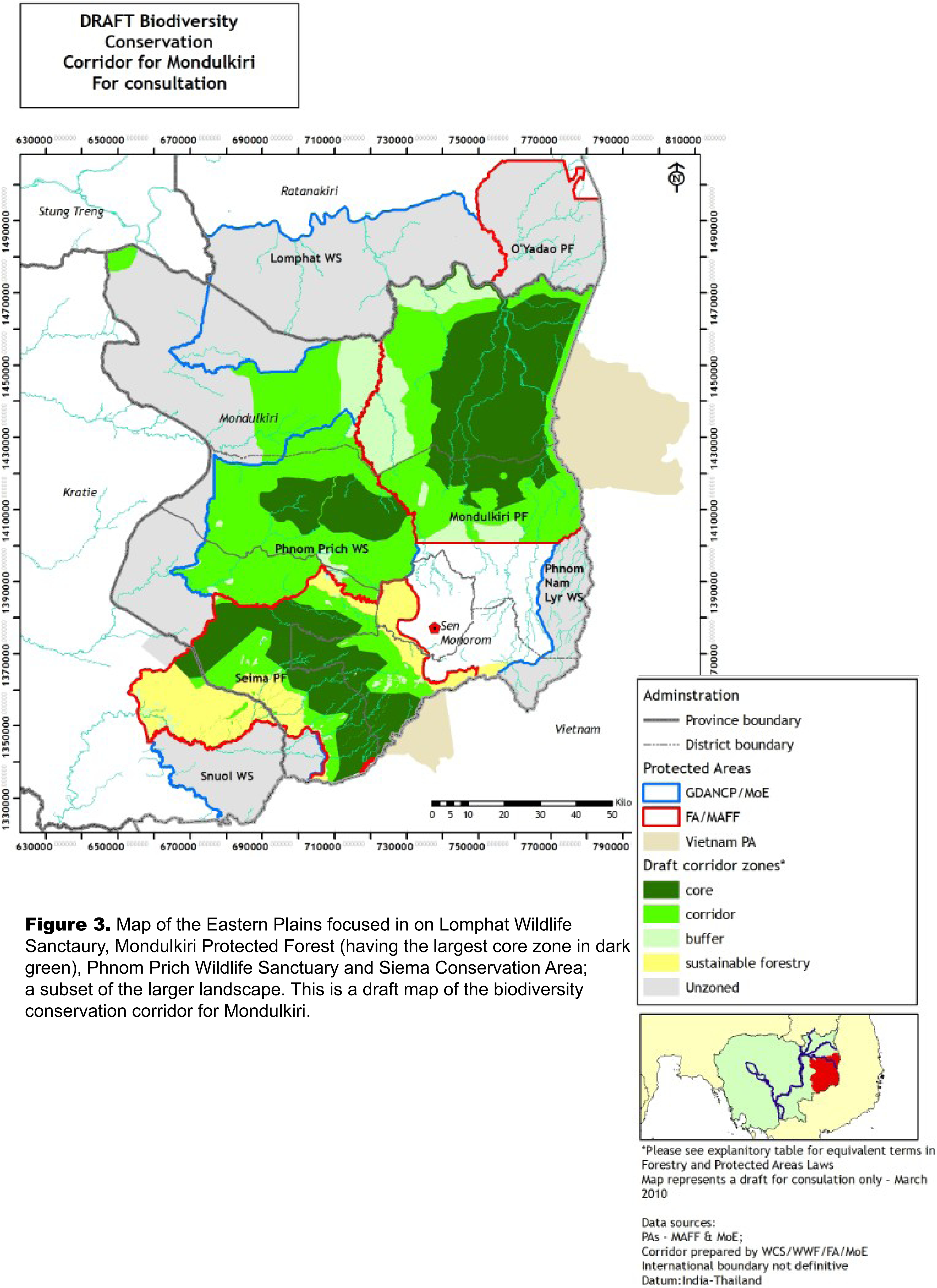
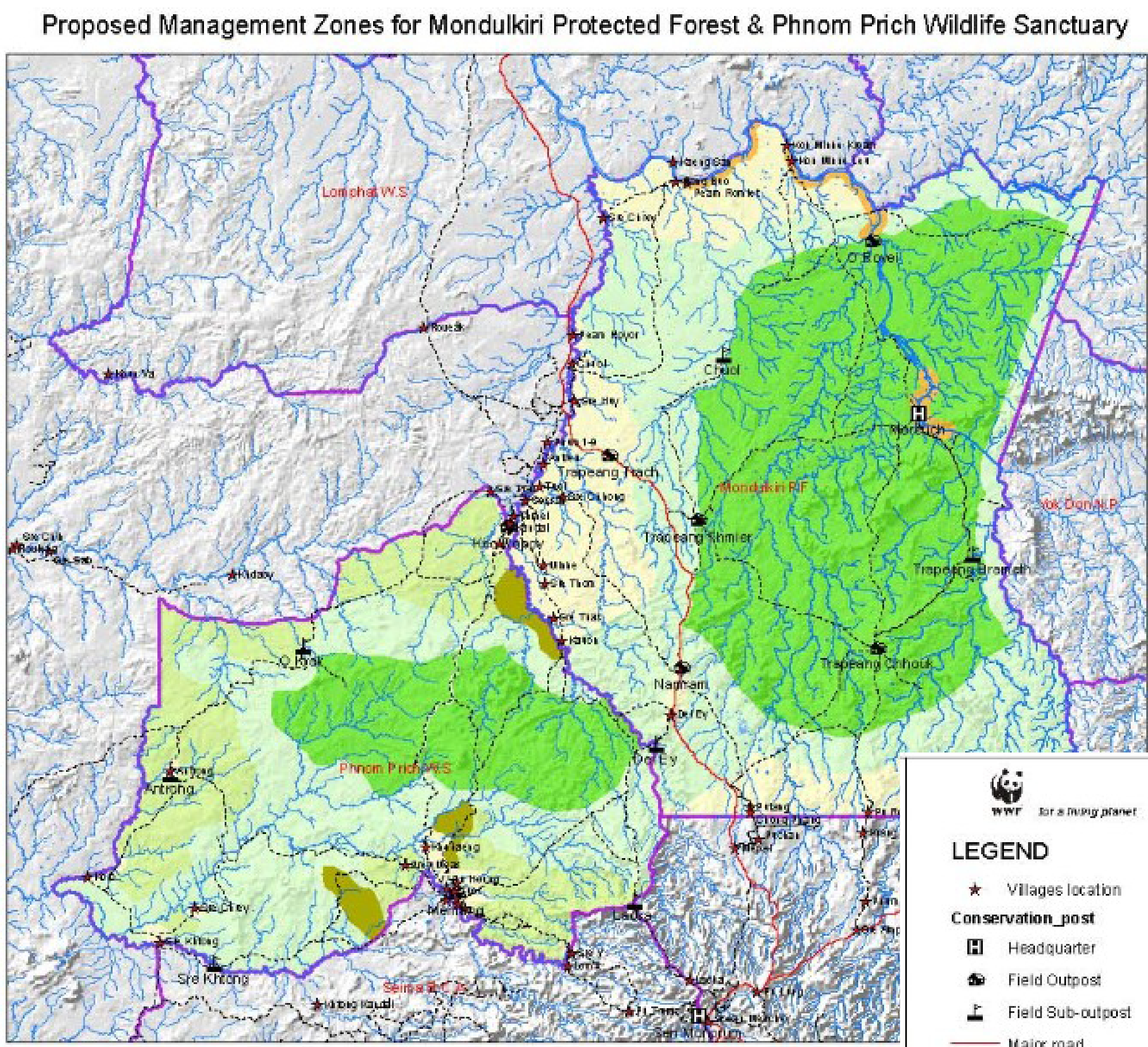


Figure 3. Map of the Eastern Plains focused in on Lomphat Wildlife Sanctaury, Mondulkiri Protected Forest (having the largest core zone in dark green), Phnom Prich Wildlife Sanctuary and Siema Conservation Area; a subset of the larger landscape. This is a draft map of the biodiversity conservation corridor for Mondulkiri.



