Ecological Principles and Biodiversity for Sustainability

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17. Climate change and its impacts on Ecology and Biodiversity

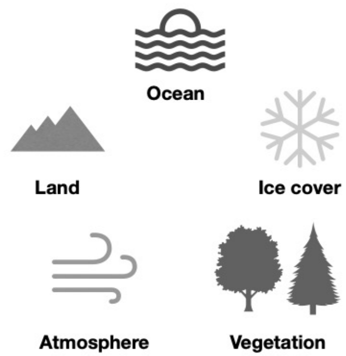
Climate[1]

"A broad composite of the average conditions of a region, measured in terms of such things as temperature, amount of rainfall or snowfall, snow and ice cover, and winds"

The classical period for taking averages is 30 years.

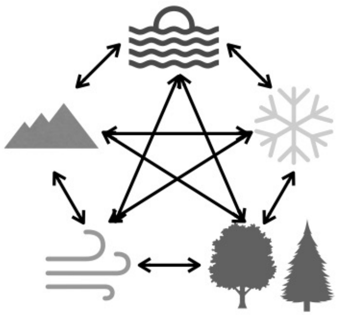
[1] Ruddiman, W. F. (2001). Earth's Climate: past and future, Macmillan.

Components of the climate system



(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

The climate system



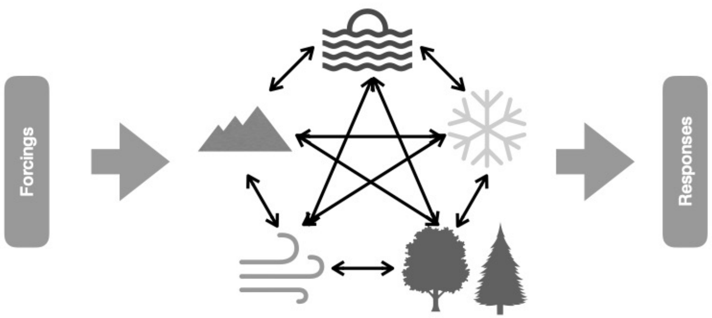
(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

What is climate change?

"Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use."[2]

[2] Baede, A. (2007). "Annex 1 IPCC Glossary." Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Forth Assessment Report of the Intergovernmental Panel on Climate Change.

The working of the climate system



(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Forcings

- Changes in plate tectonics
- Changes in Earth's orbit
- Changes in Sun's strength
- Anthropogenic forcing

Responses

Changes in atmosphere

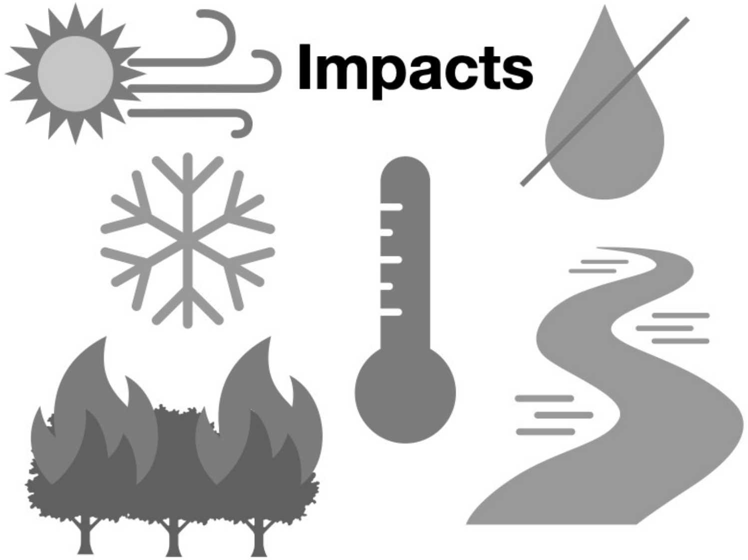
Changes in ocean

Changes in vegetation

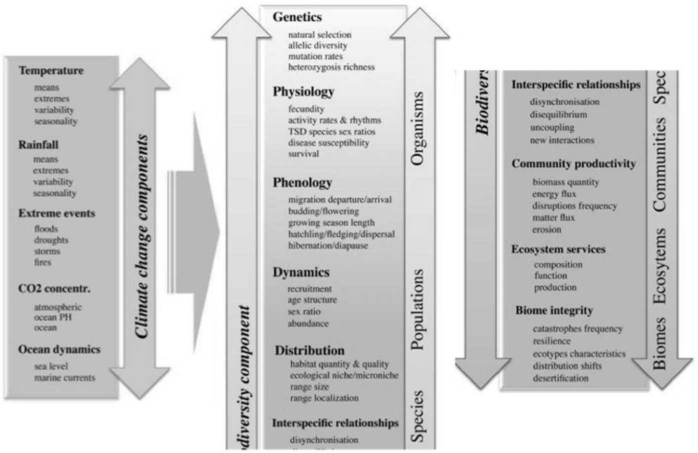
Changes in land surface

Changes in ice

Responses

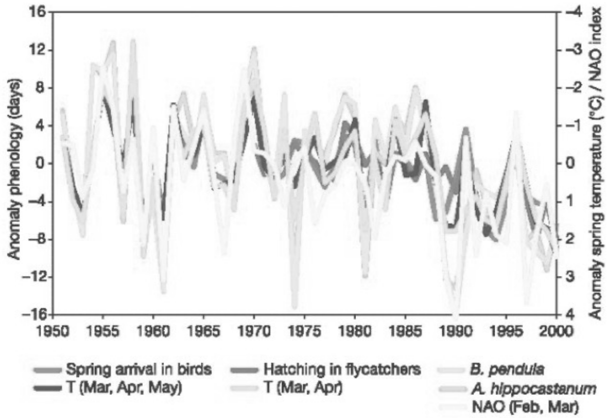


Biological responses



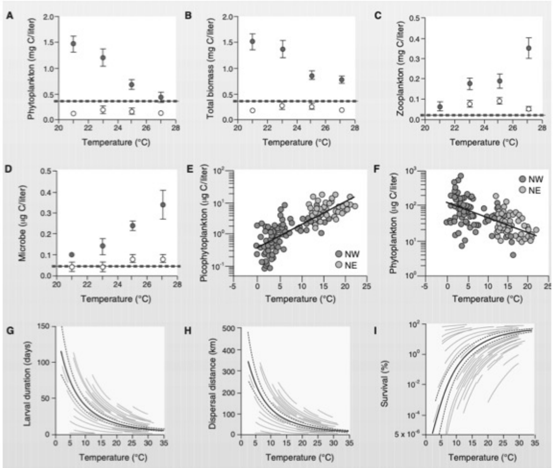
(Bellard et al., 2012. Impacts of climate change on the future of biodiversity. Ecology letters, 15(4), pp.365-377.)

Example: Phenological anomalies correlate well with temperature anomalies



(Walther et al., 2002. Ecological responses to recent climate change. Nature, 416(6879), p.389.)

Example: Habitat changes

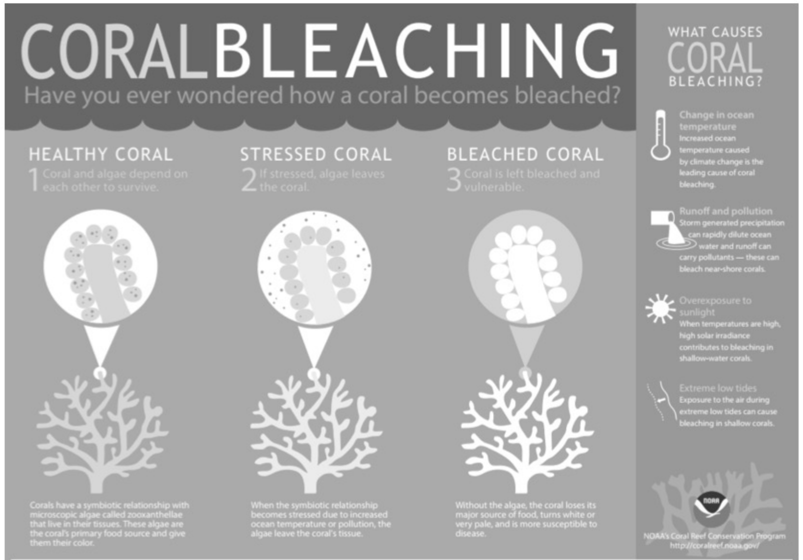


(Hoegh-Guldberg, O. and Bruno, J.F., 2010. The impact of climate change on the world's marine ecosystems. Science, 328(5985), pp.1523-1528.)

Example: Bleached corals

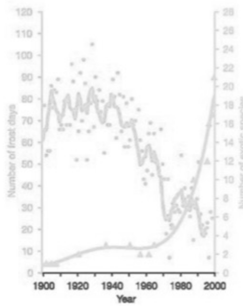
Source: NOAA https://origin-apps-pifsc.fisheries.noaa.gov/cred/coral_bleaching_and_disease.php

Example: Bleached corals



Source: NOAA https://oceanservice.noaa.gov/facts/coral_bleach.html

Example: Invasion and rise in exotic species

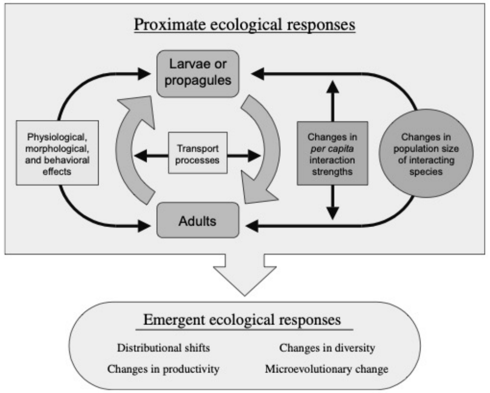


The shrub layer is dominated by the growing number of spreading exotic evergreen broad-leaved species (see illustration) that appear to profit from milder winter conditions, indicated here by the decreasing number of days with frost per year (the smoothed curve gives five year averages for the number of frost days per year)[29].

(Walther et al., 2002. Ecological responses to recent climate change. Nature, 416(6879), p.389.)

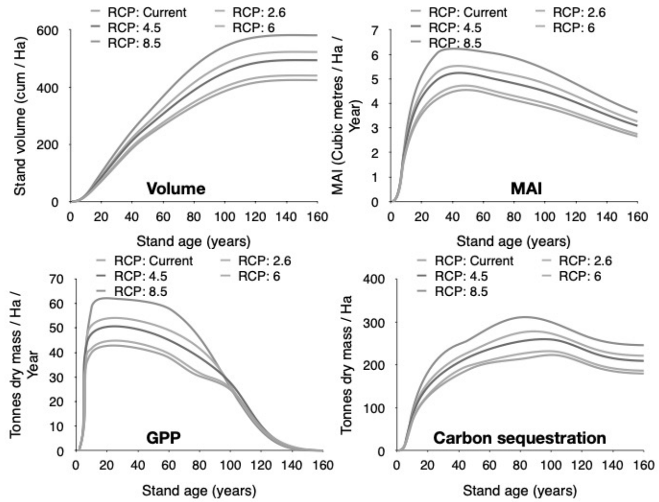
Example: Ecological Responses

Figure 3 Potential ecological responses to climate change. The life cycle of a generic marine species is shown in green. Abiotic changes in the environment have direct impacts (yellow boxes) on dispersal and recruitment, and on individual performance at various stages in the life cycle. Additional effects are felt at the community level via changes in the population size and per capita effects of interacting species (in blue). The proximate ecological effects of climate change thus include shifts in the performance of individuals, the dynamics of populations, and the structure of communities. Taken together, these proximate effects lead to emergent patterns such as changes in species distributions, biodiversity, productivity, and microevolutionary processes. See text for details.



(Harley et al., 2006. The impacts of climate change in coastal marine systems. Ecology letters, 9(2), pp.228-241.)

Example: Responses in plants



Awadhiya & Awadhiya (2017). "Impact of global warming on the carbon sequestration potential and stand dynamics of Chir Pine forests." XIX Commonwealth Forestry Conference, 2017.

