THE CONSERVATION OF THE SNOW LEOPARD (*PANTHERA UNCIA*) AND AN ACTION PLAN FOR THE INDIAN HIMALAYA POPULATION

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Msc by Research **2019**

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Submitted in Fulfilment of the Requirements for the Degree of MSc by Research

University of Salford, UK, School of Environment and Life Sciences

2019

Statement of originality

I declare that the contents of this thesis are my own work and no part has been copied from previous reports, dissertation, books, manuscripts, research papers or the internet. This work has not been submitted in part or whole for an award at any other institution.

Signed ……[redacted]……..… Print name……….. AMBER SCHOFIELD ……..…

Date ……….. 28/03/2019 ……..…..

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Acknowledgements

I want to thank University of Salford, specifically the School of Environment and Life Sciences, for the support I have received since my Undergraduate degree through into my time as a Post Graduate. I give special thanks to my supervisor Professor Jean Boubli who has also guided and supported me through this time. The past five years under the guidance of Professor Boubli have taught me copious amounts, all with a sense of humour. The initial setbacks I faced at the beginning this thesis were costly in both time and energy and I am thankful that Professor Boubli shared my determination to continue to work on snow leopard conservation despite the obstacles.

I also want to give thanks to my family and friends who have encouraged me to persevere through the moments of doubt. Special thanks must be given to my mother Lynn Schofield, my partner Harry Powell and my friend Finn O'Brien.

The memory of my father, who was the first to teach me about wildlife conservation, has stuck with me through this thesis, and his life work inspires me to continue along this career path. To that end, this piece of work is done in tribute to all he has taught me about the importance of passion and care for the environment, and the species we love.

Abbreviations

AM – Adaptive Management

CAP – Conservation Action Plan

CITES – Convention on the International Trade in Endangered Species of Wild Fauna and Flora

CMP – Conservation Measures Partnership

EAZA – European Association of Zoos and Aquaria

EE – Environmental Education

EEP – European Endangered Species Program

FOS – Foundations of Success

GSLEP – Global Snow Leopard & Ecosystem Protection Program

ICZN – International Commission on Zoological Nomenclature

IUCN – International Union for Conservation of Nature

SLC – Snow Leopard Conservancy

SLE – Snow Leopard Enterprise

SLIH – Snow Leopards of the Indian Himalayas

SLN – Snow Leopard Network

SLSS – Snow Leopard Survival Strategy

SLT – Snow Leopard Trust

TCP – Torghar Conservation Project

ToC – Theory of Change

PCR – Polymerase Chain Reaction

Snow leopard image captured by infrared camera at the Altai Liangheyuan Nature Reserve, Xinjiang Uygur Autonomous Region. Photo provided by WWF China. (Source: China Daily, 2018).

Abstract

The snow leopard (*Panthera uncia*) inhabits the high-altitude mountains of Central Asia, with 2,710 to 3,386 individuals remaining in the wild. Snow leopards were previously listed as an endangered species on the IUCN Red List, but 2017 saw the species demoted to vulnerable following a reassessment of the age of maturity used in population estimates. In addition to this change in status, there have been new discussions regarding the taxonomy, phylogeny and morphology of snow leopards. The aim of this thesis is to use the new data available to reassess snow leopard threats and to create the first action plan for the conservation of the Indian Himalayan population using principles from The Open Standards for the Practice of Conservation. The range of threats snow leopards face across the 12 countries they inhabit have been divided into direct, indirect, intrinsic and emerging. The conservation work being done to mitigate these threats has been examined and successes have been identified in livestock husbandry, insurance schemes and education programmes. The action plan to conserve snow leopards in the Indian Himalayas has been created using Miradi. A conceptual model with seven results chains has been produced in order to tackle the highest rated threats within the Indian Himalayan range. The highest rated threats in this region were found to be retribution killing and prey base depletion. The seven strategies to mitigate these threats are: improving wildlife laws, controlling feral dogs, creating and expanding Protected Areas, introducing wildlife friendly practices, creating awareness of the value of snow leopards, creating a livestock insurance scheme and developing ecotourism. Monitoring schemes include principles of adaptive management which are especially significant in this first iteration of a Miradi based action plan for the Indian Himalaya population.

Introduction

The world is currently seeing its sixth mass extinction take place, also known as the Holocene extinction event (Barnosky *et al*., 2011). More than 26,000 species are threatened with extinction from amphibians and birds to mammals and reef corals (IUCN Red List of Threatened Species, 2019). Natural disasters can be a threat to species, as shown by the Cretaceous-Palaeogene extinction event that famously killed the dinosaurs 66 million years ago. In the case of the Holocene extinction event, the growing human population has caused species to go extinct at an alarming speed, currently thought to be between 1,000 and 10,000 times higher than the natural rate (meaning the number of species that would go extinct if humans did not exist) (De Vos, Joppa, Gittleman, Stephens, & Pimm, 2015). The exact number of extinctions caused by the human race is unknown as we are currently unaware of how many species of fauna and flora there are on our planet. The need for resources to cope with the demands of the growing human race is seeing biodiversity hotspots such as the Amazon rainforest cut down for logging, palm oil and agriculture. In the period of a year, an estimated 18 million hectares of forest is felled, with unknown numbers of discovered and undiscovered species populations living within (FAO, 2012).

In recent times the threats facing our animals and environments have become an issue more widely recognised in the public eye, often used as the basis for fundraising campaigns and changing attitudes, such as the 'war' on single use plastics (Boffey, 2018). With the help of awareness campaigns from organisations like WWF, and the work of broadcasters such as David Attenborough, the threats facing our planet are becoming an issue that a larger proportion of the population is aware of, instead of purely ecologists and conservationists. Issues facing charismatic species, such as the bleaching of reef corals, is often put at the forefront of fundraising for issues that are accessible and important to the masses (Ducarme, Luque, & Courchamp, 2013). The number of threats facing our ecosystems are vast and can be overwhelming to attempt to solve from their complexity. Given this, it appears that taking a holistic approach with ability to adapt is truly important (Leser & Nagel, 2001). This is because, although the causes and links may be many, to truly reduce the threats the root of the problem must be targeted. In the case of the snow leopard (*Panthera uncia*), our knowledge of the population size and extent of threats is limited at this time, making conservation work, or getting to the 'root of the problem', a challenging field.

The snow leopard is one of the most elusive members of the Felidae family. This is a result of their inhabitancy of the remote mountainous terrain across the Himalayas and Tibetan plateau, gaining them the name *Ghost of the mountain* (Padmanabhan & Anantharajan, 2010). Their habitat range is thought to cross 12 countries including: Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russia, Tajikistan and Uzbekistan (McCarthy,T., Mallon, Jackson, Zahler, & McCarthy, K., 2017). Snow leopards typically reside at altitudes of 3,000m to over 5,000m in the Himalaya and Tibetan Plateau, but have been seen as low as 500m in the Altai mountains (Snow Leopard Network, 2014). They are an altitudinal migrant, moving to lower altitudes in the winter, following the migration of prey species (McCarthy & Chapron, 2003). The primary productivity across their range is low due to the high aridity and low temperatures (Nyhus, McCarthy, & Mallon, 2016). The principal prey of snow leopards includes blue sheep (*Pseudois nayaur*), siberian ibex (*Capra sibirica*), Argali (*Ovis ammon)* and Markhor (*Capra falconeri*) (Lyngdoh *et al.*, 2014). Their diet can also be supplemented with marmots, hares, birds, and vegetation (Mallon, Harris, & Wegge, 2016). Snow leopards have evolved physiological adaptations to enable their ability to survive at high altitudes. This includes an enlarged nasal cavity, widened feet, developed chest muscles, shortened limbs and with the densest pelage of any member of the Felidae family, with 4000 hairs per cm^2 (McCarthy & Chapron, 2003; Nyhus *et al*., 2016). These adaptations make the snow leopard a unique and valuable species.

Since their discovery in 1775 by Schreber, snow leopards have changed from the genus *Uncia* to *Panthera*. Many papers, articles and databases in current day still refer to the species as both *Uncia uncia* and *Panthera uncia* (Bagchi & Mishra, 2006; David, 2012; Dominic, 2016; Snow leopard network, 2014). Snow leopards are thought to be the closest relative to tigers (*Panthera tigris*) after diverging two million years ago (Wei, Wu, & Jiang, 2009). In more recent years, proposed changes to snow leopard phylogeny are being suggested following research, such as the possible discovery of three subspecies (Janecka *et al*, 2017). Janecka *et al* (2017) claimed to have discovered three sub-species of snow leopard from genetic clusters of mitochondrial DNA taken from 70 individuals. The three subspecies are split across different regions of terrain. One group is found across India, Pakistan, Tajikistan and Kyrgyzstan. The second group is across northern Qinghai, southern Qinghai and the Himalayas including Bhutan, Nepal and Tibet. The third group is found in western Mongolia and southern Mongolia.

The current status of the snow leopard on the International Union for Conservation of Nature's (IUCN) Red List is Vulnerable C1, meaning the global population is estimated to be more than 2,5000 mature individuals but fewer than 10,000. There is a projected decline of at least 10% over 22.62 years, the equivalent of roughly three generations (IUCN Standards and Petitions Subcommittee, 2016). The IUCN took five attempts to compile national estimates of snow leopard populations to create a global population size estimate. These estimates put the population size at 2,710 to 3,386. This figure excludes dependant cubs but may include young adults not capable of breeding (McCarthy *et al.*, 2017). Snow leopards were previously listed as Endangered C1 on the Red List. The change to Vulnerable C1 took place in 2017 and was attributed to the effective population size being used incorrectly in the previous assessment (McCarthy *et al.*, 2017). The IUCN considers only absolute numbers of mature individuals in the calculations (IUCN Standards and Petitions Subcommittee, 2016). There is little substantiated documentation of population trends over a fitting time scale to produce a reliable account of snow leopard population trends and stability (McCarthy *et al.*, 2017). From what is known, numbers are thought to be stable or humbly increasing in some areas but declining in others, including localized extinctions which are believed to have occurred in areas of the former Soviet Union (Koshkarev & Vyrypaev, 2000; McCarthy *et al.*, 2017). The lack of a backlog of data on natural population trends has created difficulty in predicting how populations may or may not recover without intervention.

Snow leopards are threatened by retaliatory killings, livestock depredation, prey declines, disease and illegal trade (Snow Leopard Network, 2014). In addition to this, new threats have also been acknowledged since 2003 including mining, climate change, large scale infrastructure and physical barriers preventing connectivity such as roads or fenced railway lines (Zahler, 2016). There is also an established link between peace and a healthy environment. Conflict from political unrest, resource competition and poverty are part of the driving force behind the threats facing snow leopards today. The potential impact of emerging threats on snow leopards and their habitat is difficult to quantify so their severity is currently unknown (McCarthy *et al.*, 2017).

Conservation efforts have seen high investments in projects to establish new Protected Areas, create initiatives to reduce conflict with herders, engage local communities, form incentive programmes, establish education programmes and improve anti-poaching measures (McCarthy *et al.*, 2017; Nyhus *et al.*, 2016; Snow Leopard Network, 2014). Mixed successes in these initiatives are part of the recent call for conservationists to make their projects more effective. The use of action planning for results-based management and monitoring is considered an answer to this call (The Conservation Measures Partnership, 2013). Adaptive Management, or Adaptive Resource Management, has grown in popularity as a guideline to improve results-based conservation projects (Rist, Felton, Samuelsson, Sandström, & Rosvall, 2013). Adaptive Management illustrates six stages that create a learning cycle. This cycle outlines how conservationists can use Adaptive Management to reduce uncertainties and increase how effective a project is (Rist *et al*., 2013). The Foundations of Success have been teaching Adaptive Management to improve its utilisation in conservation (Foundations of Success, 2009). This approach has been adopted by the Open Standards for the Practice of Conservation (The Conservation Measures Partnership, 2013). The Open Standards is a tool that helps to articulate the use of AM in conservation action plans. The Open Standards allows approaches, concepts, planning, management and monitoring to be performed together in order to contribute to conservation efforts (The Conservation Measures Partnership, 2013). The Open Standards uses a five-step cycle to encourage continuous adaptation of plans based on results, using the lessons learnt to structure future changes.

The purpose of this thesis can be divided into two objectives. The first, to compile and evaluate new research on all that may influence the current and future status of the snow leopard, with the aim to give an overall review of their status with a critical review of the literature available. Following the recent publication of new data on the abundance and distribution of snow leopards, in addition to new data on their population genetic structuring with possibly new taxa being reported, there is the need for a re-evaluation of their status.

The second objective is to use this compiled information in the creation of a conservation action plan for the snow leopard population of the Indian Himalayas. This action plan will be developed using Miradi, with the guidance of The Nature Conservancy's 'conservation action planning handbook' provided by The Open Standards. Strategies are created to mitigate the highest rated threats in an effort to intervene and protect the snow leopard population.

The first part of the thesis will give an overview of snow leopards including: fossil records, physical characteristics, morphological adaptations, behaviour, dietary composition and habitat use. The systematics and taxonomy will then be discussed before giving a critical review of the paper by Janecka *et al* (2017) on the emergence of three sub-species of snow leopard. The status of snow leopards following the downgrade made by the IUCN Red List in 2017 is outlined, and the justification given for this is debated. The threats facing snow leopards are delineated to create a picture of the complex situation snow leopards face. The third chapter gives an insight to the concept of Adaptive Management and how it has been utilised in conservation projects. The role of the Foundations of Success and the Open Standards in improving conservation efforts is also explored. The fourth chapter evaluates the conservation work being done to mitigate threats, with view to successes and shortcomings. The fifth and final chapter will give a report on the action plan created for this thesis, detailing a 30-year action plan which uses the first two steps of the Open Standards. This plan includes a Conceptual Model, seven Results Chains and the Theory of Change present in each.

Chapter 1

The snow leopard

Evolutionary history, taxonomical debate, conservation status and threats

The purpose of this chapter is to present a thorough account of the available literature on the snow leopard's evolutionary history, characteristics, taxonomy, conservation status following the downgrade by the International Union for Conservation of Nature's (IUCN) and all the threats they are facing across their habitat.

Firstly, the fossil record, physical characteristics, behaviour and adaptations of snow leopards are discussed. Building a base of knowledge on any species must begin with the historical record of their evolution before exploring their taxonomy.

In the second part of this chapter, the taxonomic history of the snow leopard will be discussed before looking at the phylogenetic tree of *Panthera*. There will then be a critical review of the debated taxonomic position of snow leopards within their genus, and the disagreement among scientists about the correct placement of the species in the *Panthera* phylogenetic tree. Clarifying the nomenclature and classification is important to understanding and conserving the species. Following this, a discussion regarding the possible changes to the phylogeny of snow leopards from the emergence of the three sub species will take place, with a discussion of the importance of this discovery to snow leopard conservation.

In the third part of this chapter, the global conservation status of snow leopards is reviewed, with an explanation of the IUCN classification system and the downgrade the species received in 2018. The debate over the IUCN's decision and justification regarding the downgrade will also be evaluated, taking into account the stance of various conservation organisations regarding the impact the decision has had. There will be commentary on how the potential emergence of three sub-species of snow leopards would change their status, according to the IUCN classification system, if the discovery were to be supported.

In the fourth and final section, the threats facing snow leopards will be reviewed, with a discussion on those classified as emerging (a newly appeared threat) and intrinsic (an animal's life history and resilience to threats). In snow leopard conservation, some scientists consider the concept of emerging threats to be changing and ongoing, making them difficult to group. In this body of work the emerging threat discussed will be climate change. There is also an aim to demonstrate links amongst the threats mentioned, creating a picture of the complexity of the situation.

Literature review

The initial step of this thesis comprised of a literary search into snow leopards (*Panthera uncia*) in India. This involved searches for relevant and accessible literature pertaining to snow leopards. These searches were conducted using the search engine available at the University of Salford's online library. Secondary keywords used to enhance the search included: Taxonomy, Genome, Himalaya, Habitat, Population, India, Threats, Conservation, Prey, Conflict and Viability. The search was further expanded to include select journal titles including: *Ecology and Evolution, Oryx, Heredity, Molecular Phylogenetic and Evolution, Journal of Asia-Pacific Biodiversity, Journal of Ecology and the Natural Environment, Biological Conservation, Journal of Threatened Tax.* Reports from *WWF India, the Snow Leopard Conservancy* and *TRAFFIC* were also accumulated. Following the initial searches, the most relevant literature was retained and used within this thesis.

1. Evolutionary history, ecology and behaviour

1.0 Fossil records

Members of *Panthera* are thought to have originated in Asia, dating back as far as six million years. This concept gained significant supporting evidence with the discovery of *Panthera blytheae* (Holland, 2013; Tseng *et al*., 2014). In 2010, within the Tibetan Plateau, palaeontologists found what was discovered to be the oldest fossil of all the big cats in the *Panthera* genus (Tseng, 2013). It is dated at 4.1 to 5.95 million years old and was a previously unknown species given the name *Panthera blytheae* (Morgan, 2013). Examinations of the phylogenetic tree of *Panthera* showed that *Panthera blytheae* was a sister species to snow leopards (*Panthera uncia)* and would have constituted the same lineage of high-altitude inhabitancy of the Himalayas (Tseng, 2013).

The fossil record for snow leopards is virtually non-existent, likely due to the difficulty in retrieving samples from their high-altitude montane habitat (Kitchener, Driscoll & Yamaguchi, 2016). This leaves a gap in knowledge preventing the use of a fossil record to track back the possible dispersion and evolution of the species (Kitchener *et al.,* 2016). However, early diagrams of snow leopards have been found in petroglyphs in Ladakh and kurgan artefacts across Tien Shan, depicting coexistence and interaction between snow leopards and humans for a substantially long period of time (Salopek, 2017).

1.1 Physical characteristics

Snow leopards are one of the smallest members of the ‘big cat’ family with adults measuring from 100cm to 130cm head to tail. Their tails measure at 80cm to 100cm, approximately 80%

of their body length (Fox & Chundawat, 2016). Their average shoulder height is 60cm, with weight ranging from 25kg to 75kg (Fox & Chundawat, 2016). Pug marks put the average adults' paws at 9cm to 10cm in length and 7cm to 8cm in width, with front paws slightly larger than the rear (Fox, Sinha, Chundawat & Das, 1988). Their coat is white to pale yellow in colour, covered with mottled grey to black spots and rosettes (Kitchener *et al.,* 2016). Individual snow leopards can be identified by their facial spot patterns (Fox, 1989).

Limited available data means there is not at present a data set to demonstrate a significant latitudinal distinction in snow leopard size/weight or appendage size, as may be expected from Bergmann's Rule or Allen's Rule (Kitchener *et al.,* 2016). Bergmann's Rule is an ecogeographical rule which states that when a taxonomic clade is over a broad distribution, populations and species of a larger body size are found in colder environments, and smaller in warmer climates (Blackburn, Gaston, & Loder, 1999). Allen's Rule states that animals in colder climates have shorter limbs and appendages than those adapted to warm climates (Tilkens, Wall-Scheffler, Weaver, & Steudel-Numbers, 2007).

1.2 Geographical range, home range and habitat preferences

Snow leopards can be found in 12 countries including: Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russia, Tajikistan, and Uzbekistan (Snow Leopard Network, 2014). Snow leopards occupy the mountains of central Asia at altitudes of 3,000m to over 5,000m in the Himalayan and Tibetan Plateau, but as low as 600m in Russia and Mongolia (Snow Leopard Conservancy, n.d.). Adult male snow leopards can occupy home ranges of 207 km^2 and females can have a home range up to $124km^2$ (Nyhus *et al*., 2016). Due to the difficulties faced in tracking snow leopards it is unknown how far they travel on a daily average in the different areas of their habitat. Estimates suggest it can vary between 7km to 12km depending on how rugged the area is, with further distances travelled daily in the less rugged areas (Mccarthy, Fuller, & Munkhtsog, 2005). Vegetation cover across their range varies from treeless alpine habitats to dense forest alpine ecotones, scrubland, montane desert and open forests (Fox & Chundawat, 2016). Typically snow leopards are found in the more rugged mountainous areas of their habitat range (Fox & Chundawat, 2016). However, they occasionally use less rugged foothills to travel over flatter expanses to access more isolated rugged montane areas (Fox & Chundawat, 2016). Preference in the use of travel routes with different slope angles varies in different countries (Mccarthy *et al.,* 2005). In Ladakh India, the winter travel routes had an average 24° slope angle, whereas in western Nepal the preference was for slopes with angles in excess of 40° (Fox & Chundawat, 2016; Jackson & Ahlborn, 1988). The best account of habitat use would come from the application of home range algorithms that include considerations for the distribution of terrain differences, from the use of rugged to flatter terrain (Nyhus *et al*., 2016).

1.3 Predation

The primary prey species of snow leopards is wild ungulates including sheep and goats such as blue sheep or bharal (*Pseudois nayaur),* mouflon (*Ovis orientalis*)*,* Siberian ibex (*Capra sibiricia),* argali (*Ovis ammon*) and markhor (*Capra falconeri*) (Jayasinghe, Sharma, Elliott, Long, & Lee, 2015). In addition, smaller mammal species have been found to be included in a snow leopards' diet such as marmots (*Marmota spp),* hares (*Lepus spp*)*,* pikas (*Ochotona spp*) and various species of bird (Mallon, Harris, & Wegge, 2016). Domestic livestock can also become a significant part of a snow leopards' diet, particularly sheep and goats (Lyngdoh *et al*., 2014). Studies have been done to work out the likely percentage of their that consists of livestock versus wild prey. The results of these studies widely vary from 27% to

40% (Mallon *et al.,* 2016). Like other solitary Felids, snow leopards stalk and kill their prey with a nape bite or asphyxia from a throat bite (Kitchener *et al.,*2016). A sub-adult snow leopard weighing an estimated 20kg was seen to be capable of killing an adult blue sheep weighing in the region of over 55kg (Lyngdoh *et al.*, 2014). Like smaller wild cats, snow leopards appear to most commonly crouch by their kill to eat (Nygren, 2015). They have been seen to remain around their kill for longer periods than other 'big cats' do, making them more vulnerable to retaliatory killings, a direct threat which will be discussed further in Chapter 1 (Nygren, 2015).

1.4 Behaviour

Snow leopards live largely solitarily with crepuscular activity patterns, but groups of up to four can be seen following the birth of cubs or during the breeding season (Jackson, 1996). The breeding season for snow leopards both in the wild and in captivity is during the late winter, from January to March (Fox & Chundawat, 2016). Commonly, two to three cubs are born between April and June, following a 90 to 105 day gestation period (Marma & Yunchis, 1968). In rare instances a single cub, or four to five cubs, can be born (Fox *et al.,* 1988; Mccarthy *et al.,* 2005). Cubs stay with their mothers for up to two years, following her as she walks her home range (Fox & Chundawat, 2016). Over time, they gradually follow her from further behind until they establish their own home range and are fully solitary (Novikov, 1956). Individuals are thought to maintain separation and minimal home range overlap by using scent marking and scraping to avoid each other (Jackson & Ahlborn, 1988). Common marking behaviour includes scraping, spraying urine and cheek rubbing on rocks (Jackson & Ahlborn, 1988). When spray marking, snow leopards raise their tail up vertically and spray behind them onto near vertical surfaces, bushes or rock overhanging's (Rieger, 1978). Scraping is done by using their hind legs to scrape loose material into a pile. They also sometimes urinate on the pile formed from the scrape (Fox & Chundawat, 2016). Scrapes are most commonly made at specific topographical sites such as cliffs and large rocks on well used travel routes. Scrape markings are most typically found in the wild as scraping is used frequently by both sexes (Jackson & Ahlborn, 1988). Scrape dimensions average at 36 cm in length, 5 cm pit depth, 19 cm pit width and 6 cm height of scraped up material (Fox *et al.*, 1988). Observations of captive snow leopards showed that males spray marked more than females, and both sexes scraped equally as often (Rieger,1978). There has not been enough study on wild snow leopard marking behaviours to establish if this is representative of behaviours in the wild (Nyhus *et al.*, 2016).

The vocal range of snow leopards is similar to other Felidae in that they use calls such as prusteen, which is a nonaggressive puffing sound made through the nostrils (Peters, 1980). They also use mew calls, hissing, growling, spitting and shrieking (Peters, 1980). Snow leopards cannot roar due to the morphology of their larynx (Nowak, 1999). Their main call is associated with the breeding period as a copulatory cry and is commonly heard in the wild as the sound can travel for miles (Fox & Chundawat, 2016).

1.5 Adaptations

The morphological adaptations of snow leopards make them a unique species as their adaptations to high altitude living are not yet fully understood despite several studies (Kitchener *et al.*, 2016). Snow leopards appear to have adaptations that enable life at higher altitudes by keeping their bodies warm against the lower temperatures (Kitchener *et al.*, 2016). They have a dense camouflaged pelage, the longest and densest of any member of the Felidae family, with 4000 hairs per cm (Heptner & Sluskii, 1992). Structurally, the skulls of snow leopards are shorter and broader than any other member of *Panthera*, with an enlarged nasal cavity which allows for more efficient counter current warming of air that is inhaled (Pocock, 1916). An extended tibia, with long thoracic and lumbar segments of the vertebral column, allows for more efficient movement which can be seen in their jumping ability (Kitchener *et al.,* 2016). The long tail of snow leopards helps in balance and insulating extremities such as the paws and face (Rieger, 1984). The small vocal cords of snow leopards are unlike any other member of *Panthera* and mean that snow leopards cannot roar (Kitchener *et al.,* 2016). Physiological adaptations such as these would be expected to show enhanced respiratory efficiency, but little work into proving or disproving this theory has been done (Nyhus *et al*., 2016). It is also expected that blood studies would show adaptations to high altitude life, but several studies have produced unexpected results (Kitchener *et al.,* 2016). Montane animals are generally expected to have haemoglobin with an improved affinity to bind oxygen (Marma & Yunchis, 1968). However, felids are known to have low oxygen affinities, making respiration in oxygen deficient environments difficult (Kitchener *et al.,* 2016). It was theorised by Janecka *et al* (2015) that the haemoglobin of snow leopards may be modified, yet analysis of the protein sequence in their blood revealed that snow leopards carry the same amino acid composition that inhibits the ability of other Felids to carry oxygen. Further study produced more unexpected results as the oxygenation of haemoglobin was tested both with and without diphosphoglycerate (DPG) (Janecka *et al.,* 2015). DPG helps enable the haemoglobin to offload oxygen when it needs to (Knight, 2015). The results of study showed that the protein had weak oxygen binding and that all of the haemoglobin was unresponsive to the effects of DPG (Janecka *et al*., 2015). Snow leopard's haemoglobin is equally as inefficient as other 'big cats', structurally and functionally almost matching that of domestic cats (Janecka *et al*., 2015). It is now suspected that snow leopards compensate with heavier breathing to accommodate the poor oxygen capacity their blood holds, making their adaptations unique (Kitchener *et al.,* 2016).

2. Systematics and Taxonomy

2.0 Taxonomy

The snow leopard was first described by naturalist Johann Schreber in 1775 who gave the cat the name *Felis uncia* (Kitchener *et al.*, 2016). Snow leopards belong to the *Panthera* genus which is one of the eight lineages of the Felidae family. The genus was first named and described in 1816 by German naturalist Lorenz Oken. In 1916 British Taxonomist Pocock revised the classification to be comprising of the species Lion (*Panthera leo*), Tiger (*Panthera tigris*), Jaguar (*Panthera once*) and common leopard (*Panthera pardus*) (Pocock, 1916). This revision was based on cranial features each of the species showed. Genetic analysis by Johnson *et al* (2006) put the snow leopard into *Panthera* after having been originally placed in its own monotypic genus, *Uncia*, by Pocock (1916). The author gave a description of the morphological differences between snow leopards and the previously accepted *Panthera* species. The pantherine lineage, comprising the lion, tiger, leopard and jaguar is thought to be the most recently evolved, within 1~8MYA, and the largest group of felids (Yu & Zhang, 2005). The complete Mitochondrial DNA (mtDNA) sequences of feline species are lacking with only three reported, consisting of the domestic cat (*Felis catus*), cheetah (*Acinonyx jubatus*) and clouded leopard (*Neofelis nebulosa*) (Christiansen, 2008). This data has proved insufficient to sort the genetic relationships of Felidae (Agnarsson *et al*., 2010) Since the placement of snow leopard in the *Panthera* genus in 2006, studies on the phylogenetic relationship of the genus have been unable to conclusively or confidently place the precise relationships among the genus, meaning there is disagreement on which species snow leopards are sister to (Agnarsson, Ingi, Matjaž Kuntner, & May-Collado, 2010; Wei, Wu, & Jiang, 2009).

2.1 Phylogeny

Agnarsson *et al* (2010) performed an analysis to try and discover the molecular species-level phylogeny of Carnivora. Their study suggested that *uncia* is a junior synonym of *Panthera*, whereas other studies place *uncia* as a sister to other species within *Panthera*. Agnarsson *et al* (2010) go on to state that the tiger subspecies (*P. tigris spp*) form a group that is sister to all of the other *Panthera* species. This in turn separates the lion from the clade, including the common leopard, jaguar and snow leopard. Agnarsson *et al* (2010) claim this finding to be largely well supported, but incongruent with previous proposed topologies within *Panthera*. They concluded that further studies, including both numerous taxa and numerous characters, are needed to resolve this incongruency.

Comparing complete mitochondrial genome sequences of animals has become common in phylogenetic reconstruction and as a way to model possible genome evolution (Wei, Wu, & Jiang, 2009). Complete mitochondrial genome sequences also provide genome-level characteristics, including relative arrangements of genes which might be particularly influential in deducing phylogenetic relationships (Wei *et al.*, 2009). Wei, Wu, and Jiang (2009) used the complete mitochondrial genome (mtDNA) of snow leopards in their study. The mtDNA was attained with the use of the polymerase chain reaction (PCR) technique based on the PCR fragments of 30 primers they designed. The recent speciation of *Panthera* makes the interspecific relationships somewhat equivocal among scientists (Kitchener *et al.*, (2017). From the results of their study, Wei *et al* suggested that the clouded leopard was the most basal member of the *Panthera* genus, with tigers as a sister taxon to the other members of the genus within the clade. Their results also indicated the common leopard was weakly supported as sister taxon to lions and snow leopards. Wei *et al* claim that the most interesting finding of this study was that snow leopards and lions are possibly sister species. Other studies contest this, with results indicating that either tigers, leopards, jaguars or all three are the sister species of snow leopards, with tigers receiving the most support as the likely sister species (Bininda-Emonds, 2001; Buckley-Beason *et al.*, 2006). The results of Wei *et al* appear to support the claim of a close affinity between snow leopards and lions. Kitchener *et al* (2017) suggest that the recent molecular studies from Davis *et al* (2010) and Li, Davis, Eizirik and Murphy (2016) support the tiger as a sister species to snow leopards. They argue that these two species should be separated from the other *Panthera spp*. or all should be retained in *Panthera,* supported by Hennig's (1965) criterion on monophyly which Kitchener *et al* (2017) endorse.

Das and Upadhyai (2016) have provided support on the insights to the mitogenome phylogeny of the Pantherine cats. They used 43 publicly available taxa to perform a reconstruction of the Pantherine phylogenetic history. They identified that lions split from their sister species the common leopard ~3MYA, and the divergence time between snow leopards and the lion leopard clade was an estimated ~5MYA. The authors also found that snow leopards are genetically distinct from tigers (7.5 – 8.1% sequence divergence) whereas lions are genetically close (5.5 – 6.1% sequence divergence). They highlight that grouping snow leopards with tigers is likely a result of improper and inadequate sampling. They also raise the point that if multiple individuals from all species are not analysed, it is possible for lions to be, at random, wrongly grouped with snow leopards. As a result of their analysis of the 43 taxa, Das and Upadhyai produced a phylogenetic tree for Pantherinae (see Figure 1). They claim this tree to be based on an unparalleled in-depth view of Pantherine taxonomy which has the capability to reconstruct the subspecies. They believe this to have answered the subspecies anomaly that has remained elusive to conclusively answer. Their work will have to be updated to recognise the data produced by Janecka *et al* (2017a) that may prove the three subspecies of snow leopards which is discussed later in this chapter.

