Range-wide Population and Habitat Viability Assessment for the Dhole, *Cuon alpinus*

Khao Yai National Park, Thailand, February 2019

Final Report

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A PDF of *Range-wide Population and Habitat Viability Assessment for the Dhole, Cuon alpinus* final workshop report can be downloaded at: www.cpsg.org and www.canids.org.

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EXECUTIVE SUMMARY

VISION: By 2040, dholes are secured and increasing under science-based monitoring in viable, connected meta-populations across their historical range. Societies and governments will have recognized their ecological, economic and cultural importance, and stakeholders will ensure co-existence between dholes and people.

Priorities:

- *Build a collaborative network among those involved in dhole research and conservation;*
- *Compile and share current data on dholes to produce an updated range map and status review for dholes;*
- *Identify key issues/threats concerning the conservation of dholes;*
- *Identify knowledge gaps and research priorities for both ex situ and in situ dhole populations;*
- *Identify ways in which ex situ activities can contribute to dhole conservation;*
- *Identify goals and priority actions to initiate a dhole long-range conservation plan; and*
- *Produce a draft workshop report, including a plan for implementation.*

BACKGROUND

Dhole, *Cuon alpinus* (Pallas, 1811), also known as Asiatic wild dog, Indian wild dog, whistling dog, red dog, and mountain wolf, is a canid native to Central, South and Southeast Asia.

Dholes have disappeared from most of their historical range. Populations are still declining in most areas due to several main threats, which include depletion of prey base, habitat loss, persecution due to livestock predation, disease transmission from domestic dogs, and possibly interspecific competition. Most if not all current subpopulations of dholes are relatively small and isolated, and often exhibit severe fluctuations in numbers. Dholes warrant listing as Endangered on the IUCN Red List.

2019 PHVA WORKSHOP

In February 2019, over 28 dhole experts from 9 countries gathered in Kasetsart University and Khao Yai National Park, Thailand for 6 days of intensive conservation planning discussion. This Population and Habitat Viability Assessment (PHVA) workshop was hosted by the IUCN SSC Canid Specialist Group's Dhole Working Group and Faculty of Forestry, Kasetsart University and was organized in collaboration with IUCN SSC Conservation Planning Specialist Group.

Participants worked together to develop a vision for the future of dholes, to identify and prioritize strategies and actions in different countries to achieving this vision, and to agree on a species distribution model that may help in evaluating the suitability of the landscape and estimate dhole populations and metapopulations. Population viability modelling helped participants to better understand the relative viability of small, fragmented dhole populations under threat.

ISSUE-BASED GOALS AND STRATEGIES

A threat analysis by workshop participants identified four main categories of threats to dhole populations across the species' range: habitat and prey loss; human-dhole conflict; domestic dogs and disease transmission; and insufficient scientific knowledge. Cross-country working groups discussed these issues and identified goals and potential strategies to address them.

POPULATION VIABILITY ANALYSIS (PVA)

Scientific data and expert opinion were used to develop a dhole population viability model. Our limited understanding of dhole ecology, numbers, distribution and threats limited viability projections for the species. PVA results identified important data gaps for dhole viability analysis and for management, including age- and sex-specific mortality rates, population size and connectivity estimates, and relative causes of mortality for specific dhole populations. Populations of several hundred dholes are projected to have good viability in the absence of significant threats. Smaller populaitons are at risk of decline or extinction, particularly if they are susceptible to human-caused threats such as persecution, and may require periodic supplementation through natural connectivity and/or through human-mediated translocations to remain viable. Sufficient habitat and prey for small populations to expand, good connectivity between fragmented populations, and reduction or mitigation of human-caused threats will be important for the future viability of dhole populations.

SPECIES DISTRIBUTION MODELING (SDM)

A species distribution model was developed for assessing dhole potential distribution to be used in species conservation planning. The results show that dholes are widely distributed in suitable patches across 12 Asian countries. Some patches seem to be structurally connected, while others are isolated by a matrix of unsuitable habitat. The degree of connectivity of dhole populations is currently unknown and should be evaluated. Model results allowed the PHVA participants to: 1) update the dhole potential distribution map across 12 countries; 2) identify the gaps in sampling database; 3) evaluate the suitability of the landscape for the species occurrence; 4) identify suitable patches for dholes with confirmed presence; 5) identify areas in need of field surveys to confirm the species' presence in other portions of suitable patches; and 6) initiate the discussion to identify dhole populations and meta-populations in different portions of the species' distribution range.

CONSERVATION STRATEGY AND ACTION IN EACH COUNTRY

Considering the different natural and social environment conditions in different countries, PHVA participants formed country-based groups to review all of the goals and potential strategies developed by four issue-based working groups and to consider information provided by the PVA and SDM models. Each group evaluated all potential strategies related to the issues and goals relevant to their country and recommended those suitable for implementation. Members of the IUCN CSG Dhole Working Group discussed and developed recommendations to support dhole research and conservation efforts from a global strategy perspective.

PART I.

Population and Habitat Viability Assessment and Modeling

WORKSHOP PROCESS

The Population and Habitat Viability Assessment (PHVA) workshop took place at Kasetsart University and Khao Yai National Park, Thailand from 10-15 February 2019 and was attended by more than 28 participants from 9 countries. The initiative was a collaboration between IUCN SSC Canid Specialist Group's (CSG) Dhole Working Group and the IUCN SSC Conservation Planning Specialist Group (CPSG).

PRE-PHVA WORKSHOP DISCUSSIONS

On 10-11 February, at Kasetsart University, biologists and researchers met to discuss final parameter inputs for the Population Viability Analysis (PVA) and Species Distribution Modeling (SDM) models built using the software programs *Vortex* (Lacy & Pollack, 2017) and *SDMToolBox* (v. 1.1.c, Brown 2014) respectively. PVA is valuble in identifying primary drivers of dhole population viability and important data gaps for viability assessment and conservation action. SDM predicts the potential species distribution across a landscape by the species presence and environmental variables such as topographic, climatic, anthropogenic and land cover. The full reports on the modelling work are included in the SDM and PVA sections of this report. In addition, a small discussion about *ex-situ* management linked to species conservation was held concurrently on 11 February, during which collaboration possibilities and barriers were identified for India, Thailand, and other Asia countries (see Appendix III).

PHVA WORKSHOP

The PHVA workshop, held on 12-15 February in Khao Yai National Park, opened with a welcome from Mr. Kriangsak Chaturasuksakul, Chief of the Khao Yai Regional Training Center and CSG Dhole Working Group Chair Nucharin Songsasen. After an introduction to CPSG's planning processes, participants were invited to introduce themselves and to describe one priority issue that they would like to discuss and or address during the PHVA. This was followed by presentations of the status of dhole population in each country.

A visioning exercise involving all delegates followed. The purpose of this was to develop main themes for an inclusive Vision that would describe a desirable but also realistic future for dholes. After all ideas and opinions were collected from each participant, a small visioning group took these themes and built a statement that was discussed on the second day.

VISION:
By 2040, dholes are secured and increasing under science-based monitoring in viable, connected meta-populations across their historical range. Societies and governments will have recognized their ecological, economic and cultural importance, and stakeholders will ensure co-existence between dholes and people.

Participants then described the threats or obstacles to achieving this vision and identified those threats directly impact dhole populations, such as reproductive rates, mortality rates, genetic diversity, and population size. The full set of threats considered is illustrated in Figure 1. These threats were themed into five main categories: Habitat Loss, Human-Dhole Conflict, Prey Loss, Scientific Data Issues, and Dogs and Disease.

Following the threats analysis, participants used sticky notes to identify dhole populations on country-specific maps, labelling the threats facing each population on these maps. Unfortunately, representatives from Vietnam, Cambodia and Laos were unable to attend the workshop; however, one participant shared some information for Cambodia and Laos. This process helped participants to review the dhole's status across its range and to prepare for strategy development in working groups. The combination of threat analysis, mapping results, and country-specific status presentations created a relatively comprehensive picture of dhole distribution and threats across their entire range (see *Status Review and Threats* section).

Four working groups were formed around the main issues identified: Scientific Data; Habitat and Prey Loss; Human-Dhole Conflict; and Dogs and Disease Transmission. The Scientific Data working group focused on data gaps in the scientific information for dholes. The other three working groups discussed, described and prioritized the issues that fell within their designated theme. Groups were tasked with developing Goal Statements that describe the changes desired and the achievement needed to reduce or eliminate the issues. For each goal, the groups brainstormed a list of strategies that could be taken to achieve the goal, providing as many (reasonable) alternatives as possible. The resulting Goals and Strategies were discussed and prioritized by all PHVA participants in plenary.

Given that the status of dholes and their habitat is different in each county, the participants then reformed into country-based groups to discuss and recommend suitable or reliable Strategies for their country, followed by development of Actions for implementing those strategies.

On the final afternoon of the PHVA, participants discussed an implementation framework, and an editing team was formed to develop the written workshop report and action plan.

STATUS REVIEW AND THREAT ANALYSIS

Workshop participants identified numerous threats to the viability of dhole populations across the species' range, as well as related issues that may present obstacles to achieving the group's long-term vision for the species. Participants were asked to consider both the primary causes of these threats or issues along with the known or hypothesized impact on dhole populations (i.e., increased juvenile mortality, increased adult mortality, decreased reproduction, population isolation, limited population size, and decreased genetic diversity).

The resulting threat causal chains were themed into five main categories: habitat-related issues; prey loss; human-dhole conflict; dogs and disease transmission; and insufficient scientific knowledge. Two additional core issues were identified – climate change and invasive species – but were not tied to specific threats and were not considered further in this workshop. Figure 1 depicts the final themed threat diagram.

Participants considered these main threats with respect to the dhole populations in their respective countries. Table 1 summarizes the population status of dholes for each country, combining country-specific status presentation information with mapping of identified threats. No representatives were present from Vietnam, Cambodia or Laos; however, participants with some knowledge of dhole populations in these countries supplied information for Cambodia and Laos for Table 1.

These threat categories formed the based for cross-country working groups to discuss the main issues and identify potential strategies to address them.

Figure 1. Existing and potential threats to the viability of dholes identified at the 2019 PHVA.

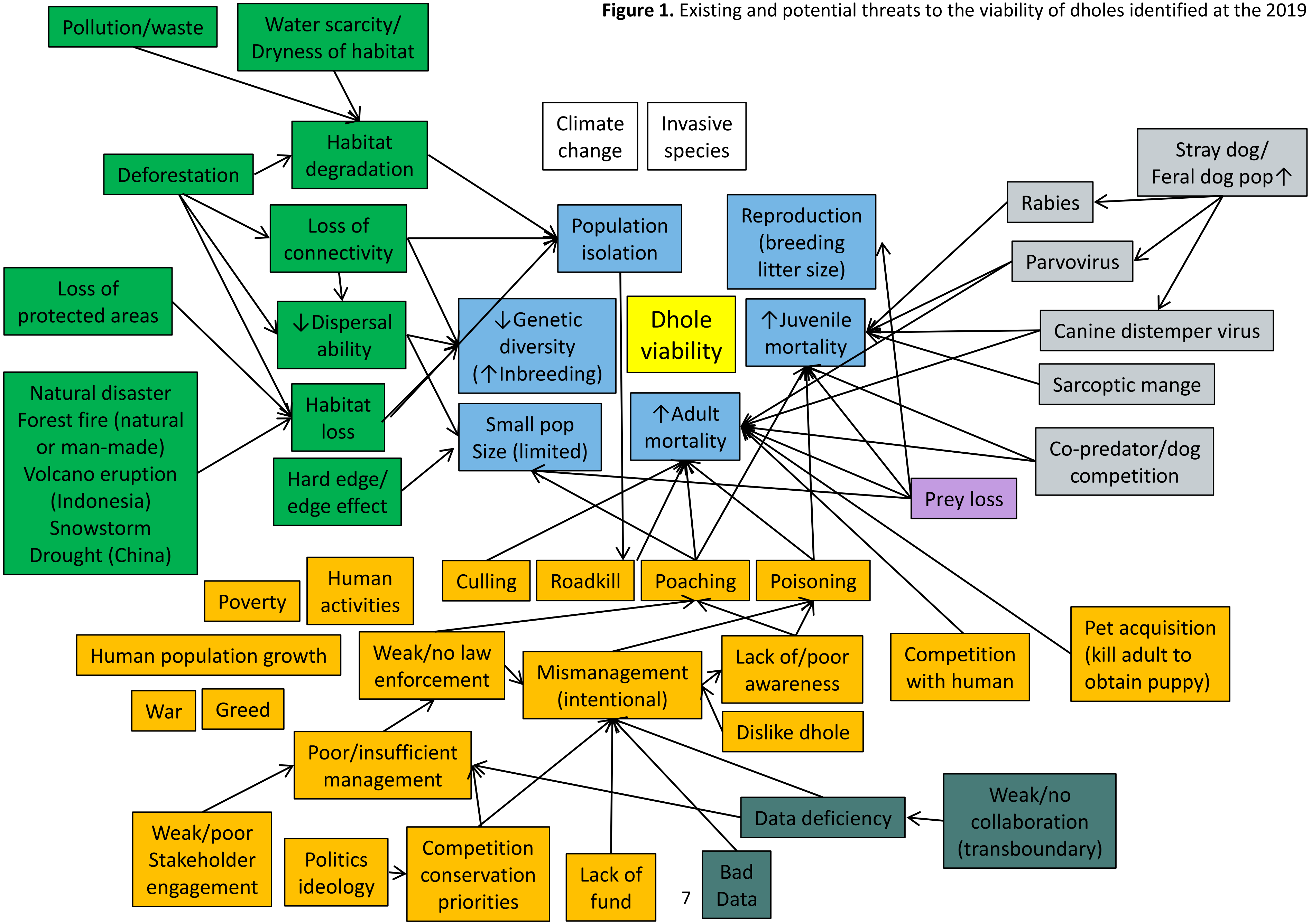


Table 1. Country-specific information on legal status, distribution, and main threats regarding dhole populations.

Country	Legal status	Distribution/ population	Main threats	Note
Bangladesh	Legally protected; listed in Schedule I of the Wildlife Protection Act 2012	Raghunandan Forest Kasalong Sangu- Matamu- Huri Forest	Habitat loss Prey loss Dogs Human-conflict Management	All three areas have all five threats
Bhutan	Not listed in Schedule I (totally protected list) of the Forest and Nature Conservation Act of Bhutan 1995	Throughout Bhutan, in all 20 districts	Habitat loss Prey loss Dogs Human-conflict	Retaliatory killings by local farmers (mainly poisoning)
China	Protected level: Class-II national protected wildlife	Historically reported in most areas of China, but there are very few records in recent decades. Current distribution is poorly known but probably highly fragmented. Confirmed records by camera-trapping since 2008 are fewer than 10 sites (e.g., nature reserves) in southern and western Gansu, southern Shaanxi, southern Qinghai, southern and western Yunnan, western Sichuan provinces, southern Xinjiang AR and south-eastern Tibet AR.	Habitat loss Prey loss Dogs Human-conflict Disease	During the past three decades, the wild population of dholes in China has been suffering severe decline and reduced range, although the reason is poorly known. Retaliatory killings using highly toxic poisons after dhole depredation on livestock, and outbreak of highly contagious, fatal disease such as rabies and canine distemper, possibly spreading out through free-ranging house dogs and hunting dogs, are speculated as the most probable causes. Poaching, especially use of snares without specific target species, is another important threat.
Cambodia		Northern Plains Eastern Plains/ Forest Cardomon Mountains	Habitat loss Prey loss Dogs Disease Management	All three areas have those five threats. No representative from Laos. Information shared by Martin Gilbert.

India		Himalayas area Northeast area Central India Eastern Ghats Western Ghats	Habitat loss Prey loss Dogs Human-conflict Disease Management	-Himalayas area: habitat loss, prey loss, dogs -Northeast area: habitat loss, prey loss, dogs, human-conflict -Central India: habitat loss, dogs, management -Eastern Ghats: habitat loss, prey loss, dogs, management -Western Ghats: habitat loss, dogs, disease
Indonesia	-Act No. 5 in 1990 with respect to the law on the conservation of biodiversity ecosystems -Ministry of Environment and Forestry Regulation No. 106 in 2018 with respect to the second change on Ministry of Environment and Forestry Regulation No. 20 in 2018 with respect to the protected flora and fauna	Java: Ujung Kulon NP, Papandayan Reserve, Sawal Reserve, Gede Pangrango NP, Halimun Salak NP, Meru Betiri NP, Alas Purwo NP, Baluran NP, Kawah Ijen Nature Tourism Park Sumatra: Leuser-Ulu Masen, Batang Toru, Rimbang Baling, Kampar-Kerumutan, Bukit Tigapuluh, Teso Nilo, Kerinci Sebelat-Batang Hari, Bukit Duabelas, Berbak Sembilan, Hutan Harapan, Bukit Barisan Selatan, Bukit Balai Rejang	Habitat loss Prey loss Dogs Human-conflict Disease Management	Only included the areas that have photographic evidence of dholes. It might be possible that dholes occur on the other protected areas in Java and Sumatra. Persecution and eradication has occurred (conflict with human)
Laos		Nam Et -Phou Louey national park	Prey loss Dogs Disease Management	No representative from Laos. Information shared by Martin Gilbert.
Malaysia		Temengor Forest Reserve (Perak) B. Tapah (Perak) Lojing (Kelantan) Ulu Jelai (Pahang) East-Coast Highway (Pahang-Cerenggc Mm -Kelantan)	Habitat loss	

Myanmar		North Myanmar DHC (Pindaya) West Myanmar Tanintharyi	Habitat loss Prey loss Human-conflict	-DHC (Pindaya): Human-conflict -North Myanmar, West Myanmar, and Tanintharyi areas have habitat loss and prey loss issues.
Nepal		Bardia National Park Annapurna Conservation Area Chitwan Parsa National Park Tinjure Milke Jaljale Kangchenjunga Conservation Area	Habitat loss Prey loss Dogs Human-conflict Disease Management	-Bardia National Park: prey loss, dogs, human-conflict, and disease -Annapurna Conservation Area: prey loss, dogs, human-conflict, disease, management -Chitwan Parsa National Park: prey loss, dogs, and disease -Tinjure Milke Jaljale and Kangchenjunga Conservation Area have all six threats.
Thailand	Fully protected	Western Forest Complex Dong Phayayen-Khao Yai Forest Complex Kaeng Krachan-Kuiburi Forest Complex Phou Kiow	Prey depletion Human-conflict Disease	

WORKING GROUP: SCIENTIFIC DATA

Participants: *Bilal Habib, Linnea Havmoller (recorder), Sheng Li, Hasan Rahman (presenter), Arjun Srivathsa (facilitator), Robert Steinmetz, Yadong Xue*

ISSUE: STATUS OF SCIENTIFIC INFORMATION ABOUT DHOLES

This working group focused on scientific information of dholes and important data gaps. After brainstorming and discussion, the working group listed the data gaps, including lack of scientific information of dhole population abundance, trends and suitable estimate methods for different counties and dhole populations. The working group also pointed out that the distance and landscapes that dholes are able to disperse and the corridors between populations are data gaps. Without the basic scientific information, it is difficult to identify a "viable" dhole population.

The working group addressed 5 critical types of information for dholes: 1) distribution; 2) meta-populations; 3) numbers in the meta-populations; 4) connectivity between meta-populations; and 5) viable populations. The distribution model (SDM) may possibly provide a basis to estimate distribution and identify potential corridors and meta-populations. This information in turn can help inform population viability analyses using the *VORTEX* population model.

For prey loss and the impact on dholes, prey abundance may be estimated by distance-sampling from camera traps, but more information is needed on prey competition and how this impacts dhole reproduction.

Some areas have human-dhole conflicts but most areas are unknown. There are data gaps on dhole-human interactions, such as people's attitudes towards dhole, numbers of livestock lost due to dholes, and the extent of these conflicts in different area and countries. Disease in dholes and the effect on dhole populations also require more information.

The working group discussed what scientists can do to support dhole conservation. So far there has been very little scientific focus on dhole distribution and genetic structure. Most research is a side product of monitoring and research on tigers and other species. There are very different knowledge gaps across countries and areas due to accessibility. For example, research data on pack sizes and genetic diversity exist for India but there are only a few camera trap evidences in China. Genetic research can be conducted on *ex situ* populations but is limited because of sample availability and provenance information. Dhole conservation and management is hindered by methodological limitations and data deficiency, which are essential for guiding science-based policy decisions across the species' range.

GOAL STATEMENTS

Based on the identification of these data gaps, the working group identified four goal statements:

S.G.1. Generate accurate information on dhole distribution, and identify sub-populations and connectivity to ensure viable populations.

S.G.2. Obtain information about abundance, vital rates and ecological requirements to monitor dhole population trends.

S.G.3. Generate knowledge about genetic diversity of dhole populations across the range to identify sub-species and inbreeding risk.

S.G.4. Use standardized methods to assess and quantify livestock depredation by dholes and dhole persecution by humans in order to priorities management intervention.

POTENTIAL STRATEGIES

The working group recommended one or more strategies for each of the four goals to ensure the collection of priority information:

<u>Distribution and Metapopulation Structure</u>

S.1.1. Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.

S.1.2. Use the SDM output to identify areas for on-ground surveys.

S.1.3. Undertake connectivity assessment across dhole range.

<u>Abundance and Demographic Rates</u>

S.2.1. Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).

<u>Genetic Diversity and Structure</u>

S.3.1. Obtain representative samples from geographically distinct dhole populations.

S.3.2. Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs).

<u>Livestock Depredation and Persecution</u>

S.4.1. Evaluate existing methods to be taken across the dhole distribution range.

S.4.2. Humbly promote the most suitable method.

Table 2. Summary of issues, goal statements, and potential strategies for the Scientific Data Working Group.

Issues	**Goal Statements**	**Potential Strategies**
• Lack of scientific information on dhole population abundance, trends, distance and landscapes that dholes are able to disperse; and corridors between populations • Difficult to identify a "viable" dhole population	S.G.1. Generate accurate information on dhole distribution and identify sub-populations and connectivity to ensure viable populations.	S.1.1. Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records. S.1.2. Use the SDM output to identify areas for on-ground surveys. S.1.3. Undertake connectivity assessment across dhole range.
• Lack of suitable estimate methods for different counties and dhole populations • Dhole conservation and management is hindered by methodological limitations and data deficiency across its range.	S.G.2. Obtain information about abundance, vital rates and ecological requirements to monitor population trends.	S.2.1. Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).
• Very little scientific focus on dhole distribution and genetic structure • Genetic research can be conducted in *ex situ* populations but is limited because of sample availability and provenance data.	S.G.3. Generate knowledge about genetic diversity of dhole populations across the range to identify sub-species and inbreeding risk.	S.3.1. Obtain representative samples from geographically distinct dhole populations. S.3.2. Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs).
• Data gaps on dhole-human interactions, such as people's attitudes towards dhole, numbers of livestock lost to dholes, and the extent of these conflicts in different area and countries.	S.G.4. Use standardized methods to assess and quantify livestock depredation by dholes and dhole persecution by humans in order to priorities management intervention.	S.G.1. Evaluate existing methods to be taken across the dhole distribution range. S.G.2. Humbly promote the most suitable method.
• Disease in dholes and the effect on dhole population		

WORKING GROUP: HABITAT AND PREY LOSS

Participants: *Naris Bhumpakphan, Iding Haidir (facilitator), Kina, Yututhum Meklin, Chhimi Namgyal (presenter), Girish Punjabi (recorder), Nay Myo Shwe, Jidapha Thongbantum*

ISSUE: LOSS OF THE FOUNDATIONS OF THE DHOLE POPULATION

This working group addressed management goals and strategies related to reducing or stopping the loss of dhole habitat and prey. Since habitat and prey are fundamental needs for dhole populations, the working group listed issues leading to the loss of habitat (including habitat clearing, fragmentation, and degradation) and to the loss of prey (including poaching, retaliatory killing, livestock competition and inadequate management), recognizing that these causes may differ among countries.

Loss of habitat and prey are together one of the most serious threats to dhole populations at this time, and are primarily caused by anthropogenic activities. Increasing human populations and the resulting overexploitation of natural resources is a daunting threat hindering conservation of dholes. Bearing this in mind, the working group discussed the following issues with respect to habitat and prey loss:

Habitat Loss

- Habitat clearing due to agricultural expansion, land encroachment, and unplanned infrastructure development in dhole habitat
- Habitat fragmentation due to unregulated development (linear infrastructure, mining, urban sprawl)
- Habitat degradation and ecological changes due to forest fires, invasive plant species, and livestock grazing

Prey Loss

- Poaching (for subsistence and for trade/commercial)
- Retaliatory killing
- Livestock competition
- Poor management of remnant habitats

GOAL STATEMENTS

Based on discussions of these issues, the working group developed the following goal statements:

H.G.1. Maintain viable dhole habitat by preventing habitat clearing, fragmentation, and degradation.

H.G.2. Increase prey populations by controlling poaching and reducing negative interactions with people and livestock.

POTENTIAL STRATEGIES

The working group brainstormed and identified the following potential strategies for these two goals, while noting the following:

The situations are very different among countries and areas where dholes are found. Therefore, all strategies developed by the working group should be further evaluated for feasibility and risk in each country and area before implementation.

<u>Habitat-Related Strategies:</u>

H.1.1. Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.

H.1.2. Define and maintain corridors/ linkages for dhole habitats within range countries and transboundary.

H.1.3. Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).

H.1.4. Advocate green development projects in dhole habitats and corridors.

H.1.5. Improve habitat quality based on scientifically accepted practices.

<u>Prey-Related Strategies:</u>

H.2.1. Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.

H.2.2. Improve prey populations through participatory approaches by providing alternative livelihoods for local hunters.

H.2.3. Provide training and resources for better crop guarding techniques and effective compensation for crop losses.

H.2.4. Promote livestock husbandry for local communities to reduce livestock populations in dhole habitats by avoiding feedback competition.

H.2.5. Increase prey populations through habitat restoration, food supplementation where necessary, reintroduction and population re-enforcement.

H.2.6. Improve multi-stakeholder collaboration and networking between border departments and agencies (government and transboundary) to control illegal trade of prey species.

Table 3. Summary of issues, goal statements, and potential strategies for the Habitat and Prey Loss Working Group.

Issues	**Goal Statements**	**Potential Strategies**
Habitat loss • Habitat clearing due to agricultural expansion, land encroachment, and unplanned infrastructure development in dhole habitats • Habitat fragmentation due to unregulated development (linear infrastructure, mining, urban sprawl) • Habitat degradation due to changes in native habitat due to forest fires, invasive plant species, and livestock grazing	H.G.1. Maintain viable dhole habitat and populations by preventing habitat clearing, fragmentation, and degradation.	H.1.1. Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones. H.1.2. Define and maintain corridors/ linkages for dhole habitats within range countries and transboundary. H.1.3. Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites). H.1.4. Advocate green development projects in dhole habitats and corridors. H.1.5. Improve habitat quality based on scientifically accepted practices.
Prey loss • Poaching (subsistence, trade/ commercial) • Retaliatory killing • Livestock competition • Poor management of remnant habitats	H.G.2. Increase prey populations by controlling poaching and reducing negative interactions with people and livestock.	H.2.1. Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement. H.2.2. Increase prey populations through participatory approaches by providing alternative livelihoods for local hunters. H.2.3. Provide training and resources for better crop guarding techniques and effective compensation for crop losses. H.2.4. Promote livestock husbandry for local communities to reduce livestock populations in dhole habitats by avoiding feedback competition. H.2.5. Increase prey populations through habitat restoration, food supplementation where necessary, reintroduction and population re-enforcement. H.2.6. Improve multi-stakeholder collaboration and networking between boarder departments and agencies (government and transboundary) to control illegal trade of prey species.

WORKING GROUP: HUMAN-DHOLE CONFLICT

Participants: *Tan Poai Ean, Ambika Pd. Khatiwada, Kyran Kunkel (facilitator), Patrick Roux, Nucharin Songsasen (recorder), Phuntsho Thinley (presenter)*

ISSUE: MISCONCEPTIONS AND COMPETITION

This working group focused on the potential conflicts between dholes and humans. Conflicts are more often human driven, stemming from dhole habitat degradation and human encroachment.

One of the dhole's ecological roles could be to control populations of prey species, such as herbivores, that may come into conflict with humans due to crop raiding. In Malaysia, dholes are not common, but may be found to be more widespread with increased monitoring. They are listed as near threatened due to habitat loss in Malaysia.

The group identified the following potential misconceptions or perceptions of competition with dholes:

- Misconceptions about dholes are due in part to a lack of understanding of the ecological value of dholes, which are often perceived as a pest species that reduces prey populations and have no recognized ecological roles.
- Unintentional killing of dholes: overdevelopment and overpopulation by humans leads to more unintentional dhole roadkill, and dholes can get caught in traps that are set for other prey, not for dholes.
- Predation of livestock by dholes, leading to human retaliation and intentional killing by poisoning or by shooting
- Human safety fears and a general dislike of dholes
- Habitat conversion: humans moving into dhole habitat results in more human-dhole conflicts.
- Desire to keep wildlife as pets: people will kill the mother dhole and keep the puppies as pets. It is not common, but the trend is increasing (also for other species such as gibbons and leopard cats); some cases have occurred in Malaysia and in Baluran, Indonesia. This issue may link to the economic issue.
- Concerns that if we educate the public about dholes, this may increase people's desire to keep dholes as pets.
- Dholes are seen as competitors for wild prey by poachers.
- Dholes create inter-human competition for space for natural resource collection (for resources such as bamboo and medicines), as humans do not want to forage in areas where there are dholes.

GOAL STATEMENTS

Four goals statements were developed by the working group to mitigate human-dhole conflict:

C.G.1. Increase understanding of the dhole's ecological, cultural, and socio-economical values to increase positive attitudes towards the species and to make it a high priority species for conservation at local, national and global levels.

C.G.2. Minimize socio-economic losses caused by dholes to prevent retaliatory killing of dholes by humans.

C.G.3. Refute the perception that dholes are evil and fearsome to reduce their persecution by humans.

C.G.4. Reduce indirect mortality of dholes in order to maintain viable populations of dholes.

POTENTIAL STRATEGIES

The working group brainstormed and developed 23 potential strategies (listed below) to achieve the goals. Because larger dhole populations may have more conflicts with human, the working group suggested that instead of focusing on dhole population growth, it is better to aim to maintain or sustain viable dhole populations. The group also noted the following:

The situations are very different among countries and areas where dholes are found. All strategies developed by the working group should be further evaluated for feasibility and risk in each country and area before implementation.

Ecological, Cultural and Socio-economic Value

C.1.1. Raise awareness about dhole biology, ecology, and prey density, as well as the species' role in ecosystem health, local culture, and its socio-economic benefits to rural communities.

C.1.2. Evaluate the perceptions of local communities, government authorities, researchers, and policy makers about dholes [(3)*].

C.1.3. Develop education and outreach programs for the general public on the conservation significance of dholes [(4)].

Economic Loss and Retaliatory Killing

C.2.1. Conduct economic evaluations of the role of dholes in controlling the population of crop predators [(1)].

C.2.2. Assess and monitor livestock losses to dholes.

C.2.3. Assess the potential of the dhole as a target species for eco-tourism.

C.2.4. Educate all stakeholders about the ecological, cultural, and socio-economic benefits of dholes [(1,3)].

C.2.5. Develop country-specific compensation/insurance schemes for livestock losses due to predation by dholes.

C.2.6. Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corrals, livestock guards in the state forests) to minimize dhole predation).

C.2.7. Develop country-specific guidelines for pasture land management.

C.2.8. Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.

C.2.9. Reduce the conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc.).

C.2.10. Increase communications with stakeholders at all levels (2,3).

C.2.11. Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).

C.2.12. Establish an incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) (4).

C.2.13. Conduct trainings on conflict resolution for community representatives/liaisons (3).

Negative Perceptions

C.3.1. Secure funds to develop documentaries that highlight the ecological, socio-economic and culture importance of dholes (1).

