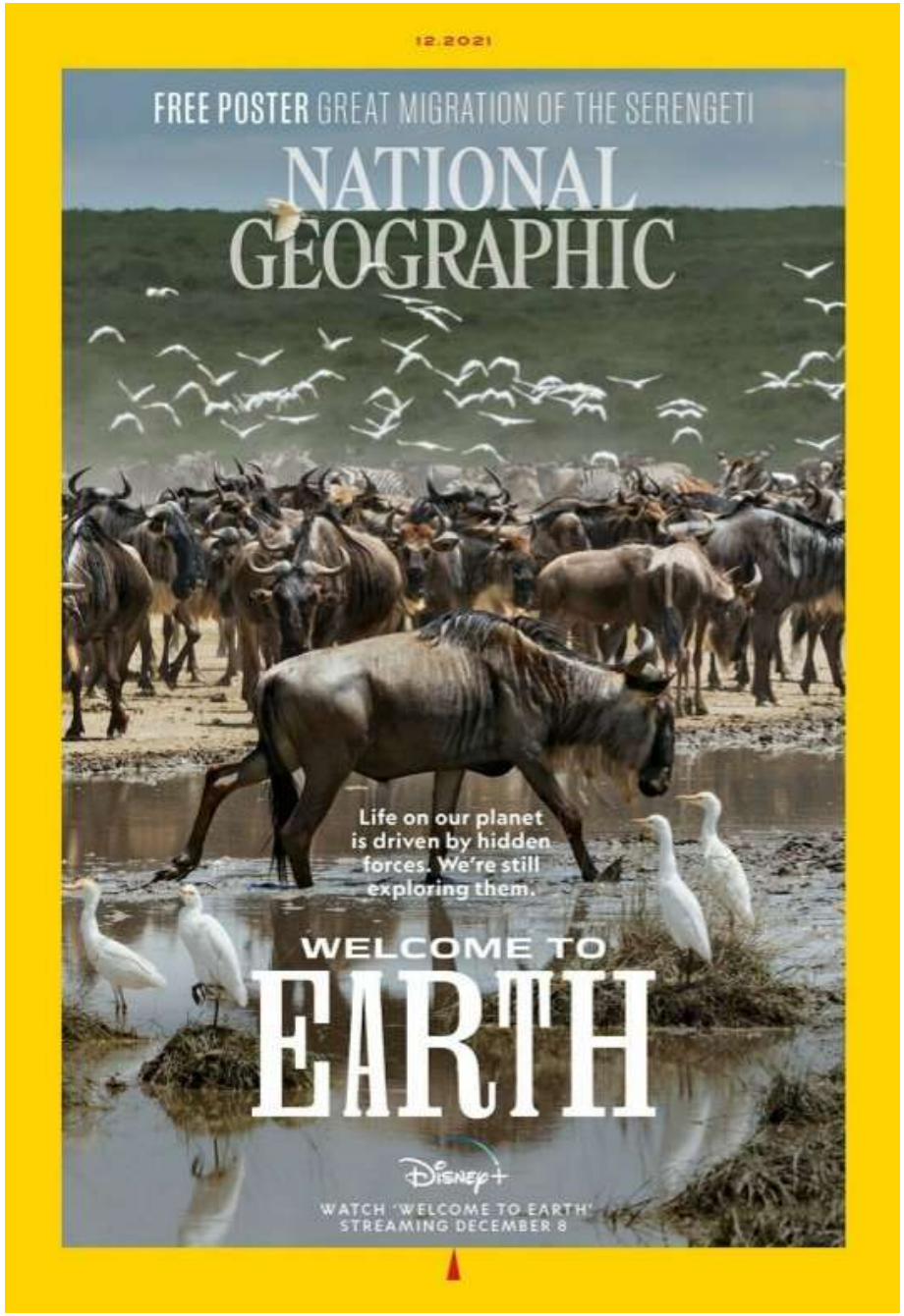
Serengeti-Mara Scientific Overview 2022

GREATER SERENGETI CONSERVATION SOCIETY

University of Glasgow

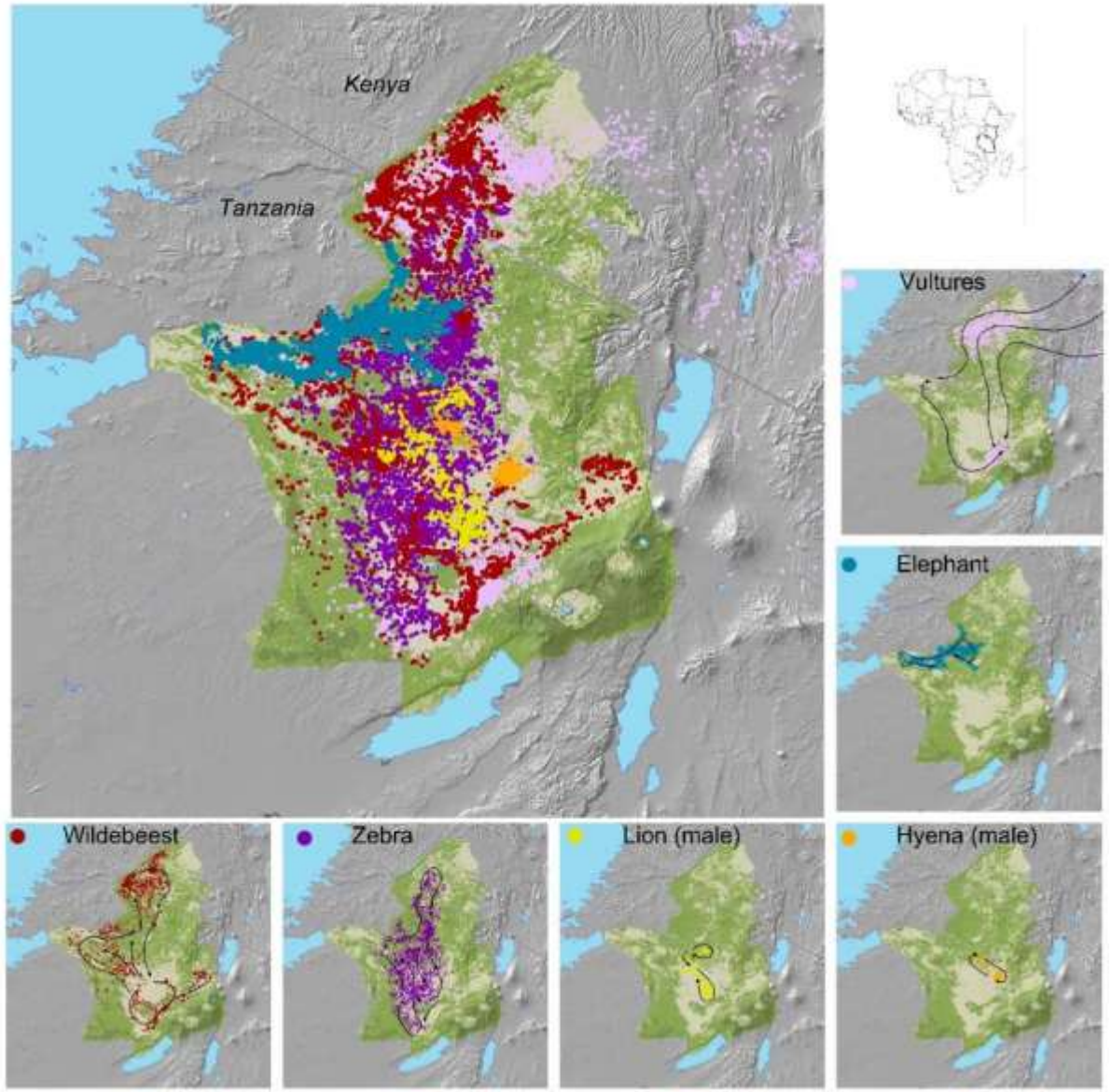
VIA VERITAS VITA

International attention: *Serengeti-Mara under pressure*



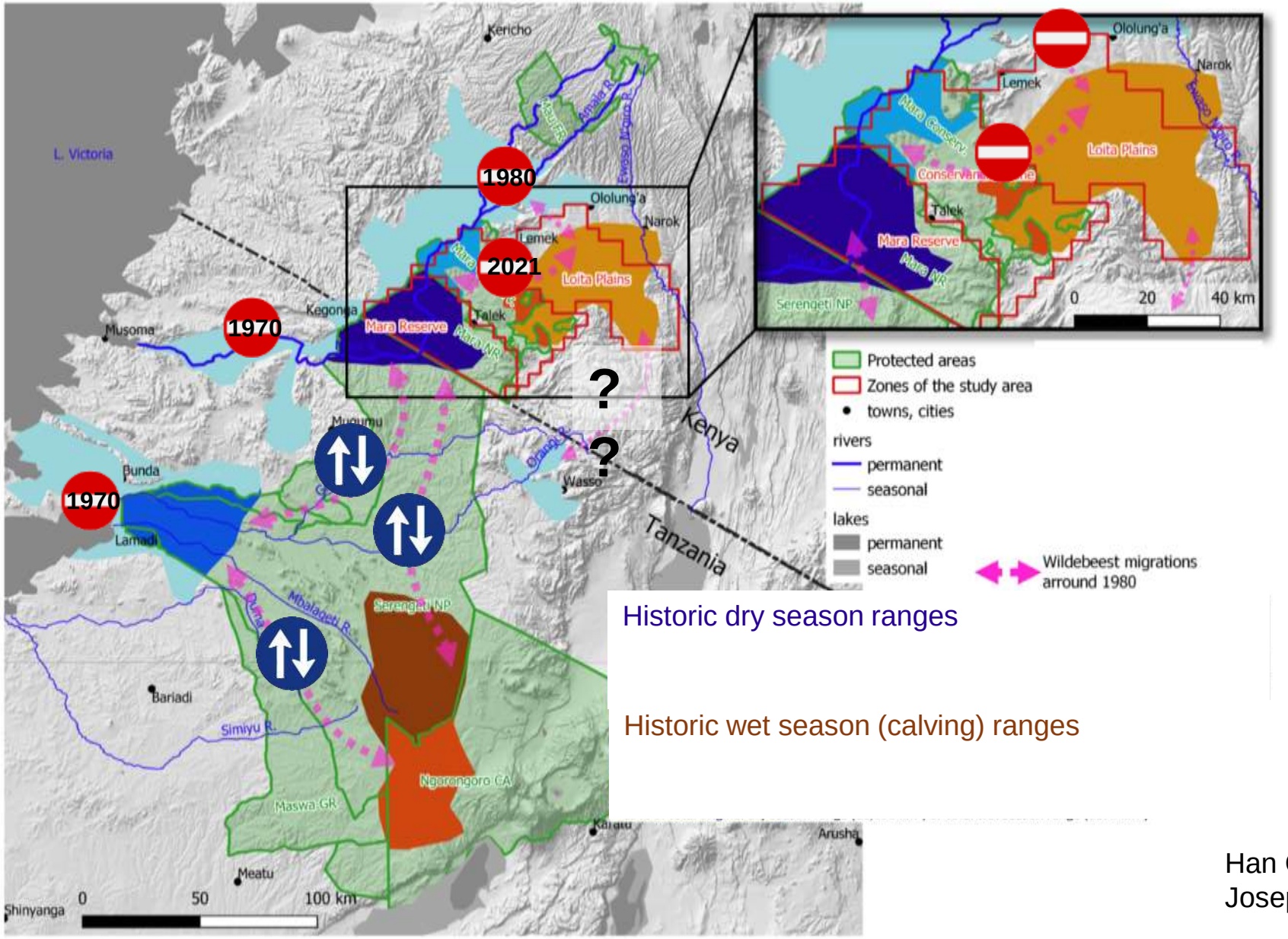
Animal movement: the key ecological attribute

Serengeti-Mara – a complex and dynamic interconnected system in which a huge diversity of species interact with each other and their habitats in a free and uninhibited way at multiple scales



Data from: Hopcraft, Estes, Packer, Craft, & Kendall

Current (2022) wildebeest & zebra mass migrations



1970 Migration extinct, with year

Migration still present

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Landscape drivers

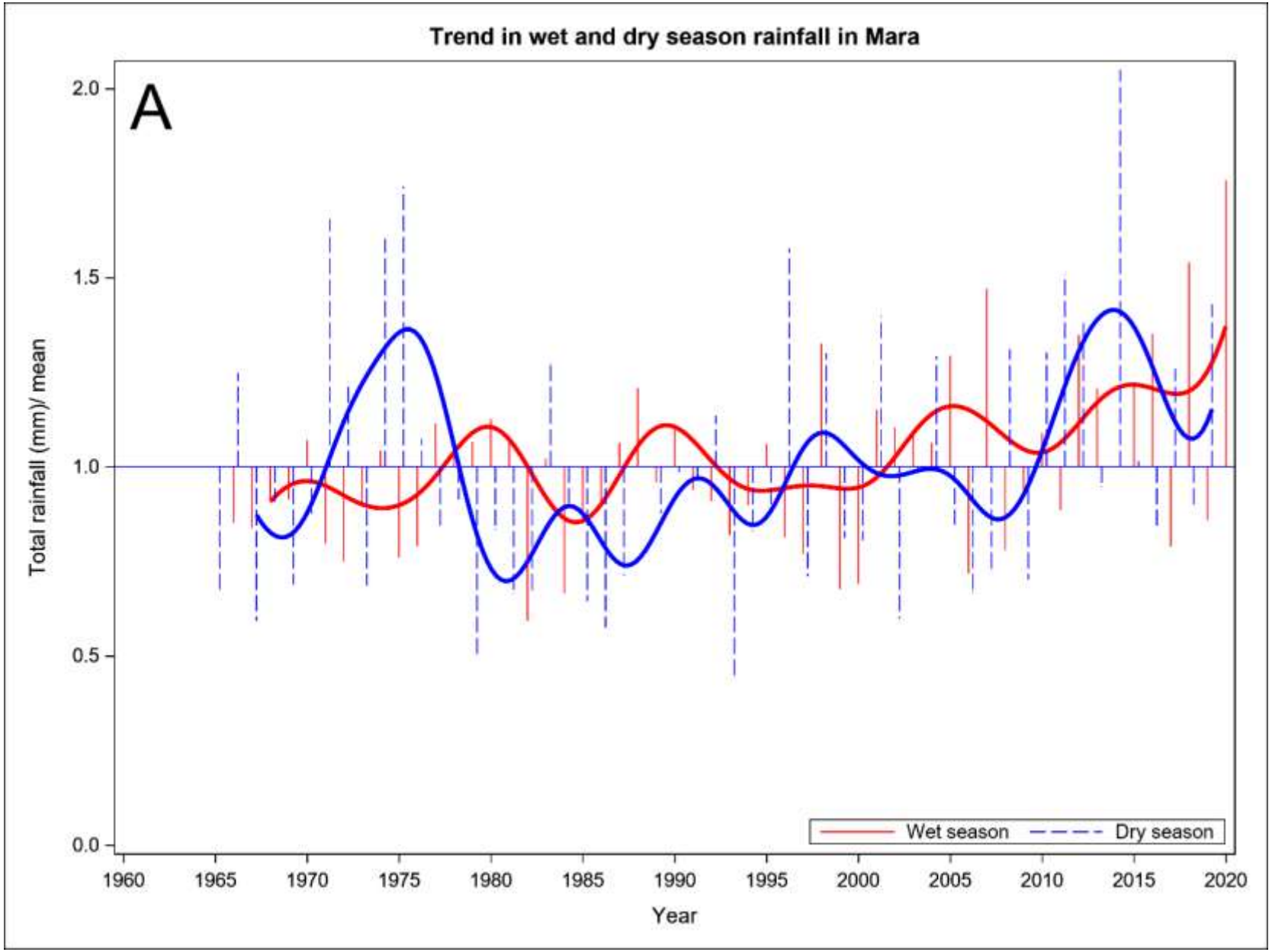
Ecosystem responses

Benefit generation

Cause, Effect, and Consequence

Changing rainfall

Mara: trends in wet and dry season rainfall anomalies



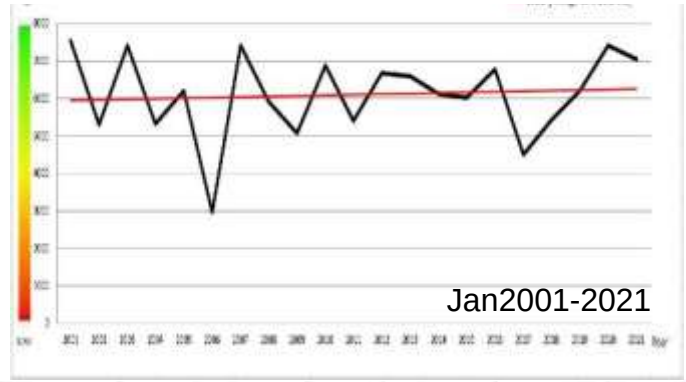
Joseph Ogutu: jogutu@uni-hohenheim.de
Ogutu et al, 2018, 2019, 2020

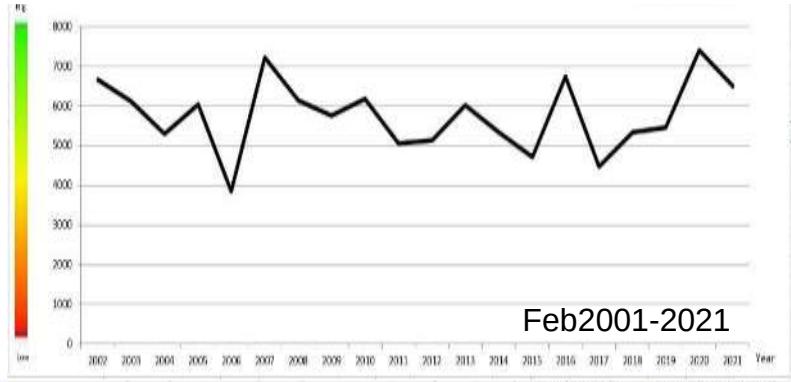
Serengeti average annual rainfall

Average annual rainfall across the entire Serengeti-Mara ecosystem, 1 km2 resolution

Data: CHIRPS pentads
Script: Han Olff

Monthly Vegetation Greenness trends (NDVI, 2001-2021)


Jan2001-2021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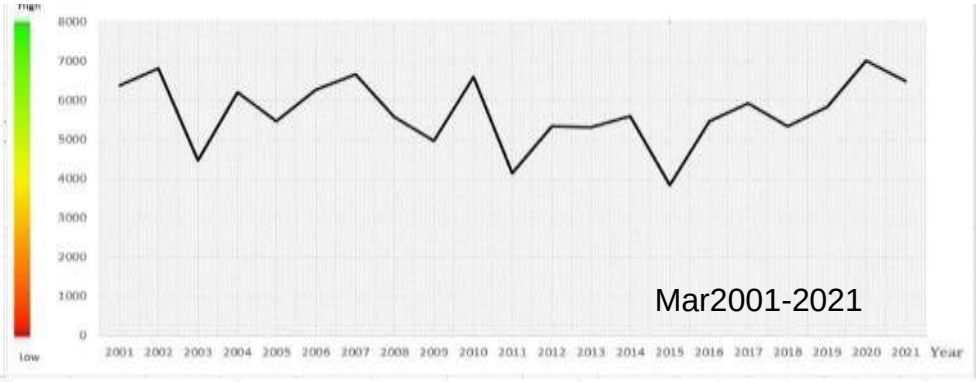
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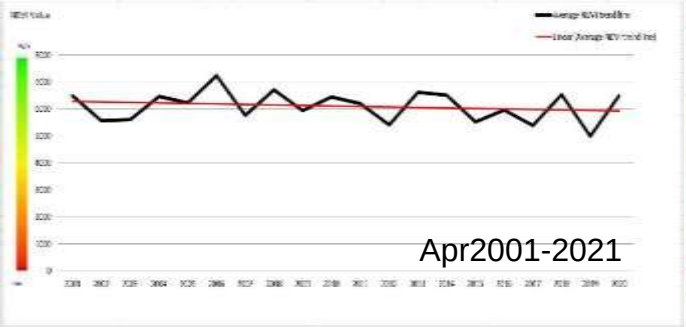
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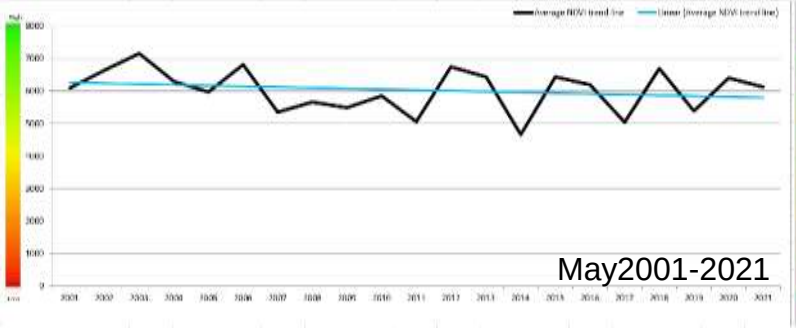
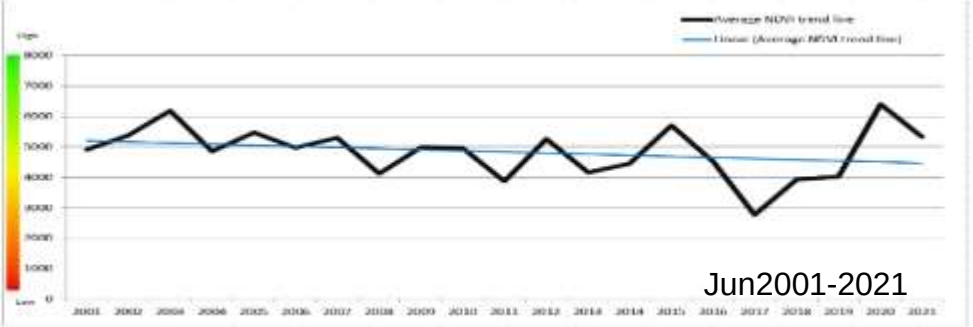