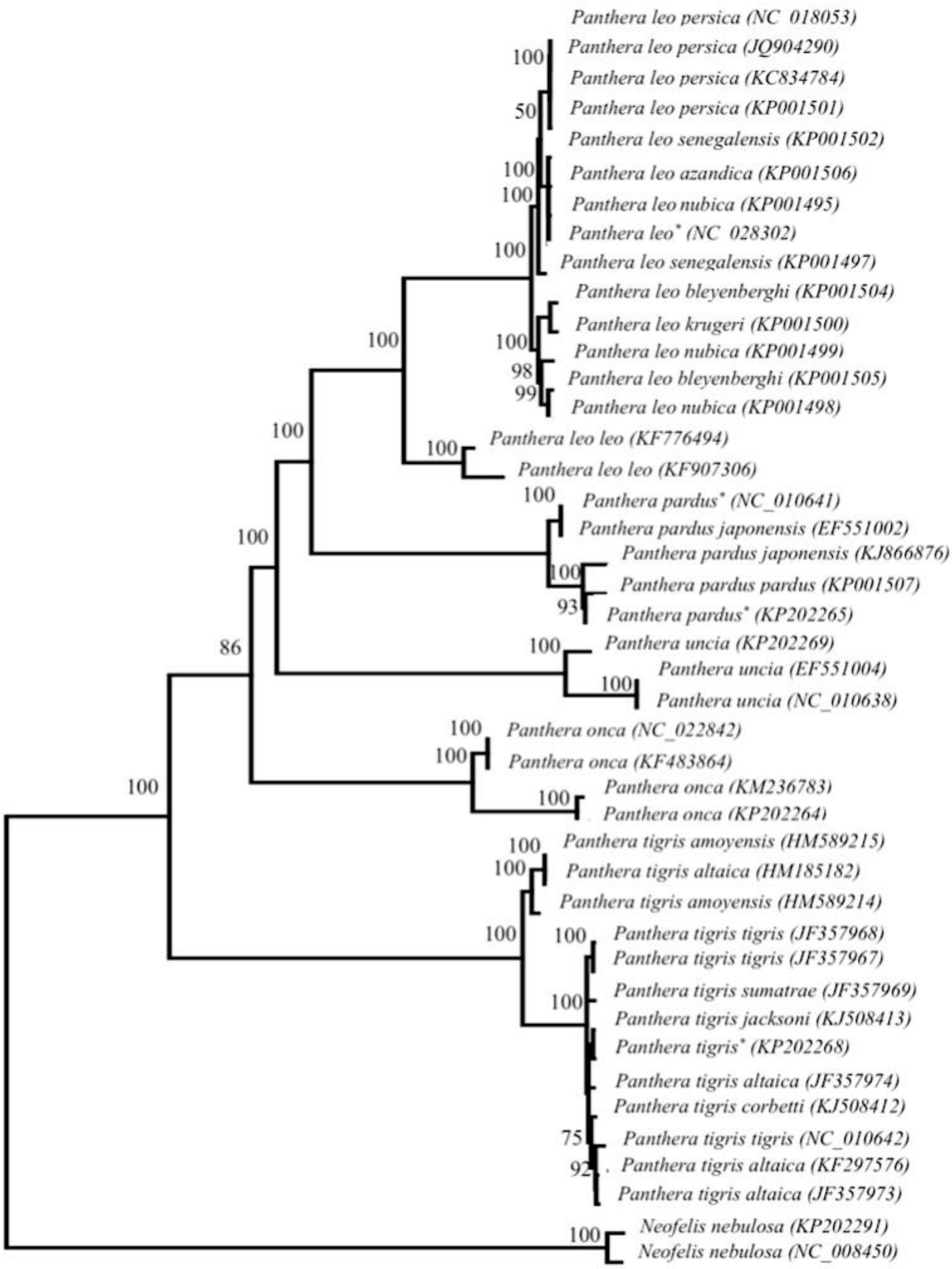

Figure 1: Phylogenetic tree of the Pantherine Taxa. Nodes with less than 50% bootstrap support where not shown. Individuals with an asterisk mark have an unknown status on their subspecies (Source: Das and Upadhyai, 2016).

2.2 Hybridisation

Inter-species hybridisation has recently been recognised as somewhat common in wild animals. The extent of how much it shapes modern genomes is yet to be fully understood (Li *et al.*, 2016). Work from Li *et al* (2016) appears to reveal hybridisation between the ancestral lineages of lions and snow leopards. In their study, a high-resolution test of recently sequenced big cat genomes by Cho *et al* (2013) gave the opportunity to examine the hypothesis that ancient introgression could have caused mitonuclear discordance in the phylogenetic position of snow leopards. The phylogenetic position of snow leopards is an issue that has yet to be conclusively resolved. Testing by Li *et al* found strong signatures of admixture between snow leopard and lion genomes. One of the more prominent signals was from the X Chromosomes, the results of which gave further support to a sister relationship between snow leopards and lions. Their results showed a reduced snow leopard and lion X Chromosome divergence and retention of a snow leopard / lion–related mitochondrion within the snow leopard genome (Li *et al.*, 2016). They hypothesised that this is best explained by a scenario of hybridisation, similar to the recent X Chromosome divergence between chimpanzees (*Pan troglodytes)* and humans (Patterson *et al*., 2006). It is likely that a female hybrid offspring of male ancestors of modern snow leopards and female ancestors of modern lions interbred with the male ancestors of modern snow leopards (Li *et al.*, 2016). Li *et al* estimated that the snow leopard and lion X Chromosome divergence were similar to the mean mitogenomic divergence of ~2.1 MYA.

2.3 Subspecies

Janecka *et al*'s (2017a) work has recently incited further controversy in the snow leopard taxonomic debate. The findings of their study indicated that there could be up to six different sub divisions of genetic clusters of snow leopards for management, which, when put into groups, suggested a possibility of three primary genetic clusters, indicating the potential for three subspecies of snow leopard. The three clusters they described are based on low admixture levels, genetic distinctness, unambiguous population assignment and geographic separation. The variation patterns detected by Janecka *et al* were coherent with barrier effects, resulting from the Gobi Desert isolating the three populations. The three geographic regions suggested to hold the subspecies are the Altai region (Northern), the Himalayan and Tibetan plateau (Central) and Tian Shan, Pamir and trans-Himalaya (Western). The Northern group was named *P. u. irbis*, the central *P. u. unciodes* and the Western was named *P. u. uncia.* Janecka *et al* attempted to improve Polymerase Chain Reaction (PCR) based genotyping by sequencing 49 microsatellites from two captive bred snow leopards using Sanger sequencing. They designed new primers specific to snow leopards from repeat micro satellite motif flanking sequences.

Janecka *et al* (2017a) used scat samples from 21 localities in seven geographic regions, with a total of 70 representative individuals genotyped. When analysed through population assignment tests, their results supported the three-region subspecies with a 0% misassignment rate. A spatially explicit Bayesian model also detected the same three genetic clusters as found in their other tests. As a conclusion from the tests run, the authors stated that, based on the differentiation of nuclear loci that separated samples into three discrete and significant genetic clusters, also occurring in non-overlapping geographic regions, there is strong support for their proposal for three subspecies. Typically, when subspecies delineation recommendations are made, mitochondrial divergence and monophyly are included (Martien *et al.*, 2017). Janecka *et al* (2017a) argue that phylogeographic studies published in the last decade show that this strict criterion may be unreasonable due to mitonuclear discordance. They go on to defend the reasons as to why, during the study, they did not observe any different mtDNA haplotypes in the three subspecies. The snow leopard mitogenome may have undergone a selective sweep as, previous studies have indicated that snow leopard lineage underwent mitochondrial replacement after hybridisation with the lion lineage (Li *et al*., 2016). This may have resulted in low mtDNA variation (Janecka *et al*., (2017a). Lack of mtDNA variation in felids, or historically isolated subspecies, is typical (Uphyrkina *et al.*, 2001). Furthermore, mtDNA has a smaller N_E compared to nuclear DNA, hence ancestral polymorphism would have been lost during the bottleneck ~800ya which was detected with microsatellites (Janecka *et al*., (2017a). Janecka *et al* also defend their results with the support that the lack of clear mtDNA lineages is coherent with prior studies in the Tibetan region exhibiting weaker Pleistocene refugia effects contrasted against those observed in European and North American taxa. Ultimately, sequencing of mitochondrial and nuclear genomes in the three subspecies would provide more insight on the mechanism that added to the studied mitonuclear discordance (Janecka *et al*., 2017a). The overall justification of Janecka *et al*'s (2017a) findings is thorough and well defended with the use of other studies and theories, incorporating the timing of the bottleneck within the Holocene, phylogeographic patterns and population genetic structures.

Janecka *et al*'s (2017a) study and findings have been criticised by Senn, Murray-Dickson, Kitchener, Riordan, and Mallon (2017) on five main points of concern. The first, an incomplete sample set. Senn *et al* identified that there is a serious lack of samples taken from the Nepali Himalaya, the north west Indian Himalaya and between the border of Nepal and the Karakorum mountain range. The proposed boundary of two of the sub species occurs within this gap of sampling, which makes interpretation of the data problematic (Senn *et al*., 2017). The second point of criticism was the lack of mtDNA diversity across the 70 samples. Senn *et al* claimed that the explanations offered by Janecka *et al* were not appropriate or sufficient in justifying the criterion for delamination of taxa. The third topic of concern was the genetic structure within the microsatellite data. The clusters identified do have evidence of admixture. However, Senn *et al*'s interpretation of this is population-level differentiation and, without other lines of evidence, should not be raised above this status. In the fourth point of disagreement, Senn *et al* highlight the debate over whether or not subspecies are a useful taxonomic division, particularly as there is no clear agreement on a definition. They also argue that they do not believe Janecka *et al* meet their own criteria on sub species, due to limited evidence of well-defined geographical boundaries between the putative subspecies and no additional supporting evidence. The fifth and final point of their argument is that the nomenclature for the three proposed subspecies is incorrect. *Irbis* was proposed as a substitute for *uncia*, and is a junior synonym of *P. uncia* since Pocock secured the type locality of *uncia* to the Altai Mountains. For the Himalayan population (Western) the next available correct name is *schneideri*, *uncioides* is a *nomen nudum*; Horsfield (1855) did not designate a type specimen for *Felis uncioides* from Nepal, meaning this population would need a new subspecies name. In conclusion of Senn *et al*'s response to Janecka *et al*, they recommend a further exploration of their justification. They also suggest that additional testing is required against multiple definitions and invite Janecka *et al* to outline their own definition of a species and a subspecies to make their claims under. Senn *et al* also identify the need for IUCN specialist groups to create appropriate guidelines on a taxonomic criterion for conservation purposes, as there is an immense need for such guidelines.

The critique by Senn *et al* (2017) appears to provide a balanced review of Janecka *et al*'s (2017a) findings, with fair questioning into the significance of their outcomes and verdicts.

Janecka *et al* (2017b) replied to Senn *et al* (2017) in an extensive response, opposing what they conceived to be "flawed and inconsistent" arguments. They mirror Senn *et al*'s paper structure by replying to four out of five of their points of critique. They do not respond to the fourth point made by Senn *et al* regarding the debate over whether or not subspecies are a useful taxonomic division. A running point of defence through Janecka *et al*'s paper is the work of Kitchener *et al* (2017) on the revision of Felidae taxonomy. Janecka *et al* claim the evidence accumulated in their study was larger than the data used by Kitchener *et al* to define subspecies for numerous felids including serval (*Leptailurus serval*), the rusty-spotted cat (*Prionailurus rubiginosus*), and the African golden cat (*Caracal aurata*). For several subspecies identified by Kitchener *et al*, biogeographic patterns of sympatric taxa are used to define the subspecies. This is a point that Senn *et al* criticised Janecka *et al* (2017a) for using to create a contributing factor to define the emergence of three subspecies of snow leopards. Additionally, Kitchener *et al* have supported two of the three subspecies. They stated that a northern subspecies could be distinct based on lines of evidence from morphology and biogeography, but a molecular study is required. Janecka *et al* (2017a) provides the third line of evidence with their molecular study, meaning a minimum of two subspecies should be supported.

The main body of Janecka *et al*'s (2017b) response begins by addressing the first point Senn *et al* (2017) raised, which was the issue of what they perceived to be an inadequate sample. Janecka *et al* identify that the sample size in their study is comparable to, and often greater than, those used in Kitchener *et al*'s (2017) study to redefine or validate subspecies for other felid taxa.

Secondly, the lack of mtDNA identified by Senn *et al* (2017) has been critiqued. Janecka *et al* (2017b) state that Senn *et al* have placed a disproportionately large weight on mtDNA when it has several properties that may explain why it was lacking in their study. MtDNA is only inherited through females, it lacks recombination, its effective population size is ¼ of the nuclear genome and is located in the organelle. Janecka *et al* state that each of these points have several complications as reviewed by Toews and Brelsford (2012). This means, in the case of the snow leopard, that the 33 independent nuclear loci provide enough evidence to outweigh data from short mtDNA segments, so it is appropriate to delineate subspecies despite a lack of mtDNA divergence.

Thirdly, Janecka *et al* (2017b) dispute the suggestion that the admixture between the three primary clusters does not mean sperate subspecies, but instead means only population-level structures. Janecka *et al* argue that divergence can happen in the presence of admixture, and that admixture is more common within Felidae than previously thought. Many felid subspecies have in fact experienced admixture, the process of which was reflected upon in the working subspecies definition given by Kitchener *et al* (2017); “gene flow is expected between subspecies”. Janecka *et al* therefore conclude that the patterns of admixture in their study do not disqualify their proposed taxonomy.

Janecka *et al*’s (2017b) penultimate response is in reference to the claims Senn *et al* (2017) make regarding the lack of geographic evidence. Janecka *et al* defend that the Gobi Desert forms a natural barrier, as does the Dzungarian Basin, which is supported by Riordan *et al* (2015) with the model they constructed showing no connectivity and extremely low population estimates across both of these regions. Even with occasional reported snow leopard sightings in these areas, Riordan *et al* state that they are still considered the least suitable habitat types and have the highest barrier to movement. Furthermore, widely accepted snow leopard distribution maps do not show residency in the vast majority of the Gobi Desert or the Dzungarian Basin. This information, when accumulated together, strongly indicates that there are biogeographic barriers in place. These barriers are consistent with at least two of the three proposed snow leopard subspecies. Moreover, the distribution of snow leopard prey species such as argali and blue sheep reveal biogeographic boundaries between Pamir-Karakorum and the Tibetan Plateau/Himalayas.

As a final point, Janecka *et al* (2017b) argue that their proposed taxonomic nomenclature is in fact correct and that the allocation of the names is supported by an argument other authors have already used in past taxonomic arrangements. Horsfield (1855) published a paper detailing that Hodgson had the name *uncioides* attributed, thereby making the name available and taking authorship from Horsfield. *Uncioides* being proclaimed as a *nomen nudum* by Senn *et al* (2017) is reasoned to be a misunderstanding in two ways. Firstly, a syntype series was available at the time of description. Secondly, the International Commission on Zoological Nomenclature (ICZN) only require an explicit fixation of name-bearing types for new species-group names proposed after the year 1999. The name *irbis* was originally proposed by Ehrenberg in 1830 as a replacement for *uncia* whilst he had a specimen from the Altai Mountains, making the name viable for the northern population of snow leopards. *Uncioides* is the earliest available name applied to central Himalayan subspecies and so concludes the suitability of the three names put forward by Janecka *et al* (2017a).

Janecka *et al*'s (2017a) paper, and the exchange that followed with Senn *et al* (2017), needs attention and clarification. This is particularly pertinent given the current debate and confusion surrounding snow leopard conservation; with the downgrade from IUCN, the uncertainty as to where snow leopards belong taxonomically and their relations to possible sister species. This possible discovery of subspecies will undoubtedly need support from corroborating studies before it will be accepted by the wider scientific community and require the IUCN to take action and adjust their assessment. Support of Janecka *et al* (2017b) would most likely come from study into defining the boundaries between possible subspecies and validating population assignments to add a further line of evidence.

Overall, it can be deduced that there is a need to fully sequence the snow leopard genome. Sequencing the genome would indicate whether the genetic diversity of the species is healthy or if there is a low genetic diversity indicating inbreeding, a possible concern following the findings of Janecka *et al* (2017a). Genome sequencing will also help to establish if populations have become isolated, additionally giving an insight into disease resistance and adaptation to environmental changes. To achieve this sequencing, higher quality DNA needs to be obtained. Scat sampling is the most common method of gathering snow leopard DNA but it is often low quality. High quality DNA is best sourced from blood or muscle samples. To achieve these higher quality samples, minimal sampling protocols could be established to include blood sampling when snow leopards are trapped.

3. The status of the snow leopard

3.0 The IUCN

The IUCN, created in 1948, is a membership union comprising of both government and civil society organisations (The IUCN Red List of Threatened Species, n.d.). In 1964, the IUCN Red List of Threatened Species was established. It is now the world leading source on information about the conservation status of plants, animals and fungi species (The IUCN Red List of Threatened Species, n.d.a). The process of assessing species has become a big enterprise involving IUCN Global Species Program staff, IUCN Species Survival Commission experts, partner organisations and partner networks. The IUCN Red List gives information on population sizes, range, habitat and ecology, threats and conservation actions that will aid in creating intelligence for necessary conservation decisions to be made (The IUCN Red List of Threatened Species, n.d.a). The information provided by the IUCN Red List is used by a range of audiences including government agencies, conservation related NGOs, natural resource planners, students and educational organisations. Alongside assessing newly recognised species, the IUCN Red List also performs re-assessments of existing species to assess if their status has changed. Currently the IUCN Red List has a goal to assess 160,000 species by 2020, including assessing every known species of tree (The IUCN Red List of Threatened Species, n.d.b). To achieve this, they hope to increase their number of trained experts and thereby increasing the number of species under assessment (The IUCN Red List of Threatened Species, n.d.b). So far, the data for over 96,000 species is being managed by the IUCN Global Species Programme, with this number set to increase considerably (The IUCN Red List of Threatened Species, n.d.b).

3.1 IUCN classification system

The IUCN Red List uses a multifaceted classification system to decide the status of a species based on the criteria they best meet. Criteria is based on biological indicators that a population has come under threat, demonstrated by changes such as rapid population decline (IUCN Standards and Petitions Subcommittee, 2016). There are five sections of quantitative criteria that a species may fall under which are listed from A to E. These sections are; A) Population size reduction (measured over 10 years or three generations), B) Geographic size range, fragmentation, decline or fluctuations (dependant on area and extent of occupancy), C) Small population size and decline, fragmentation, decline or fluctuations (measured by number of mature individuals), D) Very small or restricted population, E) Quantitative analysis of extinction risk (meaning the probability of extinction in the wild) (IUCN, 2012). If a species meets any of the criteria it can be assigned a category. The IUCN Red List categories are; Extinct, Extinct in the wild, Critically endangered, Endangered, Vulnerable, Near threatened, Least concern, Data deficient and Not evaluated (IUCN, 2012). For a species to be listed under one of these categories, only one of the criteria from A to E needs to be met. The system of classification can be flexible for taxa in which there is little information to aid in their assessment. This is done by including select extraneous factors during the assessment process, which are inference, suspicion and projection (IUCN, 2012). If these factors are used they must be documented as assumptions (IUCN, 2012). The IUCN describe the Red List criteria as "aimed at detecting symptoms of endangerment rather than causes" (IUCN, 2012). This makes the criteria applicable to any process that results in symptoms, such as population decline, small population size, and small geographic distributions (IUCN, 2012).

3.2 Snow leopards IUCN status

On the IUCN Red List, snow leopards are categorised with a status of Vulnerable C1, meaning the observed, estimated or projected decline is expected to be 10% in 10 years or three generations (22.62 years for snow leopards) and their population is above 2,500 but fewer than 10,000 (McCarthy *et al.*, 2017) This status is a downgrade since the last assessment in 2008 which stated snow leopards were Endangered C1. They had been listed as Endangered on the IUCN Red List since 1986 (McCarthy *et al.*, 2017).

The reasoning behind the downgrade is not driven by an identified increase in numbers, but rather a reassessment of the population estimates and how previous assessments had used the algorithm and age for mature adults incorrectly (IUCN Standards and Petitions Subcommittee, 2016). The IUCN Red List acknowledges that there are high levels of uncertainty when it comes to estimates of the snow leopard population (IUCN Standards and Petitions Subcommittee, 2016). They recognise five attempts to compile national estimates to create a global population size. Two of these estimates contain data from prior to 2003 these estimates were 4,080 to 6,500 and 3,290 to 6,390 (McCarthy & Chapron 2003; Snow Leopard Working Secretariat, 2013). The next two estimates are from 2008 to 2010, with the estimations at 4,500 to 7,500 and 4,678 to 8,745 (Jackson, Mishra, McCarthy, & Ale, 2010; McCarthy *et al.*, 2016).The second of these two estimates was created in a mapping workshop in 2008 using a compilation of individual population estimates for prime habitat, covering roughly a third of likely extant range (McCarthy *et al.*, 2016). This estimate was not made available until 2016. The fifth recognised set of estimates come from 2016 and put the estimate at 7,436 to 7,890 (McCarthy & Mallon, 2016). All of these estimates exclude dependant cubs (McCarthy *et al.*, 2017). The IUCN Red List used a model to create outputs for nine different scenarios and selected the most conservative global population estimate available, the result of which puts the number of mature individuals between 2,710 to 3,386 (McCarthy *et al.*, 2017). This number could be doubled if the upper bounds of recent estimates from 2016 were applied (McCarthy *et al.*, 2017).

There is a substantiated lack of information on snow leopard population trends over suitable time scales (McCarthy *et al.*, 2017). It is thought that snow leopard numbers are stable in some areas, increasing in others and decreasing elsewhere, including a suspected recent localized extinction in areas of the former Soviet Union (Koshkarev & Vyrypaev, 2000). The growing threat to snow leopards is recognised by the IUCN Red List to be primarily coming from the growing number of livestock and the threats related to this. Emerging threats such as growing road construction and mineral extraction are also acknowledged (McCarthy *et al.*, 2017). The threat of poaching is thought to have declined since the late 1990's, but with growing retaliation killings and the use of poison and snares it is near impossible to discover the true rate of poaching (Nowell, Li, & Sharma, 2016). The IUCN Red List seem to dismiss work done by Nowell *et al* (2016) on poaching estimated as it is not substantiated by hard evidence but instead employs the knowledge and intelligence from local people in the study (McCarthy *et al.*, 2017). The IUCN Red List go on to say that if the estimated from Nowell et al (2016) are "anywhere near accurate", 2% to 10% of the population could be poached annually (McCarthy *et al.*, 2017). But, using the information given in the IUCN Red List's population estimate, it would in fact be 6% to 17% poached annually, creating confusion over the IUCN's estimate. Clarification over how they produced their rate of 2% to 10% is needed to avoid misunderstandings.

3.3 Justification behind status change

The IUCN Red List recognise the difficulty in estimating snow leopard populations and density, with robust estimates only available for limited portions of the global range (McCarthy *et al.*, 2017). To extrapolate these numbers for larger areas or even range-wide would be unsubstantial, hence the IUCN Red List have avoided doing this. The national population estimates used by the IUCN Red List are considered by them to be the best available at the time of re-assessment (McCarthy *et al.*, 2017). The previous assessment in 2008 was incorrect as the effective population size was used as a surrogate for mature individuals which produces a lower figure, hence the species should have been listed as Vulnerable in 2008 if the IUCN's criteria and classification were followed correctly

(McCarthy *et al.*, 2017). There would need to be evidence of deterioration since 2008 to justify snow leopards being listed as Endangered C1. The downgrade in status constitutes a non-genuine change as the 2008 categorisation was incorrect (McCarthy *et al.*, 2017).

Uptake in conservation measures to reduce and mitigate the threats facing snow leopards has improved the situation of snow leopards since 2008. The IUCN Red List state there is no evidence to support a decline of 20% in such a period as 15.08 years, which would meet the criteria for being listed as Endangered. However, a decline of 10% in 22.62 years is considered plausible in the face of existing and emerging threats.

The Snow Leopard Trust (2017) has strongly opposed the change in status following the decision from the IUCN. They have highlighted the issue that there is not enough supporting evidence alongside the possibility that the assumption made on the age of reproduction/maturity by the IUCN Red List is incorrect (Snow Leopard Trust, 2017). The IUCN Red List set their age of maturity at two to three years old (McCarthy *et al.*, 2017). There are studies that have shown no reproduction in snow leopards at two years old (Blomqvist, 2013). Even within zoos, out of 344 recorded births, only three were from snow leopards two years old (Blomqvist, 2013). The IUCN's assumption suggests that 25% of two-year-old snow leopards are capable of reproduction in the wild. This assumption is unsubstantiated and highly criticised, along with the scientific merit of the other data used in the IUCN Red List's assessment (McCarthy *et al.*, 2017). The Snow Leopard Trust state "less than 2%" of the species range has ever been sampled for abundance using reliable techniques, and even this data is biased toward high-density areas (Snow Leopard Trust, Statement on IUCN Red List Status Change of the Snow Leopard, 2017). This underlines a running problem with the IUCN's approach to creating a population estimate to support their assessment. The data used in their assessment does not appear to have improved existing data sets or use methodologies that are scientifically accurate for estimating populations in their entirety from high density to low density areas of habitat (Snow Leopard Trust, 2017). If the downgrade stands unjustly it could become a serious conservation issue. Conservation organisations and programmes have been set up to help the species, such as the Global Snow Leopard and Ecosystem Program (GSLEP). However, political help has not been pushed which would help to ensure a safer future for snow leopards. Pushing for this help will become harder to justify if it is believed that the snow leopard situation has improved. GSLEP has stated that there will be efforts to create a scientifically robust population estimate before 2023 (Globalsnowleopard.org., n.d.).

3.4 Subspecies

If the work of Janecka *et al* (2017) were to be accepted in the future (see previous chapter), the three subspecies would need assessment. In these preliminary stages, using the IUCN Red Lists own criteria, Janecka *et al* (2017) have given a status to each of the three subspecies. Using population estimates from McCarthy *et al* (2016) in combination with the approximate range of each subspecies, preliminary popoluation estimates for each of the subspecies were formed. For *P. u. uncia* the estimate was 2,669 to 4,199, for *P. u. unciodes* 1,101 to 2,483, and for *P. u. irbis* 831 to 1,736. These estimates would make the latter two subspecies eligible for IUCN Red List criteria Endangered C1.

3.5 EDGE species approach

The EDGE programme is a conservation initiative which focuses on threatened species that represent a significant amount of unique evolutionary history (EDGE of existence, n.d.a) Species chosen to be on the EDGE programme typically have few close relatives, unusual appearances, unusual behaviour and unusual genetic make-up (EDGE of existence, n.d.a).

They thereby represent a unique part of the world’s natural heritage. EDGE scores are made up of a species’ Evolutionary Distinctness (ED) and its conservation status / Global Endangerment (GE) (EDGE of existence, n.d.a). Species with high ED and GE scores get the highest EDGE scores and become a priority species.

Evolutionary distinctness is quantified using a species phylogenetic tree which identifies the number of branches connecting them to other species (EDGE of existence, n.d.) .The fewer branches shared with other species, the higher the ED score .Global endangerment scores are based on the IUCN Red List categories (EDGE of existence, n.d.). Species that are Critically Endangered receive a higher score than less threatened species. EDGE scores are limited to species that have been assessed by IUCN and are not Data Deficient (EDGE of existence, n.d.).

The ED score given to snow leopards is 8.375174 and the GE score is 2, creating a resulting EDGE score of 3.624359, putting them rank 503 out of 581 on the list of mammals (EDGE, 2018). With the previous IUCN Red List classification of Endangered C1 for snow leopards, their score was 4.31 (EDGE, 2011). The current low rank of snow leopards on the EDGE species list means they are not receiving any conservation attention from the EDGE programme.

3.6 Regional population status

Having an accurate regional population status of snow leopards would help to create clarity over the global population size. Many attempts to create regional population estimates are not created using robust scientific methods, instead frequently using anecdotal sources such as local peoples account of snow leopard presence in the area (McCarthy *et al.*, 2017). Several estimates are additionally outdated, particularly in Bhutan which last had a robust estimate created in 1994 (Snow Leopard Trust, 2017).

Table 1 shows the largest regional population is in China at 2000 to 2500, which also hosts the largest habitat range at 1,100,00km^2. From the available data on density, Kyrgyzstan holds the highest density at 2.35 snow leopards per 100km^2. More research is needed to complete density assessments for Afghanistan, Kazakhstan, Mongolia, Russia, Tajikistan and Uzbekistan. More investigation is likewise needed to update the population estimates and range estimates to give a true reflection of the regional status of snow leopards in each of the 12 countries.

Table 1: Estimated regional snow leopard populations

Note: Data from, Dhakal & Thapa, 2013; McCarthy & Chapron, 2003; Muratov, 2004; Snow Leopard Working Secretariat, 2013; Uneland, 2005; Valentová, 2017; WWF-Nepal, 2009.

Country	Population estimate	Range	Density	Population estimate year
Afghanistan	50 - 200	50,000km^2	?	2013
Bhutan	100 - 200	15,000 km^2	1/100 km^2	1994
China	2000 - 2500	1,100,000 km^2	0.3 – 0.4/ 100km^2	1998
India	200 - 600	75,000 km^2	0.5 – 0.9/ 100km^2	2016
Kazakhstan	100 – 200	50,000 km^2	?	2002
Kyrgyzstan	150 - 200	105,000 km^2	2.35/100km^2	2005
Mongolia	500 - 1000	101,000 km^2	?	2000

Nepal	300 - 500	27,000 km^2	0.1-10 / 100km^2	2009
Pakistan	200 - 420	80,000 km^2	0.4 / 100km^2	2003
Russia	70 - 90	12,000 km^2	?	2012
Tajikistan	200 - 220	100,000 km^2	?	2004
Uzbekistan	20 - 50	10,000 km^2	?	2003

4. Threats

4.0 Prey base depletion

Prey base depletion is considered to be one of the biggest threats to snow leopards (Snow Leopard Network, 2014). The abundance and dispersal of prey populations directly affects snow leopard populations (Snow Leopard Network, 2014). Wild prey also helps to drive and maintain ecosystem functions in their montane habitat. Prey population dispersal has even been used in some studies to identify areas that are not used by prey and therefore not likely to be used by snow leopards (McCarthy, Fuller, & Munkhtsog, 2005). On the IUCN Red List, bharal and Siberian ibex are currently listed as Near Threatened, both with unknown population trends (Harris, 2014; Reading, & Shank, 2008). Markhor are Near Threatened with an increasing population trend and Mouflon are Vulnerable with a decreasing population trend (Michel & Rosen Michel, 2015; Valdez, 2008). Prey base depletion is occurring from the accumulative impacts of poaching, disease and competition with livestock (Lovari & Mishra, 2016). The loss of prey populations in turn reduces the carrying capacity for snow leopards, forcing predation of other species, including domestic animals and livestock (Lovari & Mishra, 2016).

4.0.1 Competition with livestock

Prey competition with livestock is a growing threat to snow leopards and is resultant from pervasive pastoralism and overgrazing already sparse, low productivity montane habitats that prey occupy (Lovari & Mishra, 2016). Herds of livestock are accompanied by humans and occasionally dogs, this deters predators but also excludes prey from that grazing area (Jackson, R. M., Ahlborn, Gurung, & Ale, 1996). Many studies have explored and attempted to demonstrate the conflict between traditional pastoralism and conservation (Bagchi, Mishra & Bhatnagar, 2004; Mishra, Van Wieren, Ketner, Heitkonig & Prins, 2004; Shrestha and Wegge, 2008; Suryawanshi, Bhatnagar & Mishra, 2009). Mishra, Van Wieren, Ketner, Heitkonig and Prins (2004) have even suggested that results from their theoretical analysis suggest that up to four species of wild herbivore may have become extinct in the last 3 millennia due to competitive exclusion caused by livestock. It has become a global concern that as the human population grows, the reliance and need for livestock grows alongside it. This is most prevalent in India which hosts the world's largest livestock population at over 520 million (FAO, 2002; National Diary Development Board, 2017). More than 3 million people in India are living in wildlife reserves, which cover less than 5% of the country (Mishra *et al.*, 2004). Despite this, even within these limited Protected Areas, wildlife and plant life is not free of the impact of humans and livestock (Mishra *et al.*, 2004). The Spiti Valley, which contains the Kibber wildlife sanctuary, is reported to have more than four-fifths of its rangelands overstocked (Mishra *et al.*, 2001). Mature female livestock has been identified to show lower performance in higher stocked density areas than in lower stocked density areas (Mishra *et al.*, 2001). This is presumed to be due to density dependant reduction in available resources (Mishra *et al.*, 2004). Livestock populations would not remain healthy on the natural resources available in these areas, so supplementary feeding is used (Mishra *et al.*, 2004). Mishra *et al* (2004) conducted a study on the competition between livestock and bharal in the Indian Trans-Himalaya. They aimed to establish if livestock presence excludes wild herbivores from using the same area, and if dietary overlap can convert into competition for food. By doing this they hoped to address criticisms of other similar studies which were undermined for not fully demonstrating resource competition, and instead just demonstrating patterns of resource use and partitioning among sympatric species. Prins, 2000). The results of their study supported the hypothesis that the bharal population performance decreases when livestock density increases. They suggest the overlap in diets between bharal and livestock has caused a decline in forage availability for bharal, which constitutes competition between the two. Another study on the changes in diet in bharal due to resource limitation linked this to reducing population performance, fecundity and young survival rate.