C.3.2. Develop science-based education materials for schools, social media and government officers.

C.3.3. Engage zoo education programs to include positive stories about dholes in their conservation messages.

C.3.4. Communicate with community leaders about the positive aspects of dholes.

Indirect Mortality

C.4.1. Conduct regular monitoring of traps/snares to reduce unintentional killing of dholes.

C.4.2. Improve road signage to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.

C.4.3. Establish wildlife overpasses/underpasses to prevent dhole roadkill.

Table 4. Summary of issues, goal statements, and potential strategies for the Human-Dhole Conflict Working Group.

Issues	**Goal Statements**	**Potential Strategies**
• Misconceptions (lack of understanding of conservation value of dholes, often perceived as bad guys, no ecological roles, dholes cause declines in prey populations) • Habitat conversion (people moving into dhole habitat results in human-dhole conflicts) • The desire to keep wild dholes as pets (killing the mother and keeping the puppies as pets)	C.G.1. Increase the understanding of the dhole's ecological, cultural, and socio-economical values to increase positive attitudes toward the species and to make it a high priority species for conservation at local, national and global levels.	C.1.1. Raise awareness about dhole biology, ecology, and prey density, and the species' role in ecosystem health, local culture, and its socio-economic benefit to rural communities. C.1.2. Evaluate the perceptions of local communities, government authorities, researchers, and policy makers about dholes [(3)*]. C.1.3. Develop education and outreach programs for the general public on the conservation significance of dholes [(4)].
• Dhole predation of livestock (leading to human retaliation and intentional killing of dholes by poisoning or shooting) • Dholes are seen as competition for wild prey by poachers • Dholes create inter-human competition for space for natural resource collection (of things like bamboo and medicines), as humans do not want to forage in areas where there are dholes.	C.G.2. Minimize socio-economic losses caused by dholes to prevent retaliatory killings by humans.	C.2.1. Conduct economic evaluations of the role of dholes in controlling the population of crop predators [(1)]. C.2.2. Assess and monitor livestock losses to dholes. C.2.3. Assess the potential of the dhole as a target species for eco-tourism. C.2.4. Educate all stakeholders about the ecological, cultural, and socio-economic role of dholes [(1,3)]. C.2.5. Develop country-specific compensation/insurance schemes for livestock losses due to predation by dholes. C.2.6. Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corrals, livestock guard in the state forests) to minimize dhole predation. C.2.7. Develop country-specific guidelines for pasture land management. C.2.8. Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey

Issues	Goal Statements	Potential Strategies
		species. C.2.9. Reduce the conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc.). C.2.10. Increase communications with stakeholders at all levels (2,3). C.2.11. Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options). C.2.12. Establish an incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) (4). C.2.13. Conduct trainings on conflict resolution for community representatives/liaisons (3).
• Human safety fears and a general dislike of dholes	C.G.3. Refute the perception that dholes are evils and fearsome to reduce their persecution by humans.	C.3.1. Secure funds to develop documentaries that highlight the ecological, socio-economic & culture importance of dholes (1) C.3.2. Develop science-based education materials for schools, social media and government officers. C.3.3. Engage zoo education programs to include positive stories about dholes in their conservation messages. C.3.4. Communicate with community leaders about the positive aspects of dholes.
• Unintentional killing of dholes: overdevelopment and overpopulation by humans leads to more unintentional dhole roadkill, and dhole can get caught in traps set by humans for other prey	C.G.4. Reduce indirect mortality of dholes in order to maintain viable populations.	C.4.1. Conduct regular monitoring of traps/snares to reduce unintentional killing of dholes. C.4.2. Improve road signage to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas. C.4.3. Establish wildlife overpasses/underpasses to prevent dhole roadkill.

** (#) note Strategy is also related to additional Goal statements indicated by the number.*

WORKING GROUP: DOGS AND DISEASE TRANSMISSION

Participants: *Bhaskar Acharya, Ventie Angela, Chelsea Davis, Pallavi Ghaskadbi, Martin Gilbert (facilitator/recorder/presenter), Ryan Rodrigues*

ISSUE: UNKNOWN IMPACTS OF DOGS ON DHOLES

The Dogs and Disease Transmission Working Group focused on the potential threat to dholes of domestic and feral dogs, including the potential for disease transmission. The impact of dogs and disease transmission on dhole population viability is different among countries and depends on the stray or domestic dog populations. For example, in Bhutan the domestic dogs held by villagers can be aggressive and territorial, but in Peninsular Malaysia, dogs are rare because of the local people's main religion.

The working group discussed and identified several issues for dholes around dogs and disease transmission. Dogs could have a direct effect on dhole populations by exclusion and aggressive interactions with them, or dogs could have an indirect effect on dholes through competition for prey resources, misidentification and hybridization. Disease transmission could have direct impacts on dholes through increased mortality, and indirect impacts by increasing the mortality of the prey population. However, there is not enough scientific evidence to uncover the relationships, mechanisms and regional variables between dhole and dog populations.

Dogs could have impacts on dhole population through:

- Exclusion
- Competition for prey resources
- Aggressive interactions (potentially leading to conflict)
- Misidentification
- Hybridization?

Disease transmission could have impacts on dhole population through:

- Direct - mortality of dholes
- Indirect – mortality of prey populations

There is a lack of scientific information on these impacts.

GOAL STATEMENTS

According to these issues, the working group developed the following two goal statements:

D.G.1. Identify locally appropriate measures to reduce the presence of dogs in protected areas and critical dhole habitat in order to minimize the potential for conflict, competition and disease transmission.

D.G.2. Understand the impact of infectious disease on the viability of dhole populations, either directly or through infection of prey species, in order to identify appropriate research that can guide management strategies where they are required.

POTENTIAL STRATEGIES

The following 16 strategies were generated by working group for achieving the goal statements, noting the following caution:

The dog and disease transmission situations are very different between the countries and areas where dholes are found. All strategies developed by the working group should be further evaluated for feasibility and risk in each country and area before implementation.

Dogs

D.1.1. Characterize dog ownership patterns around specified dhole populations.

D.1.2. Assess the size of free-ranging dog populations*

D.1.3. Identify critical ecological and sociological drivers affecting dog abundance and distribution.

D.1.4. Assess the attitudes of the local people to dogs and to potential dog population control measures, including the benefits of control (e.g. improved sanitation and public health).

D.1.5. Design strategies to control dog population sizes and distribution in consultation with local communities, government, health professionals and local NGOs.

D.1.6. Implement control strategies in an adaptive fashion with appropriate monitoring.

** Recognizing that the categorization of free-ranging dog populations may include a spectrum from village dogs (with some human provisioning) to feral dogs (with no human provisioning).*

Range-wide health capacity and response

D.2.1. Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.

D.2.2. Creation of a range-wide health network within the IUCN SSC Dhole Working Group for collaborative research and the sharing/publication of health data.

Local health capacity and response

D.3.1. Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease transmission and how to recognize disease outbreaks.

D.3.2. Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.

D.3.3. Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.

D.3.4. Where required, develop local laboratory capacity to perform key diagnostic protocols.

D.3.5. Incorporate identified pathogens into population viability models to assess relative threat.

D.3.6. Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes and/or prey species.

D.3.7. Interpretation of epidemiology to design locally appropriate management strategies.

D.3.8. Implement control strategies in an adaptive fashion with appropriate monitoring.

Table 5. Summary of issues, goal statements, and potential strategies for the Dog and Disease Transmission Working Group.

Issues	**Goal Statements**	**Potential Strategies**
Dogs could have impacts on dhole population through: • Exclusion • Competition for prey resources • Aggressive interactions (potentially leading to conflict) • Misidentification • Hybridization?	D.G.1. Identify locally-appropriate measures to reduce the presence of dogs in protected areas and critical dhole habitat in order to minimize the potential for conflict, competition and disease transmission.	D.1.1. Characterize dog ownership patterns around specified dhole populations. D.1.2. Assess the size of free-ranging dog populations* D.1.3. Identify critical ecological and sociological drivers affecting dog abundance and distribution. D.1.4. Assess the attitudes of the local people to dogs and to potential dog population control measures, including the benefits of control (e.g. improved sanitation and public health). D.1.5. Design strategies to control dog population sizes and distribution in consultation with local communities, government, health professionals and local NGOs. D.1.6. Implement control strategies in an adaptive fashion with appropriate monitoring.
Disease transmission could have impacts on dhole population through: • Direct - mortality of dholes • Indirect – mortality of prey populations	D.G.2. Understand the impact of infectious disease on the viability of dhole populations either directly or through infection of prey species, in order to identify appropriate research that can guide management strategies where they are required	*Develop range-wide health capacity and response* D.2.1. Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics. D.2.2. Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data. *Develop local health capacity and response* D.3.1. Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease transmission and how to recognise disease outbreaks. D.3.2. Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.

Issues	Goal Statements	Potential Strategies
		D.3.3. Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples. D.3.4. Where required, develop local laboratory capacity to perform key diagnostic protocols. D.3.5. Incorporate identified pathogens into population viability models to assess relative threat. D.3.6. Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes and/or prey species. D.3.7. Interpretation of epidemiology to design locally appropriate management strategies. D.3.8. Implement control strategies in an adaptive fashion with appropriate monitoring.

** Recognizing that categorization of free-ranging dog populations may include a spectrum of provisioning from village dogs (some human provisioning) to feral dogs (no human provisioning).*

POPULATION VIABILITY ANALYSIS

PVA Modeller: Kathy Traylor-Holzer, IUCN SSC Conservation Planning Specialist Group

POPULATION VIABILITY ANALYSIS

The purpose of this Population Viability Analysis (PVA) was to develop a *VORTEX* population model for the dhole (*Cuon alpinus*) that could be used to identify those factors that are most critical to population viability, identify important data gaps that impact dhole viability and management decisions, and provide a general assessment of viability for the taxon. PVA results informed discussions by the PHVA working groups regarding research and management recommendations.

The simulation software program *VORTEX* (v10.3.5) was used to conduct the dhole PVA. *VORTEX* is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild or captive small populations. *VORTEX* models population dynamics as discrete sequential events that occur according to defined probabilities. The program begins by either creating individuals to form the starting population or importing individuals from a studbook database and then stepping through life cycle events (e.g., births, deaths, dispersal, catastrophic events), typically on an annual basis. Events such as breeding success, litter size, sex at birth, and survival are determined based upon designated probabilities that incorporate both demographic stochasticity and annual environmental variation. Consequently, each run (iteration) of the model gives a different result. By running the model hundreds of times, it is possible to examine the probable outcome and range of possibilities. For a more detailed explanation of *VORTEX* and its use in population viability analysis, see Lacy (1993, 2000) and Lacy *et al.* (2017).

Computer modeling is a valuable and versatile tool for quantitatively assessing risk of decline and extinction of wildlife populations, both free ranging and managed. Complex and interacting factors that influence population persistence and health can be explored, including natural and anthropogenic causes. Models can also be used to evaluate the effects of alternative management strategies to identify the most effective conservation actions for a population or species and to identify research needs. Such an evaluation of population persistence under current and varying conditions is commonly referred to as a population viability analysis (PVA). The usefulness of a PVA is dependent upon the quantity and quality of data available on the biology of the species, its current population status, and current and future threats. Limited data mean limited applicability of the results; however, PVA often can provide useful information even with a modest amount of data.

DHOLE MODEL DEVELOPMENT

A preliminary *VORTEX* biological model for dholes was developed based on input values provided by dhole experts participating in the PVA and PHVA workshops and were based on a combination of published literature, unpublished data and expert opinion. This preliminary model was reviewed, discussed and revised by dhole experts (government, academic, NGO and zoo representatives) at a two-day PVA and SDM model development workshop held at Kasetsart University on 20-11 February 2019. A revised PVA model was presented to all participants during the PHVA workshop for discussion and final revisions. This model was used as a basis for sensitivity testing and general viability projections. The model operates on a one-year time step, with projections running for 50 years into the future (with 500 iterations per scenario). The final values used in the base model are described below.

Little is known about dhole ecology and population biology. Most published reports on wild dhole demographic rates are based on observations of only a few packs. The 2015 IUCN Red List assessment for dholes used the better-studied African wild dog (*Lycaon pictus*) as a surrogate species for several aspects of dhole population biology, recognizing the two species' similarity in morphology, reproduction, social behavior and feeding behavior (Kamler *et al*. 2015). In some cases, African wild dog data were considered in developing the base dhole population model. Data were also taken from analysis of captive studbook data from the Dhole EEP (Maisch, 2016) using the *PMx* software program (Ballou *et al*. 2018).

All data sources were combined along with expert opinion on both dholes and general canid biology to develop a biological model for dholes, representing a healthy dhole population with sufficient habitat and resources for positive growth and in the absence of significant threats. This enabled the development of a base model with demographic rates that match a reasonable intrinsic rate of growth expected for this type of species. This base model then was used to investigate the sensitivity of model results to different parameters, to population size (and associated stochastic effects), and to threats that result in the loss of individuals (e.g., persecution).

DEMOGRAPHIC AND GENETIC MODEL INPUTS

Breeding structure and reproductive rates

Dholes are social canids that form packs typically of 5-10 individuals, occasionally up to 30 or more. Each pack occupies a territory that varies depending upon prey characteristics, terrain and other factors. Generally, only one alpha pair breeds within the pack, and this pair can retain their alpha status and pair bond over multiple years.

VORTEX does not explicitly model packs or territories. However, it is possible to assign characteristics such as social status to individuals in the model, and to assign demographic rates based on these characteristics. Given this information, the mating system was modeled as long-term monogamy, with almost all breeding done by alpha pairs, as described below.

First age of potential reproduction was set at age 3 for both sexes (Venkataraman 1998). Individual State (IS) variables were used in *VORTEX* to assign and track alpha status of females (IS1) and track years of alpha tenure (IS2). Alpha pair formation and maintenance was modeled as follows:

- Females have 8.5% chance of becoming alpha at age 3 years (first potential reproductive year)
- Non-alpha females age 4-8 years old have a 17% chance each year of gaining alpha status
- Alpha females retain alpha status for a maximum of 4 years or until they reach age 9, whichever comes first; females over age 8 are considered to be post-reproductive.
- Male mates assigned to alpha females are considered to be alpha males. Adult males do not show reproductive senescence in the model and may breed at age 3 years and older. Young males (age 3) are half as likely to breed as males 4 years and older.
- Male alpha tenure is modeled as shorter than that of females. After two consecutive breeding seasons together as a pair, there is a 50% chance each year that the pair bond will break (i.e., male loses his alpha status). In such cases, or if the alpha male dies, the alpha female pairs with a new male.
- Alpha pairs have a 90% chance of producing a litter in any given year (with only one litter produced per year).
- Non-alpha females age 3-7 years have a 2% chance of producing a litter in any given year, allowing for a low level of reproduction by non-alpha individuals.

This model structure and input values result in a mean alpha female tenure of 2.6 years, and an average of ~28% of adult females producing a litter in a given year, matching expert opinion of 25-30%. Maximum age in the wild population was set at 10 years for both sexes (see Mortality Rates below).

Litter size

Dholes can have large litters, with up to 12 pups observed in a single litter; thus, maximum litter size was set at 12. Litter size at birth is difficult to observe in the wild. Distribution of litter sizes taken from studbook data (Maisch 2016) were reviewed along with the litters size distribution modeled for African wild dog populations in the wild (Davies-Mostert 2010), as an example of a similar pack-living canid with large litters.

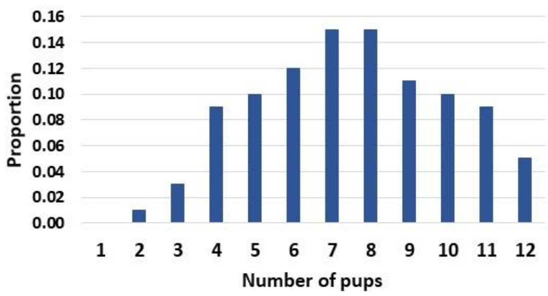


Figure P1. Litter size distribution used in PVA model.

Participants reached consensus on the littler size distribution in Figure P1 as reasonable for dholes. This distribution results in a mean litter size at birth = 7.5 pups and a reasonable intrinsic growth rate when combined with reproductive and mortality rates (see below).

Mortality rates

Few data are available for mortality rates in wild dhole populations. In addition to natural causes of mortality (e.g., injury, disease, aging), dholes are lost from the population through hunting, human-dhole conflicts and other human-related threats. In the absence of significant threat, dhole populations would be expected to be capable of growth at a rate typical for their life history characteristics. Mortality rates for dholes that assume the absence of such threats were estimated based on consideration of studbook captive data, field observations for African wild dogs and dholes, and on expert opinion informed by dhole, African wild dog and social canid life history traits.

In a pattern typical of many species, first-year mortality starting at birth was estimated to be relatively high, followed by moderate sub-adult mortality, relatively lower mortality for prime age adults, and increasing mortality in aging individuals (see Table P1 for age-specific rates).

Table P1. Annual mortality rates and EV used in the dhole *VORTEX* base model and sensitivity testing. Survival rates are given for clarification; mortality rates were used in the model. F=female; M=male

Age class (yr)	Base model values			Sensitivity testing values									
				Survival rates (%)					Resulting mortality rates (%)				
	Annual mortality (%)	EV (%)	Annual survival (%)	1.1xB	1.05xB	Base (B)	0.95xB	0.9xB	1.1xB	1.05xB	Base (B)	0.95xB	0.9xB
0	40	8	60	66	63	60	57	54	34	37	40	43	46
1 (F)	15	3	85	93.5	89.25	85	80.75	76.5	6.5	10.75	15	19.25	23.5
(M)	10	3	90	99	94.5	90	85.5	81	1	5.5	10	14.5	19
2 (F)	25	5	75	82.5	78.75	75	71.25	67.5	17.5	21.25	25	28.75	32.5
(M)	15	2	85	93.5	89.25	85	80.75	76.5	6.5	10.75	15	19.25	23.5
3-7	12	2	88	96.8	92.4	88	83.6	79.2	3.2	7.6	12	16.4	20.8
8	20	2	80	88	84	80	76	72	12	16	20	24	28
9	50	2	50	55	52.5	50	47.5	45	45	47.5	50	52.5	55

Captive dhole studbook data indicate first-year mortality at 35% (birth to one year of age), much of which occurs during the first month. Woodroffe (2011) reports 29% mortality from age 3-12 months in an African wild dog wild population. Dhole experts estimated first-year mortality (birth to one year) at 40% for this model as a reasonable value. Sub-adult females have been reported to disperse from their natal pack more frequently than sub-adult males, potentially exposing them to higher risk and resulting in a male bias in the population (Venkataraman 1998), although it is not clear how strong this bias may be across the species' range. Higher sub-adult (12-36 months) mortality was modeled for females (63.75% survival) than for males (76.5% survival). Adult annual mortality was modeled as higher than that in captivity (7%), with lower mortality in prime age adults and rising mortality as adults age (>7 years) (see Table P1). Maximum age in the wild population was set at 10 years for both sexes. While dholes can live to age 10-12 years (maximum of 16) in captivity, Venkataraman (1998) reports that older dholes disappear from wild packs at 7-8 years old. These mortality rates were developed to produce deterministic growth rates expected to match generation time and other life history traits associated with intrinsic growth rate. The resulting sex-specific survivorship curves are given in Figure P2, and resulting age pyramid in Figure P3.

When combined with the above reproductive rates, this survival schedule leads to an annual intrinsic (deterministic) growth rate of ~11% and a generation time (i.e., average age of reproduction) of ~5.8 years. These attributes are reasonable for a mammal species with this general life history not under excessive threat. Deterministic growth rate is lower than that in the African wild dog *VORTEX* model (17%) by Davies-Mostert (2010) due to lower reproductive rates and smaller mean litter size, but is believed to be a conservative and reasonable estimate for dhole populations in good conditions. Sex-specific mortaltiy rates lead to a slightly male-biased adult population (55% male, 45% female).

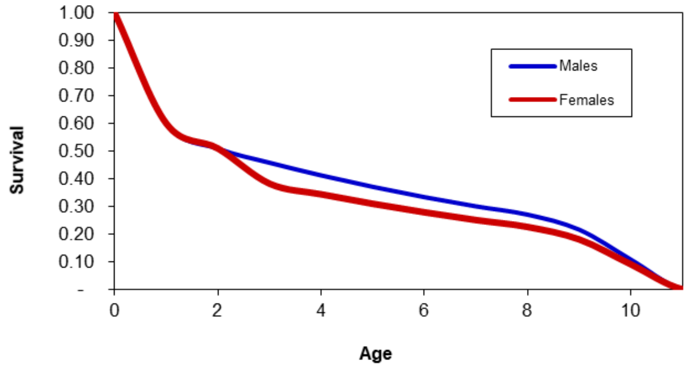


Figure P2. Survivorship curves (Lx) for males and females based on mortality rates in Table P1.

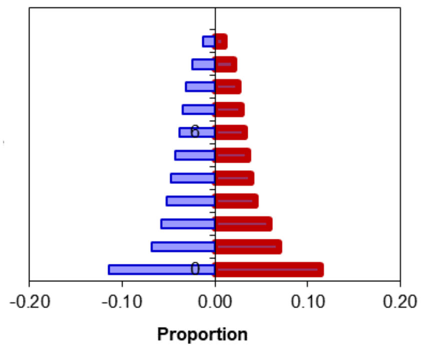


Figure P3. Age pyramid (yearly age classes) based on mortality rates in Table P1.

Variation in demographic rates

Actual reproductive and mortality rates vary from year to year in the real world and can impact population viability, especially for small populations. The *Vortex* model incorporates stochastic (chance) variation in four ways that represent the sources of stochasticity outlined by Shaffer (1981). First, the actual proportion of dholes surviving and reproducing each year varies around the mean rate due to chance based on population size, which is known as demographic variation and is an inherent property of the model. Secondly, annual variation in environmental conditions (EV) can lead to good or poor survival and/or reproduction from year to year. This was incorporated into the mortality rates in the model by adding EV (in most cases, as a standard deviation of 20% of the mean rate) for all mortality rates (see Table P1), and SD=5 for reproductive rate. EV for reproduction and survival were 75% correlated, such that model years that are good for survival also tend to be good for reproduction and vice versa.

A third source of variation are catastrophic events, which could be natural (e.g., fire, disease) or anthropogenic (e.g., toxin contamination). For dholes, a source of concern is the risk of disease outbreak posed by domestic dogs, although there may be other unforeseen risks. A non-specific catastrophic was added to the model that represents the loss of 50% of that population at a low frequency (~once in 40 years, or 2.5% risk per year). This is the default setting for the model and is based on an assessment of 88 vertebrate populations that found the risk of severe population decline (≥ 50%) to be approximately 14% per generation (Reed *et al.* 2003).

Genetic processes are also incorporated into the model, both as the random loss of genetic variation (genetic drift) and as inbreeding depression (lower viability of inbred individuals). *Vortex* models inbreeding depression as reduced survival in inbred juveniles; the severity of the effect is determined by the number of lethal equivalents (LE) in the model. O'Grady *et al.* (2006) concluded that 12.29 lethal equivalents spread across survival and reproduction is a realistic estimate of inbreeding depression for wild populations. The default setting in *Vortex* recommended as a conservative estimate of inbreeding impacts is 6.29 LEs, with 50% of these due to recessive lethal alleles and subject to purging. Given the social breeding structure of dholes, it was hypothesized that the species may be less sensitive to inbreeding impacts (i.e., lower genetic load). The dhole model incorporates 3 LEs, one of which (33%) is due to a recessive lethal allele. This equates to lower sensitivity of the model to inbreeding impacts (i.e., smaller reduction in the survival of inbred offspring than the default setting).

Regulation of population size

No density-dependent reproduction or mortality was incorporated into the model. When population size (N) exceeds carrying capacity (K), population size is controlled by the probabilistic removal of individuals across all age and sex classes (e.g., loss of a pack).

SENSITIVITY TESTING OF MORTALITY AND BREEDING RATES

Mortality rates for the base model were derived to produce a reasonable age structure, survivorship and other population characteristics expected for a large, healthy dhole population capable of positive growth. Actual mortality rates for dholes may be different, especially for populations subjected to hunting or removals due to conflict. Depending upon the mating system and other life history characteristics, species may be more vulnerable to increased mortality of certain age and/or sex classes. Sensitivity testing was conducted to explore the relative impact of proportional changes in survival for juveniles (first year), sub-adults (ages 1 and 2), and adults (age 3+). Survival was changed $\pm$ 5% of the base value (see Table P1 for specific values used). For this comparison, it is more appropriate to apply proportional changes to survival rather than to mortality. Scenarios with $\pm$ 5% change in probability of pairs breeding were also explored (i.e., % alpha females producing a litter changed from 90% to 94.5% and 85.5%, respectively). The model was initiated with the starting population (N) with a stable age distribution and at the habitat carrying capacity (K), with no future loss of habitat and no connectivity with other dhole populations. All scenarios were run with N=K=500 to minimize results being driven by random stochastic impacts affecting small populations. For comparison, base stochastic growth rate (r_{stoch}) = 0.1028.

Impact of survival by sex and age

Model results indicate that the same proportional change in survival (mean rate $\pm$5%) has very different impacts on stochastic growth rate of the population depending upon sex and, to a less extent, age class. While a change of this magnitude in male survival has essentially no effect, the same change in female survival influences growth (Figure P4). Changes in adult female survival have the greatest effect, as adult females represent the breeding potential of the male-biased (1.2M:F) population due to higher mortality rates for sub-adult females in the model. One caveat: these model scenarios assume that the relative proportion of breeding females is constant under different mortality rates; in reality, the proportion of adult females that breed may vary depending upon which females experience higher mortality; for example, death of an alpha vs non-alpha female may not have the same impact. These results suggest a potential important data gap in differential survival between sexes and also for alpha vs non-alpha adults. It also suggests that conservation management actions that help protect populations from the loss of female sub-adult and adult dholes would promote population viability.

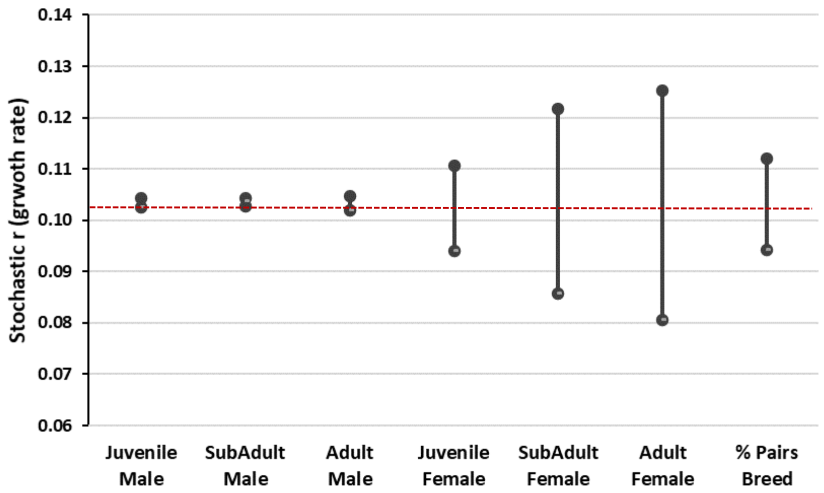


Figure P4. Sensitivity analysis results (stochastic growth rate) for +5% change in annual survival and in % alpha pairs producing a litter. Red dashed line indicates base value of 0.1028.

Impact of pair breeding success

The same proportional change in the percent of alpha females producing a litter has a measureable impact on stochastic growth, but less than that for sub-adult and adult survival (Figure P4).

FACTORS AFFECTING POPULATION VIABILITY

The *VORTEX* model for dholes was developed based on the best available data and expert opinion of the participants at the PVA and PHVA workshops. This base model represents a single isolated dhole population in the absence of significant threat (e.g., persecution or habitat loss) and with the potential for positive growth if prey and habitat availability permits. If applied to a hypothetical large panmictic (interbreeding) population of 500 dholes, model results indicate a generally healthy population with an overall stochastic annual growth of ~10%, retention of high levels of genetic variation, the ability to recover from severe short-term decline, and no risk of extinction over 100 years in the absence of additional threats.

Unfortunately, many dhole populations are not large and/or are not free from threats. There are no reliable population estimates of wild dhole populations. The Red List assessment states that dhole populations are declining in most areas due to several main threats (including depletion of prey base, habitat loss, persecution and disease transmission from domestic dogs) (Kamler *et al*. 2015). The authors state that most if not all current subpopulations are relatively small and isolated, with one of the largest subpopulations estimated at 207-304 individuals. Some subpopulations were estimated by workshop species experts to be as small as 15-20 individuals.

One consequence of small population size is greater vulnerability to stochastic processes. Demographic and environmental variation can lower stochastic growth rate in small populations. This in turn reduces the ability of small populations to recover from catastrophic events or other population losses. If isolated, small populations will accumulate inbreeding more quickly and therefore will be exposed to its impacts. These cumulative effects can lead to a feedback loop of effects of population decline known as an “extinction vortex” (Gilpin and Soulé 1986).

Without good information on population numbers, trends and threats, it is not possible to generate precise viability projections for dhole populations in the wild. However, as with survival rates, sensitivity analysis can be used to explore the impact of factors such as population size on dhole population viability. Scenarios were developed to explore the impact of population size, including the relative resilience of populations to catastrophic events and inbreeding, the impact of threats across population sizes, and the level of supplementation that may be needed to counteract these impacts. This exploration should provide a relative understanding of the viability of dhole populations across a range of conditions.

Categorizing viability

There is no one scientific definition of population viability. Viability is a socio-political construct and its interpretation can be influenced by factors such as the cultural value or ecological importance of a species and how risk tolerant managers and other stakeholders are in regards to preserving the population or species. In order to compare scenarios across population size and other factors, it is useful to develop a relative classification of viability. Table P2 outlines a set of color-coded categories (from green to red) designed to indicate relative levels of viability based upon probability of extinction, stochastic growth rate, gene diversity, and the ability of the population to fill the available habitat and resources. *These definitions are for illustrative comparisons in this report only and can be defined differently depending upon priorities and perspectives.*

Table P2. Definitions used for color-coding model scenario results.

Probability of extinction (50yrs)	≤ 1%	≤ 5%	≤ 10%	≤ 20%	>20%
Stochastic r	≥ 6%	≥ 4%	≥ 2%	≥ 1%	< 1%
Habitat saturation (N/K)	≥ 80%	≥ 65%	≥ 50%	≥ 40%	< 40%
Gene diversity	≥ 90%	≥ 85%	≥ 75%	≥ 65%	< 65%
	DECREASING RELATIVE VIABILITY →				

Impact of population size on viability

Scenarios were run on populations at carrying capacity for isolated populations with N=K=25, 50, 75, 100, 200, 300 and 400 to encompass the probable range of fragmented dhole populations. As with the sensitivity testing for survival, all scenarios were initiated with stable age distributions and assumed no connectivity and no additional threats such as hunting or habitat loss. Scenario results (500 iterations per scenario) are presented in Table P3.

Table P3. Model results for isolated dhole populations of various size at 50 years. N=population size; K=carrying capacity; GD=gene diversity; PE=probability of extinction. Mean N_{50Y} and G_{50Y} are calculated at Year 50 and for only those iterations in which the population did *not* go extinct.