Example: Responses in health

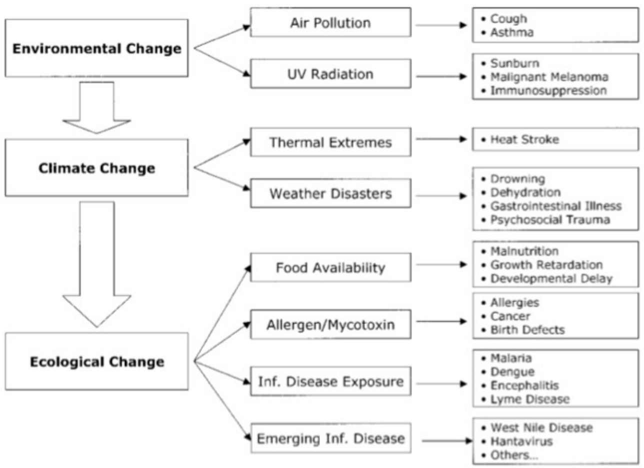
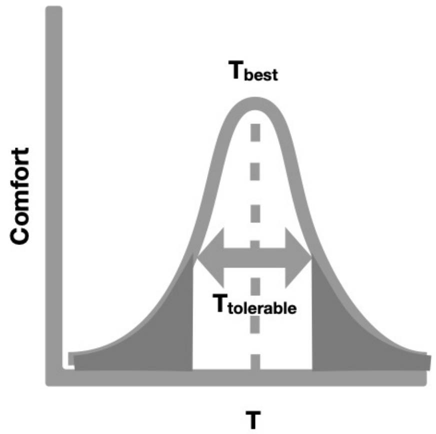


Figure 2. *The relationship between environmental change, climate change, ecologic change, and child health.*

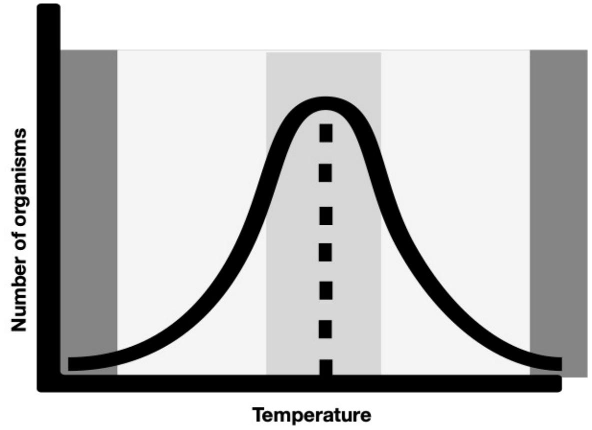
Ambulatory Pediatrics 2003;3:44 52

Comfort levels



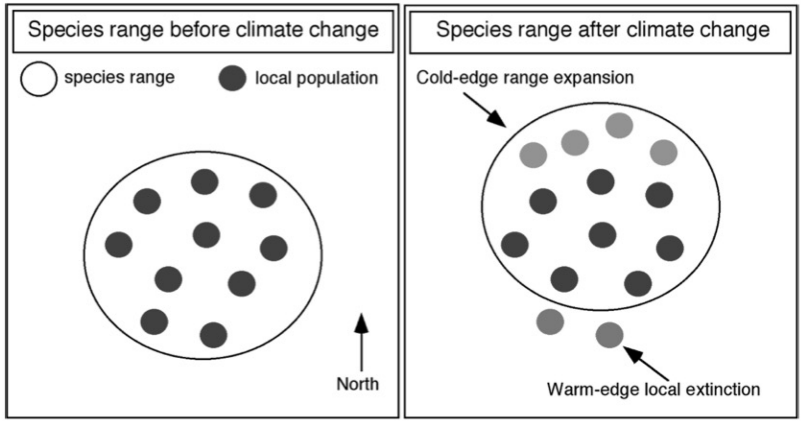
(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Tolerable temperature levels



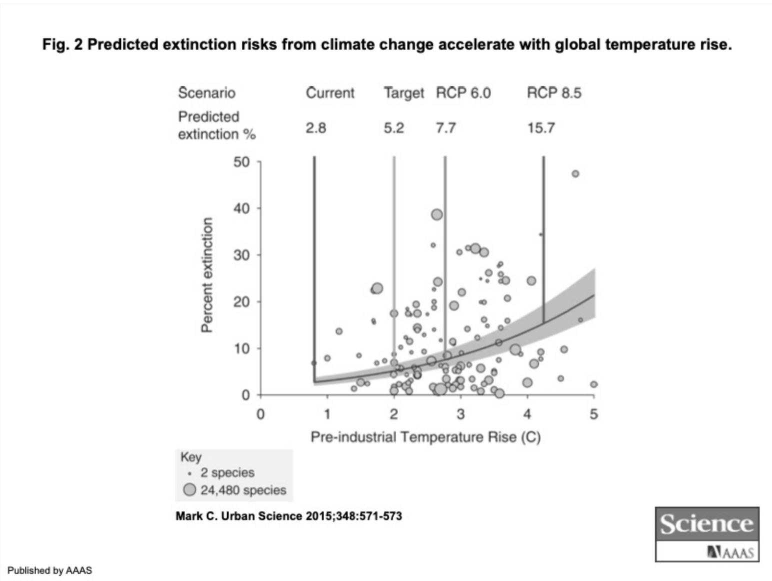
(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Local extinctions due to climate change

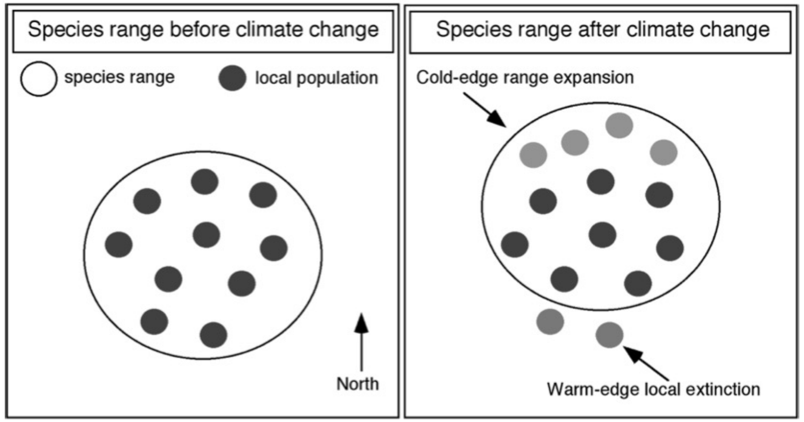


(Wiens, J.J., 2016. Climate-related local extinctions are already widespread among plant and animal species. PLoS Biology, 14(12), p.e2001104.)

Example: Rise in extinction possibilities

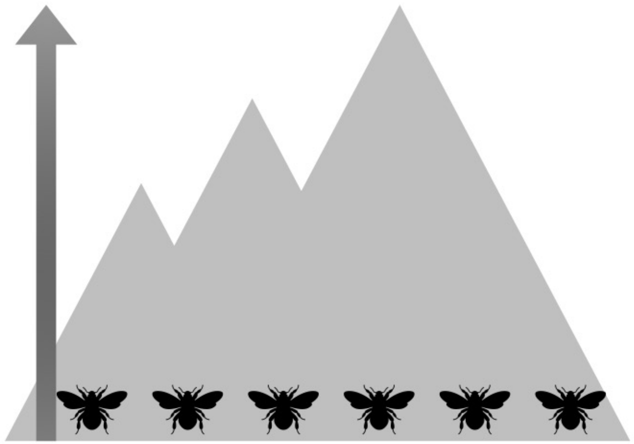


Changes in spatial distributions



(Wiens, J.J., 2016. Climate-related local extinctions are already widespread among plant and animal species. PLoS Biology, 14(12), p.e2001104.)

Example: Changes in spatial distributions of insects



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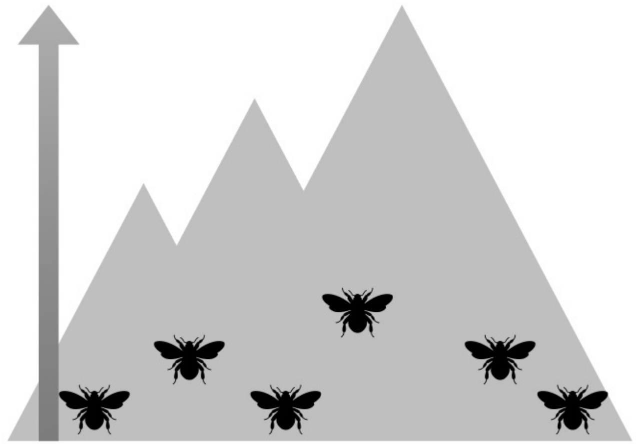

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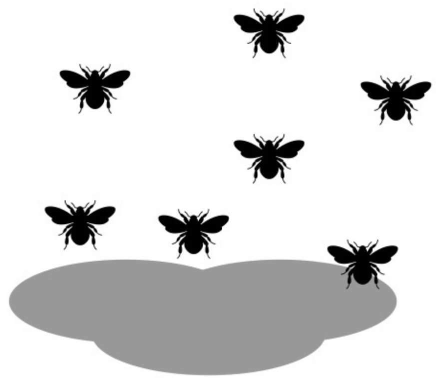
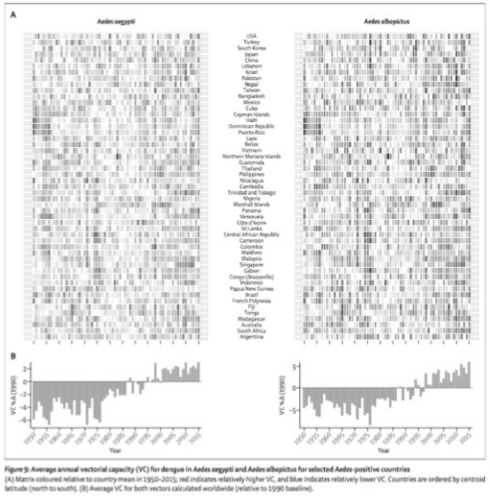


(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Example: Increase in vectorial capacity of mosquitoes

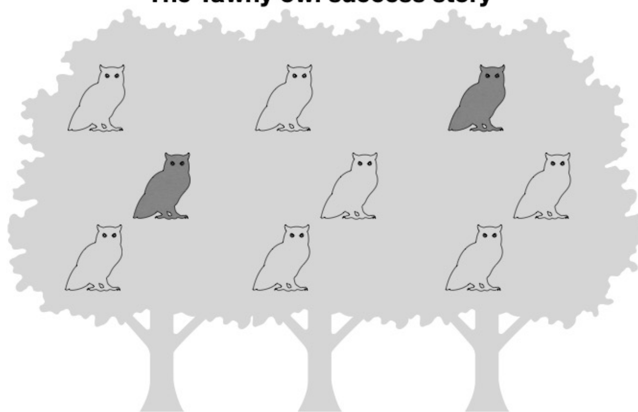


Increased vectorial capacity of *A. aegypti* and *A. albopictus*

The Lancet DOI: (10.1016/S0140-6736(17)32464-9)

Example: Changes in allele frequencies

The Tawny owl success story



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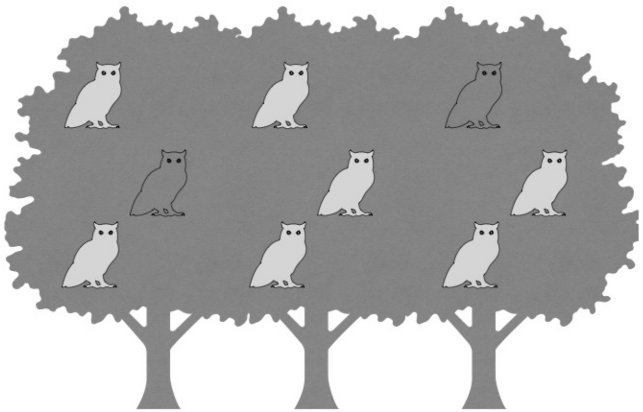
Example: Changes in allele frequencies