4.0.2 Disease in prey

Another contributing factor to prey base depletion is disease. In the cold arid environments that snow leopard prey inhabits, the microbial abundance in soil is negatively correlated to precipitation (Blankinship, Niklaus, & Hungate, 2011). This means a lower microbial encounter rate which has contributed to lower immune indices than other members of the same taxonomic families living in tropical or temperate regions (Ostrowski & Gilbert, 2016). Immune systems of bharal were identified to have weak responses to disease, likely due to protein malnutrition from limited grazing as a result of competition with livestock (Ostrowski & Gilbert, 2016). Bharal and Siberian ibex have also suffered from sarcoptic mange which is caused by mites (Dagleish, Ali, Powell, Butz, & Woodford, 2007). It is highly contagious and results in eventual hair loss and legions on the skin (Dagleish *et al.*, 2007). It caused hundreds of fatalities in a particular outbreak in northern Pakistan (Ostrowski & Gilbert, 2016).

Another prey species effected by disease is markhor. Markhor have seen population loss from Mycoplasmosis which causes respiratory problems that are often fatal (Ostrowski *et al*., 2011). In Tajikistan in 2010, an outbreak of Mycoplasmosis resulted in the death of 64 markhor (Ostrowski *et al*., 2011). A molecular study discovered a closely related respiratory disease found in domestic goats to be present in the outbreak, with possible links as the causative agent (Ostrowski *et al*., 2011).

The origin of the infection with these diseases is near impossible to prove but it is often believed to have been passed on by livestock (Dagleish *et al*., 2007). Livestock can easily outcompete wild ungulates with the aid of supplementary feeding and veterinary practices (Ostrowski & Gilbert, 2016). The links demonstrated between disease spread, livestock presence and the weakened immune systems of wild animals reiterates the threat livestock presence poses to the prey of snow leopards.

4.0.3 Hunting of ungulates

Both legal and illegal hunting of wild ungulates within snow leopard range currently takes place, adding to the depletion of prey populations (McCarthy & Chapron, 2003). Local residents are reported to hunt for subsistence and trophies (Aiyadurai, Singh, & Milner-Gulland, 2010). The increased demanded for subsistence can be attributed to livestock population decreases in central Asia, following the breakup of the Soviet Union (Thiele, 2003). Some wild game meat can be valued for medicinal purposes or as traditional food for special events (McCarthy & Chapron, 2003). There is minimal provision for legal hunting available to local residents, disenfranchising them and making compliance with laws preventing hunting minimal (Nawaz, Ud Din, Shah, & Khan, 2016). For this reason, legal hunting is likely outweighed by illegal hunting, leading to declines in snow leopard prey populations.

Many states throughout snow leopard range acknowledge trophy hunting as a means to bring in income to the government through private and state hunting reserves (Nawaz *et al.*, 2016). Trophy hunting can become a part of conservation. It can constitute community-based conservation if the trophy hunting is sustainably managed and provides economic incentives for local people (Nawaz *et al.*, 2016). Attempts to control legal hunting to ensure population stability and growth are undermined by illegal hunting and poor management, creating difficulty in setting up successful long-term trophy hunting programmes for conservation (Nawaz *et al.*, 2016). There have been cases of social instability and genetic problems in prey populations caused by poor management (Coltman *et al.*, 2003; Lindsey, Frank, Alexander, Mathieson, & Romanach, 2007). Trophy hunting also carries with it controversy and can create conflict. The case of Cecil the lion from Hwange National Park is one example of the social disruption that can be caused by participating in trophy hunting (Howard, 2015; Snow Leopard Network, 2014).

4.1 Retribution killing

Retribution killing is the act of eradicating an animal, often a carnivore, that has predated upon, or is likely to predate on, livestock or crops (Nyhus, 2016). Killing in retribution has led to the extinction of the Falkland Island wolf (*Dusicyon australis*) and the marsupial wolf (*Thylacinus cynocephalus*) (Burbidge & Woinarski, 2016; Sillero-Zubiri, 2015) It is also valued as the second biggest threat to snow leopards (Snow Leopard Network, 2014). As herders encroach further into snow leopard habitat and prey populations decrease, the rate of livestock loss to snow leopards increases. Although snow leopards are not always guilty of livestock predation, as wolves (*Canis lupus*) are often to blame, snow leopards are on occasion killed pre-emptively as a form of retribution (Jackson *et al*., 1996; Oli, Taylor & Rogers, 1993; Shehzad *et al*, 2012). This has in one case gone to the extent of herders in India entering a snow leopard den to kill two young cubs (Theile, 2003). The exact number of livestock lost to snow leopards is not known, nor is the number of snow leopards killed in retribution as most people will not admit to involvement in such a practice (Snow Leopard Network, 2014). Reports did attempt to estimate that a minimum of 16 snow leopards were killed in northern India between 1996 and 2002, with one village having killed eight of the 16 (Theile, 2003).

Studies on snow leopard diet composition have revealed that typically 15% – 30% of a snow leopards' diet can consist of livestock, but other estimates have ranged from 0% - 70% (Mallon *et al*., 2016). Scat analysis can provide evidence of snow leopard consumption of livestock, but it cannot rule out the possibility of the ingestion coming from a scavenged kill that the snow leopard was not responsible for (Mallon *et al*., 2016). Furthermore, research on the accuracy of scat analysis revealed that up to 57% of snow leopard scats may be misidentified and in fact belong to foxes or dogs (Johansson *et al*., 2015).

The behaviour and hunting preference of snow leopards is a contributing factor to this issue. Herders in Afghanistan have reported, when interviewed, that snow leopards are more likely to enter corrals holding livestock than wolves (Jackson *et al*., 1996; Snow Leopard Network, 2014; Theile, 2003). Often in these instances the snow leopard will kill every animal in the corral (Snow Leopard Network, 2014). This intrusion and large loss of livestock will often result in a retribution killing, with very few cases of the snow leopard being allowed to escape (Jackson & Wangchuk, 2004). The poor construction of corrals and ineffective guarding practices creates opportunity for snow leopard predation (Jackson & Wangchuk, 2004).

In central Asia, snow leopards are perceived to be one of the biggest killers of livestock, receiving blame for up to 63% of livestock mortality (Shehzad, 2012). Often pugmarks near the carcass are the only evidence of this (Shehzad, 2012). There is often no consideration that they may only be there after scavenging the kill or having passed by previously.

The loss of livestock has big ramifications for herders and their family, particularly in climates already struggling with poverty. This can from the perspective of herders, make retribution killings an understandable and necessary practice. Attempts to deter or reduce the conflict with snow leopards are usually non-existent, as the anger and low tolerance towards snow leopards is best felt as resolved with execution (Snow Leopard Network, 2014).

4.2 Illegal hunting

When discussing hunting, it is important to define the difference between hunting and poaching. Poaching is hunting without the permission of the land owner (The Editors of Encyclopaedia Britannica, 2019). In the case of snow leopards, much of the area they inhabit is not a Protected Area and so killing them would not constitute poaching. However, snow leopards are a protected species and, as such, it is illegal to hunt them wherever they are located (Cites, n.d.). In this thesis the term illegal hunting will be used as it is not always documented if the hunt will have constituted poaching. This clarification is important to make as many papers use the term poaching without stating where the hunting took place.

Snow leopards may be hunted for trade or to protect subsistence hunting of ungulates (Theile, 2003). Many people may depend on wild ungulates to supplement their diet, especially if they are losing livestock to predators (Theile, 2003). Therefore, hunters can decide to hunt snow leopards in the area to try and protect ungulate populations (Snow Leopard Network, 2014). This leaves more ungulates for them to hunt and reduces competition with snow leopards.

The hunting of snow leopards has been a traditional practice, with the skins used to demonstrate status and be offered as valuable gifts (Theile, 2003). Hunters of snow leopards are well respected and have been for a long time by many societies, encouraging the practice to continue (Theile, 2003).

4.3 Illegal trade

Trade in illegally hunted snow leopards holds a significant threat and has been a concern since 1975 (Nowell, Li, Paltsyn, & Sharma, 2016). Pelts are predominantly the most traded product, but claws, teeth, bones and meat also have a demand in the trade ring (Maheshwari and Meibom, 2016).

Snow leopards are legally protected under Appendix I of Conservation on International Trade in Endangered Species of Wild Flora and Fauna (CITES) and have been since 1975 (Nowell, Li, Paltsyn, & Sharma, 2016). The species was included on the appendix following reports of the number of skins being traded. It is thought that at the beginning of the twentieth century 1000 snow leopard skins were traded a year for two decades from central Asia and Russia (Maheshwari and Meibom, 2016). Appendix I of CITES specifies that trade in a listed species is illegal, making commercial trade prohibited (CITES, n.d.). All of the counties that snow leopards inhabit follow this listing and have made hunting and trade illegal (Snow Leopard Network, 2014). The only legally allowed trade is for captive bred individuals being transferred between zoos (Nowell *et al.*, 2016).

Historically, snow leopard pelts were desired as an indicator of wealth and status, being used to make garments such as coats and religious dresses (Li *et al*., 2013; Theile, 2003). The claws, teeth and sexual organs of snow leopards were used in medicinal and shamanistic practices (Bensky & Gamble, 1993; Theile, 2003). Skulls were also used as a part of ritual ceremonies (Theile, 2003).

Anecdotal reports from numerous states have suggested that they have seen an increase in the demand for snow leopard bones (Theile, 2003). The increase is speculated to be a result of stricter enforcement of trade controls for tigers, making other Felidae a target as a substitute. China proposed to lift their ban on the use of tiger parts for scientific, medicinal and cultural purposes (WWF, 2018). This was followed by an outcry of protests from environmental groups and the lift of the ban has since been postponed (BBC, 2018). Were this ban to be lifted, the impact on snow leopards is unknown. However, it is a concern for tigers which are currently listed on the IUCN Red List as Endangered C1 (Goodrich, 2015).

In 2016, Nowell, Li, Paltsyn and Sharma published a TRAFFIC report with estimations on the minimum number of illegal snow leopard trades taking place in each of the twelve range countries. TRAFFIC stands for Trade Records Analysis of Flora and Fauna in Commerce and is the leading NGO in global trade of flora and fauna (TRAFFIC n.d.). TRAFFIC is working to make the trade in wild plants and animals no longer a threat to conservation (TRAFFIC n.d.). They aim to create a world in which trade is managed sustainably, maintains healthy populations and makes a contribution towards motivating commitment to conservation of species and habitats (TRAFFIC n.d.).

The report published by Nowell *et al* had varying levels of consistency in data, some countries produced little to no data to contribute to the report. With the data that was collected, estimations put the annual number of snow leopards poached since 2008 to be 221 – 450, with 55% of snow leopards killed in retribution for livestock loss, 21% for trade and 18% by non-targeted methods like snare traps. Over 90% of the annual poaching estimate is thought to be made up by five of the range countries; China with 103 - 236, Mongolia with 34 - 53, Pakistan with 23 - 53, India with 21 – 45 and Tajikistan with 20 -25 (see Figure 2) (Nowell *et al.*, 2016). Skins are the primary product in trade, with 78% of the motivation for purchasing skins to have them for display and taxidermy (Nowell *et al.*, 2016). The skins generally cost thousands of US dollars and are still seen as a possession to indicate wealth and status (Theile, 2003). The report also suggested that the detection rate for poaching is likely less than 38%, suggesting the number of poached snow leopards could be substantially higher. The clandestine nature of the operation has made detection of illegal trade harder (Nowell *et al.*, 2016).

Globally, the worst offending countries with the highest number of snow leopards being traded are, China, Afghanistan and Russia (Nowell *et al.*, 2016). Between 2003 and 2006 a record was kept of the minimum number of snow leopard parts seized by authorities (Nowell *et al*, 2016). China had the highest with 309, second was Afghanistan with 137, Russia third with 118 (Nowell *et al.*, 2016).

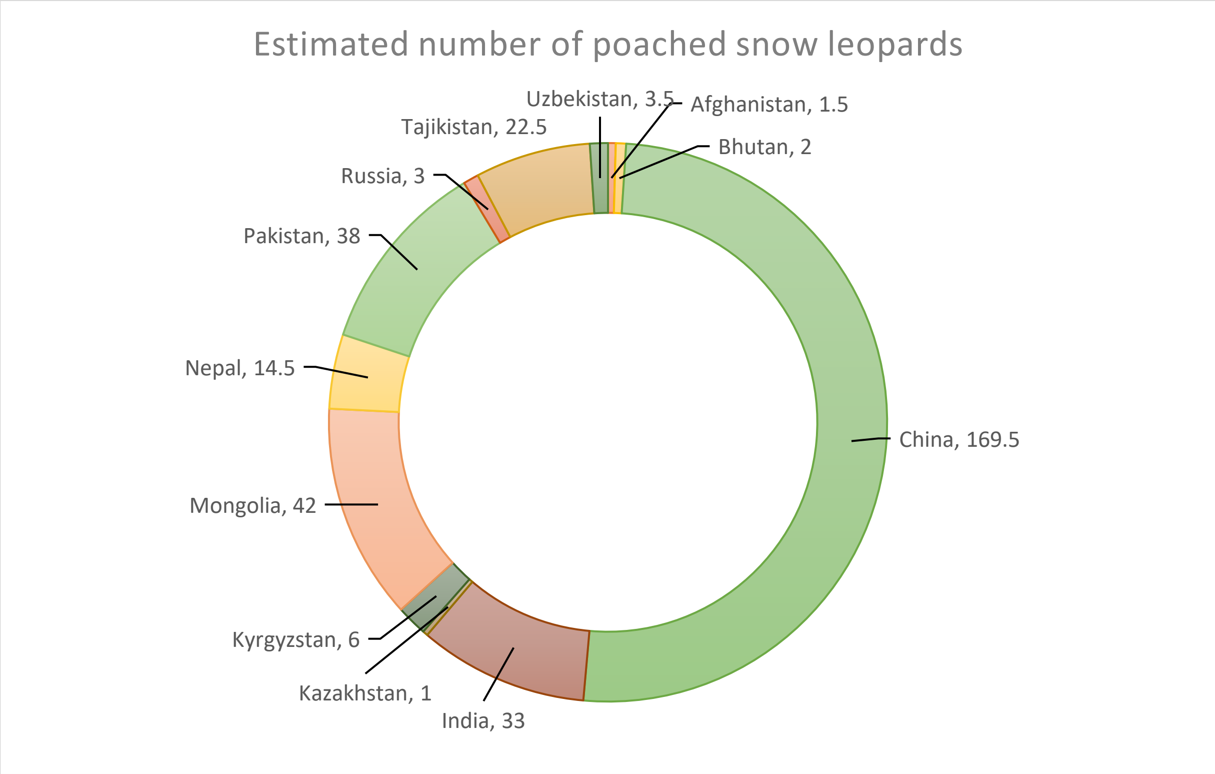

Figure 2: Estimated number of snow leopards poached as per the work of Nowell, Li, Paltsyn & Sharma (2016) annually across the range countries (Source: Nowell, Li, Paltsyn and Sharma, 2016).

4.4 Disease in snow leopards

Studies on disease in wild snow leopards have not been published. Due to this, the degree of impact that diseases could be having, and the controls needed to mitigate any risks are currently unknown (Ostrowski & Gilbert, 2016). Any specimens of wild snow leopards that have died are typically not found or reported soon enough for forensic investigation to be insightful (Ostrowski & Gilbert, 2016). Furthermore, if any evidence of disease were found in corpses, the lack of baseline evidence about the health of wild snow leopards would make an estimated projection of the impact of the disease on the local population impossible to create with certainty (WWF, 2015).The introduction of minimal sampling protocols when researchers encounter wild snow leopards would help to create a baseline (Ostrowski &

Gilbert, 2016). Despite the lack of study on disease directly affecting wild snow leopards, there is discussion over the presence of diseases in the regions that snow leopards inhabit. The use of study on captive snow leopards regarding vulnerability to disease can be used to establish if diseases found in the same range areas could be having an impact (WWF, 2015).

Canine distemper virus (CDV) and Tuberculosis have been identified as potential threats to snow leopards as they have been seen to greatly affect other members of *Panthera* (Silinski, Robert & Walzer, 2003). CDV is a contagious viral disease that effects the systems of the body, including the respiratory and gastrointestinal systems (Green, 2013).Snow leopards have been found to be susceptible to CDV, and it is possible for CDV to survive at lower temperatures for extended periods, making it viable for wild snow leopards to become infected (Fix, Riordan, Hill, Gill, & Evans, 1989). Tuberculosis is an infectious disease that primarily effects the respiratory system, particularly the lungs (Helman, Russell, Jenny, Miller, & Payeur, 1998). The disease can be passed on from an infected carcass (Helman *et al.,* 1998). Prey species need assessment to establish if the mycobacteria linked to tuberculosis are present and presenting a risk to carnivorous species in the same habitat, including snow leopards (Ostrowski & Gilbert, 2016).

Anthrax has been reported to be present in some states of snow leopard range and is suspected to have been present in the corpse of one radio collared snow leopard (Ostrowski & Gilbert, 2016). The recovered snow leopard specimen was found in Mongolia with marked neck swellings, which are an indicator of anthrax in felids (Snow Leopard Trust, 2011). A test to confirm the presence of Anthrax was not carried out and it is believed the disease is not endemic to the region (Odontsetseg *et al.*, 2007). Study to confirm this claim should be carried out to begin gathering a picture on the extent this disease may be impacting snow leopards (Ostrowski & Gilbert, 2016; Snow Leopard Trust, 2011).

Studies on captive snow leopards have revealed that they are prone to a number of diseases (Ostrowski & Gilbert, 2016). Many of these diseases may not be present in their wild habitat and so wild snow leopards may never become infected. However, these captive based studies do provide an insight into the susceptibility of snow leopards to disease as well as the consequences of disease on the species (Ostrowski & Gilbert, 2016).

4.5 Traps and poison

Often used as a form of retaliation killing, traps and poison are a threat to snow leopards. Farmers may lay out snares or poison carcasses that a snow leopard may scavenge as retaliation or in prevention of livestock loss (Snow Leopard Network, 2014). Some reports say the use of traps and poison is aimed at other predators such as wolves, making snow leopards an unintentional victim of low specificity trapping and poisoning campaigns (Nowell *et al*, 2016). The TRAFFIC report by Nowell *et al* (2016) found from their assessment of the range countries, that trappings were the most common method of killing snow leopards alongside shooting. Nowell *et al* also found that poison was the second most commonly used method. Not all of the range countries had data that could be used in the report by Nowell *et al* due to low or no participation by those countries in the survey created to collect information. Unwillingness to participate makes assessing the extent of trap and poison use across all of the range countries through surveys difficult. Hence the number of snow leopard losses resulting from poison and traps is currently unknown.

4.6 Feral dogs

Populations of feral domestic dogs are becoming an increasing threat to both snow leopards and their prey (Doherty *et al.,* 2017). Domestic dogs have been extensively documented as not only a nuisance to wildlife, but in direct contribution to population decreases, and even extinction in many cases (Doherty *et al.,* 2017). Dogs often become an intraguild predator, meaning they kill potential competitor species. They also disturb the ecosystem, add competition between predators for prey, transmit disease and interbreed with closely related species (Fix *et al.,* 1989; Vanak & Gompper, 2009). Roughly 200 species are said to be threatened by feral and free ranging dogs, with the IUCN Red List identifying 30 of those critically endangered, 71 endangered and 87 vulnerable (Doherty *et al.,* 2017). The worst affected regions are Asia, the Caribbean, Central and South America and parts of Oceania (Doherty *et al.,* 2017).

Dogs are known to kill ungulates that snow leopards predate upon, contributing to the threat of prey population reduction (Namgail, Fox, & Bhatnagar, 2007). Footage has been emerging online of packs of dogs chasing and attacking snow leopards, likely impacting stress levels and energy stores as the they are forced to run from the dogs (Fiechter, 2016). It is currently unknown if the dogs may be spreading diseases to snow leopards or their prey, or if carcasses they leave behind that may be infected are being scavenged by snow leopards. However, disease spread from feral dogs to wildlife has been seen in several other cases (Bergman, Breck, & Bender, 2009; Hughes & Macdonald, 2013).The presence of these dogs is likely to deter wildlife and disrupt foraging and roaming patterns of wild ungulates, potentially also disturbing attempts to recover populations.

4.7 Habitat loss

4.7.1 Fragmentation and degradation

The habitat of snow leopards has been degraded and fragmented, damaging already fragile and vulnerable montane ecosystems. The most common source of habitat degradation comes from livestock overgrazing (Snow Leopard Network, 2014). Unsustainable pastoral practices see herds of livestock allowed to graze areas until the land is sparse of vegetation (Wang & Batkhishig, 2014). This practice leaves the land exposed and can increase soil erosion from precipitation, some areas could even see desertification occur following overgrazing (Kairis Karavitis, Salvati, Kounalaki, & Kosmas, 2015; Wang & Batkhishig, 2014). Some species of livestock will graze vegetation down to the ground, whilst others may rip out the roots, depleting root stocks and the capacity for regeneration (Borucke *et al.*, 2013). Secondary species such as weeds can then take their place. Secondary plant species often have a lower nutritional value or are unpalatable, contributing to the issues facing snow leopard prey species with reduced performance from protein malnutrition (Snow Leopard Network, 2014).

The construction of roads and spread of urbanization has brought with it, large-scale resource extraction and mining (Zahler, 2016). Roads and fences cause disruption to natural wild animal movements and migration. Some range state borders have been fenced for national security, a problem for snow leopards with vast home ranges that may cross over borders (Zahler, 2016). Estimates have suggested that up to a third of snow leopards' potential range is situated within less than 50km to 100km of the international borders of the 12 range countries (Zahler, 2016). This impediment of the natural movement of snow leopards and their prey contributes to fragmentation of sub-populations and a loss of genetic connectivity (Zahler, 2016).

Energy and mining developments have brought the risk of significant threats from the associated cascade of direct impacts that human populations bring with them (Heiner, Oakleak, Davaa, Yunden, & Kiesecker, 2016). These are things such as illegal hunting and reductions in habitat available for livestock and prey grazing, increasing competition between the two (Heiner *et al.,* 2016). Energy and mining developments are projected to expand in the Mongolian Altai Mountains, north and south of the Tien Shan mountains in Western China and in Southern and Western Tibet (Heiner *et al.,* 2016). The immediate impact of new infrastructure will likely avoid the core of snow leopard habitat, but the impacts from additional human populations in the area will be expected to increase snow leopard mortality and reduce metapopulation connectivity (Heiner *et al.,* 2016).

4.7.2 *Cordyceps* harvesting

Cordyceps sinensis is a fungus harvested for its medicinal purposes and can be found across snow leopard range at altitudes of 3000m to 5200m, which largely coincides with the altitude snow leopards typically occupy (Farrington, 2016). It has a high value following an increased demand seen in recent years which has been compared to a gold rush (Alfred, 2016). *Cordyceps* sell on average for $8000 per kilogram, making harvesting this product a lucrative business among low earning local households (Snow Leopard Network, 2014). The harvesting process draws in a large number of people attempting to dig up *cordyceps,* which naturally presents its own challenges to the snow leopard environment (Farrington, 2016). The presence of these people disturbs local wildlife and physical damage is caused by the digging. Blue sheep with lambs have been noted to seek refuge away from *cordyceps* meadows which is prime grazing habitat for them (Farrington, 2016). The damage caused by harvesting reduces the quality of grazing for livestock and snow leopard prey species. Not only does the harvesting itself cause long lasting damage, but both the rubbish and defaecation left behind by people has contaminated water sources (Thukten, 2014). Some herders have claimed that the harvest might benefit the habitat as they are now able to keep less livestock, with some even moving into nearby towns instead of occupying their pasture (Snow Leopard Network, 2014). This is claimed to be as a result of the supported income they are receiving from sale of *cordyceps (*Farrington, 2016). However, with some of these former herders, retaining their pasture rights and leasing their land to others, the possible benefits of decreased disturbance and reduced competition with livestock is lost (Farrington, 2016). Attempts were made to control the harvest with county governments in Tibet enforcing a licencing system, but the value of the product has brought in large numbers of outsiders and the harvest is largely unlicensed and unregulated (Winkler, 2009). Recent reports are now suggesting that the number of *cordyceps* harvested is beginning to decrease and the sustainability of the harvest is being questioned (Winkler, 2009). If the limited availability of *cordyceps* continues to advance, former herders who have become harvesters may be forced to return to herding, creating yet more disturbance in snow leopard range.

4.8 Climate change

Climate change is an emerging threat that poses a risk to snow leopards as a result of the impact on their habitat. The current rate of global temperature increase is unprecedented at 0.12℃ per decade between 1951 and 2012 (WMO, 2017). Global biodiversity is expected to see declines as the global temperature increases. Samples from snow leopard habitat range revealed a higher rate temperature increase at 0.16℃ to 0.90℃ per decade (Farrington and Li, 2016). It is thought that the threat of extinction may as a result of climate change be raised for 20% to 30% of all species (Farrington and Li, 2016; Snow Leopard Network, 2014). Lacking baseline evidence of climate change effecting specific sites and individual species makes predicting fine scale effects difficult (Snow Leopard Network, 2014).

Within snow leopard habitat, the implications of rising temperatures are vast for glaciers, permafrost, precipitation and extreme weathers (Farrington and Li, 2016). Changes in permafrost affects the water table which can cause problems with plant productivity and water holes used for drinking. These impacts may reduce the carrying capacity for wild animals and livestock.

Climate change is expected to cause an upward treeline shift, reducing habitat by 30% (Farrington and Li, 2016; Forrest *et al.*, 2012). A study by Farrington and Li (2016) found, from using an extensive computer model, that the number of habitat patches in snow leopard range will increase by 22%, creating limitations to dispersal. Limited dispersal reduces population interactions, creating problems in the maintenance of genetic diversity (Farrington and Li, 2016). The use of computer models in conservation plans may be useful in creating adaptive management frameworks.

Recent camera trap footage from China has showed a snow leopard and common leopard (*Panthera pardus*) occupying the same area (Snow Leopard Trust, 2018). It is unknown whether this has always been the case historically or if it is a new occurrence. These two species may be using temporal or special niches to co-exist, or the two species could be competing, which may be escalated by habitat changes resulting from climate change (Snow Leopard Trust, 2018). Lovari, Ventimiglia and Minder (2013) theorise that the effects of climate change will create further overlaps in competition for habitat and prey between common leopards and snow leopards. Climate change has elevated the upper forest limit, meaning the common leopard’s range is growing, which may consequentially reduce snow leopard typical habitat range between the forest and higher altitudes (Lovari *et al.*, 2013).

A potential indicator in how the change in habitat caused by climate change will alter snow leopard’s habitat use, is where wild prey populations remain. One study that provides some insight into this was done by Aryal *et al* (2016) in which they used a species distribution model to analyse current and future distributions of snow leopards and blue sheep. Aryal *et al* (2016) predict that the distribution of snow leopards will reduce by 21.57% by 2050 and blue sheep distribution will reduce by 3.80%. This study illustrates that climate change may alter predator-prey spatial interaction, inducing a lower level of overlap and a higher degree of mismatch in snow leopard and blue sheep niches (Aryal *et al.*, 2016). This suggests an increase for snow leopards in the energy cost required to find preferred prey species, which is problematic for snow leopards as they already face energetic constraints due to the limited dietary resources in their montane habitat (Aryal *et al.*, 2016). This could result in higher rates of snow leopard predation in livestock if prey species are more frequently unavailable. If snow leopards are unable to compete or remain in the same areas as their wild prey, predation on livestock is again likely to see increases, creating an issue for human-wildlife conflict (Aryal *et al*., 2016). Another study also suggests that the shift in treeline causes blue sheep to move to lower altitudes to forage, which often leads them raiding crops being grown at these lower elevations (Aryal, Brunton, & Raubenheimer, 2014). The combination of crop raiding and livestock predation will severely impact people's livelihoods and likely cause an increasingly negative attitude towards snow leopards and prey, possibly causing an increase in retaliatory killings of both snow leopards and ungulates (Aryal *et al.*, 2014).

Climate change could exacerbate existing threats from infrastructure as habitats are altered, making dispersion and connectivity between subpopulations of snow leopards and prey more difficult (Farrington and Li, 2016). What habitat is left and remains resilient to the impacts of climate change should be protected. As snow leopard habitat fragments, the pervasiveness of threats such as livestock overgrazing, retaliatory killing and cordyceps harvesting will likely intensify, making protection of habitat a priority (Forest *et al.*, 2012).

4.9 Socio-economic drivers

Xu and Compton (2008) reviewed the social and economic drivers of illegal trade in China. They found that attempts to reduce poverty, increase income and add diversity to livelihoods among rural communities had a low impact on reducing participation in illegal hunting and poaching. Xu and Compton also found that trade in the area was primarily being driven by affluent people with more disposable income. Political unrest and disturbances have been linked to creating increases in illegal trade, such as that demonstrated by the increase in snow leopards trade in the 1990's following the breakup of the former Soviet Union (Snow Leopard Network, 2014; Xu and Crompton, 2008).

More than 50% of the human population in the 12 countries snow leopards inhabit rely on agropastoralism for income, with more than 40% of people below the poverty line (Nyhus *et al.,* 2016). This contributes to the perceived need for retribution killings to protect livestock and crops as individual's livelihood is so reliant on successful agropastoralism (Snow Leopard Network, 2014). This fragile source of income and subsistence can contribute to negative attitudes towards snow leopards and their prey, often resulting in human-wildlife conflict (Nyhus *et al.*, 2016).

4.10 Protected Areas

Outside of socio-economic factors, another threat comes from the size of Protected Areas. Roughly 40% of Protected Areas are smaller than the suspected home range of a single adult male snow leopard, thereby too small to hold a breeding pair (Johansonn *et al.,* 2016). Protected Areas should provide safety to the species and be a valuable resource in conservation, but this is often not the case. There are challenges in monitoring the rugged isolated terrain of snow leopard range, and law enforcement is often inadequate (Thiele, 2003). For many states, conservation is a low priority in the face of economic and political issues (Nyhus *et al.,* 2016). As discussed, there is also the issue surrounding permits for trophy hunting being given, and the often-unsustainable management of this practice.

4. 11 Intrinsic threats

The concept of intrinsic threats is primarily based around how an animal's intrinsic factors may make their populations less resilient to threats and contribute to their vulnerability. A large number of these such factors can be grouped under what is known as an animal's life history. Life history refers to the sequence of stages in an animal's life that relate to survival and reproduction, occurring from birth to death (Charnov, 1993). This includes size at birth, age of maturity, litter size, length of the inter birth interval and maximum life span (Charnov, 1993). Studies of life history on wild snow leopards are difficult to complete due to their elusive nature and the difficulty tracking them, so little is known about their life history. Studies on captive snow leopard's life history parameters may be done but it is not known how representative these parameters may be of those in the wild (McCarthy & Chapron, 2003). From what we do know of wild snow leopards, they typically have a small litter and invest a lot of time and energy into getting cubs to maturity (Blomqvist, 2013). This aspect of their life history could make them more vulnerable as raising even a few cubs is taxing for mothers (Williams, Shoo, Isaac, Hoffmann, & Langham, 2008). If these cubs then don't survive to the age of maturity and reproduce, then all of the investment from the mother will have been lost with no recruitment of the cubs into adulthood. Studies on the inter birth interval after the cubs leave their mother, either from reaching maturity or fatality, would prove useful to further understanding their vulnerability from life history.