May2001-2021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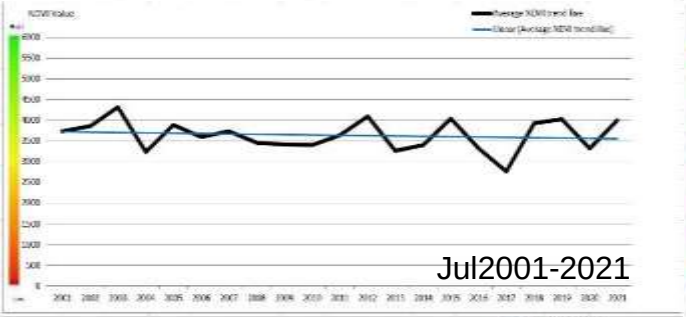
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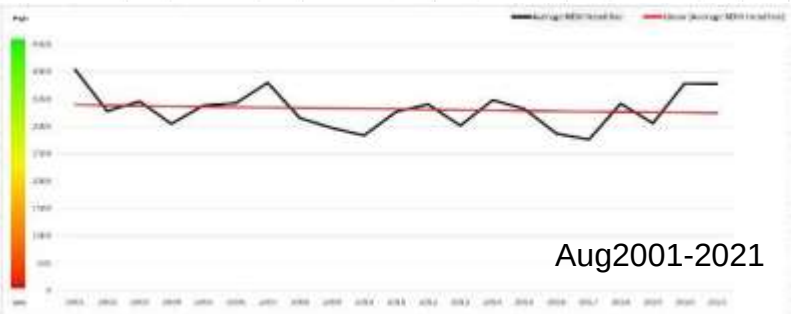
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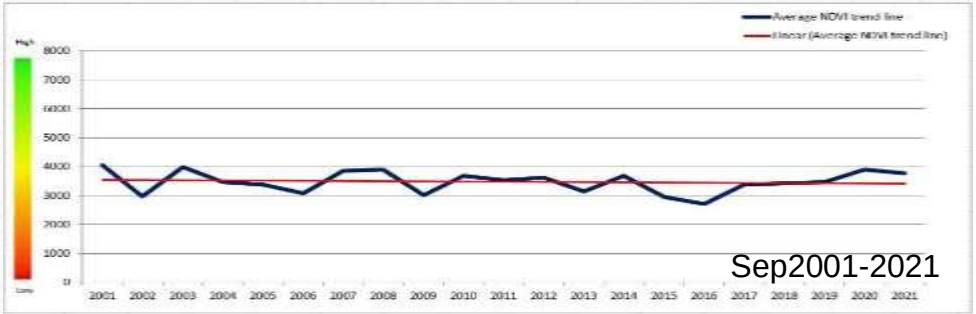
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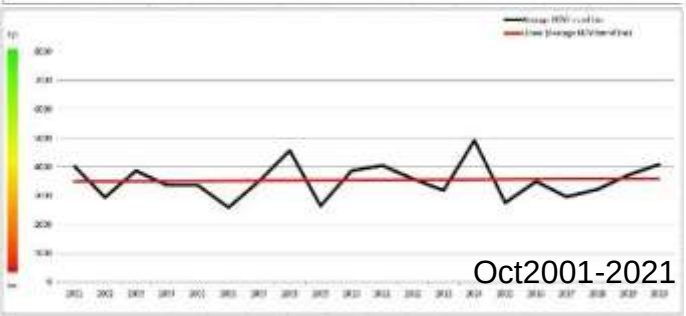
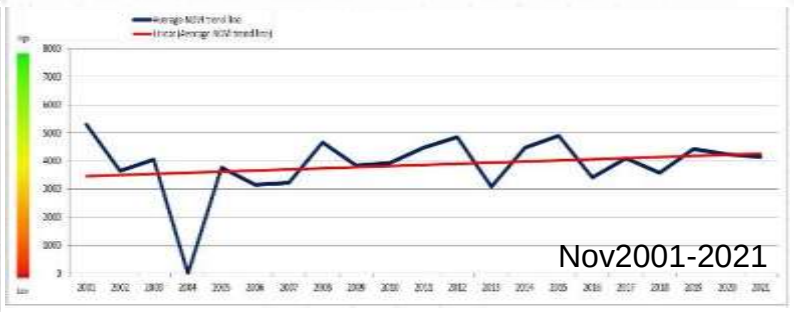
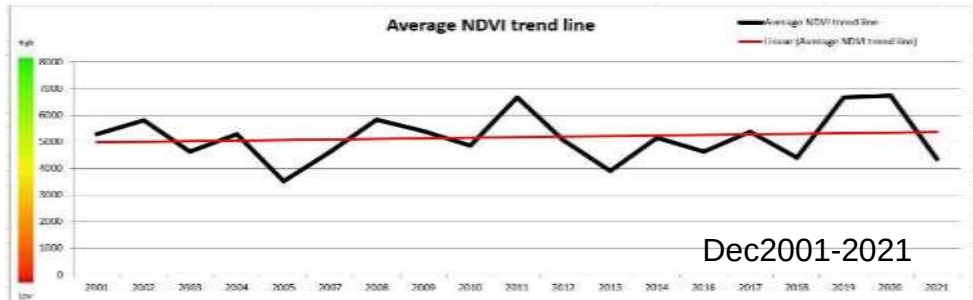
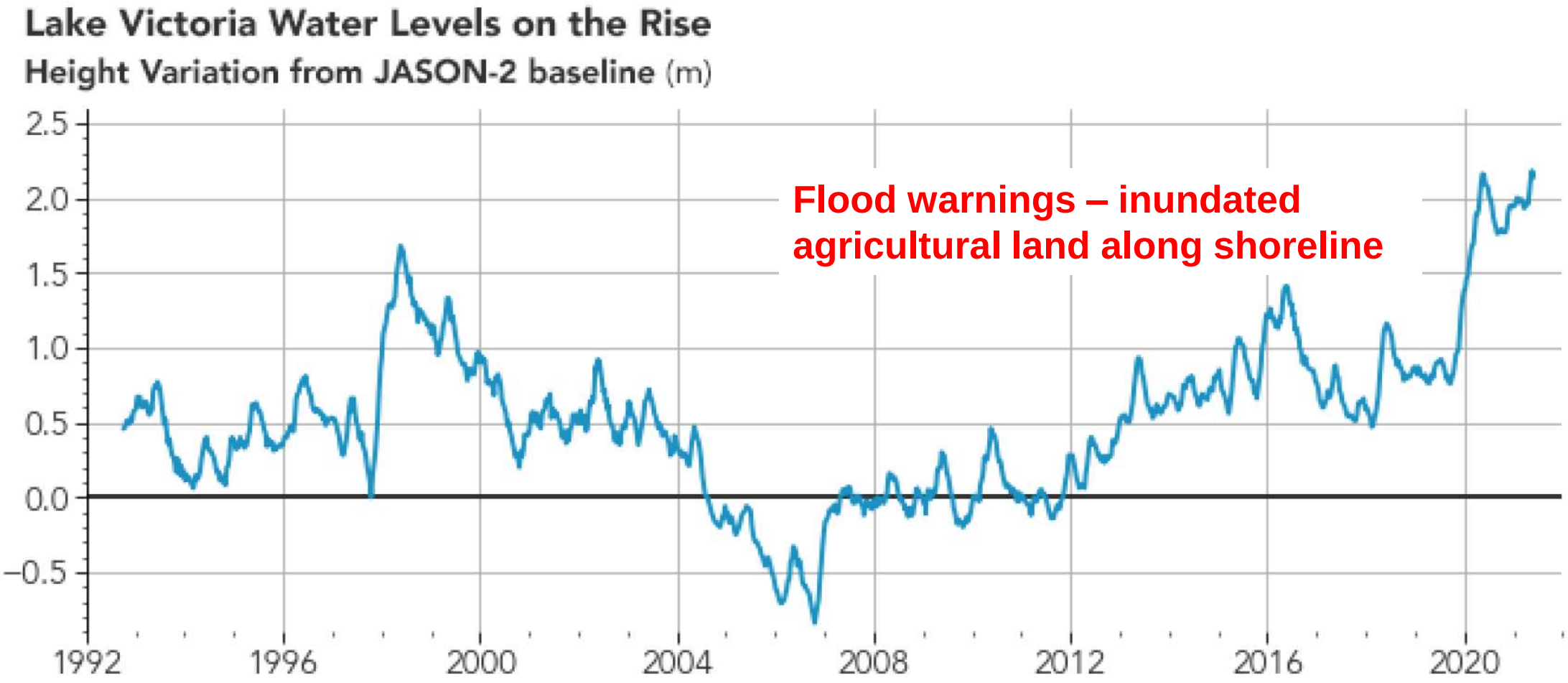

Oct2001-2021


Nov2001-2021



Dec2001-2021

Lake Victoria water level

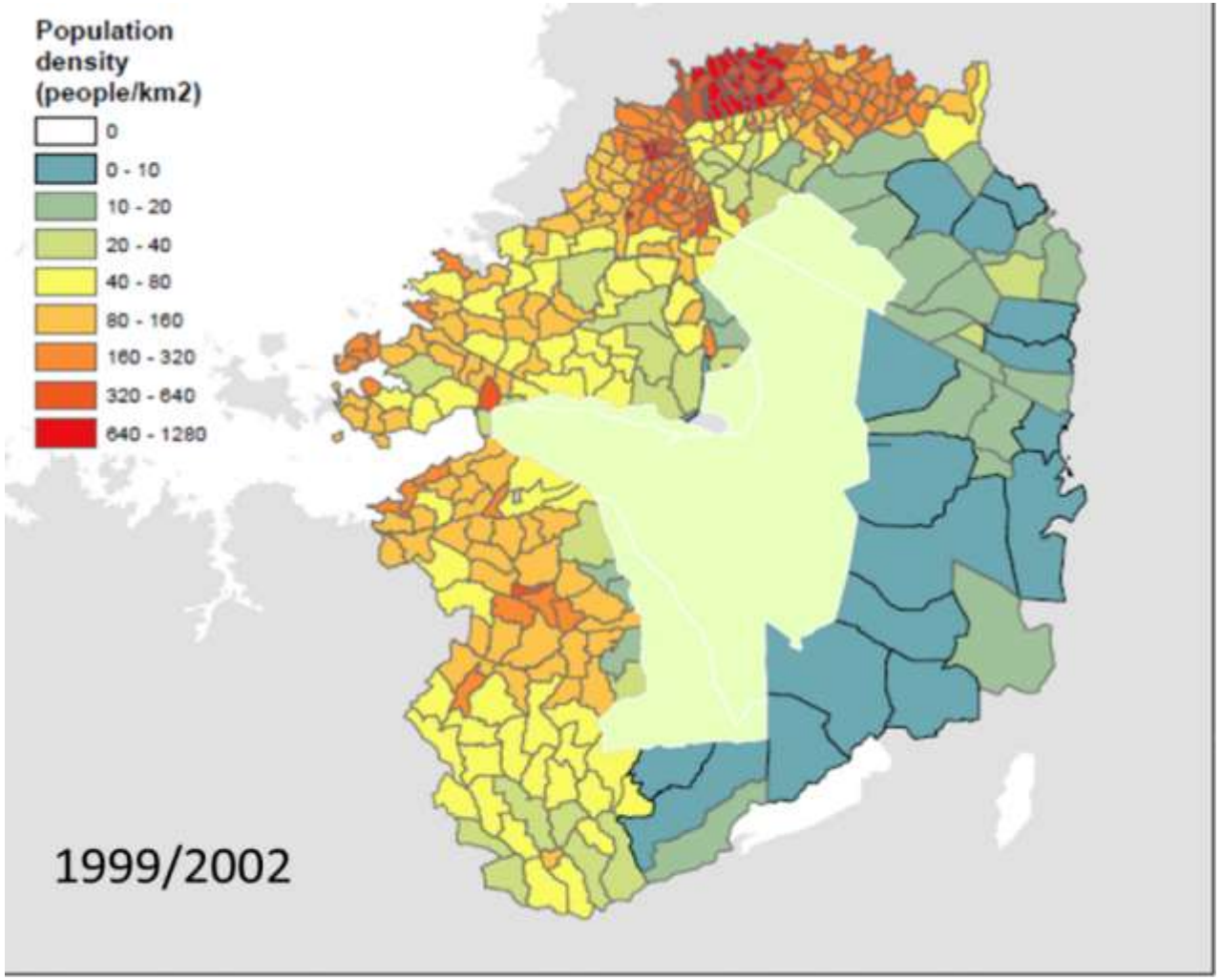


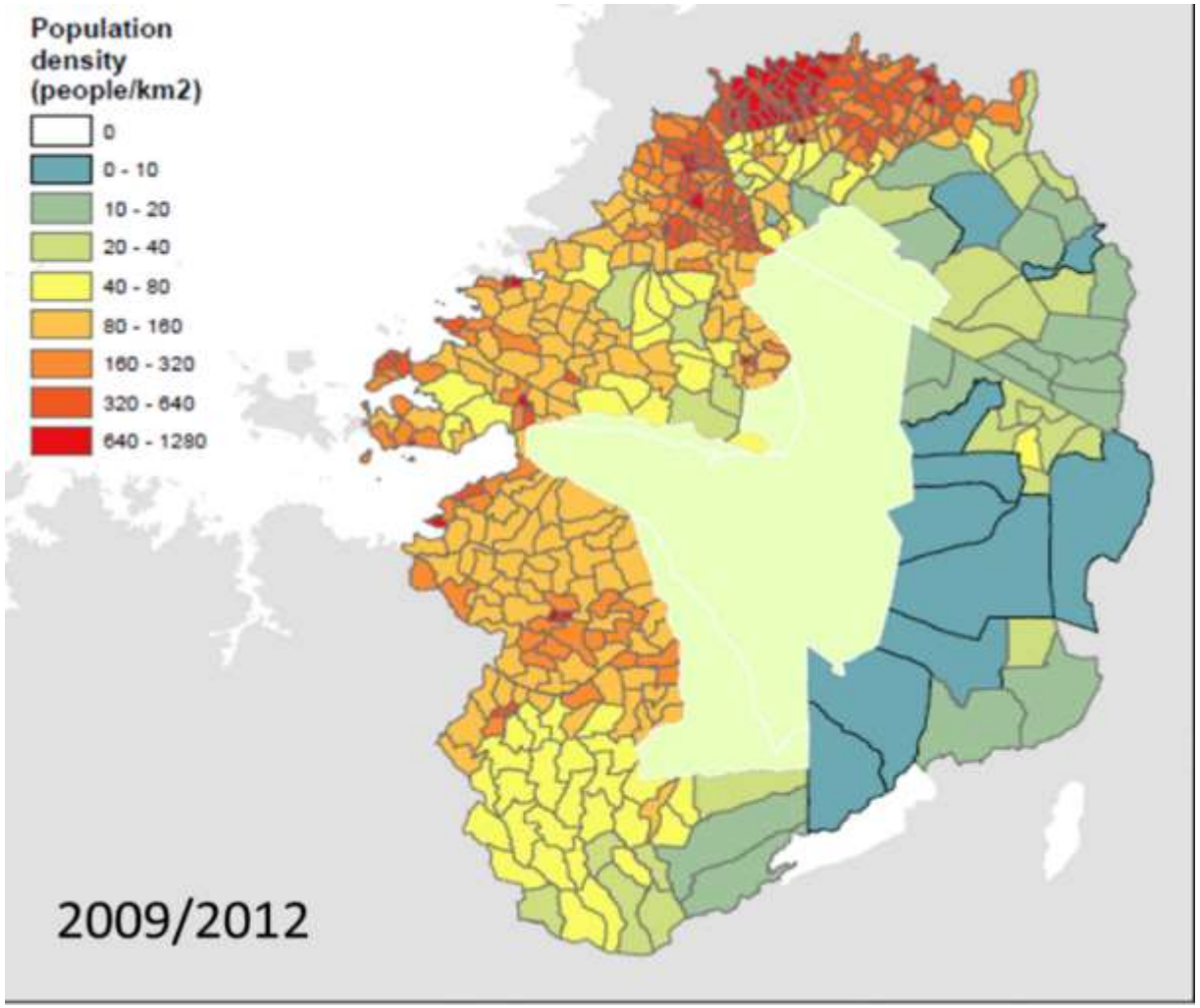
https://earthobservatory.nasa.gov/images/148414/lake-victorias-rising-waters

Near Nyatwali, Nov 2021 – this area was cropland until 2020


Population growth, land use change, agriculture

Human population growth





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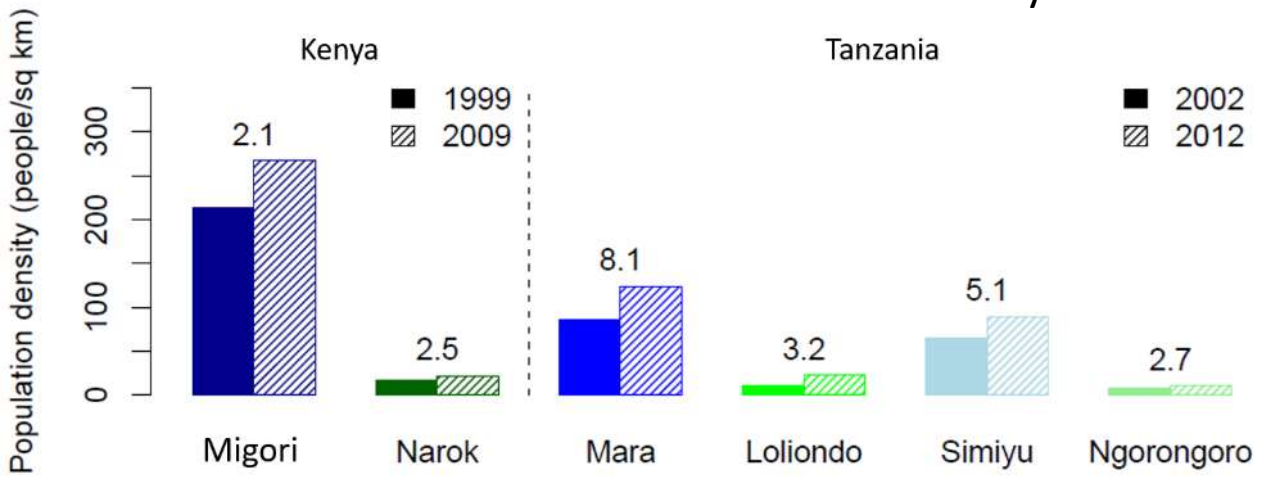
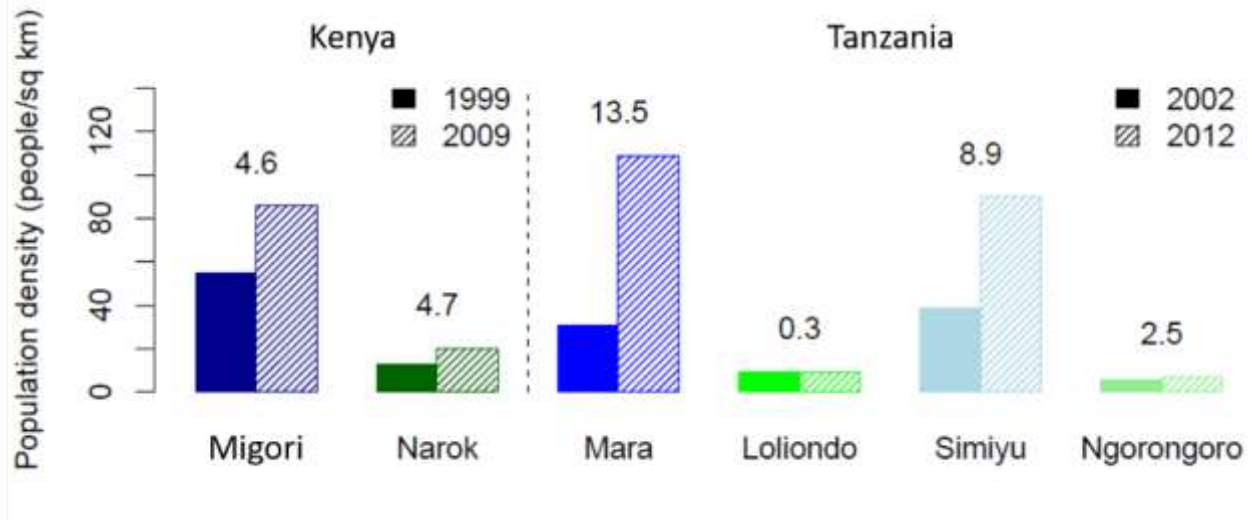
Veldhuis et al (2019) Science