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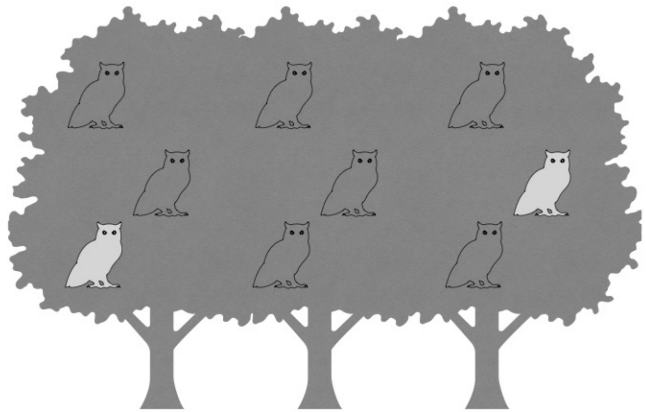
Example: Changes in allele frequencies



(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Mitigation & adaptation

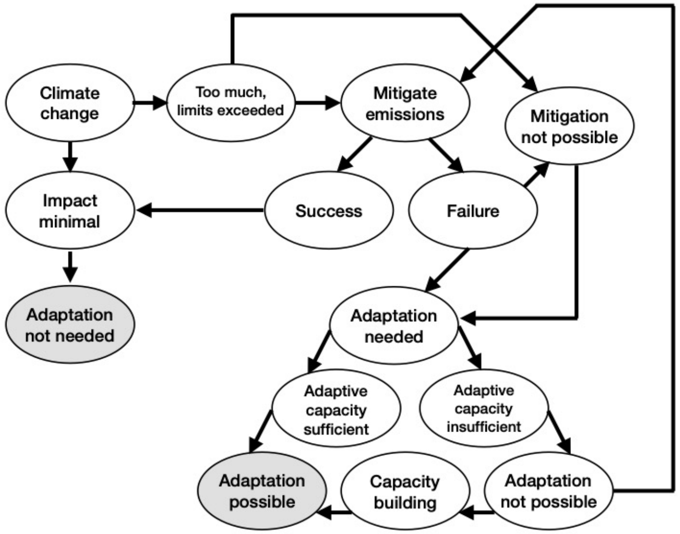
Mitigation: "A human intervention to reduce the sources or enhance the sinks of greenhouse gases."[3]

Adaptation: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[4]

[3]Baede, A. (2007). "Annex 1 IPCC Glossary." Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Forth Assessment Report of the Intergovernmental Panel on Climate Change.

[4]UNFCCC. (2014). "Focus: Adaptation." Retrieved 2017-08-06, 2017, from http://unfccc.int/focus/adaptation/items/6999.php.

The mitigation-adaptation flow-chart



Adapted from Schipper, E. L. F. (2006). "Conceptual history of adaptation in the UNFCCC process." Review of European, Comparative & International Environmental Law **15**(1): 82-92.

Mitigation options

1. Reduce emissions: Laws, Green energy, REDD (Reducing emissions from deforestation and forest degradation)
2. Create sinks: Artificial trees, carbon sequestration in geological sites, Afforestation, REDD+ (conservation, sustainable management of forests and enhancement of forest carbon stocks)

(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Kinds of adaptation

1. Anticipatory / Proactive vs. Reactive
2. Autonomous / Spontaneous vs. Planned
3. Private vs. Public

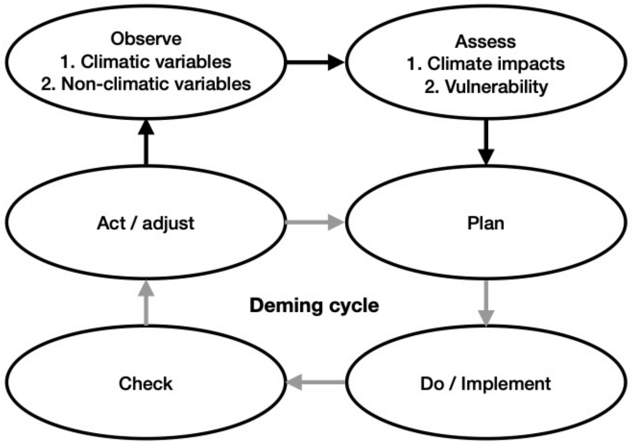
(McCarthy et al. (2001). "Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001." J Appl Meteorol 44(5))

Adaptive capacity

"The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

(McCarthy et al. (2001). "Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001." J Appl Meteorol 44(5))

Elements of adaptation



(Ankur Awadhiya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester, 144(10), 911-921, 2018.)

Adaptation options

1. Create **resistance to change**: reduce effects of fires, insects, diseases: better protection, removal of invasives, resistance breeding
2. Promote **resilience to change**: surplus seed banking, intensive management during establishment, promotion of biodiversity-rich ecosystems
3. Enable forests to **respond to change**: assist natural adaptations and transitions, assisted migration to newer areas, increase redundancy, manage for asynchrony, establish neo-native forests considering past spread, promote connected landscapes

(Millar et al. (2007). "Climate change and forests of the future: managing in the face of uncertainty." Ecological applications 17(8): 2145-2151.)

Maladaptation

"Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead."

(McCarthy, J. J., O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White (2001). "Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001." J Appl Meteorol 44(5): 7009716Messerli.)

Thank you

18. Conservation of biodiversity – In situ conservation

In-situ and ex-situ conservation

- In-situ conservation: *In situ* = on site
  Conservation within the natural habitat.
- Ex-situ conservation: *Ex situ* = off site
  Conservation outside the natural habitat.

Process of in-situ conservation

Areas in the natural habitat are designated as reserves, national parks, or protected areas.

In these areas, ecological monitoring and interventions (active management) are done.

Legislations are required to maintain these areas as protected areas.

Section 2 of the Wildlife (Protection) Act 1972

2(24A) “protected area” means a National Park, a sanctuary, a conservation reserve or a community reserve notified under sections 18, 35, 36A and 36C of the Act;

Process of ex-situ conservation

1. Designated areas with suitable conditions and facilities are created.
2. Species are moved into these designated areas for their survival and breeding.
3. (Optional) The species are later released into their natural habitats.

In-situ conservation: Advantages

1. Species continue to live in their natural environment.
2. Less disruptive, less costly.
3. Natural behaviours are maintained.
4. Protection of natural habitat provides protection to other species as well.
5. Even in case of ex-situ conservation, the animal will need to be released somewhere. In-situ conservation sites provide suitable areas for such releases.
6. Reserves double as places for scientific studies and public awareness.

In-situ conservation: Disadvantages

1. Requires very large areas.
2. Less intensive protection and management: areas may be encroached upon or animals poached.
3. Threat of diseases and disasters.
4. Large establishment required in each case.

In-situ conservation: Strategy

1. Where to make reserves
2. Size and shape of reserves
3. Management of reserves

Where to make reserves

Traditional ways of creating reserves

1. Beautiful areas: lush green mountains, lakes, beaches. e.g. Dachigam National Park, Srinagar
2. High species diversity, e.g. Silent Valley National Park, Kerala
3. Harbouring unique animals, e.g. Gir National Park, Sasan, Gujarat

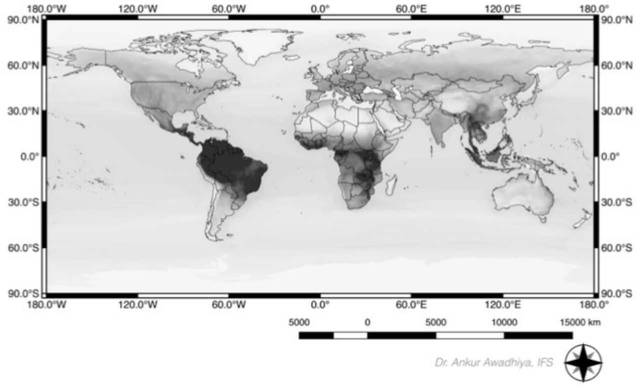
But these could be too haphazard and based on whims and fancies of the reserve creator.

Scientific ways of creating reserves

1. High species richness
2. High species endemism
3. High number of species under threat

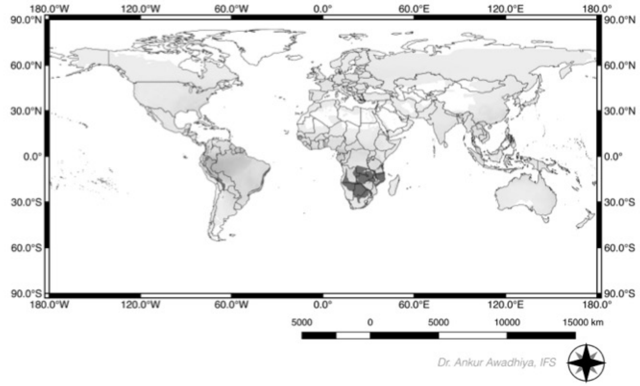
Global mammalian richness

Map of mammalian richness



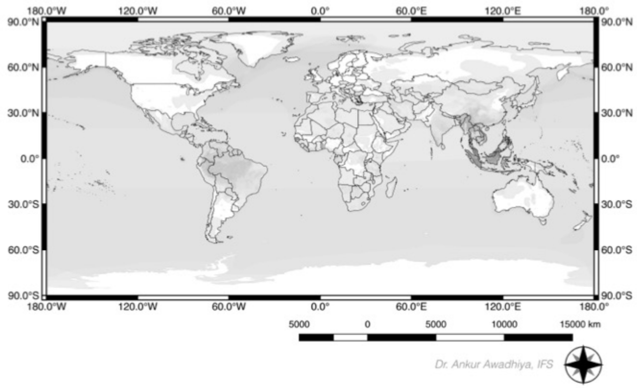
Global amphibian richness

Map of amphibian richness



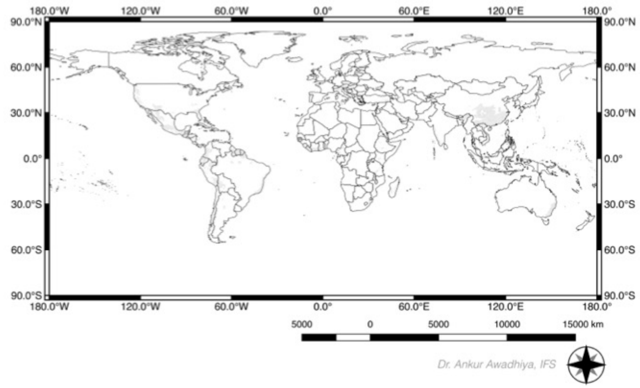
Global mammalian species under threat

Map of threatened mammalian richness



Global amphibian species under threat

Map of threatened amphibian richness

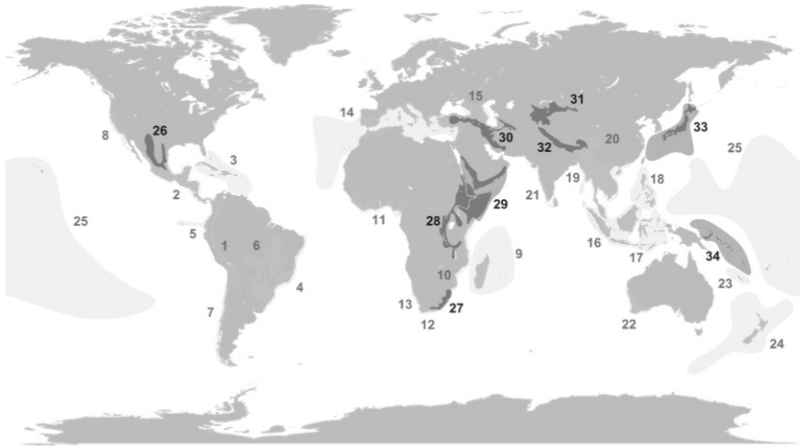


One criterion: Hotspots

Biodiversity hotspots are areas with

1. high species richness
2. high degree of endemism
3. high degrees of threat

Biodiversity hotspots of the world



(Wikimedia curid=10956104)

Threat perception: triage

The level of threat can be:

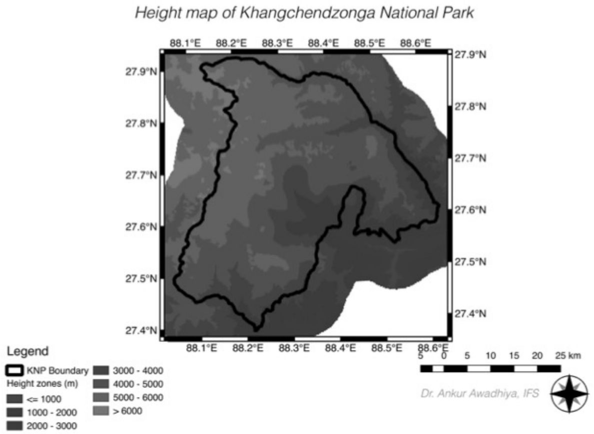
1. very high: maybe a lost cause, already!
2. *medium*: that's where most of the focus is!
3. very low: may be left for now.