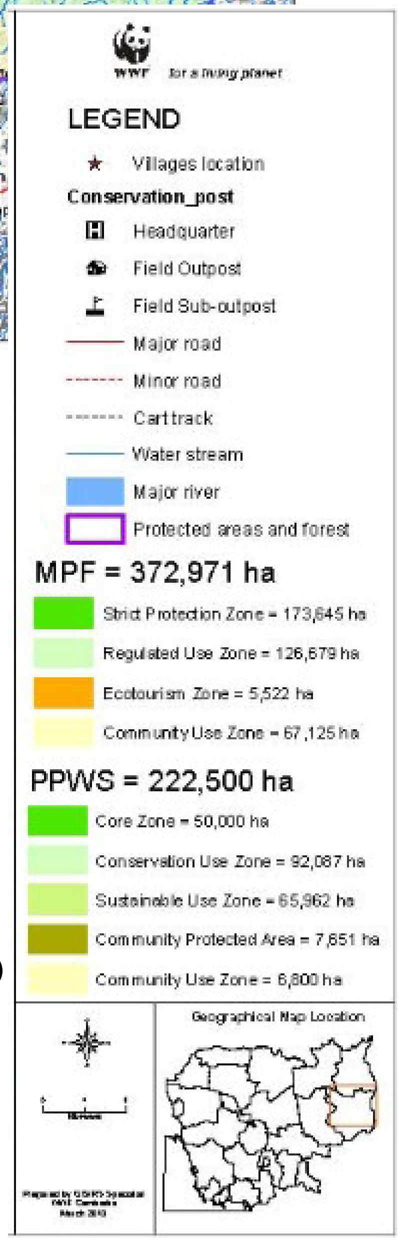


Figure 4. Proposed management zones for Mondulkiri Protected Forest (MPF) and Phnom Prich Wildlife Sanctuary (PPWS).

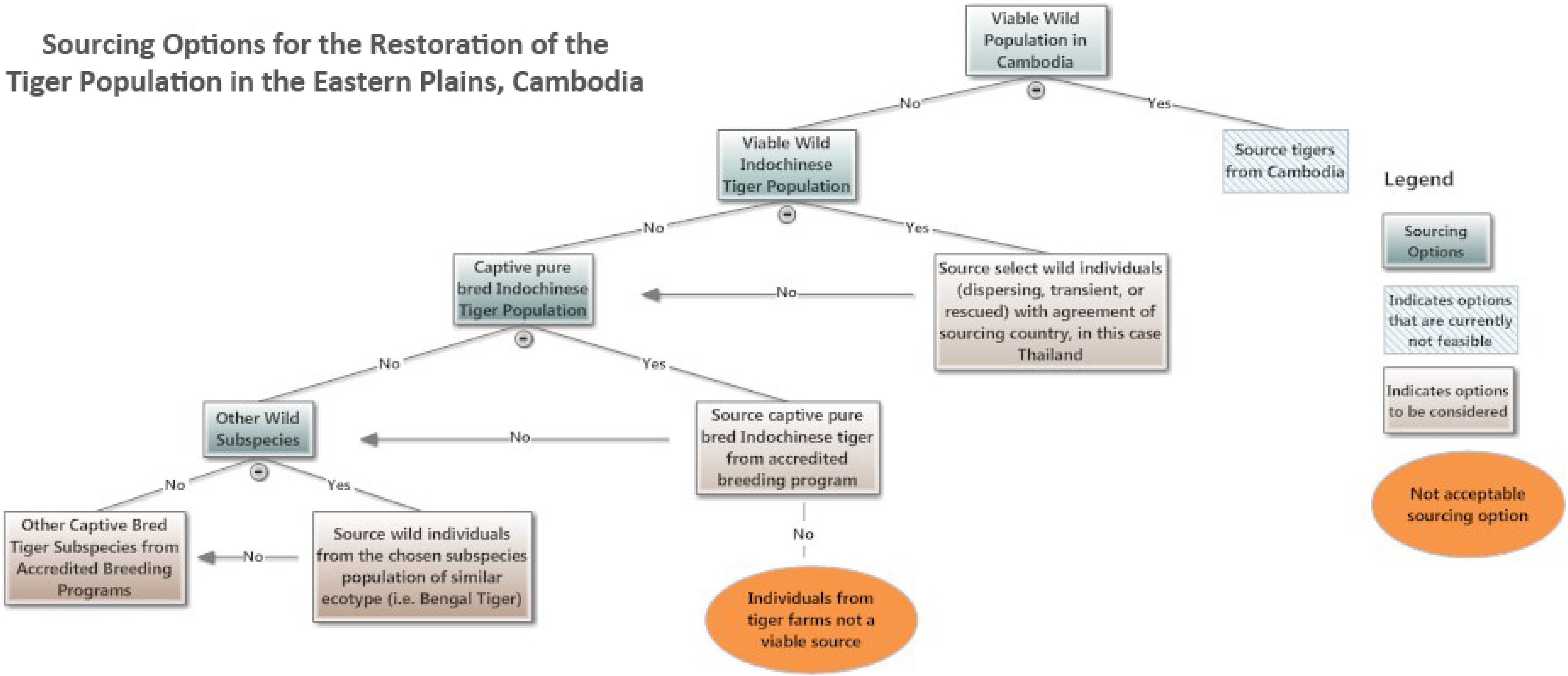


Figure 5. Decision tree for sourcing options for tiger restoration in the Eastern Plains, Cambodia. Table 4 provides a brief explanation for each branch on the above decision tree. See Appendix 2 for a discussion on tiger farming practices.

Appendix 1 - Best Practice Model: Successful Reintroduction of Tiger Population in Panna Tiger Reserve, India

Ramesh Krishnamurthy, Wildlife Institute of India

Background

Restoration and reinforcement of wildlife populations, especially of endangered species such as tigers *Panthera tigris*, are becoming increasingly important management responses (MacKinnon and MacKinnon, 1991; Stuart, 1991) to population declines and local extinctions. These responses generally involve translocation of free-ranging individuals from wild habitats, with due scientific and management processes, and in some cases, reintroduction from captive animals. Miller et al. (1999) outline the biological and technical considerations of carnivore translocation, most of which are reflected in the IUCN Guidelines for Re-introductions (1998) and the Protocol laid down by National Tiger Conservation Authority (NTCA) for Tiger Reintroduction in India.

Panna Tiger Reserve (TR) in the State of Madhya Pradesh in India once had a sizable population of tigers, owing to a large area of habitats that support moderate to high prey density and to the availability of disturbance-free habitats. The reserve is also contiguous on either side with large tracts (more than 1,000 km^2) of protected forests in Panna and Chattarpur districts, offering dispersal and positive sink habitats. Based on a camera-trap study, the tiger population in the reserve was estimated to be 29 in 2002, but the population declined rapidly due to poaching and other anthropogenic causes and was reduced to a single male by late 2008. To reinforce the population, two female tigers were introduced. However, a study by the Wildlife Institute of India (WII) revealed that Panna TR lost all its tigers in early 2009, before the females were introduced, leaving only these two females. Recognising this, a full-fledged reintroduction programme was conceived and implemented with the technical support of Wildlife Institute of India (led by Dr. Ramesh Krishnamurthy) and funding support from NTCA.

