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Assessing species vulnerability to climate change, and implementing practical solutions

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ABSTRACT

The impacts of climate change on species, and assessments of species vulnerability to climate change, have been well documented in the literature. However, translation of this research into on-the-ground interventions, for example by NGOs or protected area authorities, is lacking. Here we present a simple species climate vulnerability assessment tool, which assesses different dimensions of climate change vulnerability. The trait-based assessment leads to actionable climate-adaptive management recommendations. Additionally, we highlight projects funded by the Wildlife Adaptation Innovation Fund, which supports project ideas from around the world which reduce the vulnerability of wildlife to changes in weather and climate.

1. Introduction

The impacts of climate change on biodiversity have been extensively documented in recent literature, and the extent and magnitude of the impacts are larger than estimated in previous IPCC assessments (IPCC, 2022). Impacts on terrestrial, freshwater, and marine ecosystems have resulted from both slower onset processes such as ocean acidification, sea level rise, increasing temperatures, and changing seasonality of rainfall, as well as extreme events such as heatwaves, heavy precipitation, drought, and fires, among others (IPCC, 2022). Examples of impacts on ecosystems documented with "very high confidence" include the poleward and altitudinal (to higher elevations) shift of species' ranges (Lenoir and Svenning, 2015), and mass mortality events on land and in the ocean (Sanderson and Alexander, 2020); examples documented with "high confidence" include coral bleaching and mortality (Van Woesik et al., 2022), and drought-related tree mortality (Choat et al., 2018); and some impacts are irreversible, such as the extinction of species driven in part by climate change (Thomas et al., 2004; Cahill et al., 2013).

The vulnerability of ecosystems and species to climate change differs considerably across the globe. Near-term warming and increased frequency and severity of extreme weather events will place many ecosystems at high risk of biodiversity loss, with sea-ice and terrestrial ecosystems in the Arctic, and warm-water coral reefs, being some of the most vulnerable. Risks are highest where species exist close to their upper thermal limits, along coastlines, or in close association with ice or seasonal rivers. Many of these risks are unavoidable in the near-term, irrespective of emissions scenario, but the worst impacts can be addressed with adaptation measures (IPCC, 2022).

It is therefore with great urgency that we not only determine how different species are vulnerable to a changing climate, but that we develop actionable outcomes from these assessments. There are three primary methods for assessing species vulnerability to climate change; correlative, mechanistic, and trait-based (Pacifici et al., 2015). Correlative models infer the niche of a species based on its current geographic distribution, and the range of climatic variation found within that range currently. The results are then applied to climate projections to determine the potential future range of the species. While this is the most widely used technique to determine species vulnerability to climate change, it has many limitations, due to uncertainty around climatic projections, differences in the methods and models used, and perhaps most importantly the fact that the species fundamental niche is being determined by its currently realized niche (Pacifici et al., 2015; Conserving Nature's Stage, 2015). Mechanistic models are perhaps the most useful, for example using detailed information on the physiology of a species to determine its tolerance limits. However, the fact they require this detailed data means the application of this method is limited to a few species. Trait-based methods assess the sensitivity, adaptive capacity and exposure of a species, drawing on the biological traits of the species and their exposure to changes in weather and climate (Foden et al., 2013). This method has rapidly become the go to assessment method for conservation organizations, including World Wildlife Fund (WWF), given the relatively rapid methodology, and the resulting actionable management recommendations.

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2. Trait-based vulnerability assessments for species

In 2014, WWF developed a rapid assessment tool for assessing species vulnerability to climate change (Advani, 2014a). The tool was developed using methods from a number of existing tools, including Foden et al. (2013), Gill et al. (2013), The Heinz Center (2012), and Williams et al. (2008). The intention was to develop an easy-to-use methodology, which could be applied by conservation biologists with no background in climate science. The tool assesses the vulnerability of species to climate change based on four different dimensions: sensitivity, adaptive capacity, exposure and other threats. Each of these dimensions has a number of traits (or other variables) that are assessed. For each trait, the vulnerability should be ranked as high, medium, low or unknown. The use of rankings rather than ratings (for example a score of 1–10) was intentional, as there is no easy way to objectively rate many of the traits assessed using this tool. The goal of the tool was not to determine an overall vulnerability rating for a species, but rather to broadly identify traits which make a species vulnerable or resilient, then focus conservation actions on the areas of high vulnerability. The tool also provides guidance on how to rank the various traits. For example, users are asked to assess species traits relative to those of other similar species (e.g., African elephants relative to other large terrestrial mammals), and specify whether they are assessing the entire species or particular populations. When assessing each trait, examples are provided to guide the user. For example, elephants need to drink 150–300 l of water per day (high vulnerability to changing freshwater availability), whereas leopards can obtain moisture from prey and go for some time without drinking (low vulnerability to changing freshwater availability).

The categories of traits assessed are listed in Table 1.