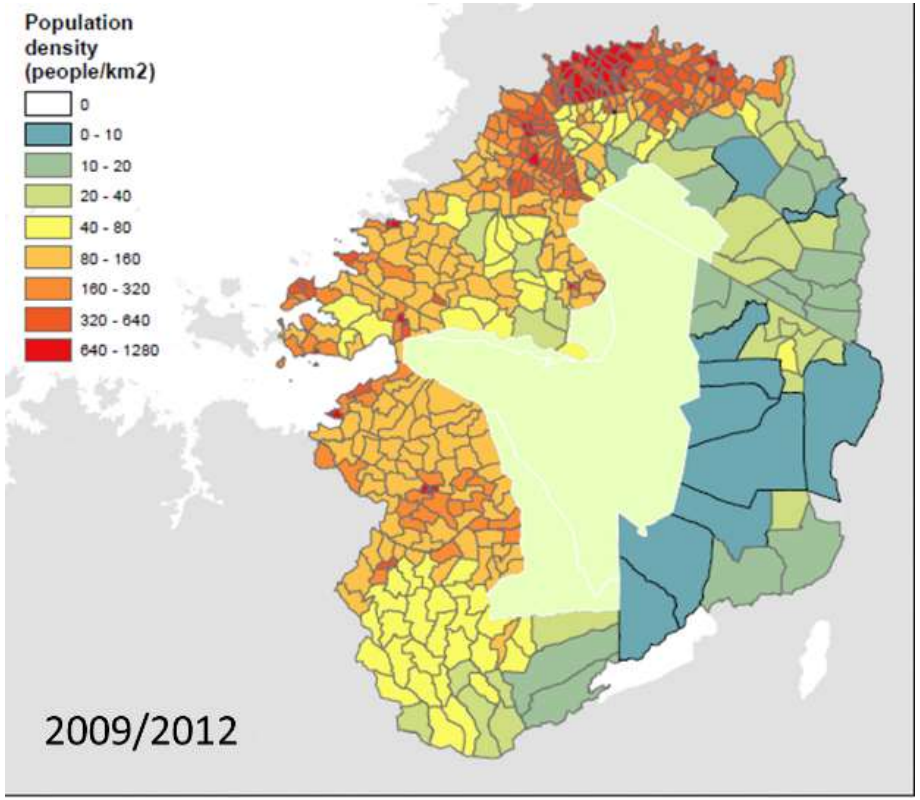
Human population growth

Within 60 km from boundary



Within 15 km from boundary





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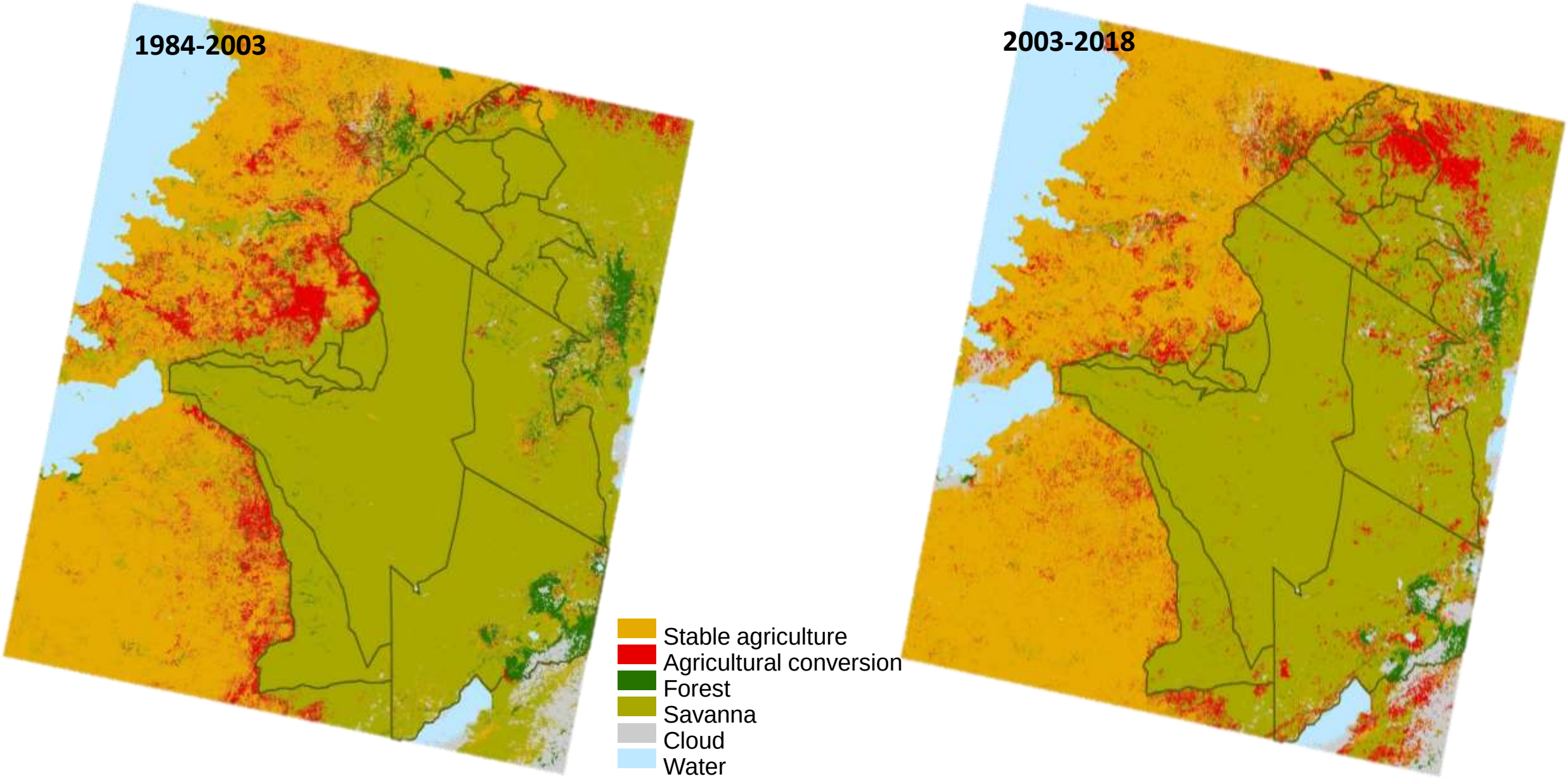
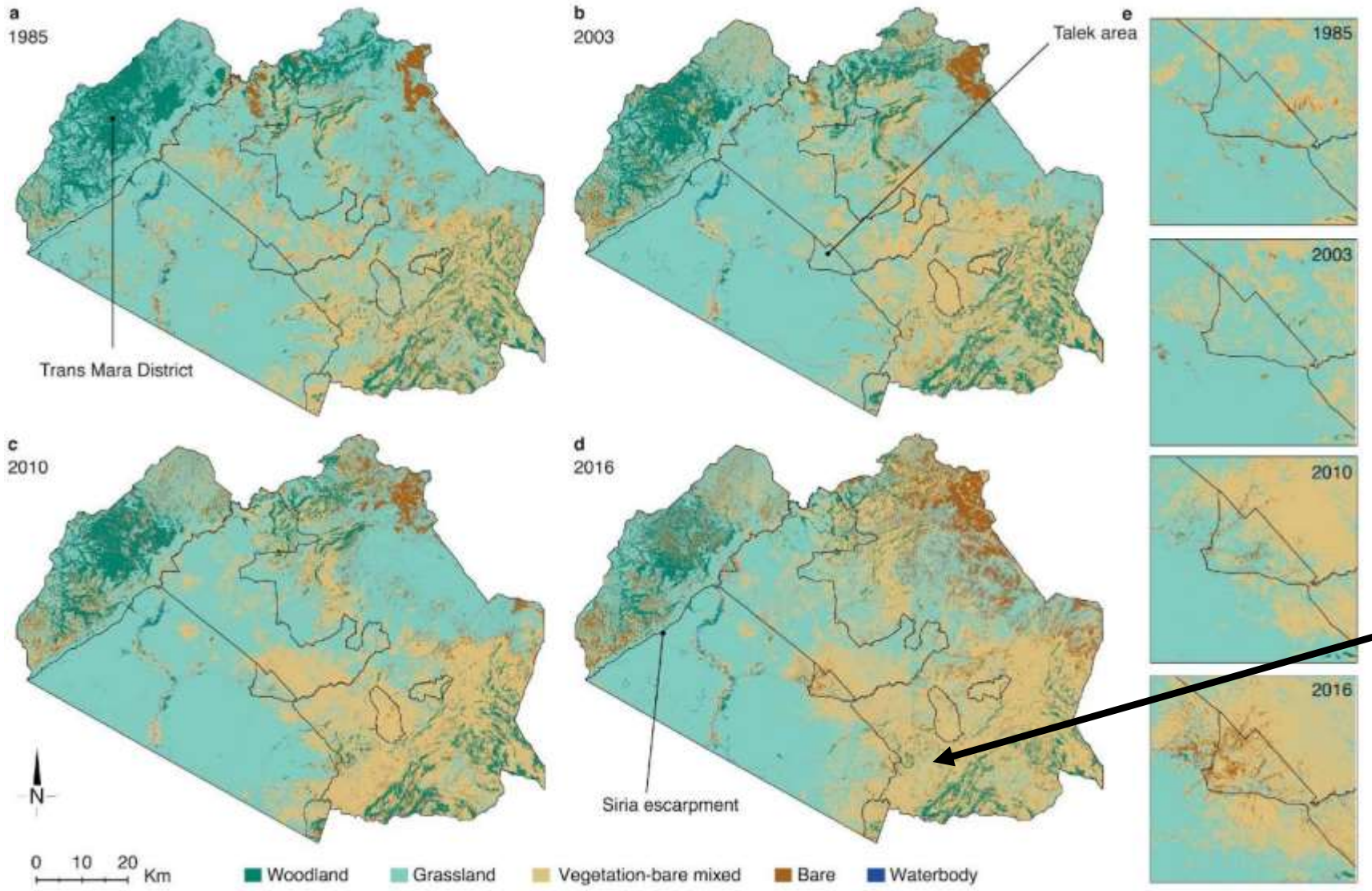
Human population growth



Land degradation in Mara more severe in unprotected areas



Grasslands in the Talek watershed area are being converted to bare with sparse mixed vegetation

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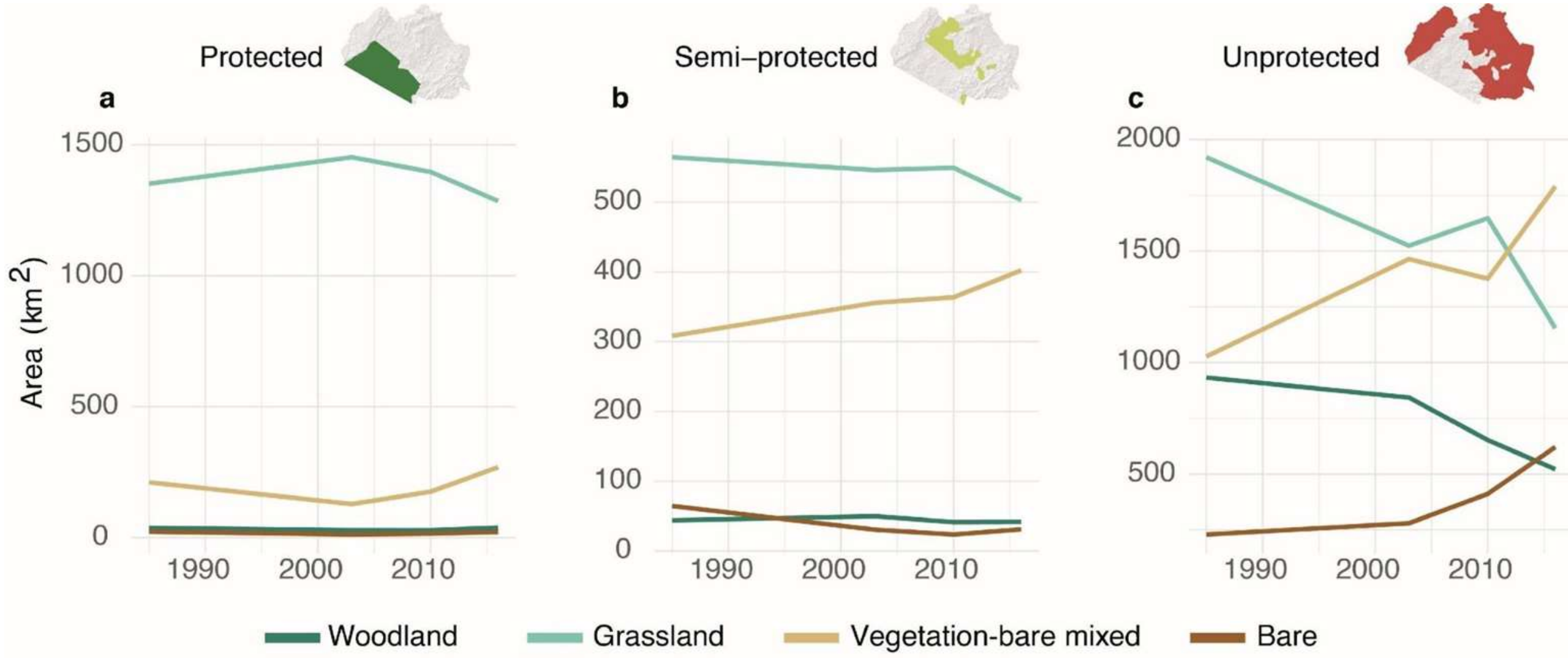
Jens Svenning: svenning@bio.au.dk
Li et al, 2020

Land degradation in Mara more severe in unprotected areas



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Li et al, 2020

Suggested recommendations for consideration

- Ensure village landuse plans are compatible with conservation objectives
- Review of land use policies particularly in high-use wildlife areas and clearly identify the priority
  - we note that uncertainty about rules and regulations is unenforceable and leads to rapid degradation as people scramble for resources
- Incentivize conservation compatible forms of land use and income generation – but think at the larger scale than villages
- Interface village land use plans with district land use plans


Water quantity, quality, aquatic biodiversity

River ecology is a critical component of savanna ecosystems

Discharge

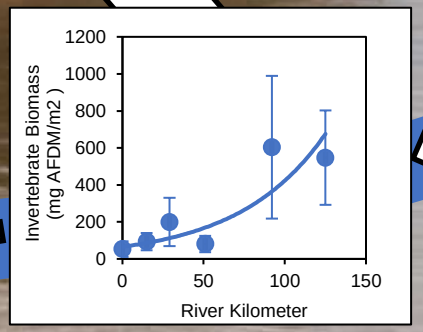
13,200 tons dung

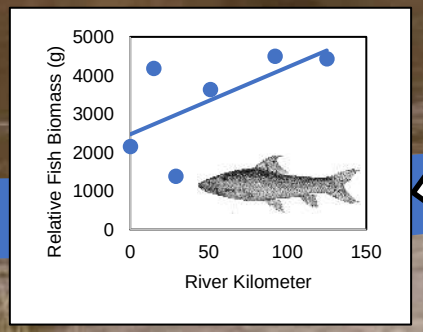
70% N
33% P
88% C

70% C
74% N
95% P

1,100 tons carcass

>2000 indiv/m²





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Aquatic biodiversity maintains a healthy river

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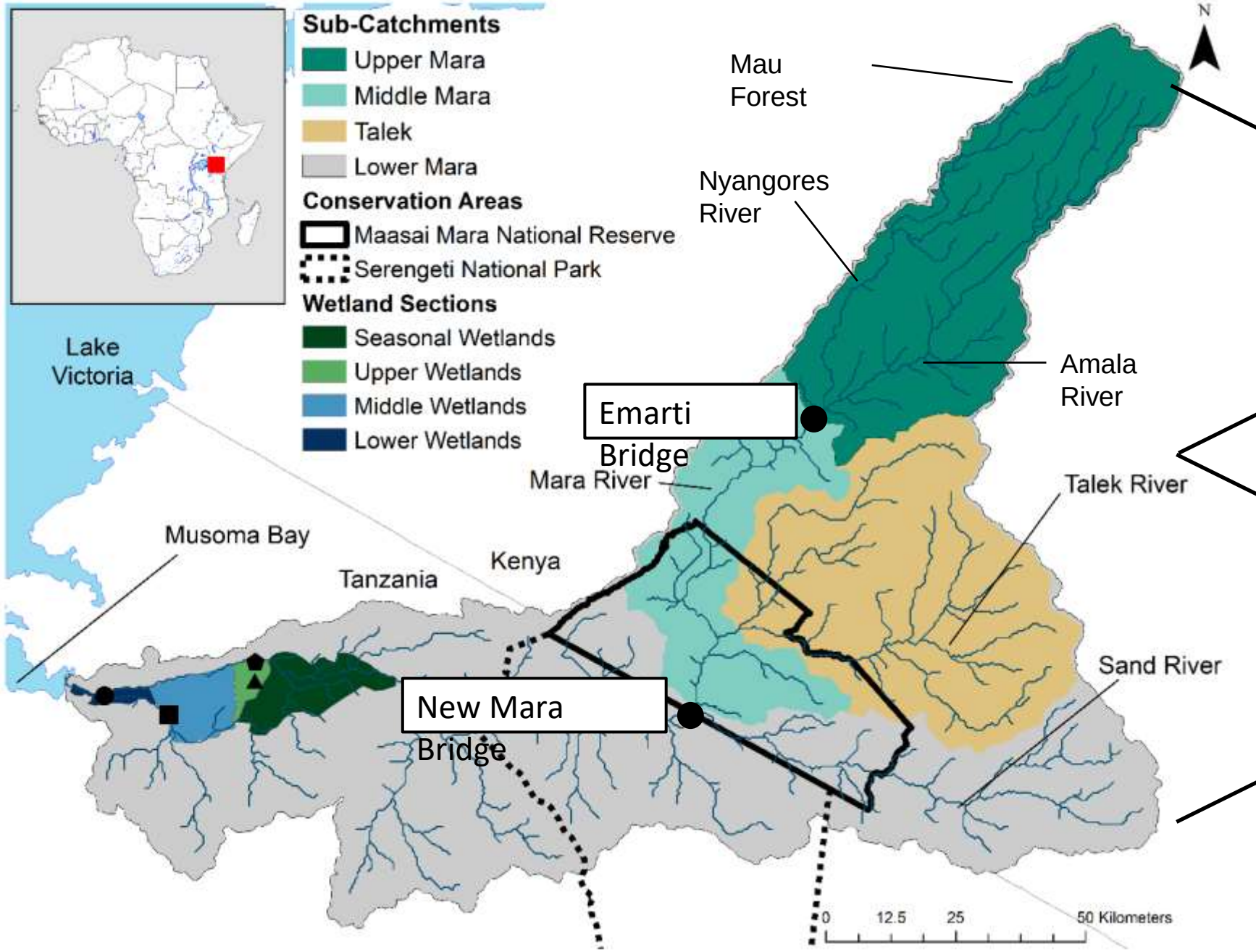