Pop size (N=K)	Growth rate (r_{stoch})	Mean $\pm$SD N_{50Y}	Mean GD_{50Y}	PE_{50Y}	Mean N_{50Y}/K
25	0.028	16$\pm$7	0.503	0.548	0.63
50	0.060	39$\pm$13	0.688	0.114	0.77
75	0.076	64$\pm$17	0.777	0.028	0.85
100	0.084	88$\pm$20	0.826	0.006	0.88
200	0.095	185$\pm$33	0.910	0	0.93
300	0.099	281$\pm$44	0.940	0	0.94
400	0.102	377$\pm$52	0.955	0	0.95

As expected, small populations have lower viability than larger ones. The smaller the population, the slower the growth rate and ability to recover from declines, the faster the loss of genetic diversity and accumulation of inbreeding, and in general the higher the risk of extinction. Isolated populations of 25 dholes have a high risk of extinction (>50%) within 50 years, with any persisting populations becoming smaller (mean N=16) and highly inbred (mean F=0.415). Populations of 50-75 dholes fare better but still are at risk due to stochastic processes (PE=0.028-0.114), with loss of genetic variation roughly equivalent to going from unrelated individuals to a full sibling population after 50 years. Model results suggest that a panmictic population of about 200 dholes, free from additional threats, is required to meet common indicators of long-term viability. Populations of this size have no estimated risk of extinction within 50 years, retain at least 90% genetic diversity, and show strong positive growth and the ability to recover from short-term catastrophic decline. Additional threats, however, such as persecution, may lower the viability of populations of this size. Actions that promote the expansion or connectivity of small dhole populations may increase viability as long as they are not associated with higher vulnerability to threats.

Impact of catastrophic events and inbreeding

Both stochastic processes – severe catastrophic decline and reduced juvenile survival in inbred individuals – have some effect on population growth and extinction risk (Table P4). These effects are more pronounced in smaller populations. However, the relative overall pattern of viability classification is the same for each population size, regardless of whether or not these processes are included in the model. Even in the absence of catastrophes and inbreeding, very small isolated populations (N=25) have significant extinction risk (PE_{50Y}=0.234) and very low genetic variation (GD_{50Y}=0.485) due to demographic and environmental variation impacts. Populations of 200 or more are sufficiently large to be buffered against catastrophes and inbreeding as modeled, at least over 50 years. Model results suggest that isolated populations of around 50 dholes show the biggest difference in viability with or without catastrophes and inbreeding depression. Given the widespread observation of catastrophic events (Reed *et al*. 2003) and inbreeding depression (O'Grady *et al*. 2006) in wild vertebrate populations, it is prudent to include these processes in viability projections as a realistic estimate of the viability of fragmented dhole populations.

Table P4. Model results for 50 years, for base scenario and removing inbreeding impacts and/or catastrophic events (N=mean population size; r = stochastic r; GD=mean gene diversity; PE=probability of extinction. Mean N and GD calculated only for iterations that did not go extinct.

	N=25	N=50	N=75	N=100	N=200
Inbreeding Catastrophes (Base)	PE_{50}=0.548 r=0.028 N/K_{50}=0.63 GD_{50}=0.503	PE_{50}=0.114 r=0.060 N/K_{50}=0.77 GD_{50}=0.668	PE_{50}=0.028 r=0.076 N/K_{50}=0.85 GD_{50}=0.777	PE_{50}=0.006 r=0.084 N/K_{50}=0.88 GD_{50}=0.826	PE_{50}=0 r=0.095 N/K_{50}=0.93 GD_{50}=0.910
Catastrophes (no inbreeding)	PE_{50}=0.370 r=0.073 N/K_{50}=0.80 GD_{50}=0.465	PE_{50}=0.056 r=0.091 N/K_{50}=0.88 GD_{50}=0.664	PE_{50}=0.018 r=0.098 N/K_{50}=0.90 GD_{50}=0.765	PE_{50}=0 r=0.100 N/K_{50}=0.91 GD_{50}=0.827	PE_{50}=0 r=0.104 N/K_{50}=0.93 GD_{50}=0.910
Inbreeding (no catastrophes)	PE_{50}=0.370 r=0.049 N/K_{50}=0.72 GD_{50}=0.505	PE_{50}=0.032 r=0.080 N/K_{50}=0.85 GD_{50}=0.707	PE_{50}=0.002 r=0.095 N/K_{50}=0.93 GD_{50}=0.796	PE_{50}=0 r=0.103 N/K_{50}=0.96 GD_{50}=0.847	PE_{50}=0 r=0.113 N/K_{50}=0.93 GD_{50}=0.918
Neither (no inbreeding) (no catastrophes)	PE_{50}=0.234 r=0.091 N/K_{50}=0.82 GD_{50}=0.485	PE_{50}=0.012 r=0.110 N/K_{50}=0.93 GD_{50}=0.692	PE_{50}=0 r=0.117 N/K_{50}=0.97 GD_{50}=0.787	PE_{50}=0 r=0.119 N/K_{50}=0.97 GD_{50}=0.836	PE_{50}=0 r=0.122 N/K_{50}=0.93 GD_{50}=0.915

Impact of harvest and other losses

Many, if not most, dhole populations do not live in secure, resource-rich habitats but may experience additional threats that impact survival, such as prey depletion, direct persecution and increased disease risk from domestic dogs. Whatever the cause, the loss of individuals from the population in addition to natural mortality can reduce viability, especially if the rate of loss exceeds the ability of the population to sustain its numbers.

Scenarios were developed to explore the viability of dhole populations (N= 25 to 400) under various levels of 'harvest' (i.e., additional loss of dholes from the population) at the annual rates of 2.5%, 5%, 7.5% and 10%. Harvest was modeled as a probability of removal for each individual age 1 and older and so incorporated some stochasticity in actual removal rates in any given year. For example, a harvest rate of 2.5% on a population of 100 dholes would remove either 2 or 3 dholes in most years, but might occasionally remove more or fewer, with an overall average of 2.5 per year.

Results of harvest scenarios can be found in Table P5. Base model results (i.e., no harvest) is also given for easy comparison. Very small isolated populations (N=25) have low viability even in the absence of additional losses. Larger populations of 200+ dholes can withstand moderate levels of loss ($\leq$ 5%) and still have relatively high long-term viability; higher levels of loss lead to population decline, loss of genetic variation and some risk of extinction. The greatest relative impact of harvest is on populations of 50-100 dholes, reducing population and genetic diversity and leading to increased risk of extinction that increase with higher harvest rates.

Across much of the species' range, actual dhole population sizes and rates of loss due to human-related threats are unknown. The results in Table P5 provide a matrix of possible conditions across population sizes and rates of loss that managers and researchers can use to estimate the range of viability estimates for particular dhole populations. These projections are simplifications and do not incorporate, for example, differential behavioral consequences of removal of alpha vs non-alpha individuals or the loss of whole packs. They can, however, inform the relative vulnerability of dhole populations to demographic and genetic challenges, and suggest the importance of actions to reduce threats that result in loss of dholes from the wild.

Table P5. Model results for 50 years, for base scenario and with various levels of annual harvest (N=mean population size; r = stochastic r; GD=mean gene diversity; PE=probability of extinction. Mean N and GD calculated only for iterations that did not go extinct.

Annual harvest	N=25	N=50	N=75	N=100	N=200	N=300	N=400
0	PE_{50}=0.548 r=0.028 N/K_{50}=0.63 GD_{50}=0.503	PE_{50}=0.114 r=0.060 N/K_{50}=0.77 GD_{50}=0.668	PE_{50}=0.028 r=0.076 N/K_{50}=0.85 GD_{50}=0.777	PE_{50}=0.006 r=0.084 N/K_{50}=0.88 GD_{50}=0.826	PE_{50}=0 r=0.095 N/K_{50}=0.93 GD_{50}=0.910	PE_{50}=0 r=0.099 N/K_{50}=0.94 GD_{50}=0.940	PE_{50}=0 r=0.102 N/K_{50}=0.95 GD_{50}=0.955
2.5%	PE_{50}=0.726 r=0.006 N/K_{50}=0.57 GD_{50}=0.450	PE_{50}=0.224 r=0.033 N/K_{50}=0.65 GD_{50}=0.652	PE_{50}=0.064 r=0.052 N/K_{50}=0.78 GD_{50}=0.757	PE_{50}=0.032 r=0.062 N/K_{50}=0.82 GD_{50}=0.813	PE_{50}=0.008 r=0.075 N/K_{50}=0.91 GD_{50}=0.909	PE_{50}=0 r=0.079 N/K_{50}=0.92 GD_{50}=0.938	PE_{50}=0 r=0.082 N/K_{50}=0.92 GD_{50}=0.954
5%	PE_{50}=0.782 r= -0.011 N/K_{50}=0.51 GD_{50}=0.438	PE_{50}=0.306 r= 0.018 N/K_{50}=0.63 GD_{50}=0.655	PE_{50}=0.134 r=0.029 N/K_{50}=0.69 GD_{50}=0.741	PE_{50}=0.064 r=0.037 N/K_{50}=0.74 GD_{50}=0.802	PE_{50}=0 r=0.054 N/K_{50}=0.85 GD_{50}=0.901	PE_{50}=0 r=0.059 N/K_{50}=0.87 GD_{50}=0.933	PE_{50}=0 r=0.060 N/K_{50}=0.89 GD_{50}=0.950
7.5%	PE_{50}=0.874 r= -0.029 N/K_{50}=0.50 GD_{50}=0.437	PE_{50}=0.468 r= -0.010 N/K_{50}=0.53 GD_{50}=0.614	PE_{50}=0.220 r=0.003 N/K_{50}=0.56 GD_{50}=0.721	PE_{50}=0.130 r=0.015 N/K_{50}=0.64 GD_{50}=0.782	PE_{50}=0.020 r=0.028 N/K_{50}=0.73 GD_{50}=0.884	PE_{50}=0.002 r=0.035 N/K_{50}=0.79 GD_{50}=0.925	PE_{50}=0.002 r=0.039 N/K_{50}=0.83 GD_{50}=0.947
10%	PE_{50}=0.924 r= -0.046 N/K_{50}=0.41 GD_{50}=0.431	PE_{50}=0.658 r= -0.034 N/K_{50}=0.42 GD_{50}=0.556	PE_{50}=0.410 r= -0.021 N/K_{50}=0.45 GD_{50}=0.695	PE_{50}=0.228 r= -0.011 N/K_{50}=0.49 GD_{50}=0.745	PE_{50}=0.038 r=0.006 N/K_{50}=0.60 GD_{50}=0.864	PE_{50}=0.012 r=0.013 N/K_{50}=0.67 GD_{50}=0.912	PE_{50}=0.010 r=0.016 N/K_{50}=0.70 GD_{50}=0.935

Impact of supplementation

In addition to threat reduction and population expansion, another option for increasing the viability of dhole populations is through periodic reinforcement (supplementation) of isolated populations. This could occur naturally through long-range dispersal and/or through human-mediated translocations. The impact of small levels of population supplementation were explored through model scenarios that added one unrelated young adult dhole (equal probability of male or female) every 5 or 10 years. All demographic rates for supplements were the same as for resident dholes; that is, supplements were no more or less likely to gain alpha status and reproduce and had the same mortality rates and threats as residents. Supplementation numbers were constant across all population sizes (i.e., 1 supplement every 5 years, or 1 supplement every 10 years).

Table P6 provides the results of supplementation across all population sizes and across harvest rates to help assess the ability for supplementation to counteract impacts of threats and small size. All supplementation scenarios led to demographic and genetic benefits, including larger mean population size, higher genetic diversity, and lower risk of extinction given the model assumptions. The general impacts of population size and harvest rate remain with these levels of supplementation, with low viability in very small populations and good viability in populations of 200 or more. Populations of 50-100 dholes under low to moderate threat levels show significant reduction in extinction risk with supplementation rates of one adult dhole per 5 years (Figure P5). This suggests that actions to improve connectivity or other methods of population reinforcement may be most valuable and effective to populations in this general size range.

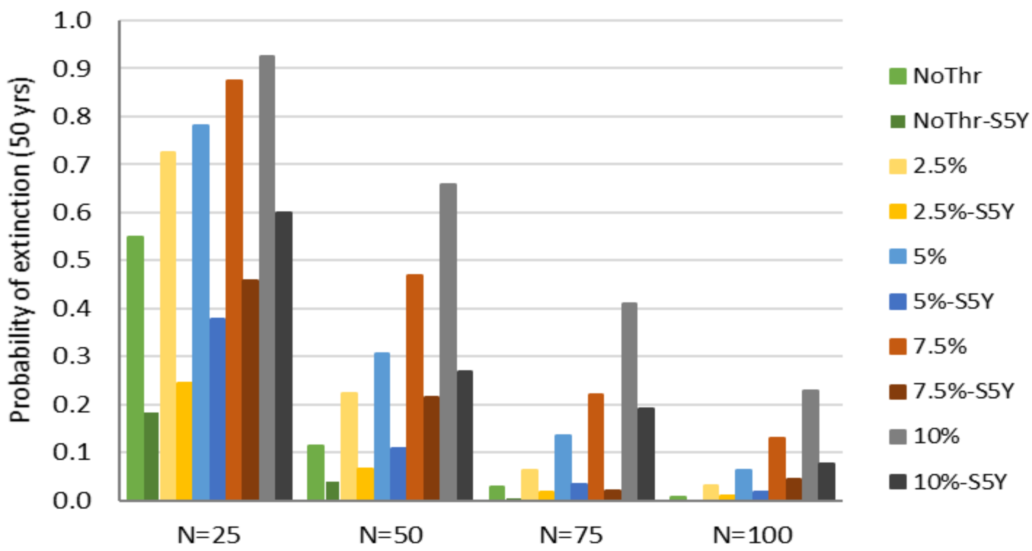


Figure P5. Probability of extinction (PE) in 50 years for dhole populations (N=K=25-100) under good conditions (NoThr) and under additional harvest (2.5-10% annually), with and without one supplement per 5 years. Paired colored bars represent scenarios for isolated populations (lighter) and when supplemented (darker).

These supplementation scenarios are based on simplifying assumptions but demonstrate that even a low level of connectivity can improve the viability of small, fragmented dhole populations through demographic and/or genetic rescue. Monitoring of small populations would enable the opportunity to access demographic (and potentially genetic) issues and inform more targeted supplementation activities to meet these needs, for example, through translocation.

Table P6. Model results for 50 years, for base scenario and with various levels of annual harvest and with supplementation (N=mean population size; r = stochastic r; GD=mean gene diversity; PE=probability of extinction. Mean N and GD calculated only for iterations that did not go extinct.

Annual harvest	N=25	N=50	N=75	N=100	N=200	N=300	N=400
	Supplement 1 dhole every 10 years						
0	PE_{50}=0.422 r=0.044 N/K_{50}=0.72 GD_{50}=0.643	PE_{50}=0.066 r=0.067 N/K_{50}=0.80 GD_{50}=0.749	PE_{50}=0.022 r=0.079 N/K_{50}=0.85 GD_{50}=0.803	PE_{50}=0.006 r=0.087 N/K_{50}=0.88 GD_{50}=0.841	PE_{50}=0 r=0.098 N/K_{50}=0.94 GD_{50}=0.918	PE_{50}=0 r=0.101 N/K_{50}=0.95 GD_{50}=0.942	PE_{50}=0 r=0.104 N/K_{50}=0.96 GD_{50}=0.956
2.5%	PE_{50}=0.490 r=0.030 N/K_{50}=0.69 GD_{50}=0.655	PE_{50}=0.132 r=0.047 N/K_{50}=0.74 GD_{50}=0.730	PE_{50}=0.034 r=0.058 N/K_{50}=0.78 GD_{50}=0.795	PE_{50}=0.010 r=0.064 N/K_{50}=0.83 GD_{50}=0.841	PE_{50}=0.002 r=0.077 N/K_{50}=0.91 GD_{50}=0.914	PE_{50}=0 r=0.081 N/K_{50}=0.92 GD_{50}=0.940	PE_{50}=0 r=0.082 N/K_{50}=0.92 GD_{50}=0.954
5%	PE_{50}=0.670 r=0.006 N/K_{50}=0.63 GD_{50}=0.652	PE_{50}=0.190 r=0.027 N/K_{50}=0.68 GD_{50}=0.723	PE_{50}=0.066 r=0.036 N/K_{50}=0.72 GD_{50}=0.788	PE_{50}=0.036 r=0.043 N/K_{50}=0.77 GD_{50}=0.830	PE_{50}=0.006 r=0.054 N/K_{50}=0.86 GD_{50}=0.909	PE_{50}=0 r=0.058 N/K_{50}=0.87 GD_{50}=0.937	PE_{50}=0 r=0.062 N/K_{50}=0.90 GD_{50}=0.952
7.5%	PE_{50}=0.676 r= -0.005 N/K_{50}=0.56 GD_{50}=0.640	PE_{50}=0.310 r=0.006 N/K_{50}=0.60 GD_{50}=0.722	PE_{50}=0.136 r=0.016 N/K_{50}=0.62 GD_{50}=0.775	PE_{50}=0.072 r=0.021 N/K_{50}=0.65 GD_{50}=0.808	PE_{50}=0.014 r=0.034 N/K_{50}=0.76 GD_{50}=0.898	PE_{50}=0.002 r=0.038 N/K_{50}=0.81 GD_{50}=0.929	PE_{50}=0 r=0.040 N/K_{50}=0.84 GD_{50}=0.947
10%	PE_{50}=0.826 r= -0.025 N/K_{50}=0.53 GD_{50}=0.641	PE_{50}=0.440 r= -0.013 N/K_{50}=0.46 GD_{50}=0.698	PE_{50}=0.246 r= -0.007 N/K_{50}=0.52 GD_{50}=0.754	PE_{50}=0.152 r= -0.005 N/K_{50}=0.53 GD_{50}=0.791	PE_{50}=0.026 r=0.011 N/K_{50}=0.63 GD_{50}=0.878	PE_{50}=0.006 r=0.014 N/K_{50}=0.68 GD_{50}=0.916	PE_{50}=0.002 r=0.018 N/K_{50}=0.72 GD_{50}=0.939
	Supplement 1 dhole every 5 years						
0	PE_{50}=0.184 r=0.065 N/K_{50}=0.72 GD_{50}=0.738	PE_{50}=0.038 r=0.076 N/K_{50}=0.83 GD_{50}=0.789	PE_{50}=0.004 r=0.085 N/K_{50}=0.87 GD_{50}=0.831	PE_{50}=0 r=0.090 N/K_{50}=0.90 GD_{50}=0.857	PE_{50}=0 r=0.098 N/K_{50}=0.93 GD_{50}=0.920	PE_{50}=0 r=0.102 N/K_{50}=0.94 GD_{50}=0.944	PE_{50}=0 r=0.103 N/K_{50}=0.95 GD_{50}=0.957
2.5%	PE_{50}=0.244 r=0.048 N/K_{50}=0.65 GD_{50}=0.722	PE_{50}=0.066 r=0.058 N/K_{50}=0.77 GD_{50}=0.774	PE_{50}=0.018 r=0.065 N/K_{50}=0.81 GD_{50}=0.817	PE_{50}=0.010 r=0.068 N/K_{50}=0.86 GD_{50}=0.854	PE_{50}=0 r=0.075 N/K_{50}=0.90 GD_{50}=0.915	PE_{50}=0 r=0.080 N/K_{50}=0.92 GD_{50}=0.942	PE_{50}=0 r=0.082 N/K_{50}=0.93 GD_{50}=0.955
5%	PE_{50}=0.378 r=0.030 N/K_{50}=0.60 GD_{50}=0.722	PE_{50}=0.108 r=0.036 N/K_{50}=0.70 GD_{50}=0.768	PE_{50}=0.034 r=0.042 N/K_{50}=0.74 GD_{50}=0.816	PE_{50}=0.018 r=0.049 N/K_{50}=0.80 GD_{50}=0.846	PE_{50}=0 r=0.056 N/K_{50}=0.85 GD_{50}=0.91	PE_{50}=0 r=0.060 N/K_{50}=0.89 GD_{50}=0.939	PE_{50}=0 r=0.061 N/K_{50}=0.89 GD_{50}=0.953
7.5%	PE_{50}=0.458 r=0.014 N/K_{50}=0.55 GD_{50}=0.726	PE_{50}=0.214 r=0.016 N/K_{50}=0.60 GD_{50}=0.762	PE_{50}=0.074 r=0.021 N/K_{50}=0.64 GD_{50}=0.803	PE_{50}=0.044 r=0.030 N/K_{50}=0.73 GD_{50}=0.842	PE_{50}=0.004 r=0.035 N/K_{50}=0.79 GD_{50}=0.905	PE_{50}=0.004 r=0.039 N/K_{50}=0.81 GD_{50}=0.935	PE_{50}=0.002 r=0.042 N/K_{50}=0.85 GD_{50}=0.948
10%	PE_{50}=0.600 r= -0.004 N/K_{50}=0.49 GD_{50}=0.722	PE_{50}=0.268 r= -0.006 N/K_{50}=0.47 GD_{50}=0.752	PE_{50}=0.190 r= -0.002 N/K_{50}=0.53 GD_{50}=0.787	PE_{50}=0.076 r=0.004 N/K_{50}=0.56 GD_{50}=0.819	PE_{50}=0.016 r=0.012 N/K_{50}=0.64 GD_{50}=0.890	PE_{50}=0.002 r=0.014 N/K_{50}=0.67 GD_{50}=0.923	PE_{50}=0.004 r=0.019 N/K_{50}=0.72 GD_{50}=0.942

CASE STUDY: KHAO YAI NATIONAL PARK DHOLE POPULATION

Given that this dhole PHVA workshop was held in Khao Yai National Park, there was some interest in exploring the general viability of its dhole population, which is believed to be geographically isolated from other wild dhole populations. Without better data on demographic rates and threats, it is not feasible to make a precise viability projection for the KYNP dhole population. However, if we assume that this population is not subject to substantial threat, is not inbred, and is not demographically unbalanced (i.e., has a relatively stable age and sex distribution), then we can consider its relative viability given population size and habitat carrying capacity estimates.

Two scenarios were developed, both with a starting (current) population of 55 dholes, but with differing habitat carrying capacities of K=60 and K=80. The scenario with K=60 assumes that the current dhole population is roughly at the park's capacity for dholes, while K=80 assumes that there are sufficient prey and other resources for some population growth and maintenance at a higher level.

Figure P6 illustrates the projected mean population size over 50 years (with significant variation around those means). While both scenarios show an average slow decline over time due to stochastic processes, including inbreeding, the conditions that allow the population to expand and maintain a larger size (K=80) lead to higher retention of gene diversity (0.783, vs 0.729) and a substantially lower extinction risk. A population with K=60 has approximately 5-fold increase in extinction risk (PE_{50Y}=0.072) than a population with K=80 (PE_{50Y}=0.016). Adding one adult dhole every 5 years through supplementation begins to stabilize population size and leads to higher gene diversity and much smaller extinction risk (PE_{50Y}=0.012 and 0.004, respectively) (Table P7). While there is uncertainty surrounding the precision of these projections, model results suggest that these two factors – population expansion and low levels of periodic supplementation – have the potential to substantially increase the viability of the KYNP dhole population.

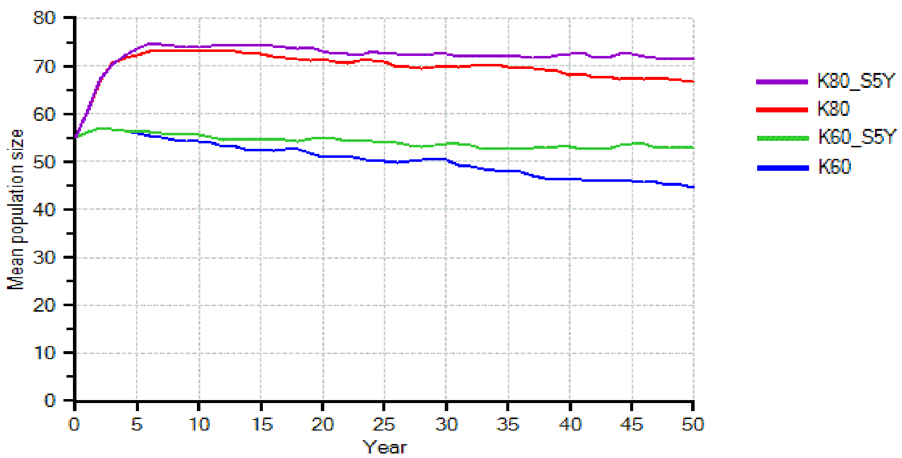


Figure P6. Mean population size projections for the Khao Yai NP dhole population over 50 years under good conditions and with K=60 or K=80, with and without one supplement per 5 years.

Table P7. Model results for the Khao Yai NP dhole populations modeled for 50 years under different K and with or without supplementation (1 adult per 5 years). N=population size; K=carrying capacity; GD=gene diversity; PE=probability of extinction. Mean N_{50Y} and G_{50Y} are calculated at Year 50 and for only those iterations in which the population did *not* go extinct.

K	Supplements	Growth rate (r_{stoch})	Mean ±SD N_{50Y}	Mean GD_{50Y}	PE_{50Y}	Mean N_{50Y}/K
60	--	0.068	48±16	0.729	0.072	0.80
60	1 per 5 years	0.090	53±11	0.813	0.012	0.89
80	--	0.077	68±18	0.783	0.016	0.85
80	1 per 5 years	0.093	72±15	0.844	0.004	0.90

IMPORTANT KNOWLEDGE GAPS

Given the results of this PVA and small population biology principles, the following factors were identified as the most important knowledge gaps for assessing the viability of wild dhole populations and to guide effective management strategies for conservation of this taxon.

Population size and degree of fragmentation: Species distribution modeling helps to identify potential suitable habitat and expected distribution of dholes. However, threats such as persecution associated with livestock depredation or recent depletion of prey species may affect dhole distribution and abundance. Better estimates are needed for current dhole population sizes and the degree of connectivity and successful movement of dholes among habitat patches. Good estimates of distribution, population size and effective connectivity will enable more reliable and population-specific long-term viability projections and also will inform effective management actions.

Demographic rates, especially mortality: Better understanding of wild dhole reproductive rates and age- and sex-specific mortality rates, as well as differences in rates of alpha vs non-alpha adults, will improve viability projections and may inform management decisions. Understanding the causes of mortality and the quantification of rates associated with various threats is also important in order to reduce or eliminate those threats.

Population-specific threats: Threats such as persecution or disease transmission from dogs may differ among different habitats, countries and dhole populations. It is important, both for viability projections and especially for management actions, to understand the type and level of threat for each population. Trends over time for each population would also be useful in understanding current and future viability.

CONCLUSIONS

Despite the uncertainty in demographic rates, population size and connectivity, and the rates of various human-caused threats of wild dholes, there is sufficient information available for PVA methods to provide useful information to help guide future research and potential management. General PVA conclusions are as follows:

- Dhole populations may be capable of strong growth in the absence of significant threats and in the presence of suitable habitat and prey.
- Panmictic single populations of several hundred dholes are likely to have good viability in the absence of significant threats. However, continuous loss of dholes due to various threats has the potential to drive such populations to decline and even potential extinction.
- In particular, the loss of sub-adult and adult female dholes due to persecution, disease or other causes may jeopardize the viability of small populations by reducing the reproductive potential for population growth and resilience to catastrophic events.
- Isolated small dhole subpopulations are highly vulnerable to stochastic processes and are not likely to be viable in the long term without some level of supplementation, either through connectivity to other wild dhole subpopulations and/or through human-mediated translocations.
- Good estimates of population size, trend, and threats (causes and sex-specific rates) are required in order to accurately understand the long-term viability of specific dhole populations.

This PVA suggests important data gaps and potential considerations for monitoring and management for dholes. As a generalist species with strong growth potential, the dhole has the potential to persist given sufficient habitat and prey and with protection from human-related threats or actions to counteract the impacts of those threats.

Acknowledgements

VORTEX and *PMx* software made available under a CreativeCommons Attribution-NoDerivatives International License, courtesy of the Species Conservation Toolkit Initiative (scti.tools).

See Appendix I for Literated Cited in the PVA Report

SPECIES DISTRIBUTION MODELLING

SDM Modeller: Katia Maria P. M. B. Ferraz, IUCN SSC CPSG Brasil

INTRODUCTION

Species Distribution Modeling (SDM) can be very useful to inform and guide decisions in conservation. Model results can help to set priorities for many different purposes such as field surveys, law enforcement, functional connectivity, conflict mitigation and others.

SDM searches for associations between species presence and a set of environmental variables (topographic, climatic, anthropogenic and/or landscape) to predict the potential species distribution across a landscape (Franklin 2009, Peterson et al. 2011). We used SDM as a tool in the Dhole Population and Habitat Viability Assessment (PHVA) workshop to model expected dhole distribution across South and Southeast Asia. We conducted model conceptualization, development and validation in an interactive process involving the active participation of dhole specialists from across the species' range to select the final model.

Participants identified the following reasons to develop a SDM for dholes: 1) identify potential areas for species survey; 2) identify areas where research may be needed to identify threats driving local extinction; 3) identify potential habitat for protected area management (e.g., potential corridors to connect population fragments); 4) identify primary limiting factors for species distribution; 5) compare historical and current distribution; 6) identify populations and meta-populations; 7) identify important information gaps to help prioritize research; 8) provide information to local authority/government/ex situ institutions to inform their management decisions; 9) help estimate carrying capacity for dhole populations for use in PVA models; and 10) improve IUCN species distribution information and map.

We ran several models with different combinations of predictors and discussed the model results with species experts at a model development meeting immediately prior to the PHVA workshop. A draft model was presented, discussed and revised by the participants at the PHVA workshop. All suggestions and inputs from the participants were incorporated into the model, and the final model was validated and accepted by consensus.

METHODS

Species Distribution Model (SDM)

Presence records (camera trapping, sightings, feces and tracks) were provided by the workshop participants and their colleagues exclusively for this modeling effort associated with the PHVA workshop. This resulted in 2520 GPS points (1495 unique points) recorded over the last 20 years (1999-present) (Figure S1). Of these, 1475 presence points were considered valid points for modeling, as 20 points were outside of the extent of the modeled area. We spatially rarified presence points at 20 km to avoid spatial autocorrelation using the SDMToolBox (v. 1.1.c, Brown 2014), resulting in 179 GPS random points selected for modeling. Seventeen additional presence points were provided after model validation and selection had been completed; of these, 9 (53%) were correctly predicted by the final model.

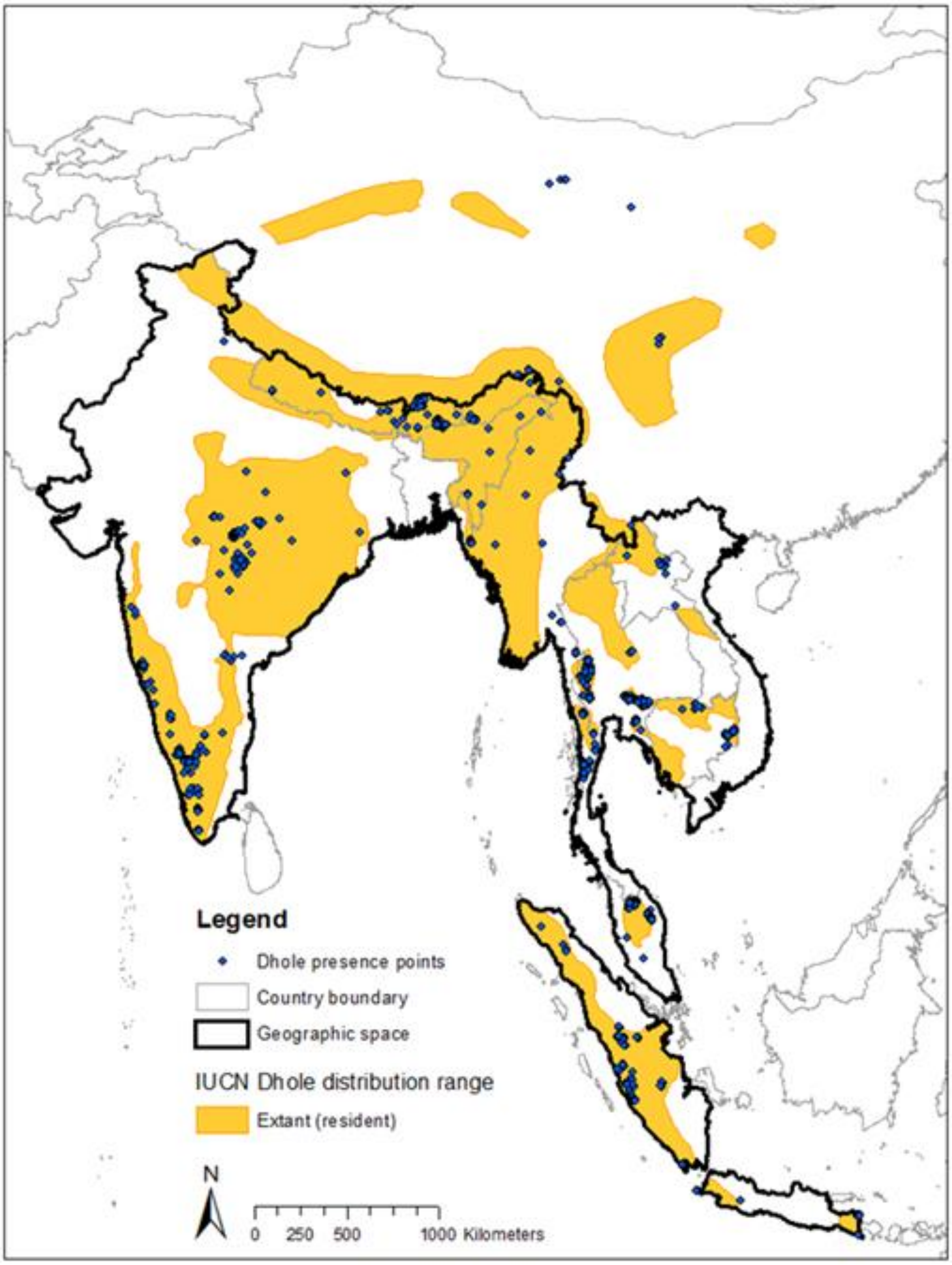


Figure S1. Presence GPS points for dholes provided for the workshop and geographic space modeled.