As an example of how the tool works in practice, when assessing the sensitivity of a species, one which has high freshwater requirements will be sensitive to changing rainfall patterns, and a species which has a narrow temperature tolerance will be sensitive to increasing temperatures. When assessing adaptive capacity, a species which has a high dispersal ability, a short generation time, a high reproductive rate, and high amounts of genetic variation, may be better able to adapt to changes in weather and climate. For exposure to changes in climate, the tool deliberately avoids climate modelling. Instead, observed changes in weather and climate across the species range are used, as well as nearer-term projections for changes in precipitation and temperature. The last category, other threats, is particularly important, as most assessments of species vulnerability focus on direct impacts to species, neglecting indirect impacts. This category assesses the ways in which humans are coping with climate change, and how these coping responses might be harmful to species (Pacifici et al., 2015).

Once the assessment is complete, areas of medium to high vulnerability can then be identified, and recommended solutions integrated into species management plans. WWF has published trait-based assessments for various WWF priority species. Some high-level findings from these assessments, and recommended management strategies, can be found in Table 2. These findings have been used to influence conservation actions in a number of projects being implemented by WWF and partners. One common theme across multiple species is their vulnerability to changing water availability, the effect this has on their direct water needs, as well as the effect on food availability, either through the plants they forage on, or their prey base. One project at WWF tackles the “other threats” category. Working with rural communities all over the world, WWF engages communities to learn how climate change affects their lives and livelihoods, analyzes the data collected, presents the data back to the communities, then works with them to co-design and implement nature-based and nature-friendly solutions that address the challenges they have identified as most important, while reducing threats to nature such as human-wildlife conflict. Project interventions include solutions such as increasing water security, climate-smart agriculture, and alternative livelihoods (Climate Crowd, 2021).

The tool has also been employed by partners who have received funding through the Wildlife Adaptation Innovation Fund. These projects have focused on species beyond those highlighted in Table 2, and are detailed in Section 3 below.

Table. 1
The different dimensions of climate change vulnerability, and the traits and other variables (such as exposure to climate change) used to assess species vulnerability (Advani, 2014b).

Dimension of climate change vulnerability	Traits (and other variables) assessed
Sensitivity (the inability of the species to persist, as is, under changing climatic conditions)	– IUCN Red List Status – Geographic range – Population size – Temperature tolerance – Reliance on environmental cues for reproduction – Reliance on environmental cues for migration – Reliance on environmental cues for hibernation – Strong or symbiotic relationships with other species – Diet – Abundance of food source – Freshwater requirements – Habitat specialization – Susceptibility to disease
Adaptive capacity (the ability of the species to respond to changes in climate)	– Dispersal ability – Generation time – Reproductive rate – Genetic variation
Exposure (the extent of climatic change and variation that the species encounters and is projected to encounter)	– The degree of climate variability the species is currently exposed to – The level of change in temperature and precipitation projected across the species range
Other threats	– Habitat destruction, poaching, and human-wildlife conflict, as well as the human responses to climate change that exacerbate these threats

3. Implementing on-the-ground adaptation projects

In 2017 WWF launched the Wildlife Adaptation Innovation Fund, to support project ideas from around the world which reduce the vulnerability of wildlife to changes in weather and climate. The projects address climate vulnerability of one or more target species, are implemented in one year or less, and focus on on-the-ground project implementation. Successes and lessons learned from these pilot projects can be replicated and scaled to help wildlife endure under conditions of rapid global change.

Between 2017 and 2022, 15 projects have been implemented around the world. The information detailed below has been gathered from project reports submitted by grantees, including the initial proposals submitted, and the end of project reports. Further details on each project can be found on the project website: worldwildlife.org/WAIF

3.1. 2017–18

3.1.1. Constructing artificial nests for shy albatross — Australia

The shy albatross (*Thalassarche cauta*) is a near threatened species which numbers over 10,000 individuals, but faces a variety of threats across its range, including climate change (BirdLife International, 2022). Higher air temperatures during the chick-rearing period are associated with fewer eggs successfully producing chicks at the end of the breeding season, and their nests are susceptible to extreme rainfall events and wind. As a result, there is a predicted decline in the number of breeding females in the Albatross Island subpopulation of over 30 % over the next 3 generations (Thomson et al., 2015).

Table. 2
Highlights from species vulnerability assessments. For the full findings, these publications can be accessed at worldwildlife.org/wildlife-and-climate.

