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VULNERABILITY OF ASIA'S KEYSTONE SPECIES TO CLIMATE CHANGE

Final Report

February, 2015

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Cover Photo: Snow Leopard in the Pamir Mountains (Creative Commons)

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FINAL REPORT

Jim Tarrant, PhD

Consultant to Asia Regional Environmental Field Support Task Order

ENGILITY| INTERNATIONAL RESOURCES GROUP

1320 Braddock Place
Alexandria, VA 22314
Tel: 703-664-2700

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GLOSSARY

AIACC	Assessments of Impacts and Adaptations to Climate Change
CCVI	Climate Change Vulnerability Index
CBD	Convention on Biological Diversity
GCC	global climate change
GEF	Global Environment Facility
GG SPA	Great Gobi Special Protected Area
GLOF	glacial lake outburst flood
GTI	Global Tiger Initiative
HKH	Hindu-Kush Himalaya, a mountainous sub-region of South Asia
HKKH	Hindu Kush-Karakorum-Himalaya, a variant of the HKH
ICIMOD	International Centre for Integrated Mountain Development
ICTP	International Centre for Theoretical Physics
IPCC	Inter-governmental Panel on Climate Change
IWSM	Integrated Watershed Management
KSLCI	Kailash Sacred Landscape Conservation Initiative
MVP	minimum viable population
NAPA	national adaptation programme of action
NBSAP	National Biodiversity Strategies and Action Plans
NGO	non-governmental organization
NWF	National Wildlife Federation
PES	payments for environmental services
RFE	Russian Far East
TCL	Tiger Conservation Landscape
UNCCD	UN Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
VA	vulnerability assessment
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

This report is an overview of the vulnerability of Asian keystone species to climate change. It focuses on keystone species mainly in the high mountains of Asia, especially predator species although it also presents a few other examples of other keystone species and describes their important roles in landscapes and ecosystem management. Climate change in high mountain Asia is having noticeably rapid impacts on the existing environment. Because of this, the role of keystone species in the larger landscape and its associated ecosystems is changing as climate change exacerbates human management of natural resources and sensitive landscapes.

This overview of the impact of climate change on Asia's keystone species and affected ecosystems suggests a number of conclusions. These include the following:

1. Climate change acts primarily as an additional stressor on the functioning and stability of ecosystems. These include the provisioning, regulatory, cultural and supporting services that ecosystems provide. Where human management of ecosystems is conservative and sustainable, climate change impacts are more likely to be successfully managed at least over the short and medium time frames. Where ecosystems are being degraded and poorly managed, climate change is likely to accelerate ecosystem degradation and local species extinction.

2. A number of methodologies have been developed to assess and prioritize the conservation of species threatened by increasing climate change. In most cases, these methodologies build on existing conservation management approaches but are more explicitly focused on developing climate adaptation plans and measures. At this point in our understanding of the impacts of climate change on natural ecosystems, the collection and analysis of monitoring data and developing standardized protocols for monitoring are essential for adaptation and mitigation planning.

3. Local communities are critical to climate change adaptation planning and implementation in most of the criticality affected ecosystems and landscapes studied in Asia. Because local people often have a good understanding of the changes that their environment have been undergoing they are, first, an important source of knowledge for researchers and planners. Second, their understanding of the threats to their environment and resource base and the active participation in monitoring and action plan implementation is essential for adaptation and mitigation to work sustainably. Community participation in monitoring changes in the environment and development of alternative livelihoods and changes in behaviors may be critically important to reducing pressures on vulnerable species including keystone species.

4. The role of national and sub-national government policy and regulation is also very important to the development and implementation of successful adaptation plans. These include sound environment and natural resource management policies and regulations. These "no regrets" actions provide environmental and socio-economic benefits now and provide additional insurance against the likely damage to vulnerable ecosystems from climate change in the near and medium term future.

5. The nature and scope of climate change reinforces the need for larger-scale climate change adaptation and mitigation action plans. Increasingly, this reinforces the need to work at a landscape or multiple landscape level and, as a number of the cases described in this paper have shown, a need to cooperate across national borders.

6. Of all keystone species discussed in this overview, the top predators (e.g. the large cats) and ecosystem engineers (e.g. the elephant) appear to experience the greatest vulnerability to increasing climate change. This is primarily because they are currently under varying degrees of severe stress from existing land management policy and practices. Chief among these current threats is the loss (conversion) or degradation of habitat for both predators and prey and the ecosystems on which both rely. Additional pressures come from illegal hunting and poaching, pollution, reduction or diversion of water supplies. Conservation of such keystone species may be critical to the survival ecosystems and even whole landscapes in some instances and so should be an important component of change adaptation.

1. INTRODUCTION

1.1 OBJECTIVES OF THE REPORT

This report examines the research on the impacts of climate change on keystone species and adaptation approaches to address these impacts. The focus on keystone species is a pragmatic choice. Trying to assess the vulnerability of all species in a community would be a daunting task even for scientists in developed countries with significant capacity and resources available. It's even less feasible for developing country researchers with much less capacity and resources to bring to the task. Hence, scientists frequently use an approach that assesses the vulnerability of the species playing the most important functional roles in the community. These species, when lost or reduced in abundance, will cause significant cascading effects on the populations of other species.

A large literature already exists on the likely impacts of climate change on natural ecosystems including those with high biodiversity. The literature also includes guides to the assessment of vulnerability and adaptation planning and management approaches to conserving biodiversity over the short, medium and long-term. The literature is not as rich for assessing biodiversity vulnerability in the developing world and in high mountain Asia in particular. Within this subset of literature, the discussion of keystone species and large predators is somewhat scattered although organizations like the International Centre for Integrated Mountain Development (ICIMOD) have made important strides to improve the amount and quality of informed analyses, especially of the Hindu-Kush Himalaya (HKH) region.

Hence, the objectives of this report are to survey the current literature to identify trends and relationships between climate change and keystone species and related ecosystems in upland/mountainous Asia and b) identify gaps and needs for further research and analysis. The analysis is not specifically focused on recommendations for future USAID regional or bilateral funding on this subject though the findings may be used to provide input into such programming.

1.2 ORGANIZATION OF THE REPORT

The first section of the report summarizes some of the methodologies and approaches used for assessing climate vulnerability of critical ecosystems and keystone species in particular, and for classifying species for management purposes. The second section is a discussion of climate adaptation planning and management approaches and best practices with respect to keystone species and important predator species in Asia. Where possible, tfhese will be related to the ecological situation of high mountain Asia, though much of the adaptation planning literature with respect to habitat conservation derives from practices and management approaches developed in the United States and other developed countries, which may not hinder adoption directly by developing countries owing to lack of technical capacity and financial resources. The final section discusses the main high mountain ecosystems in Asia and examples of Asian keystone species impacted by climate change – and development pressures – as well as specific cases of adaptation management of such species.

Lastly, the report will attempt to draw some conclusions and the apparent gaps in knowledge of this topic, though it should be noted the report should not be regarded as a comprehensive survey and assessment of the topic.

1.3 GEOGRAPHICAL SETTING

Within the context of Asia's high mountain regions, the report will focus on mammalian keystone species, especially, but not exclusively, predators. In particular, the main focus is on how climate change affecting the principles and approaches used in biodiversity conservation. The high mountains of Asia, including the Hindu Kush-Himalayas (HKH), Pamir Mountains, Altai-Sayan, the Tien Shan mountain range and associated environments are all experiencing rapid warming[1]. This warming's impacts can be seen through the melting of glaciers and changes in rainfall and snow packs that are having follow-on impacts on flora and fauna in upland and high mountain environments. As can be seen in Figure 1, these mountain ranges comprise an arc covering nearly three sides of China. These uplands and high mountain environments are characterized by a tremendous amount of diversity due, in part, to sharp changes in topography and rainfall regimes and, hence, the creation of many ecological niches even over relatively short distances. This is especially the case for the HKH. The HKH includes all or part of four Global Biodiversity Hotspots, 330 Important Bird Areas, two Mega-Diversity Countries (India and China), and 60 eco-regions of which 12 are Global 200 Eco-regions. A total of 488 protected areas cover 39% of the total area. The region directly provides essential ecosystem services to more than 200 million mountain people, and indirectly provides services, especially water, to 1.3 billion people living downstream in South and Southeast Asia. The river basins that arise in the HKH are an important source of food and hydropower for more than a billion people.[2]

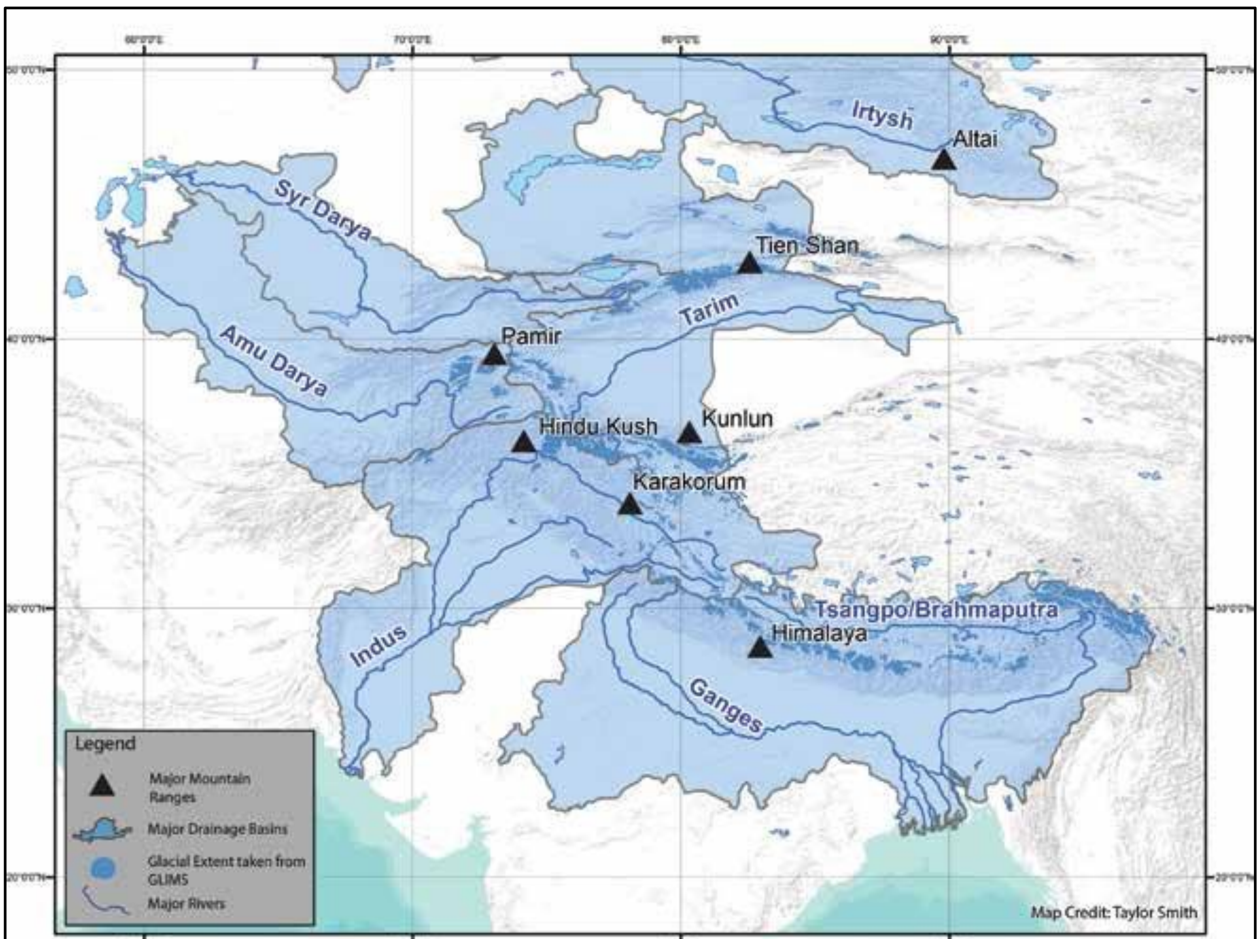
Most of the principal biome types of the world are represented in the HKH region, including arid steppe, tropical rainforests, coniferous forests, and deciduous broadleaved forests. Such diversity is even greater than that found in the forests of Amazonia. The biodiversity in this sub-region also varies widely in species' density (number of species per unit area). Across the sub-region, beta diversity, which indicates species' difference among samples, is also high.[3] In addition to the species that are permanently resident in the region the HKH also provides asylum to a host of migrant species, which either traverse the region as part

1 Singh, 2011, pp. 9-13.
2 Sharma et al., 2009, Climate Change in the Himalayas, p.10.
3 Singh., p. 22

of their migratory patterns or which are taking refuge because of changes in global temperature.[4]

The Pamir, Tien Shan and Altai-Sayan mountain ranges are less dramatic with respect to elevation and the wide range of ecosystems represented but still possess significant biodiversity and endemism. These ranges are also generally drier than the eastern HKH, in particular since they are less affected by the Asian monsoon. Nevertheless they are the source of several major river basins that support the populations and economic development of Central Asia, in particular.

Figure1. Map of Central and South Asia's Mountain Ranges



Source: Taylor Smith, **Climate Vulnerability in Asia's High Mountains,** p.17.

The wide range of mountain ecosystem diversity also greatly complicates assessing the impacts of climate change on individual ecosystems or on individual species within those ecosystems since micro-climatic effects are likely to outweigh the pattern of broader climate change at least over the short and medium terms. In addition, collecting sufficient

4 Ibid, p. 22.

long-term observations over so many different ecosystems for climate analysis purposes has been very difficult so that scientists have tended to look at actual observed changes in ecosystems and how these correlate with important climate parameters such as temperature and rainfall.