The extent of the modeled area (geographic space ~6,098,574 km^2) was defined considering the distribution polygon for dholes provided in the IUCN Red List Assessment (IUCN 2015) for dholes, selecting all countries covered by the species' distribution range. Our final model did not include China due to a small data set provided for the workshop, a broad range in bioclimatic characteristics, and an independent model currently being development in China. This decision was reached by consensus and with agreement from the Chinese representatives considering that excluding China led to a better predictive final model for other countries. The independent model developed previously for dhole distribution in China is included at the end of this report, with the permission of the authors, Sheng LI and Yadong XUE.

We selected functional predictors related to bioclimatic variables, terrain, human impacts, and landscape to run alternative models, and the correlated variables (> 0.7) were eliminated. This resulted in 14 predictors used to build the final model (Table S1). We resampled all predictors to a spatial resolution about 1 km.

We used MaxEnt (3.4.1, Phillips et al. 2006, Phillips & Dudík 2008, Phillips et al. 2017), the most well-known and used SDM algorithm, to run the predictive model. Maxent estimates a target probability distribution by finding the probability distribution of maximum entropy, subject to a set of constraints that represent incomplete information about the target distribution (Phillips et al. 2006). We set the default parameters plus random seed, write plot data, with bootstrap (30% of random test percentage and 10 replicates). The final result is a probabilistic model with pixel value ranging from 0 to 1.

We used the maximum test sensitivity plus specificity Cloglog threshold (0.3031) to cut the probabilistic model, resulting in a binary map with suitable (1) and unsuitable (0) patches for dholes. The higher the suitability value, the higher the probability is of finding the species in the field in the absence of threats not considered in the model, such as direct persecution. Therefore, in this model, suitability is mainly related to the probability of the species' presence in that area.

We generated a friction surface, a raster that depicts the ease of dispersal from each locality through the landscape, using the SDMToolBox (v.1.1.c, Brown 2014). This tool inverted the SDM for use as a friction surface, with areas of high suitability being converted to areas of low dispersal cost.

Table S1. Predictors for the dhole distribution model.

Predictors	Description	Source
Bioclimatic - bio2 (mean diurnal range) - bio3 (isothermality) - bio12 (annual precipitation) - bio15 (precipitation seasonality) - bio18 (precipitation of warmest quarter) - bio19 (precipitation of coldest quarter)	Gridded climate data, version 1.4	http://www.worldclim.org/
Tree cover	Percentage of tree cover	https://landcover.usgs.gov/glc/TreeCoverDescriptionAndDownloads.php
Land cover	Land cover map	http://due.esrin.esa.int/page_globcover.php
Human footprint	The Global Human Footprint Dataset	http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-footprint-geographic/
Elevation	Elevation raster	https://www2.jpl.nasa.gov/srtm/
Aspect	The downslope direction of the maximum rate of change in value from each cell to its neighbors	It was derived from the digital elevation model (https://www2.jpl.nasa.gov/srtm/)
Slope	Gradient, or rate of maximum change in z-value from each cell of a raster surface	It was derived from the digital elevation model (https://www2.jpl.nasa.gov/srtm/)
Ruggedness	Terrain ruggedness as the variation in three-dimensional orientation of grid cells within a neighborhood	Derived by altitude from SRTM (https://www2.jpl.nasa.gov/srtm/) and calculated by the Vector Ruggedness Measure (VRM) Toolbox for ArcGis
Human Population Density	Gridded Population of the World, Version 4 (GPWv4) Population Density Adjusted to Match 2015 Revision of UN WPP Country	http://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-adjusted-to-2015-unwpp-country-totals

RESULTS

Dhole potential distribution – across range

The potential distribution model for dholes was considered to be a good model (AUC = 0.888 ± 0.019, omission about 15%, p = 0) predicting about 1,054,303 km^2 (17.29% of total predicted area) as suitable for dholes (Figure S2a, b). Only 2.05% (~125,453 km^2) was predicted as highly suitable for dholes (suitability ≥ 0.75).

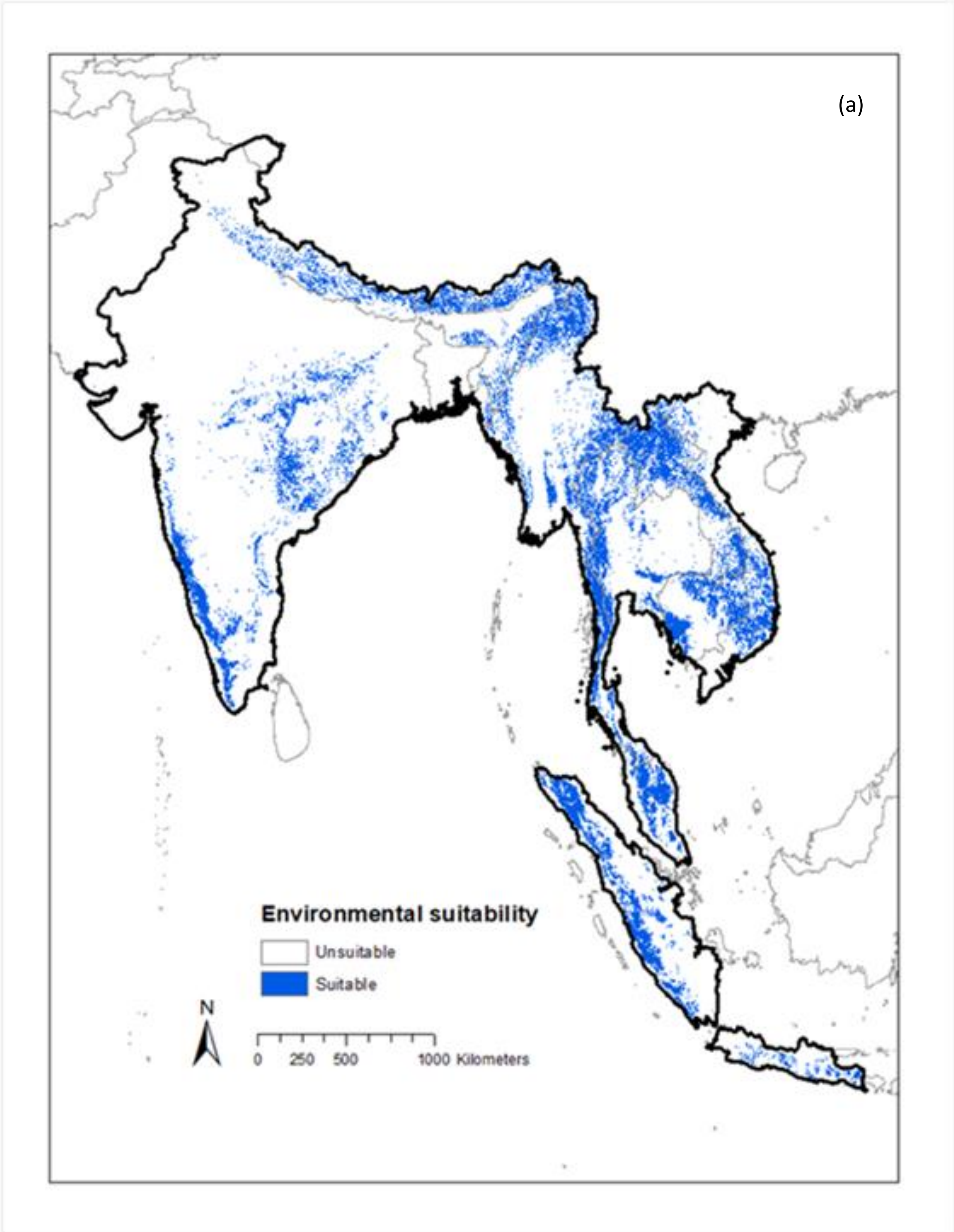


Figure S2. Potential distribution range (a) and potential probability of dhole presence (b).

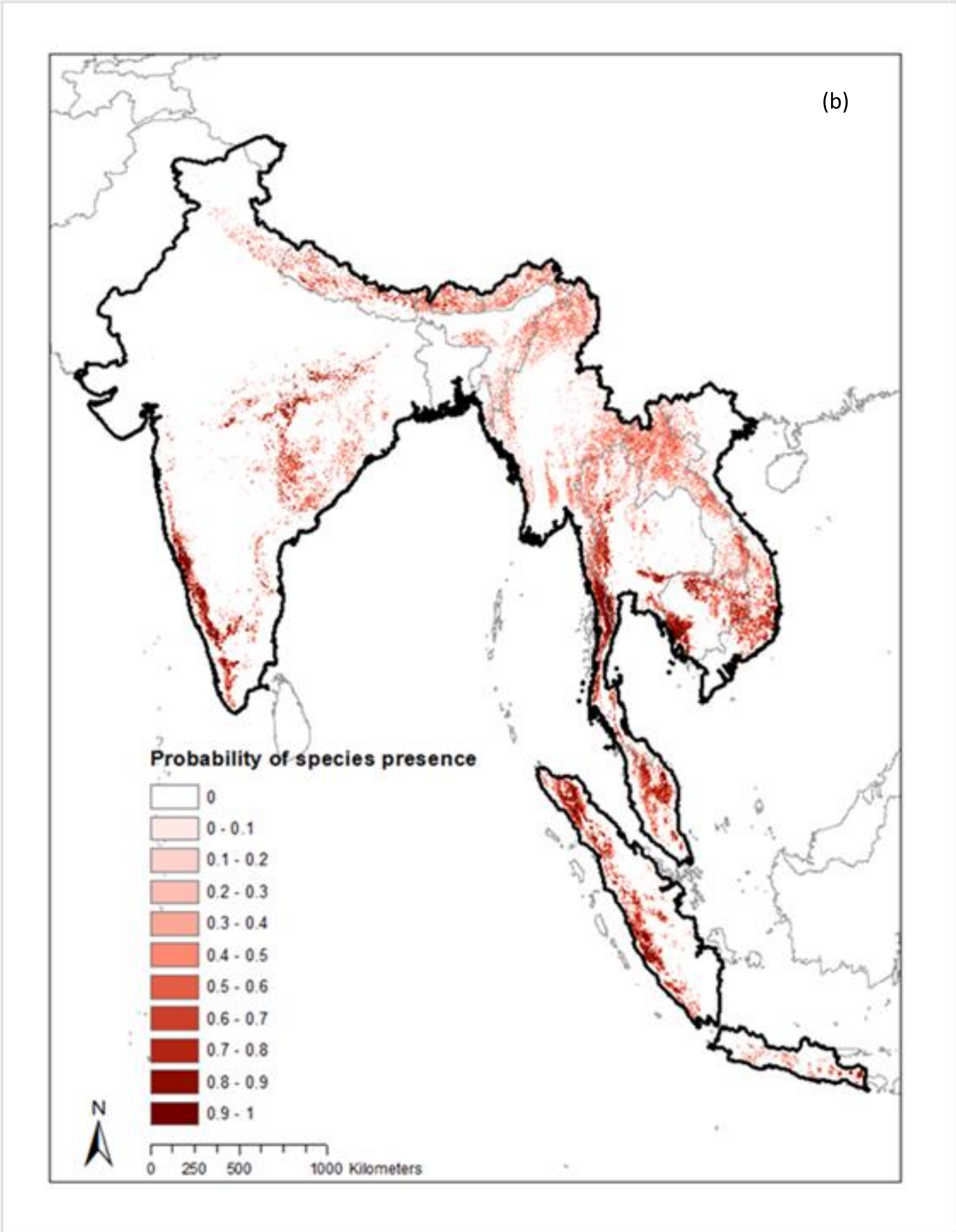


Figure S2. Potential distribution range (a) and potential probability of dhole presence (b).

Tree cover was the most important variable for model prediction, explaining about 39.49% of the model result (Figure S3), confirming that the dhole is a forest-dependent species.

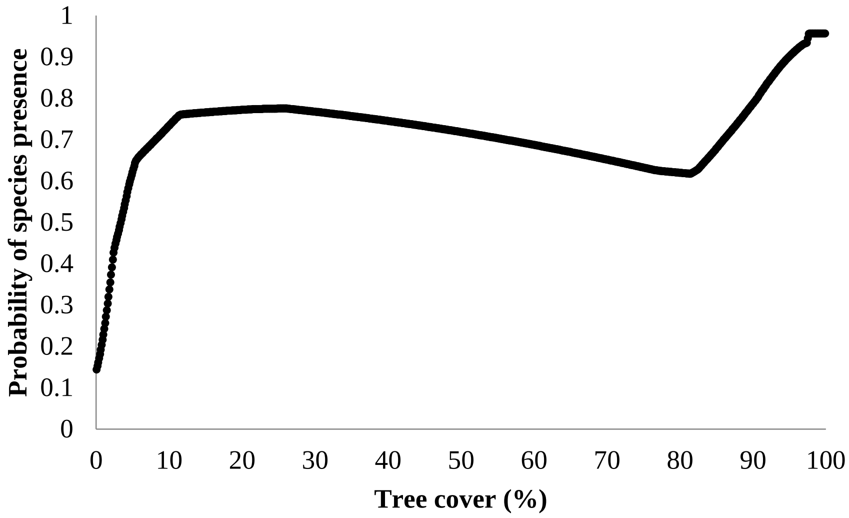


Figure S3. Response curve of the probability of species presence according to tree cover.

Dhole presence was confirmed in 38 suitable patches totaling an area about 1,044,206 km^2 (Figure S4). However, species presence still needs to be confirmed in many portions of the suitable patches selected where no points are currently available.

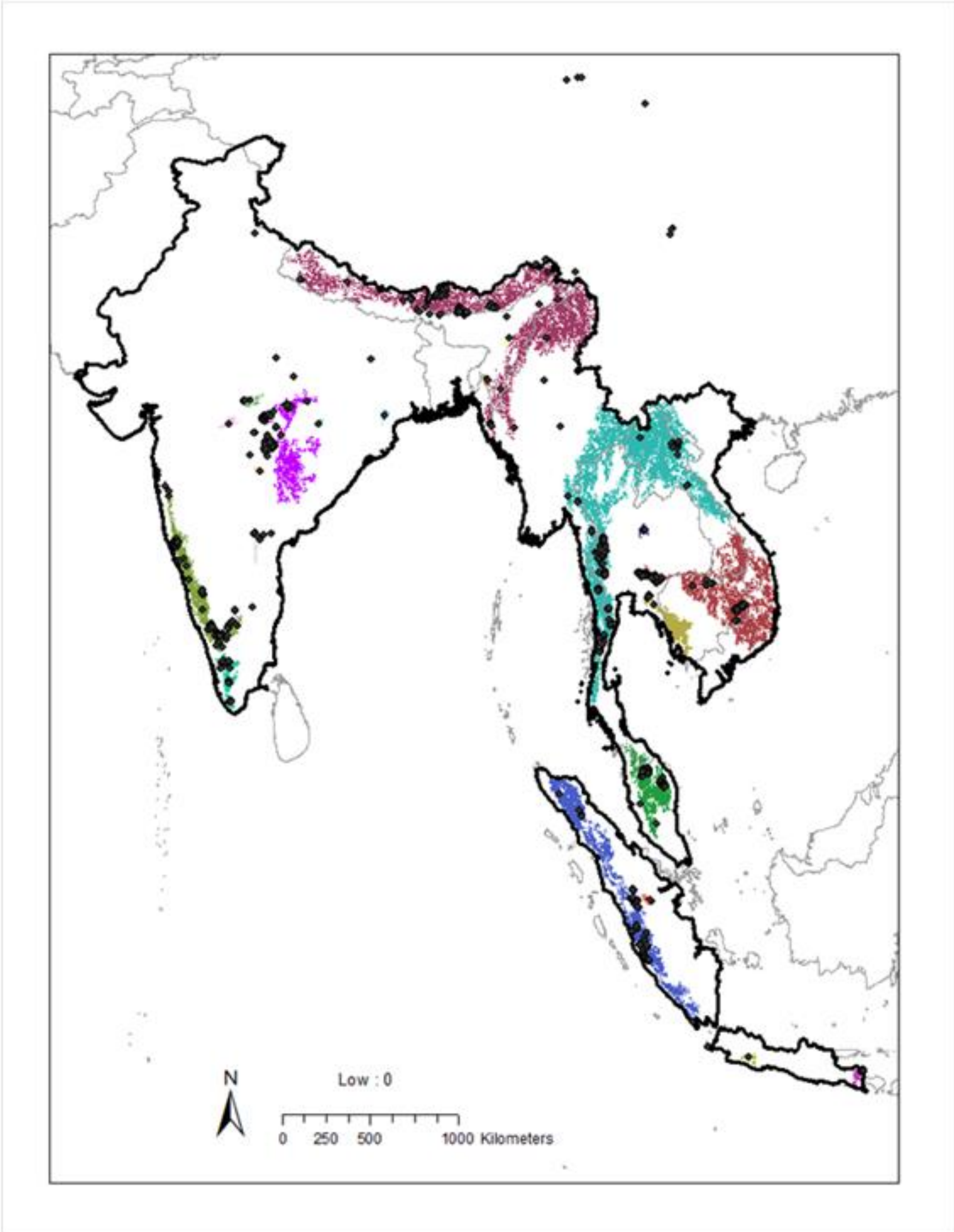


Figure S4. Suitable patches with confirmed species presence and the presence points provided.

The friction surface suggests high cost for dholes in movement between suitable patches in most portions of the species' range (Figure S5). This friction surface should be considered along with the dhole potential distribution model to help the investigation of potential population connectivity.

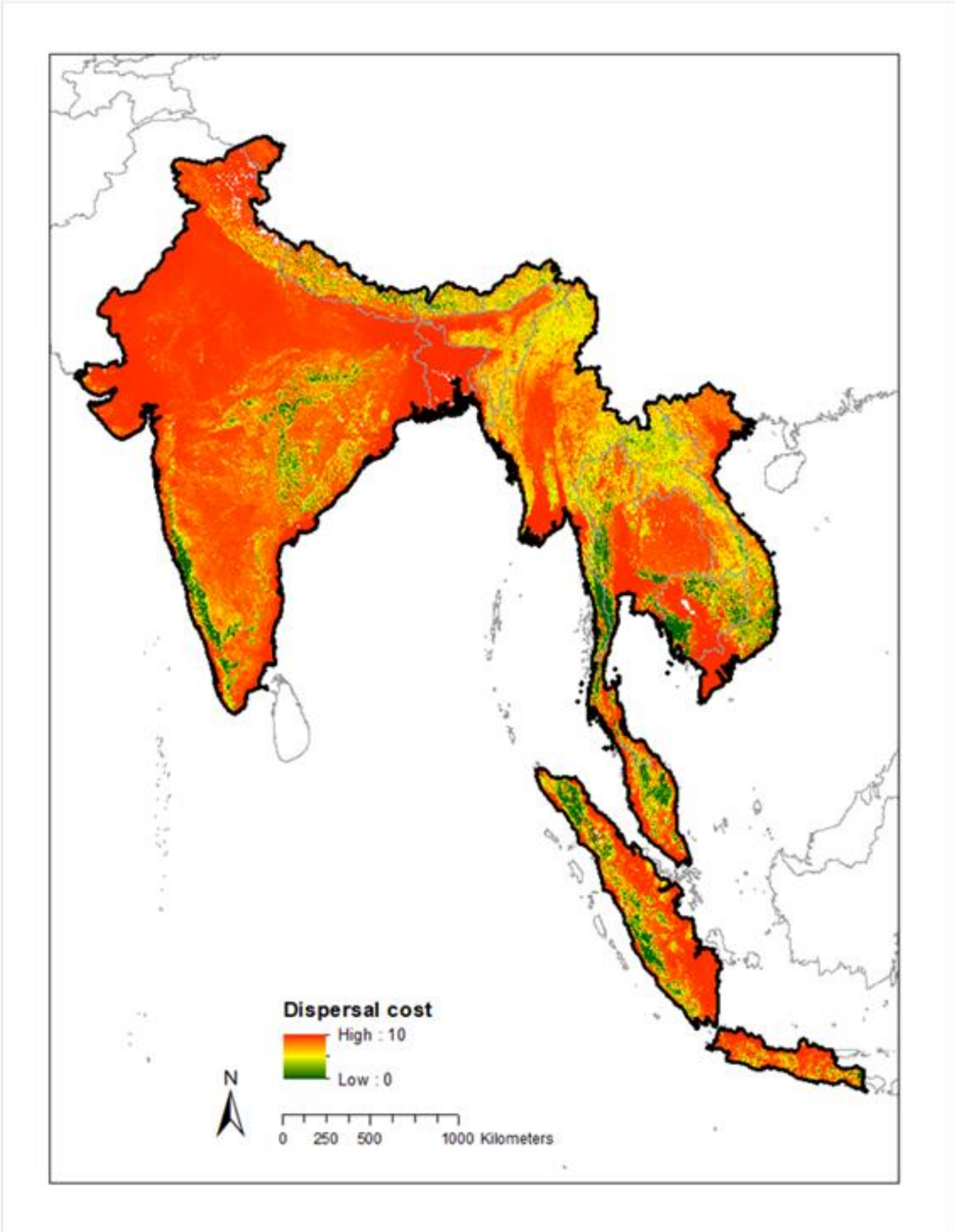


Figure S5. Friction surface with the dispersal cost for dhole movement across the landscape.

DHOLE POTENTIAL DISTRIBUTION – COUNTRY-BY-COUNTRY PERSPECTIVES

INDIA

Overall, predicted distribution (and high probability of occurrence) overlaps with forested areas (Figure S6). Based on current knowledge, highest probabilities and spatial spread coincide with three main landscapes: Western Ghats, Central India and Northeast India.

Some key protected areas in central India are omitted from predicted distribution, because of errors in the tree cover map used in the model. As a result, some important source populations were not well predicted by the model, and consequently, the 'population cluster' model for central India is moderately inaccurate. Therefore, we concluded that the percentage tree cover map used for this modeling exercise is not a reliable data layer for central India. It appears that the layer does not take into account atypical forest habitats- such as bamboo forests. Also, the map with population clusters showed only a single isolated cluster in the Eastern Ghats landscape. This is subject to verification/validation, but the area has a network of protected areas of relatively sub-optimal quality. There may be a larger connected population in this landscape.

The northern most part of western Maharashtra, abutting Gujarat and some areas in central North India do not have dholes. But the model predicts non-zero probability of dhole presence (commission error). In the central Western Ghats (State of Karnataka), the predicted probability is higher outside protected areas in some cases. This is likely a result of using "tree cover" which could also include agro-forests, orchards and plantations.

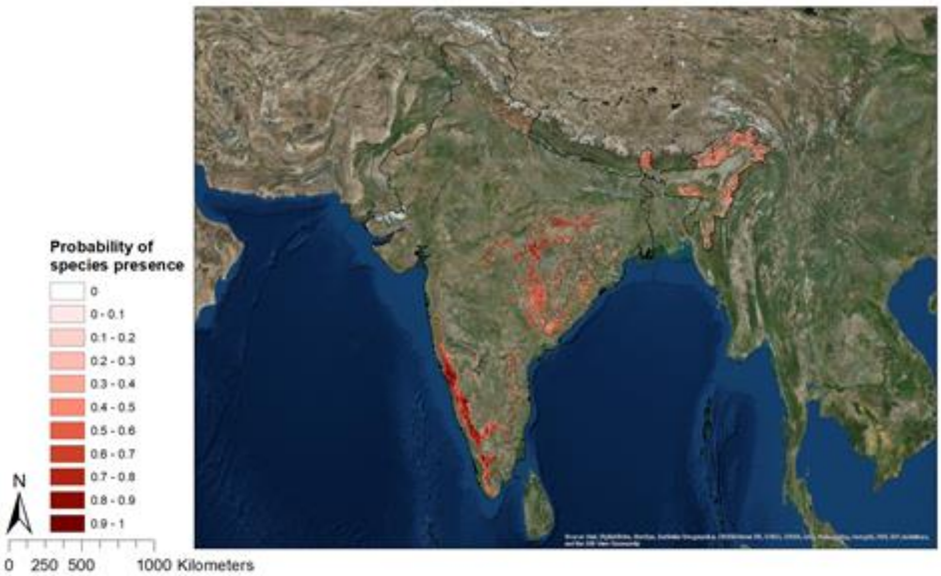


Figure S6. Potential distribution of dhole in India.

DHOLE DISTRIBUTION IN INDIA

A. Srivathsa, I. Majgaonkar, S. Sharma, G. Punjabi, P. Singh, M. Chawla, and A. Banerjee
(From Srivathsa et al. 2020 post-workshop publication; see citation below)

Data collection

We collected dhole distribution data in three phases. In phase 1, we used citizen-science data from countrywide web-based surveys over three months in 2018 (October to December 2018). In addition to our own survey, we also included carefully vetted records from other citizen-science portals*. In phase 2, we extracted data from wildlife, nature and photography pages on social media, online wildlife photo-repositories and reliable blog articles. In phase 3, we extracted information from published studies, unpublished theses, forest department reports and openly accessible project reports submitted to funding agencies. We thoroughly verified and validated each record, ensuring correct species identification, geographic location, and time (month and year) of record. We considered only reliable records of dhole presence, corresponding to the period from January 2015 to December 2018 (4-year period). At the end of this exercise, we had a total of 690 confirmed records (191 from phase 1, 417 from phase 2, and 82 from phase 3) of dhole presence from India.

Distribution model

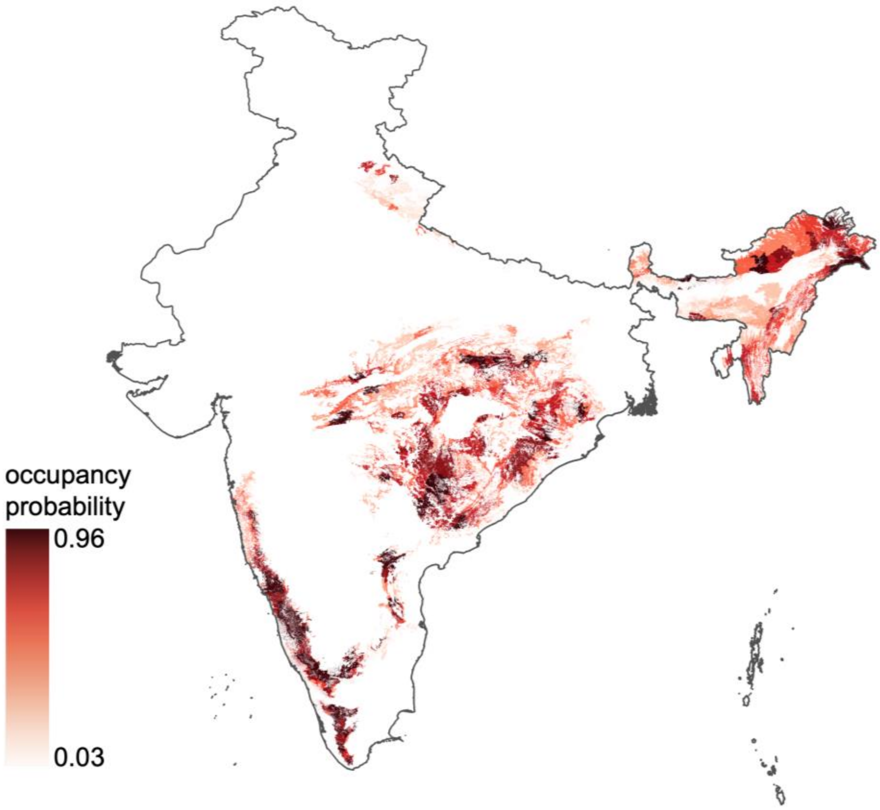
We treated administrative sub-districts ('*tehsil*' or '*taluk*') in the country as independent spatial units (mainland India has 2342 sub-districts). We first defined a plausible distribution range for dholes based on all available information from field guides, State forest department checklists, published literature and our own field-based knowledge (685 sub-districts were deemed plausible for dhole occupancy). Every presence record was then assigned to an administrative sub-district within the plausible range. We used an occupancy modelling framework that accounted for partial detectability to map distribution patterns (MacKenzie *et al*. 2018). Since our data pertained to presence-only information, we created detection histories using the following method – a given sub-district within the plausible range was labelled 'D' (detected) if we detected at least one dhole record in the four-year period; months with detections were assigned '1' and months with no detections were assigned '0'. Sub-districts were labelled 'ND' (not detected) when dhole was not detected across four years, but there was at least one detection of any of the other eight species surveyed (i.e., jackals, wolves, foxes and striped hyenas); all months in these sub-districts were assigned '0'. Sub-districts that did not have detections of any of the nine species during the four-year period were labelled 'NS' (not surveyed; see Powney et al. 2019). For analyses, we collapsed data from 48 months into four 12-month blocks, resulting in one temporal replicate per year. We built a set of candidate models with singular and additive effects of explanatory variables, based on specific *a priori* predictions. We fit occupancy models to detection/non-detection data using package 'unmarked' in program R v3.4.1 (R Core Team 2018).

Explanatory variables

We used a combination of remotely sensed data, government-generated figures, and estimates from published studies to compile information on explanatory variables. These variables (forest cover, agro-forest plantations, extent of Protected Areas, annual rainfall, terrain ruggedness, wild prey index, human population density, cattle density, and density of linear infrastructure) were chosen based on their expected influence on dhole presence. Land-use land cover categories were synthesized and combined from a total of 152 categories classified by Roy *et al.* (2015). Climate and topography data were extracted from remotely sensed satellite imagery. Data on Protected Areas, linear infrastructure (railways/ roadways) and human population densities were obtained from web-based open data sources. Population data on cattle and free-ranging dogs were sourced from government livestock census, and data on large wild prey were based on published literature. All the variables were re-processed at the sub-district scale for analyses.

Results

Our estimates suggest that dhole occupancy probability across plausible range from 0.03 to 0.96 at the sub-district level, with an average of 0.46. Dhole presence was positively associated with habitat cover (forests and agro-forests), wild prey index, extent of Protected Areas and rainfall, and negatively with terrain ruggedness, human population density and cattle density. For mapping the spatial probabilities, we first clipped each sub-district in the plausible range such that only dhole-specific habitats (forests and agro-forests) were retained. We then associated the estimated probabilities to the habitat extent in each sub-district. Our results indicate that dholes currently occupy ~49% of their potential habitats within their plausible range limits in India. This translates to roughly 2,49,606 sq. km of dhole-occupied area.