Parameters affecting snow leopards outside of life history include low recruitment and low densities (Snow Leopard Network, 2014; Jackson *et al*., 2009). The issue of naturally low densities in snow leopards creates a conservation concern. To protect viable populations large areas of habitat would need to be protected, which, as discussed previously, is a criterium that is often not met (Snow Leopard Network, 2014). The issue of low recruitment creates a need for larger populations which in turn need large areas of habitat that are unthreatened and have connectivity to allow stability and growth (Jackson *et al*., 2009).

The concept of specialists versus generalists is another area of possible intrinsic threat. Snow leopards are specialists, meaning they are adapted to a narrow range of conditions as their niche (Thiele, 2003). They do show elements of being generalist through their diet, as it can be varied, but their limited habitat range reduces prey choice (Oli, Taylor & Rogers, 1993, Shehzad *et al*., 2012). The specialisation of a species can compromise their ability to survive in a changing habitat, a concern in the face of climate change. Some have even gone as far as to say that specialisation is an 'evolutionary curse' in the wake of human modification to the planet (Sodhi, Brook, & Bradshaw, 2009).

Conclusion

The snow leopard is a unique member of *Panthera*, with their vast habitat range across 12 countries, their morphological adaptations and their behaviour in the wild. Establishing an understanding of the biology of snow leopards is beneficial to creating an idea of how their status may be affected by threats, both current and emerging. The unanticipated results of snow leopard haemoglobin testing emphasise the unexpected components of their biology.

The work done to further our knowledge of the species often raises more questions as the expected hypothesis are not met, such as with Janecka *et al*, (2015). The downgrade by the IUCN from Endangered to Vulnerable has been received with scepticism and raised alarms over the current lack of knowledge of the population size and the limitations faced in trying to create more accurate estimates (McCarthy *et al.*, 2017). Innovation in finding methods to improve population estimates is key to establishing a true reflection of the species status and the conservation attention needed. Assessment of the threats currently recognised creates a complex view of the situation snow leopards are in, with prey base depletion and retribution killings being considered the highest rated threats, both primarily driven by human-wildlife conflict stemming from socio-economic issues associated with poverty (Xu and Crompton, 2008). Concerns over the lack of clarity on snow leopard's life history creates issues in predicting their vulnerability to changes. In the face of climate change, our lack of baselines data on snow leopard's vulnerability could become an issue (Nyhus *et al.*, 2016). Research to improve our knowledge of snow leopard biology, including their life history, could help to predict and respond to declines in the population (Snow Leopard Network, 2014).

Chapter 2

Conservation

This chapter will discuss the conservation efforts currently taking place as well as offering recommendations for future conservation work. The importance of snow leopards will be discussed as a point of motivation in encouraging conservation work and changing people's attitudes. This importance has been divided into a number of categories such as cultural value, uniqueness and ecological value. Likewise, conservation work has been separated into in-situ (within a species natural environment) and ex-situ (outside of a species natural environment, e.g. a zoo). The work of conservation organisations will be reviewed, specifically looking at their action plans, approaches and successes.

5.0 Why conserve snow leopards?

Arguing that any species deserves protecting or prioritising can come from a moral or logical base of reasoning. The logical approach has been adopted here to illustrate what the impacts would be if snow leopards became extinct.

5.0.1 Ecological importance

Snow leopards play an important role in their ecosystem as a keystone species (NEASPEC, 2007). As a tertiary consumer, snow leopard's absence or abundance directly affects prey populations. Predation on wild ungulates such as blue sheep or markhor alters the vegetation cover which has impacts on the niches for all animals and plants in the habitat (Snow Leopard Working Secretariat, 2013). A long-term absence in snow leopards could cause trophic cascades as ungulate populations would likely increase, leading to depletion of vegetation cover (Silliman & Angelini, 2012). Little is known about any interaction between snow leopards and sympatric carnivores. However, it is expected that snow leopard presence can have an effect on the abundance or absence of other carnivores such as lynx (*Lynx lynx*) and wolves (Chetri, Odden, & Wegge, 2017). Protecting snow leopard abundance will result in a cascade of benefits to the diversity of plant and animal life in the habitat (Chetri, Odden, & Wegge, 2017).

5.0.2 Uniqueness

Snow leopards can be considered as a unique species because of their adaptations to high altitude life. As previously discussed, snow leopards are believed to have several morphological adaptations to high altitude, including: a dense pelage, a broad and short skull, an enlarged nasal cavity, an extended tibia, long thoracic and lumbar segments and a long tail (Kitchener *et al.*, 2016). These adaptations combined allow for the following: enhanced counter current warming of inhaled air, more efficient movement, improved balance and insulation of extremities (Kitchener *et al.*, 2016). Another difference between these cats and any other member of *panthera* is their inability to roar due to their small vocal cords Kitchener *et al.*, 2016). The previously discussed controversies from snow leopard blood studies further contribute to this species' unique adaptations (Janecka *et al*., 2015).

5.0.3 Flagship species

The position of snow leopards as a flagship species for their ecosystem has given them an ambassadorial role. Higher attention is often given to flagship species as they are more widely perceived as charismatic. This can be used in conservation work to help improve the status of other species that are sharing the same habitat or are under similar threats (WWF China, n.d.). Snow leopards are currently one of 18 species represented by the World Wide

Fund for Nature (WWF) who are responsible for selecting them as an ambassador for the protection of their shared habitat. For example, they protect local human populations through conserving resources that humans use (WWF China, n.d.). This is due to snow leopard's role as a keystone species and funds raised to conserve them (WWF China, n.d.). Snow leopards combined ambassadorial state and charismatic nature makes them an appealing species for investment from affluent western cultures (Bowen- Jones & Entwistle, 2002; WWF China, n.d.).

5.0.4 Cultural value

The snow leopard is the symbol of Tatarstan and Kazakhstan and holds value in beliefs and cultures surrounding the sacred mountain terrain that snow leopards inhabit (Snow Leopard Conservancy, 2008). The Wakhi people of Afghanistan, China, Pakistan and Tajikistan believe in entities known as pari or mergichan (Snow Leopard Conservancy, 2008). Megichan are thought to be supernatural beings that inhabit high mountainous terrain, making the mountains a sacred realm. The Whaki people believe that mergichan take the form of an animal when mankind has done wrong and damaged the realm with impure actions (Snow Leopard Conservancy, 2008). Snow leopards are believed to be one of the forms that mergichan take (Snow Leopard Conservancy, 2008). This fits with their allusivity and potential to be dangerous. However, the Wakhi people also describe snow leopards as a beautiful species, despite the danger which they fear a sighting may indicate (Snow Leopard Conservancy, 2008).

There are many monasteries within snow leopard habitat (Li *et al.*,2014). It is believed that the presence and teachings within these monasteries encourages a passive approach to snow leopards, with 42% of local herders believing harming a snow leopard to be a sin in

Buddhism (Li *et al*., 2014). The historical petroglyphs of snow leopards found in Tien Shan can be used in teachings to demonstrate the long existing coexistence of people and snow leopards (Salopek, 2017).

5.1 In situ

In situ conservation work aims to help a species by working within their natural habitat (CBD, 1992). In situ conservation for snow leopards has seen a vast range of programmes and initiatives with varying successes (Nyhus *et al.*, 2016). The majority of conservation work takes an approach that incorporates local communities' values and concerns, rather than trying to create strict rules and limits (Nyhus *et al.,* 2016). A community-based approach to mitigating human-wildlife conflict has in several cases proved to make stronger progress on reducing threats (Treves, Wallace, Naughton-Treves, & Morales, 2006). Human-wildlife conflict resolution is a somewhat new approach incorporated into conservation plans. For these plans to be effective they have to be flexible and incorporate a complex network of concerns from local people, stakeholders, scientists and conservationists; avoiding a 'one solution fits all' approach (Snow Leopard Network, 2014).

5.1.1 Incentive and reward programmes

Incentive and reward programmes are a useful strategy in resolving human-wildlife conflict as they provide financial support, diminishing an indirect threat (Thiele, 2003). Retribution killings of snow leopards to protect livestock and income is one of the threats best targeted by economic incentives (Kunkel, Hussain, & Khatiwasa, 2016). Protecting and raising income of herders helps to raise tolerance of snow leopard depredation.

The Snow Leopard Enterprise (SLE) in Mongolia is an award-winning programme set up by the Snow Leopard Trust (SLT) (Mishra *et al.,* 2003). SLE works with families living within snow leopard habitat to create sustainable economic opportunities, with the aim of reducing motivations behind illegal hunting. As a part of the SLE, local women are given the opportunity to create unique handicrafts with natural resources. Instead of selling the raw products such as wool, they are crafted into goods such as gloves and ornaments. The products are then bought by the SLT and sold through wholesale and online. Participants earn an average of $150, which raises their annual income by 4% compared to the national average for rural households (Nyhus *et al., 2016*). In some households, this is almost double their income (Nyhus *et al.,* 2016). In return, communities pledge to keep snow leopards and prey in their area from getting harmed. This is achieved by getting participants to sign a conservation agreement. If the agreement is fulfilled a 20% cash bonus is awarded (Snow Leopard Network, 2014). However, if any illegal hunting is found to have taken place, every participant in the SLE in the community will lose the bonus and may not be offered the opportunity to be in the SLE again. The level of compliance to the agreement comes from the accounts of Protected Area administrators, environmental agencies, herding communities, anti-poaching units and SLT researchers (Nyhus *et al.,* 2016). Since the launch of SLE in 1993, illegal hunting of snow leopards and their prey has decreased in SLE areas (Nyhus *et al.,* 2016). Additionally, attitudes of people have become more positive towards snow leopards as they are no longer a significant threat to their livelihood (Thiele, 2003). Overall, the SLE has managed to increase awareness of the value and benefits of snow leopards. This comes from illustrating how maintaining diversity of wildlife can benefit communities. Understanding the benefits ultimately helps to reduce illegal hunting and retribution killing (Theile, 2003).

Compensation based programmes have previously proved inadequate in reducing human-wildlife conflict (Nyhus *et al.,* 2016). Learning from this, livestock insurance schemes have been set up in certain areas to attempt to better resolve conflicts and provide support. One example of a successful compensation-based programme comes from Pakistan. The scheme was set up in 1999 with a grant from the Whitney Foundation (Thiele, 2003). An insurance system and eco-tourism programme was set up by the scheme, giving herders an incentive to protect their local environment and offering compensation for any lost livestock. The scheme worked by asking herders to pay a premium per head of livestock. This scheme then subsidized by up to 50% with money raised by private donors (Thiele, 2003). High levels of community participation was incorporated, allowing participants some ownership over the community's money (Thiele, 2003). This was done to help reduce the likelihood of fraudulent claims, keeping monitoring costs minimal. Following this scheme, surveys of participating areas have shown stable snow leopard populations that may be modestly increasing (Nyhus *et al.,* 2016). The scheme is looking to expand following the positive results, however there is a substantial issue in finding enough continuous funding (Thiele, 2003).

Livestock insurance may be more cost effective to set up and run compared to enterprises like SLE. Both projects use two key principles which are vital to mitigating the threats facing snow leopards effectively; to improve livelihood whilst simultaneously making snow leopard protection a priority (Nyhus *et al.,* 2016). Methods incorporating a community-based approach, whilst maintaining the prioritisation of conservation concerns, efficiently help to tackle socioeconomic driven threats.

5.1.2 Ecotourism

Ecotourism in snow leopard range has become a popular and particularly successful enterprise in Nepal and India (Theile, 2003). The chance to see the charismatic snow leopard in their natural habitat is widely appealing and marketed as a ‘once in a lifetime experience’ (Real Holidays, n.d.). Alongside creating an opportunity to educate people about the plight and importance of snow leopards, ecotourism creates an income for local people and instils the need to protect the species and their habitat (Snow Leopard Conservancy India Trust, (n.d.). This can contribute to the promotion of sustainable living and developments. Ecotourism needs to be well managed to ensure the groups of tourists are not disruptive to the wildlife. The impact of their visit can cause damage with issues such as litter (Snow Leopard Trek, n.d.). Limited numbers of tourists and excursions that do not coincide with the breeding season of snow leopards or prey are the most ideal for sustainable ecotourism.

5.1.3 Livestock husbandry

A contributing factor to livestock predation by snow leopards is insufficient livestock husbandry. By improving livestock husbandry practices, snow leopards will be less likely to opportunistically kill livestock (Snow Leopard Network, 2014). Often entire herds are lost to a single snow leopard if it breaks into a corral. Corrals are often poorly built to prevent predator break-ins as they are made without roofs and develop gaps in the walls from poor maintenance (Theile, 2003). Predator proofing corrals is an effective strategy to mitigate conflicts between herders and snow leopards. This strategy has helped communities in Afghanistan, India, Nepal, Pakistan and Tajikistan (Snow Leopard Network, 2014). There are several ways to make corrals to predator proof. The most effective methods have been found to be creating stone walls 2.4m high, wire mesh roofs supported by wooden beams and a single close-fitting door (Snow Leopard Network, 2014). India has seen 100 of these corrals built, 36 have also been built in Afghanistan and 30 in northeast Pakistan. This comes from the work of governments and conservation organisations (Mohammad, Mostafawi, Dadul, & Dadul, 2016). These corrals have been regarded as a success as there have been no reports of depredation or corral related retaliatory killings since their construction (Mohammad *et al.*,2016). The demand for corral funding and materials has risen, with requests to construct more of these corrals over a large portion of snow leopard range (Mohammad *et al.*,2016). Inability to meet these demands has meant only areas of higher risk to depredation are able to be targeted for corral improvements (Mohammad *et al.*,2016).

Livestock guarding is another method to deter snow leopards and decrease the likelihood of predation on livestock (Rigg, 2001). Dogs are commonly used to guard herds and deter predators or alert a human to the presence of a predator (Rigg, 2001). Studies on the use of guard dogs in snow leopard range are lacking, but studies from elsewhere have provided some insight (Ribeiro & Petrucci-Fonseca, 2007, March). Ribeiro and Petrucci-Fonesca (2007) performed a Portugal based study found that 96% of farmers who were given dogs considered the dogs' performance to be excellent or good in attentiveness, trustworthiness and protectiveness. However, several problems were identified with dogs running away, chasing wildlife and attacking each other requiring veterinary care (Ribeiro & Petrucci-Fonseca, 2007, March). This suggests that in addition to giving herders guard dogs, lessons in training the dogs appropriately should be provided. This method can prove effective in preventing livestock predation, although poor management of domestic dogs has led to increasing populations of feral dogs, which are now a direct threat to snow leopards and other wildlife (Ribeiro & Petrucci-Fonseca, 2007, March).

5.1.4 Education

Environmental education (EE) is a valuable conservation tool in improving people's awareness and tolerance of species that they may consider a nuisance (Hillard *et al.*, 2016). EE has been put into action at various levels across almost all the range countries (Snow Leopard Network, 2014). EE has been implemented through the provision of toolkits for teachers, children and the general public (Hillard *et al.*, 2016). Designated activity sessions for schools both in and out of the classroom have also been established, with the aim of developing an understanding of biodiversity and sustainability. The SLT has gone on to set up an eco-camp for 10 to 14-year olds to develop positive attitudes to local wildlife and the need for conservation (Snow Leopard Trust, n.d.). Since 2009 almost 2,000 children have attended one of the eco-camps (Snow Leopard Trust, n.d.). The SLT have also set up nature clubs through schools in which students can hike through snow leopard habitat and host nature celebrations (Snow Leopard Trust, n.d.). Although these EE programmes might not cause an immediate decrease in risks facing snow leopards, the long term pay off of improving local community attitudes and willingness to aid conservation is worth the investment (Snow Leopard Network, 2014). To ensure EE is effective in the long term, studies could be done to assess the impact EE has on attitudes towards snow leopards and conservation in comparison to areas which have not had EE.

Efforts to change opinions and attitudes on subjects like predator conservation can be highly complex and time-consuming endeavours, hence the development of EE could prove highly valuable (Mishra *et al*., 2016). Most attitudes and interest in wildlife develops through a person's experiences over their lifetime. As such, introducing positive experiences at a young age through school can aid in developing generations with more positive attitudes (Mishra *et al*., 2016). If EE is effective it can teach students a sense of connection and stewardship for the environment (Mishra *et al*., 2016). However, limited resources and a reluctance to teach

EE in schools within snow leopard range has become a barrier (Hillard *et al.*, 2016). Often educational packs are given to schools that do not have the resources to use them (Snow Leopard Network, 2014). Helping schools modernise, and tailoring educational packs to the school's resource level could help to improve this issue (Hillard *et al.*, 2016). The leading constraint in introducing EE across all range countries comes from politics (Hillard *et al.*, 2016). EE is often a low priority in the face of unstable governments and changing politics (Hillard *et al.*, 2016). Environmental education should ideally be introduced in school at a young age and taught regularly through a student's time at school to instil an awareness of how their lifestyle choices can affect wildlife, and what can be done to improve the circumstances of their indigenous species.

5.1.5 Transboundary initiatives

It is not common for multiple political borders to coincide with a species habitat range, rendering the case of the snow leopard a unique problem (Rosen & Zahler, 2016). Transboundary cooperation is not always possible due to political differences and international relations. Despite this, some developments in transboundary cooperation regarding snow leopard conservation have been able to progress through GSLEP.

GSLEP was established in 2013 to tackle high mountain development issues, using the snow leopard as a flagship species (GSLEP, 2014a). The goal of GSLEP was to achieve a unanimous agreement between the range countries and partners to secure 20 snow leopard landscapes by 2020 (GSLEP, 2014a). It defines a snow leopard landscape as an area containing at least 100 mature snow leopards, with local communities supporting security and connectivity between the landscapes (GSLEP, 2014a). As part of the GSLEP programme, the Bishkek Declaration was created in 2013 and finalized in 2017 (GSLEP, 2014b). The range countries adopted this declaration and confirmed the need to conserve snow leopards and their fragile habitat. The latest update on the progress of GSLEP was in June 2018 where a statement was released and supported by a representative from each of the 12 range countries (GSLEP, 2014b). It detailed that they will continue to accelerate the implantation of the Bishkek Declaration, agree to implement Population assessment of the World's Snow Leopards (PAWS), resolve illegal hunting and trade, and support the efforts of the Secretariat (GSLEP, 2014b).

The continued progress of GSLEP will rely on adequate funding, the ability to mitigate concerns, sharing of knowledge between the range countries and good practice (Dickman, 2010). GSLEP is a promising programme as it comprehends existing successes and how to use this knowledge to shape methods to reduce human-wildlife conflict, improve anti-poaching controls and the use of scientific monitoring in creating models (Snow Leopard Network, 2014). GSLEP has been ground breaking following success in being the first project to comprehensively coordinate global efforts to conserve snow leopards and their habitat with involvement of all the range countries (GSLEP, 2014b). Continued progress could be a big influence on the future status of snow leopards.

5.1.6 Uniting organisations

The Snow Leopard Network (SLN) is a worldwide organisation dedicated to enabling the exchange of information between governments, individuals and organisations for the purpose of snow leopard conservation (Snow Leopard Network, 2014). Since the establishment of the SLN in 2002, over 300 individuals and organisations have been united to aid snow leopard preservation efforts and promote scientifically based conservation (Snow leopard Network, n.d.). The SLN aims for stronger professional links to address severe threats. This aim has been furthered by their document, the Snow Leopard Survival Strategy (SLSS) (Snow

Leopard Network, 2014). The SLSS hosts a detailed strategy for snow leopard preservation through research, conservation actions and establishing government action plans across the range countries. Implementation of the SLSS would see assessments and ratings of threats and the defining and prioritising of appropriate conservation, education and policies (Snow Leopard Network, 2014). Furthermore, implementation would also see topics of research relating to snow leopard conservation prioritised, with preference given on the most ideal research methods (Snow Leopard Network, 2014). In addition, the SLSS has recognised technological advances in the use of camera traps, GPS satellite collars and improved methods of genetic analysis. Use of these developments have been included in the SLSS with regards to gathering research for population estimates, management plans and frameworks (Snow Leopard Network, 2014). The SLN also offers a grant program for research and education following efforts of grassroot conservation or applied research that addresses priorities of the SLSS (Snow leopard Network, n.d.). Overall, the work of the SLN has made much needed advances in developing communication for the benefit of the scientific community and conservationists. However, there is a need for reports on the impact the SLN has had on reducing threats.

5.1.7 Law enforcement

As snow leopards are a protected species under CITES, there are regulations and restrictions in place to protect them (CITES, n.d.). Inadequate law enforcement has meant that poaching and illegal trade still takes place (Thiele, 2003). Often laws and restrictions to protect wildlife are inadequate, underfunded and a low priority for governments and local people (Nyhus *et al.,* 2016). Local residents can pose a significant aid to enabling poaching as they may profit by acting as a guide or giving information to poachers (Thiele, 2003). These current weaknesses in enforcement have been exploited to benefit wildlife crime.

Cross border investigation and sharing of information would improve efforts to identify and reduce wildlife trade (Thiele, 2003). If efforts of high-level agencies, for instance INTERPOL, the World Customs Organisation, the South Asian Wildlife Enforcement Network and CITES, were to be coordinated, successes would likely be seen in creating unanimous and stronger enforcement of laws.

Currently, one method used to attempt to aid law enforcement is the deployment of anti-poaching units. Recent years have seen an increased investment in anti-poaching training, with volunteering opportunities available in Africa aimed at protecting the black rhinoceros (*Diceros bicornis*) which is currently critically endangered (Emslie, 2012). There is difficulty in monitoring snow leopard habitat due to the harsh environment and isolation. To combat this, work into designating core areas or other methods of monitoring should be considered. Core areas could be created based on the coverage of snow leopard home ranges in manageable areas of good quality habitat (Snow Leopard Network, 2014). This may involve crossing political boundaries and would need to employ the use of transboundary initiatives. Once established, core areas should be secured with patrols fully covering the area for any signs of illegal activity. Other methods could also be used as an alternative or in combination with core area patrols, working to improve efficiency and expand the size of the core areas (Nyhus *et al.*,2016). One such method is taking advantage of technological advances in drones (Mulero-Pázmány, Stolper, Van Essen, Negro, & Sassen, 2014). Drones offer the opportunity to monitor and gain insight in a non-invasive way (Pimm *et al.*,2015). As well as monitoring for illegal human activity, drone footage could be used for a plethora of study into unknown snow leopard data, including home range tracking, habitat range, population estimates and behaviour (Pimm *et al.*, 2015). In 2017 the SLT obtained their first drone and have been working to develop techniques to remotely count snow leopard prey using infrared cameras and artificial intelligence software (Matt, 2018). The Snow Leopard Conservancy (SLC) also acquired their first drone in 2017 after partnering with the Global Conservation Force (Global Conservation Force, n.d.). The SLC is working to test the drone in areas with high wind and mountainous terrain, similar to that which drone would experience in snow leopard habitat. There may be constraints on the coverage of drones due to their restrictions in being used at high altitudes, limiting their use to the lower altitude range of snow leopard habitat (Matt, 2018).

5.1.8 Trophy hunting

The role of trophy hunting in conservation is often questioned, with many studies disagreeing with the practice and others saying biodiversity will be lost without trophy hunting (Nyhus *et al.*, 2016; Lindsey *et al*, 2007; Minin, Leader-Williams, & Bradhsaw, 2016).

The longest running trophy hunting programme in Pakistan is the Torghar Conservation Project (TCP), established in 1986 (Thiele, 2003). The TCP was established on tribal lands after concerns over population declines in mouflon and markhor as a result of hunting and poaching in the region (Woodford, Frisina, & Awan, 2004). The TCP made hunting illegal on their land and hired local tribesmen as guards to prevent poaching (Woodford *et al.*, 2004). Since their establishment, the TCP has been registered as an NGO and generated USD 460,000 from 34 trophy hunts (Woodford *et al.*, 2004). Trophy hunting is their largest source of income and is used to create incentives for conservation and support for agriculture. Alongside trophy hunting, the TCP allow a small harvest of markhor. To establish sustainability the TCP conducted surveys over 14 years on population sizes and concluded that up to 18 male markhor could be hunted per year. Some research has suggested that harvesting 1% - 2% of the population is believed to cause no negative consequences, whereas other research puts the number higher at 10% - 20% if the population is stable (Wegge, 1997; Woodford *et al.,* 2004). Permit fees for hunting markhor have seen increases in cost, which is resultant from competitive bidding and influxes of foreign hunters with more disposable income (Nyhus *et al.,*2016). The price has risen from USD 35,000 in 1999 to USD 105,000 in 2014 (Woodford *et al.,* 2004).

The TCP, amongst other programmes, have successfully seen recoveries in snow leopard prey species as they prevent illicit and unsustainable hunting (Nawaz *et al.,* 2016). The programmes give local people a sense of ownership and responsibility by including them in the management of the areas, making it increasingly difficult for outsiders to openly hunt wild ungulates (Nawaz *et al.,* 2016). Development and improvement of these programs in the future can be marketed towards guarding all animals within the habitat, including protected animals and those of little interest to the community, creating a package deal for the entire habitat (Nawaz *et al.,* 2016) There is a need to establish agreements that include protection of the habitat and all related species to those being trophy hunted (Nawaz *et al.,* 2016). Protecting the habitat is fundamental, the benefits of which should be made clear to the community and become a shared priority. This can aid in reducing livestock overgrazing and disease spread caused by livestock presence (Nawaz *et al.,* 2016).

5.2 Ex situ

The current extent of ex-situ work being done for snow leopards includes zoo population management as well as rescue, rehabilitation and reintroduction centres.

5.2.1 The role of zoos

Historically, snow leopards were first caught and put into zoos in 1851, but the first litter was not successfully born until 1910 in Wroclaw Zoo (Blomqvist, 2008). Before 1960, catching wild snow leopards was common practice among most zoos (Blomqvist & Sliwa, 2016). Out of these wild caught snow leopards, only four pairs found in European zoo collections bred (Blomqvist & Sliwa, 2016). From these pairs, one successful breeding pair 'Hassan' (studbook #85) and 'Muddi' (studbook #86) are still represented in the current captive population of snow leopards (Blomqvist & Sliwa, 2016). Sporadic success in reproduction and births continued until the late 1970's when they became more common. The poor breeding results and high rates of neonatal mortality created attention for the species and a desire to establish a self-sustaining population, especially after the protection of wild snow leopards under CITES (Nowell *et al*., 2016)

The European Endangered Species Program (EEP), established in 1985, manages animals in the European Association of Zoos and Aquaria (EAZA) to help threatened and endangered species) (EAZA, n.d.). Snow leopards were integrated into the EEP in 1987 and put into the most intensive level of management (Blomqvist, 2013). Through 2012, 19 litters produced 42 cubs in total, with 71% surviving and 14 snow leopards dying (Blomqvist, 2013). Because the recruitment rate was higher than the mortality rate in 2012, fewer breeding recommendations were issued in 2013. At the start of 2014, the EEP snow leopard population stood at 216 across 81 institutions. Blomqvist (2013) notes that the EEP program is fortunate to have this population size, however it needs to be managed to ensure genetic heath is maintained to keep the population viable and safeguard against the risk of extinction. Blomqvist and Sliwa (2016) have highlighted the importance of well-planned management with pairings based on kinship values and unrepresented gene lines. Preventing closely related individuals from mating can help the gene diversity in the captive population to be improved (Blomqvist, 2013). The mean inbreeding coefficient for snow leopards is among the lowest with the rate decreasing from 0.022 in 2001 to 0.019 in 2012, indicating a healthy population (Blomqvist, 2013). Nonetheless, for a populations genetic drift to be balanced by mutation the effective population size needed is estimated to be 500 (Frankham, Ballou, & Briscoe, 2002). Genetic drift and inbreeding depression can be improved with the introduction of new genes through exchanges with other continental programmes (Blomqvist & Sliwa, 2016). Although capturing wild snow leopards is highly limited, semen collection from captured males could be explored as a way to enhance the founder base in captives.

5.2.2 Captivity value

In addition to safeguarding a species from going extinct, keeping animals in captivity can be useful in helping conservation work. The ex-situ population of snow leopards has provided help for ongoing in-situ research. Tracking wild snow leopards with methods such as GPS telemetry has only been made safe and possible following data on safe anaesthesia levels which was procured from zoological collections (Johansson, Malmsten, Mishra, Lkhagvajav, & McCarthy, 2013).

Annually, zoos have more than 700 million visitors, creating a large platform for species awareness and conservation efforts (Blomqvist & Sliwa, 2016). As a flagship species, snow leopard's ex situ can generate a lot of funding in support of zoological and conservation work. The global zoo community spends over USD 350 million on wildlife conservation (Gusset, Fa & Sutherland, 2014). Zoos also create an opportunity to introduce environmental education to their visitors, teaching them about animals, the habitats they come from, and what they can do to help conservation efforts (Blomqvist & Sliwa, 2016). Zoos also carry out fundraising for in situ conservation and their own projects, often donating funds to conservation agencies, many of whom work with snow leopards (Blomqvist & Sliwa, 2016).

5.2.3 Reintroduction

Although snow leopards are not imminently threatened with extinction, the species is viewed as extinction prone (Miquelle *et al.*, 2016). Sparse fragmented and declining populations as well as a vulnerability to the impact of humans has contributed to the concern that reintroductions will be needed in the future (Miquelle *et al.*, 2016). Assessment in population losses across ranges are needed to determine if snow leopards are anticipated to be extirpated from areas of their range.

Reintroduction efforts have increased in recent years, yet only 10% of reintroductions of large predators were considered a success following failures to establish viable populations (Miquelle *et al.*, 2016). For snow leopards, some recommend the stocking source would best come from captive bred to advance the conservation agenda, even though greater successes would likely come from ex situ translocations (Miquelle *et al.*, 2016). Translocations are currently not being explored as there is little data and study into the extent of possible subpopulations and localised extinctions (Jackson & Ale, 2009). The high recruitment rate among the ex-situ captive population creates a larger resource for replenishing depleted wild populations (Blomqvist, 2013). However, reintroducing captive individuals raises issues regarding the innate ability of captive bred individuals to survive in the wild (Jackson & Ale, 2009). Captive animals suitable for release into the wild require several traits: fear of humans, predator recognition, hunting skills and freedom of any disease such as Feline Immunodeficiency Virus (Jackson & Ale, 2009). Some of the best snow leopard candidates for release will likely be independent subadults entering the dispersal phase of their life

(Miquelle *et al.,* 2016). During this phase they are most likely to be able to learn coexistence and survival behaviour, both socially and environmentally, creating the best chance for future reproductive success (Miquelle *et al.,* 2016).

Miquelle *et al* (2017) reviewed four case studies and identified the key lessons to be learned before planning snow leopard reintroduction. The case studies included: planning Jaguar reintroduction in Argentina, restoring Iberian lynx (*Lynx pardinus*), genetic restoration of the Florida panther (*Puma concolor couguar*) and the rescue, rehabilitation and reintroduction of amur tigers (*Panthera tigris tigris*) in Russia. This selective range of studies cover the social, geographic, genetic and logistical difficulties a reintroduction of snow leopards can be expected to face (Miquelle *et al*., 2017). The cumulated lessons learned from these studies were summarised as the following: find common ground with key constituents, develop effective public outreach, exploit the knowledge and experience of scientific and conservation communities to develop a defensible plan, ensure suitable habitat exists, screen for disease, ensure captive reared individuals are not used to human contact, release females first, explore hard versus soft release, closely monitor released individuals and be prepared to remove individuals if conflict occurs (Miquelle *et al.*, 2017).

In the case of the snow leopard, there are suggestions that proposals of reintroduction are premature, burdened with uncertainty and more costly than well directed conservation initiatives in-situ (Jackson & Ale, 2009). Snow leopards have also been described as the most challenging felid species to reintroduce (Wemmer & Sunquist, 1988). The associated issues with their native habitat, the paucity of roads, the absence of funding and political unrest means meeting standardized guidelines for reintroduction would be problematic (Jackson & Ale, 2009). Addressing human-wildlife conflict issues is viewed to be more effective and holistic than waiting to reintroduce or translocate snow leopards (Miquelle *et al*., 2017). The current situation of wild snow leopards, alongside the limited knowledge on reintroduction science and our lack of full understanding of snow leopard biology indicates little need for a reintroduction effort at this stage (Jackson & Ale, 2009).