1.4 MEANINGS AND IMPORTANCE OF KEYSTONE SPECIES

Over time, scholars have developed several ways of classifying the importance of individual species or groups of species for a given ecosystem or species that have importance in various ways for habitat management. Table 1 provides a list of these and their definitions as well as representative examples.

As the table notes, a *keystone species* is a one that exerts a disproportionate effect on its associated ecosystem. The persistence of a large number of other species in that ecosystem may depend on the presence of that keystone species. If it is eliminated from that ecosystem, the species it supported also will disappear or will drastically upset the ecological balance (as may happen with the elimination of a keystone predator). These changes may lead to a chain reaction that could transform the ecosystem drastically, and by extension this could have second tier impacts on human communities depending on the same landscapes.

Keystone species may be top carnivores that keep prey in check, large herbivores that shape the habitat in which other species live, important plants that support particular insect species that are prey for birds, bats that disperse the seeds of plants, and many other types of organisms. The presence of wolves or tigers (both keystone species) changes the behavior of grazing animals as well as their population size and consequently improves native flora, enhances soil carbon sequestration and increases biodiversity throughout the food web. A number of studies reviewed suggest that a more resilient landscape is better able to withstand the extremes of climate change, reducing the costs of severe weather events.[5] Conversely, the removal of keystone species worldwide leads to increasingly simplified, degraded and less stable ecological networks.

Our selection of mammalian keystone species, especially predators, is also a function of the number of studies available that focus on the roles of these keystone species and their management as well as the impacts on them from climate change, habitat changes and development.

[5] See among others, Braatz, FAO, 2009 and the National Fish, Wildlife and Plants Climate Adaptation Partnership, among others.

Term	Concept/Definition	Examples	Selected References
Keystone Species	A species *"whose impact on the community or ecosystem is disproportionately large relative to its abundance"*	Five major categories recognized are predators and their prey species; plant pollinators & seed dispersers; hosts required for reproduction; and habitat or energy modifiers	Paine, 1969, Mills et al. 1993; Power et al. 1996

Table 1. Concepts Used for Classifying Species Importance within an Ecosystem

Indicator Species	An organism *"whose characteristics (e.g., presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest."*	closely linked predator-prey species; species whose abundance reflects local plant or animal richness or diversity; invasive species indicator of ecosystem damage	Landres et al. (1988)
Umbrella Species	A species *"whose conservation is expected to confer protection to a large number of naturally co-occurring species."*	Used as tool for determining the minimum size for protected areas, selecting sites for inclusion in reserve networks, etc.	Roberge & Angelstam (2004); Wilcox (1984)
Focal Species	*"Taxa targeted for management through vegetation-restoration efforts because they are the ones most influenced by threatening processes."*	Single or set of species for defining spatial & compositional attributes that must be present within a landscape (e.g., area-sensitive, dispersal, resource & ecological process limited taxa)	Lambeck (1997)
Flagship Species	*Species chosen to represent "an environmental cause, such as a critical ecosystem or habitat in need of conservation."*	Selected for vulnerability, attractiveness or distinctiveness in garnering public support & acknowledgement (e.g., giant panda, tiger, snow leopard, Marco Polo sheep, sea turtles)	Simberloff, D. (1998); Bowen-Jones &. Entwistle (2002)
Surrogate Species	Used as proxies for a wider range of plants and animals, thus intended as "shortcuts" for monitoring an ecosystem or community with respect to anthropogenic disturbances, population change or richness of biodiversity.	Also used with terms like indicator, umbrella and flagship	Caro and O'Doherty (1999)

From: Jackson, Rodney and Nandita Jain, 2006.

Some of these classifications may overlap, e.g. keystone and indicator species and some species may be found in several of these classifications. For example, the Asian tiger is a keystone and indicator species but is also considered an umbrella and a flagship species. In addition to the list in Table 1, some scholars have discussed the importance of cultural keystone species.[6] These include specific species of plants and animals or groups of these "that form the contextual underpinnings of a culture, as reflected in their roles in language, ceremonies, narratives, diet, and medicine."[7] Some species,

Trophy Hunter with Marco Polo Sheep in the Pamir Mountains, a source of income for low income households in mountainous Central Asia

[6] See the discussion in Cristancho and Vining, 2004.

[7] Jackson, Rodney and Nandita Jain, 2006, p.4.

such as the snow leopard are both cultural and ecological keystone species. In the case of the snow leopard, it has a traditional, symbolic importance to communities in the Pamir Mountains, which is one of its known habitats. Many other plant and animal species are (or were) cultural keystone species, e.g. tobacco to some Native Americans; the lotus flower to Buddhists; the olive tree in several Mediterranean cultures (past and present). Cultural keystone species encompass species that have symbolic importance (bald eagle for the United States), religious importance and economic importance for specific communities (ranging from olive oil to Asian elephants) and many others. One important role of cultural keystone species is in their potential to defuse perceived conflicts between conservation and economic development. Ecotourism, especially community-based ecotourism and cultural tourism are two examples of this role. However, just because a specific species has cultural importance for individual communities or even entire cultures does not mean that those communities appreciate the importance of managing those species and their habitats sustainably. This is especially the case where there are lucrative markets for these species outside the control of the affected communities. For example, in Central Asia, the Marco Polo sheep is a culturally-important animal for the ethnic Kyrgyz communities. At the same time, they are also being seriously overhunted by those communities as well as outsiders.[8]

Focusing on the changes in the distribution and/or behaviors of keystone species is one way of assessing the impact of climate change on particular ecosystems whether these are undisturbed or are already being affected by human interactions. Accelerating climate change has the potential for not only destabilizing and degrading critical ecosystems and the plant and animal species within them but also threatening traditional cultures and community relationships to culturally-important flora and fauna. This has implications for adaptation planning and management that need to be anticipated and incorporated into action plans, including the need for participatory, local adaptation planning. This is discussed later in this report.

2. METHODOLOGIES FOR ASSESSING CLIMATE CHANGE VULNERABILITY OF KEYSTONE SPECIES

2.1 FRAMEWORK FOR IDENTIFYING SPECIES AND ECOSYSTEM VULNERABILITY

Assessing the vulnerability of all species in a community is a daunting task and even more so in upland and high mountain Asia with its wide range of ecosystems and resident species of flora and fauna. This is even more challenging because of the relative paucity of good climate or biodiversity data and studies for this large region.[9] As noted in Section 1, a more practical approach might be to assess the vulnerability of keystone species as a proxy for the web of species in the keystone species' ecosystem. Determining which species should

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[8] Ibid, pp. 14-15.

[9] Sharma, et al., **Climate Change Impacts and Vulnerability in the Eastern Himalayas**, p. 20

be considered “keystone” requires an understanding of the natural history of many of the species in the community being studied. Quantitative methods of identifying keystone species via **food web analysis** (Ebenman and Jonsonn 2005) can be used, though these methods can be time and data intensive. However, if this approach is used it can clarify the functional roles of various species in the ecosystem. If an important ecosystem’s stable function is dependent upon just one species, that species is likely providing some “keystone” function. A dramatic example is the now-extinct wooly mammoth. This very large relative of the elephant consumed a huge amount of vegetation, especially tree leaves and grasslands. Their impact was such that forests were largely suppressed across much of Europe during the era when they were most numerous. When their numbers started to collapse from a number of factors, including global warming, birch forests rapidly expanded and the mammoth retreated to Siberia and eventually became extinct.[10]

Alternatively, species can be selected by answering a series of questions about which species play dominant roles in the community. Threatened and endangered species, although frequently the targets of conservation action are often too rare to qualify as keystone species even if they may have played such a role in the past. Exceptions to this observation that rare species aren’t likely to be keystone species are a) those species that are endemic and *locally* common species that structure their particular communities and b) top predators such as the various sub-species of the Asian tiger.

Table 2 lists those questions that are often asked when trying to **identify keystone species.** A number of methods are available to determine the climate change vulnerability of the keystone species once they are determined. These methods can be grouped into trait-based and bioclimatic envelope modeling approaches. As noted in Section 1, this report focuses primarily on mammalian predators that are also keystone species. But Table 2 shows that a wide range of important ecological functions can lead an organism to be designated a keystone species in a given terrestrial or marine ecosystem. Certainly, some keystone species have an outsized impact, literally and figuratively, on a variety of ecosystems. Elephants are perhaps one of the best examples of such an outsized “keystone” species as the case study in Section 4.3 shows.

Climate change acts as an additional stressor on a given ecosystem, an increasingly important stressor but also one quite variable in its impact on a given ecosystem and its constituent ecological communities, depending upon their composition and overall resilience capacity. In addition, climate change’s impact partly depends upon the nature of the existing management of the ecosystem, especially man-altered systems such as agro-ecosystems but also the management of natural ecosystems, e.g. ecosystems under some sort of conservation or wildlife management. The more the management system incorporates elements that promote resilience and stability, the more likely that climate change adaptation will be successful, at least over the short and

[10] Phil Berardelli, “Did Mammoth Extinction Warm Earth?”, in **Science**, July 2010.

medium-term timeframes. However, as discussed below, mountain ecosystems often have inherently narrow adaptive capacities due to limitations caused by elevation and sharp differences in precipitation, soils and orographic factors.

Table 2. Criteria to Determine Keystone Species

1) Which species provide or significantly contribute to essential floral and faunal community structures and functions?
2) Are there ecosystem engineering species that create habitat for others, such as beavers, cavity-excavating woodpeckers, or prairie dogs (to use American examples)?
3) Are there specific pollinators required for dominant plants, e.g. the role of tiny thrips in pollinating the giant Dipterocarps in Southeast Asia?
4) Are there species that are primarily responsible for seed predation?
5) Are there species that provide limiting nutrients in the community, e.g. the role of mycorrhizal fungi, which provide nitrogen to the roots of host plants in exchange for sugars?
6) Is there a top predator that keeps meso-predators in check?
7) Are there plants that produce unusually large amounts of nectar, fruits, or nuts that support populations of several animal species during times of scarcity?
8) Is there a fungus or disease agent that keeps populations in check?
9) Is there a species that influences fire frequency and intensity through its growth?
10) Is there an herbivore or grazer that prevents rapid expansion of plant populations? See the previously described role of the extinct wooly mammoth but the modern elephant also plays a similar role.

Source: Comer et al., **Climate Change Vulnerability and Adaptation Strategies for Natural Communities**, pp. 22-23.

As with other sectors affected by climate change, the vulnerability of critical ecosystems and the keystone species within them is evaluated using vulnerability assessment methodology. Climate change vulnerability for any given population, whether human or wild ecosystems is assessed according to three analytical components: sensitivity, exposure and adaptive capacity. *Sensitivity* refers to the system's or species' innate characteristics and tolerance for changes in critical variables such as temperature, rainfall, increased disturbance (e.g., fires, extreme storms, flooding). *Exposure* refers to external factors such as the character, magnitude and rate of change in environmental variables to which the system and species are exposed. *Adaptive capacity* is the extent to which the system or species is capable of coping with climate changes with minimal disruption.

Vulnerability assessments are critical to how decision makers will address the management of climate change impacts on the species, habitats and ecosystems with which they are dealing. Hence, the management objectives, nature and quality of the information and the adaptation and mitigation planning framework that the decision maker uses are essential to the design of the vulnerability assessment (VA)[11]

[11] Glick et al., NWF, 2011, p.3.

Because the VA is closely tied to the management system and planning and decision making process, there is no single approach to adaptation planning, though almost all methodologies employthe three components of sensitivity, exposure and adaptive capacity described above. Adaptation has emerged in recent years as the most important overall approach addressing the impacts of climate change on vulnerable ecosystems and the species within them. However, for carbon rich ecosystems such as humid tropical forests found in countries like Indonesia, Brazil and the Democratic Republic of the Congo, biodiversity conservation combined with carbon sequestration, i.e. prevention of deforestation and pursuing reforestation is also very important to addressing climate change in the long-term, especially. Such efforts are subsumed under the global climate change strategy called Reduced Emissions from Deforestation and Forest Degradation (REDD)[12]. However, even such climate mitigation approaches such as REDD (or REDD+) often incorporate climate adaptation approaches within them both for resident, vulnerable human populations and wildlife communities.

This paper will not go into a general discussion of the causes of climate change and other aspects of climate science. USAID's Global Climate Change (GCC) Office has developed both online training courses and technical and policy guidance that covers this subject in considerable depth. These can be accessed through links such as: http://www.usaid.gov/climate, www.climatechange-asiapac.com, and http://www.climate-services.org. The UNDP and the World Bank (http://sdwebx.worldbank.org/climateportal/) also provide data, guidance and other knowledge tools related to climate change adaptation.

As noted above, VA's for natural resources-related subjects will vary by objective, information requirements and technical capacity. In addition, VA tools and methods have been developed from a variety of sources according to the unit of analysis or system that is being studied. The US Fish and Wildlife Service (FWS) have compiled a wide range of these in "*Climate Change Vulnerability Assessment for Natural Resources Management: Toolbox of Methods with Case Studies"*. These are organized by species approaches, habitat approaches, place-based approaches (e.g. protected areas), ecosystem processes, ecosystem services, watershed and water resources, international and other. In Table 3, below, we list a selection of the approaches and associated tools and methods the FWS surveyed and which body of knowledge they periodically update.

Table 3: VA Approaches and Selected Associated Tools and Methods

[12] REDD, in recent years has now been enhanced to more explicitly include the roles of conservation, sustainable management of forests and enhancement of forest carbon stocks. This is "REDD+".