Gap analysis

This approach tries to identify holes in the existing network of protected areas, that are primarily in locations that are, or were historically, uninhabitable for humans due to their heights, prevalence of diseases, etc.

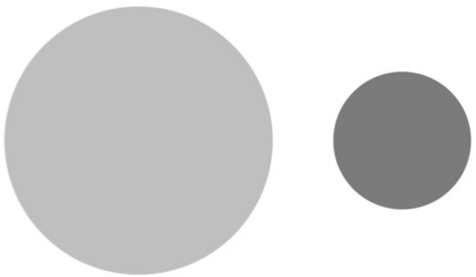
Creating some protected areas in human-dominated areas may fill the gap, allowing a different set of species to thrive.

Height map of Khangchendzonga National Park, Sikkim



Size and shape of reserves: Principles of reserve design

Big is better than small

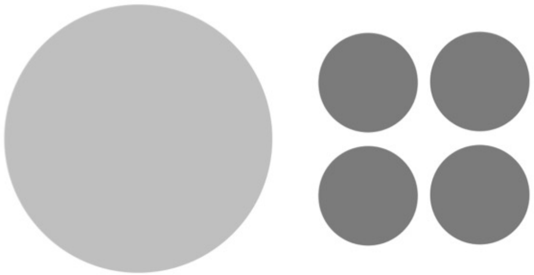


(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Reasons

1. Bigger sizes $\implies$ More habitats $\implies$ Higher species diversity
2. More secure and easier to manage (per unit area) as:
   a. Larger populations are less susceptible to extinction.
   b. Smaller perimeter / area $\implies$ less cost of protection.
   c. Less vulnerable to catastrophes since smaller catastrophes will not impact the whole area.

One big is better than several small of same total area



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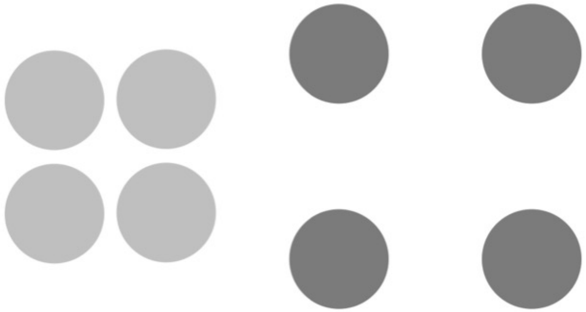
Closer reserves minimise isolation

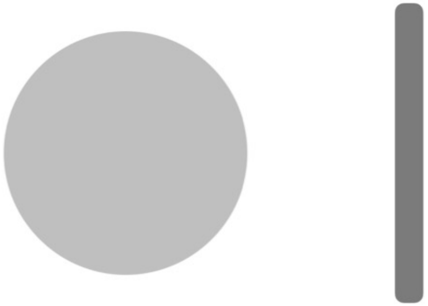


(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Cluster permits more movement than linear

(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

Circular reserves have less biotic pressure



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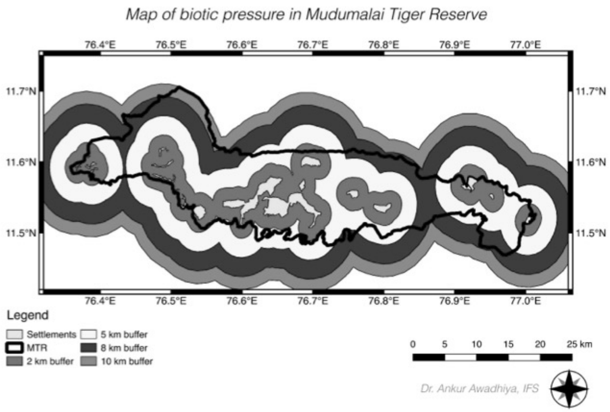
Example from Mudumalai Tiger Reserve



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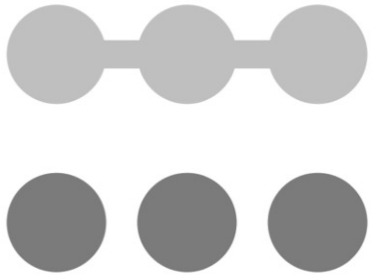
Connection is important



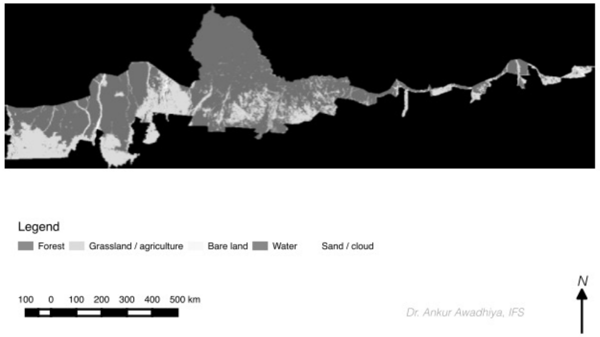
(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

If nothing else works, maintain / enhance connectivity.

But even that is increasingly under threat.

Manas Trans Boundary Conservation Area 1985

Transboundary Manas Conservation Area (Land cover classification, 1985)



(Ankur Awadhiya et al. Understanding Elephant Movement Paths in a Fragmented Corridor using Animal Energetics, Indian Forester, 149 (10), 1004-1009, 2023)

Manas Trans Boundary Conservation Area 2003

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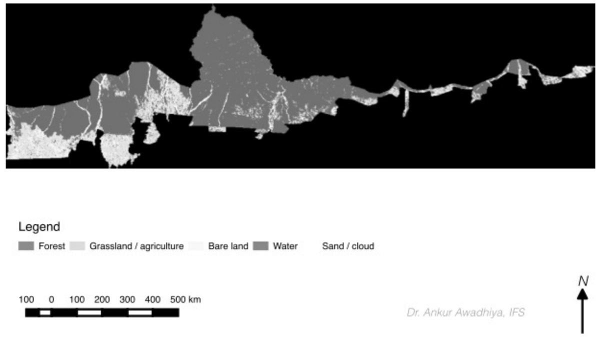

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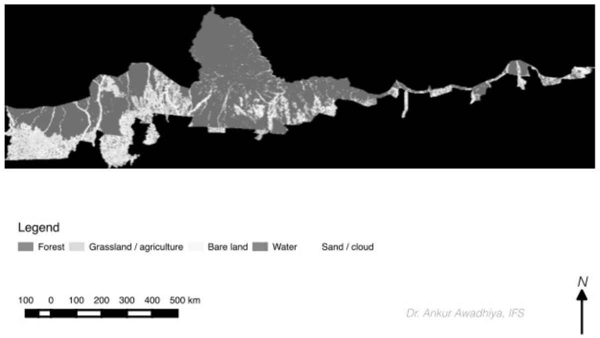
Manas Trans Boundary Conservation Area 2017

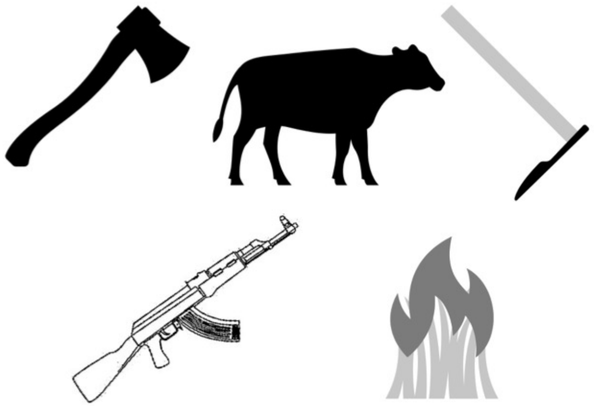
Transboundary Manas Conservation Area (Land cover classification, 2017)



(Ankur Awadhiya et al. Understanding Elephant Movement Paths in a Fragmented Corridor using Animal Energetics, Indian Forester, 149 (10), 1004-1009, 2023)

Management of reserves

The five tools of habitat management



(Leopold, A., 1933. Game management. 481 pp. Charles Scribner's Sons, New York.)

But these are also

the tools of habitat destruction!

The key is to note **how to use them**.

Negative livestock and community interactions I

1. Competition: occurs when
   a. species use the same resource e.g. land
   b. land / resource is in short supply
   c. at least one species loses fitness: weight, fertility, health, etc.

   When livestock compete with wildlife, it may result in
   a. displacement of wildlife to non-prime / sub-prime habitats e.g. hills or rocky patches
   b. encroachment of wildlife corridors and migratory routes
   c. habitat loss
   d. habitat degradation
   e. habitat fragmentation
   f. changes in behaviour and phenology
2. Spread of diseases like FMD (spread by cows) or canine distemper / rabies (spread by dogs accompanying the livestock)
3. Reduced nesting sites for game birds and waterfowl

Negative livestock and community interactions II

4. Trampling of nests by livestock
5. Overuse of pastures and other resources
6. Soil compaction
7. Reduced water quality and eutrophication
8. Disturbance to mating and fawning
9. Reduced cover for birds requiring tall grasses, due to changes in species composition
10. Conflict situations e.g. retaliatory killings

Positive impacts of livestock on habitat

1. Improved forage quality: removal of coarse tall grasses allows soft palatable grasses to grow
2. Availability of insects to birds like egrets
3. Removal and reduction of cover benefits small rodents as well as birds of prey
4. Patchy grazing creates high structurally dense habitats with lots of ecotones and species diversity
5. Opening up of dense canopies when required
6. Establishment of shrubs benefitting browsers
7. Creation of travel corridors with selective grazing
8. Reduction of weed spread
9. Fire risk reduction by reducing fuel load
10. Provisioning of food to carnivores through livestock depredation

How to manage?

The management always strives to reduce the negative consequences while promoting the positive ones.

Aims of management

1. If the habitat is good, to maintain it in a good state.
2. If the habitat is degraded, to improve it.

We'll discuss habitat management in lecture 20.

Thank you

19. Conservation of biodiversity – Ex situ conservation

In-situ and ex-situ conservation

- In-situ conservation: *In situ* = on site
  Conservation within the natural habitat.
- Ex-situ conservation: *Ex situ* = off site
  Conservation outside the natural habitat.

Process of in-situ conservation

Areas in the natural habitat are designated as reserves, national parks or protected areas.

In these areas, ecological monitoring and interventions (active management) are done.

Legislations are required to maintain these areas as protected areas.

Process of ex-situ conservation

1. Designated areas with suitable conditions and facilities are created.
2. Species are moved into these designated areas for their survival and breeding.
3. (Optional) The species are later released into their natural habitats.

Ex-situ conservation: Requirement

1. required for critically endangered species
2. provides urgent intervention

Ex-situ conservation: Advantages

1. Allows better control of variables such as climate, diseases, diet, etc.
2. Provides opportunity for close observation to better understand the species and the proximate causes of its extinction.
3. Permits intensive interventions including in-vitro fertilisation, embryo transfer, etc.

Ex-situ conservation: Disadvantages

1. Does not prevent loss of habitat.
2. Can be planned for only few species at a time.
3. Some wild behaviours may be lost.
4. Captive-bred and raised individuals may find it difficult when reintroduced.
5. May increase chances of inbreeding if not planned properly.
6. Costly.