Citation: Srivathsa, A., Majgaonkar, I., Sharma, S., Punjabi, G., Singh, P., Chawla, M., Banerjee, A. (2020). Opportunities for prioritizing and expanding conservation enterprise in India using a guild of carnivores as flagships. Environmental Research Letters. doi: https://doi.org/10.1088/1748-9326/ab7e50

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NEPAL

Nepal is one of 47 least developed (UN, 2019) and a low-income country, but it is rich in natural resources. It is the 31^{st} most biodiverse country in the world and the 10^{th} most biodiverse country in Asia (MoAD, 2017). Water availability and forest cover is more than twice the South Asian per capita average (World Bank, 2018).

Nepal is 885 km long and 193 km wide, stretching from east to west in a roughly trapezoidal shape and covering an area of 147 181 sq.km. It is landlocked by China in the north and otherwise by India. The range in elevation within the country is vast: from 60 – 8,848m above sea level (asl). The country is commonly divided into five physiographic (Figure S7) and six bioclimatic zones (Table S2). Dholes are typically recorded in the lowland Terai - Siwalik (Parsa, Chitwan and Bardia National Park) and the hills - middle mountains (Kangchenjunga Conservation Area, Tinjure-Milke Jaljale and Annapurna Conservation Area) which include tropical, sub-tropical, temperate and sub-alpine climates.

Table S2. Physiographic and Bioclimatic Zone of Nepal.

Physiographic Zone	Coverage (%)	Elevation (m)	Bioclimatic Zone
High Mountains	23	Above 5000	Nival (Tundra and Arctic)
Middle Mountains	19	4000-5000	Alpine
		3000-4000	Sub-Alpine
Hills	29	2000-3000	Montane (Temperate)
		1000-2000	Sub-Tropical
Siwalik	15	500-1000	
Terai	14	Below 500	Tropical

Source: Dobremez (1976), Biodiversity Profile Project (1995) cited from GON/MoFSC (2014)

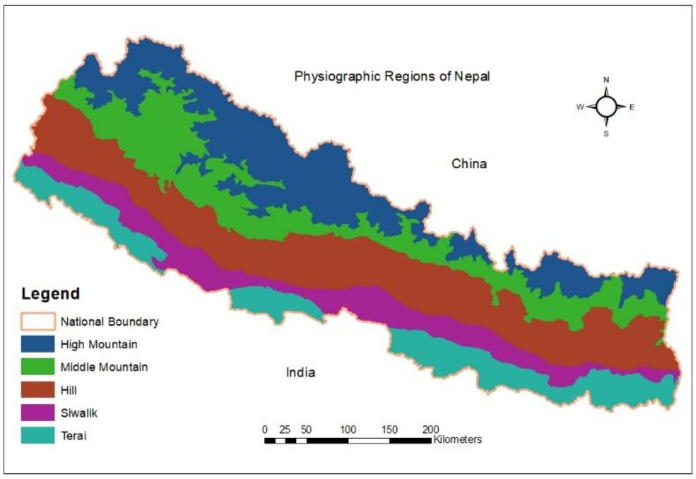

Figure S7. The physiographic regions of Nepal.

The Terai comprises about 14% of Nepal’s land and the rest is mountainous. The mountainous area is typically described as comprising the siwaliks, hills, middle mountains and the high Himalayan areas. Of the mountainous area, 33% is perennially covered by snow. Only 67% of Nepal’s land area is suitable for human settlement (Baral & Bhatta, 2005).

The SDM predicted dhole distribution from eastern to far western and from Terai to high mountain regions of Nepal (Figure S8). The predicted important areas are: Kangchenjunga Conservation Area (KCA) and surrounding landscape up to Ilam district in south eastern part, which also connects to Indian protected areas (Singhalila National Park and Barsey Rhododendron Sanctuary). The western part of KCA connects to Makalubarun National Park. The model predicted dhole distribution in and around Tinjure Milke Jaljale area of Terathum district, Sagarmatha National Park, Gaurishankar Conservation Area, Langtang National Park, Annapurna Conservation Area, Manaslu Conservation Area, Dhorpantan Hunting Reserve, Rolpa-Jaljala Area, Rukum distirct, Shey-Phoksundo National Park, Jajarot district, Rara National Park, Khaptad National Park, Suklaphanta National Park, Bardia National Park, Banke National Park, Kamdi Corridor, Chitwan National Park, Parsa National Park and surrounding areas.

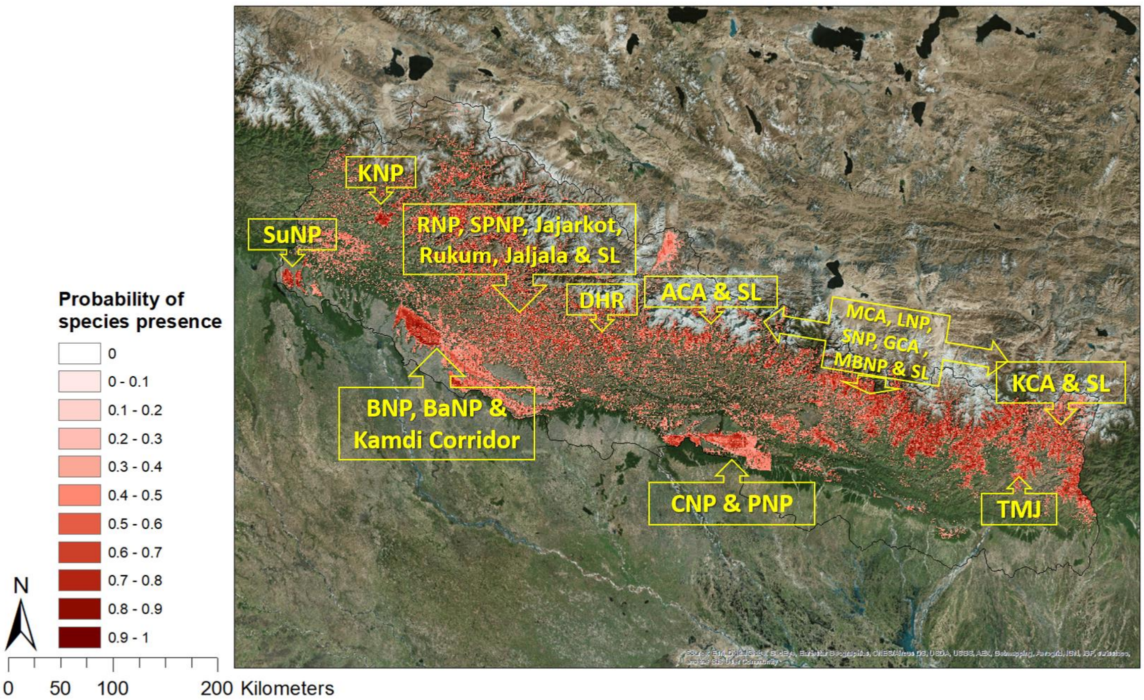

Figure S8. Potential distribution of dhole in Nepal (KCA = Kangchenjunga Conservation Area, TMJ = Tinjure Milke Jaljale, MBNP = Makalu Barun National Park, GCA= Gaurishankar Conservation Area, MCA = Manaslu Conservation Area, ACA = Annapurna Conservation Area, SNP = Sagarmatha National Park, LNP = Langtang National Park, SPNP = Shey Phuksundo National Park, RNP = Rara National Park, KNP = Khaptad National Park, SL = Surrounding Landscape, CNP = Chitwan National Park, PNP = Parsa National Park, BaNP = Banke National Park, BNP = Bardia National Park, SuNP = Suklaphanta National Park, DHR = Dhorpatan Hunting Reserve)

BHUTAN

Our model shows that dholes have the potential to occur throughout most of the country (Figure S9). In fact, historically dholes did occur throughout most of the Bhutan, although poisoning campaigns to reduce livestock predations caused the near-extirpation of dholes from the country in the early 1980s. Since the 1990s dholes have been recolonizing parts of the former range in Bhutan, and the species now occurs in most, if not all, protected areas in the country. If dhole populations are allowed to fully recover in Bhutan, then they potentially could occupy the areas shown in our model.

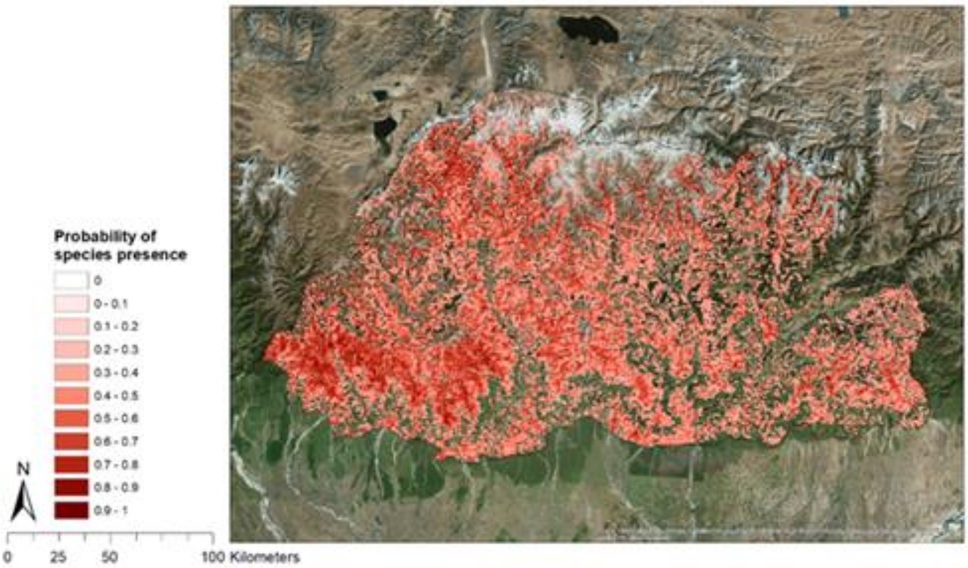

Figure S9. Potential distribution of dhole in Bhutan.

BANGLADESH

Although Bangladesh is one of the most human dominated countries on earth with 1033 persons/km^2 (BBS 2011), it also harbors a vast array of mammal diversity (Khan 2004; Chakma 2015; IUCN Bangladesh 2015). Mammal diversity in Bangladesh is primarily confined to three different sections of Bangladesh, the Sundarbans (the largest mangrove forest in the world), the Northeast (Habigonj and Moulovibazar district of Sylhet division), and the Southeast (Chittagong Hill Tracts (CHT), and some other pockets in the greater Chittagong area).

The key potential dhole distribution (Figure S10) is confined to the Chittagong Hill Tracts (CHT) Southeast Bangladesh. CHT is part of the Indo-Burma hotspot, one of 25 biodiversity hot-spots in the world (Myers et al. 2000). The flora and fauna of the CHT resembles that of Southeast Asia more than of the Indian mainland.

The CHT is a part of the 1800 km mountain range which runs from the eastern Himalayas in China to western Myanmar (Gain 2000). The CHT is bordered by Myanmar to the southeast, and the Indian states of Tripura to the north, and Mizoram to the east. The ground configuration of the area is rough, irregular, and characterized by longitudinally aligned hill ranges and river valleys. A series of ridges runs in a roughly north to south direction across the CHT, varying in height from about 700 m in the north to more than 1000 m in the south (Islam 2003, Islam et al. 2007). The average temperature in CHT varies from 14°C in January to 33°C in April. The rainfall is highest in July with an average of 572.6 mm and lowest in January with an average of 5.1 mm.

The CHT has the richest biodiversity of any area in Bangladesh. Less disturbed native habitat now only exists as scattered patches of primary forest in the northern most and southernmost parts of the region. Both of these regions are remote and difficult to access. The limited surveys of mammalian diversity that have been conducted in the CHT, as well as anecdotal information from local people, indicate an incredible diversity of wildlife that still occurs there. Notable mammals that still occur in CHT are: the elephant *Elephas maximus*, the tiger *Panthera tigris* (recent track sighting), the leopard *Panthera pardus*, the clouded leopard *Neofelis nebulosa,* the Asiatic black bear *Ursus thibetanus*, the Malayan sun bear *Helarctos malayanus,* the dhole *Cuon alpinus*, the gaur *Bos gaurus*, the sambar deer *Rusa unicolor,* the barking deer *Muntiacus vaginalis*, the red serow *Capricornis rubidus, the* binturong *Arctictis binturong,* and the Hoolock gibbon *Hoolock hoolock*.

Figure S10. Potential distribution of dhole in Bangladesh.

LAOS

The model (Figure S11) does not reflect the current distribution of dholes in Laos due to the widespread snaring crises in this country, which has caused the empty-forest syndrome. Widespread and indiscriminate snaring has caused dhole and large ungulate numbers in Laos to become decimated, and has caused the extirpations of tigers and leopards from the country. So, despite the model revealed that most of the country is suitable for dholes, the species likely occurs only in limited areas in the north and central parts of the country. If snaring and poaching is reduced throughout the country, and prey populations recover, then our model indicates that dholes have the potential to occur throughout most of the country.

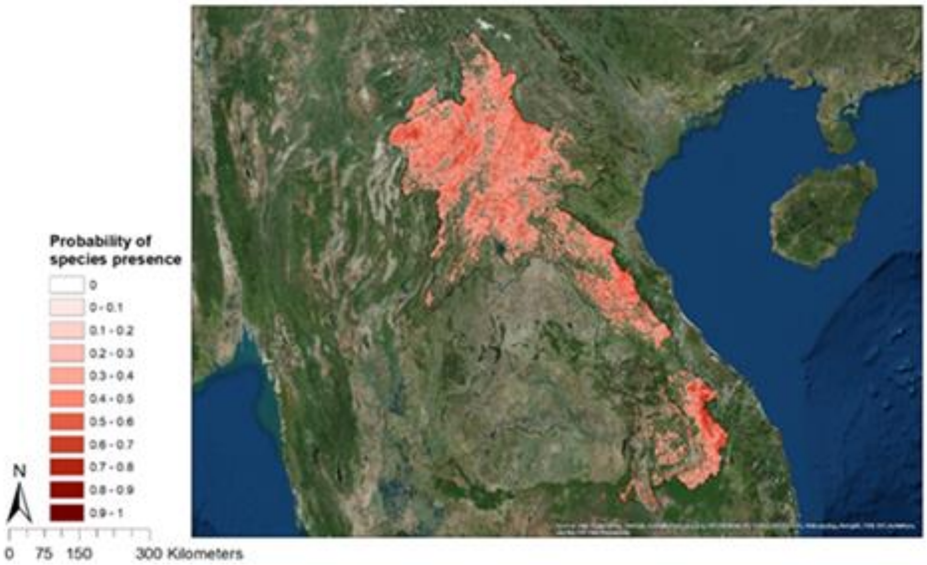

Figure S11. Potential distribution of dhole in Laos.

MYANMAR

The model shows that dholes have the potential to occur primarily in southern, northern, and extreme eastern parts of the country, with the highest probability in southern Myanmar (Figure S12). Our model accurately shows the current range of dholes in the country, the forests of southern Myanmar appear to be a stronghold for the species, and they also occur across large areas of northern and eastern Myanmar. In fact, dholes might be somewhat more widespread in western Myanmar than our model indicates, as they have recently been recorded in Mahamyaing Wildlife Sanctuary and Nat Ma Taung National Park. Nevertheless, poaching for the illegal wildlife trade is increasing in the country, especially in the northern and eastern parts of the country; thus, unless poaching is reduced, then the dhole range in the country may contract considerably in the future.

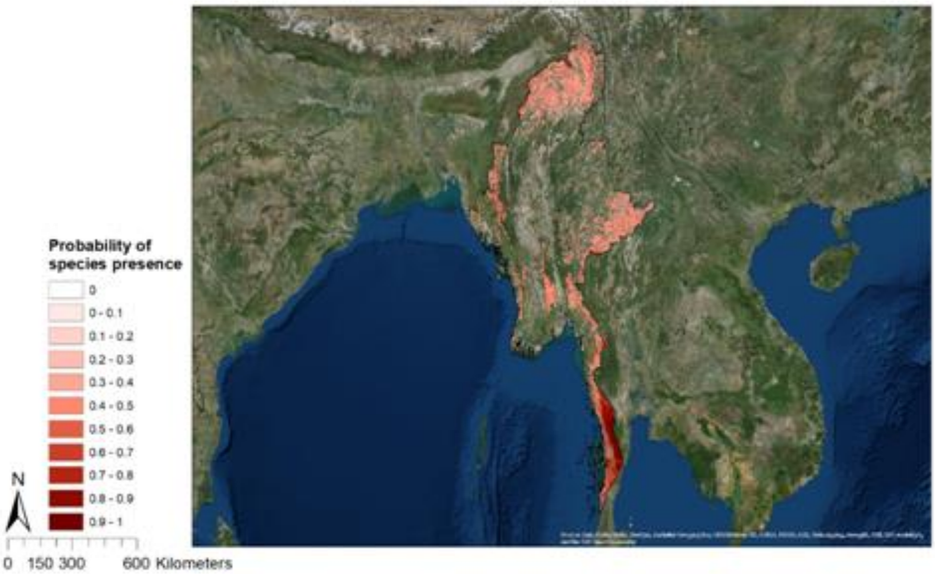

Figure S12. Potential distribution of dhole in Myanmar.

THAILAND

In Thailand, dholes occur only in protected areas. There are five key areas for dhole populations: Eastern Forest Complex, Dong-Phayayen-Khao Yai Forest Complex, Phu Kieow Wildlife Sanctuary, Western Forest Complex and Kaeng Krachan-Kuiburi Forest Complex, all of which are predicted by the SDM as potential distribution (Figure S13). The SDM also predicts potential dhole distribution in northern Thailand. Although dholes do occur in this region, the density is extremely low, and the model predicts a low probability of presence in this region. The model also predicts dhole presence in southern Thailand. Although dholes occupied the Khao Sok-Klong Saeng forest complex in the past, the species has been extirpated from this region during the past decade.

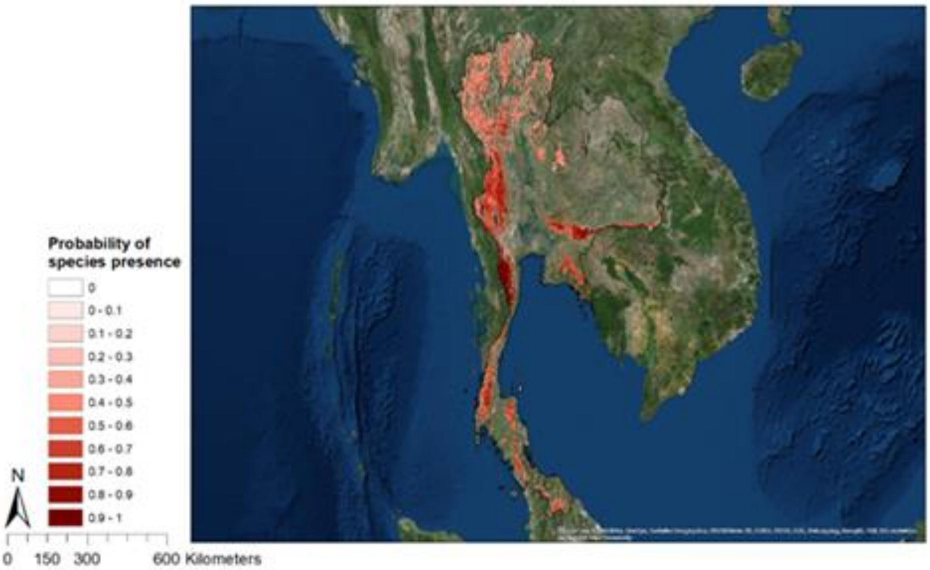

Figure S13. Potential distribution of dhole in Thailand.

CAMBODIA

The dhole model (Figure S14) for Cambodia accurately reflects the regions in the country where dhole still occur. However, dholes are not as widespread as the model shows, especially in the central part of the country where dholes have become extirpated. Also, widespread snaring and poaching is increasing in Cambodia, thus the dhole range in the country may contract considerably in the near future.

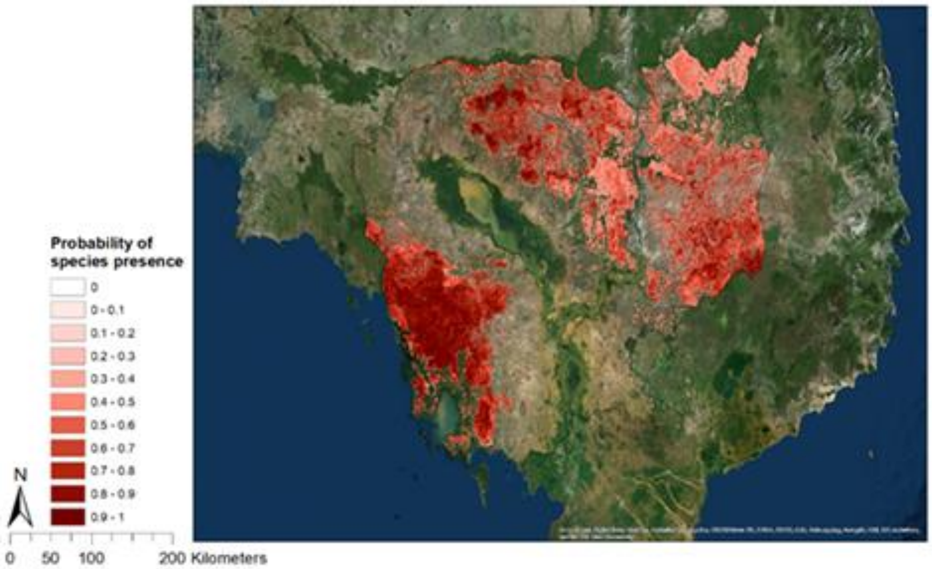

Figure S14. Potential distribution of dhole in Cambodia.

VIETNAM

The model (Figure S15) does not reflect the current distribution of dholes in Vietnam due to the widespread snaring crises in this country, similar to Laos. So, although the model revealed that most of the country is suitable for the species, dholes are likely extirpated from the entire country. This is due to the empty-forest syndrome, as decades of rampant and widespread snaring have resulted in the complete extirpation of all apex carnivores (i.e., tigers, leopards, and dholes) and large ungulates from the country. If snaring and poaching is reduced throughout the country, and prey populations recover, then our model indicates that dholes have the potential to occur throughout large parts of southern Vietnam.

Figure S15. Potential distribution of dhole in Vietnam.

MALAYSIA

The dhole potential distribution is highly dependent on the forested portions of Peninsular Malaysia (Figure S16). Hence, it also included Southern Endau-Rompin National Park region which there is no evidence of dhole presence from the past. On the other hand, the detection of dhole increases throughout the years across the central Titiwangsa main range forest as illustrated by the model.

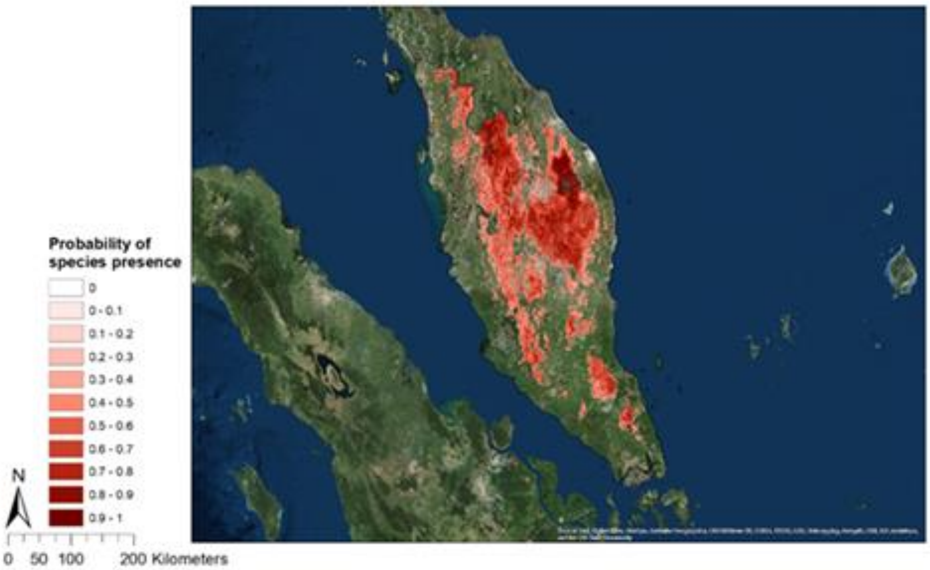

Figure S16. Potential distribution of dhole for Malaysia.

INDONESIA

Sumatra

The island of Sumatra is one of the Sundaland Biodiversity Hotspots, which encompass about 1,800 km long and 400 km wide. This island is categorized as Indo-Malayan ecoregion, which is characterized by lowland extensive evergreen rain forests. Those forests contain a biodiversity level that is comparable with those of the richest forests in Borneo and New Guinea, and have much higher biodiversity than Java, Sulawesi, and other islands in the Indonesian Archipelago.

Sumatran dhole (*Cuon alpinus sumatrensis*) is one of two sub-species of dholes in Indonesia which inhabits Sumatra. This sub-species has close genetic relatedness to Javan dhole (*Cuon alpinus javanicus*). Through genetic study, Sumatran and Javan dhole have high degree of relatedness to Indian dhole compared to sub-species found in Peninsular Malaysia and Thailand. The origin of today's Sumatran and Javan dhole is still enigmatic and further study is needed to support the conservation of these sub-species. Today, Sumatran dhole can be found in a wide variety of vegetation types, including primary forest, secondary forest, palm oil plantation, industrial forest plantation, peat swamp forest and degraded forms of tropical rain forest. Very little data on Sumatran dhole ecology is known, however, there were some study on Sumatran tigers reported the presence of dholes in several protected areas in Sumatra.

Based on SDM (Figure S17), most of Sumatran dhole are predicted to be present in the protected areas from northwest to the southeast of the island. Most reported sightings of Sumatran dhole are coming from studies and forest patrols in those protected areas including Leuser-Ulu Masen, Batang Toru, Rimbang Baling, Kampar-Kerumutan, Bukit Tigapuluh, Teso Nilo, Kerinci Sebelat-Batang Hari, Bukit Duabelas, Berbak Sembilan, Hutan Harapan, Bukit Barisan Selatan, Bukit Balai Rejang.

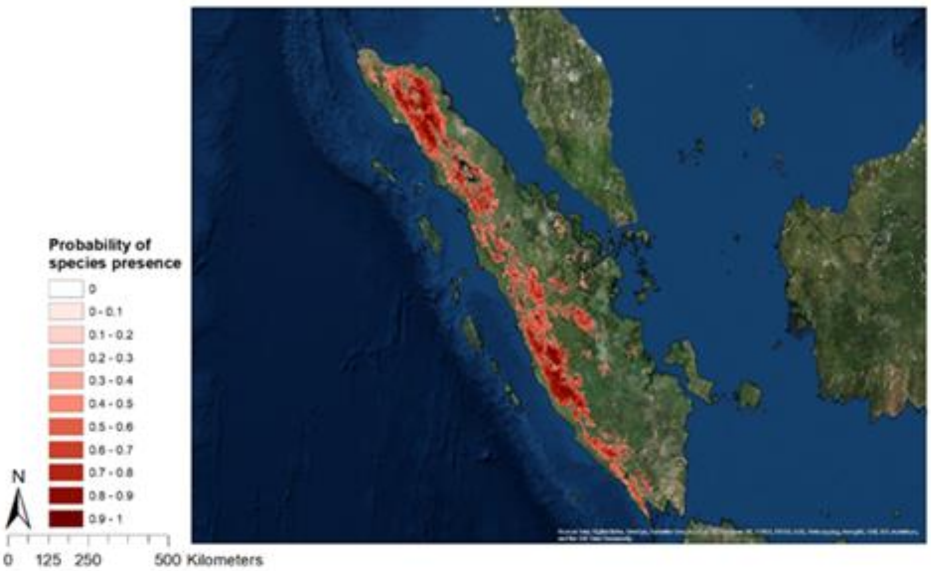

Figure S17. Potential distribution of dhole in Sumatra.

Java

The island of Java is one of the most densely populated areas in the world, which encompass about 130,000 km^2 and administratively includes the island of Madura (5.6200 km^2) north of East Java. Java is categorized as Indo-Malayan ecoregion, which is characterized by lowland extensive evergreen rain forest, semi-evergreen rain forest, moist deciduous forest and dry deciduous forest.

Javan dhole (*Cuon alpinus javanicus*) is a dhole sub-species that live in Java. From the fossil records, this species has appeared in Java since Pleistocene together with other carnivores; Javan tiger (*Panthera tigris sondaica*-EX), Javan leopard (*Panthera pardus melas* – CR) and the giant hyena (*Hyaena brevirostris*-EX) (Hertler & Volmer, 2008). In the past, dholes were widely distributed in Java (Hoogerwerf, 1970), however, nowadays its distribution is highly fragmented and restricted in the protected areas and their vicinity. The dhole is found in a wide variety of vegetation types, including primary forest, secondary forest, teak forest, savanna, and degraded forms of tropical dry and moist deciduous forest. Important factors that may influence habitat selection including the availability of medium to large ungulate prey species, water, the presence of other large carnivore species, human population levels, and suitability of breeding sites (Nurvianto et al., 2015b; Nurvianto et al., 2015a).

The SDM have shown that dholes are predicted to be present mostly in the eastern part of Java (Figure S18). Most sightings are reported from studies and forest patrol activities in protected areas including Baluran National Park, Alas Purwo National Park, Kawah Ijen and Bromo Tengger Semeru National Park. However, it is possible that dholes also occur beyond those protected areas including forested areas managed by Perhutani (state company work on timber production), local forestry department (Dinas Kehutanan) and community forest. In Central Java, dholes have been reported to be found in Mount Slamet, unfortunately the visual proof (photograph) of its existence is still missing. The signs of the dhole existence have never been reported from Gunung Merapi National Park and Gunung Merbabu National Park and surrounding areas, however, according to the SDM, those areas still have possibility to be used as dhole habitat. In western part of Java, dholes are reported to be found in protected areas including Ujung Kulon National Park, Papandayan Reserve, Sawal Reserve, Gede Pangrango National Park, Halimun Salak National Park. Overall, the lack of large prey, and the isolated small protected areas, has restricted the current range of the dhole to just a few protected areas in the extreme eastern and western parts of the islands.

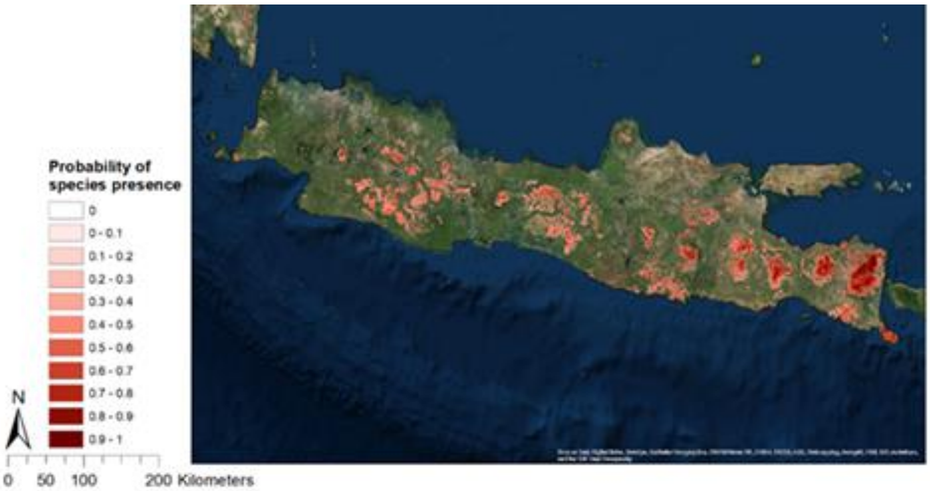

Figure S18. Potential distribution of dhole in Java.