Source: Compiled from Johnston, FWS, 2014

VA Approach	Associated Tools and Methods
Species Approaches	**Coarse-filter Species Approaches – Indices** • Climate Change Vulnerability Index, CCVI (NatureServe) • A System for Assessing Vulnerability of Species to Climate Change, SAVS (US Forest Service) • Framework for categorizing the relative vulnerability of threatened & endangered species to climate change (US Environmental Protection Agency) • Standardized Index of Vulnerability and Value, SIVVA (Reece and Noss 2014) • Climate Change Vulnerability Assessment Framework, CCVAF (IUCN) • Framework for Assessing Climate Change Vulnerability of California's At-risk Birds (Gardali et al. 2012) • Assessing the Vulnerability of Biodiversity to Climate Change Using Landscape-scale Indicators (Klausmeyer et al. 2011) • Novel predictive framework of species extinction vulnerability for coral reef fishes (Graham et al. 2011) Fine-filter Species Approaches – Modeling Migratory Species Observed Effects of Climate Change on Species
Habitat Approaches	**Coarse-filter Habitat Approaches – Indices** • Climate Change and Massachusetts Fish and Wildlife: Volume 2, Habitat and Species Vulnerability (Manomet) • Northeast Association of Fish and Wildlife Agencies Regional Habitat Vulnerability Model (Manomet) • Habitat Climate Change Vulnerability Index (HCCVI) (NatureServe) • Climate Change Vulnerability Assessment for Shorebird Habitat (CCVASH) Fine-filter Habitat Approaches – Modeling Specific Habitat Types • Modeling
Place-Based Approaches	• National Parks • National Forests and/or National Parks • National Wildlife Refuges • Tribes
Ecosystem Processes (selected)	• Potential climate change impacts on temperate forest ecosystem processes (Peters et al. 2013)
Ecosystem Services (selected)	• Ecosystem services and livelihoods – vulnerability and adaptation to a changing climate • Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services • The Impact of Climate Change on California's Ecosystem Services • Climate change's impact on key ecosystem services and the human well-being they support in the US
Watershed and Water Resources (selected)	• Assessing the Vulnerability of Watersheds to Climate Change: Results of National Forest Watershed Vulnerability Assessment Pilot Project • Climate Change Handbook for Regional Water Planning (EPA and CA DWR) • Climate Change Vulnerability Assessments: A Review of Water Utility Practices (EPA) • Vulnerability of U.S. Water Supply to Shortage: A Technical Document Supporting the Forest Service 2010 RPA Assessment
International (Selected)	• Dominican Republic Climate Change Vulnerability Assessment Report • Climate Change Vulnerability Assessment of Wangchuck Centennial Park, Bhutan

In high mountain Asia, climate change vulnerability assessment and adaptation planning is primarily focused on high mountain communities and ecosystem services, the latter being mainly water security. There aren't methodologies developed specifically to analyze species and natural ecosystem vulnerability for high mountain Asia. The analytical tools and approaches used are mainly those that have emerged from work in the U.S. and other developed countries. This report looks at some of these below.

The Asia Development Bank (ADB) has primarily employed models based on the Intergovernmental Panel on Climate Change's (IPCC) scenarios over the short, medium and long-term and using various GHG and temperature increase projections to estimate impacts on forests or water supply.[13] Specifically, they have adapted the regional climatic model (RegCM4) developed at the International Centre for Theoretical Physics (ICTP), which is in Trieste, Italy. The model is available as open source. These models need to be supplemented by country-level stocktaking and analysis. However, these models have limited utility to address individual species sensitivity, exposure or adaptive capacity as well as the ecosystems with which they are associated quite aside from the fact, as noted above, these mountain ecosystems vary significantly over relatively short distances.

2.2 SPECIES AND ECOSYSTEM BASED VULNERABILITY ASSESSMENT METHODOLOGIES

In the early to mid-2000s, the Assessments of Impacts and Adaptations to Climate Change (AIACC) program operated to support the development of scientific capacity to address ecosystem vulnerability and adaptation requirements in a variety of countries including parts of high mountain Asia. AIACC was a global initiative developed in collaboration with the UNEP/WMO Intergovernmental Panel on Climate Change (IPCC) and funded by the Global Environment Facility to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries. The AIACC, like other VA and adaptation analysis programs employed a variety of different tools including modeling, analysis of large climate datasets, building geographic information system (GIS) layers and participatory tools such as survey and participatory rural appraisal.

In Europe, a large number of regional and country studies have been undertaken to assess the impacts of climate change on biodiversity in the European Union. As with the American studies these have primarily employed downscaled global circulation models and available data on individual species' "climate space" to assess sensitivity and exposure. However, few of those studies have been able to estimate adaptive capacity because of the timescales involved and the interaction of non-climate threat factors, which can be very important.[14]

Motivated by the need for a means to rapidly assess the vulnerability of species to climate change, the U.S. organization NatureServe initiated a collaborative effort to develop a **Climate Change Vulnerability Index (CCVI)** working with the US Fish and Wildlife

[13] See, for example, Suphachalasai, Ahmed, M. and S., Assessing the costs of climate change and adaptation in South Asia.

[14] See Bertzky et al., 2011.

Service, state agencies and other NGOs. This tool uses distribution and a given species' natural history information within a specific geographical area (such as a U.S. state but it could be used for any appropriate administrative jurisdiction) to rapidly estimate the relative risk of local extinction as a result of climate change. [15]

The CCVI is an adaptation of a framework that Williams et al. (2008) developed that categorizes a species' vulnerability into two main components: exposure to climate change within its range and the sensitivity of the species to climate change. Data for these two components take the form of downscaled climate predictions across the range of the species within the assessment area and scoring of the species against 17 factors related to its anticipated climate change sensitivity, such as dispersal ability and habitat specificity. Additional factors addressing indirect exposure to climate change, such as presence in areas likely to be affected by rising sea levels, as well as documented responses to climate change (if available) are also included. These factors are all documented in the scientific literature to be correlates or predictors of vulnerability to climate change (exposure and sensitivity). The outcome is one of six possible Index categories: three degrees of "Vulnerable" (Extremely, Highly, Moderately), two degrees of "Not Vulnerable" (Presumed Stable, Increase Likely), and "Insufficient Evidence".

Assessing lists of priority species with this Index provides a means of dividing species into groupings of relative risk to climate change and of identifying key factors causing species to be vulnerable. Used with standard conservation status assessments such as the NatureServe G- and S-rank system, the Index can help land managers evaluate the likely effectiveness of alternative strategies to promote adaptation of species to climate change as well as selected key species (including keystone species) to monitor. The results can be valuable input for modifications of state (or other sub-national governmental unit) wildlife action plans to address climate change which represent one form of "no-regrets" actions that have broader benefits to address non-climatic stressors.

Lawler (2009) observes that to address climate change, managers of landscapes will need to act over different spatial and temporal scales. The focus of restoration will need to shift from historic species assemblages to potential future ecosystem services. This is described in the example presented from the HKH sub-region in this report. Active adaptive management based on potential future climate impact scenarios will need to be a part of everyday operations. And triage will likely become a critical option for landscape managers. Lawler also observes that protected areas may need to be restructured to allow for temporal corridors across biomes for species migration as climate changes. Although many concepts and tools for addressing climate change have been proposed, key pieces of information are still missing. To successfully manage for climate change, a better understanding will be needed of which species and systems will likely be most affected by climate change, how to preserve and enhance the evolutionary capacity of species where

[15] See, Comer et al., 2012.

this is even possible, and in which situations and systems will proposed general adaptation strategies actually work and how can they be cost-effectively applied.

Because it is a trait-based tool that allows relatively rapid assessment of groups of species, the CCVI is applicable, at least in theory, to all terrestrial and aquatic plant and animal species. The CCVI places species on a categorical scale from those that are extremely vulnerable to those that actually may benefit from climate change, e.g. by opening up new habitat or eliminating competitors. The CCVI has been applied to the distribution of each species within a given ecoregion at least in the U.S.

Using the CCVI method, Comer et al. (2009) observed that the variability in climate expressed by the distribution of a given community can provide another useful indication of adaptive capacity. When compared to community types occurring in a limited range of climates, those types occurring across a wide range of climates arguably have a higher likelihood of coping with the impacts of climate change over the upcoming decades.[16] However, uncertainly over the rapidity of climate change and associated impacts makes medium-term adaptive capacity problematic. As noted, this was also the case for many of the European methodologies.

2.3 TYPOLOGY OF SPECIES AND POPULATIONS MOST VULNERABLE TO CLIMATE CHANGE

St. Clair and Howe (2011) have identified the types of species most susceptible to the impacts of climate change.[17] These include the following:

- Rare species
- Species with long generation intervals (e.g., long-lived species like elephants or tortoises)
- Genetic specialists (species that are locally adapted, e.g. Darwin's finches)
- Species with limited phenotypic plasticity (i.e. the ability of an organism to change or adapt its characteristics to changes in the environment)
- Species or populations with low genetic variation, e.g. small populations or species influenced by past genetic bottlenecks, e.g. inbred species
- Species or populations with low dispersal and colonization potential (fragmented, disjointed populations)
- Populations at the trailing edge of climate change (i.e. those already living at the margins of their range; worsened by climate change)
- Populations with "nowhere to go" (lack of nearby suitable habitat)
- Populations threatened by habitat loss, fire, disease, or insects

Many species of flora and fauna may be *relatively* vulnerable by the above criteria but those with little inherent adaptive capacity for one or more of the above reasons are clearly at the greatest risk. On the other hand, species that have evolved specific traits to adapt to

[16] Comer et al., 2012, p.23.

[17] St. Clair and Howe, 2011, p. 405.

threats within their longstanding habitat may find the nature or severity of those threats changing or even disappearing under a changed climate.[18]

The probability of a serious loss of genetic diversity doesn't depend exclusively on the nature and rate of climate change in a specific locality and subsequent impacts on species but also on political, economic and social factors, i.e. the management of a given ecosystem. Hence, the usefulness of the above typology is to pinpoint those species where greater attention to adaptive management is required. Tropical forests are especially vulnerable because these forests, in their undisturbed state, especially those in Southeast Asia have very high levels of biodiversity but relatively low populations per hectare. Rapid deforestation means that whole species complexes are threatened with extinction if they haven't already been lost.

In the case of keystone species, especially keystone predators, climate-induced changes in their prey can have dramatic impacts on their numbers. This was demonstrated in an oft-cited study of seas stars in Washington State.[19] Local species of mussels and barnacles are constrained by the temperature of their habitat, i.e. inter-tidal rocks. However, these species are also regarded as "ecosystem engineers" in that they change their immediate habitats in ways that offer habitat for a diversity of other species. The yellow sea star is the local keystone predator and, without restraint of predation will radically reduce mussel and barnacle populations. By artificially reducing predation by putting the shellfish in protective cages, the barnacle numbers quickly recovered and also increased local species richness significantly. In this experiment, the author demonstrates that increased temperatures, combined with a top predator not as sensitive to temperature rise as it prey can lead to a collapse of important prey populations and destabilize the wider local ecosystem.[20]

3. MANAGEMENT STRATEGIES TO ADDRESS VULNERABILITY OF SPECIES AND ASSOCIATED ECOSYSTEMS TO CLIMATE CHANGE

In this section, we will review approaches to management of species vulnerable to climate change with attention to keystone species and top predators. Although many concepts and tools for addressing climate change have been proposed by members of the conservation and climate science communities, key pieces of information are still missing. Moreover, past global warming episodes are not a good guide for species management in the current warming period since anthropogenic warming is far more rapid than past warming periods, which allowed species to adapt over long periods of time.

[18] IUCN Workshop, 2007, p. 8.

[19] Harley, 2011, pp. 1124-1126.

[20] Ibid., p. 1126.

To successfully manage for climate change, a better understanding will be needed about which species and systems will likely be most affected by climate change, how to preserve and enhance the evolutionary capacity of species, how to implement effective adaptive management in new systems, and perhaps most importantly, in which situations and systems will the general adaptation strategies that have been proposed work and how they can be effectively applied.[21]

3.1 PRINCIPLES FOR CLIMATE CHANGE ADAPTATION MANAGEMENT IN NATIONAL STRATEGIES

The United States National Fish, Wildlife and Plants Adaptation Strategy (2012) is focused on a set of objectives, which build upon agreements in the CBD and also in the UN Framework Convention on Climate Change (UNFCCC).

These include:

- Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions.
- Update or develop species, habitat, and land and water management plans, programs and practices to incorporate climate change.
- Enhance capacity for effective management in a changing climate.
- Support adaptive management through integrated observation and monitoring and use of decision support tools.
- Increase knowledge and information on impacts and responses of fish, wildlife, and plants to a changing climate.
- Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.
- Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

The U.S. strategy is based on U.S. laws and regulations, institutional structures, including federalism and public participation, especially through NGOs.

The principles articulated in the U.S. strategy can and in many cases have been adapted to address critical species vulnerability in other parts of the world including high mountain Asia. In most of these countries, the mechanism used is the national adaptation programme of action (NAPA). NAPAs have been a significant focus of international assistance in many developing countries. They are meant to incorporate the principles of the CBD and the UN Convention to Combat Desertification with the UNFCCC. The premise is that activities that promote adaptation to climate change and climate resilience can also contribute to the conservation and sustainable use of biodiversity and sustainable land management.

[21] Lawler, 2009, p.79.

NAPAs are meant to support National Biodiversity Strategies and Action Plans (NBSAPs) under CBD; National Action Plans (NAPs) under UNCCD as well as other sustainable development plans and poverty reduction strategies. Given that all relevant stakeholders are supposed to be involved during the preparation of NAPAs, a holistic bottom-up approach focusing on both vulnerable livelihoods and ecosystems are more likely ensured thus enhancing the practical utilization of the NAPAs. The main objective of the biodiversity and nature conservation parts of NAPAs is "mainstreaming" conservation into planned adaptation and actions.