Ex-situ conservation: Examples

1. Zoos
2. Aquaria
3. Captive breeding facilities
4. Botanical gardens, bambuseta, arboreta, etc.
5. Seed banks
6. Cryopreservation facilities: tissue cultures, sperm banks, ova banks, etc.

Population growth rates compared

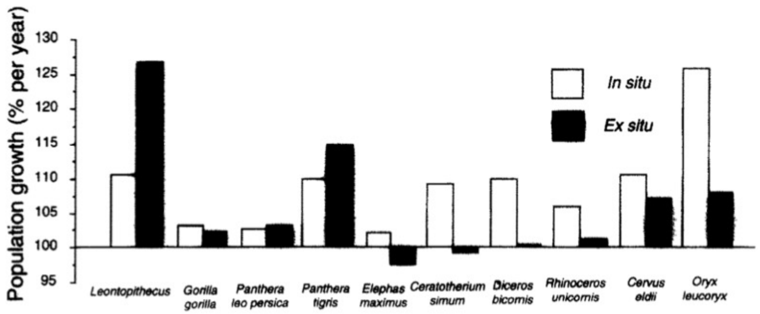


Figure 1. Population growth rates of threatened mammals in well-protected reserves and in coordinated breeding programmes.

(Blamford et al. Biodiversity and Conservation 4,595-607 (1995))

Costs compared

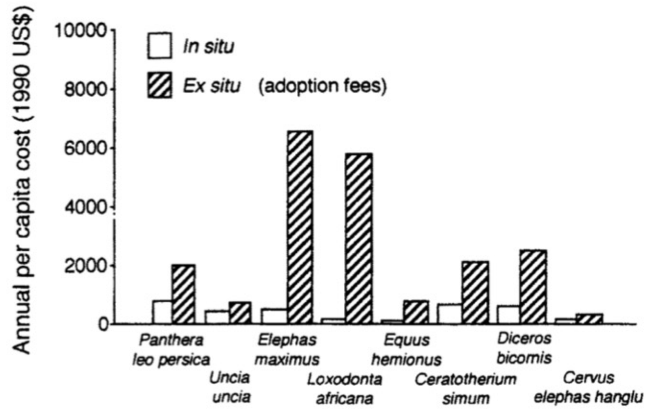
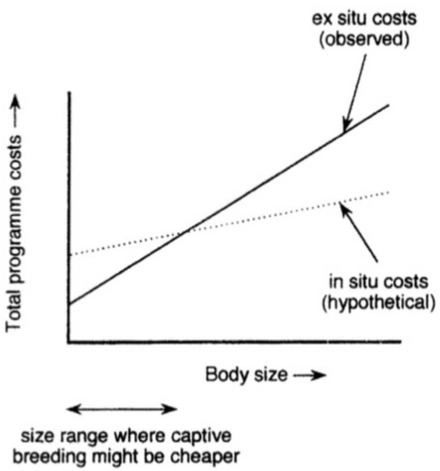


Figure 2. Annual *per capita* costs of maintaining threatened mammals in the wild and in captivity.

(Blamford et al. Biodiversity and Conservation 4,595-607 (1995))

Cost-effectiveness compared



(Blamford et al. Biodiversity and Conservation 4,595-607 (1995))

Genetic implications of ex-situ conservation I

1. Stochastic sampling of alleles: When samples are taken for a seed bank, the sampling may select some alleles, while discard some other alleles in a stochastic manner. Thus, some amount of natural variation will get lost in the sampling process. This needs to be compensated by extensive sampling from different geographical locations and meticulous collection of natural variations in the form of alleles.
2. Erosion of genetic variation in the absence of natural selection.
3. Genetic correlations / pleiotropy: e.g. same gene may increase cryopreservation stability but decrease number of seeds produced. Then selection of plants producing seeds with better cryopreservation stability will also result in selection of plants with less number of seeds, which would be antagonistic to the objectives of re-introduction.

Genetic implications of ex-situu conservation II

4. Genotype-environment interactions: Those genotypes showing favourable phenotypes in the ex-situ conservation environment may not show favourable phenotypes when put back for re-introduction.

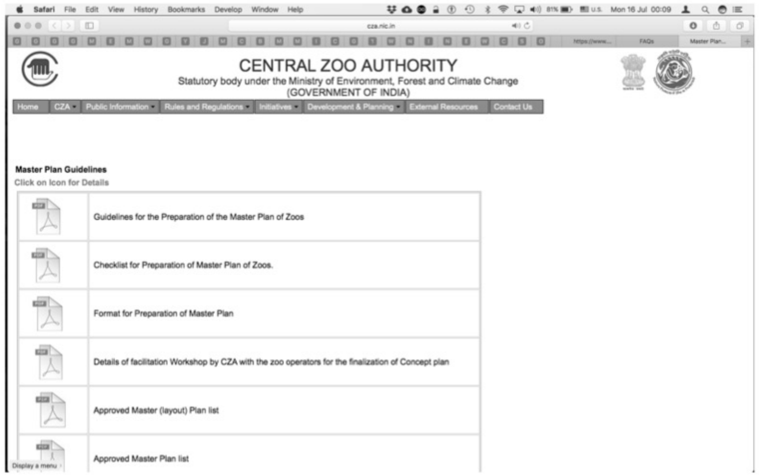
(Hamilton, Conservation Biology, Vol. 8, No. 1 (Mar., 1994), pp. 39-49)

Some ex-situ conservation facilities in detail: Zoo

Definition in Wildlife (Protection) Act 1972

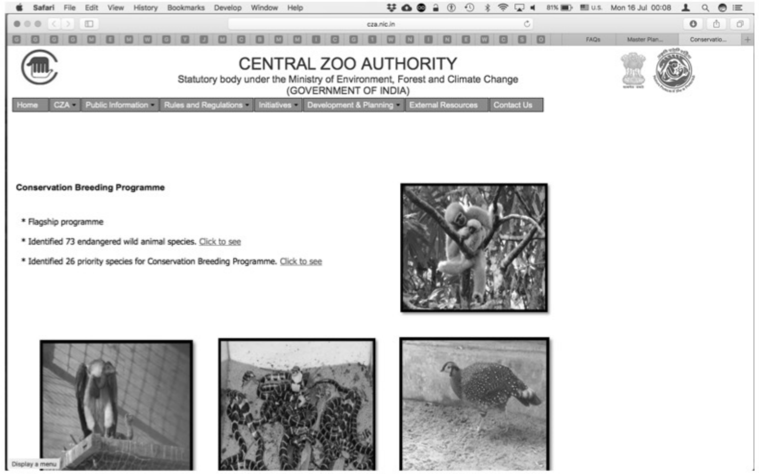
2 (39) "zoo" means an establishment, whether stationary or mobile, where captive animals are kept for exhibiting to the public or ex-situ conservation and includes a circus and off-exhibit facilities such as rescue centres and conservation breeding centres, but does not include an establishment of a licensed dealer in captive animals.

Zoo master plan



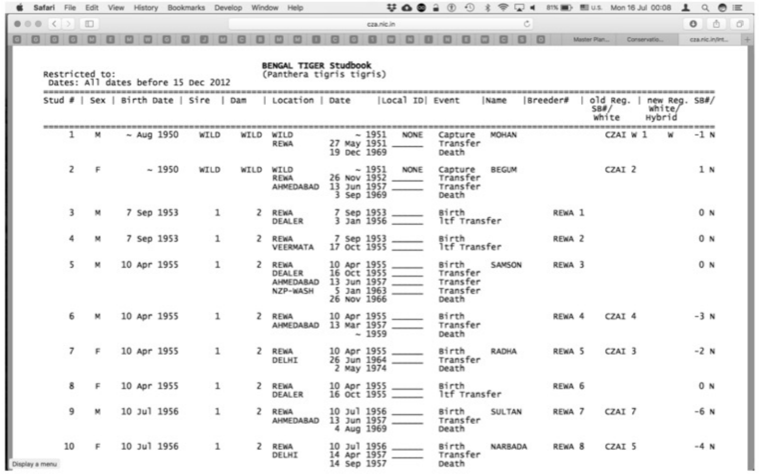
(Central Zoo Authority, http://cza.nic.in)

Conservation breeding



(Central Zoo Authority, http://cza.nic.in)

Studbook



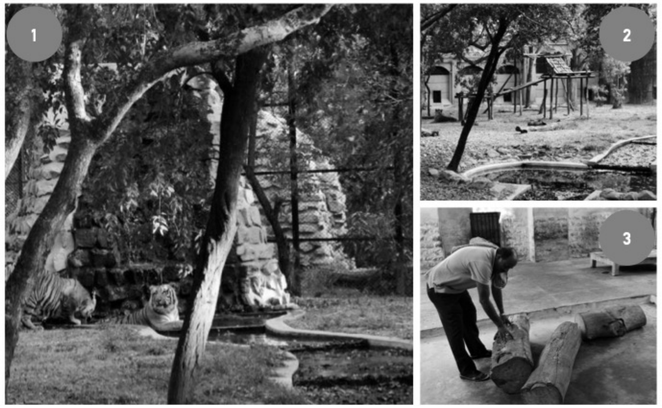
BENGAL TIGER Studbook
(Panthera tigris tigris)

Restricted to:
Dates: All dates before 15 Dec 2012

Stud #	Sex	Birth Date	Sire	Dam	Location	Date	Local ID	Event	Name	Breeder#	old Reg. SB#/ White	new Reg. White/ Hybrid	SB#/
1	M	~ Aug 1950	WILD	WILD	WILD REWA	~ 1951 27 May 1951 19 Dec 1969	NONE ______	Capture Transfer Death	MOHAN		CZAI W 1	W	-1 N
2	F	~ 1950	WILD	WILD	WILD REWA AHMEDABAD	~ 1951 26 Nov 1952 13 Jun 1957 3 Sep 1969	NONE ______ ______	Capture Transfer Transfer Death	BEGUM		CZAI 2		1 N
3	M	7 Sep 1953	1	2	REWA DEALER	7 Sep 1953 3 Jan 1956	______ ______	Birth ltf Transfer		REWA 1			0 N
4	M	7 Sep 1953	1	2	REWA VEERMATA	7 Sep 1953 17 Oct 1955	______ ______	Birth ltf Transfer		REWA 2			0 N
5	M	10 Apr 1955	1	2	REWA DEALER AHMEDABAD NZP-WASH	10 Apr 1955 16 Oct 1955 13 Jun 1957 5 Jan 1963 26 Nov 1966	______ ______ ______ ______	Birth Transfer Transfer Transfer Death	SAMSON	REWA 3			0 N
6	M	10 Apr 1955	1	2	REWA AHMEDABAD	10 Apr 1955 13 Mar 1957 ~ 1959	______ ______	Birth Transfer Death		REWA 4	CZAI 4		-3 N
7	F	10 Apr 1955	1	2	REWA DELHI	10 Apr 1955 26 Jun 1964 2 May 1974	______ ______	Birth Transfer Death	RADHA	REWA 5	CZAI 3		-2 N
8	F	10 Apr 1955	1	2	REWA DEALER	10 Apr 1955 16 Oct 1955	______ ______	Birth ltf Transfer		REWA 6			0 N
9	M	10 Jul 1956	1	2	REWA AHMEDABAD	10 Jul 1956 13 Jun 1957 4 Aug 1969	______ ______	Birth Transfer Death	SULTAN	REWA 7	CZAI 7		-6 N
10	F	10 Jul 1956	1	2	REWA DELHI	10 Jul 1956 14 Apr 1957 14 Sep 1957	______ ______	Birth Transfer Death	NARBADA	REWA 8	CZAI 5		-4 N

(Central Zoo Authority, http://cza.nic.in)

Case study: Mysore Zoo



Create a cosy environment for the residents.

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Ensure quality feeding.

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

The feeding should be time-bound, and done with precaution!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Exotic animals have exotic requirements!