FINAL CONSIDERATIONS

Dholes are widely distributed in suitable patches across 12 countries in Asia. Some patches seem to be structurally connected, while others are isolated by a matrix of unsuitable habitat. The degree of connectivity of dhole populations is currently unknown and should be evaluated considering the suitability of the landscape for dispersal and taking the friction layer into account.

The final species distribution model was approved and accepted by all PHVA participants as a good model for explaining dhole potential distribution to be used in species conservation planning. To maximize the value of this model, the presence database and the model itself should be frequently updated to be valid for conservation decisions. New points provided after the workshop will be included in the next model run, and this new model should be validated and accepted by dhole specialists before being considered valid for conservation purposes. New points can be added to this model in the future.

Model results allowed the PHVA participants to: 1) update the dhole potential distribution map across 12 countries; 2) identify the gaps in sampling database; 3) evaluate the suitability of the landscape for the species occurrence; 4) identify suitable patches for dholes with confirmed presence; 5) identify areas in need of field surveys to confirm the species' presence in other portions of suitable patches; and 6) initiate the discussion to identify dhole populations and meta-populations in different portions of the species' distribution range.

DATA SHARING AGREEMENT

Data points were generously shared with the CPSG team for SDM activities associated with the Dhole PHVA workshop (see Acknowledgments below). The following points were agreed upon relevant to the use and distribution of these data:

- Presence points provided for modelling will never be distributed or used for any other purpose than the Dhole PHVA workshop;
- The Species Distribution Model (SDM) built during the Dhole PHVA Workshop belongs to all participants of the workshop;
- SDM and derived files will be shared among participants of the workshop; however, data for India should be removed from the files as requested until such time that India requests these data be included;
- The Dhole Working Group will decide if the whole model (including India) can be shared and they will inform the participants; and
- CPSG should be contacted regarding any additional people with permission for access and use SDM files in addition to the Dhole PHVA workshop participants:

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See Appendix I for Literated Cited in the SDM Report

SPECIES DISTRIBUTION MODELING FOR DHOLE (*CUON ALPINUS*) OF CHINA

Sheng LI, Shuyi ZHU (School of Life Sciences, Peking University, China)
Yadong XUE, Chinese Academy of Forestry, China
(SDM analysis external to PHVA workshop)

BACKGROUND

Dholes were historically reported in most areas of mainland China. During the past three decades, the wild population of dholes in China has been suffering severe decline and range constriction, although the reason is unclear. Their current distribution is poorly known but probably highly fragmented. Scattered records since 2000 are mainly reported in western China, including southern and western Gansu, Qinghai, southern and western Yunnan, southern Shaanxi, western Sichuan provinces, southeastern Tibet AR and southern Xinjiang AR. They may have been eliminated from central, eastern, northern and southern China.

After examining the confirmed records during the past two decades, we found that dholes inhabit three types of habitat in China: (1) tropical and sub-tropical forests (e.g., records from southern Yunnan and southeast Tibet), (2) sub-alpine montane forests (e.g., records from western Sichuan), and (3) semi-arid deserts and grassland on the plateau (e.g., records from Qinghai, Gansu and southeastern Xinjiang). The first type is in concert with that in Southeast Asia and most of South Asia, whereas the other two types are quite different. These unique habitats, mostly on and around the Qinghai-Tibet Plateau, makes a range-wide distribution modeling rather difficult to produce robust prediction in China, given the small data set compared to that of Southeast and South Asia. Therefore, we decided to construct a separate model for the distribution of dholes in China. This decision was done by consensus and with agreement from all participates of the dhole PHVA workshop at Khao Yai National Park, Thailand, in February 2019.

METHODS

The MaxEnt model using presence-only data performs poorly when the data set is small, so we used Random Forest (RF) algorithm, which requires both Presence and Absence points, to construct the distribution model of dholes in China.

We collected the occurrence records of dholes in China since 2000, including camera-trapping images, video clips and photographs. Reports without verifiable evidence (e.g., interview with local villagers, questionable sightings, etc.) were not included. This resulted in 32 Presence points (Figure C1), 24 of which are with exact lat/lon coordinates, and the rest 8 can only be located into specific nature reserves.

Determining the Absence of dhole in specific area was a major challenge in this study, and elsewhere for any other wildlife species. Taking the advantage that camera-trapping has been widely used in wildlife survey and monitoring across the state during the past two decades, we conducted a comprehensive search on camera-trapping studies in China and identified dhole Absence sites following certain criteria. Among the study sites (primarily nature reserves) with no dhole detection, we defined those sites with an extensive survey effort of >10,000 camera-days AND >50 camera stations as dhole Absence sites. Meanwhile, we collected the baseline survey reports of numerous nature reserves and identified additional Absence sites where dhole was not recorded on the baseline species list. In total we had 45 Absence sites across the state.

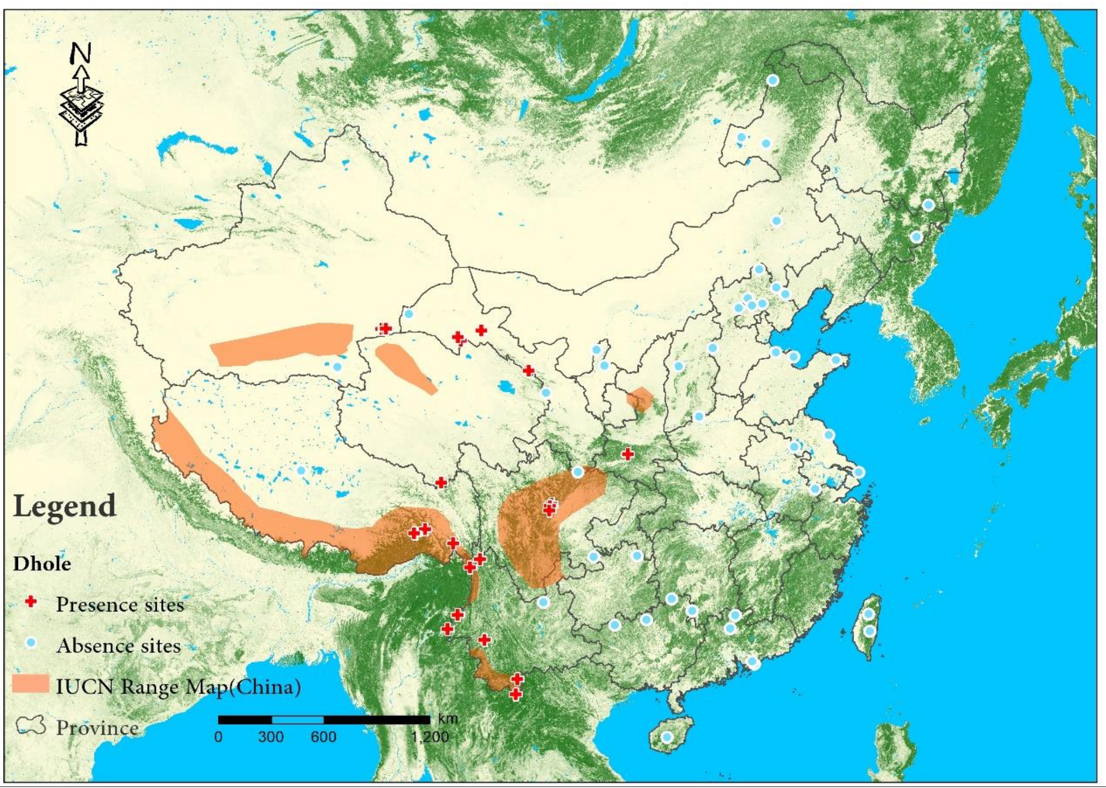

Figure C1. The occurrence sites of dholes in China (forest cover as the base map).

Given the large area of China and the small sample size, we chose a moderate spatial resolution (30-km) to build the distribution model. Therefore, prior to model construction, we conducted a spatial thinning process for both the Presence and Absence points at a 30-km scale, resulting in 21 Presence and 45 Absence points. To balance the sample size between Presence and Absence, the 21 Presence points and 24 randomly selected Absence points were finally used in the modeling.

We collected a set of 29 (19 climate, 2 topology, 3 land cover and vegetation, and 5 anthropogenic influence) candidate variables (Table C1) that may determine the habitat suitability and distribution of dholes. With all environmental predictors resampled to 30-km resolution, we used the RF algorithm to construct the SDM with 80% points as training data and the rest 20% as test data (ntree = 500). We used True Skill Statistic (TSS) and Receiver Operating Characteristic curve (ROC) to evaluate the model performance on training data set.

Table C1. Predictors for the dhole distribution RF model of China.

Predictors	Description	Spatial resolution	Source
Bioclimatic			
bio1	Annual mean temperature	1 km	V 1.4, http://www.worldclim.org
bio2	Mean diurnal range	1 km	
bio3	Isothermality	1 km	
bio4	Temperature seasonality	1 km	
bio5	Maximal temperature of warmest month	1 km	
bio6	Minimal temperature of coldest month	1 km	
bio7	Temperature annual range	1 km	
bio8	Mean T of wettest quarter	1 km	
bio9	Mean T of driest quarter	1 km	
bio10	Mean T of warmest quarter	1 km	
bio11	Mean T of coldest quarter	1 km	
bio12	Annual precipitation	1 km	
bio13	Precipitation of wettest month	1 km	
bio14	Precipitation pf driest month	1 km	
bio15	Precipitation seasonality	1 km	
bio16	Precipitation of wettest quarter	1 km	
bio17	Precipitation of driest quarter	1 km	
bio18	Precipitation of warmest quarter	1 km	
bio19	Precipitation of coldest quarter	1 km	
Land cover	Land cover map	30 m	http://due.esrin.esa.int
NDVI		500 m	http://www.gscloud.cn
Protected area		1 km	Ministry of Ecology and Environment, China
Tree cover	Percentage of tree cover	1 km	https://www.globalforestwatch.org
Human Influence Index		1 km	NASA/Columbia
Population density	Human population density	1 km	Harvard
Livestock	Livestock (cattle, goat, pig) density	1 km	https://www.livestock.geo-wiki.org
DEM	Elevation raster	90 m	http://srtm.csi.cgiar.org
Ruggedness	Terrain ruggedness as the SD of neighboring grid cells	90 m	——
GDP	GDP value	1 km	http://www.resdc.cn

RESULTS

The potential distribution model for dholes was considered to be a good model (ROC = 1, TSS = 1, sensitivity = 1, specificity = 1) (Figure C2).

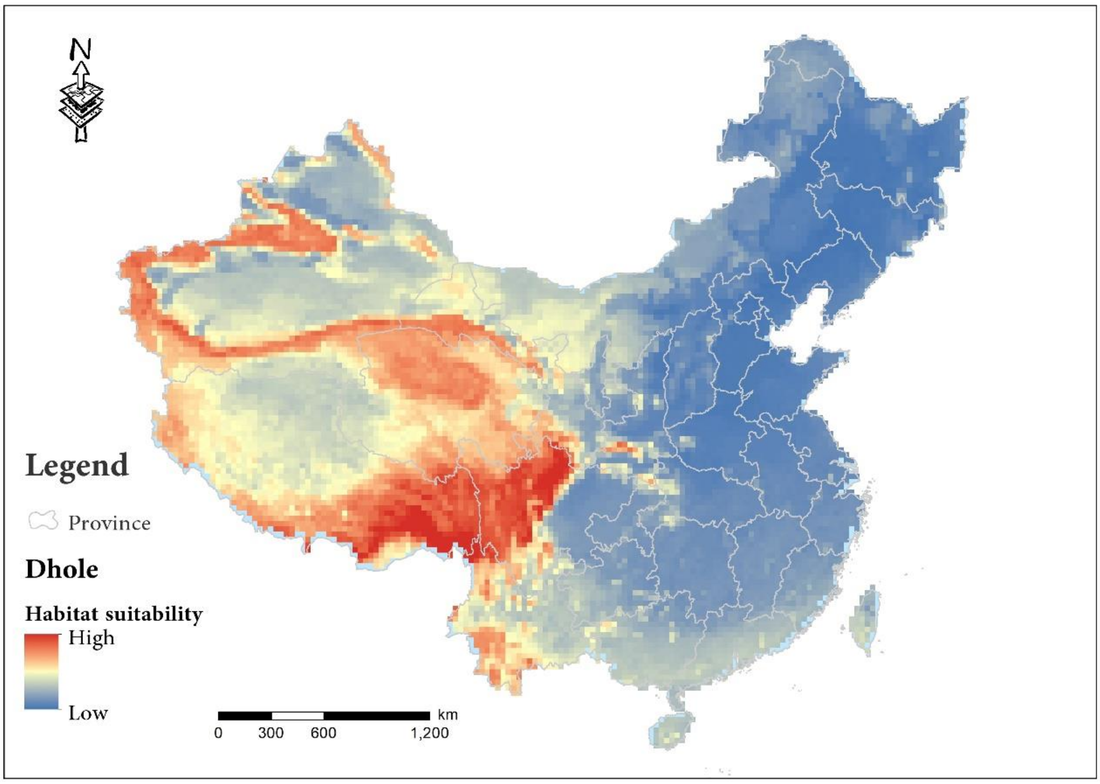

Figure C2. Model predicted potential distribution and habitat suitability of dholes in China.

Human Influence Index (HII) was the most important variable for model prediction, explaining about 32.69% of the model result, followed by elevation (26.15%) and livestock density (8.85%) (Figure C3). The results suggested that anthropogenic influence and topography might be the determining factors for the distribution of dholes in China.

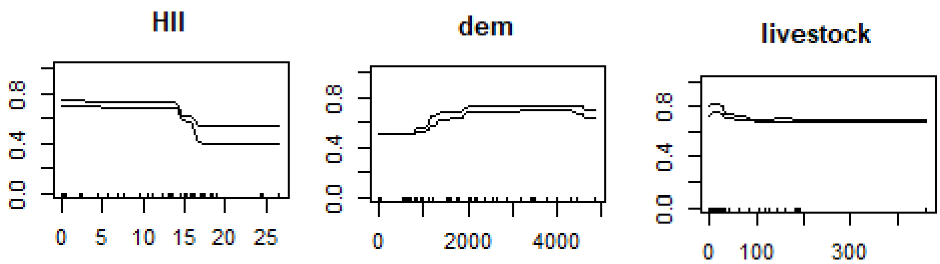

Figure C3. The top 3 predictors in the dhole distribution model of China.

We converted the probabilistic map into a binary distribution map by setting the threshold value as 0.65 (i.e., suitable as suitability≥0.65, unsuitable as suitability<0.65) (Figure C4). The model predicted about 1,286,100 km^2 (1429 pixels) as suitable for dholes.

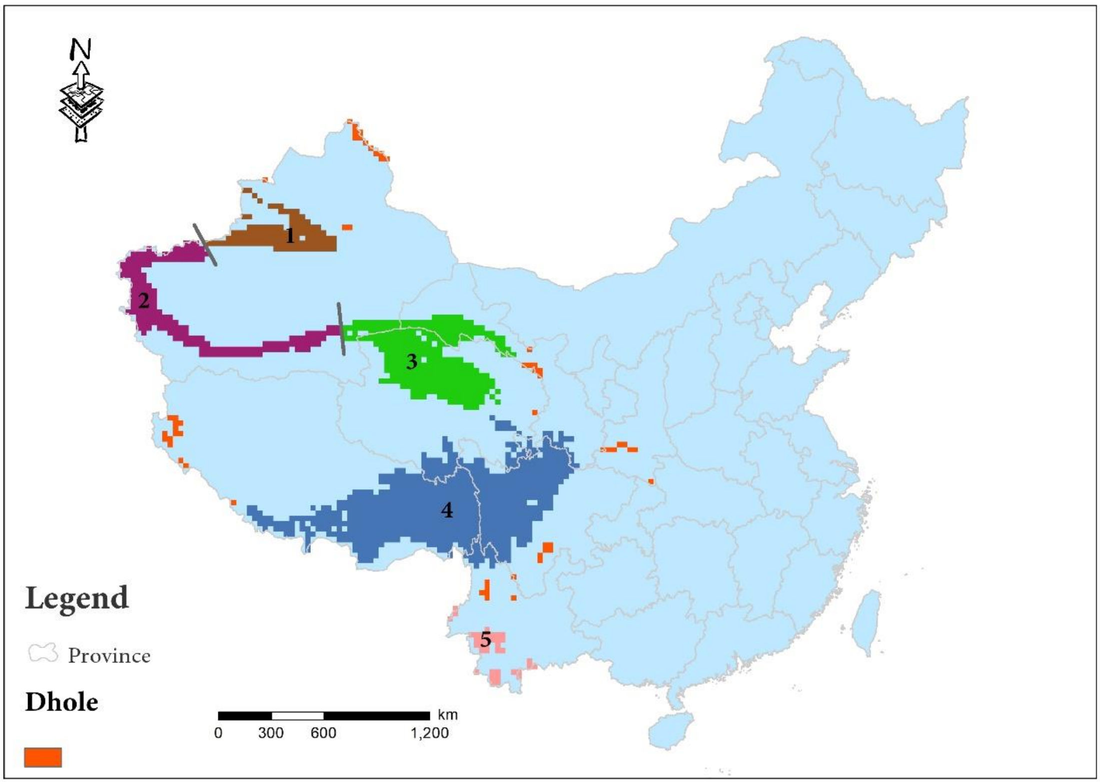

Figure C4. Model predicted potential distribution of dholes in China.

Five major distribution patches were identified (Table C2). Dholes have not been reported in Patch #1 and #2 during the past two decades, neither in the adjacent Central Asia countries. They are probably regionally extinct from these regions, whereas valid populations have been recorded in Patch #3, especially in the Qilian Mountains (i.e., the Qilianshan National Park, including former Qilianshan NR, Yanchiwan NR etc.). The connectivity between Patch #1 and #2, as well as #2 and #3, is unknown. Patch # 4 is the largest one in China, but there are vast areas in eastern Tibet and western Sichuan that have not been well surveyed, primarily due to poor accessibility. Dholes are recently recorded in western and southern Yunnan (Patch #5), all along the China borders with the main populations in neighboring countries (e.g., Laos and Myanmar).

Table C2. The major distribution patches of dholes in China.

Patch ID	Range	Area/km^2	Dhole status
1	Tianshan Mts.	97,200	Possible extinct
2	Parmirs-Kunlun Mts.	169,200	Possible extinct
3	Qilian-Altun Mts.	272,700	Present
4	W Sichuan-E Tibet	666,600	Present
5	S Yunnan	34,200	Present, marginal distribution

Person to be contacted regarding further details, questions and data sharing of the dhole distribution model of China:

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PART II.
Recommended Strategies and Actions

RECOMMENDED STRATEGIES AND ACTIONS

Considering the different natural and social environment conditions in different countries, the participants formed country-based groups, with the members of the CSG Dhole Working Group forming a global group, to review all of the goals and potential strategies developed by four issue-based working groups. Each group reviewed the issues and goals relative to their country (or globally) and evaluated all potential relevant strategies by estimating the relative level (high, medium or low) of its conservation impact, feasibility, and risks. After these assessments, the groups recommended the suitable or reliable strategies to implement for their own country. As time permitted, the groups created actions that could be taken to achieve the recommended strategies, including the relevant Lead, Timeline, Measurement, Collaborators, and Resources.

Thailand, Myanmar, and Bangladesh formed one group together due to the number of participants and potentially linked dhole population across national boundaries.

The following pages show the global and country-based recommended strategies and actions evaluation (countries are sorted alphabetically).

GLOBAL RECOMMENDATIONS (CSG DHOLE WORKING GROUP)

Participants: Chelsea Davis, Pallavi Ghaskadbi, Rasmus Havmolle, Kyran Kunkel, Nucharin Songsasen, Arjun Srivathsa

Table R1. Actions recommended by the IUCN CSG Dhole Working Group.

Working Group	Scientific Data						
Goal Statement	**S.G.1 Generate accurate information on distribution and identify sub-populations and connectivity to ensure viable populations.**						
No.	Strategy	Action description	Lead	Time-line	Measurement	Collaborators	Resources
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	Create a form of agreement for data sharing and use.	Kyran	March 2019	Form approved by working group	All members	No need
		Create and announcement to solicit interns/graduate student to conduct connectivity assessment.	Kyran	April 2019	Distribute the announcement	TBD	WG is not responsible for securing funds for the study; will only provide expertise
S.1.2	Use the SDM output to identify areas for on-ground surveys.	Request and continue communications with Katia maintain database for dholes.	Nuch	Done	Updated maps every 6 months. Validated new models annually.	All members	No need
S.1.3	Undertake connectivity assessment across dhole range.	Create a datasheet to distribute to country/regional representative(s) for reporting.	Arjun	March 2019	Datasheet approved by working group	All members	No need
		Compile the list of potential area for dhole surveys from each country	Pallavi	March 2019	List created	Country representatives	No need

Goal Statement	S.G.2 Obtain information about abundance, vital rates and ecological requirements to monitor population trends.						
No.	**Strategy**	**Action description**	**Lead**	**Time-line**	**Measurement**	**Collaborators**	**Resources**
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).	Form a scientific subcommittee with some representatives from the working group to work with experts to develop standardized method for estimating dhole abundance, demographic and ecological requirements (prey, habitat, size, threat).	Nuch	Aug 2019	Committee formed and is ready to meet	TBD	Consultant fees
		Create a manual for standardized method for estimating dhole abundance and demographic.	Com-mittee	July 2020	Manual	TBD	Consultant fees
		Distribute the manual and facilitate collaborations among researchers in range countries to validate the methods.	Arjun	Dec 2010	Methods are implemented in some countries	Researchers across dhole range	No need. Fund to be secured by researcher
Goal Statement	S.G.3 Generate knowledge about genetic diversity of dhole populations across the range to identify sub-species and inbreeding risk.						
No.	**Strategy**	**Action description**	**Lead**	**Time-line**	**Measurement**	**Collaborators**	**Resources**
S.3.1	Obtain representative samples from geographically distinct dhole populations.	Same as Goal S.G.2					
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs).	Same as Goal S.G.2					

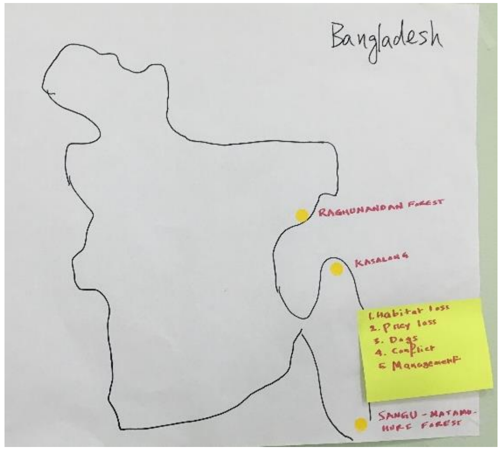
Goal Statement	S.G.4 Use standardized methods to assess and quantify livestock depredation by dholes and dhole persecution by humans in order to prioritize management intervention.						
No.	Strategy	Action description	Lead	Time-line	Measurement	Collaborators	Resources
S.4.1	Evaluate existing methods to be taken across the dhole distribution range.	Secure fund to support a study to evaluate existing methods to be taken across the dhole distribution range.	Phuntsho	March 2020	Successfully secure fund for the project	TBD	TBD
S.4.2	Humbly promote the most suitable method.	Carry out the proposed study.	Phuntsho	March 2021	Research findings report submitted to WG	TBD	TBD
		Promote the most effective method.	Working group	April 2021	Information is available	All stakeholders in dhole countries	None

Working Group	Dhole-Human Conflict						
Goal Statement	C.G.1 Increase understanding of the dhole's ecological, cultural, and socio-economical values to increase positive attitude toward the species and to make it a high priority species for conservation at local, national and global levels.						
No.	Strategy	Action description	Lead	Time-line	Measurement	Collaborators	Resources
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	Assist researchers in securing funds to support high priority research by submitting a grant proposal or endorsing and seeking funding opportunities	Claudio	Dec 2020	2 funded proposals	CSG, Researchers in range countries	none
		Create Google document about dhole research document for soliciting information to potential donors/funders	Nuch	June 2019	Document completed	All researchers	none
		Compile dhole publications and post in Dhole Conservation Foundation website	Chelsea	March 2019	All publications updated on website	CSG and DCF	none

C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).						
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	Apply a story-telling grant for increase awareness and improve perceptions about dholes. Outputs include but not limit to documentary, children/photograph books, flyers, booklets, online materials.	Rasmus	Oct 2019	Grant submitted	Country representatives and DCF	none
Goal Statement	**C.G.2 Minimize socio-economic losses caused by dholes to prevent their retaliatory killings.**						
No.	Strategy	Action description	Lead	TL	Measurement	Collaborators	Resources
C.2.2	Assess and monitor livestock losses to dholes.						
C.2.3	Assess the potential of the dhole as a target species for eco-tourism.						
Goal Statement	**C.G.3 Refute the perception that dholes are evil and fearsome to reduce their persecution by humans.**						
No.	Strategy	Action description	Lead	TL	Measurement	Collaborators	Resources
C.3.1	Secure funds to develop documentaries that highlights ecological, socio-economic and culture importance of dholes [1].	Same as Goal C.G.1					
C.3.2	Develop science-based education materials for school, social media and government officers.	Same as Goal C.G.1					
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Same as Goal C.G.1					
C.3.4	Communicate with community leaders about the positive aspects of dholes.	Same as Goal C.G.1					

Working Group	Dogs and Disease						
Goal Statement	**D.G.2 Understand the impact of infectious disease on the viability of dhole populations either directly or through infection of prey species, in order to identify appropriate research that can guide management strategies where they are required.**						
No.	Strategy	Action description	Lead	Time-line	Measurement	Collaborators	Resources
i) Develop range-wide health capacity and response							
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	Dr. Martin Gilbert will create a range-wide health network	Martin	Dec 2019	Network created	TBD	
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.						

BANGLADESH



Participants: *Kyran Kunkel, Hasan Arif Rahman*

Country	Legality	Distribution/ population	Main threats	Note
Bangladesh		Raghunandan Forest Kasalong Sangu- Matamu- Huri Forest	Habitat loss Prey loss Dogs Human-conflict Management	All three areas have all five threats

Recommended Strategies and Actions

Because the distributions of dhole population are crossboundey between Thailand, Myanmar, and Bangladesh, the participants from these three countries worked together. Most of the strategies were recommended by the participants and they reported 2 large actions instead of list actions related to each potential strategy. First one is the participants of Khai Yai Dhole PHVA meeting 2019 present this global plan to their respective organizations. This action is led by the PHVA participants and timeline is 2019. The second is developing country action plan for dhole by integrating dhole into existing plans of other relevant species. This global plan needs to be taken back each country to develop specific actions and lead by Bangladesh Forest Department and Ministry of Chittagong Hill Tracts Affairs. Before 2022 the leader conduct one workshop is held to initiate the process and could cooperate with academia, conservationists, NGOs, and other relevant stakeholders.

Table R2. Actions recommended for BANGLADESH.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Participants of Khai Yai Dhole PHVA meeting 2019 will present this global plan to their respective organizations.	Participants	2019	One meeting took place		WCS Bangladesh & Creative Conservation Alliance (CCA)
Develop country action plan for dhole by integrating dhole into existing plans of other relevant species. This global plan needs to be taken back each country to develop specific actions.	Bangladesh Forest Department and Ministry of Chittagong Hill Tracts Affairs	2022	At least one workshop is held to initiate the process	Academia, conservationists, NGOs, and other relevant stakeholders	Funding

Table R3. Recommended Strategies and the rank of Impact, Feasibility, and Risk for BANGLADESH.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	Medium	Low	Low	Yes	
S.1.2	Use the SDM output to identify areas for on-ground surveys.	Low	Medium	Low	Yes	
S.1.3	Undertake connectivity assessment across dhole range.	High	Medium	Low	Yes	Also consider transborder connectivity with Myanmar and northeast India
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).	High	Medium	Low	Yes	
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs).	Medium	Low	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	Low	High	Yes	Antagonize stakeholders, higher risk for affecting local community and big business.
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	Low	Low	Yes	
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	Medium	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	Medium	Low	High	Yes	We are not condoning building roads and linear infrastructure within dhole habitat; however, if such structure already existed then we recommend this strategy.
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	Medium	Medium	Yes	Very difficult to implement in most of the areas.
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	Low	High	Yes	This strategy is added for Thailand, however, most appropriate to Bangladesh.
	Control poaching of prey through community outreach and harvest management of subsistence hunting.	High	Low	High	Yes	This strategy is added for Thailand, however, most appropriate to Bangladesh.

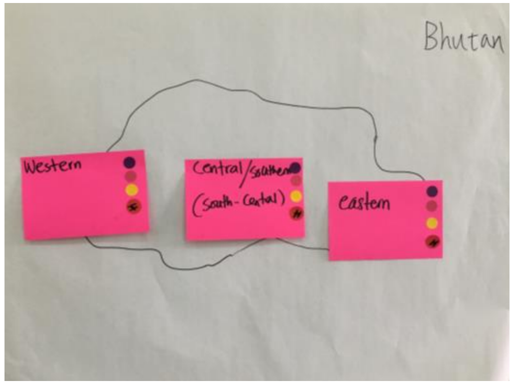
H.2.4	Promote livestock husbandry for local communities to reduce livestock population in dhole habitats by avoiding feedback competition.	High	Low	Medium	Yes	
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	Medium	Medium	Low	Yes	Consult scientific working group for appropriate method
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	Medium	Medium	Low	Yes	Consult scientific working group for appropriate method
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	High	Low	Yes	
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [1].	High	Low	Low	Yes	Devising method is very tricky
C.2.2	Assess and monitor livestock losses to dholes.	Medium	Medium	Low	Yes	
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	Medium	Medium	Low	Yes	
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	Medium	Low	Low	Yes	Might not be useful for dhole directly, however, might benefit other large carnivores
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	High	Yes	Gaining political support will be difficult.
C.2.10	Increase communications with all level stakeholders [2,3].	Low	Low	Low	Yes	
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	High	Medium	Yes	
C.3.1	Secure funds to develop documentaries that highlights ecological, socio-economic and culture importance of dholes [1].	High	High	Low	Yes	Instead of focusing solely on dhole we recommend expanding it into whole large carnivore community.
C.3.2	Develop science-based education materials for school, social media and government officers.	High	Medium	Low	Yes	Instead of focusing solely on dhole we recommend expanding it into whole large carnivore community.
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Low	Medium	Low	Yes	No zoo in Bangladesh has dhole

C.3.4	Communicate with community leaders about the positive aspects of dholes.	High	High	Low	Yes	Instead of focusing solely on dhole we recommend expanding it into whole large carnivore community.
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Medium	Yes	
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	Medium	Low	Low	Yes	
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.	Medium	Low	Low	Yes	
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognize outbreaks.	High	Low	Low	Yes	
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	Low	Medium	Yes	
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	Medium	Low	Yes	
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	Medium	Medium	Low	Yes	
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	Low	Low	Yes	
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	Low	Low	Yes	
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	Low	High	Yes	

BHUTAN

Participants: Chhimi Namgyal, Phuntsho Thinley

Country	Legality	Distribution/ population	Main threats	Note
Bhutan	Not listed in the Schedule I (totally protected list) of the Forest and Nature Conservation Act of Bhutan 1995	Throughout Bhutan, in all 20 districts.	Habitat loss Prey loss Dogs Human-conflict	Retaliatory killings by local farmers (mainly poisoning)



Recommended Strategies and Actions

Most of the strategies were recommended by the participants. They reported several strategies with high impact, high feasibility, low risk and were recommended, and developed 7 main actions listed in the following table. The group concentrated the actions on discussion with Nature Conservation Division (NCD) and Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER) for the strategies, policy in protected area, research, stakeholders consulting, etc. in 2023 and 2024.