Reintroduction Strategy

A team was constituted to implement the overall program, with major responsibilities given to the Field Director of the release site and the WII technical team. A Population Viability Analysis (PVA) modelled the future status of population growth. The reintroduction began with translocation of three tigers in 2009 from three different source populations within the Madhya Pradesh: one female from Bandhavgarh TR, one female from Kanha TR, and one male from Pench TR. These animals were captured in the source sites by chemical immobilization, radio-collared (VHF-GPS), transported by road or helicopter, and were soft-released in Panna. The male, however, strayed out of the reserve for about month and had to be recaptured and hard-released in Panna. Subsequently, all these animals established themselves in the new habitat and both females successfully bred in 2010, indicating the success of the first-ever organized reintroduction effort for tigers in India. The first female produced a litter of four cubs, but only two survived to adulthood. The second female produced a litter of four and all were surviving in mid-2012. Accordingly, the initial population size rose to nine animals: three adults and six cubs. After two years, the first and second females gave birth to second litters of four cubs and three cubs respectively in 2012, which greatly add to the population growth.

Rehabilitation of Orphaned Tigers

Although the original project document envisaged translocation of six tigers (two males and four females) based on the PVA, further releases were delayed in fears that a new individual would risk the lives of the cubs in the population, either by direct confrontation or indirectly by challenging the established animals. At the same time, it was also recognized that the population status, including sex ratio and recent trends in some of the source areas, indicated that surplus animal for sourcing to Panna were not available. However, there were orphaned tigers being raised in semi-wild conditions in Kanha and Bandhavgarh tiger reserves that needed to be rehabilitated. These animals provided an option for the Panna Tiger Reintroduction Programme and, subsequently, the Government approved the translocation of the two female tigers that were managed in Kanha TR to Panna.

Paying due consideration to the elements associated with releasing these animals in Panna, where the reintroduction efforts had already yielded breeding success, this was an experiment with a hope that these ≥ 5.5 years old animals would add to the effective founders in the reintroduction program. One of the females was captured, radio-collared, and transported on 26 March 2011 by road and was hard-released in Panna TR on 27 March 2011. Similarly, another female was translocated to Panna on 13 November 2011. After initial support in the form of live baits, these animals began hunting on wild prey on their own and established themselves in the area. The male interacted with both these animals, the result of which was the birth of two cubs by one of the orphaned tigresses. This marked a new beginning in the way tiger recovery can be conducted. It is expected that the other female would also produce litter soon, since the mating was observed in the month of August 2012.

As of now, the population size in Panna is 18 tigers; 5 adults, 5 sub-adults on the dispersal and 8 cubs. This is easily one of the best tiger recovery programme in the world and it has been achieved with an incremental approach. Rehabilitation of orphaned cubs raised in captivity and semi-wild conditions has been achieved and, significantly, successful breeding of such a female has been witnessed.

Post-Release Monitoring

In line with the NTCA protocol, a project document specific to post-release monitoring was developed, with specific roles for WII and the Field Director of Panna TR. WII is responsible for technical inputs and scientific monitoring. The Field Director has deputed dedicated teams under the guidance of a Coordinator, who is involved in security based monitoring and facilitates daily reporting on the movement status of the introduced tigers to the Field Director. In addition to monitoring, the WII team studies other aspects of tiger ecology and population dynamics, including mortality and reproductive success at various scales. The study also monitors the behaviour of the population as predicted by PVA, in order to offer a scientific assessment of the need for further supplementation. In terms of equipment, all the tigers are monitored by advanced telemetry tools such as satellite collars (Telonics brand) in Argos Platform, supported by ground-based VHF collars during the initial phase. Once the animals settled in, the satellite collars were replaced with VHF units, although GPS-Satellite units would be deployed for dispersing cubs.

The reserve's Security based Tracking Team records information hourly based on a modified home-in method[18] and the WII team records three locations per day based on the triangulation/home-in methods. The information collected includes location of the animal, vocalization, feeding, and interaction with other tigers. Additionally, location data is downloaded from the Argos satellites. The reserve management has constituted exclusive teams for each tiger and, at any given time, at least one team for each tiger will be in the field monitoring the animal around the clock, with appropriate exchanges among them. The WII research team with a dedicated workforce monitors these animals on regular basis, looking into finer details of animal behaviour and movement patterns. The monitoring also included deployment of camera traps and collection of scat samples to understand associated factors. Efforts were made to search the forest to locate kills of all the tigers to understand the food habit and to prevent potential poisoning of the kills made on the boundary and near human habitation. Information flow on a regular basis provides support for making management intervention as and when required.

Concluding Remarks

The success or failure of a reintroduction project hinges on the ability of the translocated animals to cope with the new environment in terms of resource procurement, challenges from other animals, and conflict with humans. All of these lead to physiological stress and mortality in the extreme situations. Therefore, along with protection, the reintroduced animals must be monitored from more than one perspective. In the case of animals from captive origin, the preliminary results have provided pioneering insights into the adaptability, hunting skills, and interactions with other tigers already established in the area. Significantly, the hand-reared and semi-wild tigresses were able to survive on their own by making kills and one has already produced a litter of two cubs, and the other is expected to litter in due course. Determining which age group and genetic structure were more successful in reintroduction after captive experiences would allow for recommendations to improve both in-situ and ex- situ tiger conservation efforts. The Panna experience suggests that animals between the ages of three and five years would best contribute to conservation projects[19]. Given that efforts in Panna have wider implications, any outcome needs to be

[18] Home-in method refers to locating animals using radio-collar and receiver-antenna unit.
[19] This is an observation from this example. It is unknown whether younger or older individuals would have faired better or worse.

interpreted based on careful analysis so as to provide a strong basis for emulating the experience for implementation.

Appendix 2 – Sourcing Tigers from Captive Populations

Sarah Christie, Zoological Society of London

IUCN guidelines for reintroduction (IUCN 1998) state, “If captive or artificially propagated stock is to be used [as the source population], it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.”

To be suitable for reintroduction, a source population should contain high genetic diversity; this should be as representative as possible of that (formerly) found in the wild around the location of intended release; and adaptations to captivity should have been scrupulously avoided as much as is possible. Only tigers in conservation breeding programmes can be considered as candidates for a tiger restoration programme in Cambodia.

At present, there are now many more tigers in human hands than in the wild. Most of these have been held in captivity for many generations, and can be classed in three groups based on how their breeding has been managed over the years.

1. **Tigers in conservation breeding programmes** focused on producing the maximum possible conservation support for their wild relations over the maximum possible period of time (Luo et al. 2008). These programmes involve multiple zoo locations, are managed by regional or global zoo associations, and have the following characteristics:
    a. All tigers in them can be traced back through institutional records to wild-caught founder stock; their ancestry is fully known and recorded.
    b. All tigers in each programme are of the same geographical origin (labeled using sub-specific designations) and therefore contain discrete sets of genetic adaptations to a particular habitat and climate type. Sometimes these populations include wild tigers recently removed from the wild for reasons of conflict resolution, injury, or loss of mother and inability to survive.
    c. Each regional population is managed in order to conserve a gene pool as broadly representative of the original wild population as possible (Luo et al. 2008).

These tiger populations therefore contain a good spread of the genes that might be found in a wild population, contain adaptations suitable to a given habitat type, and are (except where their numbers have been very low for many generations) unlikely to express recessive alleles.

2. **Tigers held by private breeders**, for example, in the Middle East and Texas. These tiger populations have the following general characteristics:
    a. Records kept, if any, are unreliable and confined to a single location.
    b. Ancestry and hence geographical (subspecies) origin are therefore unknown.
    c. There is no central management of the populations and it is therefore impossible to ensure that high levels of gene diversity are retained because;
        i. It is not possible to equalise founder representation.
        ii. Inbreeding may occur deliberately at a given location, or unknowingly because of the lack of central records.
        iii. Inter-birth intervals are likely to be short.