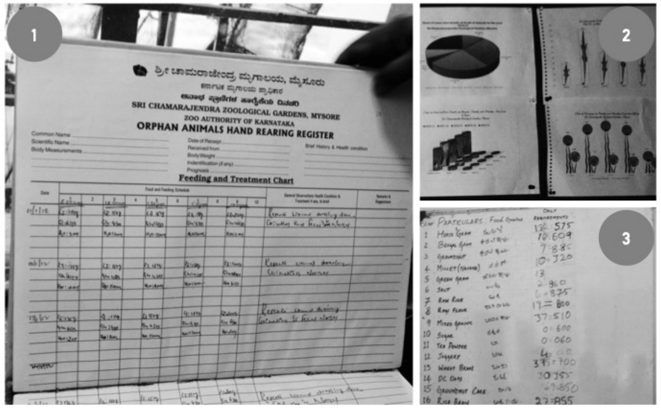
(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Synergistically leverage the landscape.

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo



What cannot be measured cannot be managed! Need for proper documentation.

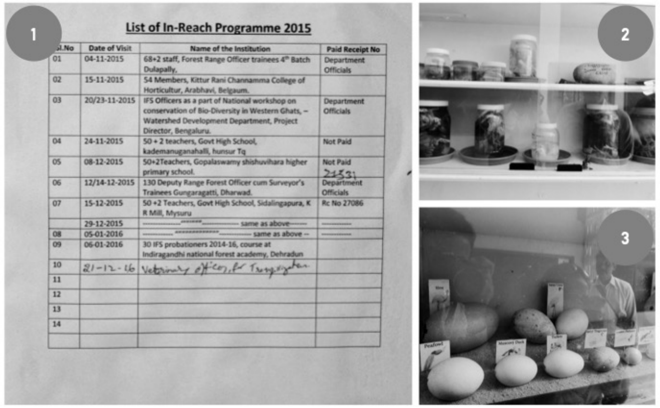
(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Capacity and infrastructure building for the beasts.

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo



List of In-Reach Programme 2015

Sl.No	Date of Visit	Name of the Institution	Paid Receipt No
01	04-11-2015	68+2 staff, Forest Range Officer trainees 4th Batch Dulapally,	Department Officials
02	15-11-2015	54 Members, Kittur Rani Channamma College of Horticultur, Arabhavi, Belgaum.	
03	20/23-11-2015	IFS Officers as a part of National workshop on conservation of Bio-Diversity in Western Ghats, – Watershed Development Department, Project Director, Bengaluru.	Department Officials
04	24-11-2015	50 + 2 teachers, Govt High School, kademanuganahalli, hunsur Tq	Not Paid
05	08-12-2015	50+2Teachers, Gopalaswamy shishuvihara higher primary school.	Not Paid 21531
06	12/14-12-2015	130 Deputy Range Forest Officer cum Surveyor's Trainees Gungaragatti, Dharwad.	Department Officials
07	15-12-2015	50 +2 Teachers, Govt High School, Sidalingapura, K R Mill, Mysuru	Rc No 27086
	29-12-2015	------------"------------ same as above------	----------
08	05-01-2016	------------"------------ same as above --	----------
09	06-01-2016	30 IFS probationers 2014-16, course at Indiragandhi national forest academy, Dehradun	
10	21-12-16	Veterinary officers, for [illegible]	
11			
12			
13			
14			

Research and in-reach activities are essential for management.

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

There are adequate opportunities to turn waste to wealth!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

The customer is important to us. Need to develop amenities for visitors!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Build image to build revenues!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Innovation helps management, helps visitors and saves costs!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Karanji lake: Creating ₹ 3 crore revenue from waste land!

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Karanji lake: Orchids, open aviary, cacti…

(Ankur Awadhiya, Mysore Zoo 2016)

Case study: Mysore Zoo

Restaurant is not only for visitors! Keep service lane separate and develop immersive edutainment boards.

(Ankur Awadhiya, Mysore Zoo 2016)

Bear rescue facility, Agra

(Ankur Awadhiya, Agra 2015)

Bear rescue facility, Agra

(Ankur Awadhiya, Agra 2015)

Lion rescue facility, Bhopal

(Ankur Awadhiya, Bhopal 2016)

Turtle rescue facility, Dwarka

(Ankur Awadhiya, Dwarka 2018)

Turtle rescue facility, Dwarka

(Ankur Awadhiya, Dwarka 2018)

Behaviour enrichment

(Ankur Awadhiya, Johannesburg 2018)

Some ex-situ conservation facilities in detail: Seed banks and cryopreservation facilities

Preservation

Regeneration of whole fertile plants from 30,000-y-old fruit tissue buried in Siberian permafrost

Svetlana Yashina[a,1], Stanislav Gubin[b], Stanislav Maksimovich[b], Alexandra Yashina[a], Edith Gakhova[a], and David Gilichinsky[b,2]

Institutes of [a]Cell Biophysics and [b]Physicochemical and Biological Problems in Soil Science, Russian Academy of Sciences, Pushchino 142290, Russia

Edited* by P. Buford Price, University of California, Berkeley, CA, and approved January 25, 2012 (received for review November 8, 2011)

Whole, fertile plants of *Silene stenophylla* Ledeb. (Caryophyllaceae) have been uniquely regenerated from maternal, immature fruit tissue of Late Pleistocene age using in vitro tissue culture and clonal micropropagation. The fruits were excavated in northeastern Siberia from fossil squirrel burrows buried at a depth of 38 m in undisturbed and never thawed Late Pleistocene permafrost sediments with a temperature of −7 °C. Accelerator mass spectrometry (AMS) radiocarbon dating showed fruits to be 31,800 ± 300 y old. The total γ-radiation dose accumulated by the fruits during this time was calculated as 0.07 kGy; this is the maximal reported dose after which tissues remain viable and seeds still germinate. Regenerated plants were brought to flowering and fruiting and they set viable seeds. At present, plants of *S. stenophylla* are the most ancient, viable, multicellular, living organisms. Morphophysiological studies comparing regenerated and extant plants obtained from modern seeds of the same species in the same region revealed that they were distinct phenotypes of *S. stenophylla*. The first generation cultivated from seeds obtained from regenerated plants progressed through all developmental stages and had the same morphological features as parent plants. The investigation showed high cryoresistance of plant placental tissue in permafrost. This natural cryopreservation of plant tissue over many thousands of years demonstrates a role for permafrost as a depository for an ancient gene pool, i.e., preexisting life, which hypothetically has long since vanished from the earth's surface, a potential source of ancient germplasm, and a laboratory for

However, to date, no viable flowering plant remains have been discovered from these ancient permafrost sediments.

Outside the permafrost zone the longevity of seeds in soil has been studied during the last 45 y in many places, including archaeological sites (10, 11). At the moment, the oldest viable seeds with the ability to germinate were radiocarbon dated to the first and eighth centuries of the Common Era. These are, respectively, *Phoenix dactylifera* found near the Dead Sea (12) and *Nelumbo nucifera* found in northeastern China (13).

The burrows from which our study material derived were buried in permanently frozen loess-ice deposits on the right bank of lower Kolyma River, northeastern Siberia (14). These deposits (Fig. 1*A*) are representative of a widely distributed, so-called Late Pleistocene ice complex found throughout the eastern Arctic, which has continuously accumulated during the last 60 ky. This complex comprises icy silts with a network of large syngenetic polygonal ice wedges and is richly fossil bearing (pollen, insects, plants, macrofossil, and mammal fossils). The studied burrows (Fig. 1*B*) were found in three exposures: Zelyony Mys, Stanchikovsky Yar, and Duvanny Yar. The last represents a key cross-section of Late Quaternary environmental history in the eastern Arctic studied by many scientists. All burrows were found at depths of 20–40 m from the present day surface and located in layers containing bones of large mammals such as mammoth, wooly rhinoceros, bison, horse, deer, and other representatives of fauna from the age of Mammoths as well as plant remnants. The deposits were formed under

Preservation

Fig. 2. Fruiting plants of *Silene stenophylla* regenerated from tissue of fossil fruits. (Scale bar, 50 mm.)

Discussion

The present study uniquely demonstrates that viable placental tissue, from immature fruits of the flowering plant *S. stenophylla*

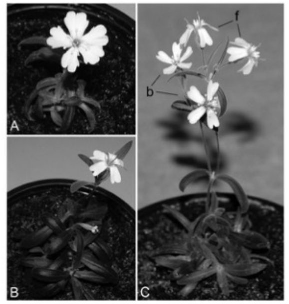
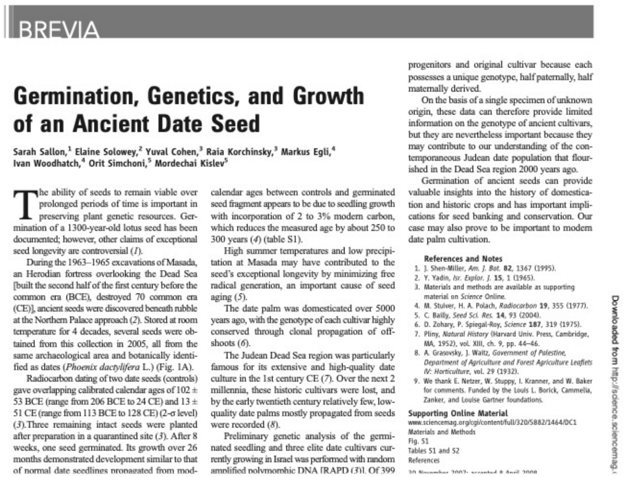


Fig. 3. Flowering plants of *Silene stenophylla*. (*A*) Plant grown in vitro culture from seed of an extant plant. (*B*) Plant regenerated in vitro culture from tissue of fossil fruit with primary strictly female flower. (*C*) Plant regenerated from tissue of fossil fruit with both female (f) and bisexual (b) flowers.

4010 | www.pnas.org/cgi/doi/10.1073/pnas.1118386109 Yashina et al.

Preservation



BREVIA

Germination, Genetics, and Growth of an Ancient Date Seed

Sarah Sallon,[1] Elaine Solowey,[2] Yuval Cohen,[3] Raia Korchinsky,[3] Markus Egli,[4] Ivan Woodhatch,[4] Orit Simchoni,[5] Mordechai Kislev[5]

The ability of seeds to remain viable over prolonged periods of time is important in preserving plant genetic resources. Germination of a 1300-year-old lotus seed has been documented; however, other claims of exceptional seed longevity are controversial (*1*).

During the 1963–1965 excavations of Masada, an Herodian fortress overlooking the Dead Sea [built the second half of the first century before the common era (BCE), destroyed 70 common era (CE)], ancient seeds were discovered beneath rubble at the Northern Palace approach (*2*). Stored at room temperature for 4 decades, several seeds were obtained from this collection in 2005, all from the same archaeological area and botanically identified as dates (*Phoenix dactylifera* L.) (Fig. 1A).

Radiocarbon dating of two date seeds (controls) gave overlapping calibrated calendar ages of 102 ± 53 BCE (range from 206 BCE to 24 CE) and 13 ± 51 CE (range from 113 BCE to 128 CE) (2-σ level) (*3*).Three remaining intact seeds were planted after preparation in a quarantined site (*3*). After 8 weeks, one seed germinated. Its growth over 26 months demonstrated development similar to that of normal date seedlings propagated from mod-calendar ages between controls and germinated seed fragment appears to be due to seedling growth with incorporation of 2 to 3% modern carbon, which reduces the measured age by about 250 to 300 years (*4*) (table S1).

High summer temperatures and low precipitation at Masada may have contributed to the seed's exceptional longevity by minimizing free radical generation, an important cause of seed aging (*5*).

The date palm was domesticated over 5000 years ago, with the genotype of each cultivar highly conserved through clonal propagation of offshoots (*6*).

The Judean Dead Sea region was particularly famous for its extensive and high-quality date culture in the 1st century CE (*7*). Over the next 2 millennia, these historic cultivars were lost, and by the early twentieth century relatively few, low-quality date palms mostly propagated from seeds were recorded (*8*).

Preliminary genetic analysis of the germinated seedling and three elite date cultivars currently growing in Israel was performed with random amplified polymorphic DNA [RAPD (*3*)]. Of 399 progenitors and original cultivar because each possesses a unique genotype, half paternally, half maternally derived.