30% loss of forest cover, 200% increase in agriculture from 1973-2000 (*Mati et al. 2008*)

500% increase in tourism facilities, 400% increase in local population from 1988-2013 (*Green 2015*)

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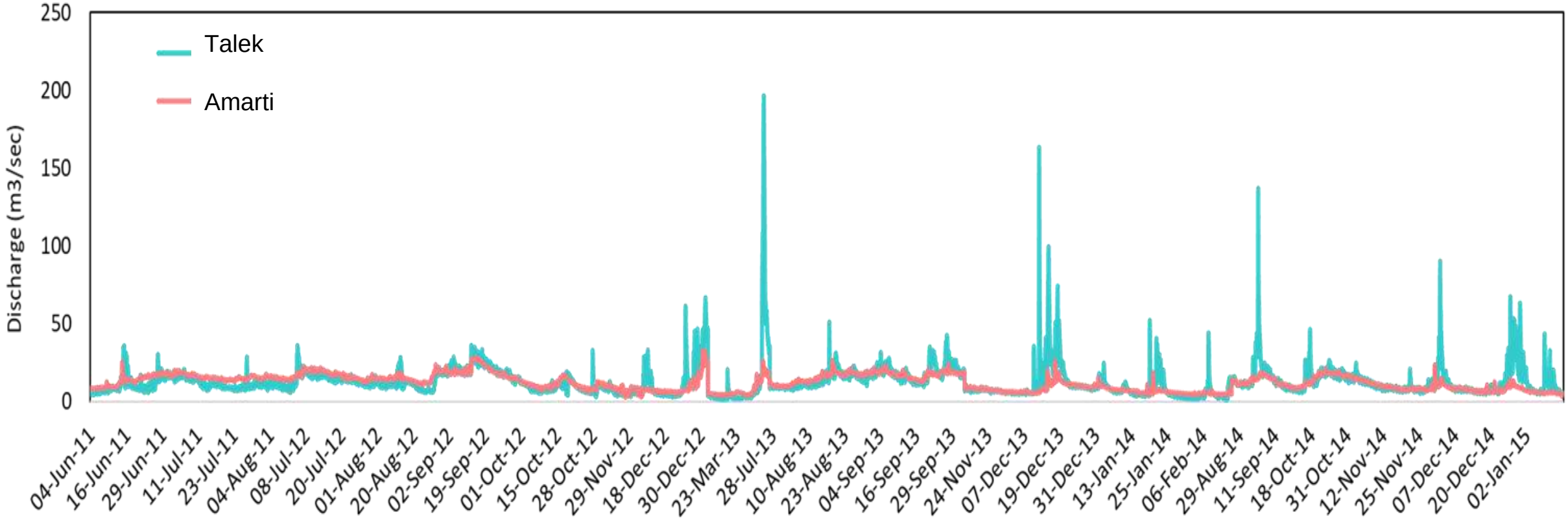
Variation of Mara River flow rates



Talek – increasingly variable over time suggesting that Mara fluctuations are a result of the Talek.

Amala - likely contributes to the continuous and stable flow of Mara

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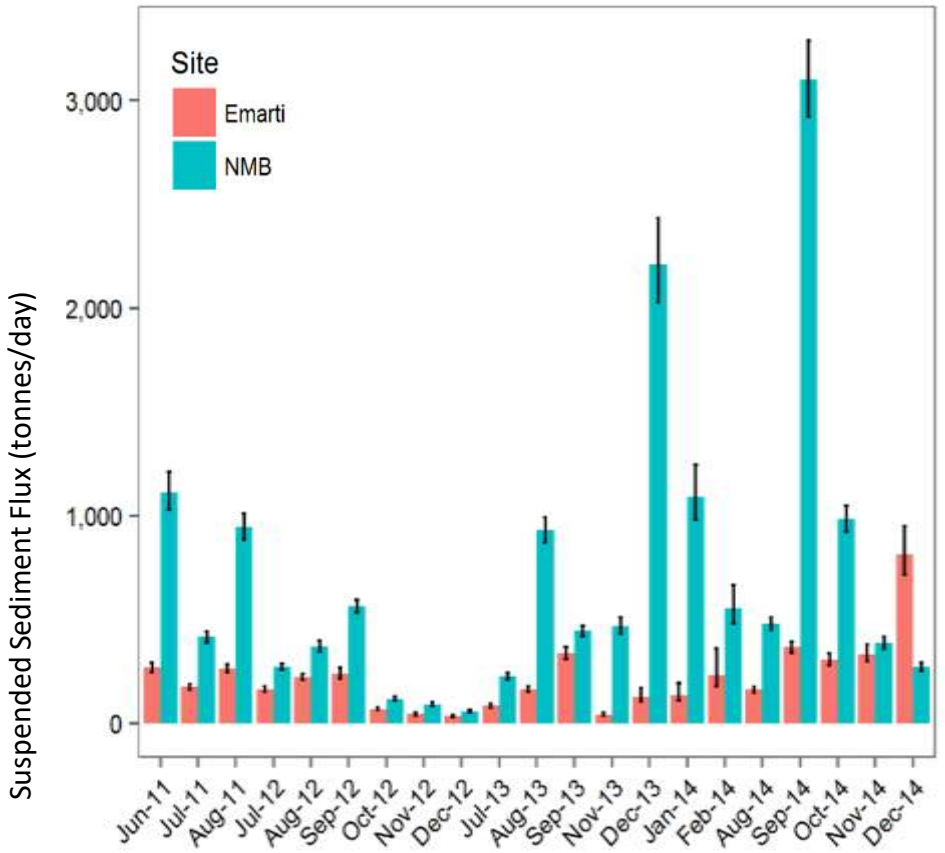
Chris Dutton: cldutton@gmail.com
Dutton et al. 2018

Recent data from river monitoring



Site	Mean discharge (m3/sec)	Flashiness Index	Sediment Flux (tonnes/day)
Emarti Bridge *(Upper Catchment)*	13.3	0.05	220
New Mara Bridge *(Upper, Middle, and Talek catchments)*	12.5	0.19	710

The Mara River becomes lower, flashier, and more sediment-laden as it moves downstream

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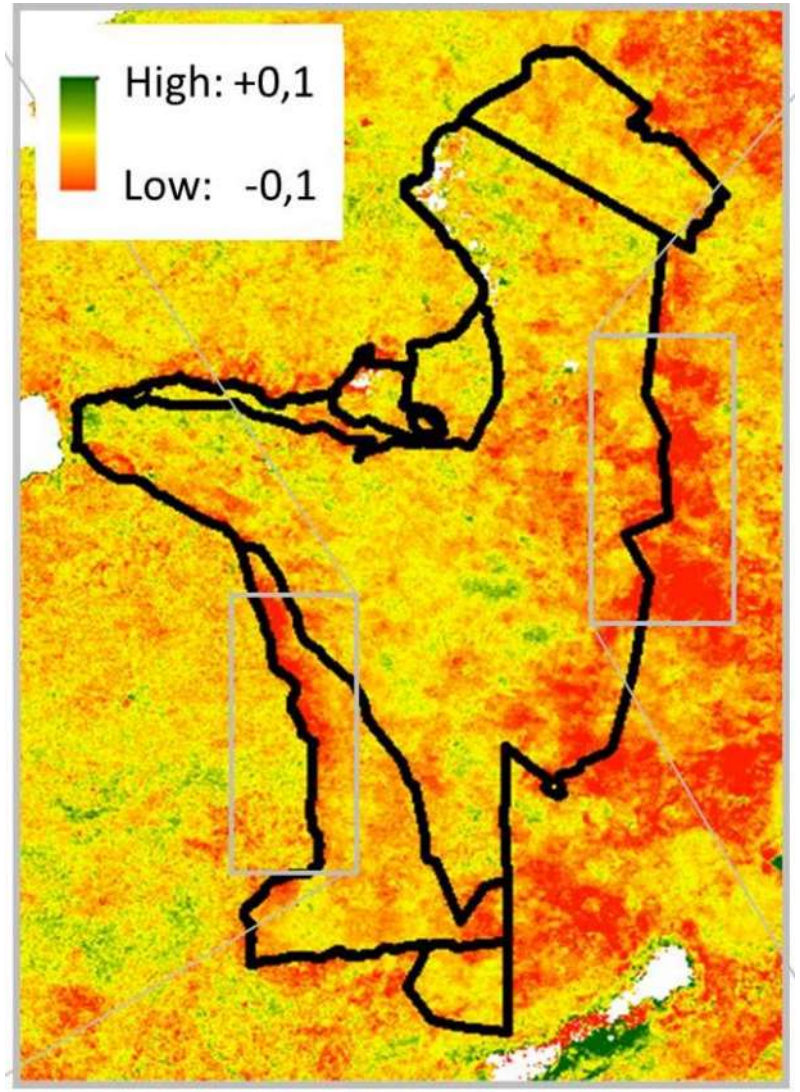
Dutton et al. 2018

Suggested recommendations for consideration

- Protect upland catchments of the watershed (both forests and grasslands)
- Do not use rivers as hard boundary because ecological processes and ecosystem benefits/services are lost. Both sides of the rivers should be protected by core areas.
- Reduce water abstraction to maintain flow and especially during extreme droughts

Livestock & Fencing

Livestock incursions in Serengeti



Rate of change in NDVI

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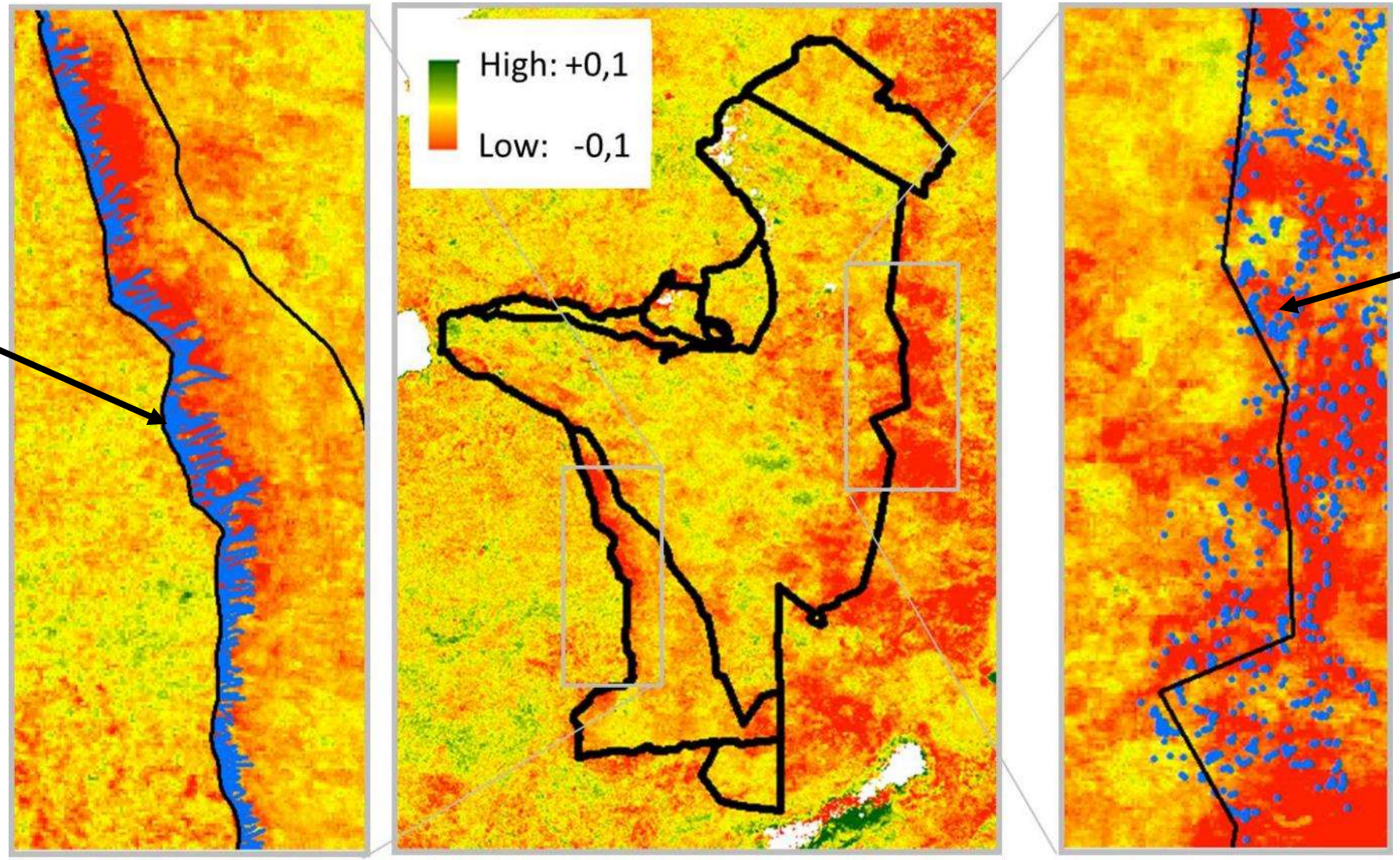
Veldhuis et al (2019) Science

Livestock incursions squeeze the Serengeti



Cattle paths

Livestock bomas

Rate of change in NDVI

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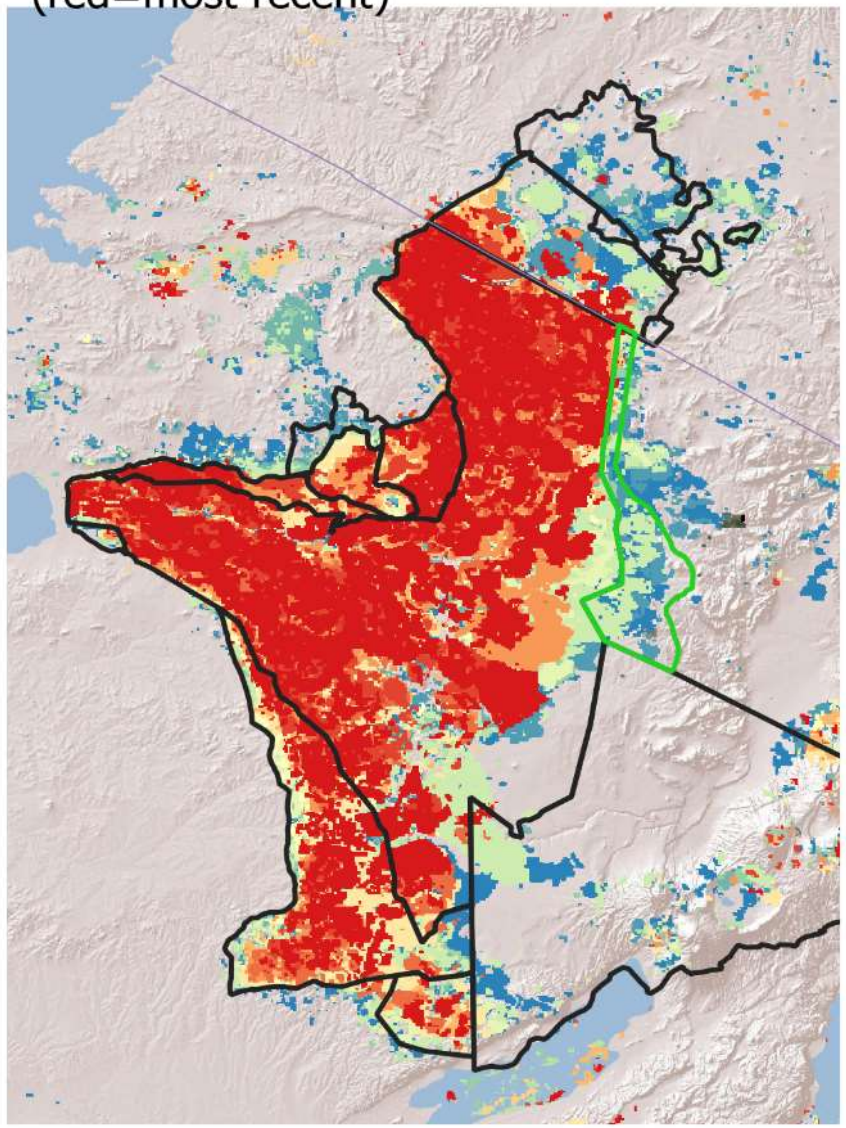
Success over the last 5 years in fighting illegal grazing in protected areas as indicated by fire data

Year last burned - 2001 - 2016
(red=most recent)