Most NAPAs have tried to make a strong linkage between the conservation of critical ecosystems with vulnerable populations and livelihoods because of the large proportion of their populations directly dependent upon natural resources and ecosystem services like water. NAPA also focus strongly on identifying strategies for building capacity to implement NAPAs including the more active involvement of the public and the private sector.

Regarding biodiversity and nature conservation mainstreaming, the aim of the NAPA process is to "maintain biological options for adaptation – integrating biodiversity into [climate] adaptation and mitigation projects."[22]

The existence of non-climate stressors, including habitat fragmentation, pollution and the introduction of invasive species limit the resilience of ecosystems to climate change. In addition, climate change may further accelerate current high rates of biodiversity loss, precisely at the time when diversity, and the range of ecosystem adaptation options and resilience that diversity provides, are most needed.

Incorporating biodiversity conservation objectives into climate change adaptation and mitigation activities may help to maintain the "biological capital" of adaptation options, and promote the achievement of maximum mitigation benefits.

Guidelines for mainstreaming biodiversity into NAPA adaptation and mitigation strategies include the following:

• Initial activities should focus on win-win options. These adaptation options will lead to benefits even if the rate of climate change is slow[23]. These kinds of mitigation options may lead to benefits for local communities in the absence of external financial incentives.

[22] IUCN, 2004, pp.31

[23] Also known as the "no regrets" option. "No regrets" policies and other measures are those designed to achieve more sustainable management of ecosystems and the human environment irrespective of whether they mitigate the impacts of future climate change or not. The argument for such actions is that the specific impacts of future climate change on a particular ecosystem or species may be uncertain now for many reasons but "no regrets" actions have demonstrated benefits and protective effects on affected ecosystems/species now and in the future.

• Prioritize projects that offer multiple benefits (adaptation in conjunction with mitigation, biodiversity or local livelihoods goals)

• Adaptation and mitigation activities should be consistent with the local goals for sustainable development. This may require a more intensive public education on what is "sustainable".

• All mainstreaming measures should have clearly defined objectives, and measurable outcomes.

• The support of local communities is critical to the success of adaptation and mitigation activities. Ensuring stakeholder involvement and documenting and using local knowledge and expertise as much as possible will help attain support.

• Measures should be regularly reviewed for their social and environmental impacts.

• Adaptation measures should clearly identify the aspects of climate change and adaptation needs that they are addressing.

• Adaptation planning and associated measures cannot be static. Activities and policies must evolve based on past experiences and observing which practices are successful and which are not, and based on improved understanding of on-the-ground impacts of climate change.

• Adaptation planning is most relevant in the short-term. Projects should be tailored to these short-term needs. This is because the short-term is when climate predictions are most reliable, while considering how activities can be modified to meet future needs.

• Promoting insurance for ecosystems and humans should be considered to minimize economic and ecological losses in the event of a climate-related disaster.

• Carbon sequestration initiatives must improve or maintain local livelihoods. Initiatives that protect carbon sinks at the expense of local communities are likely to fail.

• Reforestation and afforestation should be done using local species whenever possible. Planting a mixture of species will provide greater biodiversity benefits, and may provide more benefits to local communities due to the greater variety of non-timber forest products.

• Mitigation measures should address issues of leakage.

Three categories of adaptation responses have emerged that are relevant to the relationship between climate vulnerable ecosystems and their floral and faunal dependents:

Species or Ecosystem Protection: This response seeks to improve the climatic resilience of species or ecosystems in a particularly vulnerable area. The USEPA (2008) suggests that such responses focus management protections on characteristics, organisms, or areas that represent important 'underpinnings' of the overall system (e.g. keystone species such as top predators). Some examples of these approaches include reducing anthropogenic stresses (especially minimizing localized human stressors) that hinder the ability of keystone species or critical ecosystems to withstand climatic events; restoring ecosystems that have been lost or compromised; and establishing refuges that are more resilient to climate change and can be used as sources of "propagules" for recovery or as destinations for climate-sensitive migrants.

Traditional Engineering and Planning Solutions: This response seeks to improve the climate resilience of human development activities but, in doing so, may have a negative impact on the resilience of local ecosystems, which may then jeopardize development gains in the long term. For example, infrastructure, in the form of dams or flood channels, that seeks to constrain natural, regular ecological cycles, e.g. seasonal flooding, invariably leads to habitat loss, in so doing likely compromising the natural storage and recharge benefits of the remaining forests and wetlands. Similarly, reservoirs and freshwater lakes can be a source of greenhouse gases as methane (CH_4) can be produced within bottom sediments and released through ebullition (bubbles). This is an increasing problem in the densely populated Mekong River Basin, for example.

Ecosystem-based Adaptation: This response consists of harnessing the natural provisioning and regulatory functions of ecosystems to promote human adaptation to climate change, while minimizing environmental damage. Ecosystem-based adaptation recognizes the critical nature of the services that biodiversity and ecosystems generally provide to human communities and that help build resilience to climate change. The argument is that incorporating ecosystem-based adaptation into an integrated approach to climate change adaptation can provide longer term, more effective and more cost-efficient solutions that support human well-being and a healthy environment. This approach is particularly relevant to freshwater habitats due to the complex and dynamic nature of these systems and their often critical support roles in larger landscape scales/river basins.

3.2 STAKEHOLDER ENGAGEMENT IN ADAPTATION PLANNING AND MANAGEMENT

As with conservation management strategies, climate change adaptation strategies depend critically on public awareness, understanding and participation in planning and decision-making processes. The US Fish and Wildlife Service (FWS) and the Convention on Biodiversity (CBD), among many others, endorse stakeholder engagement of human populations dependent upon or otherwise involved in the management of a given ecosystem and habitats of potentially vulnerable species within those ecosystems. Of course, this has been recommended best practice for years even without the added stress of climate change on ecosystem management.

Stakeholder engagement involves a number of steps:

- Broad awareness campaigns to provide general knowledge of climate change as a policy and planning issue and how it relates to citizens and landscapes. This can be done initially through the media, social, educational and religious institutions and other venues reaching the public at large.
- Nature conservation and habitat management inherently involves site-based mitigation and adaptation planning and actions so, the next step is to identify those stakeholders most affected by climate change in those landscapes and/or who are managing resources in those landscapes.

This is important because local communities often have significant knowledge of the vulnerable habitats that the planning process will address and changes that have occurred in them over time. In addition, it is increasingly recognized that greater sustainability in a changing environment requires a better understanding of the adaptive management requirements for those ecosystems and that the people most likely involved in the management system need to be a part of that management system. FWS and CBD advocate using participatory workshops involving a wide range of affected stakeholders (land managers, i.e. farmers, pastoralists, foresters, foragers (mushrooms, honeys, insects, etc.), protected area managers, ecologists, biologists, etc., and government officials. As noted above, the NAPA process also involves public participation.

The **objectives** of these workshops should be:

- Communicate the results of climate change vulnerability assessments of the affected landscapes to participants.
- Receive feedback on the methods employed and results obtained in the vulnerability assessments.
- Document ecological stressors commonly affecting these communities within managed lands.
- Discuss and identify specific strategies that can be employed on the ground in protected areas and community managed areas to reduce climate change impacts on the natural communities.
- Create awareness about climate change in affected ecosystems, potential synergies among non-climate and climate-induced stressors, and the options for managing for change, as well as resources available for managers.

However, as a practical matter, such a large group of stakeholders with disparate short-term interests (e.g. livelihoods vs. protection; administrative governance vs. scientific research) cannot easily be managed in the context of planning workshops. More usefully, it is recommended to undertake a simultaneous series of activities, which can provide synergies across the stakeholder categories.

The values of stakeholder participation are the following:

- **To map out diversity**. Given the complexity and time scales of climate change and mitigation and adaptation to it, a range of legitimate opinions to strategic options and potential adaptation actions need to be raised and discussed.

- **To reach consensus**. Developing a sense of those options, particularly short term ones that are win-win, as previously discussed in the NAPA discussion.

- **Democratization**. The use of methods that enable participants to bring forth their own knowledge and experience to clarify and refine proposed options that will directly affect them in one way or another.

- **Advising**. This is the process and specific methods for eliciting stakeholder knowledge, values and ideas that need to be incorporated into mitigation and adaptation strategies and plans.

Examples of simultaneous activities include:

Scientific research on climate change impacts on landscapes and specific habitats that involves and takes advantage of local knowledge of changes in resource and habitat management and climate change trends over time.

Pilot activities to change landscape management patterns to incorporate improved environmental management and climate resilience and that also improve rural livelihoods. Such win-win pilot activities should be explicitly learning focused so that communities and landscape managers together continuously evaluate what works and doesn't work in order to scale up best practices across multiple landscapes.

Partnerships based on collaborations beneficial to adaptation planning and management between private sector, civil society organizations, government agencies and communities and focused on improved environmental management, nature conservation and livelihoods, and to inform adaptive management. Some partnerships have been started in high mountain Asia such as the Waste Free Everest Program, the 12 nation Global Snow Leopard Ecosystem Recovery Program (GSLEP) and smaller scale community-private sector partnerships oriented towards ecotourism, recreation and sustainable agribusinesses.

While these recommendations regarding public participation are relevant to most climate change adaptation contexts, they are certainly relevant to keystone species conservation since local communities often play a key role in both threats to those species and to the potential for their conservation.

3.3 RISK MANAGEMENT BASED ADAPTATION APPROACHES

For the last quarter century, the number and severity of natural disasters has steadily increased globally. Part of the reason for this increase is the greatly increased concentrations of people in cities and especially in coastal cities, globally (more than half the world's population now lives in urban centers) and another part are the impacts of global warming, which is causing increased violent storms and resultant storm surges, sea level rise and other non-geotectonic disasters. Since the early 2000s, disaster risk management has become an explicit component of climate change adaptation planning. The common link between disaster risk management and climate change adaptation is vulnerability. Vulnerability is a socially constructed condition implying a lack of resilience and viable alternatives when faced with environmental extremes. This lack of resilience may be manifested at the structural, physical, economic, social and political and institutional levels.[24] Hence, vulnerability assessments and how they are undertaken have taken on a central importance to climate change adaptation and mitigation.

Along with the recognition of the importance of vulnerability, it has increasingly been recognized that climate change adaptation is a social process where learning plays a critical role precisely because uncertainty is a major aspect of climate change science and prediction. While the effects of GHG emissions on ecosystems and humans have become much better understood over time, a conditional forecast when used as a trigger for action may be more important than whether or not that forecast proves to be exactly correct. Vulnerability assessments will be more successful if they incorporate participation and learning from those populations that have the greatest exposure and sensitivity to both disaster and climate change impacts. These tend to be overwhelmingly poor and marginalized populations and women and the young in particular.

Ideally, an action plan should emerge from vulnerable assessments with actions grouped around the following timeframes.

- "No regrets" actions , <5 years
- Actions to anticipate over the coming 5-15 years of increasing climate change
- "Watch and Wait" Potential actions to anticipate over the 15-30 year timeframe, with indicators to monitor and inform those future decisions.[25]

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[24] UNDP, 2002, p.5.

[25] Comer et al., 2012, pp. 40-41.

Within these timeframes, the action plan should consider the following adaptation types of measures in planning the management of vulnerable species and ecosystems:

- Steps to address climate change adaptation that can affect keystone species.
- Increased support for research to reduce scientific uncertainty and better predict climate change impacts on key species, ecosystems, and the built environment.
- Consider climate change impacts for decision-making on long-term management issues such as: master planning, land purchases, rare species management, dam removal, fish passage, rule-making.
- Develop "toolboxes" of management practices that are appropriate for adaptation to particular climate change impacts as identified by modeling and vulnerability assessments. One potential example could be Indonesia's climate field schools. These field schools educate farmers on adaptation to climate change and provide tools for collecting valuable field level data on precipitation and temperature.
- Communicate to the public how climate change is likely to impact key species, ecosystems, facilities, and communities, and identify adaptation options.
- For those ecosystems in which a REDD+ strategy is planned, the above action plan steps should complement the mitigation plan developed under the REDD strategy for a given site.

The US Forest Service (USFS) (Cleaves, 2011) adopts a risk management approach to adaptation priority-setting and planning. Cleaves defines risk as exposure to a chance of loss. Losses can be ecological, social, or economic, expressed in absolute terms or in a sense of failure to reach a goal or a desired condition. The National Wildlife Federation has expressed risk (in the context of climate change) as involving the estimation of both the probability of an event happening and the relative severity of the impacts or consequences of that event.[26] The link between exposure and loss is vulnerability, shaped by the likelihood and magnitude of hazards (stressors) and by the sensitivity of resources to stressors and its capacity to cope with and recover from stress (adaptive resilience). Understanding exposures, vulnerabilities, and losses and taking actions to reduce losses within the limits of financial and organizational capacities is the discipline of risk management. Risk management can help to seize opportunities as well as reduce or avoid losses. A stressor event, e.g. fire, epidemic, flood, and landslide, can create opportunities for transition to more resilient conditions, for retreat from high exposure zones, or for learning to avoid similar losses in other places. Disturbances of this sort also sometimes provide opportunities for new species or species assemblages to appear in the disturbed habitat, as noted previously.