5.2.4 Rescue, rehabilitation and release

There are some rescue centres that will capture snow leopards that are injured, malnourished or have strayed into an urbanised area (Miquelle *et al*., 2017). These rescues see the animal taken back to a rehabilitation centre to allow recovery time before being released back into the wild.

In conservation, the long-term goal is commonly to ensure long-term persistence, thus taking up rescues of individual snow leopards is often unfeasible (Miquelle *et al*., 2017). Rescue attempts of lone individuals are often perceived to not contribute to conservation efforts (Miquelle *et al*., 2017). Limitations on funding, personnel and time often mean that the labour involved in a rescue makes it difficult to justify and complete. However, cases of animals in need of rescue can often gain a lot of attention on social media. This attention can create an expectation from the general public for a response, to which justifying it as 'not a conservation priority' is not deemed appropriate (Miquelle *et al*., 2017). Yet, there is a value to the platform social media offers. Social media can be used as a tool to influence and inform both locally and internationally. This could become an important component of environmental education and raising awareness of the threats facing snow leopards. Therefore, whilst in the short-term rescue and rehabilitation may require significant financial and logistical investment, the payoff in public and political support can further conservation initiatives and goals.

Conclusion

The role of snow leopards in their habitat as a keystone species raises concerns over the potential trophic cascades that could follow if their population continues to decline (Silliman & Angelini, 2012). They also have importance as a symbol of cultural values and as an ambassador for their habitat (Snow Leopard Conservancy, 2008). The role and value of snow leopards creates a foundation for the reasoning and justification of the conservation efforts taking place. In terms of in-situ and ex-situ, it can be deduced that in-situ should take priority for conservation endeavours (Miquelle *et al*., 2017). This is in part due to the lack of research currently done on snow leopard biology. Jackson and Ale (2009) state that this prevents reintroductions from being possible at this time. Ex-situ work can be useful in creating public awareness with campaigns and performing rescue operations (Blomqvist & Sliwa, 2016). Future endeavours need to be directed into developing the knowledge base on the biology and behaviour of wild snow leopards so that reintroductions may be a possible venture in the future. The in-situ work of the SLE and GSLEP show innovation and can be expected to improve the situation of snow leopards (Nyhus *et al.,* 2016). These enterprises could provide more regular and detailed reports of their progress and what lessons they have learnt. This may help shape the future conservation efforts of other organisations to improve how effective they are.

Chapter 3

Adaptive management, Theory of change and the Open Standards

In this chapter the concept of adaptive management will be discussed, linking into the theory of change and the Open Standards approach. These three matters all form a cohesive ideology of how conservationists can make their work more effective by learning from mistakes and using their insight to improve future efforts. It is argued that if conservation is to be more effective, decision makers need to be provided with more information on successes and failures alongside details on how effective an action may be in achieving goals under certain conditions (Redford & Taber, 2000; Pullin & Knight, 2001; Bottrill *et al*., 2011). In the majority of cases conservationists have been unable to respond to this challenge as the monitoring and evaluation of effectiveness is largely absent for most conservation actions. These actions continue to be experience based as opposed to evidence based (Pullin, Knight, Stone, & Charman, 2004; Sutherland, Pullin, Dolman, & Knight, 2004; Brooks, Franzen, Holmes, Grote, & Mulder, 2006; Pullin & Knight, 2001). To address this problem, several frameworks have been created to facilitate adaptive management, including the Open Standards for the Practice of Conservation (referred to as Open Standards).

6.0 Adaptive management

The adaptive management (AM) approach has been proposed as method of managing natural resources to combat the often-associated uncertainty (Rist *et al*., 2013). The use of AM in managing the environment was first put forward by Holling (1978) and was originally called Adaptive Environmental Assessment and Management. AM emphasizes the importance of identifying uncertainties in natural resource management dynamics, and how the design of diagnostic management experiments can be used to reduce these uncertainties (Walters, 2007). AM uses six stages that link together to create a learning cycle. Environmental, economic and social understandings are integrated from the outset. The six stages are: 1) Assess problem, 2) Current knowledge, 3) Identify uncertainty, 4) Implement, 5) Monitor, 6) Evaluate (see Figure 3). During stage one (Assess problem), the management problem is defined, and objectives are set. In stage two (Current knowledge), all existing understanding is used in system models that also incorporate assumptions and predictions as a base for further learning. For stage three (Identify uncertainty), alternative hypotheses based on evidence and experience are created in the face of uncertainty. During stage four (Implement) the actions or policies created are implemented, whilst allowing continued resource management and learning. Stakeholders are described throughout AM to be central to the process. The participation of stakeholders greatly contributes to the success of natural resource management in AM.

Figure 3: The adaptive management process outlined by Holling (1978), designed by Rist *et al* (2013) (Source Rist *et al.*, 2013).

In the four decades since the introduction of AM, many frameworks have been created that use its basic principles, such as: Landscape species approach, developed by the Wildlife Conservation Society, the Cambridge Conservation Forum framework and evaluation tool, and The Nature Conservancy's Conservation Action Planning Basic Practices (Lasch, Pintea, Traylor-Holzer, & Kamenya, 2011). Despite the broad appeal, much confusion remains over what the approach entails and if it is feasible to apply AM successfully (Allen, Fontaine, Pope, & Garmestani, 2011). This in itself causes debate as definitions of success in AM differ. Some authors describe the ability to strictly commit to the AM cycle as a success whereas others consider reductions in uncertainty following the use of AM to be a success (The Conservation Measures Partnership, 2013). There is also debate over the capability of AM to apply in both large-scale and small-scale applications, as large-scale experiments have had varying hindrances with complexity and 'messy' processes (The Conservation Measures Partnership, 2013). The implementation of any management tool has to take place within a broader management framework (Allen *et al.*, 2011). As such, the decisions regarding implementation must be made in the context of broader considerations, both social and political. Trade-offs must also be made between different stakeholder objectives, risks and productivity and short-term and long-term goals. Ultimately, practitioners need to be able to distinguish between goals which reduce ecological uncertainty via experimentation, and broader goals and processes (The Conservation Measures Partnership, 2013).

6.1 Theory of change

Theory of change (ToC) is a comprehensive illustration of how a desired change is expected to happen following the implementation of an action (Theoryofchange, n.d.). Assumptions are made about how the implementation will cause changes to achieve an overall desired change (UN Environment, n.d.) These assumptions create the basis of ToC. Using a ToC approach in evaluation creates the ability to forefront assumptions that underpin chains from inputs to outputs, intermediate states and impact (UN Environment, n.d.). ToC can be used as an intervention to determine if all contributing factors affecting outcomes have been appropriately considered (RARE, 2014). Hence, using ToC provides support in both project planning, monitoring and evaluation (The Conservation Measures Partnership, 2013.

ToC has been developed as a community-based initiative as it aids in the management of achieving ambitious goals (Birgé, Allen, Garmestani, & Pope, 2016). The ToC offers a framework in which program staff and stakeholders can develop their comprehensive illustrations of both how and why a desired change is expected to happen. This is outcome-based which helps involved parties to clearly define long-term goals and then work back to clarify the necessary preconditions that will work towards the goals set (Birgé *et al.,* 2016).

Weiss (1995) produced an important paper regarding identifying and improving upon problems with stakeholders within theory-based evaluation. Weiss suggested that complex programs may be challenging to evaluate due to poorly articulated assumptions. Stakeholders within complex community initiatives typically have unclear understandings of how the change process will proceed (Birgé *et al.*, 2016). This often means that stakeholders do not give adequate attention to the early and mid-term changes that must take place to achieve any long-term goals (Birgé *et al.*, 2016). However, when stakeholder involvement is thorough and present throughout changes as suggested in AM, evaluating complex initiatives becomes less challenging and increases the likelihood of all the important contributing factors being fully addressed (Weiss, 1995).

6.2 Foundations of Success

Foundations of success (FOS) is a non-profit organisation that aids practitioners in understanding the process of AM so that they may improve their conservation efforts (FOS, n.d.). FOS have worked with conservation organisations, government agencies and donors to develop AM systems. The FOS use the guide from Salafsky, Margoluis and Redford (2001) to structure their teachings on the use of AM. Salafsky, Margoluis and Redford explain AM as an experimental or scientific approach to managing conservation projects. Following on from this, they gave AM the following definition "Adaptive management incorporates research into conservation action. Specifically, it is the integration of design, management, and monitoring to systematically test assumptions in order to adapt and learn" (Salafsky, Margoulis, & Redford, 2001, p. 12). This definition has been expanded upon by the authors into three points. Firstly, assumptions should be systematically tested and not as a random trial and error experiment. The site, desired state and most likely outcomes of actions should be considered thoroughly. Once any actions are implemented, results must be compared with assumptions to establish an understanding of which actions will work to achieve goals. The authors secondly highlighted that adaption is key to improving a project. Wherever the expected results were not achieved, assumptions and interventions should be adapted in response to the results of the monitoring. Thirdly, Salafsky, Margoluis and Redford emphasize the value of learning from the process and systematically documenting results. This will help both the practitioner's team and the wider conservation community to avoid repeating the same mistakes. Sharing information among groups of practitioners will improve the advancement of the AM conservation initiative. The FOS is helping the popularity of AM grow through the lessons and guidance they offer to organisations, agencies, institutions and donors.

6.3 Open Standards for the Practice of Conservation

Members of the Conservation Measures Partnership (CMP) stress the importance of AM in results-based project planning, management and monitoring. To meet needs for better practices, the CMP created the Open Standards for the Practice of Conservation (Open Standards) to guide result-based project planning, management and monitoring (CMP, 2013). The Open Standards brings together concepts, approaches and terminology of conservation into project design, management and monitoring. The Open Standards are designed so that they can be applied at any temporal, programmatic or geographic scale (CMP, 2013).

The Open Standards is organised into a five-step management cycle that is designed to be used as a guide to the process necessary for successful implementation of a conservation project, not as an exact formula (See Figure 4). It is not designed to fully address administrative processes such as budgets and contracts (CMP, 2013).

The first step is to Conceptualise. This involves Defining the Purpose of Planning and the Project Team. The Planning Purpose should be clearly outlined from the offset, with transparency over the decision-making process (CMP, 2013). The Project Team should typically have one leader and each member should be clear on their responsibilities and role within the team (CMP, 2013). However, it is also important to recognise that the team composition may change as the management cycle progresses. Ideally, a team should have advisors that can aid with any gaps in expertise. Project Teams need to remain flexible as they may consider making stakeholders part of the team if it is warranted. Also within step one, is creating a Scope, Vision and Conservation Targets. The Scope of a project is defined by the Open Standards as what the project intends to affect, which may be place-based or thematic-based. The Vision depicts the desired state the project is working to achieve. The Vision statement can be relatively general, brief and visionary (CMP, 2013). The conservation or biodiversity Targets are specific species or systems/habitats that are selected to encompass biodiversity in the project area for place-based, or as the focus for a thematic-based project. Identification of Critical Threats is also completed within the Conceptualisation. Once the Conservation Targets are selected, the Direct Threats influencing them are identified and prioritised. Threat rating and ranking tools can be used to aid in the process of prioritisation. The final component of this step is to Analyse the Conservation Situation (CMP, 2013). This consists of performing a study of the area/problem via a situation analysis that identifies key factors driving direct threats. Stakeholder analysis can also be done to establish links between threats and driving factors (CMP, 2013). Mapping out the relationship between the Conservation Target, Direct Threats and driving factors or indirect threats, is conceptualised in an initial 'Conceptual Model' (see Figure 5).

The second step is to Plan Actions and Monitoring. In this step, Goals, Strategies, Assumptions and Objectives are developed. Goals are linked to the Conservation Target and represent a part of the desired state for the project. Goals are set out as a formal statement of the impacts the Project Team hope to achieve (CMP, 2013). A 'good' Goal, as described by CMP (2013), will be linked to Targets, impact orientated, measurable, time limited and specific. Strategies are the strategic planning that takes form as key intervention points to be used to achieve the projects Vision. A Strategy describes a group of actions with a common focus that work together to reduce threats, capitalise on opportunities, or restore natural systems (CMP, 2013). A 'good' Strategy directly affects one or more critical factors, is focused with specific courses of action, is feasible to accomplish and is appropriate in accordance with cultural, social and biological norms. Intervention can include direct restoration of a Target, removal of a Direct Threat or actions that influence an indirect threat. Once the intervention points are finalised, the Project Team can brainstorm possible Strategies that may achieve the Goals set (CMP, 2013). Strategies can then be ranked to create a final selection that are feasible, focused and appropriate. Assumptions are made over how Strategies are believed to achieve Goals. A set of Assumptions is created and put into a 'Results Chain'. A Results Chain follows a casual cause-effect (if – then) progression with 'Intermediate Results', leading to a long-term conservation result (CMP, 2013). A Results Chain can be structured in accordance with the Conceptual Model created (see Figure 6). Within a Results Chain, Objectives can be set. Objectives are formal statements of outcomes and desired changes that relate to any Goals. A 'good' Objective is results oriented, measurable, time limited, specific and practical. Also within the second step is to Develop a Formal Monitoring Plan. A Monitoring Plan evaluates the Assumptions from a Results Chain to observe progress in Goals and Objectives. Part of developing a Monitoring Plan involves specifying the Project Teams audience and their information needs (CMP, 2013). Once this is determined, Indicators can be created. Indicators are used to detail data that the Project Team will collect and analyse to meet the audience's information needs. Objectives and Indicators are both found in Results Chains. The final point of step two is to Develop an Operational Plan. The Operational Plan looks at the funding required, resources needed, risk factors and longevity (CMP, 2013).

Step three is to Implement Actions and Monitoring. Works plans and timelines are created to detail what activities need to take place, who is responsible for those activities, when they are to be undertaken and how much money and resources they need. The Work Plan should be detailed enough to develop a timeline and ensure members of the Project Team are not overbooked, which could affect the planned budget (CMP, 2013). The budget must be developed and refined with estimated costs for specific activities and the projected potential costs over the duration of the entire project. A vital stage to step three, and the entire process, is to Implement Actions. This is when the strategic plan are put into action.

Step four, is to Analyse, Use and Adapt. Data analysis of results is performed to identify successes and failures, which then directs the next steps to be taken. The strategic plan is adapted in accordance with the results of the data analysis to optimize the impact of activities. Determination over how effective intervention points have been and how they could be adjusted is key to reaching Goals and Objectives more efficiently. As changes are made, the rationale behind them must be documented so other practitioners can identify what was learned and why the changes that were made were chosen (CMP, 2013). This forms part of step five which is Capture and Share Learning.

Step five outlines the value in regularly documenting lessons learned throughout the steps and the projects implementation. This can be formal or anecdotal and could even be used to form a basis in tracking expenses. CMP (2013) recommends the Project Team using online tools to document their lessons learnt. This could be advantageous to other practitioners as they can follow the progress and teachings of other projects as they unfold. Sharing what is learnt prevents repetition of mistakes both within a Project Teams own project, and in relation to other practitioners wanting to create their own project (CMP, 2013).

There are additional general principles that apply throughout the steps. These principles are: Involve stakeholders, develop and cultivate partnerships, embrace learning, document decisions, adjust as necessary (CMP, 2013). These principles largely coincide with the teachings of Salafsky, Margoulis and Redford (2001), in the expansion of their definition of AM used by FOS.

The five steps are set out in a loop to remind the Project Team that as a part of AM, these steps are a dynamic process that require changes over time as more is learnt. A Project Team should be prepared to revisit their Conservation Targets, Direct Threats, indirect threats, Goals and Objectives to address new information or changes to the current situation (CMP, 2013). Keeping the loop open to augment and develop until the loop can be closed is the essence of making ordinary management into AM (CMP, 2013).

Figure 4: Open Standards five step project management cycle Version 3.0. (CMP, 2013)

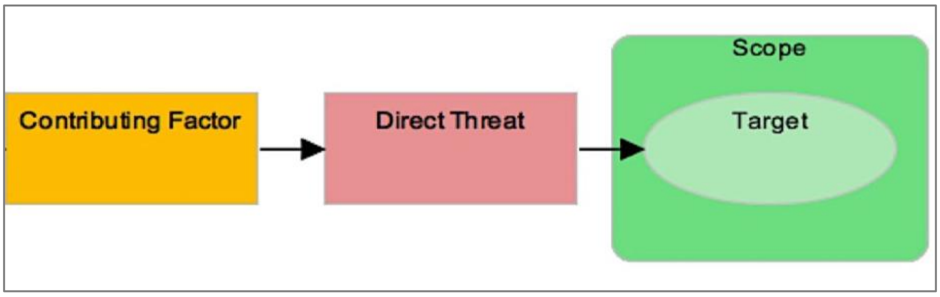

Figure 5: The four initial elements of a conceptual model within Miradi Version 4.5.0.

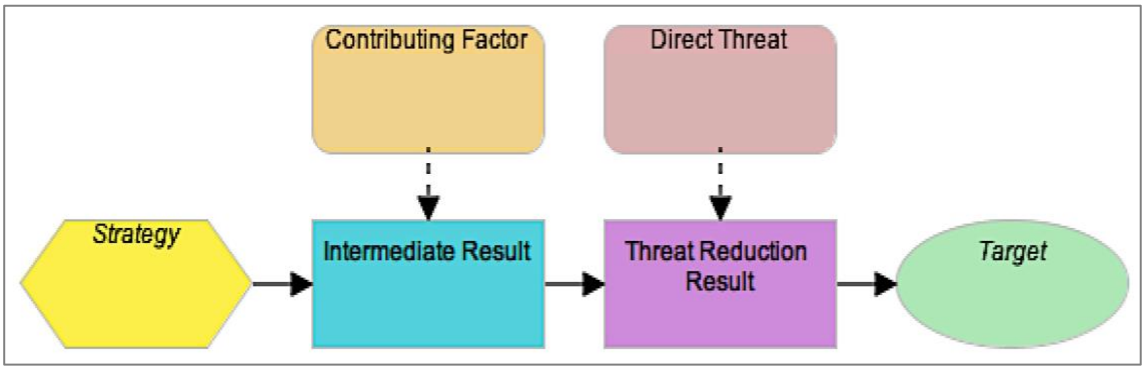

Figure 6: Representation of the construction of a results chain with inputs from the conceptual model within Miradi 4.5.0.

6.4 Direct and indirect threats

As part of the Open Standards logic, threats facing a species or habitat are split up into Direct Threats and Contributing Factors. This is also known and Direct and Indirect Threats. Direct and indirect threats are closely linked components in creating an understanding of the risks facing a species alongside what is causing them. Identifying the cause can be key to completely eliminating a threat. Indirect threats tend to be the result of socio-economic issues. The poverty levels across snow leopard range countries have been identified as a driving force behind several of the threats facing snow leopards, including retribution killing, illegal hunting and trade. Identifying the chain of indirect threats can aid in structuring Strategies that will tackle the 'root of the problem' more effectively.

6.5 Miradi

Miradi is an adaptive management software for conservation projects, supported by Open Standards and created by the CMP and the Sitka Technology Group (CMP, 2013; Miradi, n.d.). Miradi is used in conservation planning alongside the Open Standards to help practitioners design, monitor, manage and learn from projects to meet their conservation goals (CMP, 2013). Miradi has specific tools and commands that help practitioners formulate Threat Ratings, Target Viability and a Work Plan among various other inputs described within the Open Standards steps.

Following the rise of popularity in AM, Miradi has become a more frequented tool in conservation planning as it enables the concepts of AM to be used. Johnson *et al* (2012) adopted the use of conservation planning frameworks in their case study to recover wild tiger populations and their prey species in the Loa People's Democratic Republic. They went on to primarily follow the Open Standards management cycle and use Miradi to design elements of their plan. The Conceptual Models they created demonstrated the value of creating an initial model and reviewing it intermittently to support better monitoring and evaluation in accordance with the Open Standards guidelines. Lasch *et al* (2011) also used the Open Standards alongside Miradi to create a conservation action plan for Tanzanian chimpanzees (*Pan troglodytes*), which was organised by the Jane Goodall Institute. The decision was made to use Miradi as it supports AM (Lasch *et al.*, 2011).

Miradi itself has a platform for project sharing among practitioners called Miradi Share. This allows Project Teams, advisors and interested parties to view and collaborate on shared projects (MiradiShare, n.d.). Projects can be uploaded at any stage of their development as a draft, ready to publish or as ready for review. There are over 950 projects on Miradi Share with the majority accessible to the public (MiradiShare, n.d.). Among these projects are several different programs from organisations such as The Nature Conservancy. The Nature Conservancy's public programme includes various Miradi project portfolios and numerous reports on the progress of key actions. This is an invaluable resource for the conservation community as it shows the entire conceptualisation process through to implementation and adaption. Meeting step five of the Open Standards embodies the reiterated need for information sharing highlighted by AM and FOS to improve learning among practitioners, conservationists and stakeholders.

Chapter 4

Conservation action plan for the Indian Himalaya population of snow leopards 2019 – 2049

In this chapter, the framework from the Open Standards for the Practice of Conservation has been conceptualised to create a conservation action plan (CAP) for the Indian Himalaya population of snow leopards (See figure 7). A Conceptual Model with seven result chains has been created using Miradi version 4.5.0. The information collated in Chapter 2 has been used as the basis to structure the Conceptual Model. Inspiration from Chapter 3 was used to structure Strategies and Results Chains, building on where existing successes have been seen. Other Strategies that have been put forward in this CAP target Direct Threats that are currently not being addressed and require intervention.

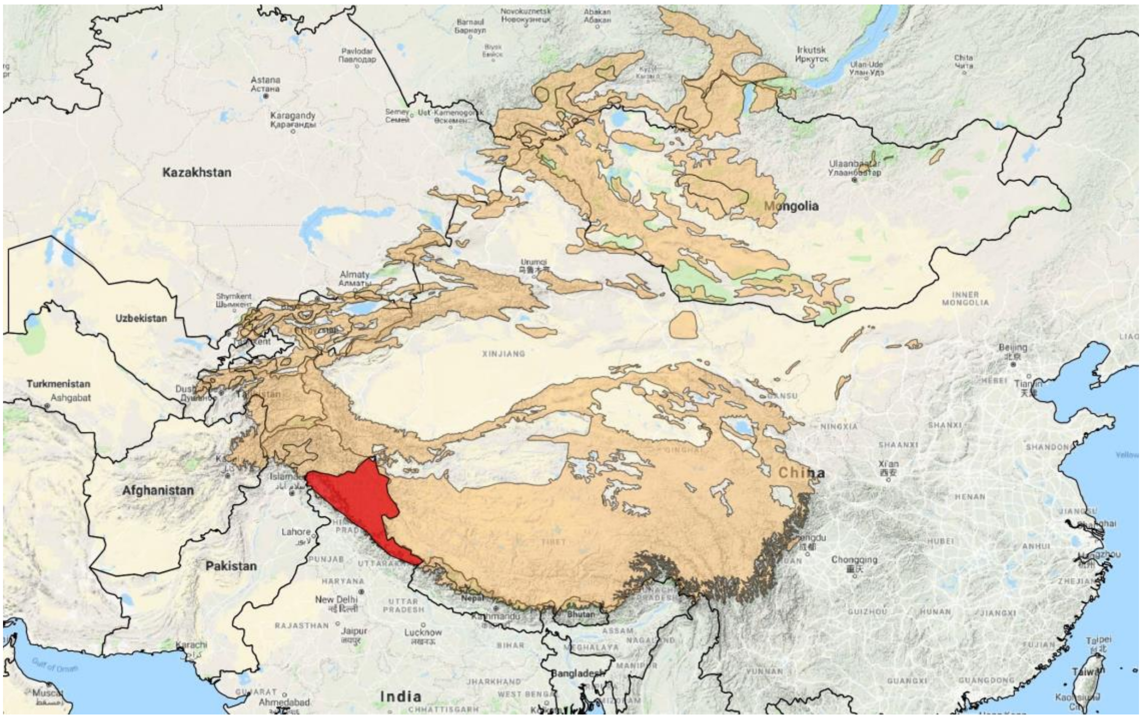

Figure 7: Map of the current estimated distribution of snow leopards (in orange) with the suspected Indian Himalaya population highlighted in red. Made in QGIS version 2.18.20 with data from the IUCN Red List.

7.0 Methodology

In the CAP created for this thesis, Miradi version 4.5.0 was used whilst following the guidance of the Open Standards. The CAP created is limited to steps one and two of the Open Standards. The CAP in this thesis used academic research conducted in the United Kingdom to create a draft of a 30-year plan for snow leopards in the Indian Himalayas from 2019 to 2049.

7.1 Conceptualisation

Following the information gathered in chapters One and Two, Miradi software was used whilst following specific commands and steps to conceptualise the CAP. This consisted of implementing the first stage of the Open Standards which is to conceptualise and create an initial Conceptual Model (CMP, 2013). Alongside following the steps in the Open Standards, guidance from Margoulis and Salafsky (1998) was used to support each of the stages of the Open Standards. The stages that were used in this project as outlined by Margoulis and Salafsky (1998) have been summarised in Figure 8. Through this process a thematic Conservation Target and Scope were assigned and Direct Threats to the targets were identified along with their Contributing Factors.

The following step encompassed the completion of a Threat Rating assessment in which each Direct Threat was evaluated using Miradi commands. These commands outlined the evaluation of a threat based on its Scope, Severity and Irreversibility (CMP, 2013).

Stage 1: Design a Conceptual Model
Step A1: Review and Compile Existing Information
Step A2: Develop an Initial Conceptual Model
Step A3: Identify and Rank Threats

Stage 2: Develop a Management plan
Step B1: Develop a Goal
Step B2: Develop Objectives
Step B3: Develop Activities

Stage 3: Develop a Monitoring Plan
Step C1: Determine Needs, Strategies and Indicators
Step C2: Select Methods

Figure 8: The stages and steps of designing, managing and monitoring conservation projects. Adapted from Margoluis and Salafsky (1998).

7.2 Development

Completion of conceptualisation or stage one of the Open Standards, led into using further Miradi commands to develop the CAP. This included stages two and three of the Open Standards being used to construct a full Conceptual Model. Once the Goals had been created, the associated Direct Threats and Contributing Factors could be selected to begin brainstorming draft Strategies. Once the draft Strategies had been chosen, they were ranked to determine which of them would likely be the best method to deliver a positive change to a Direct Threat. The best ranked Strategies were then linked to their relevant chain within the Conceptual Model and Results Chains were created for them. Result Chains, as with the Conceptual Model, are read from left to right. Once the Result Chains were finalised, Objectives and Indicators were individually assigned throughout the Results Chain.

A draft 30-year Conservation Action Plan for the snow leopard (*Panthera uncia*) population of the Indian Himalayas, 2019 – 2049.

8.0 Project Team

As this project is a draft CAP that will not be implemented, a theoretical team with positions and roles were created. These positions included: Director of Operations, Director of Human Wellbeing, Director of Ecology, Director of Education, Director of Law and Director of Communications (see Figure 9). The name created for this Project Team is The Snow Leopards of the Indian Himalayas (SLIH).

First Name	Last Name	ID	Organization	Position	Roles
Amber	Schofield	AS	Snow Leopards of the Indian Himalayas	Director of Operations	Leader/Manager, Project Advisor, Team Member
Position	–	DoHW	Snow Leopards of the Indian Himalayas	Director of Human Wellbeing	Team Member
Position	–	DoEc	Snow Leopards of the Indian Himalayas	Director of Ecology	Team Member
Position	–	DoEd	Snow Leopards of the Indian Himalayas	Director of Education	Team Member
Position	–	DoL	Snow Leopards of the Indian Himalayas	Director of Law	Team Member
Position	–	DoC	Snow Leopards of the Indian Himalayas	Director of Communications	Team Member

Figure 9: Miradi core team diagram showing the leadership roles within the team of the theoretical Non-Governmental Organisation Snow Leopards of the Indian Himalayas.

8.1 Project Description

The snow leopard (*Panthera uncia*) is by nature one of the most elusive members of the *Panthera* family and very little is known about their ecology and life history. They are a vulnerable species with population estimates widely varying. The IUCN’s assessment suggests the population estimate is between 2,710 – 3,386 globally (McCarthy *et al.*, 2017). There is estimated to be a population of 450 - 500 snow leopards in the Indian Himalayas (McCarthy *et al.*, 2017). The total potential habitat range in the Indian Himalayas is approximated to be up to 89,000 km2, with 75,000km2 estimated occupied, and only 20% protected (McCarthy *et al*, 2017). Home ranges of snow leopards vary from as little as 12km^2 to over 400km^2, the distance of a snow leopards home range depends on the scarcity of prey from country to country (Nyhus *et al.*, 2016). Adult males typically have larger ranges than the females (Nyhus *et al.*, 2016).

Scientific suggestions of three subspecies developing, due to population isolation, has raised concerns on the future of the genetic viability of this species if the populations become permanently isolated (Janecka *et al*., 2017). Viability assessments that were conducted revealed illegal trade, secondary poisoning and trapping, feral dogs, illegal hunting, retribution killing, prey base depletion and habitat loss and degradation to be the most damaging threats to the population (Thiele, 2003). These threats had the highest rankings and without intervention would diminish the population, increasing the risk of upgrading the IUCN's classification to endangered (Snow Leopard Network, 2014). A conceptual model and results chain were created with the purpose to minimise the direct threats. Six strategies were proposed: Improve wildlife laws and international cooperation, control feral dogs, create new and expand Protected Areas to create wildlife corridors, introduce widespread adoption of wildlife friendly best practices, increase awareness for the value of snow leopards as a keystone species and set up a livestock insurance scheme. Indicators and objectives were formed for the strategies to create an effective monitoring plan that could alter the implementation of the strategies if appropriate. For example, if climate change became a higher-ranking threat, or if emerging threats affect the indicators during the duration of the project. The main aim of this action plan was to protect the ecosystem to allow the snow leopard population to grow, whilst creating awareness of the plight of the snow leopard.

8.2 Site Description

The snow leopard is one of few carnivore's endemic to the high-altitude montane region of the Indian Himalayas. The range of snow leopards within the Himalayas is 75,000 km^2 and is threatened by proposed industrial developments and climate change (Bhatnagar, 2016). The global snow leopard population has had "An estimated continuing decline of at least 10% within 10 years or three generations" (McCarthy *et al.*, 2017). The Himalayas as a whole are thought to hold up to 10% of the global snow leopard population (Bhatnagar, 2016). The Himalayas are widely regarded as a biodiversity hotspot for their lowland forests, glacier fed fresh water rivers (Allen, 2010; Mittermeier, Turner, Larsen, Brooks,& Gascon,2011). There is additionally a rich historical value to the area, with geomorphic history and transpiring as the source of many major religions, cultures and traditions. The current Protected Areas in the India Himalayas are estimated to cover less than 20% of the range that snow leopards inhabit (Bhatnagar, 2016).

8.3 Vision Statement

"The vision is to protect and preserve the ecological health of the ecosystem in the Himalaya. This will be achieved by reducing the highest risk threats, creating an awareness of the role that snow leopards serve as a keystone species, and connecting populations across the Himalayas that may have become isolated, thereby preventing fragmentation and isolation. These accumulatively will increase the population of snow leopard from 450 – 500 to 750 individuals. The intention is to protect the ecosystem from the disruption of human development to allow the snow leopard population to thrive."