Species	IUCN Red List, n.d. Status (iucnredlist.org)	Climate vulnerabilities and recommended management strategies
African savanna elephant (*Loxodonta africana africana*)	Endangered	African savanna elephants require 150–300 l of water a day for drinking alone (Bothma, 2002; Bothma and Van Rooyen, 2005), and this influences their daily activities, reproduction and migration. Major threats facing elephants include poaching, habitat loss and human-elephant conflict (Gobush et al., 2022), and these have the potential to increase due to the effects of climate stressors on humans and resulting changes in livelihoods, particularly since so much of African elephant range is outside protected areas. Priorities for climate-informed African elephant conservation should include securing sources of fresh water, and creating improved conditions for people to adapt to climate change, thus reducing pressure on elephants and other species (Advani, 2014c)
Snow leopard (*Panthera uncia*)	Vulnerable	Snow leopards are found in the high mountains of Central Asia, between 3000 and 5400 m (McCarthy T et al., 2017), and are particularly vulnerable to the effects of climate stressors on humans, and how these may exacerbate the ongoing human impacts on snow leopards, including poaching and habitat encroachment, particularly as people shift their activities to higher elevations. Priorities for climate-informed snow leopard conservation should include creating conditions for people living in or near snow leopard range to better adapt to the impacts of climate change; and continuing to focus on reducing current threats, such as poaching, retaliatory killings and habitat degradation (Advani, 2014d).
Mountain gorilla (*Gorilla beringei beringei*)	Endangered	Mountain gorillas have a small population size, a highly restricted range, limited dispersal ability (due to human settlements), a long generation time, a low reproductive rate, and relatively low genetic variation, all of which will limit the ability of the species to adapt to a changing climate (Robbins and Williamson, 2008; Robbins, 2010; Yamagiwa et al., 2003; African Wildlife Federation et al., 2010; Garner and Ryder, 1996). Other threats like habitat destruction, poaching, socio-political instability, commercial activities, and growing human population pressure, remain high and have the potential to increase due to the effects of climate stressors on humans and resulting changes in livelihoods (Robbins and Williamson, 2008). Priorities for climate-informed conservation of mountain gorillas should include maintaining suitable habitat, including connectivity between different groups and populations. It is also essential to create improved conditions for people to adapt to climate change, particularly due to the increasing human population pressure surrounding mountain gorilla habitat (Advani, 2014d).
Polar bear (*Ursus maritimus*)	Vulnerable	Polar bears rely heavily on the sea ice environment for traveling, hunting, mating, resting, maternal dens, and in particular sea ice-dependent prey, such as ringed and bearded seals (Wiig et al., 2008, 2015), making them highly vulnerable to a changing climate. Priorities for climate-informed polar bear conservation should include identifying and protecting the “last ice areas,” the parts of the Arctic that are projected to retain sea ice farthest into the future (Durner et al., 2009). It is also important to increase monitoring of polar bear populations, particularly their responses to declining sea ice, which may lead polar bears to spend more time on land and result in increased human-polar bear conflict (Advani, 2016).
Giant panda (*Ailuropoda melanoleuca*)	Vulnerable	Bamboo makes up almost 90 % of giant panda diet, and may itself be quite vulnerable in a changing climate. It is subject to periodic, synchronous flowering and die-off, forcing giant pandas to relocate to areas with healthy bamboo (Swaisgood et al., 2016). Bamboo has a slow colonization rate, and may not be able to shift to higher elevations or latitudes at the same rate as giant pandas might (Shen et al., 2015). Human activities such as agriculture, logging, and infrastructure development also pose a big threat, and giant pandas persist only at elevations higher than land that can be used for productive agriculture. However, as the agricultural value of land in current panda habitat increases under a changing climate, activities like growing crops and grazing livestock may further encroach on their habitat (Swaisgood et al., 2016). Priorities for climate-informed giant panda conservation should include maintaining and increasing suitable, connected habitat, and restoration of habitat with bamboo species or genotypes which are adapted to a warmer

(continued on next page)

Table. 2 (*continued*)

Species	IUCN Red List, n.d. Status (iucnredlist.org)	Climate vulnerabilities and recommended management strategies
		climate. It is also essential to help people adapt to the changing climate, and minimize habitat loss and fragmentation caused by agriculture and other land uses (Advani, 2017).
Monarch butterfly (*Danaus plexippus*)	Least concern	Monarchs have a high dispersal ability across a large geographic range, and this combined with their short generation time and high reproductive rate suggests that monarchs may have a high capacity to adapt to longer term changes in climate (Oberhauser and Solensky, 2004; Lyons et al., 2012; Brower, 1996). However, a number of traits make them vulnerable to a changing climate. Like most butterflies, monarchs are highly sensitive to weather and climate. Their dependence on milkweed alone as a host plant is a further vulnerability, particularly as milkweed abundance is declining throughout the monarch range. Priorities for climate-informed monarch conservation should include restoring and increasing the extent of habitat in their migratory flyway with appropriate milkweed species and nectar sources, maintain and restore overwinter habitat, reduce the use of herbicides and pesticides, and address issues related to land-use change (Advani, 2015a).