On the basis of a single specimen of unknown origin, these data can therefore provide limited information on the genotype of ancient cultivars, but they are nevertheless important because they may contribute to our understanding of the contemporaneous Judean date population that flourished in the Dead Sea region 2000 years ago.

Germination of ancient seeds can provide valuable insights into the history of domestication and historic crops and has important implications for seed banking and conservation. Our case may also prove to be important to modern date palm cultivation.

References and Notes

1. J. Shen-Miller, *Am. J. Bot.* **82**, 1367 (1995).
2. Y. Yadin, *Isr. Explor. J.* **15**, 1 (1965).
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4. M. Stuiver, H. A. Polach, *Radiocarbon* **19**, 355 (1977).
5. C. Bailly, *Seed Sci. Res.* **14**, 93 (2004).
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8. A. Grasovsky, J. Waltz, *Government of Palestine, Department of Agriculture and Forest Agriculture Leaflets IV: Horticulture*, vol. 29 (1932).
9. We thank E. Netzer, W. Stuppy, I. Kranner, and W. Baker for comments. Funded by the Louis L. Borick, Cammelia, Zanker, and Louise Gartner foundations.

Supporting Online Material

www.sciencemag.org/cgi/content/full/320/5882/1464/DC1
Materials and Methods
Fig. S1
Tables S1 and S2
References

Preservation

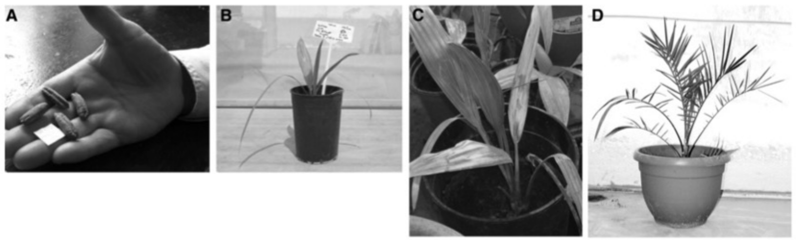

Fig. 1. (**A**) Ancient date seeds from Masada. (**B**) Germinated seedling age 3 months: normal development of simple juvenile leaves. Height = 15 cm. (**C**) Age 7.5 months: some leaves showing white patches. Height = 31 cm. (**D**) Age 26 months: normal seedling development with compound leaves. Height = 121 cm. [Photo credit: G. Eisner]

Seed

An embryonic plant enclosed in an outer protective coating.

Seed

(Ankur Awadhiya, Kruger National Park 2018)

How to make a seed bank?

1. Construct a seed stand
2. Collect seeds
3. Treat seeds
4. Store seeds
5. If required, re-collect seeds from wild or by re-planting

Creation of ex-situ conservation stands

1. Sampling of source population
2. Site selection
3. Deciding the plantation size
4. Establishment of plantation
5. Management operations, including weeding, irrigation, fertilisation, etc.
6. Regeneration and collection of seeds

(T. Skroppa in Conservation and Management of Forest Genetic Resources in Europe)

Characteristics of good seeds

1. Well ripened and healthy
2. Pure and free from inert materials and weed seeds
3. Viable and having good germination capacity
4. Uniform in their structure and appearance
5. Free from damage
6. Should not be broken and infested with pests and diseases

(Courtesy: Dr. M. Gera)

Determining best days for seed collection

1. Laboratory methods
   a. maximum dry weight
   b. chemical analysis of fat and nitrogen content
   c. examination of embryo development and endosperm of sample seeds through X-ray radiographs
   d. moisture content of fruits
2. Field methods
   a. density of fruits
   b. colour of fruits
   c. visual examination of seed contents after cutting

(A Guide to Forest Seed Handling - FAO)

Determining trees to collect seeds from

1. collect from dominant or co-dominant trees
2. collect from minimum of 10 trees at a time, preferably from 25 – 50 trees
3. collect from trees that are far from each other, to avoid collecting from half-siblings or parents
4. before collecting, mark individual trees
5. collect equal numbers of cones, fruits or seeds per tree
6. mixing of seeds can be done for large-scale collections

(A Guide to Forest Seed Handling - FAO)

Collections for conservation

1. use larger number of trees per genepool (50 – 100)
2. random sampling, including poorer than average trees
3. collection in better seed years for better representation of parents
4. larger quantity of seeds to be collected for each provenance

(A Guide to Forest Seed Handling - FAO)

Requirements for proper seed collection

1. organisation of collecting teams
2. organisation of transport
3. organisation of equipment
4. organisation of records
5. organisation of permits
6. organisation of seed extraction from fruits

(A Guide to Forest Seed Handling - FAO)

Ways of collecting seeds

1. natural seedfall
2. manual shaking
3. mechanical shaking
4. use of tree funnels
5. raiding of animal caches, e.g. squirrels and ants
6. collection by plucking
7. collection by cutting, breaking, and sawing

(A Guide to Forest Seed Handling - FAO)

Other operations

1. depulping
2. drying under shade
3. sun drying
4. drying with artificial heat / kilns
5. dewinging
6. threshing
7. sieving
8. sorting
9. blowing
10. grading, etc.

(A Guide to Forest Seed Handling - FAO)

Natural longevity of tree seeds

1. Microbiotic: seed life span not exceeding 3 years
2. Mesobiotic: seed life span from 3 to 15 years
3. Macrobiotic: seed life span from 15 to over 100 years.

(A Guide to Forest Seed Handling - FAO)

Two main seed classes (Roberts 1973)

1. Orthodox: Seeds which can be dried down to a low moisture content of around 5% and successfully stored at low or sub-freezing temperatures for long periods. e.g. grass seeds
2. Recalcitrant: Seeds which cannot survive drying below a relatively high moisture content (often in the range 20-50%) and which cannot be successfully stored for long periods. e.g. sal seeds

(A Guide to Forest Seed Handling - FAO)

Factors affecting longevity in storage

1. seed condition
   a. seed maturity
   b. mechanical damage
   c. fungi and insects
   d. initial viability
2. age of seeds
3. storage conditions
   a. atmosphere: level of oxygen should be low
   b. moisture: should be low
   c. temperature: should be low
   d. light: should be absent

(A Guide to Forest Seed Handling - FAO)

Ecological Principles and Biodiversity for Sustainability Dr. Ankur Awadhiya, IFS

Underlying principles of seed banking

1. identity of accessions should be clear: use of passport data, together with a herbarium voucher specimen for identification
2. maintenance of viability and propagability
3. maintenance of genetic integrity
4. maintenance of germplasm health: ensure seeds are free from diseases and pests
5. physical security of collections, including safety from earthquakes, floods, fires, and global warming
6. availability and use of germplasm
7. availability of information

(FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rev. ed. Rome)

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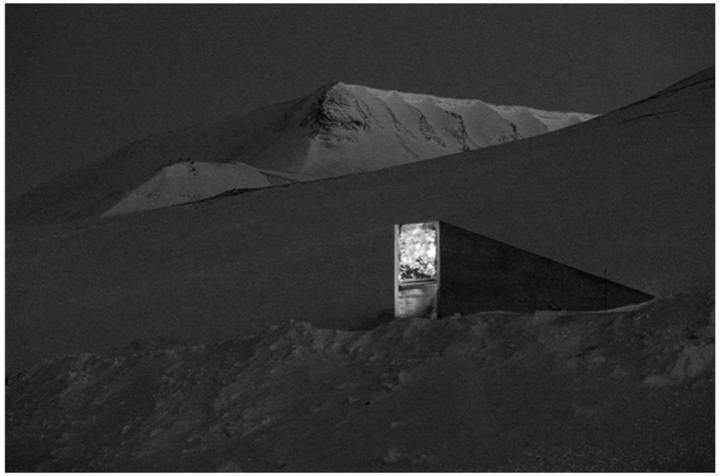
Svalbard Global Seed Vault, Norway



(Westengen, O.T., Jeppson, S. and Guarino, L., 2013. Global ex-situ crop diversity conservation and the Svalbard Global Seed Vault: Assessing the current status. PloS one, 8(5), p.e64146.)

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Svalbard Global Seed Vault, Norway

(Westengen, O.T., Jeppson, S. and Guarino, L., 2013. Global ex-situ crop diversity conservation and the Svalbard Global Seed Vault: Assessing the current status. PloS one, 8(5), p.e64146.)

Cryopreservation facility

Similar low temperature principles are also used for animal cells and tissues.

e.g. sperms, ova, embryos, tissue samples, etc.

Cryopreservation in Kruger National Park

(Ankur Awadhiya, Kruger National Park 2018)

Cryopreservation in Kruger National Park

(Ankur Awadhiya, Kruger National Park 2018)

Cryopreservation in Kruger National Park

(Ankur Awadhiya, Kruger National Park 2018)

Thank you

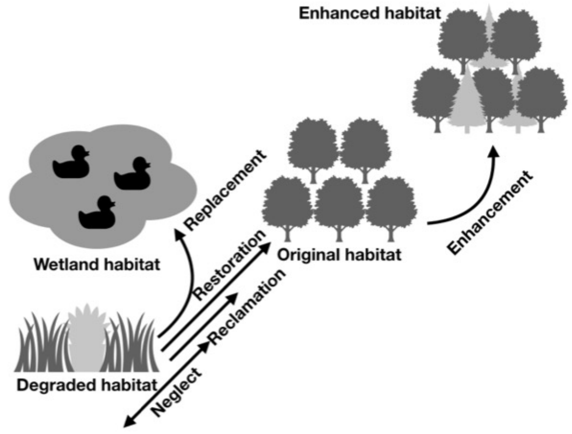
20. Employing Ecology and Biodiversity for sustainable development

Case Study: Habitat improvement options

Improving degraded habitats: Options available

1. Recovery / Neglect: "Let nature take its own course."
   May ameliorate the degraded habitat, or make it even more degraded.
   e.g. leaving land fallow
2. Rehabilitation / Reclamation: "Shifting the degraded habitat towards greater value, not necessarily the original state."
3. Restoration: "Actively trying to return the habitat to its original state."
4. Enhancement: "Improving the value of the habitat."
   e.g. construction of water holes for animals
5. Replacement: "Creating a new habitat in place of the degraded habitat."
   e.g. Forest $\xrightarrow{\text{Mining}}$ Mine pit $\xrightarrow[\text{Water filling}]{\text{Earth work}}$ Marshy wetland

Improvement options



(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

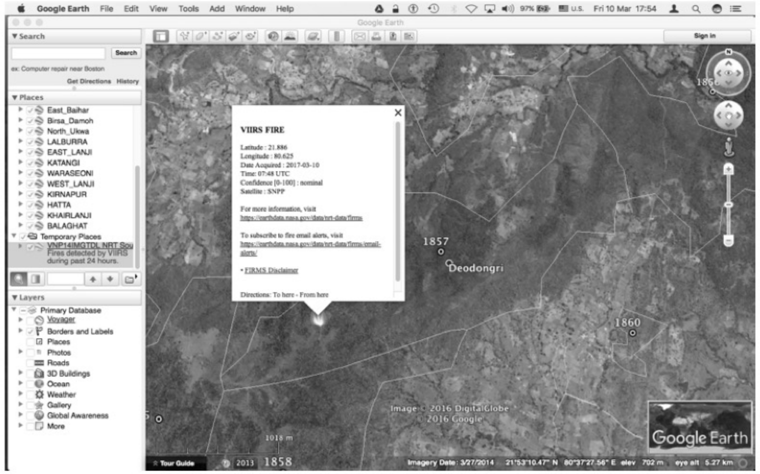
These also serve as mitigation options for proposed development

1. Avoiding development at important habitats
2. Restoration of site after the work is done. e.g. mining sites
3. If restoration is difficult due to permanent nature of work, replacement of another nearby degraded site in lieu.
4. Protection and management of other habitats in lieu of the one being lost, often in ratios $>> 1$.