8.4 Conceptual model

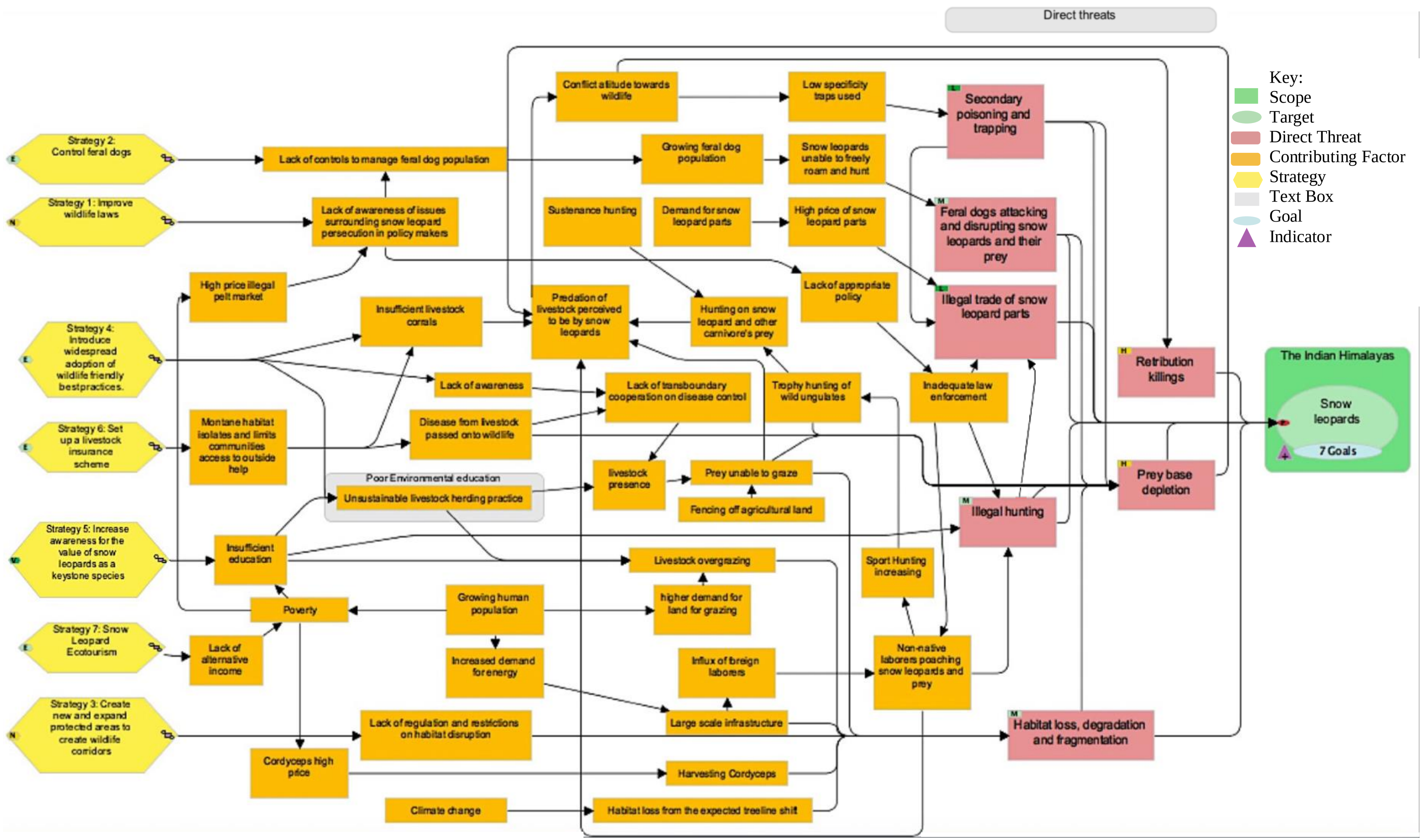

Figure 10: Miradi version 4.5.0 Conceptual Model displaying the Scope, Target, Direct Threats, Contributing Factors and Strategies.

Following the Conceptual Model, the Scope, Target, Direct Threats, Contributing Factors and Strategies will be displayed as they would be within the Miradi file through this report.

8.5 **Scope**: The Indian Himalayas

Details: The Indian region of the Himalayas spans over ten Indian states and supplies water to a large part of the Indian subcontinent. The Himalayas form the northern boundary of the country to separate India from China. The mountains of the Himalayas are home to many sacred human traditions and practices, such as pilgrimages and Buddhist temples. The region also has a rich ecological value being home to montane grasslands and shrublands, temperate, tropical and sub-tropical forests. Central to this project, the previously endangered snow leopard is also found in this region. Snow leopards have naturally far reaching home ranges to search for prey and mates across baron mountainous steppe landscapes. Protecting snow leopard habitat range from human industrial development is becoming of growing importance as the demand for hydropower grows. Although there are currently Protected Areas within the Indian Himalayas these are only believed to cover less than 20% of snow leopard range. This would struggle to contain more than one adult male.

8.6 **Target**: Snow leopards

Details: The snow leopard (*Panthera uncia*) was described in 1775 by Schreber and is the closest relative of the tiger (*Panthera tigris*). Globally they inhabit 12 countries at elevations of 3,000m to over 5,000m in the Himalayan and Tibetan Plateau. Physically the snow leopard is one of the smallest 'big cats', with it being the smallest member of *Panthera*. Almost all members of the *Panthera* genus are vulnerable or endangered on the IUCN's red list apart from Jaguars which are near threatened. All members have a declining population trend. The population decline in snow leopards began to grow in the late 1900's with the desire to have skins as a symbol of status, pushing the illegal trade and hunting of the species. This has continued to be one of the biggest direct threats to the species despite its listing in CITES in 1975. More threats have emerged and become prominent in the decline of snow leopard populations, namely retribution killings, habitat fragmentation and prey base depletion. Climate change poses a threat to the global population and the extent of this emerging threat is currently unknown and the impacts are difficult to predict. This is because little is currently known about the ecological niche limits of snow leopard's adaptability. Snow leopards are a keystone species in their ecosystem and so play a key role in maintaining the carrying capacity of the habitat. They also serve importance as a symbol of cultural value and beliefs held by many religions. Snow leopards hold a vital role as a flagship species and ambassador for their habitat, viewed by many as an icon of the mountains which need protecting from human driven threats.

8.7 Goals

For the thematic Conservation Target, seven goals were created. The Goals target efforts to increase the snow leopard population size. The 30-year long period of this CAP provides enough of a period of time to substantially increase the snow leopard population in accordance with their age of maturity, litter sizes and inter birth interval. Alongside each of the seven Goals, Indicators were created.

Goal 1: Population

A healthy population of snow leopards within the Indian Himalayas with at least 750 individuals by 2049. A healthy population means a self-sustaining population.

Indicator: # of mature snow leopards from new population estimates.

Goal 2: Prey population

By 2049 the overall prey population for snow leopards will increase by >25%.

Indicator: # of infant prey ungulate species recruited into mature population.

Goal 3: Protected Areas

Increase Protected Areas to cover 50% (37,500 km2) of suspected snow leopard range within the Indian Himalayas by 2049.

Indicator 1: Results of land quality assessments.

Indicator 2: % of new land designated as PA now under protection.

Goal 4: Persecution

By 2039 retribution killings have been reduced by 100%.

Indicator: # of snow leopards killed in retribution following predation or pre-emptively.

Goal 5: Illegal Hunting

By 2040 Illegal hunting no longer takes place within the Indian Himalayas.

Indicator 1: # of cases of illegal activity.

Indicator 2: # of poison baits being set.

Indicator 3: # of traps or snares being set

Goal 6: Illegal Trade

By 2045 the illegal trade ring has been broken up and the trade of snow leopard parts from the Indian Himalayas no longer takes place.

Indicator 1: Detection of illegal trade taking place.

Indicator 2: # of snow leopard parts confiscated.

Goal 7: Feral Dogs

By 2049 feral dog populations are stable and harassment of snow leopards and their prey has decreased by 30%.

Indicator 1: # feral dog population density.

Indicator 2: # of reports of feral dog attacks on wildlife.

8.8 Direct Threats

During the initial conceptualisation a number of Threats were identified. This was reduced down to seven key Direct Threats which were identified as: secondary poisoning and trapping, illegal trade, illegal hunting, retribution killing, habitat loss, prey base depletion and feral dogs attacking and disrupting snow leopards and their prey.

Using the Miradi Threat Ratings tool, retribution killing, illegal hunting, prey base depletion and habitat loss, degradation and fragmentation were identified as the highest rated threats. Threat ratings can vary from *Low* to *Very High* and are created from the scope, severity and irreversibility of a threat. Once a rating had been selected for the scope, severity and irreversibility, the Threat Ratings tool created a summary rating. The accumulated ratings of the threats in this project were *High*, with an overall project rating of *Very High* (see Figure 11).

Threats \ Targets	Snow leopards	Summary Threat Rating
Illegal hunting	Medium	Low
Illegal trade of snow leopard parts	Medium	Low
Secondary poisoning and trapping	Low	Low
Retribution killings	High	Medium
Feral dogs attacking and disrupting snow	High	Medium
Habitat loss, degradation and	High	Medium
Prey base depletion	High	Medium
Summary Target Ratings:	High	**Overall Project Rating** Very High

Figure 11: The Low, Medium, High and Very High ratings given to the identified threats and their summary ratings.

8.8.1 Retribution killings

Details: Retribution killing of snow leopards in revenge for livestock predation is one of the highest rated threats. Up to 30% of people living in Nepal are below the poverty line, and up to 88% of mountain inhabitants are dependent on agriculture and livestock. The high dependency on livestock creates high tensions within human-wildlife conflict when there is a prospect of losing livestock to a wild animal. Snow leopards will opportunistically hunt livestock and have even been caught in corrals. Inefficient guarding practices and poorly constructed corrals give snow leopards the opportunity to access livestock to hunt. Snow leopards are often wrongly blamed as the culprit of livestock predation as wolves and feral dogs can make up to in the region of 60% of livestock predation. Some herders have gone as far to pre-emptively kill snow leopards in an effort to prevent livestock predation.

Ratings:

- Scope: Very High
- Severity: High
- Irreversibility: High
- **Summary Threat Rating: Medium**

8.8.2 Secondary poisoning and trapping

Traps and poison are often used to defend livestock and crops from vermin and carnivorous species such as wolves (*Canis lupus*). Non-selective trapping and poisoning methods often result in snow leopards being an unintended victim. Wide ranging use of these low specificity, fatal traps and baits threatens the snow leopard population in the Himalayas. Poisoning snow leopards often results in their skin being able to be harvested fully intact, creating temptation to opportunistically trade parts of snow leopards that were unintentionally killed.

Ratings:

- Scope: Low
- Severity: High
- Irreversibility: High
- **Summary Threat Rating: Low**

8.8.3 Feral dogs attacking and disrupting snow leopards and their prey

Feral dogs are beginning to emerge as a threat to snow leopards and their prey in the Himalayas. Historically, free roaming or feral dogs have proven to be damaging to wildlife and disrupt ecosystems as an intraguild competitor. Dogs can spread disease and often roam in packs, harassing and killing wildlife. Footage is more frequently emerging of dogs chasing and harassing snow leopards, impacting upon the cat’s stress levels and energy stores. The presence of dogs is likely to deter wildlife from inhabiting the same areas, potentially disrupting snow leopards and their preys roaming patterns. The presence of these dogs may disrupt attempts to recover populations of wildlife.

Ratings:

- Scope: High
- Severity: High
- Irreversibility: High
- **Summary Threat Rating: Medium**

8.8.4 Illegal trade of snow leopard parts

Illegal trade in snow leopard parts, particularly: skins, bones, teeth and claws has been on the rise globally in recent years despite the species being listed under Appendix 1 of the Conservation on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Snow leopards are trapped and hunted deliberately or opportunistically before their parts are brought onto the black-market trade. Due to the clandestine nature of the trade it has been difficult to assess the number of snow leopard parts annually traded in the Himalayas. Global estimations put the rate between 220 to 450 snow leopard parts traded annually since 2000.

Ratings:

- Scope: Medium
- Severity: Medium
- Irreversibility: Medium
- **Summary Threat Rating: Low**

8.8.5 Prey base depletion

Snow leopards prey base in the Indian Himalayas primarily consists of blue sheep (*Pseudois nayaur*), Siberian ibex (*Capra sibirica*), argali (*Ovis ammon*) and marmots (*Marmota himalayana*). Currently all of these prey species except for argali are Least Concern with an unknown population trend on the IUCN's Red List. Argali are listed as Near Threatened with a decreasing population trend after an assessment performed on their population in 2008. Livestock herding is posing a threat to these species as competition with livestock for pasture, and disease from unvaccinated livestock is damaging populations. These populations are also under threat from illegal and legal trophy hunting. Legal trophy hunting can be a tool for conservation but unsustainably managed hunting during the breeding season or when young are being cared for can result in increased decline of the population size. Prey populations are a direct determinant of snow leopard abundance and drive ecosystem functions. The loss of any prey populations reduces the carrying capacity for snow leopards.

Ratings:

- Scope: Very high
- Severity: High
- Irreversibility: Medium
- **Summary Threat Rating: Medium**

8.8.6 Illegal hunting

The direct threat of illegal hunting is a highly rated threat to the Indian Himalayan snow leopard population. In the countries of the Himalayas the most common methods of hunting and killing snow leopards are using poison, shooting, steel traps and snares. Snow leopards are killed most often in retaliation or as an unintended target, with a slim amount being killed as a result of intentional targeting for later trade. Reports indicate that China has the highest annual rate of snow leopard poaching throughout the Himalayas with an estimate of 103 -

236 adult snow leopard being poached annually. The total rate for the Himalayas is estimated at 156 - 361 adults poached annually. Average suspected detection rates suggest < 33% of poaching cases are detected in the countries throughout the Himalayas, meaning poaching rates could be much higher.

Ratings:

- Scope: Medium
- Severity: High
- Irreversibility: High
- **Summary Threat Rating: Low**

8.8.7 Habitat loss, degradation and fragmentation

At altitudes between 9,800 and 18,000 feet you find the rugged montane habitat which is home to the snow leopard. Over the suspected 75,000 km2 that snow leopards inhabit Within the Indian Himalayas they follow their prey across montane grasslands, alpine meadows and subalpine forests. A snow leopards home range can vary between 12 km2 to 400 km2. The Himalayan mountain range influence the climate of the Tibetan Plateau by preventing the influx of dry winds blowing south, keeping south Asia warmer than subsequent temperate regions in other continents. Within the ecosystem of the Himalayas, melting ice creates freshwater systems that both humans and wildlife are dependent on. The habitat is under threat from infrastructure and the predicted repercussions of climate change. Human population density in snow leopard habitat is among the lowest in the world but the impacts from human development are pervasive. Snow leopards naturally low density and large home ranges make them particularly vulnerable to habitat fragmentation and loss. Recent findings have shown the common leopard (*Panthera pardus*) occupying the same habitat as snow leopards, thought to be due to the warmer summer temperatures from climate changes. The introduction of new competitor species could increase the vulnerability of snow leopards, alongside prey species possibly adopting new distributions as their habitat changes. Studies have found that under simulations of current predicted levels of climate change, the expected treeline shift will result in a loss of 30% of snow leopard habitat.

Ratings:

- Scope: High
- Severity: High
- Irreversibility: High
- **Summary Threat Rating: Medium**

8.9 Contributing factors

The Contributing Factors combine Direct Threats and Indirect Threats that influence the key Direct Threats. Direct threats were first identified before establishing links to indirect threats. A total of 40 Contributing Factors/Indirect threats were recognised in the final draft.

The 40 Contributing Factors have been summarised in Table 2 below. The links between the chain of each Contributing Factor can be seen in Figure 10.

Table 2: Contents of contributing factors identified in the Conceptual Model.

Contributing factor	Details	All Direct Threats linked to
Conflict attitude towards wildlife	Human-wildlife conflict often arises when the interaction between people and wild animals negatively impacts upon human resources or wildlife and their habitat.	• Retribution killings • Secondary poisoning and trapping • Illegal trade of snow leopard parts • Prey base depletion
Low specificity traps used	Traps are used to catch carnivores that are perceived as a threat to livestock, most commonly intended	• Secondary poisoning and trapping

	to catch wolves (Canis lupus). The low specificity of the traps often means snow leopards are caught.	• Illegal trade of snow leopard parts • Prey base depletion
Lack of controls to manage feral dog population	Inadequate attention to sterilisation has allowed the stray dog population to grow without constraint. The impact on livestock, wildlife and the local economy needs to be brought to the forefront.	• Feral dogs attacking and disrupting snow leopards and their prey. • Prey base depletion
Growing feral population	Stray dogs can hunt in packs of five to eighteen and have been responsible for in the region of 60% of livestock predation. Breeding with wolves is becoming a common occurrence.	• Feral dogs attacking and disrupting snow leopards and their prey. • Prey base depletion
Snow leopards unable to freely roam and hunt	Video footage has emerged showing packs of wild dogs harassing, chasing, cornering and injuring snow leopards.	• Feral dogs attacking and disrupting snow leopards and their prey. • Prey base depletion
Lack of awareness of issues surrounding snow leopard persecution in policy makers	Policy makers may be unaware of the issues facing the snow leopard with illegal hunting and trade. As such, they do not create laws or policies sufficient to combat the issue or that can be successfully enforced.	• Illegal trade of snow leopard parts
Sustenance hunting	Wild ungulates are often hunted by humans for sustenance in regions where access to other means or resources is limited from cultural or logistical boundaries. Sustenance hunting of snow leopard prey can lead to snow leopards hunting livestock as an alternative.	• Retribution killings • Secondary poisoning and trapping • Illegal trade of snow leopard parts • Prey base depletion
Demand for snow leopard parts	Snow leopard parts are used in traditional cultural practices and for medicinal purposes. Snow leopard parts are also desired as a symbol of status and wealth.	• Illegal trade of snow leopard parts

High price of snow leopard parts	Pelts, bones, claws and skulls all retail for high prices.	• Illegal trade of snow leopard parts
Lack of appropriate policy	Policy surrounding the protection of snow leopards may not be clear. They do not succinctly outline the principles and actions that should be taken to reduce illegal trade and hunting.	• Illegal trade of snow leopard parts
High price illegal pelt market	Snow leopard skins can be sold for up to $1,500.	• Illegal trade of snow leopard parts
Insufficient livestock corrals	Livestock corrals are frequently not built well enough to keep carnivores out due to limited materials or herders are not aware of the faults in the structural design and so do not know how to improve the security of the corrals.	• Retribution killings • Secondary poisoning and trapping
Predation of livestock perceived to be by snow leopards	Lack of wild prey and livestock left unattended can contribute to snow leopard predation on livestock.	• Retribution killings • Secondary poisoning and trapping
Hunting on snow leopard and other carnivore's prey	Prey depletion forces snow leopards as an apex predator to attack livestock.	• Retribution killings • Secondary poisoning and trapping
Trophy hunting of wild ungulates	Trophy hunting of snow leopard prey species has caused a decline in their populations as they are becoming over hunted from unsustainable management of the trophy hunting.	• Prey base depletion
Lack of awareness	Limited awareness of the patterns of disease spread and the impact it has on the surrounding environment.	• Prey base depletion • Habitat loss, degradation and fragmentation
Lack of transboundary cooperation on disease control	Transboundary disease control may not be adequately funded or researched. As such, diseases spread between herds of livestock often get passed onto wildlife (such as prey species of the snow leopard) which can be fatal. Loosing livestock to disease may	• Prey base depletion • Habitat loss, degradation and fragmentation

	provoke herders to partake in retaliatory killings or pre-emptively hunting snow leopards to prevent any further livestock loss.	
Sport hunting increasing	Foreigners have been found by studies to be more likely to opportunistically hunt wild animals than the local people are.	• Prey base depletion
Inadequate law enforcement	Laws supporting governmental policy could be difficult to enforce due to political disruption, limited information on possible offenders and trading rings, and difficulty manning and patrolling montane habitat to search for signs of poachers. The laws may also have unfit procedures in place to deal with instances when an offence is committed.	• Illegal hunting • Illegal trade of snow leopard parts
Montane habitat isolates and limits communities' access to outside help	In the montane villages access to outside help is restricted as the rocky terrain is difficult to navigate and access with vehicles.	• Retribution killings • Prey base depletion
Disease from livestock passed onto wildlife	Studies in the area have shown the ability of livestock to pass disease onto wild ungulates.	• Prey base depletion
Prey unable to graze	Livestock can disrupt prey from their grazing on the sparse landscape and force them to move.	• Prey base depletion • Habitat loss, degradation and fragmentation
Insufficient education	Limited education available to locals makes a heavy reliance on livestock herding from lack of other taught and learned skills. External education on livestock husbandry practices is often not available in remote montane locations where herding takes place. Passed down practices within villages may not be ideal for coexisting with snow leopards and their prey species.	• Prey base depletion • Habitat loss, degradation and fragmentation • Illegal hunting • Illegal trade of snow leopard parts

Unsustainable livestock herding practice	Herding practice may result in prey disruption from overgrazing due to not knowing, understanding, or being able to follow sustainable practices.	• Prey base depletion • Habitat loss, degradation and fragmentation
Livestock presence	Livestock are often accompanied by a herder and occasionally dogs which provide disruption to snow leopard prey species.	• Prey base depletion • Habitat loss, degradation and fragmentation
Fencing off agricultural land	Farmers and herders can fence off land to stop wild ungulates using the land to graze or to protect their crops.	• Prey base depletion • Habitat loss, degradation and fragmentation
Higher demand for grazing	As the livestock population grows to meet the demands of human need for resources, the need for grazing areas increases. The montane habitat in snow leopard range is sparse of vegetation. The increased numbers of livestock grazing deplete the little vegetation that does grow.	• Habitat loss, degradation and fragmentation
Livestock overgrazing	Herding practices often lead to overgrazing due to reluctance or inability to travel longer distances to find adequate pasture for livestock. Due to the natural low productivity in the Himalayan ecosystem, livestock grazing has a high impact on biomass and plant cover, creating a suboptimal habitat.	• Habitat loss, degradation and fragmentation
Poverty	In the Eastern Himalayas poverty rates are high and exacerbated by environmental vulnerability. Additionally, people suffer from livelihood insecurity, resource stress and exclusion from the mainstream economy.	• Habitat loss, degradation and fragmentation • Feral dogs attacking and disrupting snow leopards and their prey • Illegal trade of snow leopard parts • Prey base depletion

		• Illegal hunting
Influx of foreign labourers	As job opportunities in infrastructure arise, foreign workers who differ socio-economically and culturally are brought into the area.	• Illegal hunting • Illegal trade of snow leopard parts
Lack of alternative income	Lack of opportunity for alternative income limits livelihood options and can lead to contributing to illegal activity.	• Habitat loss, degradation and fragmentation • Feral dogs attacking and disrupting snow leopards and their prey • Illegal trade of snow leopard parts • Prey base depletion • Illegal hunting
Growing human population	The earth is now populated by over 7 billion people with the number still rising at an unprecedented rate. As the population grows, demand for resources and services grows alongside it.	• Habitat loss, degradation and fragmentation • Illegal hunting • Illegal trade of snow leopard parts
Increased demand for energy	The growing human population creates an increasing demand for energy production. If every human consumes as much as the average US citizen, four earths would be needed to sustain their demands.	• Illegal hunting • Illegal trade of snow leopard parts
Large scale Infrastructure	In the Eastern Himalayas, solar, wind and hydro power are projected as the fastest growing energy sectors. The construction rate in the Himalayas is currently experiencing unprecedented levels. In India the Himalayas have the world's highest density of planned dams.	• Habitat loss, degradation and fragmentation • Illegal hunting • Illegal trade of snow leopard parts
Non-native laborers poaching snow leopards and prey	Non-native locals have been found to illegally hunt snow leopards and hunt their prey for trade.	• Illegal hunting • Illegal trade of snow leopard parts

Lack of regulation and restrictions on habitat disruption	Restrictions on disturbance to wildlife are often not considered or enforced from a difficulty to prove or maintain. The process of developing infrastructure fragments the habitat with road construction and infrastructure surrounding the power plants.	• Habitat loss, degradation and fragmentation • Illegal hunting • Illegal trade of snow leopard parts
Cordyceps high price	Cordyceps is a fungus that can be used medicinally and to improve sporting performance. As a product it is in high demand. The value of the fungus has increased by roughly 1000% between 1997 and 2011.	• Habitat loss, degradation and fragmentation • Prey base depletion
Harvesting Cordyceps	Cordyceps is a fungus harvested for use in medicinal products. The season for harvesting can see hundreds of people entering snow leopard habitat, disrupting prey and altering the landscape as the fungus is extracted.	• Habitat loss, degradation and fragmentation • Prey base depletion
Climate change	The global temperature has increased by 1.8 degrees since 1880 and ice sheets are losing 413 Gigatons per year. As the climate changes, habitats and ecosystems are impacted upon, affecting population numbers. The extent to which climate change will affect snow leopard populations is unknown. As the dynamics of the Himalayas shift due to climate changes it is unknown how snow leopard numbers will respond.	• Habitat loss, degradation and fragmentation • Prey base depletion
Habitat loss from the expected treeline shift	Forrest *et al*., (2012) predict up to 30% of Himalayan snow leopard habitat will be lost to climate change. The changes in climate and habitat may also change competitor predator and prey species presence in the Himalayas.	• Habitat loss, degradation and fragmentation • Prey base depletion

8.10 Strategies

Seven strategies have been created for this CAP. These strategies are: 1) Improve wildlife laws, 2) Control feral dogs, 3) Create new and expand Protected Areas to create wildlife corridors, 4) Introduce widespread adoption of wildlife friendly best practices, 5) Increase awareness for the value of snow leopards as a keystone species, 6) Set up a livestock insurance scheme and 7) Snow leopard Ecotourism.

8.10.1 Results chains

The chains are created with a Strategy, Intermediate Result, Threat Reduction Result and the Conservation Target (see Figure 6). The Intermediate Result and Threat Reduction Result have been given Objectives and Indicators to create a basis for measuring successes. Every objective created has been given at least one Indicator. The chains are based on sections of the Conceptual Model and effectively change Contributing Factors into positive assumptions.

8.10.2 Strategy Ratings and Classification

The Miradi Rating Tool was used to give each Strategy a rating. The assumed Potential Impact and Feasibility are selected to create an overall rating or ‘Roll-up’. For Potential Impact, the rating selected is based on confidence in evidence that this strategy will achieve the Goals and/or Objectives set. The scale for the rating included: Not Specified, Low, Medium, High and Very High. The Feasibility rating follows the same scale as the Potential Impact but looks at whether strategy could be implemented within likely time, finances, staffing and ethics. Depending on the ratings chosen for Potential Impact and Feasibility, the overall rating given to the strategy can be: Unknown, Not Effective, Need More Info, Effective or Very Effective.

Within each strategy a Standard Classification can be selected as a way to identify and categorise Strategies. Within Miradi, the available classifications included sub-divisions of Land/Water Protection, Land/Water Management, Species Management, Education & Awareness, Law & Policy, External Capacity Building and Livelihood, Economic & Other Incentives (see Figure 12).

Figure 12: The Standard Classification tool options for Strategy classification.

8.11 Strategy One: Improve wildlife laws

Strategy 1: Improve wildlife laws, has been split into three lines of approach to give more clarity on the theory of change and add more detail into the range and reach of the strategy (see Figure 13).

Details: Often laws in place to protect wildlife are inadequate or the enforcement of the laws is inconsistent. In the case of snow leopards, they are protected under CITES appendix I, meaning all hunting and trade of the species is illegal. Despite this, 21 to 45 snow leopards are estimated to be poached annually, with a suspected 38% detection rate for poaching, the true number could be substantially higher. The improvement of wildlife laws, tailored to protect snow leopards, will drastically reduce and ultimately stop illegal hunting by 2040 and illegal trade by 2045. This will be achieved through three approaches: Lobbying the local government, providing support to law enforcement, and raising awareness of the consequences of illegal hunting and trade.

Classification: 5.2 Policies & Regulations

Rating: Need More Info

Section A1: Lobby government

Details: By 2033, appropriate laws to protect snow leopards will have passed through government procedure and can be enforced by 2035.

Classification: 5.1 Legislation

Rating: Need more Info

Section A2: Support law enforcement

Details: Law enforcement will be supported by strengthening the evidence base to convict guilty individuals and ensure governments are upholding and meeting requirements on promises to reduce illegal activity surrounding snow leopard conservation.

Classification: 5.4 Compliance & Enforcement

Rating: Effective

Section B: Raising awareness strategy

Details: Social media outlets will be used in this strategy to create widespread awareness of the severity of charges and fines given to individuals found guilty of partaking in illegal hunting or trading of snow leopards.

Classification: 4.3 Awareness & Communications

Rating: Need More Info

8.11.1 Theory of change for Results Chain One: Improve wildlife laws

Section A1 of the strategy will lobby the government. Once the Indian government has been lobbied, the improvement in wildlife laws will lead to a decrease in illegal hunting and illegal trade. This assumption relies on both policy makers understanding the need for better measures to protect snow leopards and that lobbying the government will not be a finite effort. Lobbying of the government will be continuous to monitor changes in laws and the environmental impact across India. In the process of lobbying the government, the awareness of conservation issues in policy makers will be improved. This creates a greater ease in lobbying the government to establish appropriate laws and policies. The policies will then be enforced globally, ensuring more widespread acknowledgement of protections in place for snow leopards. Following this, improvements will be made in transboundary cooperation to ensure policy enforcement is equal and unbiased.

In section A2 the law enforcement will be enhanced. This will be achieved by increasing the investigative capacity into snow leopard trafficking. This will create a strengthened evidence base, leading to more prosecutions of known traders and traffickers. Sentences and fines for prosecuted individuals will be enforced and illegal snow leopard parts confiscated. The confiscated parts can be donated for use in research, display in museums or education programs. Overall, there will be decreases in illegal trade following the improved evidence base, as making detection of the trade easier and providing more proof will make prosecutions more likely. An assumption throughout this strategy is that the legal process will not be interfered with by corruption following the introduction of an impartial external supervisor.

In section B awareness of the legal process will be raised which will cause decreases in illegal trade. Using media and social media to cover and broadcast court proceedings and fines will deter involvement in illegal trade. The use of social media to publicise the consequences of illegal trade utilises modern and progressive ways to communicate issues with the public.

In conclusion, this strategy will improve the laws in place and ensure they are enforced, increasing the detection rate and number of prosecutions, and raising awareness of the existing illegal trade and the penalties in place for involvement. This will contribute to achieving Goals One, Five and Six.

8.11.2 Content of Results Chains

Within each Intermediate Result put into a Results Chain, details on the theory of change, assumptions and any Objectives and Indicators were specified. All of these inputs have been collated into tables for each Results Chain. In some instances, an Indicator may be given without an Objective. In these cases, the Intermediate Result is taking advantage of all exploits available in the situation and may not directly benefit any conservation aims, however, this could improve human wellbeing and animal welfare. Any details regarding the theory of change, Objectives and Indicators have been included in the tables below. A '–' symbol has been used to indicate that an objective or indicator as they were not applicable.

8.11.3 Intermediate Result inputs for Results Chain One Section A1.

Table 3: Content of Intermediate results in results chain one section A1 that can be seen in Figure 13.

Intermediate result	Details	Objective	Indicator
Awareness of wildlife conservation issues in policy makers is improved	Improving awareness of the plight of the snow leopard in policy makers will create the means for development of better laws and policy.	By 2021, the majority of policy makers understand what is required in new policies to protect snow leopards.	# of policy makers aware of snow leopard threats.
Lobby government for appropriate wildlife policy and laws to exist	The establishment of realistic and appropriate laws will help assure the future of snow leopards by providing legal protection.	Laws created by 2033.	Progress of development of law proposals.
Policies enforced nationally	National enforcement of laws and policies created will ensure that there is widespread acknowledgment of snow leopard protection is in place.	By 2035, the new laws have passed and can be put in place.	# of laws accepted and passed through the government. Changes in federal and local government policy.

Transboundary cooperation on policy awareness and enforcement improved	A clear set of laws and policies on handling what counts as illegal activity against snow leopards.	By 2037, policies and laws are adopted and can be seen to be working.	# of discussions held between policy enforcers.

8.11.4 Intermediate Result Inputs for Results Chain One Section A2.

Table 4: Content of Intermediate results in results chain one section A2 that can be seen in Figure 13.

Intermediate result	Details	Objective	Indicator
Investigative capacity into snow leopard trafficking enhanced	Creating a team to enhance the investigative capacity and gather evidence on the illegal snow leopard trade will create valuable insight and help with court cases.	By 2020, a team of investigators is established with a minimum of 5 members on the team.	# of investigators actively examining existing and possible cases.
Evidence base strengthened	A strengthened evidence base creates stronger court cases to prosecute individuals involved in illegal trade.	By 2025, the evidence base has increased by >35%.	Knowledge of number of cases of proven illegal activity against snow leopards.
The effect of corruption within legal affairs is reduced	The introduction of an external supervision eliminates opportunity for corruption.	-	-
Known traders/traffickers prosecuted	Prosecuting offenders reduces the spread and cohesion of the illegal trade ring.	By 2035, all outstanding offenders have been prosecuted.	Number of annual court proceedings that have followed procedure to its entirety.