Table R4. Actions recommended for BHUTAN.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Discuss the strategies with the Director of the Department of Forests and Park Services.	NCD	2023	Minutes of the meeting	UWICER and Field Divisions	Fund for meeting
Conduct consultative meetings with the key stakeholders.	NCD	2023	Minutes of the meeting	UWICER and Field Divisions	Fund for meeting
Dovetail the strategies with NCD's infrastructure development policy in the protected areas.	NCD	2023	Minutes of the meeting	UWICER and Field Divisions	Fund for meeting
Conduct research on dhole ecology.	UWICER	2023	Survey reports, project proposals, project reports, publications	NCD and Field Divisions	Funding, collars, research equipment, field assistants
Conduct questionnaire survey to understand people's perception of the dholes.	UWICER	2023	Survey reports, publications	NCD and Field Divisions	Funding, field assistants

Consult with animal welfare groups already involved in controlling feral dog numbers.	NCD	2023	Minutes, estimates, reports	Animal welfare groups, DoL, Department of Public Health	Funds for meeting
Workshop to train local personal, resources funding, sample collection for SOP written, develop network, introduce.	NCD	2024	SOP, training document	DOL, TCB, Field offices	

Table R5. Recommended Strategies and the rank of Impact, Feasibility, and Risk for BHUTAN.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	Medium	Low	Yes	Field people may not be willing to share data; some data may not be reliable
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	Medium	Low	Yes	Need funding
S.1.3	Undertake connectivity assessment across dhole range.	High	Medium	Low	Yes	Need funding
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).	High	Medium	Low	Yes	Requires substantial funding for purchase of research equipment and hire of field assistants
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs).	High	Med	Low	Yes	
S.4.1	Evaluate existing methods to be taken across the dhole distribution range.	High	Med	Low	Yes	Funding limits
S.4.2	Humbly promote the most suitable method.	High	Med	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	High	Medium	Yes	The Forest and Nature Conservation Act prohibits developmental activities in the core/restricted zones
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	High	Low	Yes	Bhutan already has corridors connecting the protected areas.

H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	The Nature Conservation Division of the Department of Forests and Park Services would like to develop a dhole conservation plan
H.1.4	Advocate green development projects in dhole habitats and corridors.	High	Medium	Low	Yes	This will require a strong smart-green infrastructure development policy; it will be constrained by low budget.
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	High	Low	Yes	There is a national interest in wildlife habitat improvement.
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	High	Low	Yes	Field staff are trained in smart patrolling which is regularly conducted
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	Medium	Low	Low	Yes	Limited funding will affect the feasibility
H.2.3	Provide training & resources for better crop guarding techniques and effective crop compensation.	High	Medium	Low	Yes	Electric fencing materials are provided by the government; crop compensation is deemed not feasible
H.2.4	Promote livestock husbandry for local communities to reduce livestock population in dhole habitats by avoiding feedback competition.	High	Low	Low	Yes	There is acute shortage of farm labor in the villages due to high rural-urban migration
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	High	Low	Yes	There is a dearth of information on dhole ecology in Bhutan
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	High	High	Low	Yes	Perception of local communities is already completed
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	Med	Low	Yes	More research needed to understand dhole ecology and its roles in the ecosystem
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators (1).	High	Medium	Low	Yes	More studies needed on the ecological roles of dholes
C.2.2	Assess and monitor livestock losses to dholes.	High	Medium	Low	Yes	Some of the losses may not be reported in absence of an incentive

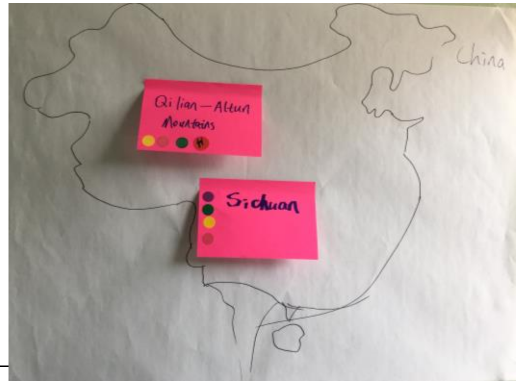
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	High	Medium	Low	Yes	More studies needed on the ecological roles of dholes
C.2.5	Develop country and/or state-specific compensation/insurance schemes for livestock predation by dholes.	High	Low	Low	Yes	Lack of fund will severely impede implementation of this strategy
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	High	High	Low	Yes	Build on the already published studies on this issue in Bhutan.
C.2.7	Develop country-specific guidelines for pasture land management.	High	High	Low	Yes	The Department of Livestock is willing to collaborate on this strategy.
C.2.8	Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	Low	Yes	Incorporate into the current SMART patrolling regime
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	High	Yes	Will have to seriously negotiate with the development planners; Development priorities may override conservation priorities
C.2.10	Increase communications with all level stakeholders [2,3].	High	High	Low	Yes	Funding required for meetings
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	Medium	Medium	High	Yes	Limited funding will affect the feasibility; Local people may leak sensitive information and may also become more effective poachers after the end of their tenure
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) [4].	High	Medium	Low	Yes	Poor coordination among the stakeholders and teams will affect its implementation; the central authorities may not take immediate actions to the reports submitted by the response team.
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons [3].	High	High	Low	Yes	Potential conflicts may be averted.
C.3.1	Secure funds to develop documentaries that highlights ecological, socio-economic and culture importance of dholes [1].	High	High	Low	Yes	Need to secure funding for hire of camera men and cameras

C.3.2	Develop science-based education materials for school, social media and government officers.	High	High	Low	Yes	Need funding to recruit graphic designers
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	High	Low	Low	Yes	Bhutan does not have dholes in captivity.
C.3.4	Communicate with community leaders about the positive aspects of dholes.	High	High	Low	Yes	Need funding for awareness campaigns and developing education materials
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Low	Yes	Build into the current SMART Patrolling regime
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	High	High	Low	Yes	Collaborate with Road Safety and Transport Authority and Traffic Police
C.4.3	Establish wildlife overpasses/underpasses to prevent road-kills.	High	Low	Low	Yes	High cost and lack of funding are the bottlenecks.
D.1.1	Characterize dog ownership patterns, around specified dhole population.	Medium	High	Low	Yes	No prospect of reducing stray dog population in the dhole habitats
D.1.2	Assess size of free-ranging dog populations*	High	High	Low	Yes	Do mark-capture-recapture or similar approach, using digital cameras and photographs
D.1.3	Identify critical ecological and sociological drivers affecting dog abundance and distribution.	High	High	Low	Yes	Focus on stray (free-ranging) dogs
D.1.4	Assess attitudes of local people to dogs and potential control measures, including the benefits of control (e.g. improved sanitation and public health).	High	High	Low	Yes	Partner with Department of Livestock and Tourism Council of Bhutan
D.1.5	Design of control strategies for dog numbers and distribution in consultation with local communities, government, health professionals and local NGOs.	High	Medium	High	Yes	May incur huge cost; local people may not cooperate; Likely objection from the animal right groups and religious bodies.
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	High	High	Low	Yes	
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	High	High	Low	Yes	

D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	High	Low	Yes	
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	High	Low	Yes	
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.	High	High	Low	Yes	
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	High	High	Low	Yes	Focus on Dhole population
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	High	Low	Yes	Only indicated pathogen likely to impact population
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	High	Low	Yes	Focus on dhole population
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	High	Low	Yes	

CHINA

Participants: *Sheng Li, Yadong Xue*



Country	Legality	Distribution/ population	Main threats	Note
China	Protected level: Class-II national protected wildlife	It was historically reported in most areas of China, but there are very few records in recent decades. Their current distribution is poorly known but probably highly fragmented. Confirmed records by camera-trapping since 2008 are fewer than 10 sites (e.g., nature reserves) in southern and western Gansu, southern Shaanxi, southern Qinghai, southern and western Yunnan, western Sichuan provinces, southern Xinjiang AR and south-eastern Tibet AR.	Habitat loss Prey loss Dogs Human-conflict Disease	During the past three decades, the wild population of dholes in China has been suffering severe decline and reduced range, although the reason is poorly known. Retaliatory killings using highly toxic poisons after dholes prey on livestock, and outbreak of highly contagious, fatal disease such as rabies and canine distemper, possibly spreading out through free-ranging house dogs and hunting dogs, are speculated as the most probable causes. Poaching, especially use of snares without specific target species, is another important threat.

Recommended Strategies and Actions

The participants reported Actions including collecting historical and current occurrence dhole data, completing SDM model, and drafting a report on dhole status of China in 2019. They recommended Chinese Academy of Forestry (CAF) and Peking University (PKU) take the lead to identify dhole population by camera-trapping and conducting field survey in potential dhole habitat. Establishing large-scale national parks within dhole range (Qilianshan, Sanjiangyuan, Giant Panda) and conducting community development projects and public education by 2030 were also recommended. Sheng Ki and PKU will conduct research on dog movements and free-ranging dogs related pathogen with the collaboration of Smithsonian Institution, Fudan University, and Hong kong Ocean Park Conservation Foundation by 2022.

Table R6. Actions recommended for CHINA.

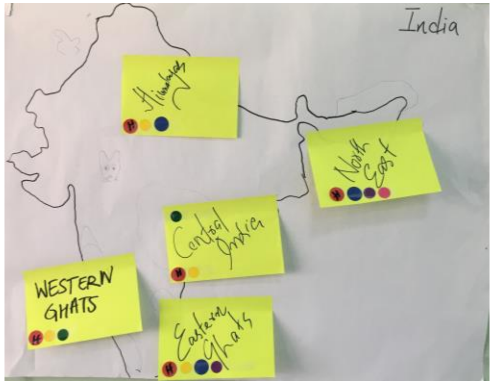
Action description	Lead	Timeline	Measurement	Collaborators	Resources
Collect historical and current occurrence data of dhole in China.	PKU, CAF	By 2019	Number of records	NGOs, Beijing Forest University	
Complete SDM for dhole distribution of China.	Li Sheng/PKU	By 2019	Manuscript on dhole distribution of China	CAF, CFCA, etc.	
Continue and expend camera-trapping monitoring across the current range.	CAF, PKU	By 2030	Number of camera-trapping stations	PAs	
Collect dhole samples (tissues, feces, etc) for future genetic analysis.	CAF/PKU	By 2030	Number of samples	PAs, museums	
Establish large-scale national parks within dhole range (Qilianshan, Sanjiangyuan, Giant Panda).	China government	By 2020	Three national parks established		
Conduct community development projects to improve the livelihood of local people.	Protected area administrations	By 2030	Increased household income	Conservation NGOs	
Promote public education to increase the awareness and toleration of local community to dhole.	Protected area administrations	By 2030	Awareness of dhole and higher toleration	Conservation NGOs	
Conduct field survey in potential dhole habitat to determine its distribution status across the state.	CAF, PKU	By 2025	Increased occurrence data of China	SFA, local PAs	The present camera-trapping network run by CAF and PKU
Draft a report on dhole status of China and submit to government authorities.	CAF, PKU	By 2019	Report		
Include dhole as one focus species in current patrolling within PAs.	PAs				
Conduct trap/snares searching and removing in key protected areas.	PAs	annual	Number of field activities	NGOs, local communities	
Conduct research on dog movements using GPS tracking at sites where dhole declined.	Sheng Li/PKU	By 2022	Manuscript on dog movement	Smithsonian Institution, Fudan University	SI, Hongkong Ocean Park Conservation Foundation, PKU
Conduct survey on free-ranging dogs for key pathogen(s) in key areas where dhole declined.	Li Sheng/PKU	By 2022	Manuscript	Smithsonian Institution, Fudan University	SI, Hongkong Ocean Park Conservation Foundation, PKU

Table R7. Recommended Strategies and the rank of Impact, Feasibility, and Risk for CHINA.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	Medium	Low	Yes	
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	High	Low	Yes	
S.1.3	Undertake connectivity assessment across dhole range	High	High	Low	Yes	
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	Medium	Low	Yes	
S.3.1	Obtain representative samples from geographically distinct dhole populations	High	Medium	Low	Yes	
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs)	High	Medium	Low	Yes	
S.4.2	Humbly promote the most suitable method	High	High	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	High	Low	Yes	Agree with China's policy of Eco-Redline and Ecological Zoning
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	High	Medium	Low	Yes	
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	High	Low	Yes	
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	High	High	Low	Yes	
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	Medium	Low	Yes	
C.2.2	Assess and monitor livestock losses to dholes.	High	High	Low	Yes	
C.2.8	Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	Low	Yes	
C.2.10	Increase communications with all level stakeholders [2,3].	High	High	Low	Yes	
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	High	Low	Yes	

C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons (3).	High	High	Low	Yes	
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Low	Yes	
D.1.4	Assess attitudes of local people to dogs and potential control measures, including the benefits of control (e.g. improved sanitation and public health).	High	High	Low	Yes	
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	High	High	Low	Yes	
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.	High	High	Low	Yes	

INDIA



Participants: *Pallavi Ghaskadbi, Bilal Habib, Girish Punjabi, Ryan Rodrigues, Arjun Srivathsa*

Country	Legality	Distribution/ population	Main threats	Note
India		Himalayas area Northeast area Central India Eastern Ghats Western Ghats	Habitat loss Prey loss Dogs Human-conflict Disease Management	Himalaya: Habitat loss, Prey loss, and Dogs issues. Northeast: Habitat loss, Prey loss, Dogs, and Human-conflict issues. Central India: Habitat loss, Dogs, and management issues. Eastern Ghats: Habitat loss, Prey loss, Dogs, and management issues. Western Ghats: Habitat loss, Dogs, and Disease issues.

Recommended Strategies and Actions

Most of the strategies were recommended by the participants and they reported several strategies are high impact; high feasible; low risk and recommended working close with Dhole Working Group for creating online database, researchers and conservationists group, conducting joint workshop, and compiling a list of potential training courses available for veterinary professionals, wildlife biologists, managers in India. They recommended developing landscape and national connectivity maps for dhole habitats to make further action plans. Evaluating and monitoring the on-going government projects such as eco-sensitive zones / no-development zones around protected areas, and promoting implementation of SMART / MSTRIPES/EPATROL tools for dhole protected areas were also recommended. They suggested review of livestock depredation studies and evaluate crop compensation schemes for source dhole populations.

Table R8. Actions recommended for INDA.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Create a database to constantly update dhole presence locations.	Dhole Working Group		Online database		
Create a group to connect all dhole researchers, conservationists in the dhole Range.	Dhole Working Group	1 year	Online group		

A joint workshop for dhole researchers across India	Dhole Working Group (Pallavi?)	2 years	One joint workshop		
A joint workshop for dhole researchers across India	Dhole Working Group	2 years	One joint workshop		
Review of livestock depredation studies	Dhole Working Group (Arjun?)	2 years	Review of studies		
Government of India is implementing eco-sensitive zones/ no-development zones around protected areas and in the Western Ghats. Evaluation and monitoring of this on-going process is required so as to understand overlaps with dhole habitats and corridors.	Dhole Working group	2 years	Proportion of protected areas/ corridors (after being identified) which are notified Eco-sensitive zones.	Independent dhole researchers, Wildlife Institute of India, NGOs	
Develop landscape/ national connectivity maps for dhole habitats	Dhole Working Group	2 years	All existing corridors from source areas and landscapes identified using robust scientific studies	Independent dhole researchers, Wildlife Institute of India, NGOs	
Make an action plan	Dhole Working Group	2 years	Action plan document to be prepared	IUCN SSC, CPSG, CSG Independent dhole researchers, NGOs, Wildlife Institute of India	
Make an action plan with baseline information on dhole habitats, corridors and dhole conservation landscapes to help plan green development	Dhole Working Group	2 years	Action plan document to be prepared	IUCN SSC, CPSG, CSG Independent dhole researchers, NGOs, Wildlife Institute of India	
Sensitize government departments on prey poaching and implementation of SMART/ MSTRIPES/EPATROL	Dhole Working Group, Wildlife Institute of India	On-going process	Number of dhole protected areas with SMART/MSTRIPES /EPATROL tools	State Forest Departments, Indian NGOs	
Compile and evaluate crop compensation schemes for source dhole populations in India in the Action Plan	Dhole Working Group, Wildlife Institute of India	2 years	State-wise percentage of source PA with crop compensation schemes	State Forest Departments	Funds
Continue on-going research and advocate/ motivate new research projects where there are knowledge gaps	Dhole Working Group	5 years	Number of dhole populations researched	State Forest Departments, Government Research institutions, Indian NGOs	Funds

Standard protocols if exist should be included in the Dhole Action Plan. If not, then standard protocols need to be prepared and included.	Dhole Working Group	1-2 years	Standard Protocol available for major dhole/prey diseases	IVRI, NIV, WII, State University laboratories	
Compile a list of potential training courses available for veterinary professionals, wildlife biologists, managers.	Martin Gilbert, Wildlife Institute of India	1 year	A list of courses in Action Plan	ZSL, University of Edinborough, Cornell?	

Table R9. Recommended Strategies and the rank of Impact, Feasibility, and Risk for INDIA

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	High	Low	Yes	
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	High	Low	Yes	
S.1.3	Undertake connectivity assessment across dhole range	High	High	Low	Yes	Subject to data and fund availability
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	Medium	Low	Yes	A joint workshop for researchers across the dhole range could be a good starting point.
S.3.1	Obtain representative samples from geographically distinct dhole populations	High	Medium	Low	Yes	Fund intensive and needs collaborations across Range Countries
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs)	High	Medium	Low	Yes	
S.4.1	Evaluate existing methods to be taken across the dhole distribution range	High	High	Low	Yes	
S.4.2	Humbly Promote the most suitable method	High	High	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	Medium /High	Low/ Medium	Low	Yes	The value of this strategy is considered high since it will be effective in regulating red industries. Feasibility is low to medium as govt. willingness is low, but courts are effective. Risk of backlash is low. Strategy is recommended as it can protect habitats outside parks.

H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	Medium /High	Low	Yes	The value of this strategy is high. It is highly feasible to define the corridors using better data. But maintaining corridors has medium/ high feasibility since they may overlap with tiger corridors and get incorporated in Tiger Conservation plans
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	Areas outside protected areas the option of having community/ conservation reserves can help protect these habitats.
H.1.4	Advocate green development projects in dhole habitats and corridors.	High	Medium	Low	Yes	This is highly feasible and can be implemented as risk associated with upgradation projects is low. But no new linear infrastructure projects should be advocated. Mitigation measures need to be evaluated for their effectiveness so as to improve their design and use.
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	Low	Low	Yes	This is highly feasible and desired but the feasibility is low as it is cost-intensive to improve habitat quality. Also large areas cannot be effectively targeted. For example: Removal of invasive species.
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	Medium	Low/ Medium	Yes	
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	High	Medium	Low	Yes	Low Feasibility in North East of India, but medium feasibility in peninsular India. This is on-going by Govt. of India
H.2.3	Provide training & resources for better crop guarding techniques and effective crop compensation.	High	Medium	High	Yes	Recommended in site-specific situations. Fences may be an obstruction in corridors for dhole movement.
H.2.4	Promote livestock husbandry for local communities to reduce livestock population in dhole habitats by avoiding feedback competition.	High	Low	Low	Yes	Strategy is effective but very difficult to achieve this in India. Over a long time period (20-years) this may be achievable. But there are practical difficulties in stall-feeding, maintaining high-cost breeds, etc.

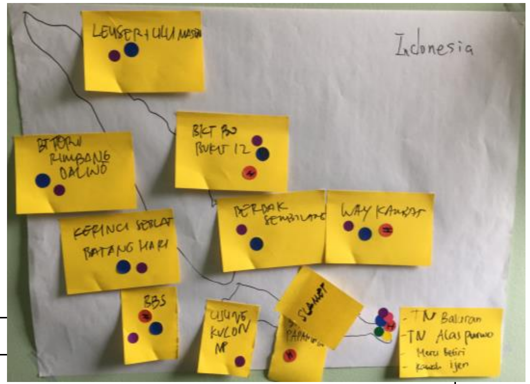
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	High	High	Yes	Raising funds is a problem for many projects exclusively studying dholes.
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	Medium	High	Low	Yes	Provided there are funds to conduct social studies.
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	High	Low	Yes	Provided there are funds to conduct education and outreach programs.
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [1].	Medium	High	Low	Yes	For the North East of India where conflict by dholes is perceived to be high. Other areas in a case-specific manner.
C.2.2	Assess and monitor livestock losses to dholes.	High	High	Low	Yes	For the North East of India where conflict by dholes is perceived to be high. Other areas in a case-specific manner.
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	High	High	Low	Yes	
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	Low	Low	Low	Yes	For the North East of India where conflict by dholes is perceived to be high.
C.2.8	Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	Low	Yes	
C.2.10	Increase communications with all level stakeholders [2,3].	High	High	Low	Yes	Funds required
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	High	Low	Yes	Tailored to local situations and availability of funds.
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) [4].	High	High	Low	Yes	For the North East of India where conflict by dholes is perceived to be high. Already exists in many Tiger Reserves.
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons [3].	High	High	Low	Yes	Tailored to local situations and availability of funds.
C.3.1	Secure funds to develop documentaries that highlight eco-logical, socio-economic and culture importance of dholes [1].	High	High	Low	Yes	

C.3.2	Develop science-based education materials for school, social media and government officers.	High	High	Low	Yes	Funds need to be secured. Similar to other outreach programs
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Medium	High	Low	Yes	
C.3.4	Communicate with community leaders about the positive aspects of dholes.	High	High	Low	Yes	
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	Medium	High	Low	Yes	
D.1.1	Characterize dog ownership patterns, around specified dhole population.	High	Medium	Low	Yes	Subject to availability of funds
D.1.2	Assess size of free-ranging dog populations.*	High	Medium	Medium	Yes	Subject to availability of funds
D.1.3	Identify critical ecological and sociological drivers affecting dog abundance and distribution.	High	Medium	Low	Yes	Subject to availability of funds
D.1.4	Assess attitudes of local people to dogs and potential control measures, including the benefits of control (e.g. improved sanitation and public health).	High	Medium	Low	Yes	Subject to availability of funds
D.1.5	Design of control strategies for dog numbers and distribution in consultation with local communities, government, health professionals and local NGOs.	High	Medium	Low	Yes	Subject to availability of funds
D.1.6	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	Low	High	Yes	High risk but can be taken up subject to availability of funds
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	High	High	Low	Yes	Compile available protocols in the Action Plan, which can be tailored to local situations
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.	High	High	Low	Yes	Can potentially connect with local government veterinarians trained in implementing protocols.
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	Medium	High	Low	Yes	Awareness programs are already on-going in many parks across India. Efforts need to be increased across India.

D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	Medium ?	Low	Yes	Difficult to implement in the field, but it is achievable.
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	Medium ?	Low	Yes	Difficult to implement in the field, but it is achievable.
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.	High	Low	Low	Yes	Subject to availability of funds
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	High	High	Low	Yes	Subject to availability of funds
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	High	Low	Yes	Subject to availability of funds
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	Medium	Low	Yes	
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	High	Low	Yes	

INDONESIA

Participants: *Linnea Havmoeller, Fitty Machmudah, Sandy Nurvianto*



Country	Legality	Distribution/ population	Main threats	Note
Indonesia	Act No. 5 in 1990 with respect to the law on the conservation of biodiversity ecosystems Ministry of Environment and Forestry Regulation No. 106 in 2018 with respect to the second change on Ministry of Environment and Forestry Regulation No. 20 in 2018 with respect to the protected flora and fauna	Java: Ujung Kulon NP, Papandayan Reserve, Sawal Reserve, Gede Pangrango NP, Halimun Salak NP, Meru Betiri NP, Alas Purwo NP, Baluran NP, Kawah Ijen Nature Tourism Park Sumatera: Leuser-Ulu Masen, Batang Toru, Rimbang Baling, Kampar-Kerumutan, Bukit Tigapuluh, Teso Nilo, Kerinci Sebelat-Batang Hari, Bukit Duabelas, Berbak Sembilan, Hutan Harapan, Bukit Barisan Selatan, Bukit Balai Rejang	Habitat loss Prey loss Dogs Human-conflict Disease Management	Only show the areas that have photographic evidences. It might be possibl3 5hq5 dhole occur on the other protected areas in Java and Sumatra. Persecution and eradication happened (Conflict with human)

Recommended Strategies and Actions

The participants reported Actions and recommended to disseminate the workshop results to authority. For short-term, they suggested to initiate a dhole conservation network for Indonesia, conduct camera trap survey based on SDM results, cooperate with existing educational institutions, zoos, NGOs, and media and other implementation programme such as ONE health. For long-term they recommended to work with Indonesia Ministry of Environment and Forestry (KKH) for sampling in Baluran national park, Sumatra and Java, and obtain existing national documents that into dhole Conservation.

Table R10. Actions recommended for INDONESIA.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Conduct camera trap survey in protected areas and important habitat based on the SDM	Sandy, Ventie, Linnea	1 year	Report	Collaboration with local universities, national park, local NGO	National budget, international donors and collaboration
Disseminate workshop results to authority	All	3 months	Report submission	NGO, Gajah Mada University and universities near dhole habitats, WildCRU	National budget, international donors and collaboration
Initiate a dhole conservation network for Indonesia	Directorate of KKH	1 year	Mailing list of dhole people	All stakeholders	National budget, international donors and collaboration
Collect genetic samples in Baluran NP	Ventie, Linnea, Sandy	5 years	Tissue, blood, feces, hair	Researchers, local universities, NGOs	National budget and Copenhagen Zoo
Establish network and initiate process to get island-wide samples from Sumatra and Java	KKH	10 years	Forum established	Researchers, local universities, NGO's	National budget, international donors and cooperation
Make an Indonesian dhole conservation network	Ventie	2 years	National network of practitioners in dhole conservation established	Government, universities, NGO's, practitioners	National budget, international donors and cooperation
Collect information of island spatial planning for Sumatra and Java	Ventie, Sandy	6 month	Document of island spatial planning	Ministry of Forestry, NGO	
Obtain information on Landuse Map	Fitty	3 months	Landuse map	Ministry of Forestry	
Obtain existing national documents that in to Dhole Conservation	Fitty	3 months	Matrix of dhole habitats that fit into national status (by law)	Ministry of Forestry	
Work with existing educational institutions, zoos and NGO project also with media	Ventie	1 year	Education materials/ improved draft	MoEF, NGOs and universities	PKBSI, national budget, international donors and cooperations
Combine and sinergize with other prioirity species, ONE health implementation programme	KKH	1 year	ONE health document improved with dhole included	MoEF, M of Agriculture, Min of Health	

Table R11. Recommended Strategies and the rank of Impact, Feasibility, and Risk for INDONESIA.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	High	Low	Yes	For Java (close to Baluran NP) already have camera traps for warty pigs
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	High	Low	Yes	Collaborate with local organizations and communities to gather more information of dhole distribution
S.1.3	Undertake connectivity assessment across dhole range	High	Medium	Medium	Yes	Need long-term studies with GPS collar, funding to do research
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	High	Low	Yes	Feasible but will take time, no method for estimating dhole abundance currently
S.3.1	Obtain representative samples from geographically distinct dhole populations	High	High	Low	Yes	It will take time and effort, takes time to get samples, permits
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs)	High	High	Low	Yes	Need samples from east, west and central Java, and from southern, central and northen Sumatra
S.4.1	Evaluate existing methods to be taken across the dhole distribution range	Medium	Medium	Low	Yes	Data deficient
S.4.2	Humbly Promote the most suitable method	Medium	Medium	Low	Yes	Specific to Java (particularly in isolated habitats)
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	Medium	Hi	Yes	Highly dependent on the government
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	High	High	Yes	Feasibility high in Sumatra, low in Java
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	High	Medium	High	Yes	
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	Medium	High	Yes	

H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	High	High	Yes	Existing forest patrol team that implement SMART-RBM
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	Medium	High	Medium	yes	Improve habitat quality especially in Java
H.2.3	Provide training & resources for better crop guarding techniques and effective crop compensation.	Low	High	Low	Yes	In some protected areas/ dhole habitats in Java, need improvement
H.2.4	Promote livestock husbandry for local communities to reduce livestock population in dhole habitats by avoiding feedback competition.	High	Low	High	Yes	The case in Baluran National Park, Need long term planning
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	High	Low	Yes	Collaborate with universities and institute of science/ scientific community
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	High	High	Low	Yes	
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	High	Low	Yes	Work with existing educational institutions, zoos and NGO project also with media
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [(1)].	High	Medium	Low	Yes	*need long process to coordinate with stakeholders
C.2.2	Assess and monitor livestock losses to dholes.	Medium	High	Low	Yes	Collaborate with other species conservation projects
C.2.3	Assess the potential of the dhole as a target species for eco-tourism.	High	High	Low	Yes	Apply to Java, but need improvement
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [(1,3)].	High	High	Low	Yes	Collaboration wih local community, local Ngo, goverment, etc
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	High	Low	High	YES	Highly depend on specific region
C.2.8	Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	High	Yes	SMART-RBM
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	High	Yes	Highly depend on the policy and regulation of Local Government
C.2.10	Increase communications with all level stakeholders [(2,3)].	High	High	Low	Yes	Integrated Programme and Funding

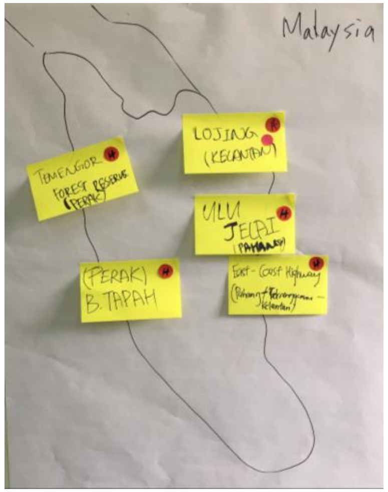
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	High	High	Yes	National programme, SMART-RBM and MMP
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) (4).	Low	Low	High	Yes	WRU in each BKSDA (provincial biodiversity conservation agency)
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons (3).	High	High	High	Yes	Indonesia has Conservation Cadre program for each region
C.3.1	Secure funds to develop documentaries that highlights ecological, socio-economic and culture importance of dholes (1).	High	Low	Low	Yes	Dhole is not considered as priority species
C.3.2	Develop science-based education materials for school, social media and government officers.	High	High	Low	Yes	To be aligned with national programmes
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Medium	High	Low	Yes	Collaborate with zoo assocation
C.3.4	Communicate with community leaders about the positive aspects of dholes.	High	High	Medium	Yes	To be aligned with national programmes
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Low	Yes	Routine patrol is one of the job description of the ranger
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	Low	High	Low	Yes	Most people do not pay attention to road sign
C.4.3	Establish wildlife overpasses/underpasses to prevent road-kills.	High	Low	Low	Yes	Feasible but expensive, see point on green infrastucture development plan
D.1.1	Characterize dog ownership patterns, around specified dhole population.	High	Medium	Low	Yes	One Health Implementation Programme
D.1.2	Assess size of free-ranging dog populations.*	High	Low	High	Yes	Need funding and collaboration with university
D.1.3	Identify critical ecological and sociological drivers affecting dog abundance and distribution.	High	Low	Low	Yes	Need funding and collaboration with university
D.1.4	Assess attitudes of local people to dogs and potential control measures, including the benefits of control (e.g. improved sanitation and public health).	Medium	Low	Medium	Yes	Need funding and collaboration with university
D.1.5	Design of control strategies for dog numbers and distribution in consultation with local communities, government, health professionals and local NGOs.	Medium	Medium	High	Yes	Combine and sinergize with other priority species programme

D.1.6	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	High	High	Yes	Combine and sinergize with other priority species
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	High	Medium	High	Yes	Combine and sinergize with other prioirity species, ONE health implementatin programme
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.	High	Medium	High	Yes	Combine and sinergize with other prioirity species
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	High	Medium	High	Yes	ONE health program
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	Medium	High	Yes	ONE health program
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	Medium	High	Yes	ONE health program
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.	High	Medium	High	Yes	ONE health program
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	High	Medium	High	Yes	ONE health program
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	Medium	High	Yes	ONE health program
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	Medium	High	Yes	ONE health program
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	Medium	High	Yes	ONE health program

MALAYSIA

Participants: *Tan Cheng Cheng, Tan Poai Ean*

Country	Legality	Distribution/ population	Main threats	Note
Malaysia		Temengor Forest Reserve (Perak) B. Tapah (Perak) Lojing (Kelantan) Ulu Jelai (Pahang) East-Coast Highway (Pahang-Cerenggc Mm - Kelantan)	Habitat loss	



Recommended Strategies and Actions

The participants recommended focusing on working with Malaysia Department of Wildlife and National Parks (DWNP) for red list assessment, monitoring, SMART Patrol, and discussion through collaborating platform. They also suggested integrated dhole conservation, with projects linked with Protected area agencies, Institutions, Ministry of Water, Land and Natural Resources (KATS), research groups and NGOs such as National Tiger Conservation Action Plan, National Elephant Conservation Action Plan, Master Plan for Ecological Linkages of Central Forest Spine, National Blue Ocean Strategy (NBOS), Communication, Education, and Public Awareness (CEPA) program, for raising public awareness, developing wildlife friendly infrastructures, and identifying Environmental Sensitive Areas.