This project tested artificial nests as a way to boost the reproductive success of shy albatross, using two different designs, mudbrick and aerated concrete. A total of 123 artificial nests were constructed and installed on Albatross Island in July 2017. The albatross readily adopted their new nests, even personalizing them with mud and vegetation. Follow-up monitoring throughout the breeding season confirmed high rates of uptake, with eggs laid in 90 % of the artificial nests. By the end of the season, breeding success (that is, the proportion of eggs laid that produce chicks that survive to fledging) in the artificial nests was more than twice as high as in the naturally built nests in the study.

3.1.2. Reducing vulnerability of red pandas and their habitat in the Khangchendzonga Landscape — India

The red panda (*Ailurus fulgens*) is an endangered species which has declined by as much as 50 % over the past 3 generations, and is projected to continue this decline (Glatston et al., 2015). Habitat loss and fragmentation are the major threats to their conservation, and there is increasing pressure on their habitat due to roads, livestock herding, over-extraction of forest resources, human population growth, and climate change (Glatston et al., 2015).

This project focused on decreasing human impacts on Sikkim's forests through use of improved cookstoves, sustainable harvesting of forest products, and reducing the risk of forest fires. Households were trained in the manufacture and installation of new cookstoves that require less fuel, and this has reduced fuelwood use by up to 35 % per household, cut cooking times in half, and significantly lowered indoor air pollution. Additionally, an action plan was developed to regulate use of forest resources and harvest plants more sustainably, and recommendations were developed for improved fire prevention and management.

3.1.3. Relocating Pacific walrus carcasses to minimize predator disturbance — Russia

Pacific walrus (*Odobenus rosmarus* ssp. *Divergens*) populations have experienced a significant decline since the 1980s, in large part due to a reduction in the extent of summer sea ice in the Arctic, and their dependence on the sea ice for birthing, caring for their young, and accessing feeding areas (Lowry, 2015). Without sufficient sea ice cover, walruses have increasingly been “hauling out” on land, where the numbers can reach tens of thousands of individuals (Chadwick et al., 2017). Sometimes, these haulouts result in stampedes due to disturbance caused by humans or predators such as polar bears, resulting in the death of weaker individuals and young calves.

This project in the village of Enurmino, Russia, focused on removing walrus carcasses from the rookery, and relocating the remains to known feeding areas of polar bears. The goal was to reduce the number of polar bears disturbing the walrus haulouts, and also help to mitigate conflict between humans and polar bears. Hunters from the village proposed the best locations for polar bear feeding areas. Over 80 walrus carcasses were transported from the rookeries to the feeding areas. Monitoring suggested that walruses gathered at the rookery a month earlier than expected—possibly as a result of reduced predator activity in the area. Approximately 80,000 walruses came ashore, and data suggested a 43.5 % decrease in the number of polar bear appearances at the rookery when compared with data from the previous year. Additionally, there was a reduction in the number of encounters between polar bears and members of the village.

3.2. 2018–19

3.2.1. Controlling sand temperatures for sea turtles in the Choco Region — Colombia

The olive Ridley (*Lepidochelys olivacea*) is a vulnerable species with a circumtropical distribution, which is decreasing globally due to a slow intrinsic growth rate as well as other anthropogenic threats (Abreu-Grobois and Plotkin, 2008). Sea turtles have temperature-dependent sex determination, with higher temperatures producing more females, and temperatures above certain thresholds leading to increased mortality (Janzen, 1994). Jensen et al. (2018) documented a population of subadult green sea turtles in the northern Great Barrier Reef beaches that was 99.8 % female due to warmer sand temperatures.

This project in the Chocó region of Colombia, investigated different ways to control the sand temperature of olive Ridley sea turtle nests, with a view to producing more even sex ratios in hatchlings and reducing heat related mortality. Different experimental setups were tested to determine their effectiveness and feasibility, including three different levels of shade installed above some nests (one, two and three layers of poly-shade), and some with no treatment. Temperature recorders were placed in the center of each nest to log daily temperatures. From August 2018 to February 2019, a total of 11,299 temperature measurements were recorded. The lowest average incubation temperature (28.29 °C) was obtained from the single and double shade treatments, the triple shade treatment was slightly warmer (28.69 °C), and the highest average temperatures (29.34 °C) were registered in the nests without any treatment. Identification of the sex of turtle hatchlings was not possible due to the difficulty and cost of doing so.

3.2.2. Establishing a network of artificial watering holes for Saiga antelope – Russia

Saiga antelope (*Saiga tatarica*) are a critically endangered species, with a global population of approximately 165,000, spanning Russia, Kazakhstan and Mongolia. The population suffers from mass mortality events due to disease outbreaks, exacerbated by climatic and environmental factors, as well as poaching pressure for their horns (IUCN SSC Antelope Specialist Group, 2018).