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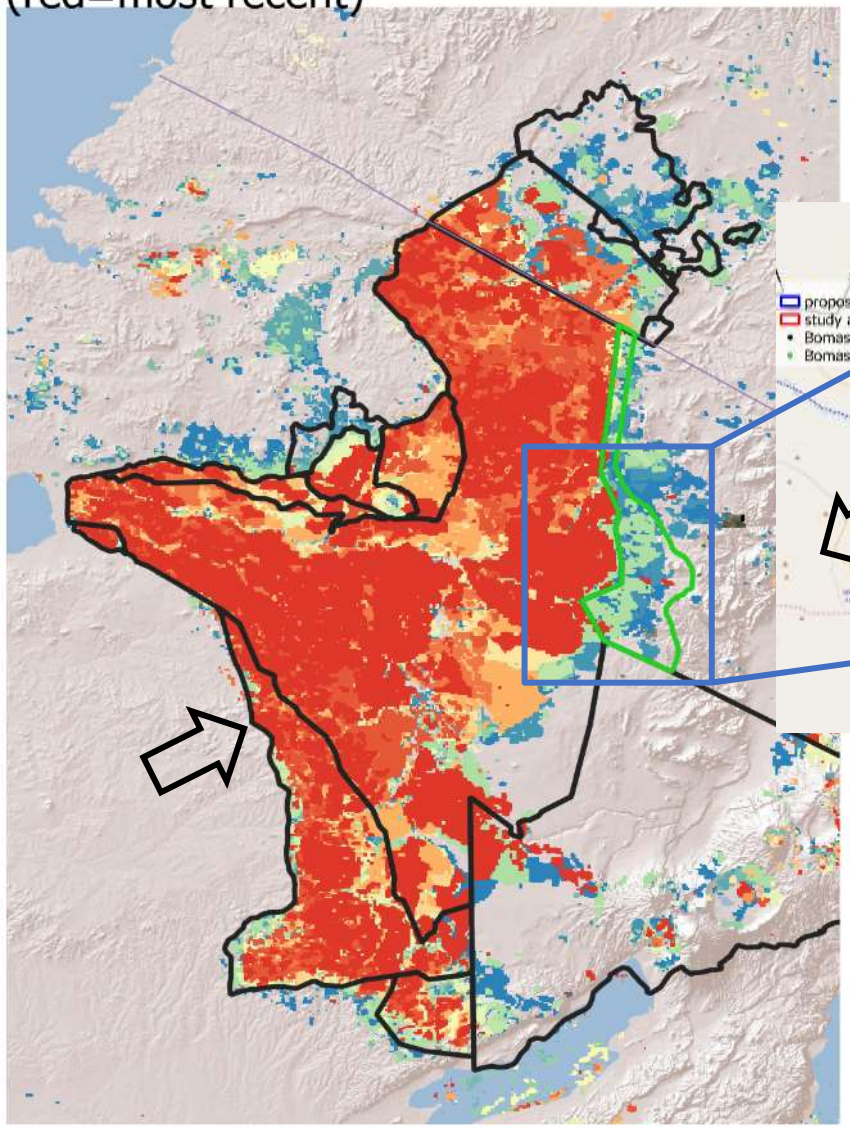
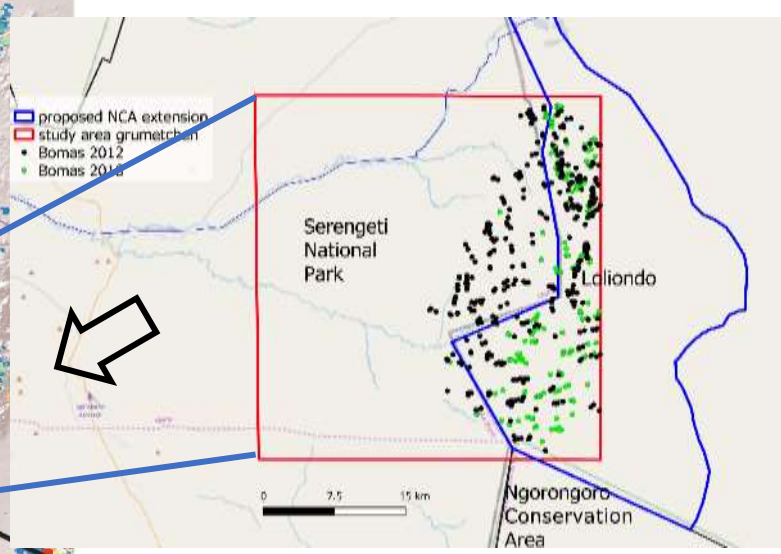
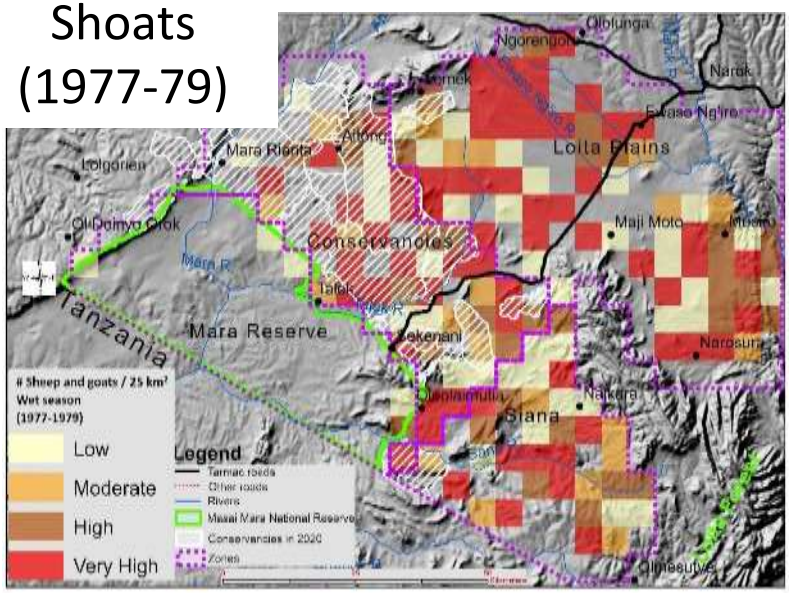


Boma removal from SENAPA
in 2017

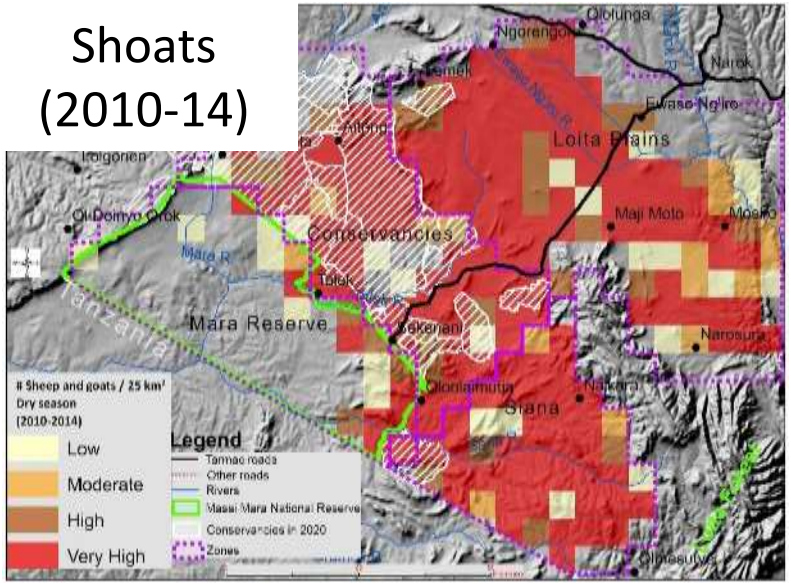


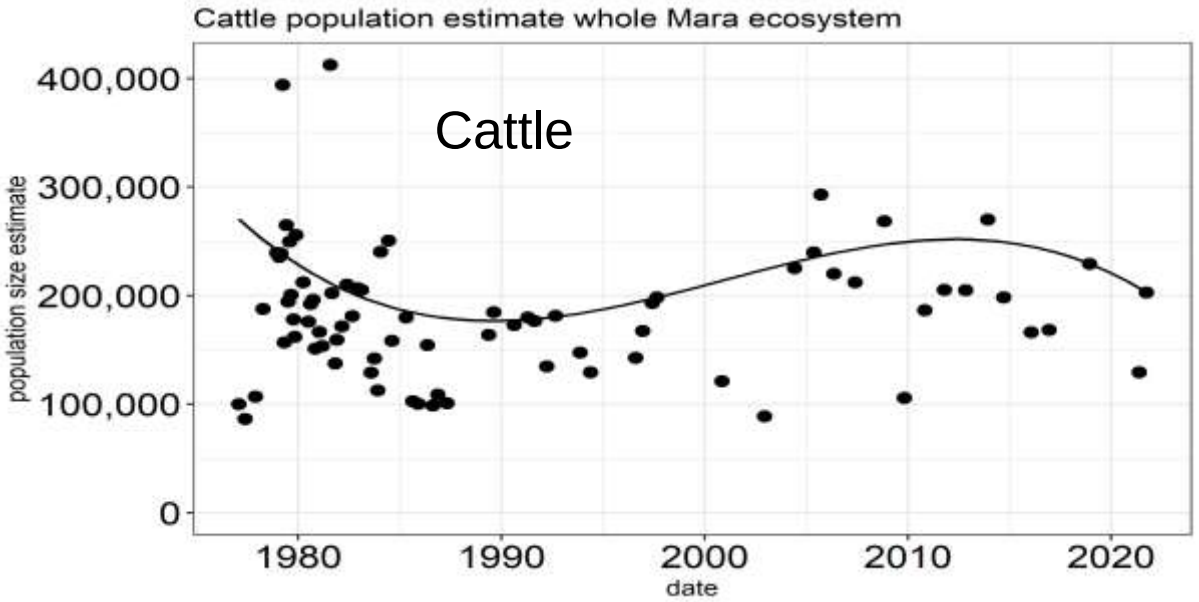
Domestic animals replacing wild animals in the Greater Mara

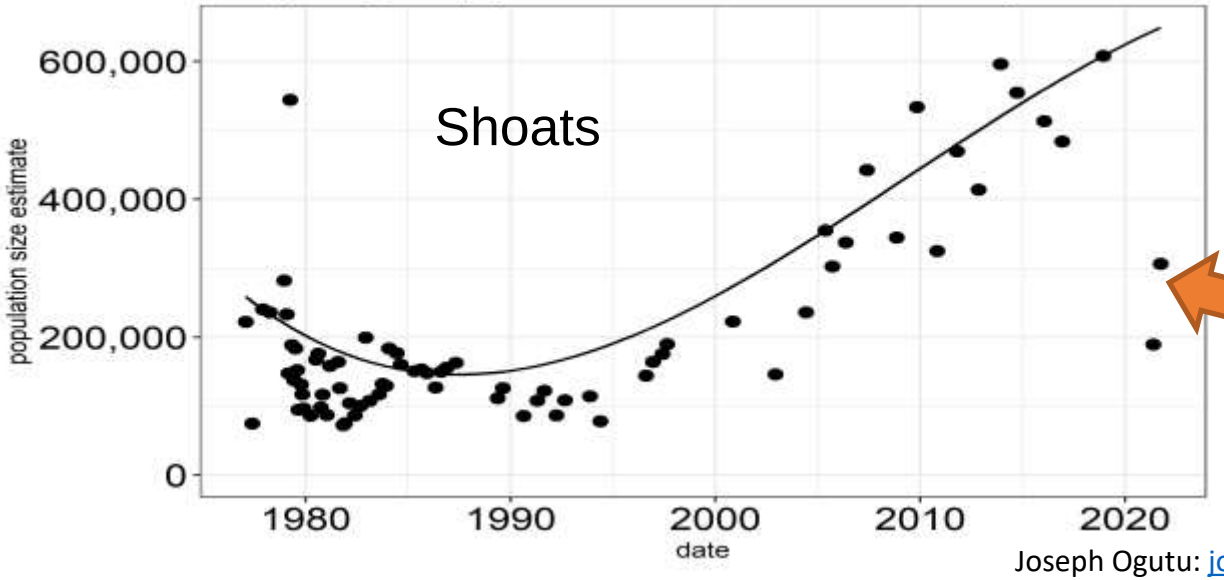
Shoats (1977-79)



Shoats (2010-14)







COVID-19?

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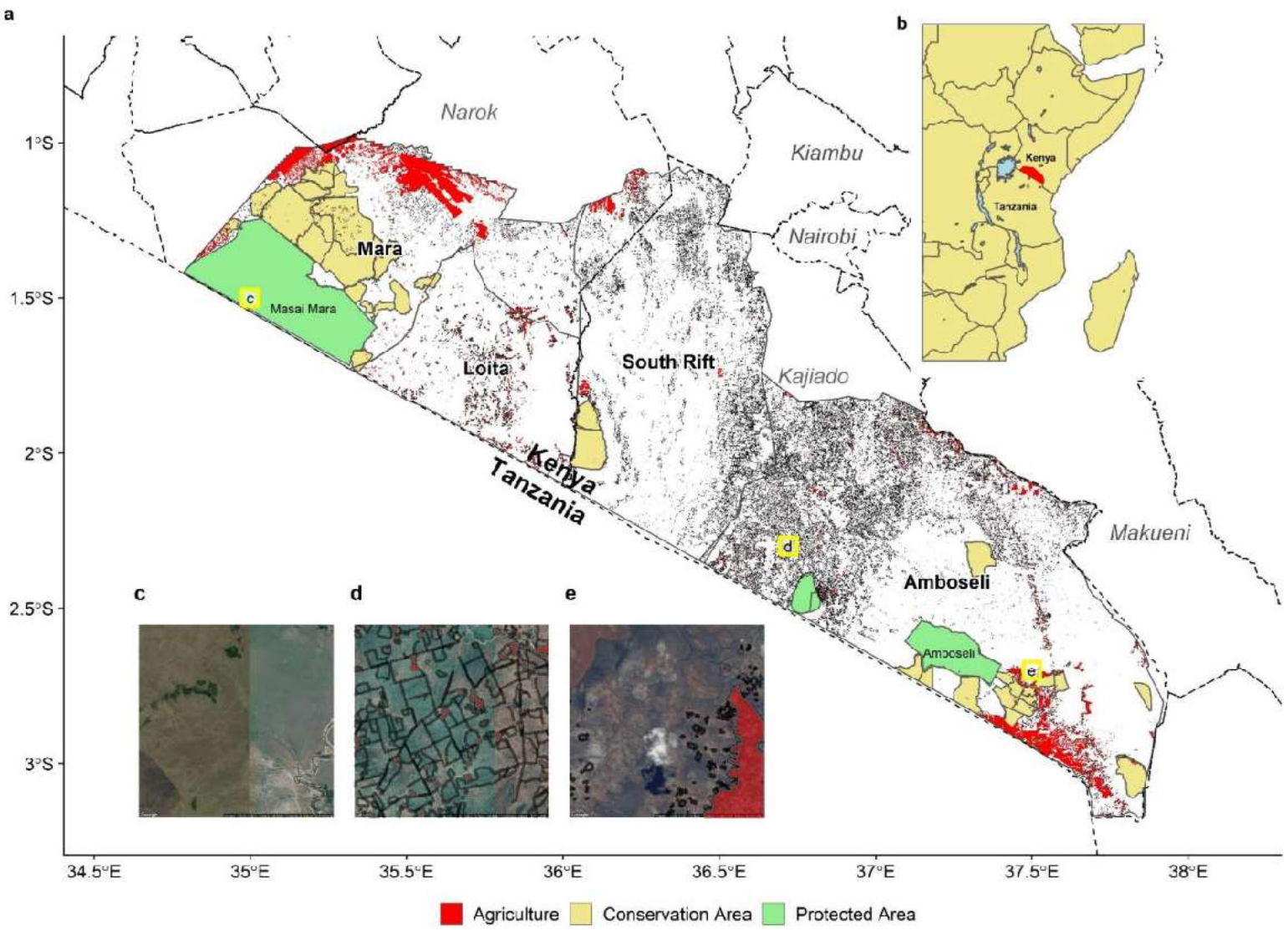
Ogutu et al, 2018, 2019, 2020

Private fencing

Largely a result of:

- Land subdivision to individual owners
- Breakdown of community-level agreements
- Increased livestock densities, more competition for grazing resource
- Economic growth due to government devolution
- Unequal and unfair land and wealth sharing due to role of elites and corruption

Fencing – a wider problem across southern Kenya



- Over 40,000km of fencing across southern Kenya (equivalent to the circumference of the earth)
- Land prices are higher in close proximity to the Mara boundary (speculators)
- Land value as a major driver for subdivision, fencing, and sale
- In Mara agricultural fencing is largely a result of a feeling of land insecurity and the threat of loss of land
- Mara Elephant Program has mapped over 4965 km of fencing in the Mara alone (electric: 1267 kms , wire: 3320 kms, other: 379 kms)

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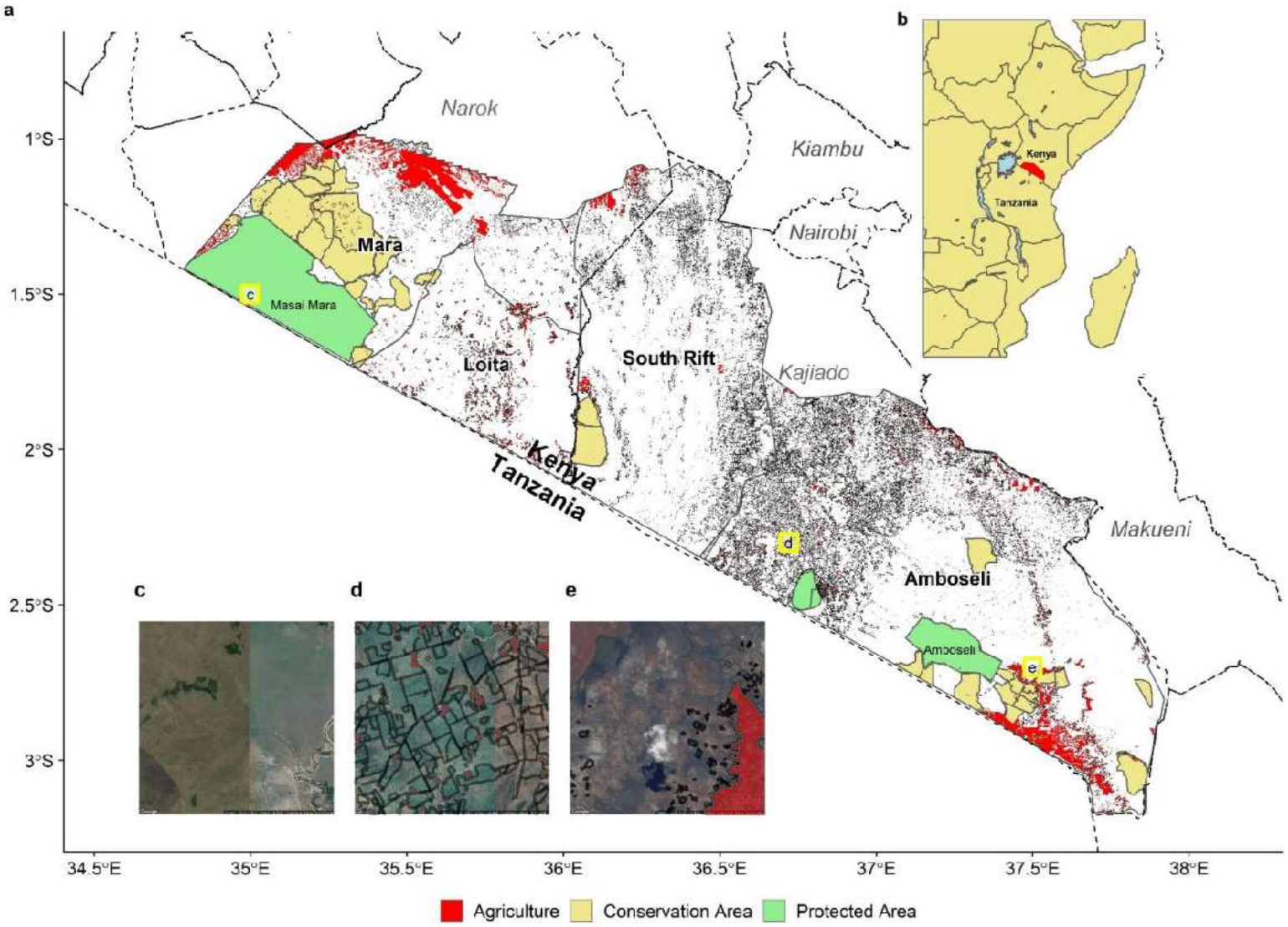
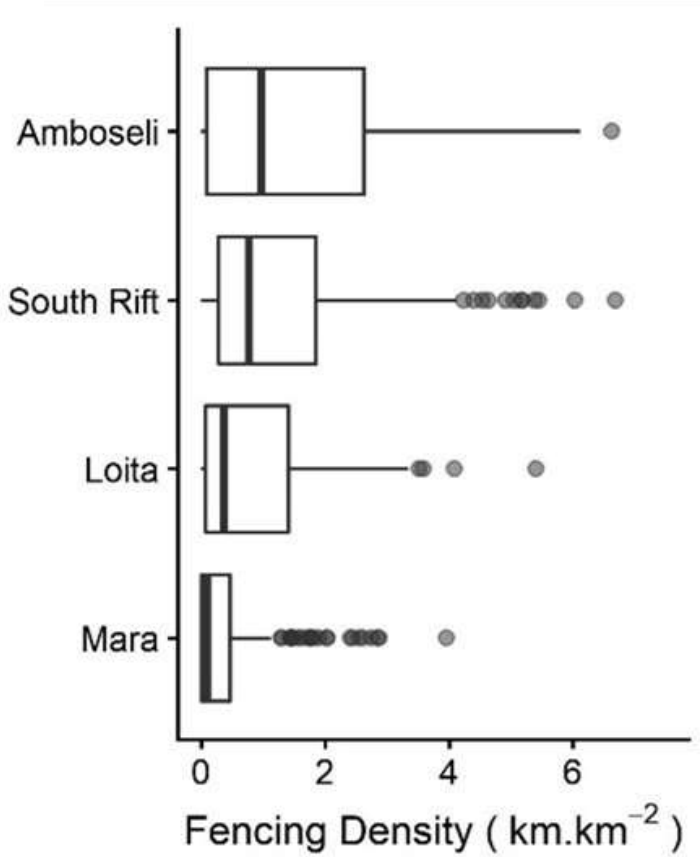
Tyrrrell et al, in prep