Table R12. Actions recommended for MALAYSIA.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Continuous red list assessment for mammals in Peninsular Malaysia	DWNP	On-going process	Reports and journals	Protected area agencies, research groups, institutions and NGOs	
Wildlife monitoring and inventories at Protected areas and ecological linkages	DWNP, Pelindung, WWF Malaysia, WCS Malaysia	On-going process	Reports	Protected area agencies, research groups, institutions and NGOs	National Tiger Surveys, Wildlife Inventories

Platform to collaborate, discuss	DWNP, NGO	2 years	Workshop	Protected area agencies and NGOs	
Strengthen and integrate species conservation programs in National Tiger Conservation Action Plan, National Elephant Conservation Action Plan, Master Plan for Ecological Linkages of Central Forest Spine and other conservation action plans	DWNP, Pelindung, WWF Malaysia, WCS Malaysia, University	On-going process	Reports	Protected area agencies, institutions, research groups and NGOs	
Routine habitat improvement in protected areas and ecological linkages.	DWNP	On-going process	Programs, reports	Other enforcement agencies	
Integrated enforcement operations under National Blue Ocean Strategy (NBOS) to combat encroachment, poaching and illegal trade	DWNP	On-going process	Report published	Other enforcement agencies and protected area agencies	
Application of SMART Patrol in protected areas and forest reserves	DWNP & PA authorities	On-going process	Programs, reports	NGOs	
Combating wildlife cybercrime campaign	DWNP	On-going process	Social media response	Social media operators and enforcement agencies	
Gather baseline information on dhole – Ecology and socio-economic	DWNP	1 year	Reports	Research institutions and NGOs	Co-financing
Outreach and awareness program on dhole for policy makers, stakeholders, public and local communities	NGOs/ Social Enterprises	3 years	Reports, programs, publications	DWNP and institutions, Ministry of Water, Land and Natural Resources (KATS), Education Department	Co-financing
Communication, Education, and Public Awareness (CEPA) program for Dhole	NGOs/ Social Enterprises	3 years	Reports	DWNP	Co-financing
DWNP awareness educational publications	DWNP	3 years	Educational materials		
Malaysian local zoos' wildlife captive breeding and education programs	DWNP	5 years	Live stock	MAZPA, local zoos	
Awareness for Malaysian Public Works Department, road authorities and infrastructure developers to develop wildlife-friendly infrastructures	DWNP	On-going process	Talks, meetings, workshops	EIA companies, Association of Consulting Engineers Malaysia, KATS, JKR, Industries	
Compulsory Wildlife Impact Assessment for development projects in Environmental Sensitive Areas	DWNP	3 years	WIA reports	KATS	

Table R13. Recommended Strategies and the rank of Impact, Feasibility, and Risk for MALAYSIA. H=high; M=medium; L=low; Y=yes (recommended)

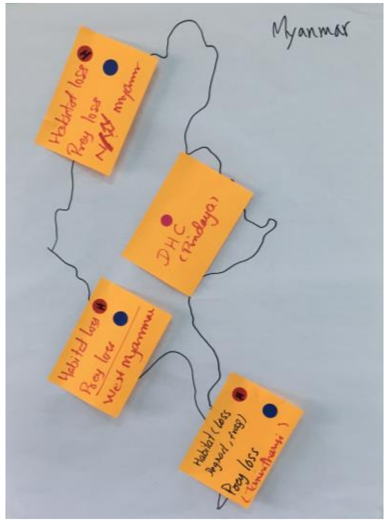
No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	High	Low	Yes	
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	High	Low	Yes	
S.1.3	Undertake connectivity assessment across dhole range	High	Medium	Medium	Yes	
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	Low	Medium	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	Medium	High	Yes	Require committed support among key decision makers to establish and implement the policy
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	Medium	Low	Yes	
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	Medium	Medium	High	Yes/ No	Require committed support among key decision makers to establish and implement the policy
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	High	Low	Yes	
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement	High	High	Low	Yes	
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	Medium	High	Yes	
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	Medium	Medium	Medium	Yes	
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	Medium	Medium	Yes	
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [(1)].	High	Medium	Medium	Yes	

C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	High	Medium	Medium	Yes	
C.2.7	Develop country-specific guidelines for pasture land management.	High	High	Low	Yes	There are existing guidelines?
C.2.8	Increase patrolling, surveillance, and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	Low	Yes	
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	High	Yes	Require committed support among key decision makers to establish and implement the policy
C.2.10	Increase communications with all level stakeholders [2,3].	High	Medium	Medium	Yes	
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	Medium	Medium	Yes	
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) [4].	High	High	Low	Yes	Existing human-wildlife conflict response team
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons [3].	High	Medium	Medium	Yes	
C.3.2	Develop science-based education materials for school, social media and government officers.	High	Medium	Low	Yes	Dhole education materials for schools and public.
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	High	Medium	Low	Yes	Zoo education program on dhole conservation
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Low	Yes	On-going
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	High	High	Low	Yes	Facilities for roadkill mitigation deployed
C.4.3	Establish wildlife overpasses/underpasses to prevent road-kills.	High	High	Low	Yes	Existing overpasses. Continuous monitoring for feasibility study
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	High	High	Low	Yes	Existing Standard of Procedures
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and sharing/publication of health data	High	High	Low	Yes	
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	High	Low	Yes	

D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	High	Low	Yes	
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.	High	High	Low	Yes	Existing National Wildlife Forensic Laboratory (DWNP)

MYANMAR

Participants: *Nay Myo Shwe*



Country	Legality	Distribution/ population	Main threats	Note
Myanmar		North Myanmar DHC (Pindaya) West Myanmar Tanintharyi	Habitat loss Prey loss Human-conflict	DHC (Pindaya) has Human-conflict issue. North Myanmar, West Myanmar, and Tanintharyi area have Habitat loss and Prey loss issues.

Recommended Strategies and Actions

Because the distributions of dhole population are crossboundey between Thailand, Myanmar, and Bangladesh, the participants from these three countries worked together. Most of the strategies were recommended by the participants and they reported 2 large actions instead of list actions related to each potential strategy. First one is the participants of Khai Yai Dhole PHVA meeting 2019 present this global plan to their respective organizations. This action is led by the PHVA participants and timeline is 2019. The second is developing country action plan for dhole by integrating dhole into existing plans of other relevant species.

Table R14. Actions recommended for MYANMAR.

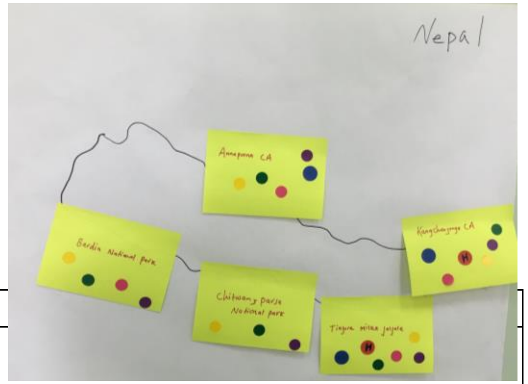
Action description	Lead	Timeline	Measurement	Collaborators	Resources
Participant of Khao Yai Dhole PHVA meeting Present this global plan within respective and other relevant organizations	Participant	2019	One meeting		FFI
Country action plan by integrated into other existing plan of other relevant species	NWCD		Meeting and draft plan	INGOs, Academic, conservationist, parlimant representative	?

Table R15. Recommended Strategies and the rank of Impact, Feasibility, and Risk for MYANMAR.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	Medium	Medium	Low	Yes	Highly recommended
S.1.2	Use the SDM output to identify areas for on-ground surveys	Medium	Medium	Low	Yes	Need more survey in Myanmar
S.1.3	Undertake connectivity assessment across dhole range	Medium	Medium	Low	Yes	Connectivity with Thailand_Myanmar_Bangladesh
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	Medium	Low	Yes	
S.3.1	Obtain representative samples from geographically distinct dhole populations	High	Medium	Medium	Yes	
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs)	Medium	Low	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	Low	High	Yes	High risk for local
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries & transboundary.	High	High	Low	Yes	Dhole habitat between Myanmar and Thailand
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	Medium	Low	High	Yes	Cost is high
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	Medium	High	Yes	The law is can be applied discrimanately
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	High	Medium	High	Yes	Risk is high due to uncertain of identify high threats hunters
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	Medium	Medium	Low	Yes	Consult with scientific working group
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	Medium	Medium	Medium	Yes	

C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	Medium	Low	Yes	
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [1].	Low	Low	Low	Yes	Not directly relevant to Myanmar
C.2.2	Assess and monitor livestock losses to dholes.	Low	Medium	Low	Yes	in high reported conflict areas
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	Low	Medium	Low	Yes	Pre preparation for Myanmar
C.2.5	Develop country and/or state-specific compensation/insurance schemes for livestock predation by dholes.	Low	Low	Low	Yes	Not urgent for Myanmar
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	Medium	Medium	Low	Yes	
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	Low	Yes	Similar to habitat loss. Need commitment from decision makers to develop and implement policies which can be very difficult
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	Medium	Medium	Yes	
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) [4].	Low	Low	Low	Yes	
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons [3].	Low	Low	Low	Yes	
C.3.2	Develop science-based education materials for school, social media and government officers.	Medium	Low	Medium	Yes	
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Low	Medium	Low	Yes	
C.3.4	Communicate with community leaders about the positive aspects of dholes.	Medium	Medium	Medium	Yes	
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	Low	Medium	Yes	
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	Low	Low	Low	Yes	not relate to Myanmar yet

C.4.3	Establish wildlife overpasses/underpasses to prevent road-kills.	Medium	Medium	Medium	Yes	Not relate to Myanmar yet
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	High	Low	Medium	Yes	
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	Medium	Medium	Yes	
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	Medium	Low	Medium	Yes	
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	Medium	Low	Medium	Yes	
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	Low	Low	Yes	
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	Low	Low	Yes	
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	Low	High	Yes	



NEPAL

Participants: *Kyran Kunkel, Ambika Prasad Khatiwada*

Country	Legality	Distribution/ population	Main threats	Note
Nepal		Bardia National Park Annapurna Conservation Area Chitwan Parsa National Park Tinjure Milke Jaljale Kangchenjunga Conservation Area	Habitat loss Prey loss Dogs Human-conflict Disease Management	Bardia National Park has Prey loss, Dogs, Human-conflict, and Disease issues. Annapurna Conservation Area has Prey loss, Dogs, Human-conflict, Disease, management issues. Chitwan Parsa National Park has Prey loss, Dogs, and Disease issues. Tinjure Milke Jaljale and Kangchenjunga Conservation Area have all six threats.

Recommended Strategies and Actions

The participants Ambika and Kyran made 32 recommended Actions including recruiting a full-time dhole specialist/coordinator to help project implementation. They developed several Actions, including survey, database, application of SDM, study site, local communication, sampling protocol, etc. to explore possibility of diet, genetic, movement and home range, and free-ranging dog effect research. Assessing local attitudes and socioeconomic significance and developing educational materials for children were also recommended. They suggested assessing local laboratory capacity for testing key pathogens and introducing essential laboratory protocols to fill diagnostic gaps by collaborating with Cornell University. They also suggest holding workshop or meeting for sampling, raise awareness, and creating networks.

Table R16. Actions recommended for NEPAL.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Recruit dedicated dhole specialist/coordinator (full-time)	?	2022	Person in position and funding secure	NTNC/ZSL/WWF/Govt (national and local)	Funds
Implement presence/absence surveys in potential sites (camera trap, interview, genetic analysis of scats)		2024	Coverage of all potential areas	NTNC or CMDN or NAST	Funding, dedicated dhole specialist, graduate student

Develop a Nepal-specific SDM to enable conservation planning		2024	Nepal SDM created	IUCN CPSG, IUCN Dhole Working Group, NGOs (all!)	Funding
Refer to SDM to identify new potential sites for ground-truthing		2019	Completion of prioritization	Dhole specialist	SDM
Create a national dhole record database		2019	Database exists	NTNC/ZSL/WWF/Govt (national and local)	Dedicated dhole specialist
Communication with other wildlife researchers and data sharing to obtain new dhole records.		2022	Regular meetings between groups	NTNC/ZSL/WWF/Govt (national and local)	Dedicated dhole specialist
Identify key study sites		2019-2024	Site identified		SDM, national dhole record database, personal knowledge
Interview surveys in local communities (attitudes and threats)		2019-2024	Interviews completed		Funding
Collect scats for diet analyses		2019-2024	Representative sample size from whole yr.	NTNC/CMDN/NAST	Laboratory partner to identify species
Process scat samples for population genetics		2025	Functional system for measuring population genetics	Dhole Working Group NTNC/CMDN/NAST	Knowledge of appropriate SNPs Laboratory partner to obtain sequences
Collar representatives from dhole packs to monitor movement and home range		2025	Movement data analysed	NTNC/ZSL/WWF/Govt (national and local)	Government permission Funding
Use new ecology data to revisit SDM and undertake PHVA		2026	New SDM and key PVHA questions answered	Dhole Working Group IUCN CPSG	Funding
Collect samples on an opportunistic basis		On-going	Samples collected	NTNC/ZSL/WWF/Govt (national and local)	Protocols for sample collection Supplies to collect the samples
Export samples to international partner		Depends on previous	Samples exported	Dhole Working Group	Government support Funding
Explore opportunity for local partner to assist with sequencing and SNP design		2019	Partner agency approached	CMDN	Further work depends on partner interest.

Interview surveys to assess local attitudes and socioeconomic significance		2024	Surveys complete	NTNC/ZSL/WWF/Govt (national and local), universities	Funding
Workshops at national and regional level to assess perceptions and to educate		2024	Workshops complete	NTNC/ZSL/WWF/Govt (national and local), universities	Funding
Develop educational materials for children including curricula, story books, TV and radio programs		2029	Material developed	Educators and media companies	Funding and interest from partners
Surveys to assess numbers of free-ranging dogs		2024	Estimates finished	Animal welfare charities, public health and veterinary dept.	Funding for surveys
Attitude surveys and community meetings to assess local perceptions and priorities.		2024	Meetings held, survey completed	Animal welfare charities, public health and veterinary dept. and local govt.	Funding
Consult with animal welfare charities and groups already involved in controlling feral dog numbers.		2020	Contacts made	Animal welfare charities, public health and veterinary dept.	
Stakeholder meeting/workshop to design acceptable and effective control methods		2025	Workshop complete	Local people, animal welfare charities, public health and veterinary dept. and local govt.	Funding
Implement outcome of workshop with monitoring		2026 onward	Dog numbers declining	Local people, animal welfare charities, public health and veterinary dept. and local govt.	FUNDING!
Workshop to raise awareness, train personnel and create networks		2020	Workshop complete, attendees trained	NTNC/ZSL/WWF/Govt (national and local), rangers	Funding
Sample collection SOPs		2020	SOPs written	Dhole Working Group	
Introduce essential laboratory protocols to fill diagnostic gaps		2019-2022	Laboratories able to perform all tests needed	Cornell University, NTNC, AFU and government	Funding
Assess local laboratory capacity for testing key pathogens		2019	Laboratory capabilities assessed	Cornell University, NTNC and AFU	
Undertake epidemiological investigation of important pathogens		As needed	Investigation complete	Cornell University, NTNC, AFU and government	FUNDING!
Following outbreak diagnosis undertake PVA-epidemiology modelling		As needed	Model complete	Cornell University, NTNC, AFU and government	Good information on local dhole populations and demography

Design control measures based on epidemiology		As needed	Control strategy identified	Cornell University, NTNC, AFU and government	
Implement control strategy with appropriate monitoring		As needed	Disease threat reduced	Cornell University, NTNC, AFU and government	

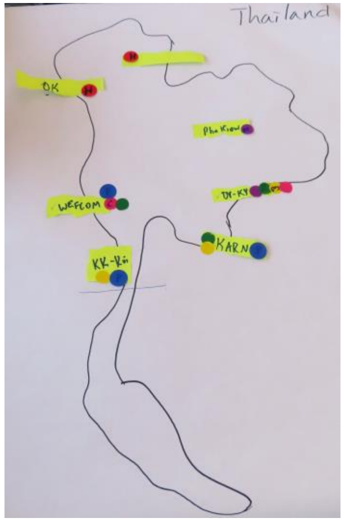
Table R17. Recommended Strategies and the rank of Impact, Feasibility, and Risk for NEPAL.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	High	High	Low	Yes	Dedicated dhole specialist needed.
S.1.2	Use the SDM output to identify areas for on-ground surveys	High	High	Low	Yes	Dedicated dhole specialist needed.
S.1.3	Undertake connectivity assessment across dhole range	High	High	Low	Yes	Need consultation from IUCN CPSG
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat)	High	High	Low	Yes	
H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	Medium	Medium	Yes	Challenging outside protected areas, which can be important for dholes in Nepal.
H.2.2	Improve prey populations through participatory approaches by providing alternative livelihood for local hunters.	High	Medium	Low	Yes	Funding essential. Can be very demanding
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	High	High	Low	Yes	
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	High	High	Low	Yes	
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	High	Low	Yes	
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [(1)].	High	High	Low	Yes	
C.2.2	Assess and monitor livestock losses to dholes.	High	High	Low	Yes	
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [(1,3)].	High	High	Low	Yes	

C.2.5	Develop country and/or state-specific compensation/insurance schemes for livestock predation by dholes.	High	High	Low	Yes	
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	High	High	Low	Yes	
C.2.7	Develop country-specific guidelines for pasture land management.	High	High	Low	Yes	
C.2.8	Increase patrolling, surveillance and law enforcement to prevent direct and indirect killing of dholes and their prey species.	High	High	Low	Yes	
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Medium / Low	High	Yes	Ability to influence government may be limited.
C.2.10	Increase communications with all level stakeholders [2,3].	High	High	Low	Yes	
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	High	Low	Yes	
C.2.12	Establish incident response team to rapidly respond to livestock losses (and, if necessary, to remove and translocate problem animals) [4].	High	High	Low	Yes	
C.2.13	Conduct trainings on conflict resolution for community representatives/liaisons [3].	High	High	Low	Yes	
C.3.1	Secure funds to develop documentaries that highlights ecological, socio-economic and culture importance of dholes [1].	High	High	Low	Yes	
C.3.2	Develop science-based education materials for school, social media and government officers.	High	High	Low	Yes	
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	High	High	Low	Yes	
C.3.4	Communicate with community leaders about the positive aspects of dholes.	High	High	Low	Yes	
C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	Medium	Low	Yes	More challenging outside protected areas
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	Medium	Medium	Medium	Yes	Coordinate with national parks and conservation projects aimed at other species
D.1.2	Assess size of free-ranging dog populations.*	High	High	Low	Yes	CMC or similar approach

D.1.3	Identify critical ecological and sociological drivers affecting dog abundance and distribution.	High	High	Low	Yes	Focused on free-ranging dogs Funding
D.1.4	Assess attitudes of local people to dogs and potential control measures, including the benefits of control (e.g. improved sanitation and public health).	High	High	Low	Yes	Funding
D.1.5	Design of control strategies for dog numbers and distribution in consultation with local communities, government, health professionals and local NGOs.	High	High	Low	Yes	Local people likely to be supportive
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	High	High	Low	Yes	
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	High	Low	Yes	Needs collaboration with government stakeholders.
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	High	Low	Yes	
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.	High	High	Low	Yes	
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	High	High	Low	Yes	Success depends on understanding of dhole population size and demography

THAILAND



Participants: *Naris Bhumpakphan, Yututhum Meklin, Nucharin Songsasen, Rob Steinmetz, Ronglarp Sukmasuang, Jidapha Thongbantum*

Country	Legality	Distribution/ population	Main threats	Note
Thailand	Fully protected	Western Forest Complex, Dong Phayayen-Khao Yai Forest Complex, Kaeng Krachan-Kuiburi Forest Complex, Phou Kiow	Prey depletion Human-conflict Disease	

Recommended Strategies and Actions

Because the distributions of dhole population are cros-sboundary between Thailand, Myanmar, and Bangladesh, the participants from these three countries worked together. Most of the strategies were recommended by the participants and they reported 2 large actions instead of listing actions related to each potential strategy. The first one is for the participants of Khai Yai Dhole PHVA meeting 2019 to present this global plan to their respective organizations. This action is led by the PHVA participants and timeline is 2019. The second is to develop the country action plan for dhole by integrating dhole into existing plans of other relevant species. This global plan needs to be taken back each country to develop specific actions and lead by Department of National Park. Before 2022 the leader conduct one workshop is held to initiate the process and could cooperate with academia, conservationists, NGOs, and other relevant stakeholders.

Table R18. Actions recommended for THAILAND.

Action description	Lead	Timeline	Measurement	Collaborators	Resources
Participants of Khai Yai Dhole PHVA meeting 2019 will present this global plan to their respective organizations.	Participants	2019	One meeting took place		WWF Thailand & Smithsonian
Develop country action plan for dhole by integrating dhole into existing plans of other relevant species. This global plan needs to be taken back each country to develop specific actions.	Department of National Park	2022	At least one workshop is held to initiate the process	Academia, conservationists, NGOs, and other relevant stakeholders	Funding

Table R19. Recommended Strategies and the rank of Impact, Feasibility, and Risk for THAILAND.

No.	Strategy	Impact	Feasible	Risk	Rec?	Note
S.1.1	Generate more accurate information on dhole presence to periodically update dhole distribution by reducing the timeframe for records.	Low	High	Low	Yes	We already know distribution of dhole across Thailand
S.1.2	Use the SDM output to identify areas for on-ground surveys.	Low	Medium	Low	Yes	We would recommend it mainly for corridor
S.1.3	Undertake connectivity assessment across dhole range.	High	Medium	Low	Yes	Also consider transborder connectivity with Myanmar
S.2.1	Develop context-specific methods for estimating dhole abundance, demographics and ecological requirements (prey, habitat, size, threat).	High	Medium	Low	Yes	
S.3.1	Obtain representative samples from geographically distinct dhole populations.	Low	Medium	Low	Yes	
S.3.2	Assess the genetic diversity across dhole range based on mutually agreeable standardized methods (SNPs)	Medium	Low	Low	Yes	
H.1.1	Establish and strongly implement a better land-use policy for dhole habitats and connectivity by defining no-development/ eco-sensitive zones.	High	Low	High	Yes	Antagonize stakeholders, higher risk for affecting local community and big business.
H.1.2	Define & maintain corridors/ linkages for dhole habitats within range countries and transboundary.	High	High	Low	Yes	From distribution mapping we can see dhole habitats are connected in the region; however, there are needs to assess the functionality of the connectivity.
H.1.3	Synergize dhole habitat conservation by means of an action plan aligned with existing national conservation strategies (protected areas, biosphere spheres, world heritage sites).	High	High	Low	Yes	
H.1.4	Advocate green development projects in dhole habitats and corridors.	Medium	Low	High	Yes	We are not condoning building roads and linear infrastructure within dhole habitat, however, if such structure already existed then we recommend this strategy.
H.1.5	Improve habitat quality based on scientifically accepted practice.	High	Medium	Medium	Yes	Although it’s feasible in some parts, still could be difficult to implement in remote areas.

H.2.1	Control poaching of prey (for commercial trade) through sensitization, patrolling and better law enforcement.	High	Medium	High	Yes	Careful with implementing such plans, as law can be applied discriminately
	Control poaching of prey through community outreach and harvest management of subsistence hunting.	High	High	Medium	Yes	This strategy is added for Thailand, however, might be applicable to other countries.
C.1.1	Generate more knowledge about dhole's biology, ecology, and prey density, its roles in ecosystem health, local culture, and its benefits to rural socio-economy.	Medium	Medium	Low	Yes	Consult scientific working group for appropriate method
C.1.2	Evaluate perceptions of local communities, government authorities, researchers, and policy makers about dholes (3).	Medium	Medium	Low	Yes	Consult scientific working group for appropriate method
C.1.3	Develop education and outreach programs for general public about the conservation significance of dholes (4).	High	High	Low	Yes	
C.2.1	Conduct economic valuations of the roles of dholes in controlling the population of crop depredators [1].	High	Low	Low	Yes	
C.2.2	Assess and monitor livestock losses to dholes.	Medium	Medium	Low	Yes	In reported high conflict areas
C.2.4	Educate all stakeholders about ecological, cultural, and socio-economic roles of dholes [1,3].	Medium	Medium	Low	Yes	
C.2.6	Assess livestock husbandry practices in human-dhole conflict areas and design an improved livestock management scheme (e.g. corral, livestock guard in the state forests) to minimize dhole predation.	Medium	Medium	Low	Yes	Might not be useful for dhole directly, however, might benefit other large carnivores
C.2.9	Reduce conversion of natural habitats into other land-use (road, infrastructure, agriculture, mining, ranching etc).	High	Low	High	Yes	Gaining political support will be difficult.
C.2.11	Engage or recruit local communities in anti-poaching, wildlife monitoring and outreach activities (as a way to provide alternative livelihood options).	High	Medium	Medium	Yes	
C.3.2	Develop science-based education materials for school, social media and government officers.	Medium	Medium	Low	Yes	Instead of focusing solely on dhole we recommend expanding it into large carnivore community.
C.3.3	Engage zoo education program to include (positive) dhole story in their conservation messages.	Low	Medium	Low	Yes	If only any zoo in Thailand have dholes already
C.3.4	Communicate with community leaders about the positive aspects of dholes.	Medium	Medium	Low	Yes	Instead of focusing solely on dhole we recommend expanding it into large carnivore community.

C.4.1	Conduct regular monitoring of traps/snares to reduce indirect killing of dholes.	High	High	Medium	Yes	
C.4.2	Improve road signages to enforce vehicular speed limits in dhole habitats and potential dhole crossing areas.	Low	Medium	Low	Yes	
D.2.1	Develop and distribute standard protocols for collection and storage of health samples, with guidance on accessing appropriate diagnostics.	Medium	Medium	Low	Yes	
D.2.2	Creation of a range-wide health network within the Dhole Working Group for collaborative research and the sharing/publication of health data.	Medium	Medium	Low	Yes	
D.3.1	Increase the awareness of protected area authorities, rangers, biologists and wildlife managers about the potential threat of disease and how to recognise outbreaks.	High	Medium	Low	Yes	
D.3.2	Train local personnel in the safe collection and storage of diagnostic samples from live and dead wildlife at every available opportunity.	High	Lowe	Mdium	Yes	
D.3.3	Develop collaborative networks involving wildlife professionals, veterinarians and diagnosticians to enable the rapid analysis of wildlife samples.	High	Medium	Low	Yes	
D.3.4	Where required, develop local laboratory capacity to perform key diagnostic protocols.					Covered in 2.2.3
D.3.5	Incorporate identified pathogens into population viability models to assess relative threat.	Medium	Medium	Low	Yes	
D.3.6	Epidemiological investigation of key pathogen(s) to identify disease reservoirs and/or drivers of exposure for dholes/prey species.	High	Low	Low	Yes	
D.3.7	Interpretation of epidemiology to design locally appropriate management strategies.	High	Low	Low	Yes	
D.3.8	Implement control strategies in an adaptive fashion with appropriate monitoring.	High	Low	High	Yes	

PART III.
Appendices

APPENDIX I. LITERATURE CITED

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APPENDIX III.
EX-SITU POPULATION DISCUSSION

Participants: *Brij Kishor Gupta (Central Zoo Authority); Jim Kao (SEAZA Species Management Committee); Boripat Siriaroonrat (Zoological Park Organization Thailand); Nucharin Songsasen (CSG Dholes Working Group)*

On 11 February, at Kasetsart University, a small group formed to discuss potential collaboration on dhole *ex-situ* population management. The group reviewed the *ex-situ* conservation management recommendations for dholes from the 2016 Global Integrated Collection Assessment and Planning (ICAP) Workshop for Canids and Hyaenids (Traylor-Holzer *et al*. 2018), shared updates on the dhole's *ex-situ* situation in each country/region, and proposed a set of corresponding actions, listed below.

2016 Canids and Hyaenids ICAP *Ex-Situ* Recommendations

1. Molecular analysis needs to be completed to determine taxonomic status for dholes.
2. CZA is recommended to maintain and possibly expand an intensively-managed *ex-situ* breeding population as an insurance population and potential future source population.
3. EAZA is recommended to maintain an intensively-managed *ex-situ* breeding population as an insurance population (pending results of molecular work).
4. AZA is recommended to maintain their current population; likely role is training and research if genetically redundant (testing needed) and therefore could remain as a small population supporting larger populations (together with SEAZA and JAZA).
5. Research, Education and Fundraising roles can be applied in all regions.
6. Regional programs are encouraged to support *in-situ* projects. Contact Brij Gupta regarding projects in India (to secure habitat and prey); contact Nucharin Songsasen regarding projects in SE Asia.

Additional Comments and Proposed *Ex-Situ* Actions (2019 meeting)

EAZA (European Association of Zoos and Aquaria)

- The source of EAZA captive population may come from northern region of China.

CZA (Central Zoo Authority of India)

- Dholes in northern and southern India may be different subspecies. There may be three dhole subspecies in India.
  Action: Genetic analysis is needed to confirm subspecies in India.
- Dholes are a priority among carnivores in India. But there are too many species to prioritize in addition to dholes, funding is lacking.
  Action: CSG can write to CZA to recommend prioritizing dholes as an important species.
- So far no animal exchanges have occurred between Asian and European zoos.
- Husbandry guidelines are needed in India.

Action: EAZA published Best Practice Guideline Dhole (C. alpinus) in 2017. Jim Kao will circulate to participants.

- There are health concerns, e.g. CDV in wild leopard populations.
  Action: Keep Martin Gilbert in the circle. Dholes should be a priority species for biomedical survey (Indira Gandhi Zoo can be the first one).
- The *ex-situ* population has low gene diversity.
  Action: Dholes that are rescued and not suitable for release could be new founders for an ex-situ insurance population.
- *Action: With support from CSG endorsement, make a request to India (Central Zoo Authority) to recommend genetic assessment of dholes in Thailand (fecal assessment, non-invasive methods). For further communication, CZA will find the responsible person, and Nuch will find a PI from US.*
- *Action: Nucharin Songsasen should go to India and invite the Member of Secretary to SCBI.*
- *Action: Consider developing a WAZA- branded project.*

ZPO (Zoological Parks Organization of Thailand)

- There is no need to establish a captive population since the wild population is stable.
- There are dhole ecology projects in three locations.
  Action: Project results can contribute to dhole conservation education materials.

AZA (Association of Zoos and Aquariums)

- Four AZA institutions have dholes. Population source of these animals may be from Northern China.
  Action: AZA could link with EAZA to manage as a meta- population, but there may be genetic issues.
- The population roles are Education, Research, and Insurance population.

SEAZA (Southeast Asian Zoo Association)

- *Action: Jim Kao will report results of this discussion to the SEAZA Species Management Committee.*