In Russia, Saiga are found in the Pre-Caspian steppes north-west of the Caspian Sea in Kalmykia and the Astrakhan Region, with an estimated population size of 5000–6000 (IUCN SSC Antelope Specialist Group., 2018). Over the past few decades, temperatures in the North-west Pre-Caspian Region of Russia have risen while precipitation has declined, resulting in small lakes and streams drying up during the summer months.

This project focused on increasing water available for Saiga antelope by restoring three wells within the Stepnoi wildlife refuge, Russia. Water holes play a particularly important role during the summer calving period. Several abandoned artesian wells installed during the Soviet era remained in the refuge, but had degraded over the years (Fig. 1). Repairs were completed in late 2018, and water flows at each well improved significantly. Camera traps documented Saiga antelope using the wells, as well as other animals such as foxes and wolves. The intervention has also reduced competition between livestock and wildlife for access to water, and ensured Saiga spend less time outside the protected area searching for water.

3.2.3. *Building artificial mounds for one-horned rhinos in Chitwan National Park – Nepal*

Greater one-horned rhino (*Rhinoceros unicornis*) are a vulnerable species, estimated at just over 3500 individuals found only in India and Nepal (Ellis and Talukdar, 2019), Major threats to the species include poaching, invasive plant species, reduction in the extent of grassland and wetland habitat, livestock, and changes in weather and climate such as severe flooding (Ellis and Talukdar, 2019). The intensity and magnitude of precipitation events in Nepal have increased over the past few decades, and this trend is likely to continue. Within Chitwan National Park, many animals have died as a result of severe flooding, including greater one-horned rhinos.

This project focused on constructing an artificial soil mound (Fig. 2) in a buffer area of Chitwan National Park, to serve as a refuge for rhinos and other wildlife during extreme flooding events. The location of the mound was determined based on elevation, proximity to flood prone rivers, presence of resident rhino populations, distance from human settlements, recommendations by park authorities, and consultations and approval by local communities. A 40 m × 30 m × 2 m mound was constructed near the Narayani River. Camera traps have documented rhinos and other wildlife using the mound, and continued monitoring will assess the ability of the mound to provide refuge to rhinos and other wildlife during severe flooding events.

3.3. *2019–20*

3.3.1. *Grassland creation and water provision for tiger prey — Thailand*

Tigers (*Panthera tigris*) are an endangered species, whose population numbers between 3726 and 5578 individuals and is restricted to ten countries. Poaching for illegal trade is the primary threat to tigers, along with prey depletion (Goodrich et al., 2022). Availability of a sufficient prey base of large ungulates is the primary habitat requirement for tigers, as they need to kill 50–60 large prey animals per year (Karanth et al., 2004).

Kaeng Krachan national park is the largest national park in Thailand, situated in the west of the country and part of the Dawna Tenasserim landscape. Due to historic poaching, there are only a handful of tigers remaining in the park, and efforts to restore the tiger population have been hampered by low prey abundance. Drought is a contributing factor, resulting in the depletion of freshwater sources and pasture. This project focused on habitat restoration, including clearing undergrowth and weeds from 32 ha, seeding the area with plants which will be consumed by tiger prey, maintaining salt licks, and restoring a waterhole with a 30,000 l capacity. Post-project camera trap monitoring suggests the habitat restoration project has been a success, with increased abundance of gaur, sambar deer, and other tiger prey documented at the project site, as well as tigers.

3.3.2. *Improved nesting, management and monitoring for African penguins — South Africa*

The African penguin (*Spheniscus demersus*) is an endangered species endemic to southern Africa which is undergoing a rapid population decline, most likely due to commercial fisheries and shifts in bird populations (BirdLife International, 2020). Climate change and industrial fishing have depleted forage fish, and Western Cape populations

Fig. 1. An old well in the Stepnoi wildlife refuge, Russia, prior to being rehabilitated by the project. Color image.

Fig. 2. Artificial mound constructed for rhinos and other wildlife in the buffer zone of Chitwan National Park, Nepal. Color image.

declined by 69 % between 2001 and 2009 (Sherley et al., 2017). Additionally, an increase in the frequency of extreme weather events, including storm surges and heavy rainfall events, has resulted in the destruction of penguin habitat. During heat waves, chick-rearing penguins often abandon their nests to cool themselves in the water, leaving their eggs and chicks exposed and vulnerable to hyperthermia and/or dehydration.

This project in the Simonstown colony in the Western Cape, tested

Fig. 3. Different nest designs being tested in the Simonstown African penguin colony, South Africa. Color image.

three different types of artificial nests (Fig. 3), constructed from cement, ceramic and fiberglass, to provide protection to chicks from predation, heat waves and winter storms. The project monitored breeding success at each nest, and weather data was collected from a weather station and temperature sensors installed within artificial nests. Ceramic nests had the highest usage levels, and also the highest hatching success. Overall breeding success (chicks fledged as a percentage of eggs laid) however was similar between ceramic and fiberglass nests. Older cement nests were less frequently used and also had the lowest breeding success.