In adaptive risk management, the USFS emphasizes changing conditions, never assuming that the agency has a particular risk "nailed down." The agency is constantly reassessing particular risk chances and consequences, managing the risks it sees emerging and

[26] Glick, Stein and Edelson, 2011, p.68.

preparing to handle the surprises that inevitably occur despite careful attempts to forecast them. The USFS uses a "climate change scorecard" to assess internal capacity to address climate change knowledge and adaptive management. The adaptation dimension of the scorecard is focused on adaptive risk management. Assessing vulnerability is the process of identifying and characterizing (a) exposures of key resources and values to interacting climate-driven and non-climate stressors, (b) the sensitivity of these resources to this exposure, and (c) the adaptive capacity of the resource to recover after being exposed or to gracefully transition to a new condition. So, not only do these three components comprise the structure of VA's they also comprise the components of climate risk management, at least for the USFS. The adaptation options and associated actions may be designed to reduce exposure, build resilience (reduce sensitivity or increase adaptive capacity), or facilitate the transition to a new management regime with the least harmful disruption to important ecological functions and processes. Monitoring is essential to adaptive management. In this context, monitoring is viewed as a focused process to check the efficacy of the chosen adaptation measures and to detect signals of changing conditions that would justify a reassessment and readjustment of the unit's actions. [27]

Models are important tools both for understanding the existing ecosystem or landscape and possible changes and their degree due to the impacts of climate change. Downscaled climate data are continuously being developed and refined so that these can be used in various types of models for adaptation planners and landscape managers. Some of these datasets may be used to create layers for a geographical information system (GIS), which may inform climate modeling within one or more landscapes.[28] Habitat suitability models use historical data to predict the suitability of a future changed landscape (due to predicted climate change impacts) for various target or focal species. Spatially explicit population models may be used to simulate the potential impacts of climate change on populations of focal species of interest to ecosystem managers. In the US Pacific Northwest, the Hex-Sim model is used as a part of vulnerability assessments because they are able to predict species dispersal (or changes in location) across a landscape due to climate change impacts.[29]

4. EXAMPLES AND CASES OF CLIMATE CHANGE KEYSTONE SPECIES AND VULNERABLE ECOSYSTEMS FROM MOUNTAINOUS ASIA

In this section, we will examine a number of cases of the interaction of climate change, development and the vulnerability of selected keystone species, with particular attention to vulnerable ecosystems in mountainous Asia and the adaptation requirements associated

[27] Cleaves, 2011, p.2,

[28] Palmieri, 2014, has developed a resource guide of publicly available databases that can be used to develop models for ecosystem management under changing climate conditions.

[29] These models are discussed at the following website: http://www.climatevulnerability.org/

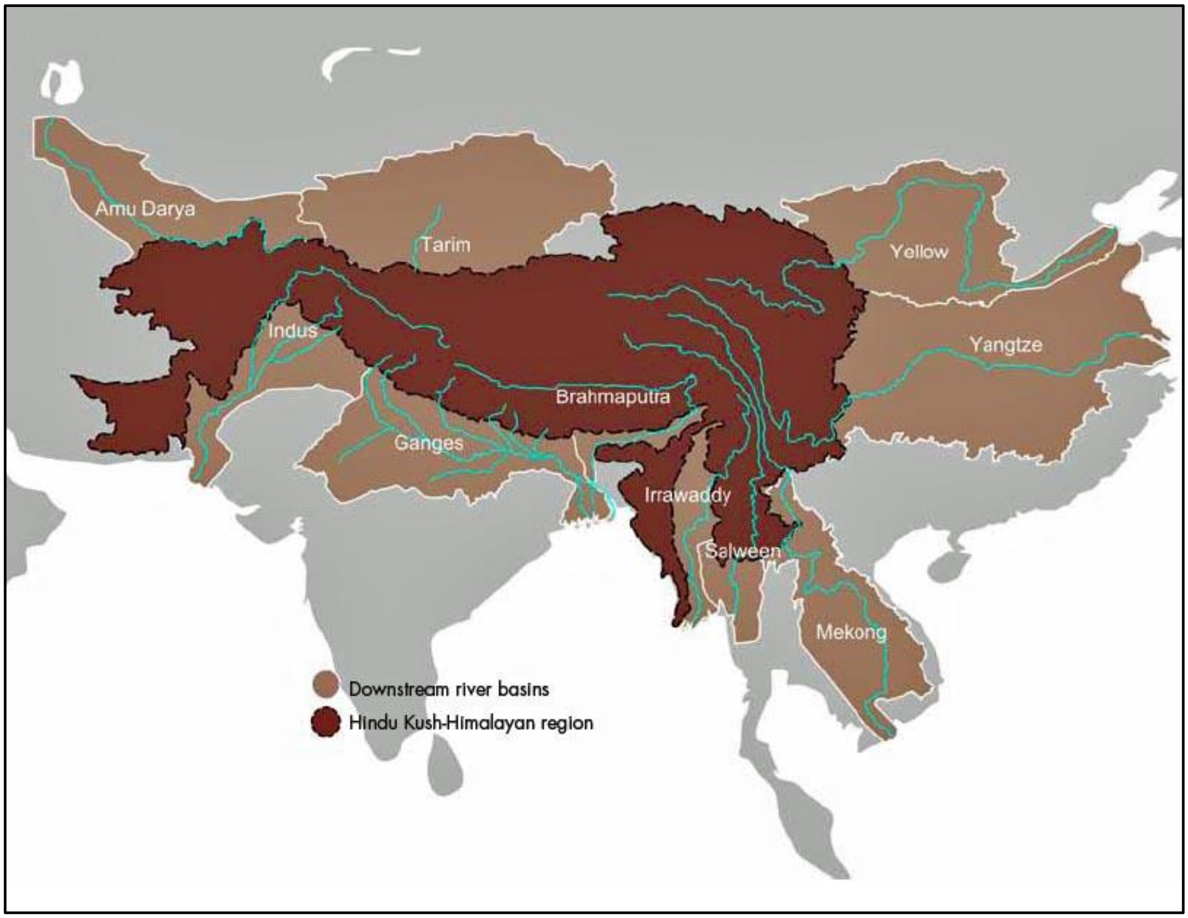
with conserving these ecosystems undergoing both development and climate change pressures. We will also address management approaches in response to climate change adaptation concerns where these exist and have been documented in the literature.

4.1 HINDU KUSH HIMALAYAS.

The Kailash Sacred Landscape Conservation Initiative (KSLCI) is a collaborative effort among ICIMOD, the United Nations Environment Programme (UNEP), and partners in China, India, and Nepal. The KSL consists of the Greater Mt Kailash region, which is in the remote southwestern portion of the Tibet Autonomous Region (TAR) of China and adjacent parts of northwest Nepal and India. This is a vast region 20,000 km^2 and contains a highly diverse array of ecosystems, biomes, indigenous and endemic species, local cultures, and ethnic communities (see Figure 2). This environmentally fragile landscape is also home to a range of endemic flora and fauna that are important in maintaining both global biodiversity and local livelihoods. The KSLCI area and communities are also rich in traditional knowledge and contains a high diversity of medicinal plants. The Initiative aims to develop a Conservation Strategy with a supporting regional knowledge-sharing platform, and a comprehensive environmental monitoring plan for the Kailash Sacred Landscape, which, in turn is within the Hindu Kush-Karakorum-Himalaya (HKKH). This large, linked set of landscapes is the source of several of the most important river systems in South Asia and is considered sacred to millions of people in South Asia. Thousands of religious and spiritual pilgrims from around the world journey to this sacred landscape every year, coming primarily through India, Nepal, and from other parts of the Tibetan Plateau.[30]

Figure 2. Map of the Hindu Kush Himalaya Region

[30] ICIMOD and UNEP, 2009, pp. 1-2.



Source: Farshad Tami, *Afghanistan and climate change in the Hindu Kush-Himalayan region*, p. 1

The region is subject to a range of pressures including tourism (from China to Tibet and from mountain climbers and spiritual tourists coming from the South Asia side). Increasing population and resource exploitation activities already had been damaging the inherently fragile mountain ecosystems even before climate change started adding new stressors such as the risk of glacial lake outburst floods (GLOFs). Each of the participating countries recognizes the need for transboundary management of the KSL not only for essential river basin management but also because of the socio-economic and cultural importance and threats to the biodiversity of the region.

Dhole or Asiatic Wild Dog, an endangered predator in the HKH Region

The KSLCI is intended to develop and engage regional, national, and local partners and other stakeholders in a consultative process to achieve a transboundary Regional Cooperation Framework (RCF) for the implementation of the Mountain Biodiversity Goals as formulated in the Mountain Biodiversity Programme of Work (adopted at COP 7) of the CBD.[31] The three major component s of the RCF are boundary delineation of the KSL; development of a conservation strategy, and community-based climate change adaptation and co-management activities. The RCF emphasizes certain management principles including consultation with and participation of the affected public, especially those living in the region; the use of a range of institutional stakeholders including resource managers, environmental agencies, universities and non-governmental organizations; and a data-driven approach, which includes knowledge sharing. As described in the previous section, these are also principles advocated by leading species and ecosystem management organizations generally.

For the purposes of this discussion, one of the most serious challenges in the development of the KSLCI conservation strategy is the competition for prime rangelands between community-managed, domesticated and wild ungulates. The latter include blue sheep, kiang (Asiatic wild ass), takin (Chamois cattle), yaks, Tibetan antelope and several kinds of large-horned sheep and goats. The predominant predators include the snow leopard, wolves, common leopard, lynxes, the dhole and the brown bear.[32] Management of rangelands in this region can be divided into "marginal" rangelands, generally high elevation, drier lands that communities generally do not use for domesticated herds and lower altitude, "productive" rangelands where domesticated herds predominate or, in some cases, where both wild and domesticated ungulates share the same pastures. In the marginal rangelands, wildlife and associated predators still exist though the habitat cannot support large populations unless the marginal areas are quite large.[33]

While the pressures of large herds of domesticated grazing animals has led to habitat displacement for wild herbivores, competition for grazing lands especially with wild ungulates, predation of domesticated animals and soil alteration and degradation from some small mammals have led some communities to try to eliminate wildlife from their prime grazing lands, including top predators.[34] On the other hand, the likely impacts of climate change in this region will be to gradually transform currently productive rangelands into more marginal lands, which, absent any changes in pastoral management would increase pressures on wild herbivores and their keystone predators in this region.

However, recent research[35] indicates that climate change is not uniform in this region, in fact, especially in the higher regions. For example, the eastern Himalayas are experiencing

[31] Ibid., p. 9.

[32] Fox, 1997, p. 54.

[33] Ibid., pp. 53-54.

[34] Ibid., p.54

[35] See Fowler and Archer, 2006, among others.

significant warming and associated glacial melting but the western Karakorum range has actually seen an increase in its glaciers. In both cases, different patterns of wind circulation have led to increased warming in the east and relatively increased cooling and increased summer precipitation in the west. In the Indus River Basin, summer time high temperatures have actually declined.[36] Archer et al., conclude that the sustainability of water resources appears more threatened by socio-economic changes than by climatic trends at least in the Karakorum sub-region, at least currently. However, even if differential warming was not happening, the high level of ecosystem diversity characteristic of mountainous regions would require locally varying adaptation plans anyway.

Given the varying degrees of climate change in the HKH, the overall aim of the sub-regional implementation plan for the Kailash Sacred Landscape is to contribute to sustainable development by applying ecosystem management approaches and building on the strengths of the region while considering both the risks and opportunities of the changing climate. The broad objectives of the plan are:

- to strengthen regional, transboundary cooperation by institutionalizing the elements of the regional cooperation framework;

- to mainstream sustainable ecosystem management approaches and practices in the context of climate change adaptation in the KSL and in national policies and plans at all levels;

- to build the capacity of key institutions for long-term environmental monitoring and socioeconomic research for better planning and decision making; and

- to establish a regional knowledge sharing platform to support evidence-based decision making at regional and national levels.

4.2 LINKING BIODIVERSITY AND CLIMATE CHANGE: PERMAFROST MELT ANDBIODIVERSITY LOSS IN PARTS OF MONGOLIA

Around 80% of the land area of Mongolia consists of grasslands. These include three main types: meadows, typical steppes and desert steppes (see Figure _). Species richness and diversity decreases from meadows to desert steppes.[37] The World Wildlife Fund's Mongolia Program has further delineated six basic natural zones in Mongolia, differing by climate, landscape, soil, flora and fauna. The Mongolian Altai-Sayan – one of the Global 200 Ecoregions contains examples of all these natural zones even over a relatively short distance. These include the historic Gobi Desert, semi-desert, steppe, taiga, tundra, flood

[36] Archer, Forsythe, Fowler, and Shah, 2010, pp. 1670-1675 and 1679.