These tigers are therefore likely to be of mixed geographical ancestry and/or to contain relatively low levels of genetic diversity. Selection for tigers that breed well in private hands and for traits of docility and friendliness is highly likely to have occurred; the latter two traits are highly likely to be maladaptive for wild living.

3. **Tigers farmed for profit** in commercial facilities in Asia. Many of these tiger populations have the following characteristics:

    a. Records are likely to be unreliable and are confined to a single location.

    b. Ancestry and hence geographical (subspecies) origin are therefore unknown.

    c. The tigers are actively managed within each farm, which may hold many hundreds of tigers, but not with the aim of conserving genetic diversity. The aim here is to maximise profit via tourist viewing and via clandestine sale of bones and other parts. Tiger farms interests are not in tiger conservation, and they have been supplying products to the illegal market in tiger trade (Gratwicke et al. 2007) To save money, the cubs are often hand-reared or reared on pigs and then housed in large groups of same-age youngsters for maximum tourist entertainment at minimum cost. By the time they are four years old, they are fighting, but they have also reached maximum size and so there is little point in further investment in feeding and housing them; apart from the breeding stock, tigers aged over four years old are nowhere to be seen in a tiger farm, despite the vast numbers of cubs produced[20].

        i. There is no attempt to equalise founder representation, instead tigers that do well in the highly unnatural social groups described above, and that produce high yields of bone, are likely to be actively selected for.

        ii. There are likely to have been many inbreeding events in the ancestry of any tiger, although some farms now claim not to be inbreeding.

        iii. Inter-birth intervals are likely to be *extremely* short; the hand-rearing process means that it is possible to produce several litters a year from a single female if desired.

These tigers are therefore likely to be of mixed geographical ancestry and the populations have become adapted to the farming conditions of hand-rearing and unnatural social groups; their gene pool rapidly narrows and they are essentially in the process of becoming domesticated. The genetic management regime for conservation breeding programmes is in fact the exact opposite of that for farming purposes.

There has been a tendency to focus strongly on the mixed subspecies ancestry of farmed tigers as a major reason for not sourcing animals from these populations, but in fact this is less important than the strong selection for adaptations to captivity that are consequences of the type of breeding management used. For many potential population restoration sites, a population of mixed geographic origin but with high allelic diversity and without adaptation to captive or farming conditions would actually be preferable as a source to one that was originally of a single geographic origin but had been managed over generations for farming, because it would contain more capability to adapt to the wild habitat involved.

While claims are made that tiger farms are created to support reintroduction programmes, no tiger has yet been reintroduced to the wild from a tiger farm. Tiger farms are clearly for commercial purposes and have no role in their present format in tiger conservation. On the contrary, tiger farms perpetuate and increase the high demand for wild tiger parts, leading to the cause of much of the decline in wild tiger numbers. It is therefore both impractical and counter to conservation efforts to source tiger from commercial tiger farms.

Further, for a restoration programme to succeed in the long-term, releases will need to run for some years. It is unlikely to be sufficient to simply locate a few tigers, breed a few litters and release them. Success is far more likely by using a source population that can be drawn from for successive releases over time without rendering the source population itself unviable. Whichever source population is chosen, modelling in PMx and Vortex should be used to predict the consequences of removing stock from it for release, if necessary in combination with modelling growth of the source population first. This approach is being taken for the reintroduction of other captive felids into the wild.

[20] Personal experience and communications of the authors and their colleagues are used here.

Sourcing Options from Conservation Breeding Programmes

Strictly from the biological point of view, sourcing from captive populations of Indochinese tigers would be ideal, followed by Bengal tigers, based on similarity of habitat, followed by Malayan tigers, the subspecies nearest geographically but living in a different habitat in the wild (Figure 1 in Appendix 2).

Indochinese Tiger Captive Stock

Options for Indochinese tigers are very limited[21] (Table 1). The source tiger population would be low in overall genetic diversity compared to the available in Malayan or Bengal tigers, and the individuals may also be problematic to obtain politically. It would take a significant amount of time to breed enough tigers to be able to begin to risk some of them in a release programme, and facilities for so doing would have to be built and managed in Cambodia.

Table 1. Location and number of captive Indochinese tigers.

Location	**Number of Tigers**	**Notes**
Cambodia	1.1*, possibly 1.2	Male getting old. Second female needs re-testing for subspecies verification.
Thailand zoos	1.1 to 3.3	Khao Kheow and Songkla zoos only. Would need to check purity of Songkla line, find out about current young stock at both zoos, and unravel ancestry to avoid inbred individuals if possible. Would represent 2-4 founders.
Thailand DNP	0.1	Wild caught. Not yet adult.
Minimum Total	2.3	Representing a minimum of 5 founders.
Maximum Total	4.5	Representing a maximum of 8 founders

* Tiger numbers are written in standard zoo note form; 1.1 means one male and one female.

In Cambodia, there is one male in good condition at Phnom Tamao, but aged at least 14 and hence approaching the end of his breeding life. There is also a young female, born to the pair that were tested as Indochinese in 2002 and now housed at a private facility that could be returned. A further female at Phnom Tamao, tested hybrid previously, could be re-tested with modern techniques Thailand.

ISIS (the International Species Inventory System, to which all responsible zoos around the world submit annual animal records) information indicates that there are at least 20 Indochinese tigers in zoos in Thailand, but also that these represent only a few founder animals that have been bred in an uncontrolled way.

Only two of the Thai zoos in question – Khao Kheow and Songkla – are members of both ISIS and the Thai Zoological Parks organisation (ZPO). A sibling pair of wild-caught founder stock at Khao Kheow have bred prolifically. At Songkla, many cubs have been bred from a rescued female and a male traded to the zoo from Pattani. If this pair can be shown to be Indochinese, this line would be unrelated to the Khao Kheow one.

If genetic testing shows the Songkla stock to be Indochinese, it is possible that perhaps 2.2 or 3.3 young individuals could be identified from the two zoos for use in breeding with the Cambodian tigers. There have been sibling and parent-offspring matings recorded, so care should be taken to ensure that the selected cats are from non-inbred matings, if options allow. The youngest female currently shown at Khao Kheow is nine years old. It may be that others have been bred but are not yet recorded. There appears to be plenty of young stock at Songkla.

At best these tigers would represent only four founders, as that is the maximum present in the population. They would, however, carry between them more of the genes of those founders than could be gained if only one cat from each original line were used. Taking more young stock than 2.2 or 3.3, however, would probably not be productive, as there would be insufficient stock of other lines to cross with them

[21] Note that following the re-classification of Malayan tigers as *P. t. jacksoni*, some Asian zoo records still show their *P. t. jacksoni* as *P. t. corbetti*. The information presented in this document is considered to be a more accurate record.

and the important genes from the Cambodian tigers would get swamped. Modelling could establish the best options. If the Songkla stock is not Indochinese, two founders would be lost; this is the basis of the minimum figures shown in Table 1.

Given the prevalence of the tiger farming problem in Thailand, it is recommended that only these two zoos, which are members of internationally recognised organisations, be considered as sources. The other zoos almost certainly have only the same lines, in any case.

The Department of National Parks operates a captive facility for felids at Ratchaburi. There is a young wild-caught female tiger there, about one year old. It would be necessary to negotiate separately for this female and the zoo tigers; an agreement on one would not necessarily produce the other.