The data will be used to assess the most favorable nest types and placements to improve breeding success, develop an early warning system to alert managing authorities to extreme weather events for coordinated rescue of eggs and chicks in danger, and penguin rangers will continue to rescue eggs for hand-rearing when chicks or eggs are abandoned during extreme weather.

3.3.3. *Creating wetlands and improved nesting sites for Sarus cranes — Nepal*

The Sarus crane (*Antigone antigone*) is listed as vulnerable, and is suspected to have suffered a rapid population decline as a result of widespread reduction in the extent and quality of its wetland habitats, overexploitation, and pollution (BirdLife International, 2016a). The global population is estimated at 15,000–20,000 individuals, divided among three populations found in the Indian subcontinent, South-East Asia and northern Australia (Archibald et al., 2003).

Sarus cranes prefer a mixture of flooded, partially flooded and dry ground for foraging, roosting and nesting. Nepal's second largest population of Sarus crane is found in the Lumbini World Heritage site. In recent years the area has experienced prolonged dry spells which have caused wetlands and water sources to shrink. Additionally, erratic and extreme rainfall events can destroy the breeding grounds and nests of Sarus cranes.

This project focused on a number of habitat improvement measures, including modifying wetlands that can better store water during dry spells, establishing raised nesting grounds made of excavated soil and grass to minimize impacts of flooding during heavy rainfall events, creating dykes and embankments to reduce sedimentation, and planting native varieties of rice which provide a food source for cranes.

3.4. *2020–21*

3.4.1. *Creating wildlife corridors for tigers in the Churia range – Nepal*

In 2010, global tiger range states made a commitment to double the population of tigers (Fig. 4) in the wild by 2022, the next year of the tiger. Nepal nearly tripled that number, with the 2022 census revealing a total of 355 tigers, compared to 121 in 2010 (DNPWC and DFSC, 2022). In recent years, tigers in Nepal have been recorded at high altitude locations, including in Ilam (3165 m) and Dadeldhura (2511 m). These forested areas at high altitude have been identified as potential habitats for tiger dispersal, and as potential climate refugia (DNPWC and DFSC, 2022).

This project focused on improving habitat for Nepal's tigers and their prey base (including wild boar, barking deer, and goral) at higher elevations. The project constructed twelve strategically placed artificial ponds in the drier parts of the Churia range in the Shukla-Brahmadev-Jogbuda complex of Nepal, an area that connects the existing habitat, Shuklaphanta National Park, and a potential climate refugia in the Mahabharata range. The intervention sites were selected and assessed through consultations and field visits. The ponds collect water from nearby springs and feature a wildlife-friendly design to mitigate any risk to animals. Monitoring has shown a significant increase in water availability, as well as an increased presence of prey species around these waterholes. The sites will continue to be monitored over time using camera traps, particularly during the dry seasons.

Fig. 4. Bengal tiger (*Panthera tigris tigris*). Color image.

3.4.2. Providing shade for birds of the Tankwa Karoo desert — South Africa

Tankwa Karoo national park is South Africa's most extreme desert, and forms part of an arid biome with a large diversity of succulent plants (Saaed et al., 2020). Rainfall amounts range from 100 mm/year in the lowlands, to 265 mm/year in the highlands. Air temperatures regularly exceed 40 °C in the summer, sometimes reaching temperatures over 50 °C. Ground surface temperatures can reach 60 °C on a very hot day. These conditions pose serious challenges to wildlife in Tankwa Karoo, in particular birds. Water availability is very important, as birds will need more water to keep cool as temperatures increase.

This project tested a solution to mitigate the impact of extreme heat on these desert birds, by installing artificial shade structures at waterholes (Fig. 5). The shade structures were constructed from wood, with a heavy shade cloth attached to the top. The structures were installed beside some of the waterholes. A "before-after control-impact" (BACI) experimental design was used to assess whether the birds would accept the shade structures and if the provision of shade allowed them to continue to drink when air temperatures were high. Camera traps were installed at waterpoints to monitor bird species using the water points, and black-bulb thermometers were installed at the edge of each waterpoint to monitor temperatures.

Results show that birds visited the shaded sites to drink water at higher frequency than they did unshaded control sites, and a higher proportion of bird visits to the waterholes occurred in the heat of the afternoon rather than the cool of the morning, once shade was available. The presence of shade also significantly reduced the temperatures birds experienced at the water's edge, with shade temperatures below 45 °C even on the hottest days, while temperatures in the sun regularly reached 50 °C–60 °C.

3.4.3. Installing and monitoring artificial water sources to help endangered species in the Maya forest — Mexico

Situated at the base of Mexico's Yucatan Peninsula, the Calakmul Biosphere Reserve (CBR) is home to a diverse array of flora and fauna, including the Central American tapir, white-lipped peccary, ornate hawk-eagle, and jaguars. Water availability determines the presence, abundance and distribution of species in the reserve, and rainfall has become more intense and more unevenly distributed throughout the year (Mardero et al., 2020). Droughts in 2018 and 2019 affected the seasonal small bodies of surface water that are locally known as "aguadas."