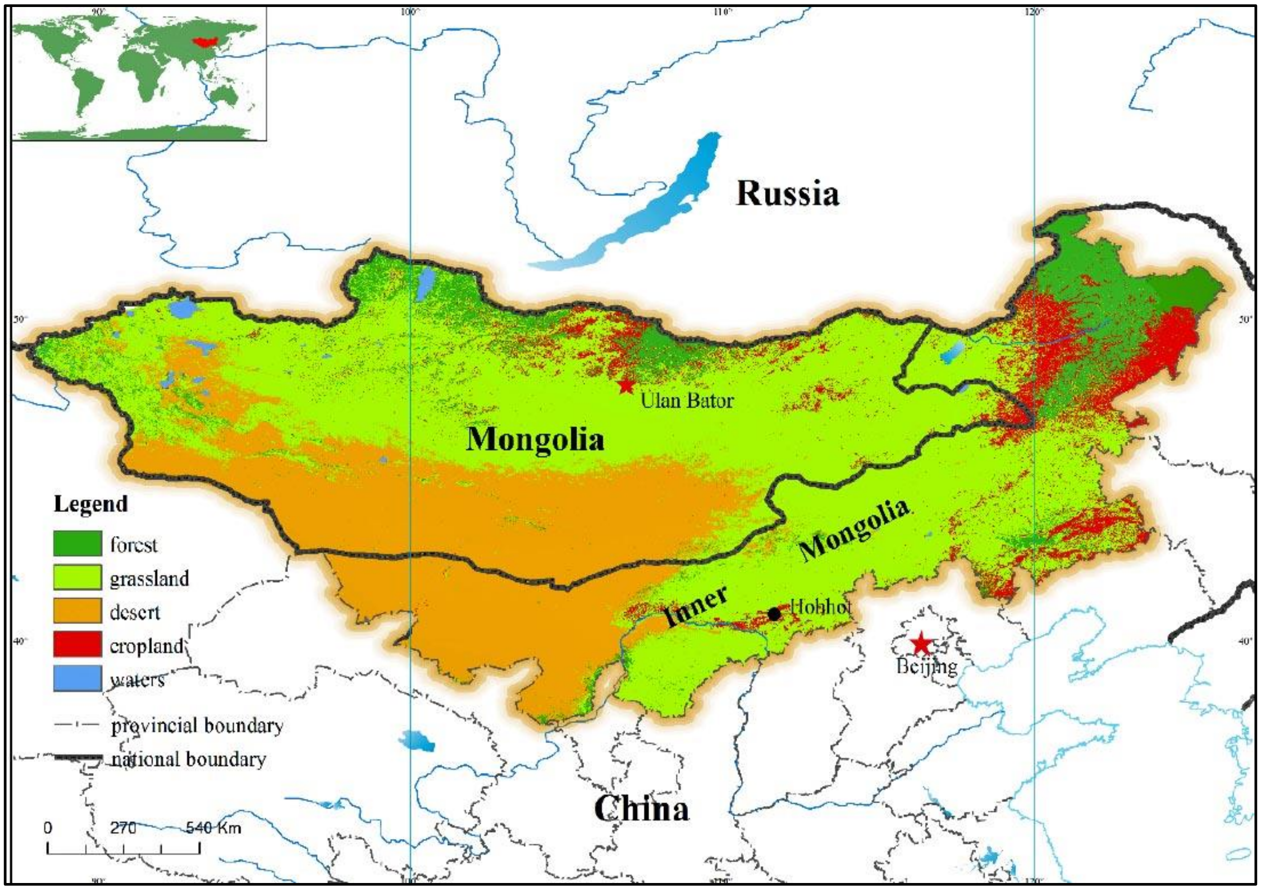
[37] Guofang, 2013, Introduction.

plain forest, freshwater ecosystems and salty marshes, among others. The conservation of the Altai-Sayan Ecoregion's biological diversity is regarded as having global significance. This region represents one of the great opportunities to conserve relatively intact ecosystems, large enough to allow ecological processes and wildlife populations to fluctuate naturally.[38]

Mongolia supports a wide variety of wild life: 139 species of mammals, 449 species of birds (330 migratory and 119 Mongolian year round residents). It also has 22 species of reptiles, 6 species of amphibians, and 76 fish species. The Mongolian Altai-Sayan includes a number of rare and endangered species such as the Snow Leopard (*Uncia uncia*), Wild sheep (*Ovis ammon*) or Argal, Siberian Ibex (*Capra sibirica*), Mongolian Saiga (*Saiga tatarica mongolica*), Musk Deer (*Moschus moschiferus*) Pallas' cat (*Felis manul*) or Manul, Black Tailed Gazelle (*Gazelle subgutturosa*) and several others. Endemic, native and rare plant species are also highly represented in this region.

Figure 3.Mongolian Landscape Types

[38] Onon Yo et al., 2004,, p. 1



Source: Miao, et al., *Analysis of the Phenology in the Mongolian Plateau*, p. 5196

The Mongolian Red Book (1997) lists 30 species of mammals, 30 species of birds, 5 species of reptiles, 4 species of amphibians, 6 species of fish, 1 agnathan (a class of jawless fish), 19 insects, 2 crustaceans, and 4 mollusk species as endangered, vulnerable, or rare. The major threats to Mongolian wildlife come from illegal hunting, competition with livestock for pasture and water, climate change, prairie (steppe) and forest fire, harsh winters and periodic drought.[39]

One example of the problems with addressing biodiversity conservation under conditions of increasing climate change in Mongolia can be seen in the Hövsgöl National Park. The park is centered on Lake Hövsgöl, one of the of the world's ancient lakes located about 200 km southwest of Lake Baikal, in mountainous northern Mongolia. The lake lies at 1,700m above sea level. It is 135 km long, about 20-30 km wide, with a depth of 262 m. Primary production in the lake is quite low, and the deep penetration of light down to 30 m gives it a blue hue, thus the name, "the blue pearl of Mongolia." The winters are long and vicious, with temperatures dropping to below -40° C. The Lake Hövsgöl area lies at the southern edge of the taiga forest, and is underlain by permafrost (layers of frozen soil).

[39] As reported in Mongolia's Fourth National Report to the CBD, 2009.

Uncontrolled grazing by domestic animals—sheep, goats, and cattle—on the mountain slopes around the lake and the gathering of fuel wood have caused the forest edge to retreat. The loss of forest then exposes the ground to sunlight; as a result, the permafrost melts at a faster rate than normal, and aerobic decomposition occurs, producing carbon dioxide. The region has already had an average temperature increase of about 1.4 C° over the last 35 years. As annual temperatures increase in this sub-region, due to climate change, the forests and underlying permafrost will both be threatened both by climate change and poor pasture management in so doing setting the stage for a vicious cycle since the melted permafrost will yield large amounts of greenhouse gases.

In 2001, the Mongolian Academy of Sciences received a five-year GEF grant to study the dynamics of biodiversity loss and permafrost melt in Hövsgöl National Park. The objectives of this study were to:

- Identify the impacts of pasture use and forest cutting on the dynamics of forest, steppe, riparian zones, and streams in tributary valleys of Lake Hövsgöl.
- Define how those impacts interact and are affecting the melting of permafrost (and thus release of carbon dioxide), soil characteristics, and plant and animal biodiversity.
- Inventory climate change effects in the Hövsgöl National Park.
- Determine sustainable resource use patterns that will also protect biodiversity, permafrost, and soil sequestration of carbon.
- Calculate the costs and benefits of alternative land use practices, especially as related to pastoral nomads.

The research determined that the active-layer thickness of the permafrost in the Hovsgol region varied in association with livestock grazing pressure. Surface ground data shows that different plant covers have different insulation values; removal of forest vegetation cover increases mean summer surface and ground temperatures, accelerating the rate of permafrost melt. Thus, the key to preserving the permafrost and the local ecosystems, especially in the Hövsgöl taiga zone, must be based on the protection of appropriate vegetation cover. The researchers concluded that climate change impacts on the steppe and forests are very similar to, and magnify, those caused by nomadic pastoralism and forest cutting. Accordingly herders need to change grazing strategies to adapt to changing conditions in this harsh and fragile environment.

The conclusions regarding land use practices have been summarized in the recently published Herders' Handbook (English version on www.hovsgolecology.org). This includes recommendations for more frequent movements of livestock to reduce grazing pressure and improve range management. While little can be done to alter the immediate course of climate change, protecting vegetation cover through appropriate land-use practices can slow the rate of permafrost melt and help to protect Mongolia's water resources, biodiversity, and natural ecosystems. These lessons are also relevant to other areas within the great band of temperate forest-grassland mosaic in the mountains between Eastern Europe and eastern Russia/northern China.

Research on the steppe environments that dominate the rest of Mongolia have found similar trends. Species richness in the typical steppes has decreased largely through poor, unsustainable pastoral practices and, in the case of predators, also because of indiscriminate hunting.

In addition to the Lake Hövsgöl protected area, the Great Gobi Special Protected Area (GG SPA) is one of the most significant protected areas (PAs) in the world, both in terms of size and the biodiversity it supports. It has a complex desert environment that includes not only true deserts but also lakes, mountains and semi-desert environments. Hence, biodiversity is significant in parts of this protected area, especially the mountains (Altai and Tien Shan ranges) and grasslands. Though the Gobi has long been lightly populated, overgrazing in parts of the GG SPA has been a significant problem. However, a more significant potential threat has emerged with the discovery of economically exploitable deposits of gold, copper and coal in or around the GG SPA. The most important problems are the use of very scarce water resources in mining operations and the disposal of mining wastes (tailings). In addition, mining operations would entail a relatively significant increase in the local population, which, if not managed correctly could put yet more strain on this fragile environment. Foreign donors are working with the Mongolian government, NGOs and mining companies on a protocol for water resources and waste management.[40] Another threat to wildlife is the increase in road and railway infrastructure, partly in response to the development of mining operations. These improvements break up migratory routes, especially in Mongolia's desert and steppe environments where animal ranges, especially larger animals (ungulates and their predators) are quite large. The Wildlife Conservation Society (WCS), among others has been working with the Mongolian government to plan over passes and culverts to facilitate wildlife migratory corridors for animals, which function also as safety measures for humans driving those roads and riding the trains. Other barriers of concern to the free movement of wildlife include fences, pipelines and other physical barriers.[41]

Mongolia's wild Bactrian camel, an umbrella species for its biodiverse, but fragile desert environment

[40] Joshua Friedman, 2010

[41] Buyanaa Chimeddorj, et al., p.46.

The impact of climate change in Mongolia has become a major government priority and, like the Maldives, the government has made managing climate change a significant foreign policy initiative. This concern was heightened by a disastrous summer drought and harsh winter weather with extreme temperatures in 2009-2010, locally called a "zud". This event killed 20% of Mongolia's herds of goats, sheep, cows, horses and other livestock. Most of these animals were the main assets of some of Mongolia's poorest people, the third of its population that are nomadic or semi-nomadic herders.[42] It is not clear what the impact of the zud was on Mongolia's wildlife broadly but it had a disastrous impact on the re-introduced species, Przewalski's horse, which, because it did not move from its known and established range lost 60% of its known population. The other known mammal affected, the Asiatic wild ass loss relatively fewer of its population because it readily moved out of the worst affected areas in the Gobi Desert since it had developed, over time, a greater resilience to periodic disasters like the zud.[43] Wild camels and snow leopards to mention two keystone species have a very broad range and are likely to have escaped significant losses from this event though adequate research appears to be lacking in this area.

4.3 SIGNIFICANT ASIAN KEYSTONE SPECIES

The following section is a review of some of Asia's high mountain keystone species. The review is not meant to be comprehensive and is intended just to show the importance of these species in their habitats and especially the impact on other flora and fauna. This section focuses just on keystone species that are also mammals, especially predators but, as discussed Section 1, it is understood that many different organisms can be key to their particular ecosystem or are cultural keystone species.

Until recently, the largest threats to keystone species have come from human activity. Anthropogenic climate change, as noted, heightens those threats by adding relatively rapid changes to the conditions in the species' habitats requiring special management (i.e. adaptation measures) of these habitats. Whereas Earth has experienced previous global warming periods, these had developed over many hundreds of years, giving many species and ecosystems a better chance to adapt and become resilient. The presence of humans and especially their industrial technologies has greatly compressed the timeframe of global warming acceleration significantly. There is an increasing concern that both anthropogenic climate change as well as unsustainable exploitation of natural resources and destruction of critical habitats may be leading to an increase in larger extinction events.[44]

[42] Tania Branigan, The Guardian, 2010.

[43] P. Kaczensky, et al., 2011

[44] Lande, 1998

4.3.1 ASIAN ELEPHANT (ELEPHAS MAXIMUS)

The elephant is the largest land mammal in Asia. This intelligent, highly social animal lives in small groups led by the dominant female, or 'matriarch'. Although not a mountain species, it is an important keystone species in parts of South and Southeast Asia. The elephant plays a crucial role in the forest ecosystem in which it inhabits. It helps to open up forest clearings and distributes the seeds of trees and shrubs. Threatened by poaching and the destruction of the forests in which they live, elephants have increasingly come into conflict with the people sharing their habitat. Unlike the African elephant, some of Asia's elephants have been domesticated and work in the forestry and tourism sectors and other economic activities (mainly but not only in South Asia). However, domestication effectively takes them out of their keystone species role by removing them from their natural ecosystem functions, as described below. Effective management of the species and its environment is required in order to resolve conflicts, especially in those areas where forests have been cleared for agriculture.

Asian elephant with its baby

Elephants are, in fact, one of the best examples of an ecological "keystone" species: the lives of so many other organisms depend on their existence and they truly define the ecosystems in which they are found. Their consumption of vast amounts of vegetation, and even how they physically open up clearings, for example, ensures that certain plant species don't come to dominate in any one environment. This results in a much greater variety of plants and also the animals that feed on them and the predators that feed on those animals in turn. Elephants' feeding behavior is also such that what they spill or shake free from high branches can suddenly become available to other animals. Elephants are also known to enlarge and deepen water supplies with their tusks in times of drought, and this too benefits many other animals. Furthermore, numerous plants rely on them to disperse their seeds and help them germinate in their very own parcels of organic fertilizer. Animals that subsequently feed on these plants, and the animals that feed on them, therefore indirectly depend on the elephants. Because of the great quantity of seeds that they are passing and the distances over which they do so, it is easy to see how elephants genuinely do shape their environments. Lose the elephants and their associated ecosystems rapidly deteriorate. Although anthropogenic degradation and destruction of elephants and their habitat is the main threat to them, climate change can definitely worsen the situation through, for example, water scarcity and loss of vegetation.

Given the importance of the elephant in creating and maintaining diversity in the Asian lowland forest ecosystems where they still exist, their conservation can be viewed as a climate adaptation tool. Asian elephants are particularly vulnerable to climate change because they have a narrow tolerance for body temperature rise. They typically use water or wind to regulate their body temperature. Aside from reduced habitats, the likely rise in temperatures of 1° - 3° C over the next decades puts the Asian elephant at great risk. This is especially true for infant elephants, which are significantly more vulnerable than adult elephants.[45] At a minimum, adaptation measures to support elephants and their habitats (including salt licks and establishment of transmigration corridors) should include the preservation (or establishment) of water bodies in vulnerable elephant habitat.