Malayan Tigers Captive Stock

Malayan tigers could be obtained only from Malaysian and U.S. zoos; these populations represent a reasonable amount of genetic diversity. U.S. zoos would likely be enthusiastic to get involved and would be able to carry out extensive disease checks thus helping with costs; but shipping the individuals would be expensive. A mutually acceptable arrangement might also be made with Malaysian zoos, but for the best genetic diversity, both sources would need to be used. There would not be a need to build up a population within Cambodia; the source tigers could mostly stay in the U.S. and Malaysia. Proven breeding/rearing pairs of appropriate genetic makeup and age could be shipped to breed offspring for release.

There are about 55 Malayan tigers in the U.S. managed programme and at least another 12 in Malaysian zoos and the Singapore zoo (this population may have increased slightly since these data were collected a few years ago). A further 14 animals in Europe should be discounted, as some are descended from an animal with an unresolved pedigree and in any case they do not represent additional genetic lines. Between them, the Malaysian and U.S. populations represent 12 founders, so tigers from both countries would be required. Four of the founders are present only in the U.S., which also has more stock and more space, and so would be at least as important a source as Malaysia.

Any release programme would involve building up numbers first and U.S. zoos may be able make space available to do so, provided of course that the protocols and facilities to be used in Cambodia were of sufficient standard to comply with their animal transaction policies and other internal checks. Active assistance from U.S. zoos would probably also be a possibility, in terms of staff at least. There is little space available in Malaysia, and conditions there are already cramped.

Bengal Tiger Captive Stock

Bengal tigers are present only in zoos in the Indian subcontinent but there are many of them there, including both recently wild-caught individuals and captive-bred stock. Most are in India, with a few in Nepal. (The few that are in Bangladesh should not be considered, as the Sundarbans are a very different habitat). Stock from Nepal might be suitable, but would be insufficient alone. Given the several hundred Bengal tigers in Indian zoos, if Indian agreement were obtained, it would be unnecessary to include any other countries. Indian laws against export would need to be overcome, but that could probably be done, as India would be pleased to be supporting other tiger countries and showing them the way forward.

However, sourcing wild Bengal tigers is the far better option, and if India and/or Nepal agreed to supply them, there would be no need to use captive-bred stock. There would instead be a range of wild tiger options, from deliberate capture of wild tigers for translocation and release, through opportunistic capture of wild conflict tigers for translocation and release, to opportunistic capture of wild conflict tigers to breed cubs for release in facilities in Cambodia.

Facility Needs for Cambodian Tiger Restoration

If Indochinese tigers are used, there will be a need to build up a population capable of providing individuals for release without compromising the viability of the source population. This would necessitate additional breeding facilities at Phnom Tamao, perhaps capable of holding ten pairs of tigers and their litters. This would need to include extra enclosures for moving litters away from their parents. Tigers are sexually mature quickly and will fight or even try to mate by two years old. A veterinary facility would also be needed.

Ideally, the individuals for final release would be bred in a large facility in the habitat, designed to contain nothing built by humans and to ensure they could be monitored and fed at long range, and big enough to allow for the introduction and hunting of live prey, so that they grow up unfamiliar with people and accustomed to feeding on live prey of the appropriate kind. This would not be cheap, but it is critical that released individuals are shy of humans. There could be two or more such facilities at different locations over time. The reintroduction plan for Amur leopards offers details of suggested enclosure design and the necessary supporting facilities (Spitzen et al. 2012).

If Malayan tigers are used, both a quarantine holding facility and the large breed and release enclosure(s) and supporting facilities would be needed, as the source stock would be familiar with people. However, individuals could be shipped as needed from the U.S. or Malaysia, and there would be no need to build up stocks within Cambodia.

If Bengal are used, and from India itself, there would be no need to use captive-bred or even captive-held stock. One option would be to simply translocate wild tigers, but it may be more expedient thing to take tigers that have fallen foul of humans and ship them to Cambodia rather than the usual practice of placing them in an Indian zoo. The minimum requirement would be a holding facility capable of maintaining the tigers' antipathy to humans while veterinary tests are done; once cleared, each tiger could be released. An alternative would be to breed from this stock in Cambodia and release cubs, thus avoiding any learned behaviour patterns of eating livestock or going into villages. In this case, the large breed and release enclosure(s) and supporting facilities, as well as the quarantine holding enclosures, would be needed as for Indochinese tigers.

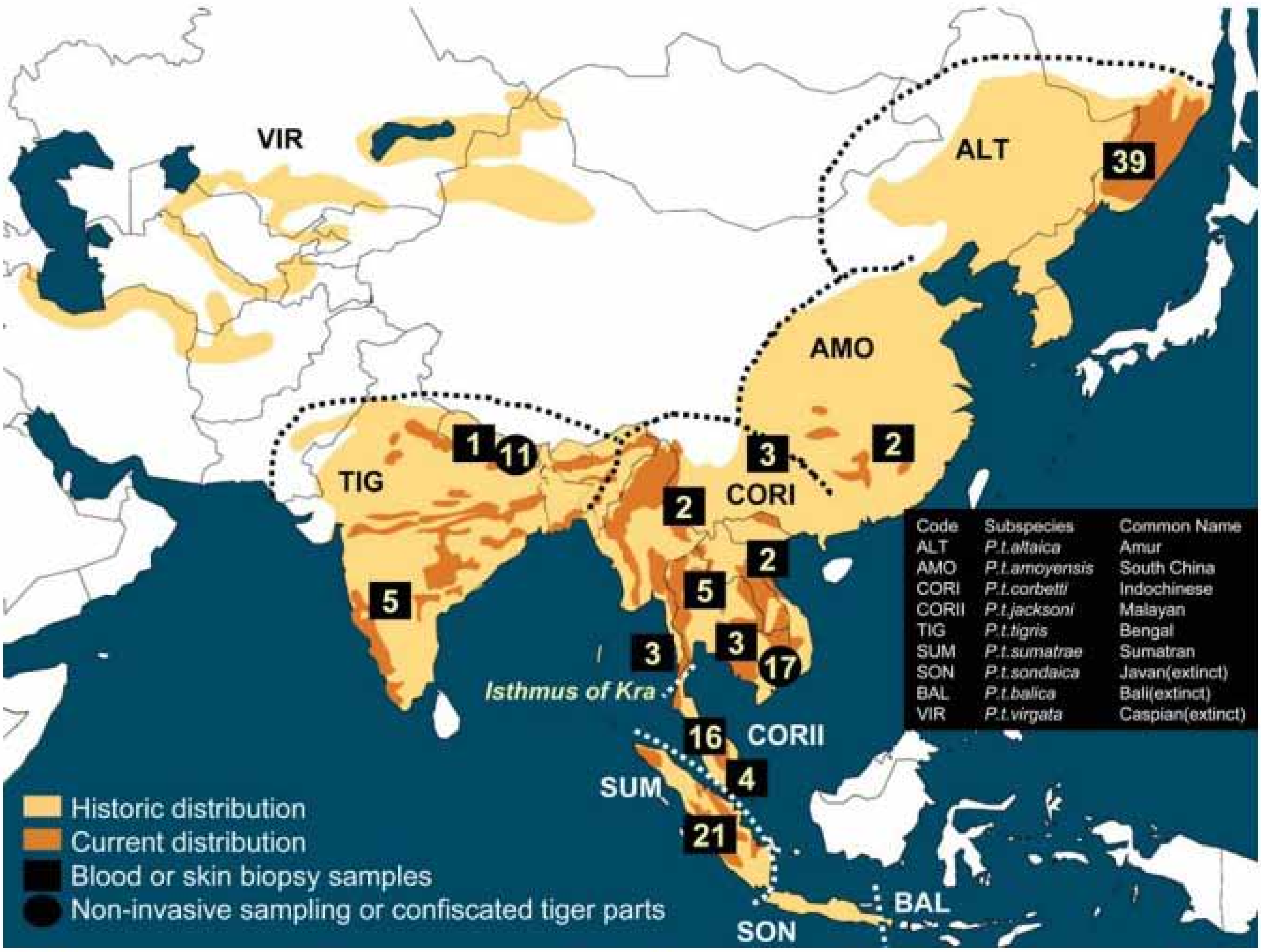


Figure 1. Historic and Current Geographic Distribution of Tigers Corresponding to the Eight Traditional Subspecies Designation