This project focused on installing artificial water sources in critical areas, monitoring species using the water sources, and conducting a spatial analysis to determine the areas of greatest vulnerability to drought. 30 water collection and storage systems were installed. Camera traps revealed 90+ species of vertebrates using the water sources. Additionally, an adult male tapir was fitted with a GPS collar to follow its movements and better understand how it uses water during the dry season. Results suggest the artificial water sources are a useful intervention to reduce the effects of drought on wildlife.

3.4.4. Restoring elephant habitat through enrichment planting and check dams – Myanmar

Asian elephants (*Elephas maximus*) (Fig. 6) are an endangered species, whose populations have suffered a reduction of at least 50 % over the last three generations, and have a current estimated wild population size of approximately 50,000 individuals (Williams et al., 2020). The primary threats to the species are habitat loss and fragmentation, human-elephant conflict, and poaching and illegal trade. These threats have the potential to increase due to the effects of climate stressors on humans and resulting changes in livelihoods. Asian elephants also have very high freshwater and food requirements, drinking up to 225 l of water a day, and eating approximately 150 kg of vegetation, both of which are affected by changing rainfall patterns (Advani, 2015b).

This project focused on restoring habitat for Asian elephants in the Ayeyarwady region of Myanmar, by increasing food and water availability. An area of degraded forest spanning 20 acres was restored, including planting of banana, cane, and htanmasai grass, all of which are ideal food for elephants. Two check dams were constructed for water storage during the dry seasons, storing up to 30,000 l of water. Monitoring suggests increased elephant presence around the check dams and restored grassland, and according to local communities, wild elephants do not enter villages as often as they used to, thus reducing human-

Fig. 5. Artificial shade structure at a waterhole, Tankwa Karoo National Park, South Africa. Color image.

Fig. 6. Asian elephant (*Elephas maximus*). Color image.

elephant conflict.

3.5. 2022-23

3.5.1. Providing artificial nests for Southern Ground Hornbills in the Zambezi Region, Namibia

The Southern Ground Hornbill (*Bucorvus leadbeateri*) is a vulnerable species facing a number of threats, including loss of nesting habitat due to agriculture, fires, storms, livestock grazing, persecution, and poisoning (BirdLife International, 2016b). Additionally, the species suffers from heat stress and exhibits heat avoidance behavior at temperatures above 26 °C. Heatwaves are increasing in severity and frequency, and this is impacting their foraging ability, as well as embryo development.

This project in the Zambezi region of Namibia focuses on installing insulated artificial nests, which will encourage breeding through increasing the availability of suitable nest sites, and will provide hens, developing embryos and chicks a higher chance of survival during the hottest times of the breeding season. The nest boxes are also likely to provide some protection for the birds and their eggs during fires occurring in the area.

3.5.2. Improving habitat for Baer's Pochard in the Chonghu wetland, China

Baer's Pochard (*Aythya baeri*) is a critically endangered species which breeds from the Amur and Ussuri basins in Russia southwards to the central and lower Yangtze floodplain in central-eastern China, and mainly winters in central-eastern China (BirdLife International, 2019). Chonghu Wetland is the largest breeding population known in China. The species is experiencing an extremely rapid population decline, with population estimates of less than 1000 individuals. The principal threats are thought to be wetland destruction and overharvesting of birds and eggs, though a growing threat is an increase in the severity and frequency of flooding. As their wetland habitat is shallow and connected to adjacent waterbodies, water levels can rise very quickly.

This project in Chonghu Wetland in China focuses on creating more resilient breeding habitat for the birds. This will include modifying the terrain by creating higher areas for nesting, and planting preferred vegetation for the birds. In order to reduce disturbance by visitors, ditches will be dug surrounding the habitat, and common reeds will be planted to form a barrier.

4. Lessons learned from project implementation

The Wildlife Adaptation Innovation Fund started in 2017 as a pilot concept. The fund has allowed grantees to put species climate vulnerability research and management recommendations into practice, and has grown from funding 3 projects per year at $15,000 each, to 5 projects per year funded at $30,000 each.

The projects funded to date have varied focal areas, including improved nesting, habitat restoration, water provision, and trialing unique structures to alleviate threats such as extreme heat. The projects also occur across different timescales. Some projects, such as the Pacific walrus, are heavily managed. The moment the intervention stops, the problem could resurface. Other projects are implemented over a few years, such as the bird nesting projects. These interventions give the species population numbers a temporary boost, in the hope that the species will be well on its way to recovery when the intervention stops. Lastly, some projects play out over very long time periods, for example facilitating the shift of species' ranges to higher elevations as the climate changes.