Activities taken up for habitat management

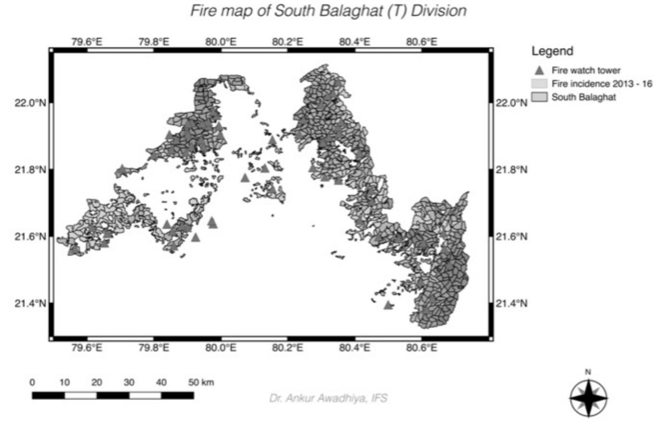
1. Control of unregulated fires

SimplyFire



(Ankur Awadhiya 2016)

FireMap



(Ankur Awadhiya 2018. Generation of Division Level Fire Maps Using Satellite-derived Fire Data. Indian Forester, 144(4), pp.471-476.)

Fire breaker

(Ankur Awadhiya, Fire Breakers: Novel Devices for the Control of Forest Surface Fires, Indian Forester 143, no. 8 (2017): 737-744.)

Activities taken up for habitat management

1. Control of unregulated fires
2. Control of invasive species

Control of invasives

(Ankur Awadhiya, Balaghat 2016)

Activities taken up for habitat management

1. Control of unregulated fires
2. Control of invasive species
3. Provisioning of waterholes and salt licks

Artificial water hole

(Ankur Awadhiya, Mudumalai Tiger Reserve 2018)

Artificial salt lick

(Ankur Awadhiya, Buxa Tiger Reserve 2016)

Activities taken up for habitat management

1. Control of unregulated fires
2. Control of invasive species
3. Provisioning of waterholes and salt licks
4. Involvement of locals and stakeholders

Involvement of locals and stakeholders

(Ankur Awadhiya, Balaghat 2016)

Activities taken up for habitat management

1. Control of unregulated fires
2. Control of invasive species
3. Provisioning of waterholes and salt licks
4. Involvement of locals and stakeholders
5. Habitat monitoring

Habitat monitoring with AutoCam

(Ankur Awadhiya, Use of novel devices for monitoring habitat use by wildlife and other ecological parameters – Case study from M.P. Proc. Int. Conf. on Wildlife Conservation, 2023.)

Activities taken up for habitat management

1. Control of unregulated fires
2. Control of invasive species
3. Provisioning of waterholes and salt licks
4. Involvement of locals and stakeholders
5. Habitat monitoring
6. Plantation drives, trash collection, etc.

Plantation drive

(Ankur Awadhiya, Betul 2017)

Trash collection

(Ankur Awadhiya, Balaghat 2016)

Case Study: Linear infrastructure

Case study: Linear infrastructure

"those basic physical and organisational structures and facilities needed for the operation of a society or enterprise that can be represented as straight or curved lines"

e.g. roads, railways, power lines, canals, pipelines, etc.

Linear infrastructure: Roads

(Ankur Awadhiya, Kaziranga National Park 2016)

Linear infrastructure: Railway

(Ankur Awadhiya, Dehradun 2018)

Linear infrastructure: Pipelines

(Ankur Awadhiya, Mudumalai 2018)

Case study: Linear infrastructure

"those basic physical and organisational structures and facilities needed for the operation of a society or enterprise that can be represented as straight or curved lines"

e.g. roads, railways, power lines, canals, pipelines, etc.

Linear infrastructure through wildlife areas can lead to conflicts.

Animals use roads

(Ankur Awadhiya, Kruger National Park 2018)

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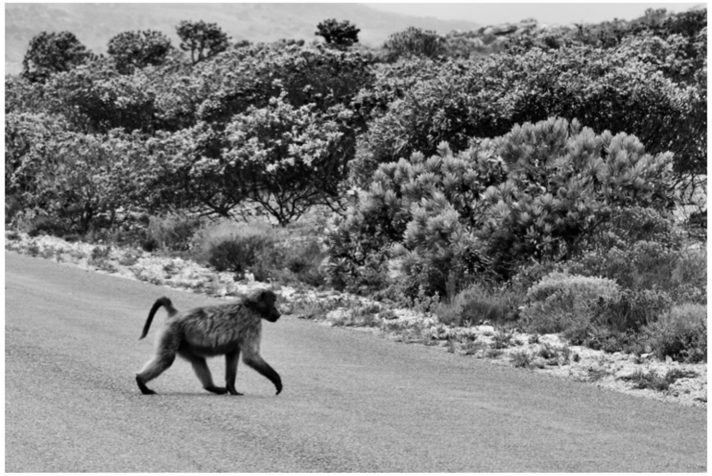
Animals use roads



(Ankur Awadhiya, Kruger National Park 2018)

Animals use roads

(Ankur Awadhiya, Kruger National Park 2018)

Roads kill

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2019)

Roads kill

(Ankur Awadhiya, Balaghat 2016)

Roads kill

(Ankur Awadhiya, Kruger National Park 2018)

Roads kill

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2019)

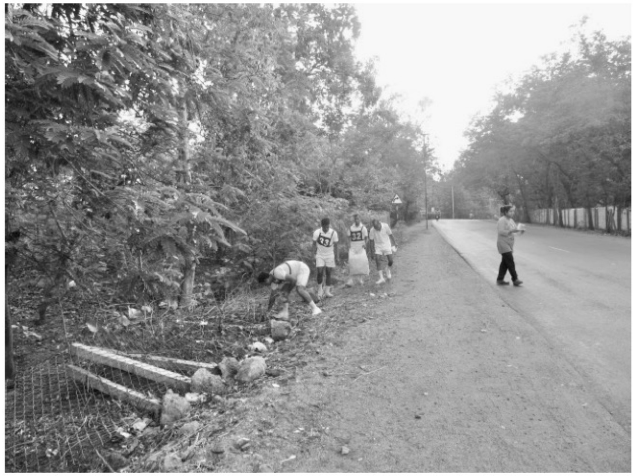
Roads cause pollution: air, sound, light

(Ankur Awadhiya, Pretoria 2018)

Roads cause pollution: air, sound, light

(Ankur Awadhiya, New Delhi 2013)

Roads cause pollution: air, sound, light

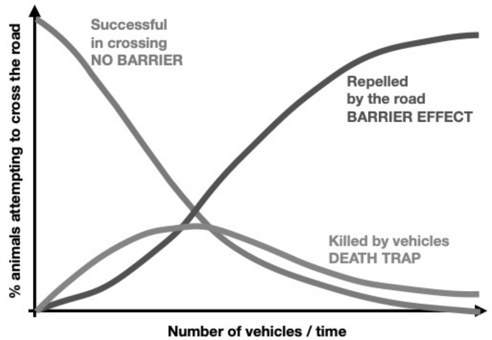


(Ankur Awadhiya, Balaghat 2016)

Roads act as barriers to wildlife movement

(Ankur Awadhiya, Kruger National Park 2018)

Traffic intensity governs road behaviour



(Ankur Awadhiya 2021 Principles of Wildlife Conservation. Florida and Oxfordshire: CRC Press / Taylor & Francis)

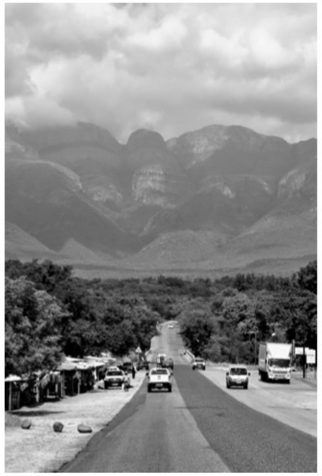
Factors governing barrier effect

1. traffic intensity: more traffic may create a 'wall'
2. vehicle speed
3. driver sensitivity: use of headlight, horns, etc.
4. presence and location of animal crossings
5. movement pattern of species
6. species specific preference of road use
7. road edge features (e.g. height of embankment)
8. time of day and year
9. species diversity in the surroundings

Roads fragment habitats

(Ankur Awadhiya, Pretoria 2018)

Roads fragment habitats



(Ankur Awadhiya, Pretoria 2018)

Construction causes loss and destruction of habitat

(Ankur Awadhiya, Lonavala 2018)

Construction causes loss and destruction of habitat

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2018)

Construction causes loss and destruction of habitat

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2019)

Roads facilitate destruction of habitat

(Ankur Awadhiya, Balaghat 2016)

Roads increase interaction with humans

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2019)

Roads change animal behaviour

(Ankur Awadhiya, Nauradehi Wildlife Sanctuary 2019)

Roads change animal behaviour

(Ankur Awadhiya, Sariska Tiger Reserve 2017)

Issue for humans too!

(Ankur Awadhiya, Kruger National Park 2018)

Issue for humans too!

(Ankur Awadhiya, Kruger National Park 2018)

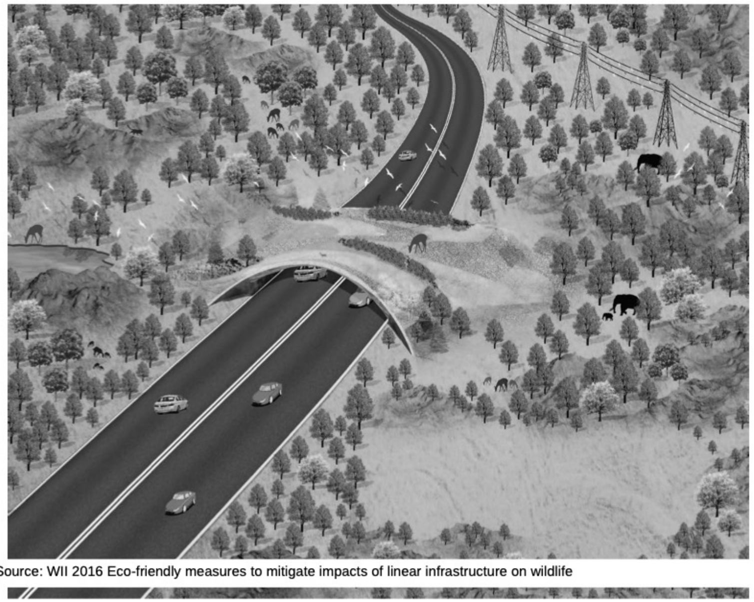
Issue for humans too!

(Ankur Awadhiya, Kruger National Park 2018)

The way out: mitigation measures

"measures to avoid, reduce or remedy harm"

A search for co-existence



Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Land bridge

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Canopy bridge

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Glider pole

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Bridge underpass

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Box culvert

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Pipe culvert

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Fences

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

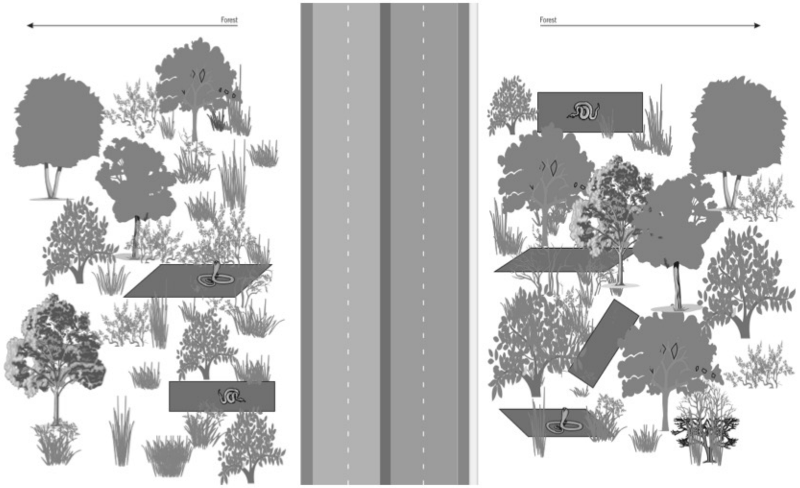
Canopy bridge for Hoolock gibbon

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Maintaining canopy connectivity

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Measures for reptiles



Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Technology to detect animals

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Warning signs

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

Sound barriers

Source: WII 2016 Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife

These options are not expensive.

They just require a bit of thought and compassion.

Is that too much to ask for?

Thank you