Geographic origin of samples and sample size (circles or squares) from each location are indicated (see Table 3 for sources). Three-letter codes (TIG, ALT, etc.) are indicated subspecies abbreviations. Dotted lines are approximate boundaries between tiger subspecies studied here. The Isthmus of Kra divides the traditional Indochinese tigers into the northern Indochinese tigers *P. t. corbetti* I and the Malayan tigers *P. t. corbetti* II based on the present study. We propose the Malayan tiger subspecies, COR II, be named *P. t. jacksoni*, to honor Peter Jackson, the former Chair of the IUCN's Cat Specialist Group who has contributed significantly to worldwide tiger conservation.
DOI: 10.1371/journal.pbio.0020442.g001

Source: Luo et al. 2004

Appendix 3 - IUCN Guidelines for Reintroductions and Other Conservation Translocations [A subset]

IUCN Guidelines

for

Reintroductions

and

Other Conservation Translocations

August 2012

Adopted by SSC Steering Committee at Meeting SC 4 6, 5th September 2012

Design: Interim

IUCN Species Survival Commission Guidelines for Reintroductions and Other Conservation Translocations[22]

Executive summary

Conservation translocation is the deliberate movement of organisms from one site for release in another. It must be intended to yield a measurable conservation benefit at the levels of a population, species or ecosystem, and not only provide benefit to translocated individuals.

Conservation translocations consist of (i) reinforcement and reintroduction within a species' indigenous range, and (ii) conservation introductions, comprising assisted colonisation and ecological replacement, outside indigenous range.

Translocation is an effective conservation tool but its use either on its own or in conjunction with other conservation solutions needs rigorous justification. Feasibility assessment should include a balance of the conservation benefits against the costs and risks of both the translocation and alternative conservation actions.

Risks in a translocation are multiple, affecting in many ways the focal species, their associated communities and ecosystem functions in both source and destination areas; there are also risks around human concerns. Any proposed translocation should have a comprehensive risk assessment with a level of effort appropriate to the situation. Where risk is high and/or uncertainty remains about risks and their impacts, a translocation should not proceed.

Translocations of organisms outside of their indigenous range are considered to be especially high risk given the numerous examples of species released outside their indigenous ranges subsequently becoming invasive, often with massively adverse impacts.

Any translocation will impact and be impacted by human interests. Social, economic and political factors must be integral to translocation feasibility and design. These factors will also influence implementation and often require an effective, multi-disciplinary team, with technical and social expertise representing all interests.

Design and implementation of conservation translocations should follow the standard stages of project design and management, including gathering baseline information and analysis of threats, and iterative rounds of monitoring and management adjustment once the translocation is underway. This ensures that process and progress are recorded; changes in translocation objectives or management regime can then be justified, and outcomes can be determined objectively. Finally, translocations should be fully documented, and their outcomes made publicly and suitably available to inform future conservation planning.

Section 1: Introduction and scope of Guidelines

These Guidelines are designed to be applicable to the full spectrum of conservation translocations. They are based on principle rather than example. Throughout the Guidelines there are references to accompanying Annexes that give further detail.

The background and rationale for developing these Guidelines are described in Annex 1.

Translocation is the human-mediated movement of living organisms[23] from one area, with release in another. These Guidelines focus on conservation translocations, namely a translocation that yields quantifiable conservation benefit. For this purpose the beneficiaries should be the populations of the translocated species, or the ecosystems that it occupies. Situations in which there is benefit only to the translocated individuals do not meet this requirement.

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[22] See full *IUCN Guidelines for Reintroductions and other Conservation Translocations* for all sections (additional sections 3-9, figures and annexes).
[23] 'organism' refers to a species, subspecies or lower taxon, and includes any part, gametes, seeds, eggs, or proagules of such species that might survive and subsequently reproduce (After: Convention on Biological Diversity Decision VI/23 http://www.cbd.int/decision/cop/?id=7197).

Conservation through intervention is now common, but with increasing evidence and appreciation of the risks. Consequently, any conservation translocation must be justified, with development of clear objectives, identification and assessment of risks, and with measures of performance. These Guidelines are designed to provide guidance on the justification, design and implementation of any conservation translocation. But, they should not be construed as promoting conservation translocation over any other form of conservation action, and specific elements should not be selected in isolation to justify a translocation.

These Guidelines are a response to the present era of accelerating ecological change: there are increasing and acute pressures on much of the world's biodiversity due to loss of habitats and reduction in their quality, biological invasions, and climate change. The latter is the main force behind the proposition to move organisms deliberately outside their indigenous ranges (defined in Section 2), an exercise of greater potential risks than a reinforcement or reintroduction. While such 'assisted colonisation' is controversial, it is expected to be increasingly used in future biodiversity conservation.

Because of such anticipated developments, these Guidelines emphasise the need to consider the alternatives to translocation, to appreciate uncertainty of ecological knowledge, and to understand the risks behind any translocation. Many conservation translocations are long-term commitments, and every case is an opportunity to research the challenges for establishing populations, in order to increase the success rate of these interventions.

Section 2: Definitions and classification

Translocation is the human-mediated movement of living organisms from one area, with release[24] in another.

Translocation is therefore the overarching term. Translocations may move living organisms from the wild or from captive origins. Translocations can be accidental (e.g. stowaways) or intentional. Intentional translocations can address a variety of motivations, including for reducing population size, for welfare, political, commercial or recreational interests, or for conservation objecti ves.

Conservation Translocation is the intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem functions or processes.

A translocation involves releasing organisms. Release here specifically excludes the act of placing organisms into conditions that, for management purposes, differ significantly from those experienced by these organisms in their natural habitats. These differences may include the density under which individuals are kept, their sex ratio and group size, breeding system, environmental conditions, dependence on provisioning and, consequently, the selection pressures imposed.

Conservation translocations can entail releases either within or outside the species' indigenous range. The indigenous range of a species is the known or inferred distribution generated from historical (written or verbal) records, or physical evidence of the species' occurrence. Where direct evidence is inadequate to confirm previous occupancy, the existence of suitable habitat wi thin ecologically appropriate proximity to proven range may be taken as adequate evidence of previous occupation.

1. Population Restoration is any conservation translocation to within indigenous range, and comprises two activities:

a. **Reinforcement** is the intentional movement and release of an organism into an existing population conspecifics.

Reinforcement aims to enhance population viability, for instance by increasing population size, by increasing genetic diversity, or by increasing the representation of specific demographic groups or stages.

[Synonyms: Augmentation; Supplementation; Re-stocking; Enhancement (plants only)]

b. **Reintroduction** is the intentional movement and release of an organism inside its indigenous range from which it has disappeared.

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[24] 'release' is applicable here to individuals of any taxon.

Reintroduction aims to re-establish a viable population of the focal species within its indigenous range.

2. Conservation Introduction is the intentional movement and release of an organism outside its indigenous range.

Two types of Conservation Introduction are recognised:

a. Assisted Colonisation is the intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species.

This is carried out primarily where protection from current or likely future threats in current range is deemed less feasible than at alternative sites.

The term includes a wide spectrum of operations, from those involving the movement of organisms into areas that are both far from current range and separated by non-habitat areas, to those involving small range extensions into contiguous areas.