As the fund has grown and evolved over the years, some key trends have emerged:

– Project ideas submitted to the fund often lack a clear climate rationale. Grant applicants fail to document the climate threats currently facing the species, and/or how the proposed intervention reduces species vulnerability to identified climate threats.

- Developing a robust monitoring & evaluation (M&E) framework is key for each project, without being overbearing, given the funding and timeline for these projects. Key components of the M&E framework include the project outcomes and objectives, indicators, a target and baseline for each of the indicators, and the data source/frequency of collection/method of collection.
- Measuring the success of adaptation interventions is not always straightforward. Often, measuring climate adaptation is about avoided impacts, i.e. what would have happened in the absence of adaptation measures (Christiansen et al., 2018). This make developing useful project indicators challenging.
- Grantees are required to carry out a number of reporting steps. This begins with a detailed implementation plan, including activities, budget, partners, M&E table, timeline, and project safeguards. Once the funding is disbursed, and planning is complete, a site report is submitted which contains maps of the project location, pictures prior to the intervention, details of partner meetings, and any project updates. At the end of the project, a report is submitted with a completed M&E table, project summary, lessons learned, recommendations for replicating or scaling the work, and how the results will be monitored in future years. The biggest challenge throughout this process is monitoring the continued success of projects after they end, given the one-year project life cycle. Once the grant has ended, there is no obligation for grantees to continue reporting on project success or failure.
- Involving local communities in the project can be crucial to its success. Many of the projects detailed above include working with local communities. However, having a clear plan to engage them, and ensuring that they feel a sense of ownership, is key to their continued involvement.
- Innovative ideas do not always succeed. The goal of the fund is to test innovative ideas, but if they fail, the investment of time and funding were moderate, and lessons learned can be applied to future similar ideas.
- The ability to scale or replicate successful projects is limited by funding availability. To date, funding has been prioritized for new projects, rather than continuation of existing projects.
- The project interventions are typically in response to ongoing changes in weather and climate, and the impact these have on the species of concern. In some cases, particularly extreme weather events, the climate impacts which motivated the project intervention may not have occurred since with the same intensity. This was the case for the artificial mound project for one-horned rhinos in Nepal. As a result, the efficacy of the intervention has yet to be fully tested.
- Project interventions may solve one problem, but create another. For example, the improved nest designs for African penguins helped to increase the hatching success of eggs, but they also attracted increased numbers of mites.
- Project timelines must be adaptable. Given the range of projects funded, across so many geographies, obstacles can, and have, appeared. From political instability to weather-related delays to the global pandemic, the partners implementing these projects have faced many obstacles. Their commitment to the cause did however ensure that all projects crossed the finish line, even if not according to the original timeline.

5. Looking forward

Climate change is perhaps the greatest challenge of our time. Global attention to climate change is increasing, in part due to the efforts of the United Nations Framework Convention on Climate Change (UNFCCC), and the Intergovernmental Panel on Climate Change (IPCC). Funding commitments from countries are not near the levels needed, but are trending in the right direction. There is also a very rich and growing scientific literature on the climate vulnerability of people, ecosystems, and species, with a much needed shift from projected impacts to observed impacts. However, while progress is being made on conducting impact and vulnerability assessments, and other climate adaptation research, translation of this knowledge into tangible adaptation initiatives across different countries is still limited (Lesnikowski et al., 2015). The same is true for species. Research must translate into on-the-ground implementation projects that help species adapt, both through direct human interventions, and by facilitating their natural capacity to adapt to these changes.

The vulnerability assessment method presented in this paper was designed for conducting a rapid assessment, particularly by species biologists, and does not require a technical background in climate science. The uptake of this methodology appears to be quite high, due to ease of use, and because of the actionable adaptation outcomes it generates. These assessments are often used to guide projects funded under the Wildlife Adaptation Innovation Fund, which has received numerous strong proposals since its inception in 2017. The fund is now supporting more projects every year, at higher funding levels.

It is important to remember that there isn't a need for the perfect science when doing on-the-ground implementation, if in fact something such as the perfect science even exists. A drought is a drought, and how species respond to it today is indicative of how they might continue to respond in the future. Along similar lines, no matter how far the science of climate projections has advanced, projections of future climate will always contain levels of uncertainty. What is known is that certain climatic variables are largely unidirectional, like increased warming, and some are bi-directional, like precipitation amounts and seasonality. This makes the latter harder to plan for, and may instead necessitate the use of scenario planning. For example, conservation managers can have a particular suite of interventions during times of severe drought, and a different set of interventions during times of flooding. However, uncertainty should not be an excuse for inaction. Conservation practitioners have the tools at our disposal to help people and nature in a changing climate, and with the changes we are already seeing, we have no time to lose.

Photo credits

Nikhil Advani.

Declaration of competing interest

The author states there is no actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

Data availability

Data will be made available on request.

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