Fencing – a wider problem across southern Kenya





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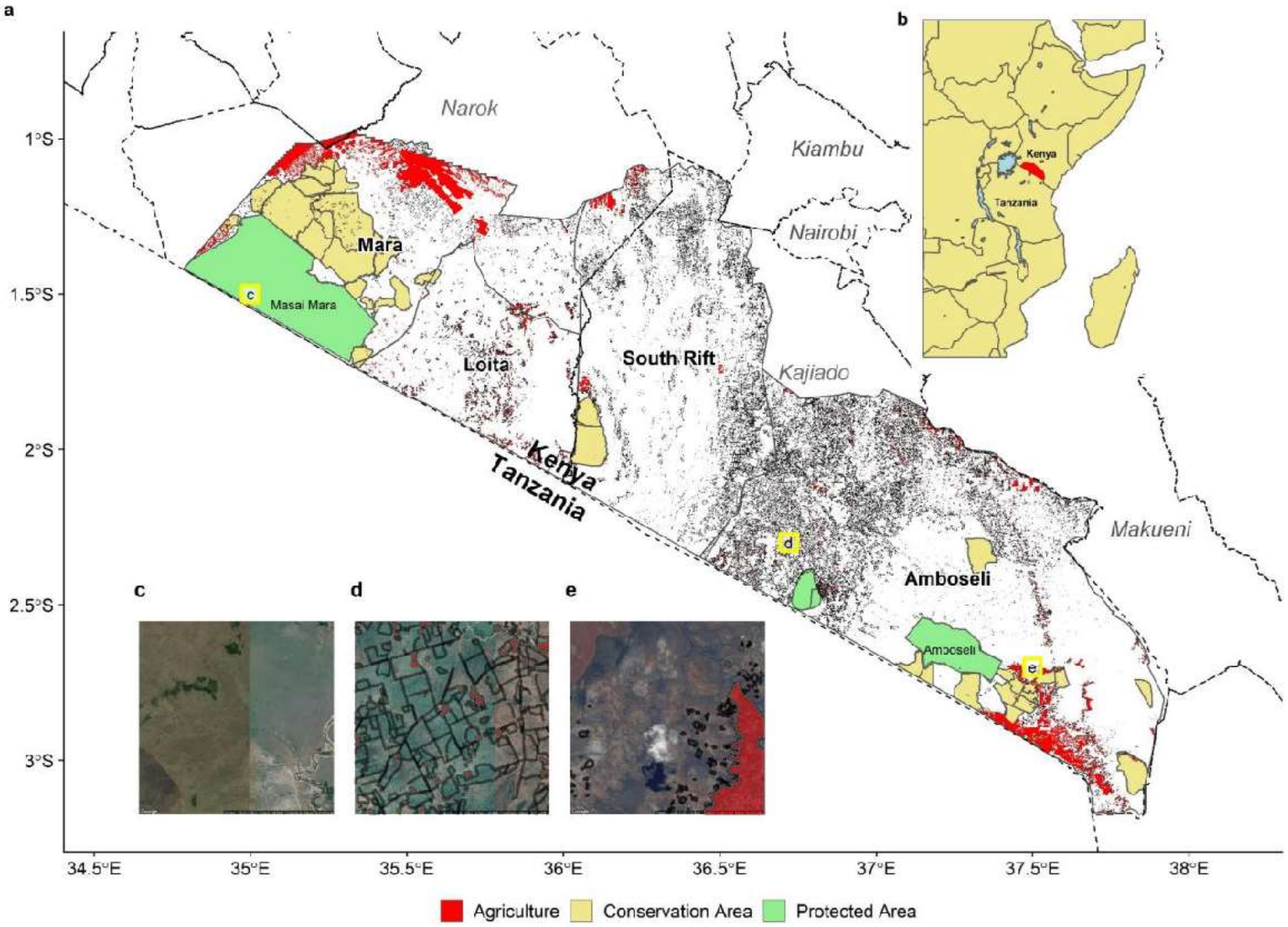
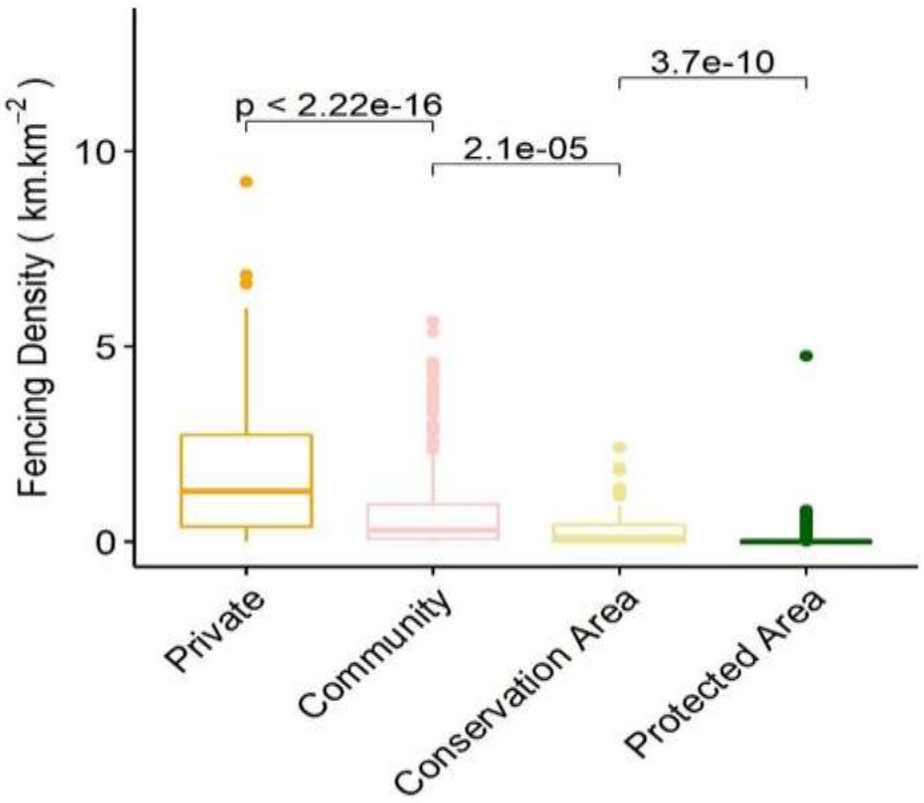
Tyrrrell et al, in prep

Fencing – a wider problem across southern Kenya





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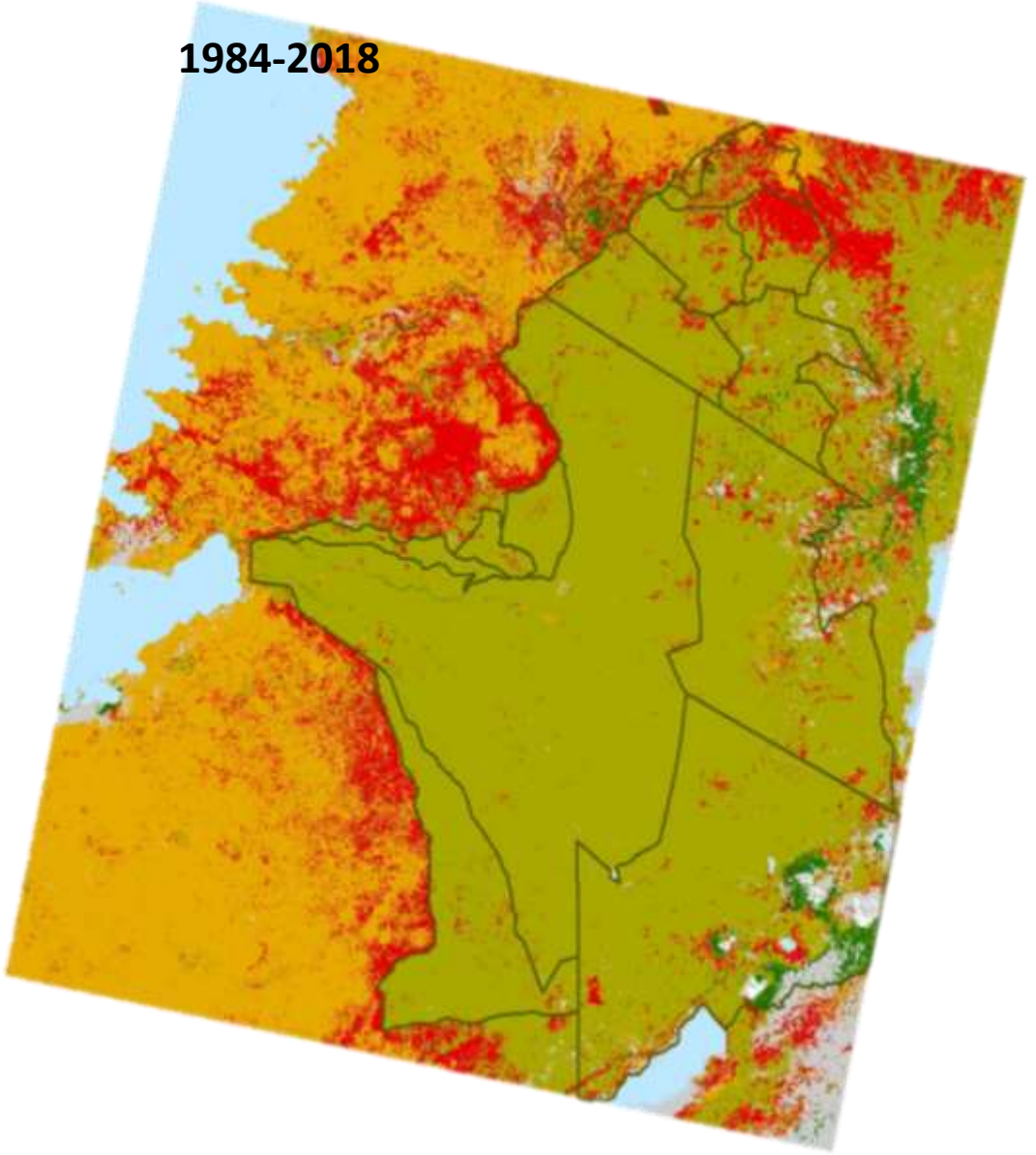
Tyrrrell et al, in prep

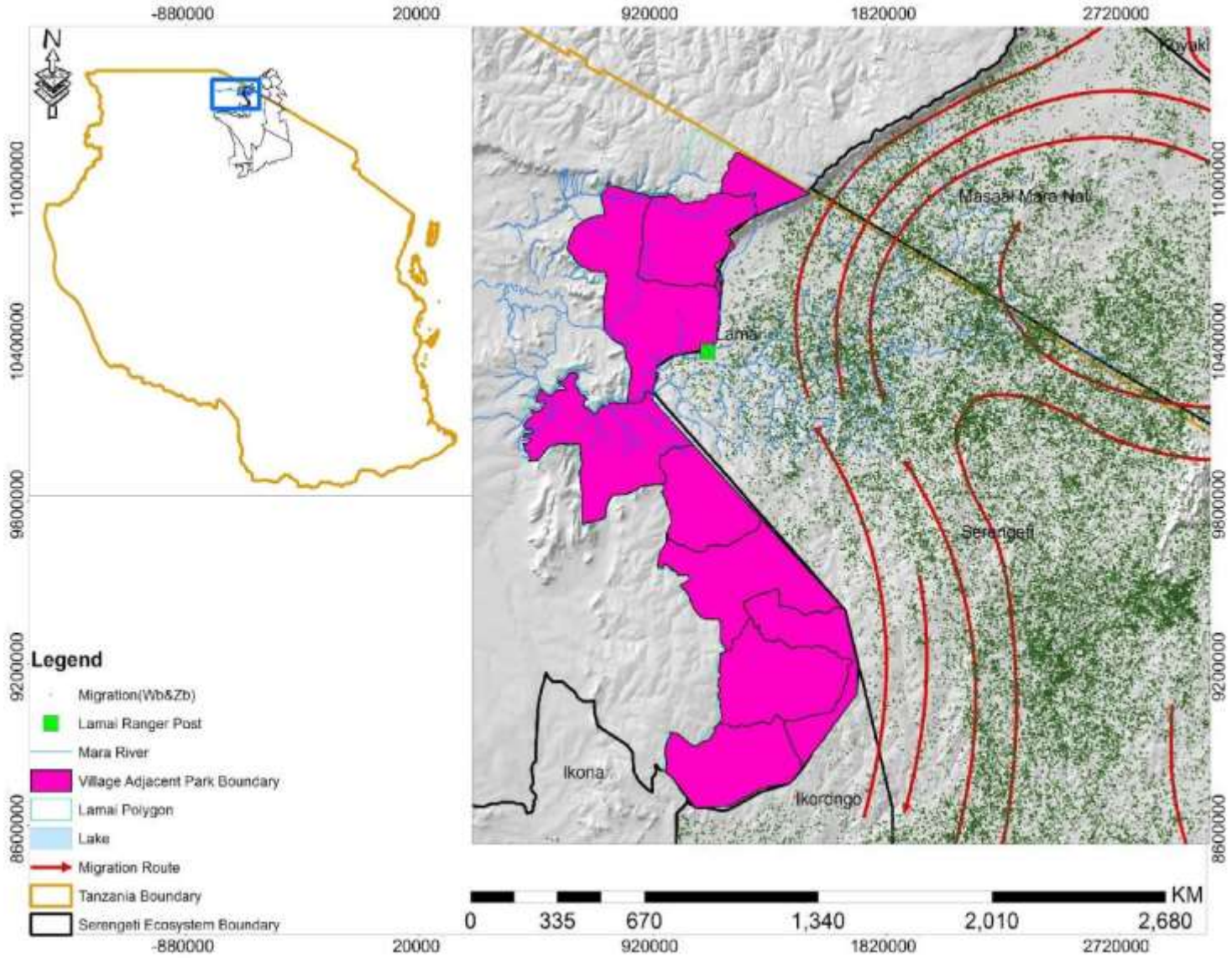
Managing the boundaries

Options are:

- Wildlife fences
- Conservation friendly village landuse plans that create a buffers
- Effective Wildlife Management Areas (WMA) or Game Controlled Areas (GCA)
- Increase patrol effort



Developing village land use plans (TANAPA, KfW and FZS)



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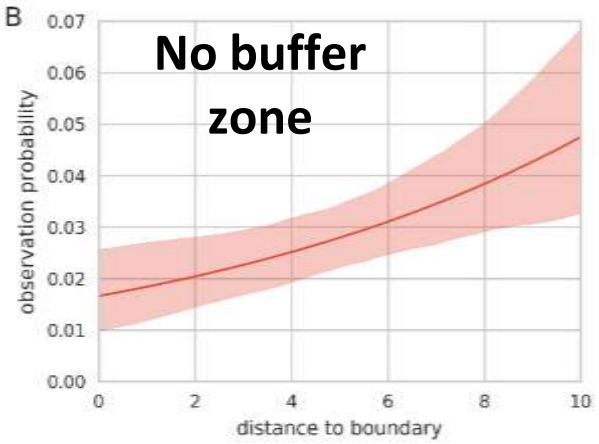
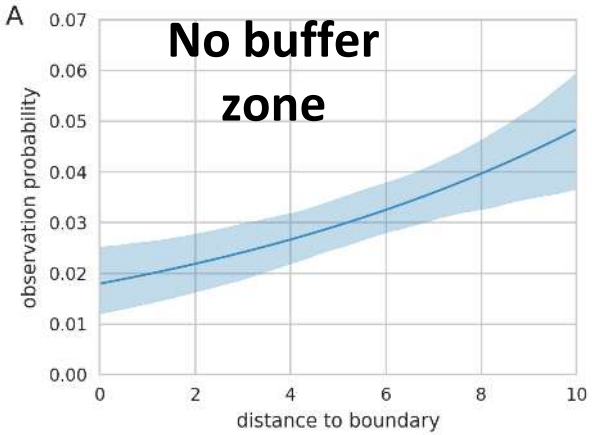
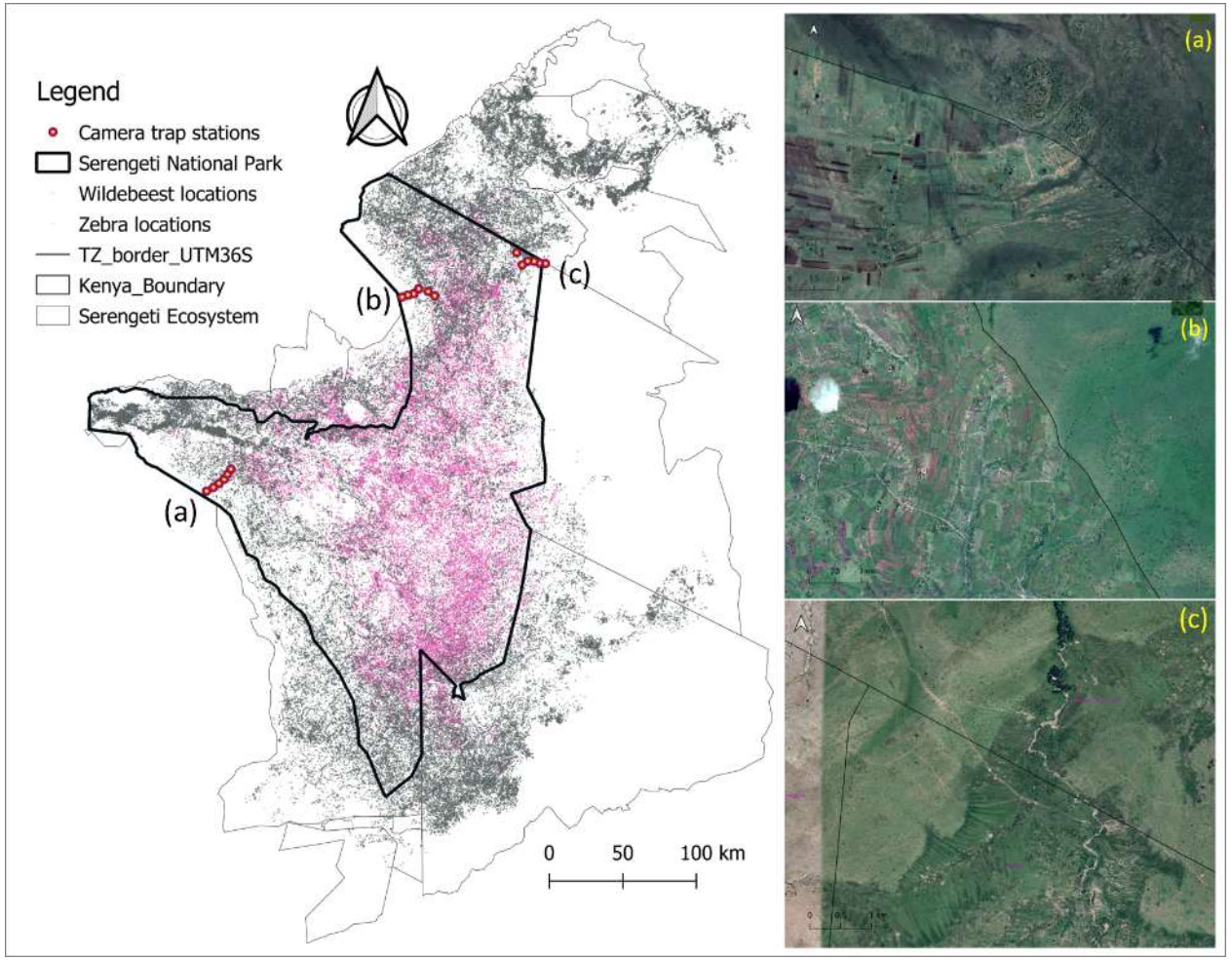
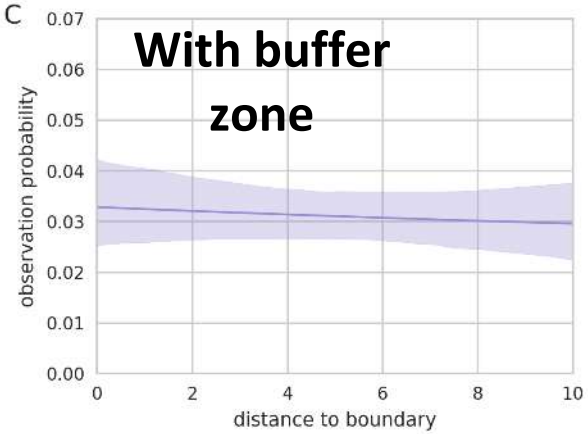
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk

Effects of hard versus soft boundaries on wildlife







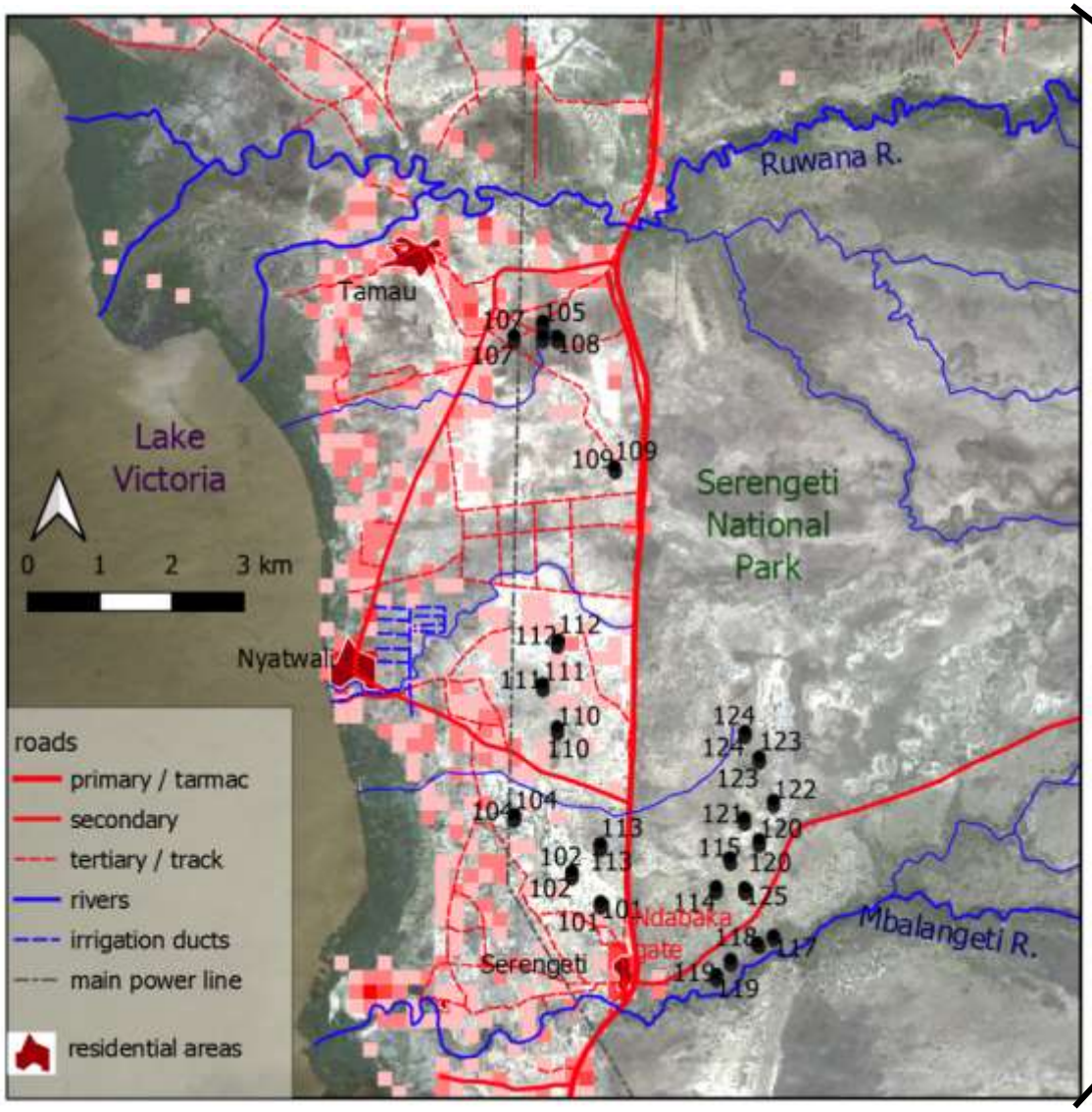


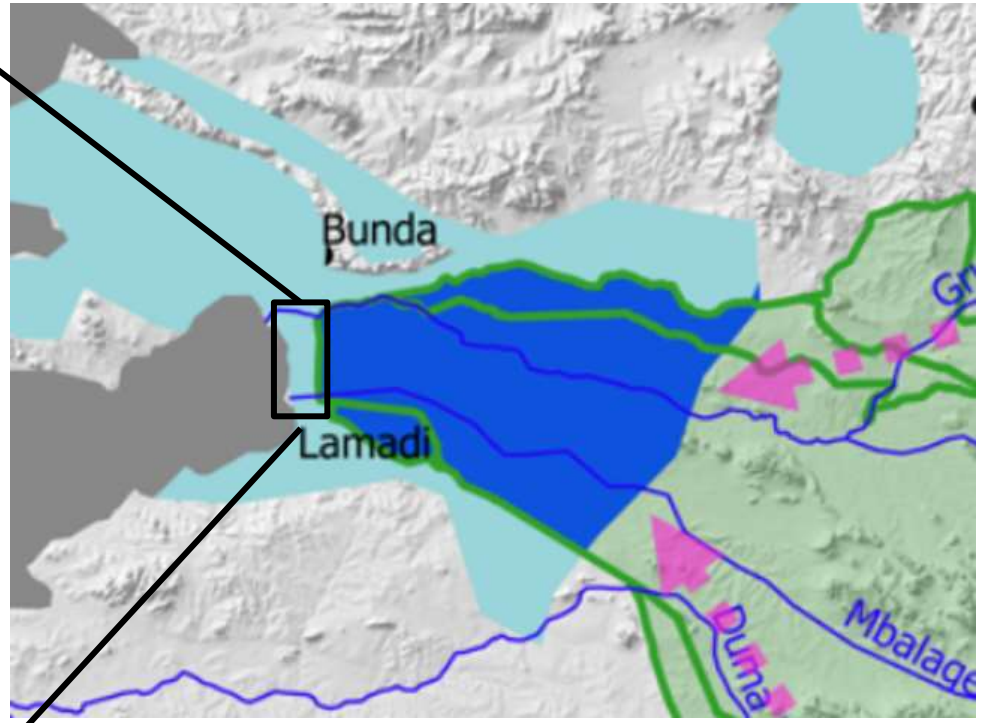
- 129.3km (17.4%) of Serengeti NP boundary is “hard”
- Equivalent to 1000km2 legally protected but rarely used by the migration because of associated risk

Cyrus Kavwele: c.kavwele.1@research.gla.ac.uk
Grant Hopcraft: Grant.Hopcraft@glasgow.ac.uk
Kavwele et al, in review

Speke Gulf GCA: increasing challenges from lake level rise on humans

distribution of infrastructure and buildings (red)

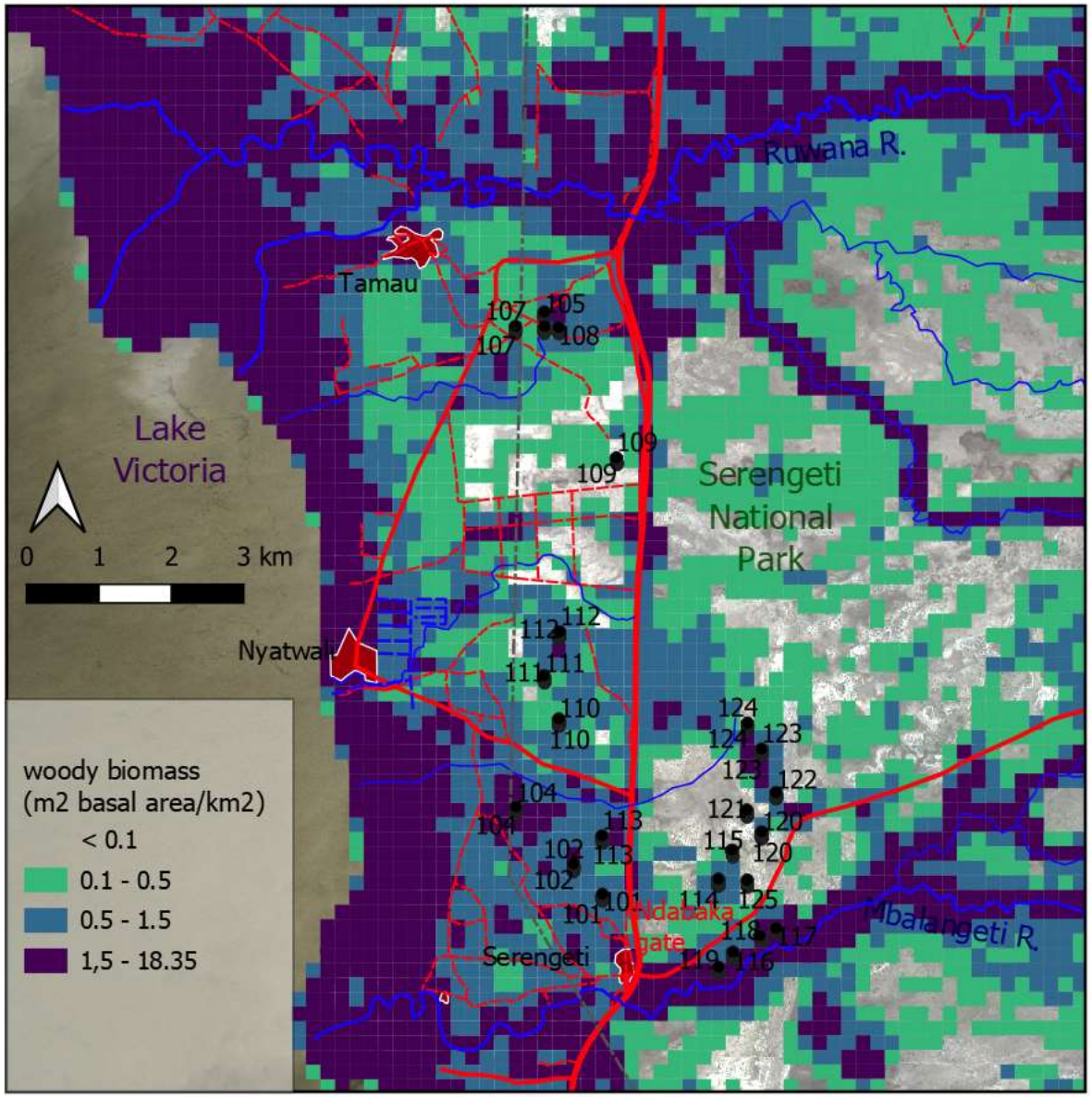




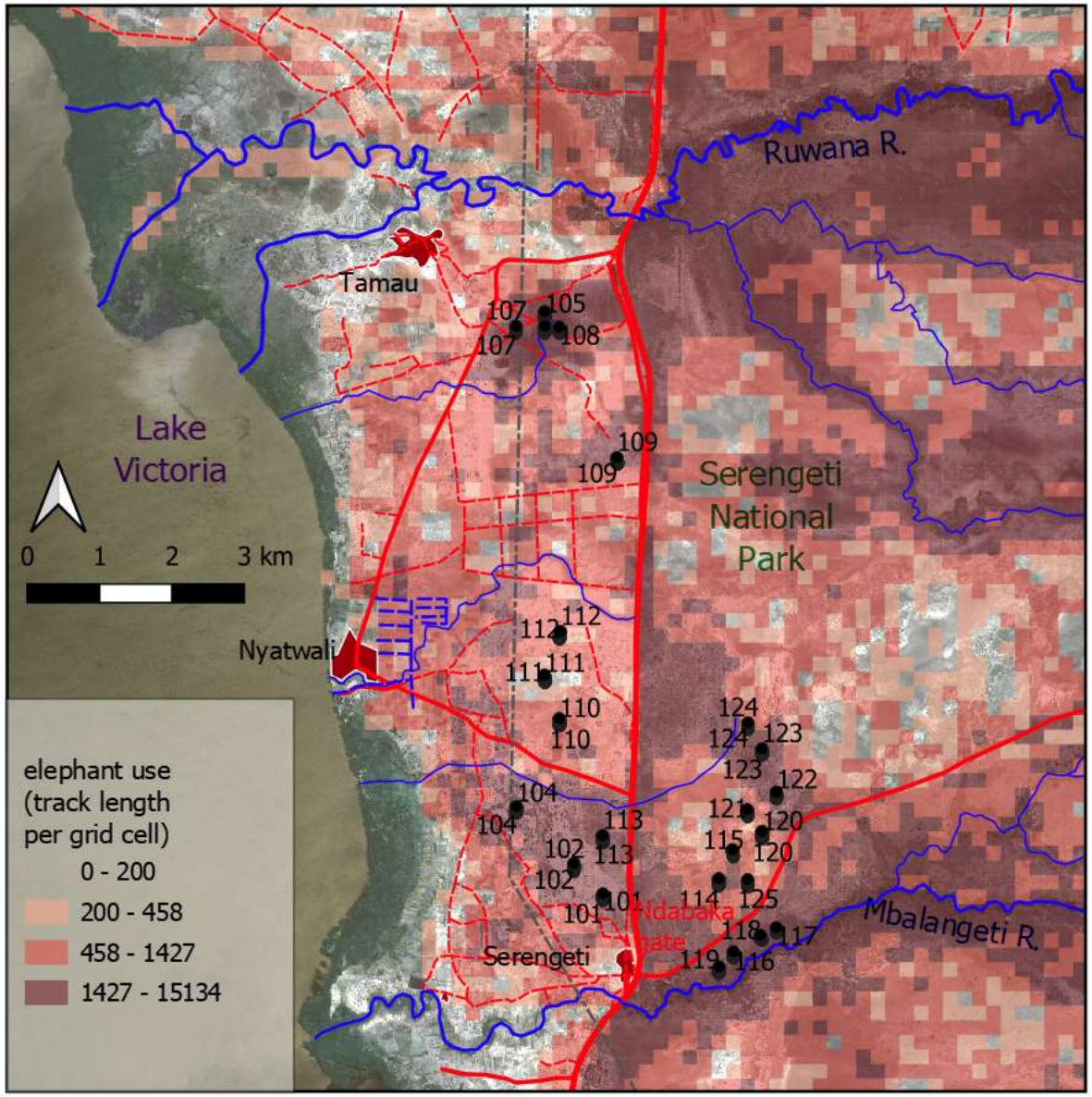
Han Olff, h.olff@rug.nl
Yustina Kiwango yustina.kiwango@tanzaniaparks.go.tz

Elephant follow woody biomass in the GCA, and foray into crops (not lake water)

Woody biomass



Elephant use



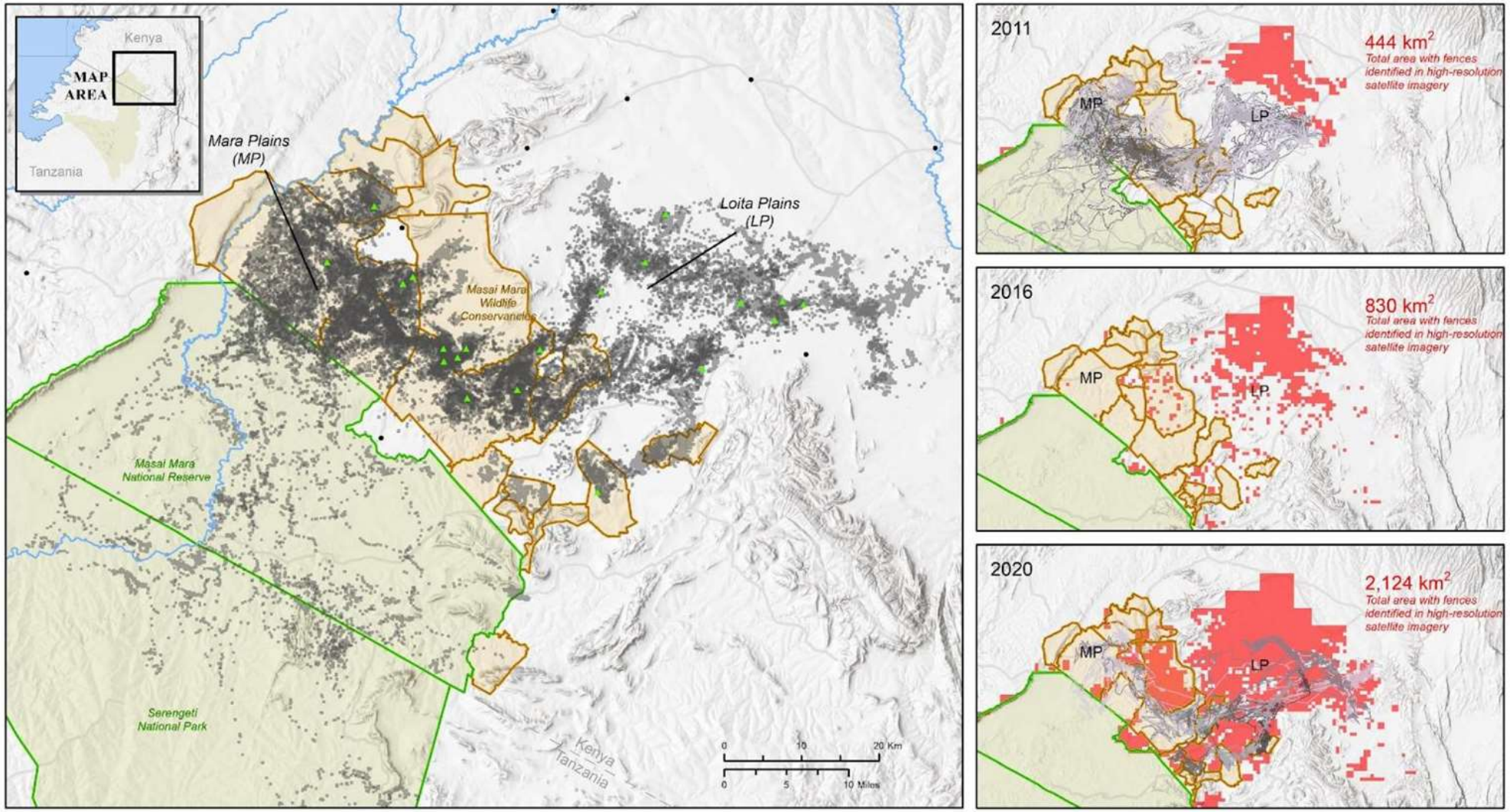
Yustina Kiwango ykiwango@yahoo.com, Kristen Snyder kristens@grumetifund.org, Han Olff, h.olff@rug.nl

Suggested recommendations for consideration

- Continue improved protection of ecosystem boundaries using suitable techniques (ie graded intensity of patrol effort, buffer zones, strong penalties)
- Clear and well defined land use zoning, particularly regarding policy on agricultural fence
- Speke’s gulf and Loliondo extensions are implemented