Convicted traffickers' sentence or fine enforced	Enforcement of sentences and ensuring individuals prosecuted fulfil their sentence discourages involvement in illegal trade.	-	-
Confiscated items do not re-enter trade	Removal of items from the trade prevents them re-entering and effectively helps to shut the trade ring down knowing items are likely to be discovered and confiscated.	Number of confiscations decreases over time as less parts are remaining in trade network. By 2043, there are no more parts to confiscate.	# of confiscations made by authorities.
Items confiscated are donated to biological research or museums.	Parts can be used to help build evidence and knowledge base on snow leopards and be used for educating the general public about the plight of the snow leopard.	-	-

8.11.5 Intermediate Result inputs for Results Chain One Section B

Table 5: Content of Intermediate results in results chain one section B that can be seen in Figure 13.

Intermediate result	Details	Objective	Indicator
Increased media coverage of snow leopard related arrests and court proceedings	The media coverage can be followed online to raise awareness of the severity of illegal activity that effects snow leopards.	-	-
News coverage of fines and arrests targeted at	Targeting media coverage at countries driving demand	-	-

countries driving demand.	discourages interest and involvement in driving the trade.		
Public understand that wildlife law is enforced, and it is illegal to trade snow leopards	General public understanding that wildlife law is taken seriously, and actively enforced and illegal activity will be prosecuted discourages illegal trade.	-	-
Future wildlife trade deterred	These assumptions will lead to a decrease in interest in the wildlife trade.	-	-

8.11.6 Threat Reduction Results in Result Chain One

Table 6: Content of Threat Reduction Result inputs for Results Chain One that can be seen in Figure 13.

Threat reduction result	Details	Objectives	Indicators
Decrease in illegal trade	If the legal repercussions of illegal trade are made harder to escape and become common knowledge in public interest, there should be a decrease in illegal trade as it is a less appealing risk.	By 2045, illegal trade has decreased by 100%.	# of snow leopard parts entering the trade. # of parts confiscated. # of reports of poaching.
Decrease in illegal hunting	If laws are put in place and successfully enforced the assumption is that this will result in a reduction in illegal hunting.	By 2030, when interviewed, local residents show they no longer harm snow leopards. By 2040 illegal hunting no longer takes place.	Local residents' attitude towards snow leopards. Snow leopard population size.

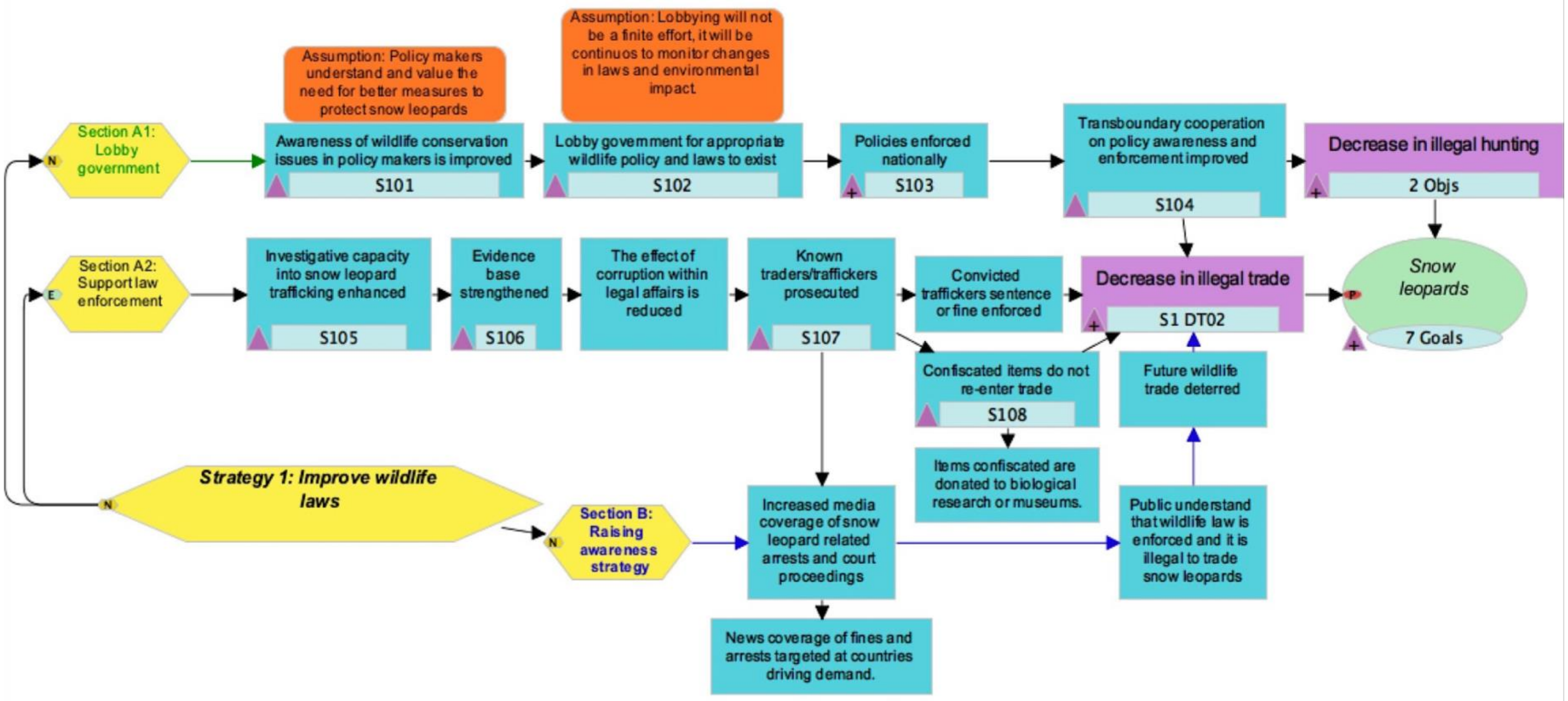

Figure 13: Results chain for Strategy 1: Improve wildlife laws.

8.12 Strategy Two: Control feral dogs

Details: This strategy will target the growing threat of increasing feral dog populations and the harm they cause to snow leopards and their prey. Historically, dogs have in numerous cases exacerbated conservation concerns for vulnerable species. Packs of feral dogs have been documented harassing snow leopards by chasing and cornering them, causing injuries. These packs of feral dogs predate upon snow leopards' prey and livestock, depleting the prey base and creating tensions with human-wildlife conflict. This has a wide-reaching negative effect, lowering tolerance for snow leopard livestock predation. Dog predation on livestock is thought to make up 60% of livestock loss to predation, which is more than snow leopards and wolves (*Canis lupus*) combined. With the lack of funding and controls the feral dog population has exponentially grown without any constraints and is now proving to be one of the highest-ranking direct threats facing snow leopards. This strategy will use the creation and implementation of governmental policies to control the feral dog population by 2049. Close work with the Nagar Nigam and Nagar Parishad will be key to the progress and success of this strategy.

Classification: 2.2 Invasive/Problematic Species Control

Rating: Effective

8.12.1 Theory of change for Results Chain Two: Control feral dogs

The assumptions made behind this strategy predict that introducing controls to the feral dog population in India will cause the overall population to decrease. This will then in turn reduce the persecution of snow leopards, prey species and other wildlife. This results chain takes several informal lines of approach. These approaches generally consist of educating people about the problem of dogs and offering veterinary contraceptive procedures. The assumption is that the dog owners approached will agree to neuter their dogs and possibly give them up for adoption. Translocating dogs through adoption will help in reducing the population within snow leopard range. In this chain the assumption is made that veterinary procedures will be free of charge or offered at a reduced rate for locals. Through the accumulated assumptions the threat reduction results will be: a decreased number of feral dogs attacking snow leopards and their prey, fewer livestock losses to feral dogs and a reduction in human-wildlife conflicts. Overall, this will primarily contribute to achieving Goal Seven.

8.12.2 Intermediate result inputs for Results Chain Two

Table 7: Intermediate Result inputs for Results Chain Two that can be seen in Figure 14.

Intermediate result	Details	Objective	Indicator
Local communities given information on how to work with animal control teams to catch and remove stray dogs	Providing local people with the relevant information on how animal control can be contacted will improve communication and contribute to the reduction of stray dog populations.	Information packs created by 2020. Information packs distributed to all local communities by 2021.	# of successful call outs for animal control.
Implement monthly visits from animal control to help communities	The implementation of monthly visits will help to build relations with a dog control team, which should encourage local people to use their services.	By 2023, animal control visits to local communities happen twice a month.	% of local communities receiving regular visits.
Stray dogs are removed for neutering and adoption	Removing stray dogs for contraceptive procedures and putting them up for adoption if suitable prevents dogs going back to being strays	-	-

	and contributing to wildlife disruption.		
Number of fertile dogs decreases	Introducing neutering will decrease the number of dogs capable of reproducing.	-	-
Locals are made aware of the option to give dogs up for adoption	Locals with too many pet dogs being able to give them up for adoption would relieve pressure and decrease the dog population in that area.	-	-
Increase in number of people giving up dogs for adoption	An increased number of dogs being given up for adoption will help to decrease dog numbers within the community.	By 2030, communities are giving up dogs as often as needed to keep the population within their community stable.	# of pet dogs within each community.
Fewer breeding dogs within the community	Fewer dogs within the community lowers the number of breeding dogs which helps to reduce the population.	By 2029, the number of puppies being born has decreased by >75%.	# of dogs getting pregnant.
The population of feral dogs decreases	A feral dog population decrease will result in fewer attacks on snow leopards and their prey, fewer attacks on livestock and natural migration and roaming going uninterrupted.	By 2045, the feral dog population is no longer increasing and begins to stabilise. By 2049, the feral dog population is modestly decreasing.	# feral dog population density.
Decreased likelihood of cross-breeding between dogs and wolves	The number of dog and wolf hybrids are rising and poses an increased threat to wildlife. A reduction in their population	-	-

	will therefore reduce wildlife persecution.		
Fewer crossbreeds of dog and wolf are created	Decreases in the opportunity and likelihood of wolves and feral dogs breeding will reduce the number of crossbreeds produced.	-	-
Policies made to control feral dog populations	Creating policies will help to change the state of the feral dog population by putting legal support in place.	By 2023, all meetings and conferences about the policies to be made have been held and a final set of policies and laws are agreed upon.	# of meetings held. # of policies created.
All national governments in the Eastern Himalayas agree to enforce policies	National enforcement of the policies will start a widespread reduction in feral dog populations left without interference.	By 2025, all provinces and levels of government agree on the laws and they are passed to be put into force.	Rate at which the policies are adopted into enforcement.
Policies are successfully enforced	Successful policy enforcement will ensure the national feral dog population begins to decrease.	By 2027, all people within snow leopard habitat range in the Indian Himalayas accept and act on the policies made about reporting stray dogs.	# of cases of people reporting stray dogs.
Awareness is created over the feral dog problem	The creation of laws and policies will reiterate the threat and problem of feral dogs.	-	-
Animal welfare organisations are more aware of the threat that feral dogs pose to snow leopards	If animal welfare organisations are made aware of the threats that wild dogs pose they will be more likely to help raise further awareness and intervene.	-	-

Implement biweekly veterinary visits to communities	The implementation of biweekly vet visits to local communities will help build relations with local residents and begin the groundwork for scaling the extent of the problems that need tackling.	By 2024, vets are visiting communities once every two weeks.	# of vets signed up for community visits.
Local communities given information on dog overpopulation and neutering	Giving appropriate information will help to promote an understanding of the importance to neutering dogs.	By 2022, people understand their options to neuter their dogs and the benefits to their dog, their lifestyle and the environment.	% of people that recognise and understand the impacts of dog neutering.
More people become interested in canine contraceptive procedures	An increase in the understanding of current and potential dog owners in regard to canine contraceptive procedures will help to control the growing dog population.	By 2024, local residents are prepared to have contraceptive procedures performed on their pet dogs.	% of people interested in contraceptive procedures of their canine.
Increased number of pet dog spaying and neutering in local communities	The increased number of spaying and neutering will result in fewer litters of puppies.	By 2025, there is a rise in the number of participant dog owners getting their dog spayed or neutered.	# of procedures to neuter or spay pet dogs in the community.
Increased number of infertile pet dogs	Increased numbers of infertile dogs mean the population of feral dogs will see a decrease.	By 2027, there are more infertile than fertile dogs within communities.	# of infertile pet dogs.
Veterinary visits are performed regularly to check the health of dogs	The importance of regular visits is to both build relations with locals and to closely monitor dog health and numbers	-	# of vet visits.

Health of dogs improves	Overall dog health improvements will be of benefit to both wildlife and people as fewer diseases and health conditions will be present in the dogs that could be spread.	-	# cases of mortality caused by disease that could be vaccinated against.
Better disease control	Better disease control reduces the chances of diseases spreading to wildlife.	-	-

8.12.3 Threat Reduction Results in Result Chain Two

Table 8: Content of Threat Reduction Result inputs for Results Chain Two that can be seen in Figure 14.

Threat reduction result	Details	Objectives	Indicators
Occurrence of feral dog attacks and disruption decreases	If the feral dog population begins to decrease, the number of attacks will also decrease. Disruption to snow leopards and their prey will also decrease.	Reduced sightings of snow leopards and prey getting injured or killed by dog attacks to fewer than three a month by 2040.	# of reports of feral dog persecution of snow leopards and prey.
Prey base population no longer significantly impacted upon by feral dog predation	If there are decreases in attacks and disruption from feral dogs, the prey population will increase.	By 2045, prey base population density has increased by >30%.	# of mature prey species being recruited.

Snow leopards hunt and roam without persecution	If the feral dog population decreases and the occurrence of attacks on snow leopards decrease, snow leopards natural roaming and hunting patterns will be able to resume.	Snow leopard population trend changes from declining to increasing by 2045.	# of mature snow leopards from new population estimates.
Reduced disease spread to wildlife	If feral dogs are given veterinary care and are free of diseases, disease spread from feral dogs to wildlife will decrease.	By 2025, the number of dogs within snow leopard habitat with diseases has decreased by 60%.	# of infant prey ungulate species recruited into mature population. # of wildlife fatalities to disease from feral dogs.

8.12.4 Human wellbeing in Results Chain Two

Table 9: Contents of Human wellbeing Targets in Results Chain Two that can be seen in Figure 14.

Human wellbeing target	Details	Objectives	Indicators
Livestock predation decreases	If the feral dog population decreases, there will be fewer cases of livestock predation by feral dogs, protecting the livelihood of farmers and herders.	By 2030, instances of Livestock loss to predation decrease.	Livelihood stability relating to livestock improves for local herders and farmers.

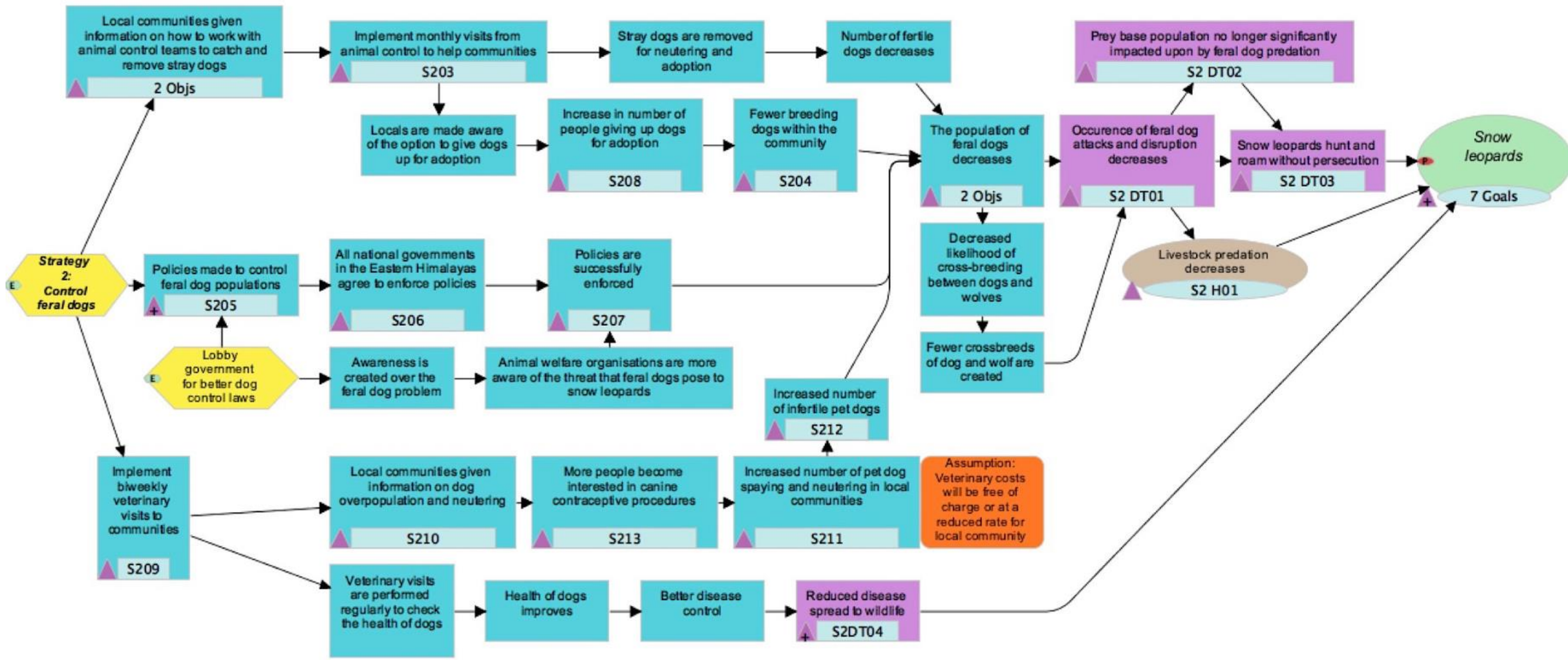

Figure 14: Results chain for Strategy 2: Control feral dogs.

8.13 Strategy Three: Create new and expand Protected Areas, and create wildlife corridors

Details: The implementation of this strategy will create pockets of protected habitat with connecting corridors to ensure the future of the snow leopards. Snow leopards cover huge distances to hunt and find mates, by protecting large sections of their habitat it will help to prevent any further decline of the population and allow for both snow leopards and their prey to thrive in their natural habitat without disruption. As part of the designation of these new areas, meetings with locals that use the land will be held to discuss the use of other areas for grazing or pasture rotations. Communication with both stakeholders and the general public throughout the decision-making process will be important to resolving any issues that may create future conflicts, so meetings will be held regularly to give fair opportunity to raise concerns. This strategy is split into two approaches: creation of new Protected Areas and creation of wildlife corridors.

Classification: 1.1 Site/Area Protection

Rating: Need More Info

Section A: Creation of new Protected Areas

Details: Create new and expand Protected Areas. A Protected Area is a distinctly outlined geographical region that is dedicated to the long-term conservation of nature, the associated ecosystem services and any cultural values. A Protected Area is managed through legal or other means to achieve effective long-term conservation. This section of the strategy aims to expand Nanda Devi Protected Area to include the Panch Chuli mountain to create a close proximity to the close neighbouring Api Nampa Conservation Area in Nepal. This will help in beginning to bridge the proposed subpopulations of snow leopards proposed by Janecka *et al* (2017) by linking the two of the three sub populations.

Classification:1.1 Site/Area Protection

Rating: Need More Info

Section B: Creation of wildlife corridors

Details: Creating a wildlife corridor is a strategy which connects habitat and wildlife populations that have become fragmented. Corridors help to maintain ecological processes and allow for the movement of wildlife to keep genetically viable populations. This section of the strategy will aim to connect the Rajaji National Park with corridors to the Jim Corbett National Park. It will also look to create a corridor to the Nanda Devi National Park via another Protected Area in the Chamoli Gopeshwar region spanning through Dungari to Gwaldam.

Classification:1.1 Site/Area Protection

Rating: Need More Info

8.13.1 Theory of change for Results Chain Three: Create new and expand Protected Areas, and create wildlife corridors

The theory of change for Results Chain Three is that the creation of wildlife corridors, new Protected Areas and expanding existing Protected Areas will lead to prey base population increases, reduced illegal hunting and reduced habitat loss and degradation. This is assumed to be the outcome of this strategy as the wildlife corridors will allow spread of wild ungulates free of persecution and competition with livestock, which will improve their fecundity. Illegal hunting will be harder to perform without detection in any of the areas which were previously unprotected or unmonitored. Wildlife corridors will be monitored with camera traps to analyse their effectiveness for data feedback, but they may also catch signs of illegal hunting which can be used to aid prevention techniques. This will cause a decrease in illegal hunting. The creation and expansion of Protected Areas will prevent the habitat from being fragmented and degraded by human activity and urbanisation. All of these positive changes will lead to increases in the snow leopard population. This will .contribute to achieving Goal Three.

8.13.2 Intermediate Result inputs for Results Chain Three Section A

Table 10: Content of Intermediate Result inputs for Results Chain Three Section A that can be seen in Figure 15.

Intermediate result	Details	Objective	Indicator
Research shows the most suitable locations and habitat for current and future viable snow leopard populations	Identifying suitable locations for expansion of Protected Areas will ensure viable populations of snow leopards are protected. This will be achieved through habitat suitability assessment and dispersal patterns of snow leopards and prey species. The targeted areas are the Rajaji National Park, Jim Corbett National Park and Nanda Devi National Park.	By 2021, all research into the most suitable locations is completed.	% of land that has been identified as appropriate based on the goal size.
Regulations and restrictions are put in place to diminish human disruption in proposed buffer zones	Regulations and restrictions on human intrusion and activity in buffer zones surrounding Protected Areas will create stable core areas.	By 2026, regulations and restrictions have been created and put through the appropriate governances.	Progress of regulations and restrictions.

Population estimates are done within each Protected Area to monitor changes to illegal hunting occurrences	The population will begin to see increases and these changes will be monitored.	-	-
Mining and resource extraction reduced and performed sustainably	The implementation of restrictions and regulations will lead to mining and resource extraction in the area being performed more sustainably.	-	-
New Protected Areas or expansions are put into place	Protected areas and expansions will improve the opportunity for connectivity between populations of snow leopards across India. The first proposal is a new Protected Area within the Chamoli Gopeshwar region, spanning through Dungari to end in Gwaldam. The second proposal is to expand the Nanda Devi National Park to include the Panch Chuli mountain.	By 2033, the new Protected Areas (including expansions to existing) are established and in place.	% of new land designated as a PA.
Signs are created to indicate Protected Area boundaries and the laws which are in place within them	The new Protected Areas will have signs created to accompany them. This will help raise awareness about the laws that are in place.	By 2034, all signs indicating boundaries and restrictions are in place.	# of signs created.

8.13.3 Intermediate Result inputs for Results Chain Three Section B

Table 11: Content of Intermediate Result inputs for Results Chain Three Section B that can be seen in Figure 15.

Intermediate result	Details	Objective	Indicator
Research shows the most suitable locations and habitat for current and future viable snow leopard populations	Identifying suitable locations for expansion of Protected Areas will ensure viable populations of snow leopards are protected. This will be achieved through habitat suitability assessment and dispersal patterns of snow leopards and prey species. The targeted areas are the Rajaji National Park, Jim Corbett National Park and Nanda Devi National Park.	By 2021, all research into the most suitable locations is completed.	% of land that has been identified as appropriate out of the goal size.
Proposed corridors between Protected Areas are mapped out	Corridors between the Rajaji National Park and the Jim Corbett National Park.	By 2025, plans and designs on areas to be established as corridors are agreed upon by all stakeholders.	Progress of plan proposals.
The corridors are established and functional	Corridors are set up and ready for use by wildlife in the area.	By 2030, the corridors are established and ready for use by wildlife.	% of designated area ready to be used as a corridor.
There is no human disruption or urban development within the corridors	There is no development or urbanisation within the designated corridor areas.	By 2026, the regulations and restrictions have been created and put through the appropriate governances.	Progress of regulations and restrictions.
Wildlife is safely able to disperse between Protected Areas and maintain genetic viability	Wildlife can use the corridors which will enable connectivity between populations, maintaining genetic variability.	By 2035, wildlife is using the corridors to travel and migrate.	Rate of wildlife traffic through corridors.
Camera traps are set up by local people to monitor dispersal and create population estimates	Willing locals are offered the opportunity to be taught how to set up camera traps and given the equipment	By 2035 participating locals have set up a network of camera traps.	# of cameras that are successfully capturing target species.

	to send updates of any successfully captured images. The employment gives individuals an added income to support themselves.	By 2037, employed locals and rangers are regularly sending successful footage captures of snow leopards.	

8.13.4 Threat Reduction Results in Result Chain Three

Table 12: Content of Threat Reduction Results in Result Chain Three that can be seen in Figure 15.

Threat reduction result	Details	Objectives	Indicators
Reduced habitat loss and degradation	If new Protected Areas are put into place, with additional signage and ranger patrols, the habitat is less likely to be harmed by human development which degrades and fragments the land. If wildlife corridors are created, a greater portion of habitat will be protected and the addition of buffer zones will create a greater proportion of habitat protected from urban development.	By 2035, snow leopard habitat is no longer damaged as a consequence of illegal activity. By 2045, the carrying capacity of the ecosystem is able to remain stable without stress from human activity.	Results of land quality assessments.
Prey base population increased	If new Protected Areas are created, grazing pasture for livestock will be preserved and lead to stabilised and increasing wild ungulate populations. If wildlife corridors are created, the opportunity for connectivity between populations and possible expansion into new areas will lead to increases in the prey	By 2045, the number of adult prey species individuals capable of breeding has increased by 25%.	# of infant prey ungulate species recruited into mature population.

	base population from improved fecundity.		
Fewer reports of illegal hunting	If Protected Areas are created or existing Protected Areas are expanded, the laws in place will prohibit any hunting of animals within those areas, hence prey populations occupying those areas will be able to increase with less persecution from hunting.	By 2035, reports of illegal hunting are declining in frequency. By 2040, illegal hunting no longer takes place.	# of reports of hunting taking place. # evidence found showing illegal hunting.

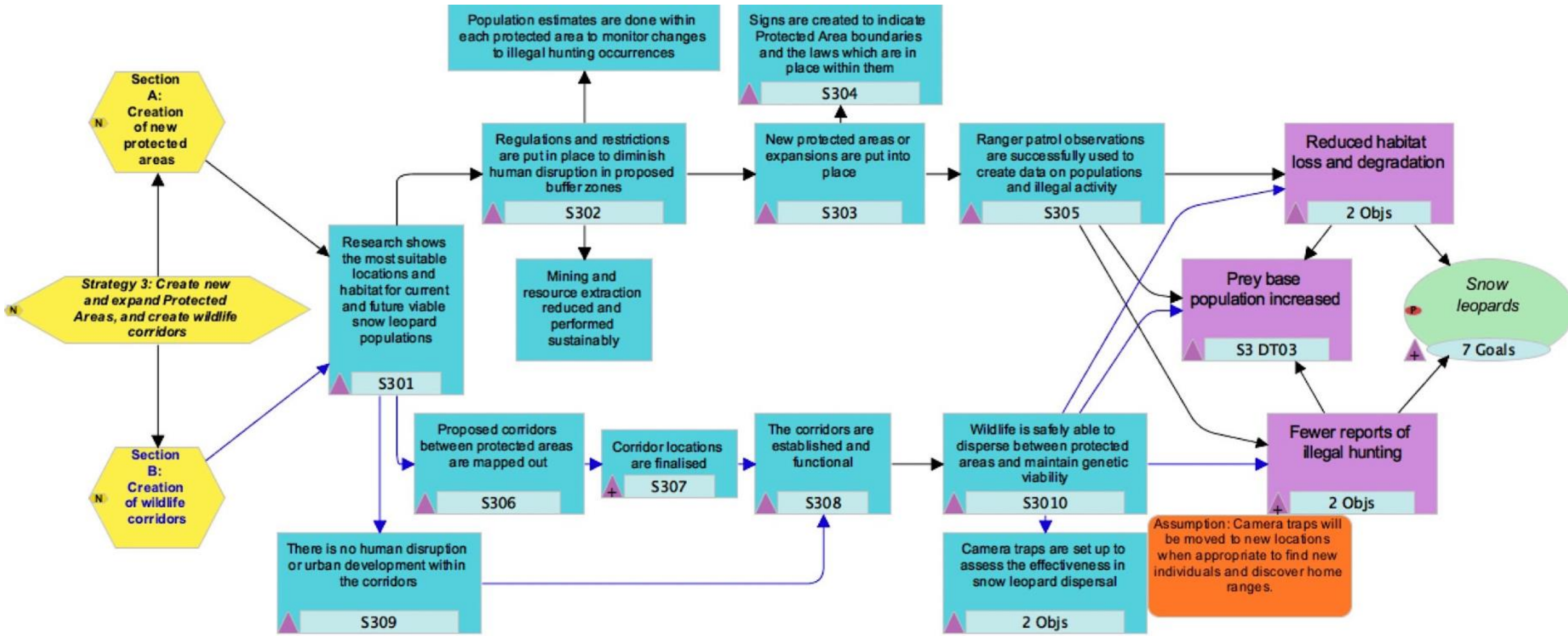

Figure 15: Results chain for Strategy 3: Create new and expand Protected Areas, and create wildlife corridors.

8.14 Strategy Four: Introduce widespread adoption of wildlife friendly best practices

Details: Awareness workshops will create an outreach programme for the best interests of conservation by introducing wildlife friendly agropastoralism practices. These practices can be split into three focal points which are as follows; corral improvement, sustainable herding and disease control. By taking these issues as focal points for a threefold approach, retribution killings of snow leopards and the prey base depletion should be relieved and improve by 2049. This strategy will target the threats of retribution killings and prey populations decreasing as a result of competition with livestock.

Classification:4.2 Training

Rating: Effective

Section A: Corral improvement

Details: Locals will be shown and helped in creating predator proof corrals. Insufficient corrals allow multiple predator species access to livestock. Presentations and practical sessions will take place to ensure people are capable of constructing and maintaining corrals. The creating of these improved corrals will help to prevent predators such as snow leopards getting inside and killing livestock, resulting in reduced human-wildlife conflict and retribution killings stopping by 2039.

Classification: 4.2 Training

Rating: Effective

Section B: Sustainable herding

Details: Unsustainable herding practices are depleting the already sparse landscape that snow leopards and their prey inhabit. Creating sustainable grazing practices will be developed from establishing limited areas acceptable for grazing based on vegetation cover, ensuring enough vegetation is left available for wild ungulates. Sessions with the local herders and farmers will be held to discuss their current practices. Following this, corrections and improvements to their practices will be suggested, with a clear explanation of the importance of why practices must be altered to benefit wildlife.

Classification: 4.2 Training

Rating: Effective

Section C: Disease Control

Details: Diseases passed from livestock to wildlife poses a threat to wildlife populations. This part of the strategy will focus on giving vaccinations and offering education on livestock husbandry to help control and reduce disease spread.

Classification: 3.1 Species Management

Rating: Need More Info

8.14.1 Theory of Change for Results Chain Four: Introduce widespread adoption of wildlife friendly best practices

The theory of change for Results Chain Four takes three routes of assumptions following on from corral improvement, sustainable herding and disease control.

Within the corral improvement chain, the assumption is that if herders with corrals are shown how to improve and maintain their corrals, and are provided with the necessary resources, their corrals will become predator proof. Predator proofing the corrals means less livestock will be lost to predation and this will reduce human-wildlife conflicts. This will then lead to a reduction in retribution killings of snow leopards.

The introduction of sustainable herding is assumed to create a better understanding among herders regarding wildlife friendly practices that benefit the ecosystem and longevity of their grazing supplies by using them sustainably. This will lead to increases in snow leopard prey as competition with livestock will have been reduced.

Disease control for livestock will be done by administering vaccinations and performing check-ups. This project assumes the veterinary procedures will be able to be given free of charge or at a reduced cost to the local people as poverty is commonly an issue. The vaccinations will reduce livestock losses whilst simultaneously reducing disease spread to wild animals that can be fatal.

The accumulated results of this strategy will help to increase the snow leopard prey population base, which will improve the situation of snow leopards. this contributes towards achieving Goal Two.