[Synonyms: Benign Introduction; Assisted Migration; Managed Relocation]

b. Ecological Replacement is the intentional movement and release of an organism outside its indigenous range to perform a specific ecological function.

This is used to re-establish an ecological function lost through extinction, and will often involve the most suitable existing subspecies, or a close relative of the extinct species within the same genus[25].

[Synonyms: Taxon Substitution; Ecological Substitutes/Proxies/Surrogates; Subspecific Substitution, Analogue Species]

[25] An organism might be released into indigenous range to perform an ecological function, but this would be considered a reintroduction.

Population Viability Analysis (PVA)

Ramesh Krishnamurthy, Wildlife Institute of India, and Thomas Gray, World Wide Fund for Nature

Population Viability Analysis was performed using VORTEX Program (Version 9.96) to visualize the nature of population growth and survival probability of the proposed reintroduction efforts in the Eastern Plain Landscape (EPL). The analysis was performed with 500 iterations for the carrying capacity of 30 individuals with the survival probability for 25 years. Two founder populations were considered i.e. four individuals (1 male and three females) and eight individuals (2 males and 6 females). The PVA was done involving six scenarios in which reintroduction efforts could be considered in EPL and these are;

(a) Scenario 1 - only demographic parameters with a founder of four individuals; (b) Scenario 2 - demographic parameters with founder of a four individuals and supplementation of two males within first year; (c) Scenario 3 - demographic parameters with a founder of four individuals, supplementation of two males within first year and poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years); (d) Scenario 4 - demographic parameters with a founder of eight individuals; (e) Scenario 5 - demographic parameters with a founder of eight individuals and poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years); (f) Scenario 6 - demographic parameters with a founder of eight individuals, poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years) and supplementation of one pair every three years for three consecutive terms. The PVA did not include other parameters such as environmental catastrophe and inbreeding effects on account of the knowledge that these factors are not immediate concerns, although they contribute significantly to the population status when occurs. Given that poaching will have detrimental effects, the model included the poaching effect so that the implementation would include practical situations on the ground. Poaching and emigration could cause loss to the founder and growing populations, and therefore, the option of poaching (or harvest) considered in the model include poaching as well emigration possibilities. The extinction was defined as the condition when the population is reduced to only one sex.

The following life history parameters were included in the PVA;

Year 1	40%
Year 2	25%
Year 3	25%
Year 4	10%
Cub mortality (%)	50 (in both male and female)
Adult mortality (%)	10 (in both male and female)
Maximum breeding age	15
Start of breeding	4 (males) and 3 (females)
Sex ratio at birth	50%
Adult males in breeding pool	33%
Adult females in breeding pool	50%
Mean progeny per female	2.5 (1 SD)

Scenario 1: *Model with only demographic parameters with a founder of four individuals.*

In 500 simulations of the population for 25 years, 44 went extinct and 456 survived, giving a probability of survival 0.91 (0.01 SE), and mean final population was 24.21 (0.42 SE; 9.36 SD) (Figure 1). The mean time to first extinction to occur was 4.3 years (0.56 SE, 3.73 SD). Across all years, prior to carrying capacity truncation, mean growth rate (r) was 0.15 (0.001 SE; 0.19 SD). The final observed heterozygosity was 0.7359 (0.01 SE; 0.13 SD) and final number of alleles was 5.08 (0.05 SE; 1.09 SD). This scenario is an ideal one, although the mean time to fist extinction to occur is early and that it is unlikely option since there is always a possibility of few individuals being removed from the population, either from poaching or emigration events or other unforeseen losses.

Scenario 2: *Model with demographic parameters with founder of a four individuals and supplementation of two males within first year.*

In 500 simulations of the population 18 went extinct and 482 survived, translated into a probability of survival of 0.96 (0.001 SE). The mean final population size and mean time for first extinction were 26.16 (0.35 SE; 7.73 SD) and 5.42 years (1.24 SE, 6.34 SD) respectively. Across all years, prior to carrying capacity truncation, mean growth rate (r) was 0.15 (0.002 SE; 0.19 SD). The final observed heterozygosity was 0.79 (0.01 SE; 0.11 SD) and alleles number was 6.44 (0.06 SE; 1.41 SD). With supplement to the founder within a year, there was marginal increase in the final population status, probability of survival and population growth.

Scenario 3: *Model with demographic parameters with a founder of four individuals, supplementation of two males within first year and poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years).*

In 500 simulations, 129 went extinct and 371 survived (i.e. 0.74 probability of survival), thus suggesting that poaching at a rate of 1 per three year can reduce the population survival significantly. The mean time to first extinction was 2.50 years (0.21 SE, 3.01 SD), and the mean final population size would be 19.05 (0.56 SE; 12.50 SD). The high variation associated with population estimate presents huge uncertainty to the population status. The mean growth rate (r) was 0.12 (0.002 SE; 0.21 SD). The results obtained from this model reaffirms that poaching or any other form of individual loss cannot be tolerated at all.

Scenario 4: *Model with only demographic parameters with a founder of eight individuals.*

Of the 500 simulations, none went extinct and all 500 survived (100% probability of survival). Mean final population was 26.83 (0.24 SE, 5.40 SD). The mean growth rate (r) was 0.16 (0.002 SE, 0.17 SD). The final observed heterozygosity was 0.82 (0.005 SE; 0.11 SD) and the number of alleles was 7.16 (0.06 SE: 1.45 SD). It is an ideal model without the effects of catastrophe, inbreeding and poaching. If the management team on the ground is able to ensure poaching does not take place or the individuals are not lost to any other causes, the reintroduction would find rapid and stable population growth. This is assuming that no catastrophe takes place.

Scenario 5: *Model with demographic parameters with a founder of four individuals and poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years).*

In 500 simulations, 32 went extinct and 468 survived, giving a survival probability 0.93 (0.01 SE). Mean time to first extinction was 3.31 years (0.38 SE, 2.13 SD). Mean final population was 27.34 (0.24 SE; 5.27 SD). Across all years, prior to carrying capacity truncation, mean growth rate (r) was 0.13 (0.002 SE; 0.18 SD). The final observed heterozygosity was 0.78 (0.01 SE; 0.12 SD) and the number of alleles was 6.31 (0.07 SE; 1.51 SD). Although such marginal loss from poaching and other losses does not affect the overall population status, the growth rate and probability of survival are affected.

Scenario 6: *Model with demographic parameters with a founder of four individuals, poaching of one animal every three year for three terms (total poaching of 2 females and 1 male 10 years) and supplementation of one pair every three years for three consecutive terms.*

In 500 simulations, 1 went extinct and 499 survived, giving a survival probability 0.99 (0.002 SE). Mean time to first extinction was 13.00 years (10.00 SE, 14.14 SD). Mean final population was 25.50 (0.38 SE; 8.55 SD). Across all years, prior to carrying capacity truncation, mean growth rate (r) was 0.16 (0.002 SE; 0.16 SD). The final observed heterozygosity was 0.80 (0.002 SE; 0.06 SD) and the number of alleles was 8.10 (0.08 SE; 1.71 SD). The supplementation option appears to offset the population loss to poaching and the final outcome in terms of population size, growth rate, heterozygosity and alleles number are higher in this scenario.

A careful analysis of the results obtained based on various scenarios including the mean population size over years (Figure 1) and probability of survival (Figure 2), it seems plausible that the Scenarios 4 and 6 are the best options. However, in case of difficulties in sourcing eight founders at a time, the Scenario 2 could be considered with a condition that the individuals are not lost to poaching or other elements, since such removal is likely to cause substantial decrease in the survival probability as predicted by PVA.