4.3.2 ASIAN TIGER CONSERVATION AND CLIMATE CHANGE: THE CASE OF THE AMUR TIGER

The Asian tiger, in its various sub-species is one of Asia's most iconic keystone species. It is also one of the most endangered species in all of its habitats. The Global Tiger Initiative (GTI), launched by the World Bank and other partners, including the GEF and members of the International Tiger Coalition, is aimed at arresting and reversing the dangerous decline of wild tiger populations (see http://www.worldbank.org/tigers). Tigers once ranged in an arc stretching from the Caspian Sea to the islands of Indonesia; today, they occupy only 7 percent of that original area. Under threat across their range, they are currently found in 14 countries—from the prey-rich grasslands of northern India, through the mangrove swamps of Bangladesh's Sunderban, to the forests of East Asia and Sumatra as well as a highly vulnerable population of the Amur Tiger in the Russian Far East (RFE).[46] As Asia's largest top predator, the tiger is the region's most important and charismatic umbrella species.[47] The health of tiger populations is a useful indicator of the health, effectiveness, and sustainability of the region's protected area networks and other conservation efforts, including efforts to combat poaching and the illegal wildlife trade. To maintain viable populations, effective conservation measures are required both within and beyond protected area boundaries to maintain biological corridors and tiger habitats within the broader production landscape. Conservation scientists have identified 76 Tiger Conservation Landscapes (TCLs) across the tiger's current range. Many of these critical forests and grasslands are also important carbon stores.[48]

Amur Tiger and cub in the RFE

Under the Global Tiger Initiative, the World Bank is committed to work with the tiger range states and

[45] See Mumby, et al. 2013.

[46] The RFE refers to Primorsky Krai, the capital of which is Vladivostok, Khabarovsky Krai and The Autonomous Jewish Oblast.

[47] World Bank, 2011, p. 1

[48] Ibid., p. 3.

other partners to ensure the long-term conservation of the tiger. Specifically, the Bank will support a five-point agenda to further the GTI, including:

- Reviewing, through the Bank's Independent Evaluation Group (IEG), Bank projects in tiger habitats
- Facilitating country workshops to develop new models of conservation
- Reviewing existing efforts and strategies to address illegal tiger trade
- Exploring and developing new funding mechanisms for tiger conservation
- Provided World Bank Group support to host a Tiger Summit in 2010.

At one time, carbon markets were considered to have the potential to be a new mechanism for supporting conservation of important tiger habitats in tropical forests. However, with the exception of the small voluntary carbon market, carbon sequestration through market-based agreements have struggled to get off the ground owing to a variety of factors, including monitoring and verification issues, the allocation of financial benefits vs. the costs of such agreements and institutional capacity to develop and maintain such agreements.

Important tiger conservation and climate change issues exist in all the areas in which the various sub-species of the Asian tiger are still found. This paper will discuss one, in particular, as an example of the human-tiger-climate change dynamic in Asia.

In the Russian Far East (RFE), the Amur Tiger has a very important role, especially in the broadleaved forest ecosystem and less so in the pine and spruce forests in the more northern extent of their habitat (though Korean pine forest is considered the best overall habitat for the Amur Tiger).[49] The Amur Tiger's current population mainly migrated from northern China (Manchuria – the Amur River defines the northeast boundary of China and Russia (see Figure 4). The Amur Tiger's prey consists mainly of deer (especially the large red deer, wild boar, moose and the smaller Sika deer).[50]

The Amur Tiger and the tiny remnant population of the Amur Leopard (the latter mainly along the Russian and North Korean border) are seriously threatened by a loss of habitat. For decades, indiscriminate logging destroyed much of the best tiger habitat, i.e. Korean pine forests. Loggers then started on the broad-leaved forests. In 1935, the Sikhote-Alin Reserve was created in Primorsky Krai specifically to conserve the tiger and its associated prey.[51] With additional conservation measures, including the creation of other reserves, in the latter part of the 20th century, the tiger population has stabilized at about 350 individuals.

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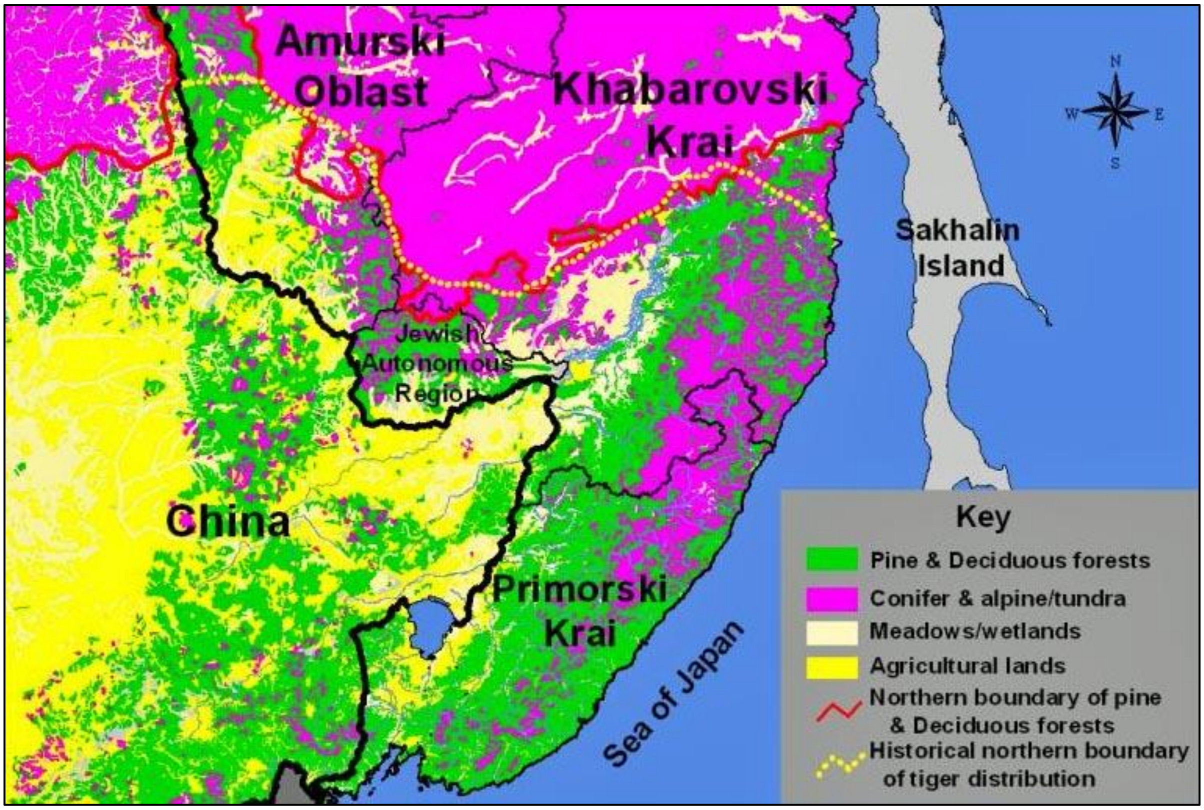
[49] Loboda., p.4.

[50] Loboda, pp. 11 and194.

[51] Ibid., p.4

Figure 4 . Distribution of the Amur Tiger by Habitat Type



Source: WCS, *The Amur Tiger: Ecology,* p. 5.

However, this is below the minimum viable population (MVP) of 876 for this sub-species to thrive genetically.[52] However, since a single Amur Tiger requires a range of 500 km^2, reaching and maintaining this population promises to be an extremely challenging task. Nevertheless, conservation of this eco-region is important not only for the tiger as its apex predator but also, as with other remaining tiger sub-species because tigers maintain a critical balance over their prey populations, which in turn affect the structure and health of the forests and the many endemic and rare species in this eco-region.

Although human disturbance of the tiger's habitat, mainly through logging but, to a lesser extent, also from hunting remains the biggest threat to the Amur tiger, climate change is already having a significant role in the forest landscape. The boreal forests in the northern part of the tiger's range have always experienced forest fires as a part of their natural cycle, mainly in the Spring and Fall. However, fragmentation of the landscape through logging and the buildup of tinder have been exacerbated by higher temperatures and longer dry periods leading to more catastrophic fires. (A similar syndrome has afflicted the humid moist forests of Southeast Asia.) The projected trend towards higher temperatures in the boreal zone will affect vegetation flammability through its impact on fuel moisture, fire

[52] Ibid., p. 4

season length, and water levels. In addition, increasing temperatures have led to an increase in forest insect pests that create greater amounts of dry tinder that then fuel more fires.[53] A similar phenomenon also has been happening in parts of North America as well.

Modeling fire risk to assist in overall natural resource management and tiger conservation in particular for the RFE has been very difficult since the forest fire service has kept poor records. As a result, remote sensing has played an increasingly important role in monitoring forest health in this region.[54] In fact, remote sensing of this region had been going on for years during the Cold War since Vladivostok, the capital of Primorsky Krai was the home base of the Soviet Far Eastern naval fleet[55] Given the very large area of the RFE relative to its population, continued use of remote sensing for fire hazard detection and risk modeling will continue to be critical especially given the additional threat posed by climate change. Both China and Russia have begun transboundary activities to put as much as 25% of the total tiger range under protection within the current decade.[56]

4.3.3 THE SNOW LEOPARD IN THE HKH AND IN CENTRAL ASIA

Few top predators in high mountain Asia are both ecological and cultural keystone species. But the snow leopard plays both roles particularly in the HKH but also in the Pamir and Tai Shan mountain ranges (see Figure 5). Elephants and tigers also play these dual roles. In the case of the elephant, they have three roles, in fact, since they also play an important economic role as well as cultural and ecological roles, as described previously. Forrest et al., (2012) studied the impact of climate change on the snow leopard's habitat and prey populations in order to assess both the adaptive capacity of the snow leopard and changes in its habitat focusing on the HKH. They also proposed a hybrid approach to climate-adaptive conservation landscape planning for snow leopards in the HKH. Their team started their research by mapping current snow leopard habitat using a mechanistic approach[57] that also incorporated field-based data. They then combined this mapping with a climate impact model using a correlative approach. For the latter, the team used statistical methods to test hypotheses about climatic drivers of treeline changes in the HKH and its potential response to climate change under three IPCC greenhouse gas emissions scenarios. They then assessed how changes in the treeline might affect the distribution of snow leopard habitat. Their results indicate that about 30% of current snow leopard

[53] Ibid., pp.6, 7.

[54] Ibid., p. 9.

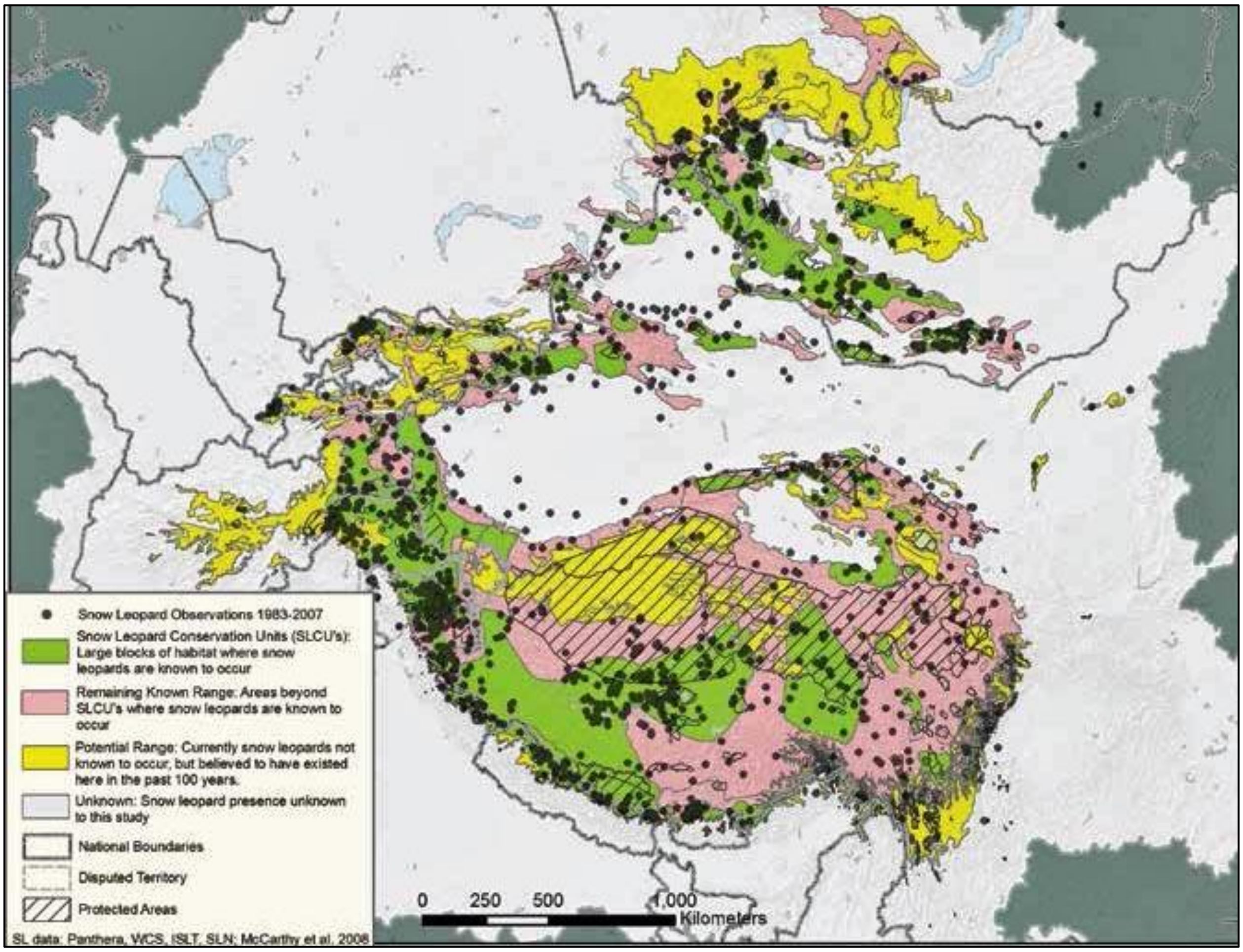
[55] Personal communication from Environmental Research Institute of Michigan (ERIM) to the author in 1995. ERIM helped to develop remote sensing technology for the U.S. military from the early 1970s. It later played a role in the Gore-Chernomyrdin Commission's joint U.S. – Russian cooperation activities during the Clinton Administration including forest activities in the RFE..