8.14.2 Intermediate Result inputs for Results Chain Four Section A

Table 13: Content of Intermediate Result inputs for Results Chain Four Section A that can be seen in Figure 16.

Intermediate result	Details	Objective	Indicator
Locals are shown how to construct a predator proof corral	Corrals will be built with stone or brick walls 2.4m high with wire mesh roofs, no windows and a single close-fitting door.	Lessons are being given to all interested people in predator proof corral construction by 2020.	# number of lessons being given with attendance of herders.
Resources are provided where needed	Bricks, stone, mesh and doors will be given where additional resources are needed.	By 2024, corral construction is ready to begin.	Number of materials and resources needed to construct all corrals.
New predator proof corrals are built	Construction of corrals will have an immediate effect in reducing the	By 2025, corral construction in every community applicable has begun	# of corrals built out of total to be built.

	likelihood of livestock predation.	By 2026, all corral construction has been completed.	
Locals are shown how to maintain corrals.	Maintenance of corrals will ensure long term safety for livestock and reductions to human-wildlife conflicts.	-	-
Corrals remain predator proof in the long-term	Following the maintenance lessons, corral owners will be able to maintain the structural integrity of their corrals to keep them predator proof.	-	-
Snow leopard's predation on livestock is reduced	Snow leopards will not be able to gain access to livestock within corrals, reducing the number of livestock killed.	By 2033, snow leopards are no longer able to get access into corrals.	# of livestock owners reporting proof of snow leopards predating on livestock in corrals.
Less livestock is lost	If corrals are built and cause a decrease in predation on livestock then less livestock will be lost.	-	-
Human-wildlife conflict is reduced	Improvements to corrals help with local people's livelihood. This in turn relieves some human-wildlife conflict.	By 2035, herders show an improved attitude to snow leopards when questioned.	% of herders that respond positively to questions about snow leopards.

8.14.3 Intermediate Result inputs for Results Chain Four Section B

Table 14: Content of Intermediate Result inputs for Results Chain Four Section B that can be seen in Figure 16.

Intermediate result	Details	Objective	Indicator
Current herding practices analysed,	Study on herding practise in the areas will establish what is	By 2023, analysis on herding practices used has	Progress with identifying

and all problems identified	currently sustainable and what is unsustainable, creating a basis for recommendations for lessons to be given to herders.	been completed and results evaluated.	successes and problems.
Lessons given to herders in sustainable grazing practices	Lessons will be given to address the problems identified with any unsustainable practices that are negatively impacting prey populations.	By 2025, herders are taking part in meetings with experts to teach them sustainable practices.	# of meeting held with regular attendance from herders.
Herders understand the benefits of practicing sustainable grazing	Following the lessons, herders will understand that grazing sustainably preserves the habitat they depend upon for long-term future grazing.	-	-
Increased knowledge among locals regarding the importance of sustainable practices	Local people will understand the concept of sustainability, carrying capacity and the threat that diminishing natural resources poses to their livelihood and wild animals occupying the same area.	-	-
Herders agree to use sustainable practices	Herders will agree to use sustainable practices following education on the importance of sustainability to ensure long term use of the area for grazing.	By 2030, >75% of herders agree to use sustainable practices.	# of herders using sustainable practices.
Livestock grazing no longer threatens wild herbivores	Sustainable livestock grazing in controlled areas will increase the available foraging variety for wild ungulates.	Increased % of land untouched by livestock grazing by 2040.	Km2 of land left untouched by livestock grazing.

Supplementary feeding for livestock is given	To support controlled grazing that is sustainable, supplementary feeding will be given to herders to alleviate over grazing.	-	-

8.14.4 Intermediate Result inputs for Results Chain Four Section C

Table 15: Content of Intermediate Result inputs for Results Chain Four Section C that can be seen in Figure 16.

Intermediate result	Details	Objective	Indicator
Agreements are made for livestock to be assessed annually for any required vaccinations	Herders will agree to have livestock health checks annually.	By 2021, >75% of herders agree to sign up for livestock vaccinations.	% of herders agreeing to have livestock vaccinations.
Vaccinations are given to livestock	Vaccinations will be given to prevent any infections, reducing the chances of disease spread.	Starting 2024, vets are visiting once every four months to check livestock and give any vaccinations or treatments.	Health stats of livestock through the year.
Less livestock lost due to disease	Vaccinations will reduce livestock loss to disease.	A reduced number of livestock is lost to disease in communities.	# of livestock fatalities due to disease.
Lower number of cases of disease spread to wild animals	Vaccinated livestock will be significantly less likely to spread any diseases they are infected with to wild animals in their shared habitat.	By 2030, the number of cases of wild animals dying to disease from livestock has dropped by >50%.	# of wildlife fatalities to disease spread by livestock.

8.14.5 Threat Reduction Results in Result Chain Four

Table 16: Content of Threat Reduction Results in Result Chain Four that can be seen in Figure 16.

Threat reduction result	Details	Objectives	Indicators
Retribution killings stop	If human-wildlife conflicts are minimised, the perceived need for retribution killings will drastically reduce and ultimately retribution killings will stop.	By 2039, retribution killings no longer occur.	# of local residents with a positive attitude towards snow leopards. # of snow leopards killed in retribution following predation or pre-emptively.
Increased snow leopard prey numbers	If livestock grazing is made sustainable and disease spread is reduced or stopped altogether, prey populations will increase. The improved foraging will help boost fecundity.	By 2045, the number of adult prey species individuals capable of breeding has increased by 25%.	# of infant prey ungulate species recruited into mature population.

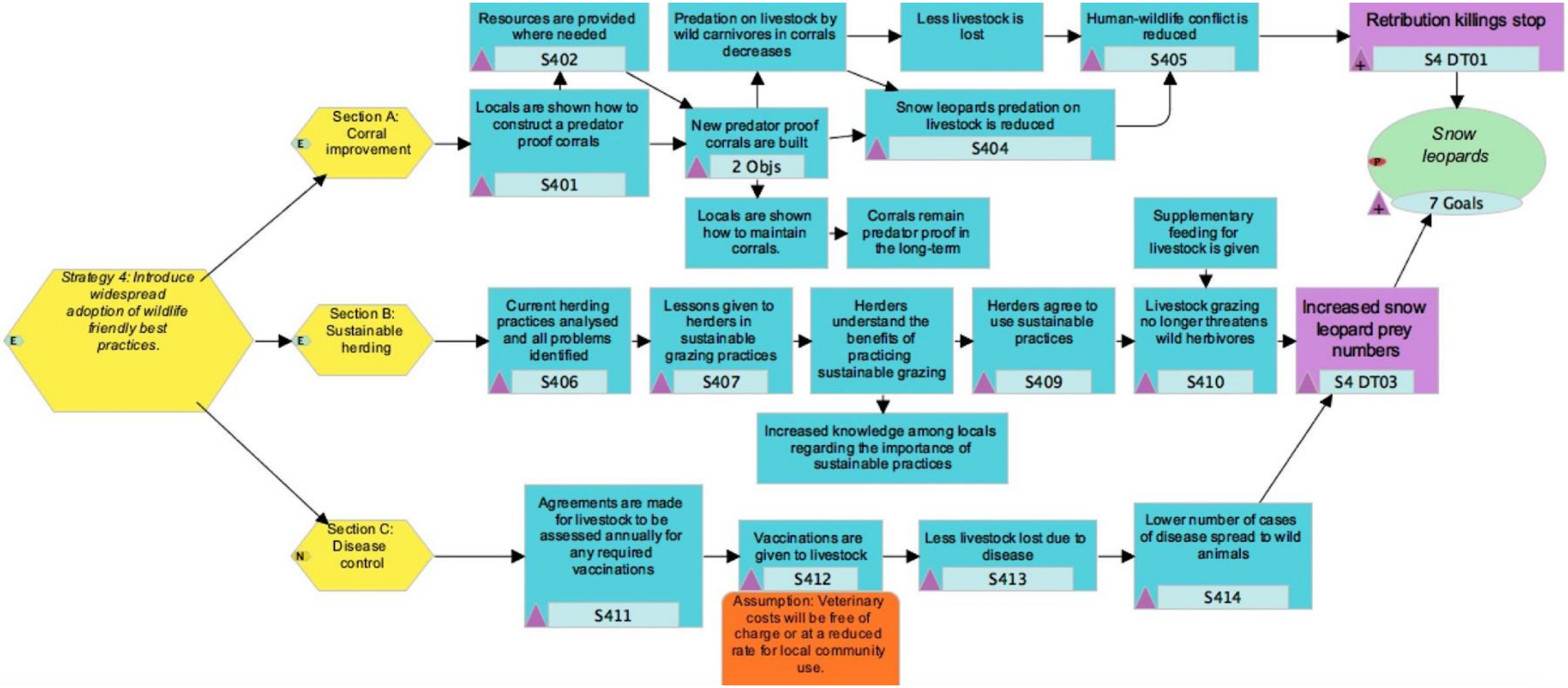

Figure 16: Results chain for Strategy 4: Introduce widespread adoption of wildlife friendly best practices.

8.15 Strategy Five: Increase awareness for the value of snow leopards as a keystone species

Details: In this strategy awareness workshops will create an outreach programme of conservation education for local people. The purpose of this is so that locals may be taught about the role of a keystone species in its ecosystem and why it is important for their long-term livelihood to protect the snow leopard as a keystone species. Environmental education has been proven to help improve attitudes towards wildlife, particularly species that may be considered a nuisance to livelihood like snow leopards. Using education programmes for both children and adults will help to increase the tolerance of snow leopards.

Classification: Formal Education

Rating: Very Effective

8.15.1 Theory of Change for Results Chain Five: Increase awareness for the value of snow leopards as a keystone species

The theory of change for this strategy is that if information is given to local people, the increased understanding for the value of snow leopard in the ecosystem will reduce several Direct Threats. Information packs will be created which can be used to teach local people about the concept of keystone species to maintaining biodiversity and how this benefits local wildlife and people's livelihoods. As a result of people understanding the role snow leopards play in the habitat, local people's attitudes towards snow leopards will improve enough for them to agree a pledge to not harm snow leopards or their prey. This will reduce the use of traps and poison that may affect snow leopards, stop retribution killings in the area and decrease illegal activity retaining to harming snow leopards. This will ultimately lead to increases in the snow leopard population following the reduced persecution from local people, contributing to achieving Goals One, Two and Four.

8.15.2 Intermediate Result inputs for Results Chain Five

Table 17: Content of Intermediate Result inputs for Results Chain Five that can be seen in Figure 17.

Intermediate result	Details	Objective	Indicator
Information packs are made to help teach people about the value of snow leopards as a keystone species.	Information packs can be used by the teacher as well as the participants in the sessions.	-	-
Packs used to teach local residents about the value of keystone species	Using the approved packs to educate individuals on the value of a keystone species and how useful it is to uptake snow leopard conservation.	-	-
Sessions with conservation experts and locals are set up to promote snow leopard conservation and awareness	Question and answer sessions between experts and locals will help to further understanding and give experts the opportunity to tailor their teachings to the concerns of locals.	By 2023, lessons with the locals are taking place.	Attendance by locals.
A series of three lesson sessions are given	The principal teaching points of the three sessions will cover: What the role of a keystone species is, How snow leopards influence the habitat as a keystone species and how humans can help to conserve snow leopards.	-	-
Local residents attend the sessions	Regular attendance to the sessions means local people will have a deepened understanding of the value a snow leopard has, the threats they	-	Number of people in attendance.

	are facing, and the conservation work being done in their area.		
Local residents understand and accept the importance of snow leopards to biodiversity	Attendance to the lessons alongside the information within the packs will result in locals understanding and appreciating the role of snow leopards in maintaining biodiversity.	-	-
Attitudes towards snow leopards are improved	Understanding the plight of snow leopards and their value to the ecosystem will promote positive attitudes towards the species.	By 2030, interviews with local residents' show >80% have a positive attitude towards snow leopards.	# of positive responses to interviews.
Local residents pledge to not interfere or harm snow leopards or their prey	Following the education programme, locals will agree to not harm or aid in the harming of snow leopards or their prey.	By 2030, >80% local residents have agreed to a contract to not harm or interfere with snow leopards or their prey.	# of residents prepared to sign agreement.
Local residents agree to report any illegal activity related to snow leopards they witness	Reporting of suspected activity in the area harming snow leopards will reduce opportunity for local or foreign people to harm snow leopards without detection and repercussions.	-	-
Documentation and evidence of illegal activity increases	Documentation following reports of illegal activity will help in estimating the extent and severing of illegal hunting.	By 2025, the evidence base has increased by >35%.	Knowledge of number of cases of proven illegal activity against snow leopards.
Number of arrests of perpetrators increases	The number of arrests will increase following a strengthened	-	-

	evidence base and the higher detection rate established from local people reporting illegal activity.		

8.15.3 Threat Reduction Results in Result Chain Five

Table 18: Content of Threat Reduction Results in Result Chain Five that can be seen in Figure 17.

Threat reduction result	Details	Objectives	Indicators
The use of poison and traps for carnivores stop	The use of traps and poison by local people in attendance of the education programme will stop.	By 2039, traps and snares are no longer used. By 2039 poison is no longer used.	# of traps or snares being set. # of poison baits being set.
Snow leopard retribution killings stop	People who attended the education programme will not kill snow leopards in retribution.	By 2039, there are no more reports of retribution killings.	# of snow leopards killed pre-emptively or in retribution following predation.
Decreased % of illegal activity affecting snow leopards	If local people help in improving the detection rate of illegal activity, the rate of illegal activity impacting upon snow leopards will decrease.	By 2037, illegal activity affecting snow leopards has declined by >75%.	# of cases of illegal activity.
Snow leopard population increases	The snow leopard population will increase after illegal hunting for trade and retribution killing stops.	Snow leopard population trend changes from declining to increasing by 2045.	# of mature snow leopards from new population estimates.

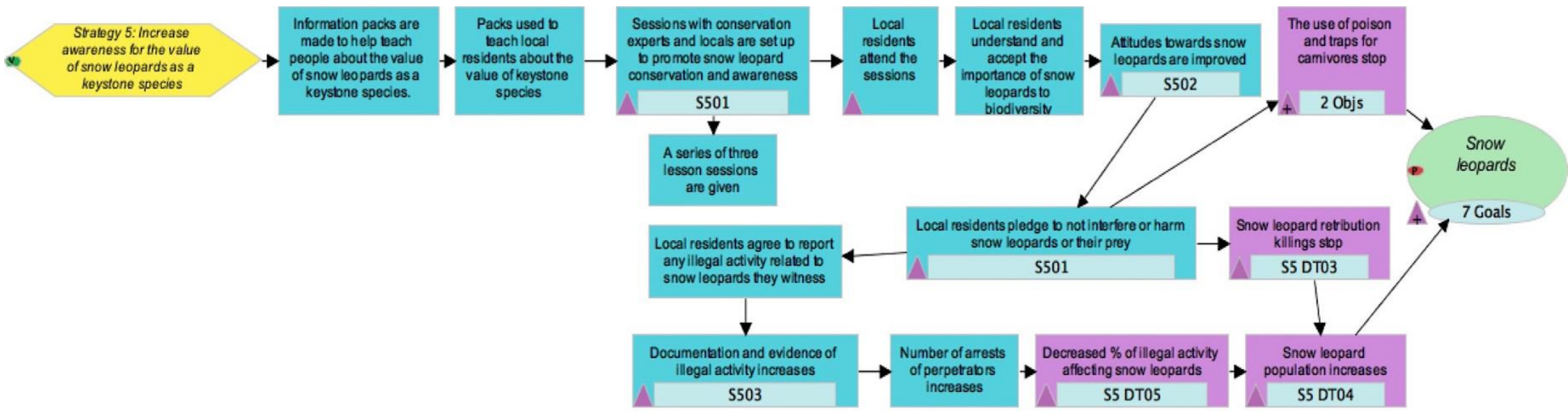

Figure 17: Results chain for Strategy 5: Increase awareness for the value of snow leopards as a keystone species.

8.16 Strategy Six: Set up a livestock insurance scheme

Details: Snow leopard retribution killing is a high rated threat which is driven by livestock lost to predation. Setting up a livestock insurance scheme for communities across the Indian Himalayas will help to reduce tensions over livelihood losses, mitigating human-wildlife conflict. Herder involvement in the scheme will form community-based conservation as livestock insurance contracts will include a vow to protect snow leopards and their prey, creating a sense of ownership and care for the status of snow leopards.

Classification: 6.4 Conservation Payments

Rating: Effective

8.16.1 Theory of Change for Results Chain Six: Set up a livestock insurance scheme

The theory of change for Strategy Six is that if an insurance scheme is set up, there will be no more retribution killings, and the prey base populations for snow leopards will increase. This outcome follows the assumptions that if external donors and fundraising create the funds for livestock insurance, herders will sign contracts to receive livestock insurance. These contracts will also detail that, as part of the eligibility for claiming on the insurance, herders cannot harm snow leopards or their prey species without facing negative consequences. Once herders have signed the contracts they will be able to claim back financial losses from their livestock being predated upon by snow leopards or other wild carnivores. Being able to claim back the money will help reduce human-wildlife conflicts as their livelihood security will have been improved. This, alongside the promises made in the contract, will cause a reduction in the killing of snow leopards in retribution or for future prevention of predation. The promises within the contract will also mean any use of traps and poison that may harm snow leopard prey will cease. This will reduce the persecution of prey species and allow their populations to increase, benefitting the snow leopard population and contributing to achieving Goals One and Two.

8.16.2 Intermediate Result inputs for Results Chain Six

Table 19: Content of Intermediate Result inputs for Results Chain Six that can be seen in Figure 18.

Intermediate result	Details	Objective	Indicator
Meetings with local residents are held to discuss the implementation of a livestock scheme	Communication with local people in the decision-making process during the creation of the insurance scheme increases the likelihood of fewer problems stemming from miscommunication.	-	-
Money raised by fundraising and external donators	Money for the insurance policy is raised from continuous fundraising, support from organisations and donors.	-	-
Livestock insurance scheme is set up	A livestock insurance scheme reduces economic pressure and increases livelihood security. This in turn reduces human-wildlife conflict as predators are not killed in retribution for livestock predation.	By 2022, an official insurance scheme is set up.	Insurance Scheme official notice.
Parameters are set to clarify what kind of loss is eligible (e.g. predation)	Setting parameters prevents any manipulation of the insurance scheme or misunderstandings from participants.	-	-

Herders are able to sign up for the livestock insurance scheme	Herders being able to sign up for insurance will begin to relieve tensions causing human-wildlife conflict.	By 2023, 70% of herds sign up.	% of herds that sign up.
Contracts for livestock insurance detail that herders may no longer interfere with snow leopard prey species	Establishing a contract to prevent interference with snow leopards and their prey adds a second line of defence against human-wildlife conflict that will reduce retribution killings and the use of traps, snares and poison.	-	-
Contracts are signed by the herders to prevent cheating	All claims will be checked, if any signs of dishonesty and attempts to cheat the system are found then the individuals found responsible will be removed from the scheme. When herders sign the contract, they understand the consequences of lying when claiming on their insurance.	-	# of fraudulent claims.
Herders are able to claim back appropriate livestock losses	Claiming back losses will give herders livelihood security which helps to reduce the perceived need for retribution killings to protect livestock from predation.	-	-
Pressure from economic losses is relieved	These assumptions will lead to herders being under less pressure from economic losses.	-	-
Human-wildlife conflict is reduced	Estimates claim at least one snow		

	leopard is lost every day to retribution killings in the Himalayas. Reducing one of the sources of conflict will result in fewer retribution killings.		

8.16.3 Threat Reduction Result inputs for Results Chain Six

Table 20: Content of Threat Reduction Results in Result Chain Six that can be seen in Figure 18.

Threat reduction result	Details	Objectives	Indicators
There are no more occurrences of retribution killings	Following these assumptions on the reduction of human-wildlife conflict by creating a livestock insurance scheme, there will be a lower perceived need for retribution killings and a pledge to not take part in any activity that constitutes a retribution killing.	By 2039, there are no more reports of retribution killings.	# of reported killings.
Traps and poison are no longer used on wild ungulates	If livestock is protected under an insurance scheme that includes a promise to not harm snow leopards and their prey, the use of traps and poison will see an overall reduction.	By 2039, traps and snares are no longer used. By 2039, poison is no longer used.	# of poison baits being set. # of traps or snares being set.
Snow leopard prey population has reduced persecution	If herders pledge to not interfere with snow leopard prey then their persecution will reduce, leading to a population increase.	By 2045, prey base population density has increased by >30%.	# of infant prey ungulate species recruited into mature population.
Snow leopard prey population increases	Following these assumptions will result in an increase in snow leopard prey population size, as prey species will be able to roam without persecution.	By 2045, prey base population density has increased by >30%.	# of infant prey ungulate species recruited into mature population.

8.16.4 Human wellbeing in Results Chain Six

Table 21: Contents of Human wellbeing Targets in Results Chain Six that can be seen in Figure 18.

Human wellbeing target	Details	Objectives	Indicators
Livelihood security	Herders will have improved livelihood security with the support of the livestock insurance scheme.	-	-

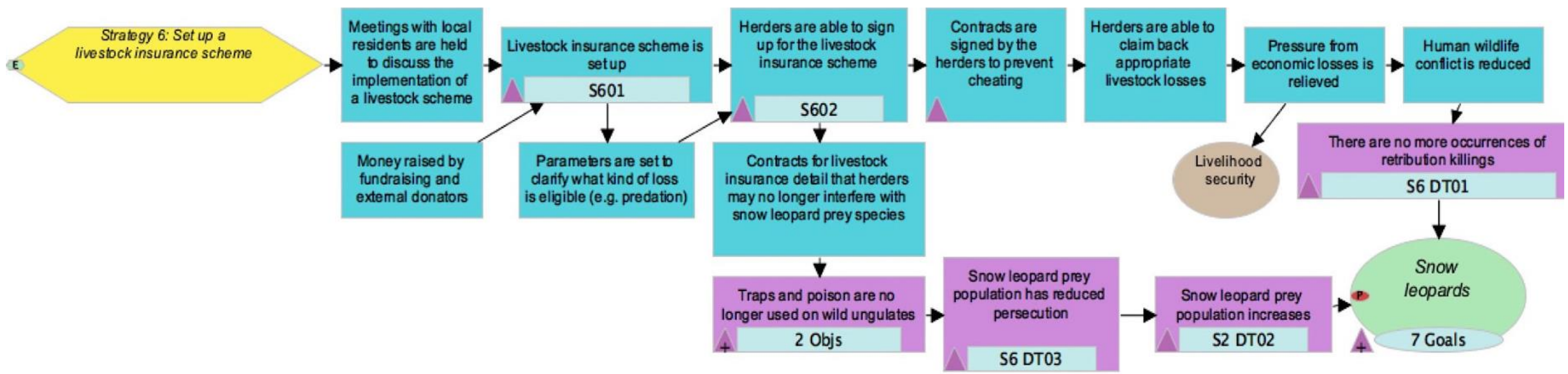

Figure 18: Results chain for Strategy 6: Set up a livestock insurance scheme.

8.17 Strategy Seven: Snow leopard Ecotourism

Details: The establishment of sustainable ecotourism will create a source of income for both conservation work and local people hired to be tour guides. This strategy will aim to help local people by increasing employment opportunities and bringing in revenue from tourists visiting the area. Locals will be trained in health and safety as well as languages and conduct. The chance to take advantage of bringing in tourists to the area will be fully utilised by helping to create a gift shop for locals to sell handmade products online to promote ecotourism and conservation. The opportunity for communities to increase their livelihood can help to alleviate human-wildlife conflicts and instil respect and value for snow leopards, as their presence will be one of the main attractions to tourists.

Classification: 6.1 Linked Enterprises & Livelihood Alternatives

Rating: Effective

8.17.1 Theory of Change for Results Chain Seven: Snow leopard Ecotourism

The series of assumptions made for this strategy outline that if ecotourism is set up, prey base depletion and illegal activity will decrease. A majority of illegal activity is believed to be linked to poverty. By introducing a source of income that also increases appreciation for wildlife, illegal activity affecting snow leopards and their prey will decrease. Introduction of this source of income will be achieved by giving locals the opportunity to become tour guides. Once the guides are properly trained, sustainable tours can begin to take place. The influx of tourists to the area will create a demand for gifts and memorabilia. Local people who have not become guides will have the opportunity to create handmade sustainable products that can be sold to tourists. This enterprise will then be developed by creating an online store and organising the shipping of the products made. This will improve the economic stability of local people which will cause reductions in human-wildlife conflicts.

Illegal hunting and illegal trade of snow leopard parts will also decrease following the results of the strategy. The reduced persecution of snow leopards and the prey base will contribute to increasing snow leopard and prey base populations. This will contribute to achieving Goals One, Two and Four.

8.17.2 Intermediate Result inputs for Results Chain Seven

Table 22: Content of Intermediate Result inputs for Results Chain Seven that can be seen in Figure 19.

Intermediate result	Details	Objective	Indicator
Locals are taught how to be tour guides	Applicants will be given lessons in conduct, languages and health and safety. This will help increase the popularity and appeal of ecotourism.	By 2025, a team of locals are ready to be tour guides.	# of local people ready to give tours within appropriate guidelines.
Ecotourism tours run by locals are established	Small ecotourism tours are set up to create an income for local people and support the local economy whilst offering tourists a chance to learn about the ecosystem and how they can help with conservation efforts.	By 2025, tours are operational and available to tourists.	# of tours being run.
Local people are used as tour guides	Using local people is preferential due to their existing knowledge of the area.	-	-
Local people have increased income	Income from tourism will contribute to the livelihood of the local community.	-	% of household income increases.
Small % of profits are used to maintain signs	Some of the profit margin will be used to create and	-	-

indicating Protected Area boundaries and the laws in place	maintain signs indicating Protected Areas and protected species, outlining the consequences of breaking the laws.		
Increased demand for tourist memorabilia	The increased promotion and accessibility of ecotourism following implementation will lead to an opportunity to meet a demand for memorabilia to sell to tourists.	-	-
Increased incentive to establish a shop with homemade products	Incentive to develop an outlet to sell local produce to tourists will result in the desire to set up a shop.	-	-
Products are available to sell to tourists and online	Products made by local people can be sold to tourists or online.	By 2020, production of products is fully operational.	# of products ready for sale.
External conservation organisation establishes an online shop to sell products	Online shop is established with appropriate distribution channels.	-	-
Products are sold online	Products begin to sell online with the option to leave feedback.	By 2023, the online shop is functional and able to receive orders.	Rate of online demand. Occurrence or absence of instances of waiting for stock to become available.
Profits of online shop are given back to the community	Majority of the profits made from the online shop are given back to the community to be used to expand their products and productivity.	-	-

Source of income for local people	Locals will have additional income to improve their livelihood.	-	-
Profits can be used to improve human, pet and livestock wellbeing	Livelihood increases from profits can be used to improve all aspects of their way of life.	-	-
Improved economic stability	The increased income provides economic stability for local people.	-	-
Reduced pressures on human-wildlife conflict	Once the economic stability is improved, pressures contributing to human-wildlife conflict will decrease.	-	-

8.17.3 Threat Reduction Result inputs for Results Chain Seven

Table 23: Content of Threat Reduction Results in Result Chain Seven that can be seen in Figure 19.

Threat reduction result	Details	Objectives	Indicators
Reduction in the perceived need for secondary poisoning and trapping	If economic stability and livelihood is improved by ecotourism, the perceived need to trap and poison will decrease.	By 2039, poison is no longer used. By 2039 traps and snares are no longer used.	# of poison baits being set. # of traps or snares being set.
Reduced prey base depletion	If secondary poisoning and trapping stops as a result of improved livelihood, fewer wild ungulates will be affected by trapping and poisoning.	By 2045, prey base population density has increased by >30%.	# of infant prey ungulate species recruited into mature population.
Less Illegal hunting	If pressures on human-wildlife conflict are reduced, the rate of illegal hunting will decrease.	By 2040, illegal hunting no longer takes place.	# of cases of illegal activity.

Reduced illegal trade	If illegal hunting decreases, the lessened supply will in turn decrease availability for illegal trade.	2045, illegal trade has decreased by 100%.	# of cases of illegal activity.

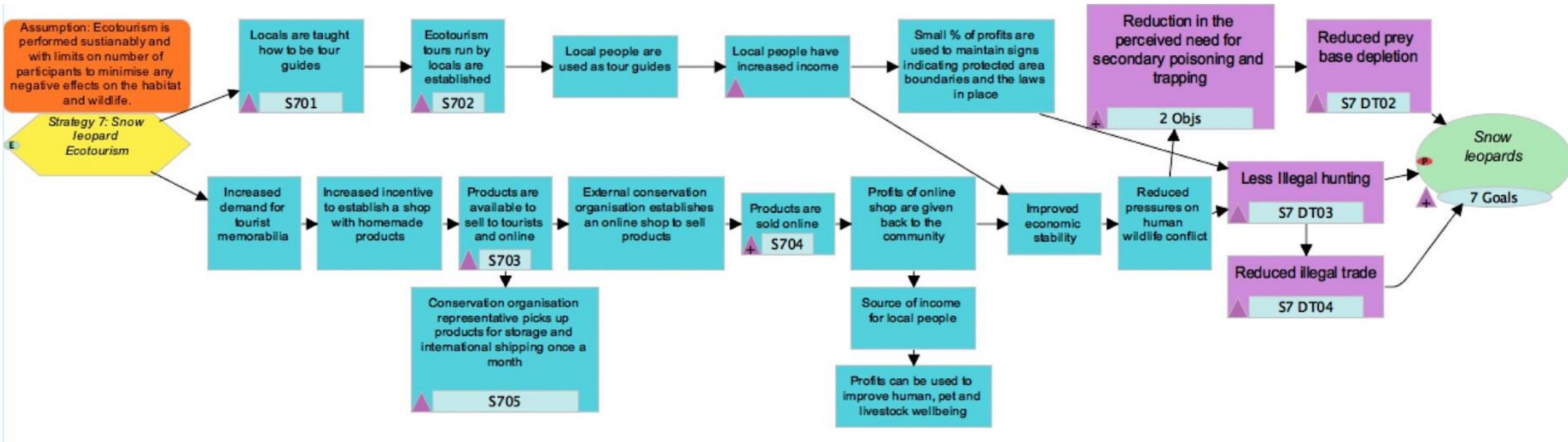

Figure 19: Results chain for Strategy 7: Snow leopard Ecotourism.

Conclusion

This thesis involved the creation of a thirty-year CAP for the Indian Himalaya population of snow leopards from 2019 - 2049 using Miradi and following the Open Standards. Only stages One and Two were completed out of the Five Open Standards steps as this project will not be implemented, yet it has been designed and the conceptualisation carried out as if it were to be. Snow leopards were selected as a thematic conservation target because of their ecological value to the ecosystem. The recent controversial downgrade by the IUCN has raised the need to work towards improving the measures in place to protect the species as we learn more about their biology, habitat range and population size (McCarthy *et al.*, 2017). The vision of the CAP was to protect and preserve the ecological health of the ecosystem in the Himalaya. The seven Strategies that have been created work to achieve this vision by mitigating the key direct threats identified by providing intervention. The concerns over the possible fragmentation of the species are also addressed in the CAP's Strategies in an effort to prevent further isolation of populations. The ultimate aim of the CAP's Strategies was to allow for the snow leopard population to increase from 450 – 500 to 750 individuals. Implementation of the next steps of the Open Standards would help to increase the understanding of the assumed cause and effect relationships outlined in this project to develop it under the guidance of AM. Although limited to the first two steps of Open Standards, the Objectives and Indicators created do give some provision for the initial development of monitoring plans. Some of the Strategies have been ambitious in trying to utilise all possible positive outcomes that could be gained from a given situation. This may make some Strategies harder to implement, whereas others have taken inspiration from existing conservation successes and are likely to achieve all of the Goals set. Researchers should look to establish if snow leopard metapopulations are present or if the emergence of subspecies is evident. This will likely structure the future of CAP's and the necessary Goals needed to ensure genetic viability of the species or subspecies. The rise in application of AM to answer criticism of conservationists calls for more uptake of AM and the Open Standards. Adopting the principles of these frameworks creates a logical science-based approach that will lead to increased effectiveness and important information sharing among the scientific community.

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