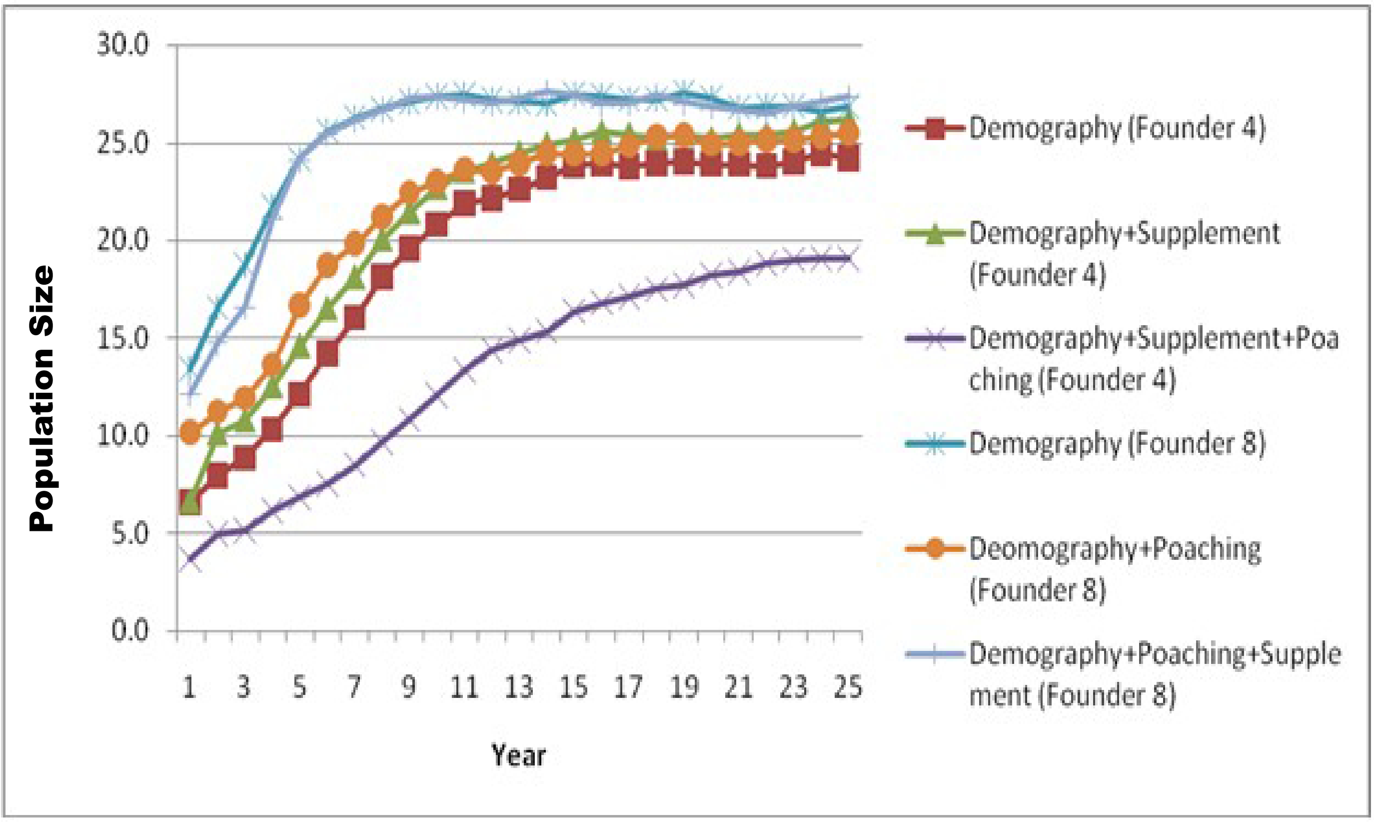

Figure 1: Mean popultion size from various scenarios as predicted by the Population Viability Analysis involving 500 iterations and 25 years.

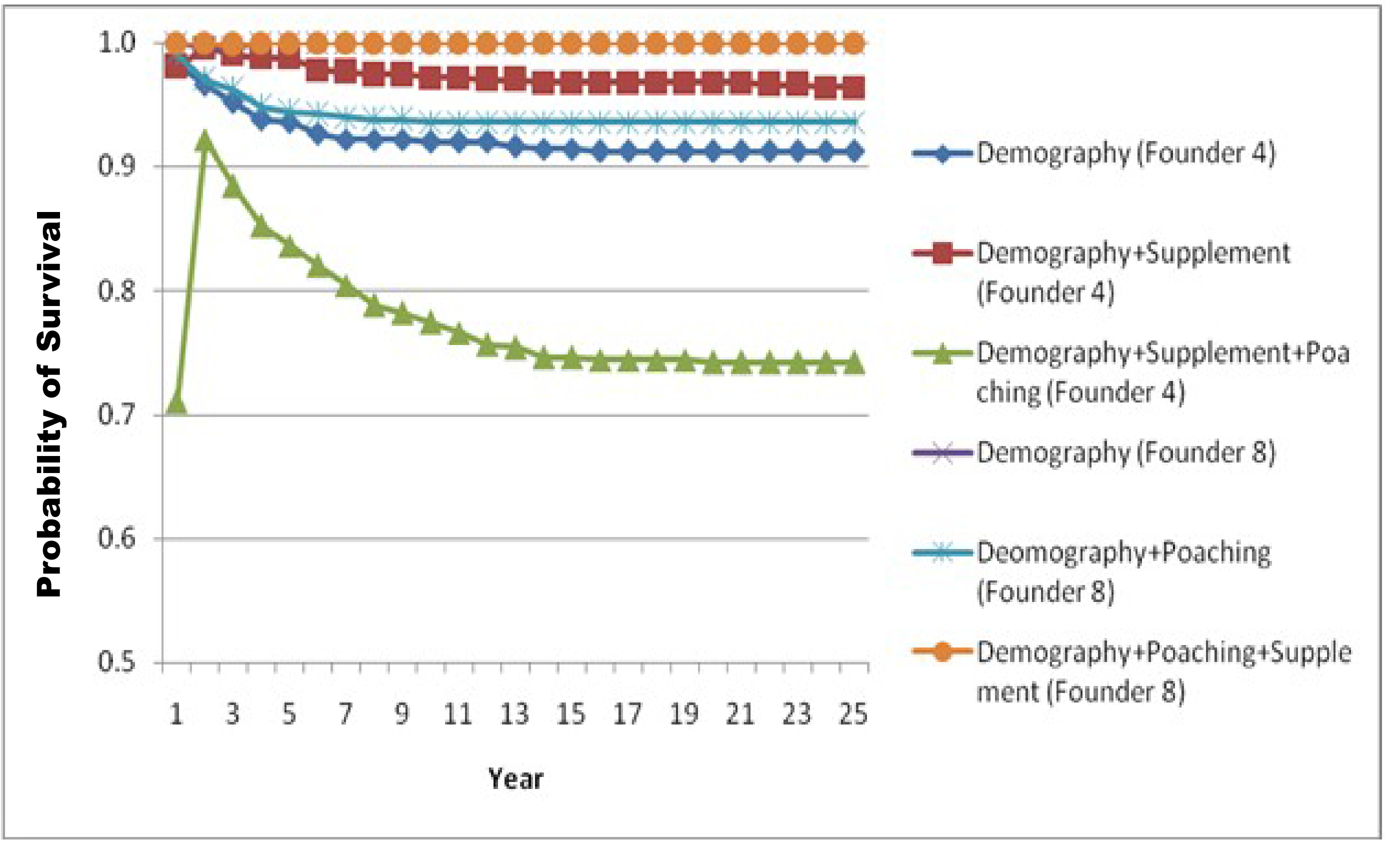

Figure 2: Probability of survival from various scenarios as predicted by the Population Viability Analysis involving 500 iterations and 25 years.

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