[56] World Bank, 2011, p. 45.

[57] A "mechanistic" (also known as process-oriented or conceptual) model uses expert knowledge of the animal and its habitat to model likely wildlife range (prey and predator). This contrasts with empirical models based on field observations, including spatial imagery. Forrest et al., have combined aspects of both approaches in their study.

habitat in the HKH may be lost due to a shifting treeline and consequent shrinking of the alpine zone, mostly along the southern edge of the range and in river valleys.

Figure 5. Snow Leopard Biomes and Known Sightings



Source: Based on a workshop of snow leopard experts, cited in: Sindorff et al**., Guardians of the Headwaters**, p. 4.

But, they also predict that a considerable amount of snow leopard habitat and linkages are likely to remain resilient to climate change, and these other areas should be secured. This is because, as the area of snow leopard habitat fragments and shrinks, threats such as livestock grazing, retaliatory killing and medicinal plant collection can intensify. They propose consolidating and protecting endangered habitat for landscape conservation planning for other species with extensive spatial requirements and that can also act as umbrella species for securing the overall biodiversity of this region.

In the HKH sub-region, and especially in the southern and eastern parts of this sub-region, IPCC climate scenarios predict a 3-4 ° C rise in average temperatures compared to 1980-90 time period. This will have the effect of not only making the sub-region warmer but also significantly wetter. The warmer and wetter conditions consistent with these climate predictions may result in forests ascending into alpine areas, which are the preferred habitats snow leopards.[58] Typically, in this sub-region, snow leopard habitat includes grassy meadows and shrub land and marginal, rugged lands below 5500 m. in altitude. The snow leopard's range ideally should be 500 km^2 up to 1500 km^2. The latter area could support resident populations of at least 50 snow leopards. Some studies cited by Forrest et al. have indicated average density estimates of 1–2 snow leopards per 100 km^2 in Bhutan to 4–5 per 100 km^2 in Nepal are possible in a climate-altered landscape.[59]

The snow leopard's principal prey species in the HKH sub-region include blue sheep (*Pseudois nayaur*), Asiatic ibex (*Capra sibirica*), Himalayan tahr (*Hemitragus jemlahicus*), argali (*Ovis ammon*), and marmots (*Marmota himalayana*). These species also live in rugged alpine habitats. Some of these species are under shrinking habitat or hunting pressures but the greatest issue facing the snow leopard's preferred prey is fragmentation of alpine habitat whether due to agriculture or mining along with changes caused by climate change as noted.

Forrest et al. (2012) examined several different climate warming scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Their analysis indicates that even if GHG emissions remain relatively low or begin to decrease below current levels by 2050, up to 10% of snow leopard habitat still could be lost. Under the high emissions scenario, the number of large snow leopard habitat blocks in the HKH sub-region will fragment from 9 to 15, and become smaller on average. In practical terms, this means that Bhutan would lose about 55% of its current snow leopard habitat, while habitat in Nepal could decrease by as much as 40%. India and China would lose about 25% of their existing habitat in the Himalayan mountain range.[60] Interestingly, with a potential increase in forest habitat in areas previously alpine, other predators could occupy this area, including common leopards (*Panthera pardus*), wild dogs (*Cuon alpinus*), and in Bhutan, tigers (*Panthera tigris*). On the other hand, the snow leopard would have difficulty responding by moving into higher altitudes due to low oxygen levels and also lower numbers of prey species at very high altitudes.

The Forrest et al. study nevertheless concluded that though some loss of snow leopard habitat in the HKH will undoubtedly occur, substantial habitat will remain intact but that this remaining habitat would likely shift northwards towards the Chinese border region. The authors recommend that governments continue with climate adaptive approaches that include monitoring of changes in habitat and in human communities, while implementing adaptive management measures that continually respond to evolving outcomes.

The other regions of interest regarding the snow leopard and climate change are the Pamir Mountains that lie to the west and north of the HKH sub-region, the Tien Shan Mountains,

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[58] Forrest et al., 2012, pp. 129-30

[59] Ibid., p. 130.

[60] Ibid., p. 132

north of the Pamir and the Altai Sian range which extends into Kazakhstan, Russia, China and Mongolia. The Pamir Mountains form parts of Afghanistan, Pakistan and Tajikistan while the Tien Shan Mountains are mainly in Kyrgyzstan, Kazakhstan and China.

Unlike snow leopards in the HKH region, populations in the north and western part of their range can live as low as 1000 m. altitude whereas the HKH population generally inhabits an altitudinal range of 3,000 – 5,000 m. This is partly due to the drier nature of these western and northern ranges and a smaller proportion of the lands under forest. In the HKH, the main prey is the blue sheep whereas in the western parts of their range their main prey is an ibex, (*Capra siberica*) and wild argali sheep (*Ovis ammon*).

Extremely rare photo of a snow leopard successfulyl hunting a blue sheep in NW India. (Adam Riley/INDRI)

The threats to the snow leopard have somewhat different origins in these ranges compared to the HKH. Since the break-up of the former Soviet Union, poaching, especially of larger mammals and birds, has increased sharply. Mountain ungulates are increasingly seen as a source of food, and snow leopard numbers in Kyrgyzstan are estimated to have decreased by 75 percent during the 1990s, as a result of heavy hunting pressure on them and their prey. Rural poverty has increased significantly since the end of the Soviet Union, which has forced populations to rely more on the region’s natural resources for subsistence.

A variety of efforts have been made to promote transboundary cooperation for conservation and habitat protection that includes protection of the snow leopard. In 2006, the first meeting on the Pamir Peace Park initiative was convened, which brought together Tajikistan, China, Afghanistan and Pakistan to discuss closer collaboration in the southern Pamir region, a snow leopard hotspot. This proposal was further developed in late 2011, with several high-level meetings held in Dushanbe, Tajikistan to move the concept forward, encouraging cross-border collaboration on environmental protection, especially in relation to migratory species.

Of particular relevance to snow leopard conservation in this region are the mountain ranges which form the borders between neighboring states, the Wakhan range in the south, and the Pamir-Alai mountains in the north, have snow leopard populations which migrate seasonally in response to their prey species’ (including the Argali sheep) movements.[61] Hence, in many cases transboundary cooperation is essential for the conservation of snow leopard habitat.

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[61] Flora and Fauna International (webpage)

The snow leopard is also a focus of an ambitious regional USAID biodiversity conservation and climate adaptation project. The Conservation and Adaptation in Asia's High Mountain Landscapes and Communities Project (2012-2016) is a cooperation with World Wildlife Fund (WWF) and extends across 12 south and central Asia countries which have snow leopard habitat but which also face serious climate change challenges, especially changes in water supply. The project focuses on working with vulnerable high mountain communities to promote alternative and more sustainable agricultural practices (e.g. promoting the husbandry of yaks vs sheep and goats). At the same time, the project will build capacity of cooperating country agencies to better monitor snow leopard populations and prevent poaching of the animals among other activities.

It is increasingly appreciated that snow leopards are indicative of the health and vitality of entire ecosystems across their range. They are an integral part of the ecosystems in which they live, and the well-being of countless other species and human communities depends on the health of those ecosystems.[62] A key element for both the adaptation activities and snow leopard conservation is public awareness and education, including both government and civil society. This is a critically important component not just for the above-mentioned USAID project but also climate change adaptation and conservation activities generally because the pace of climate change and its differential impacts require a comprehensive approach across large landscapes including mobilizing communities, governments and private actors.

The governments of the 12 countries participating in this project are trying to work through a multi-year plan called the Global Snow Leopard Ecosystem Recovery Program (GSLEP). This was established in 2012 and is supported by the World Bank Group, Global Environment Facility, and United Nations Development Program, among others.[63] The objectives of the GSLEP are to:

- Engage local communities in conservation, promote sustainable livelihoods, and address human-wildlife conflict;
- Combat poaching and illegal trade networks, including through transboundary collaboration and enforcement;
- Seek to manage habitats on a landscape level;
- Work with industry and enterprises that operate in snow leopard habitats;
- Establish a core Secretariat to coordinate conservation activities, monitor program implementation, and mobilize financial resources for the program

[62] http://www.worldwildlife.org/projects/conserving-snow-leopards-securing-water-resources-and-benefiting-communities

[63] World Bank, 2013, press release,

5. SUMMARY OF FINDINGS AND CONCLUSIONS

This overview of the impact of climate change on Asia's keystone species and affected ecosystems suggests a number of conclusions. This section also will try to identify those responsible for proposed actions, timeframes and milestones for implementation, including decision points and resources needed for implementation.

1. Climate change acts primarily as an additional stressor on the functioning and stability of ecosystems. These include impacting the provisioning, regulatory, cultural and supporting services that ecosystems provide. Where human management of ecosystems is conservative and sustainable, climate change impacts are more likely to be successfully managed at least over the short and medium time frames. Where ecosystems are being degraded and poorly managed, climate change is likely to accelerate ecosystem degradation and local species extinction.

   In recent years, the rate of global warming appears to be accelerating. In part, this is due to a vicious cycle in which critical ecosystem degradation, especially tropical forests, is increasing GHG emissions, including both CO2 and methane (from exposed peat bogs, degraded mangroves and melting permafrost). Hence, the urgency of conserving ecosystems that can provide carbon sequestration as well as other important ecological services, especially water supply. Improved management of critical ecosystems for their own sake and to slow global warming should be an urgent priority of the public and private sectors and civil society.

2. A number of methodologies have been developed to assess and prioritize the conservation of species threatened by increasing climate change. In most cases, these methodologies build on existing conservation management approaches but are more explicitly focused on developing climate adaptation plans and measures. While most developed countries have now integrated climate change mitigation and adaptation planning into natural resource management but developing country NAPAs need to be more systematically implemented and integrated into poverty reduction and sustainable economic growth plans. At this point in our understanding of the impacts of climate change on natural ecosystems, the collection and analysis of monitoring data and developing standardized protocols for monitoring are essential for adaptation and mitigation planning. This, in turn, requires that protocols for climate change impact monitoring extend down to the community level. Indonesia's climate field schools, which educate farmers on adaptation to climate change and provide tools for collecting valuable field level data on precipitation and temperature, may be one kind of model that might be studied for potential wider adoption.

3. Local communities are critical to climate change adaptation planning and implementation in most of the critically affected ecosystems and landscapes studied in Asia. Because local people often have a good understanding of the changes that

their environment have been undergoing they are, first, an important source of knowledge for researchers and planners. Second, their understanding of the threats to their environment and resource base and the active participation in monitoring and action plan implementation is essential for adaptation and mitigation to work sustainably. Community participation in monitoring changes in the environment and development of alternative livelihoods and changes in behaviors may be critically important to reducing pressures on vulnerable species including keystone species. A number of projects have tried to incorporate this model in high mountain Asia, including projects funded by USAID, World Bank/Global Environmental Facility (GEF) and the European Union but this model needs to be more systematically evaluated and adapted to different kinds of communities.

4. The role of national and sub-national government policy and regulation is also very important to the development and implementation of successful adaptation plans. These include sound environment and natural resource management policies and regulations. These "no regrets" actions provide environmental and socio-economic benefits now and provide additional insurance against the likely damage to vulnerable ecosystems from climate change in the near and medium term future.

   Governments, especially major GHG emitters need to develop comprehensive partnerships with major private and publicly financed sources of carbon with hard achievement milestones and transparency. With the important exception of China, none of the high mountain Asia states are significant GHG emitters so the emphasis will be on sound environmental management of critical ecosystems. The single most important impact of climate change in high mountain Asia will be water security for more than a billion people so preserving the integrity of upland forests, developing engineering solutions to prevent GLOFs and involving mountain communities in activities focused on water security should be a top priority for all high mountain Asia countries.

5. The nature and scope of climate change reinforces the need for larger-scale climate change adaptation and mitigation action plans. Increasingly, this reinforces the need to work at a landscape or multiple landscape level and, as a number of the cases described in this paper have shown, a need to cooperate across national borders. The Global Snow Leopard project, which involves 12 nations and the Asia High Mountains projects are two examples of transboundary environmental management. In the critically important HKH region, the transboundary Kailash Sacred Landscape Conservation Initiative, which focuses on conservation of mountain ecosystems, employs both a cultural value approach and the need to conserve the water supply for more than a billion people. These transboundary efforts require careful monitoring that they are having genuine on the ground impacts and are not just plans and declarations.

6. Of all keystone species discussed in this overview, the top predators (e.g. the large cats) and ecosystem engineers (e.g. the elephant) appear to experience the greatest

vulnerability to increasing climate change. This is primarily because they are currently under varying degrees of severe stress from existing land management policy and practices. This stress arises, in large part, because of the very large range they require to maintain large enough populations to avoid genetic decline and possible extinction. Chief among these current threats is the loss (conversion) or degradation of habitat for both predators and prey and the ecosystems on which both rely. Additional pressures come from illegal hunting and poaching, pollution, reduction or diversion of water supplies. Conservation of such keystone species may be critical to the survival of ecosystems and even whole landscapes in some instances and so should be an important component of change adaptation.

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U.S. Agency for International Development

1300 Pennsylvania Avenue, NW

Washington, DC 20523

Tel: (202) 712-0000

Fax: (202) 216-3524

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