Wildlife abundance, displacement

Private fencing and wildebeest space use in the Greater Mara



Smithsonian National Zoological Park Conservation Biology Institute

Movement of Life

University of Glasgow

Kenya Wildlife Service

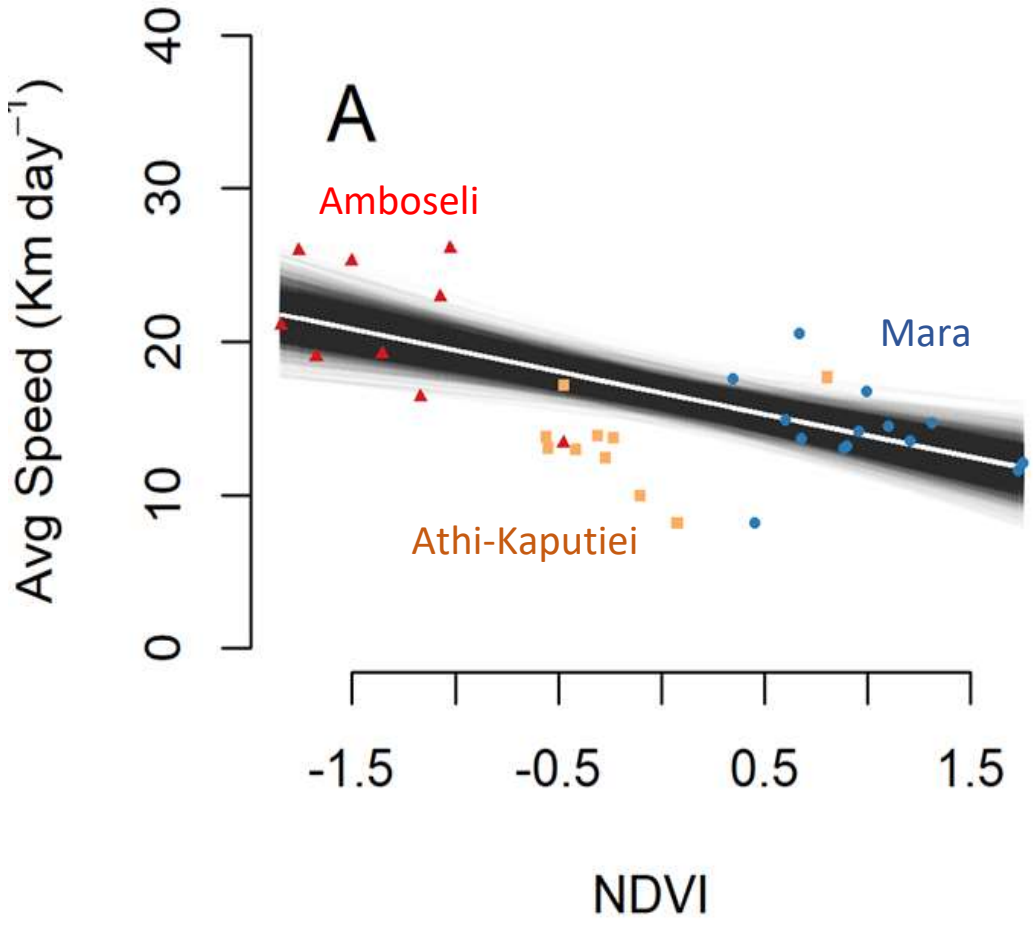
Colorado State University

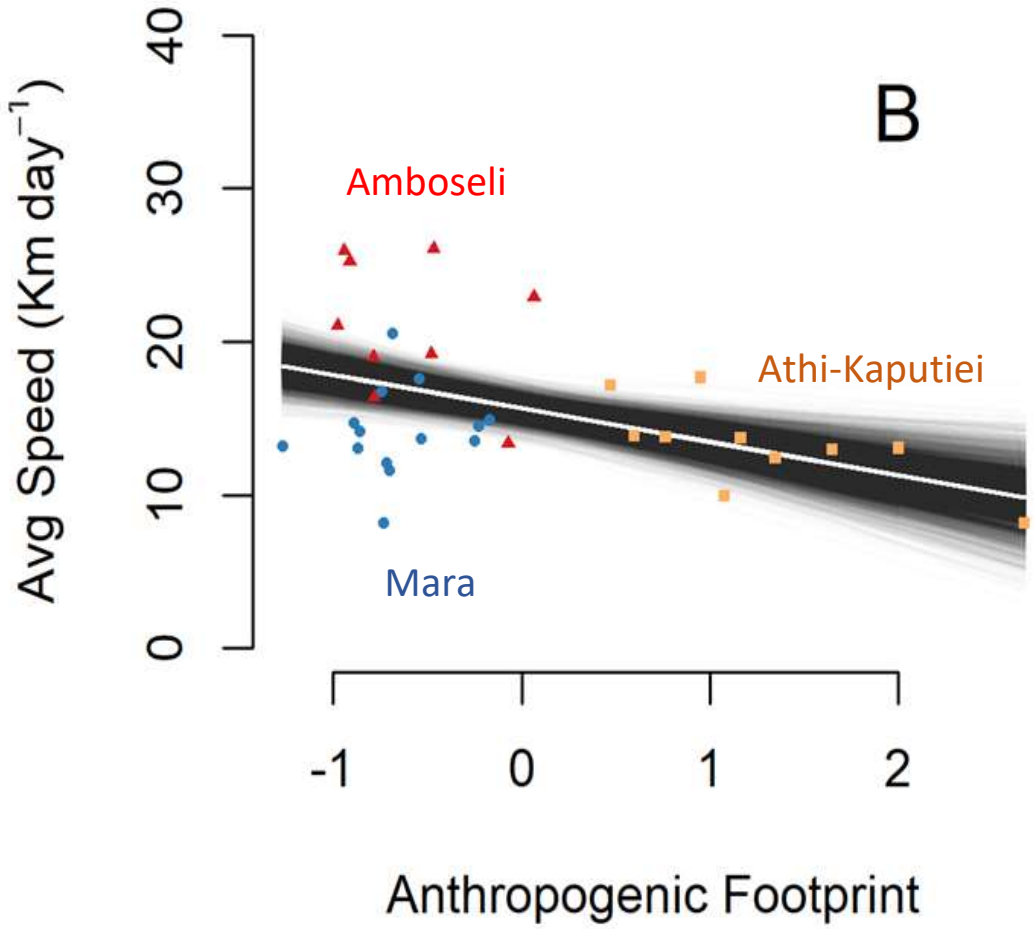
NSF

Jared Stabach: stabachj@si.edu
Lacey Hughy: HugheyL@si.edu

Kifugo et al, in prep

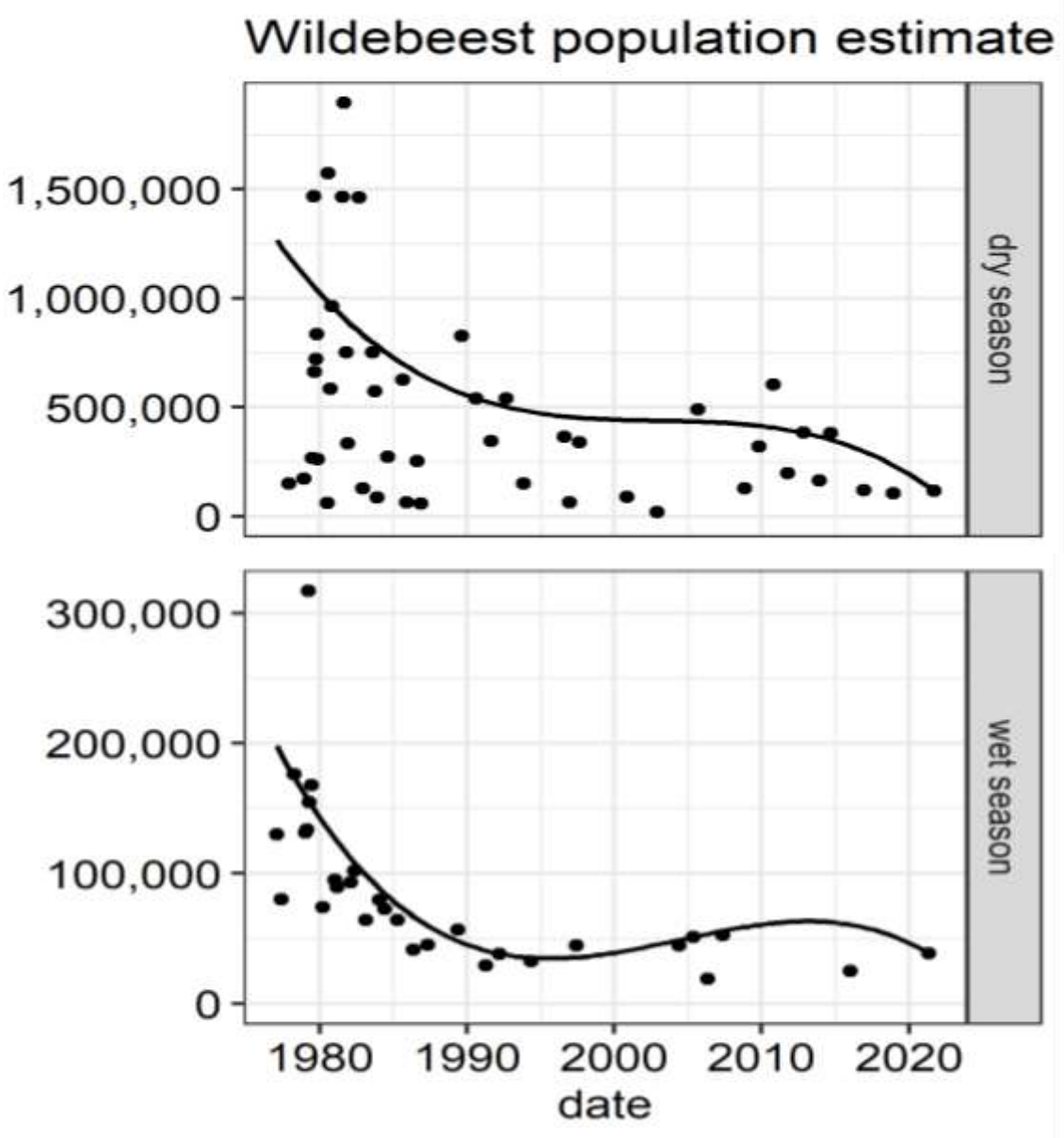
A cautionary tale: Increased human disturbance leads to restrictions in wildebeest movement

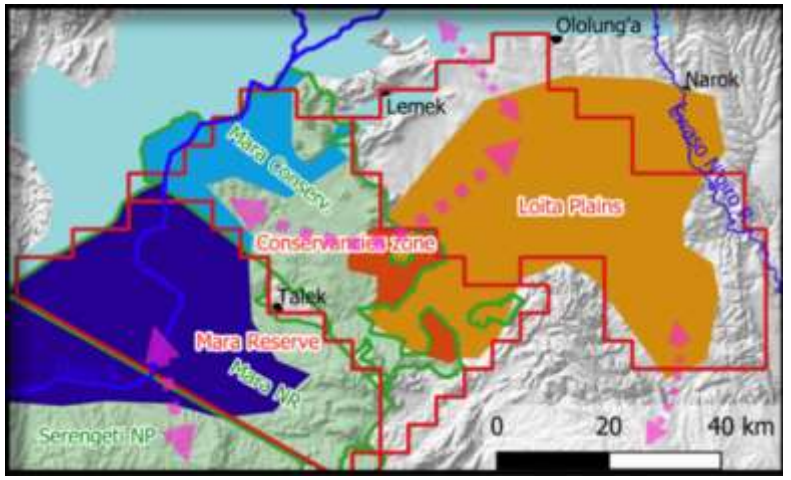


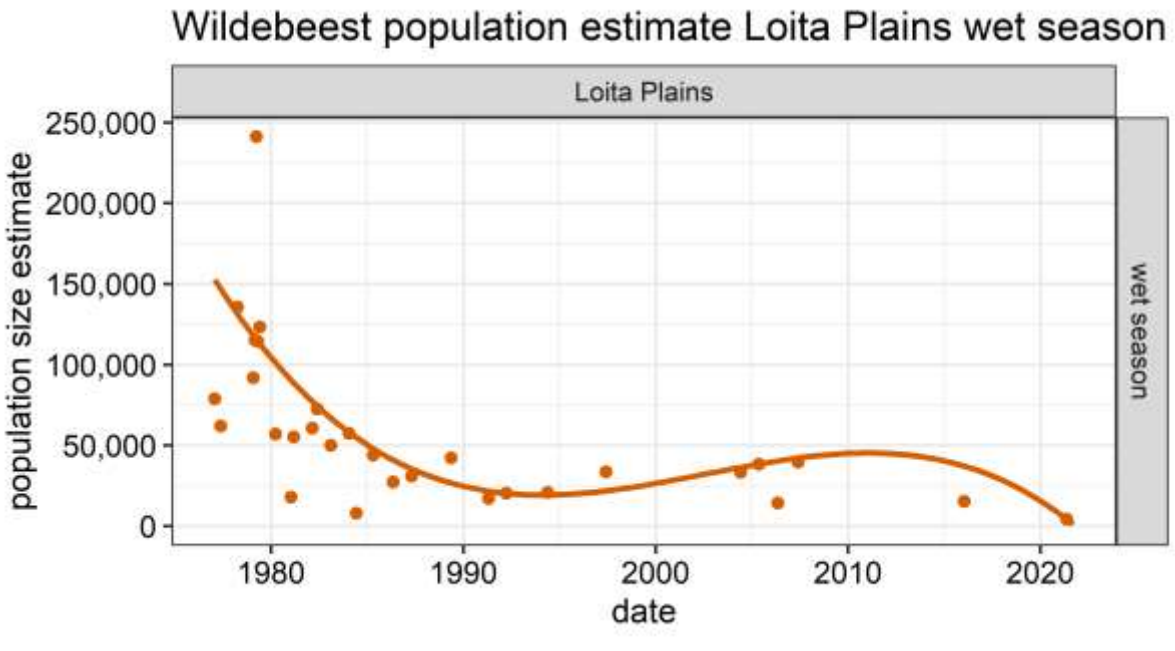


Jared Stabach: stabachj@si.edu
Lacey Hughey: hugheyl@si.edu
Stabach et al. In Press

Declining Mara wildebeest: collapse of Loita population and displacement of Serengeti population

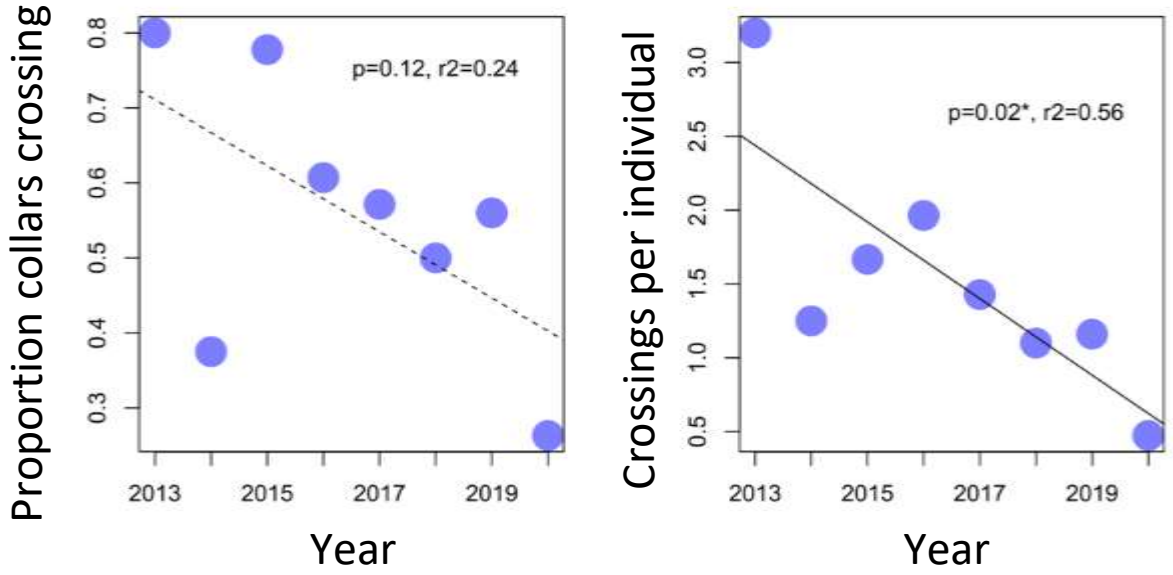




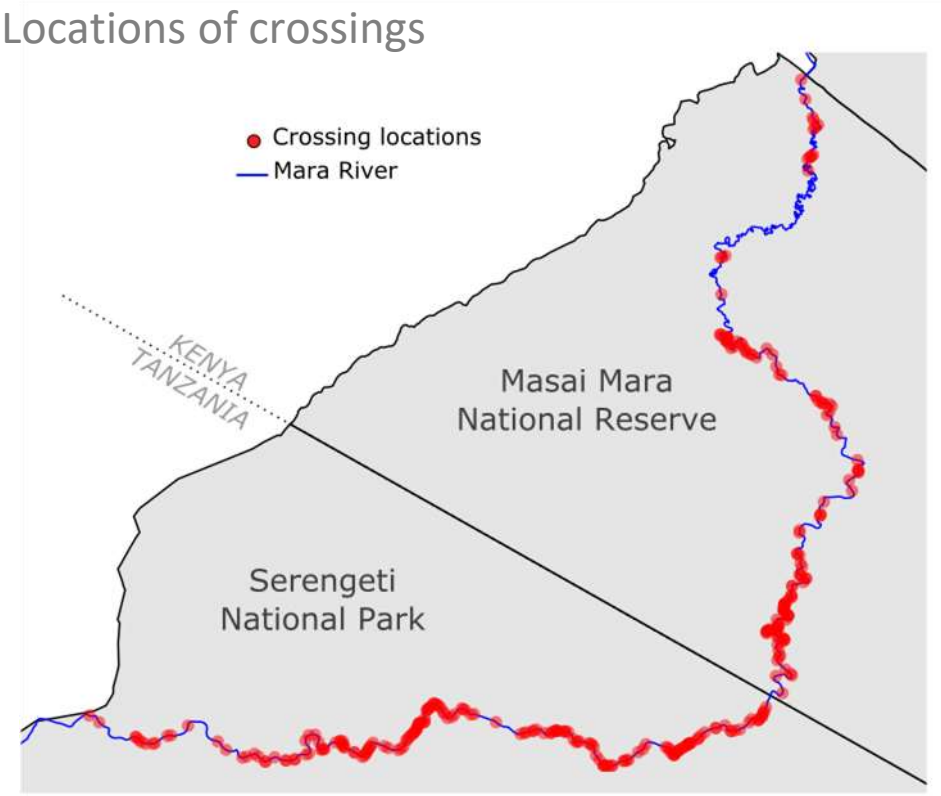


Mara River crossings

Crossings over time



Locations of crossings



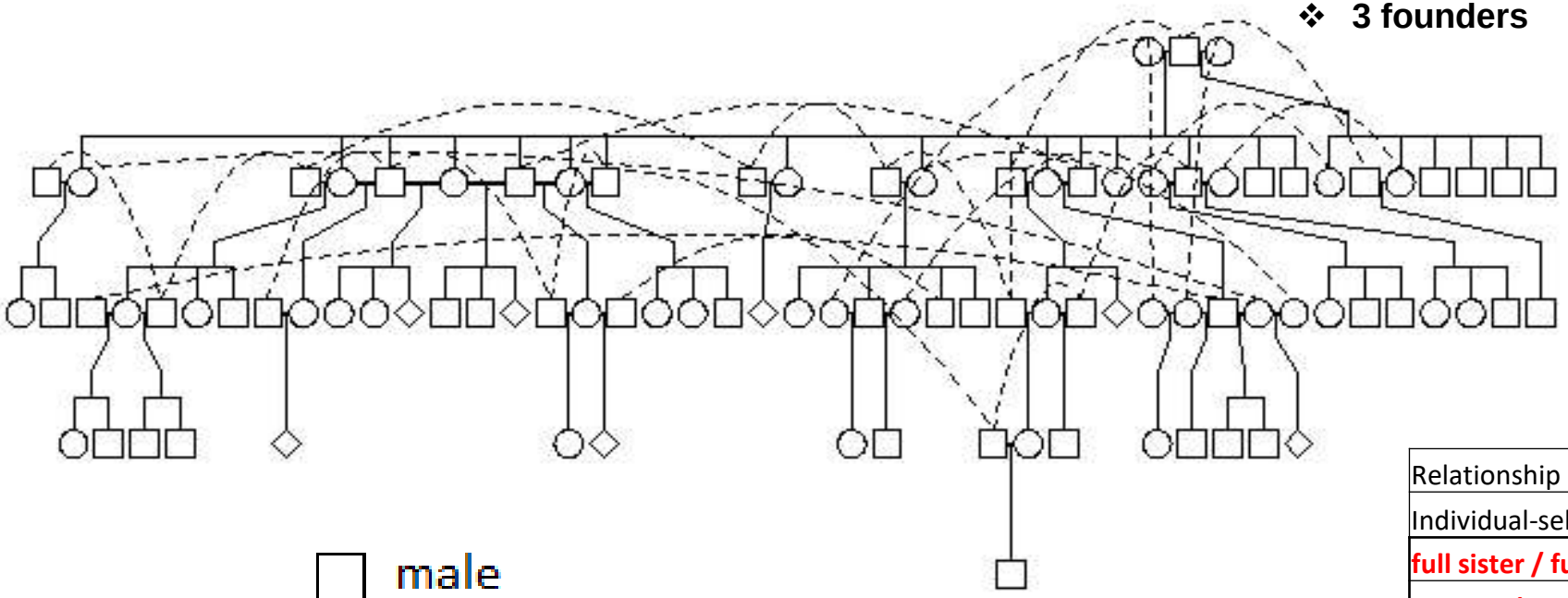
- Number of crossings are decreasing over last 7 years
- Concern that tourism is having an impact on Mara crossings

Tom Morrison: thomas.morrison@glasgow.ac.uk
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk
Morrison et al, in prep

Rhino: Pedigree based on observational data

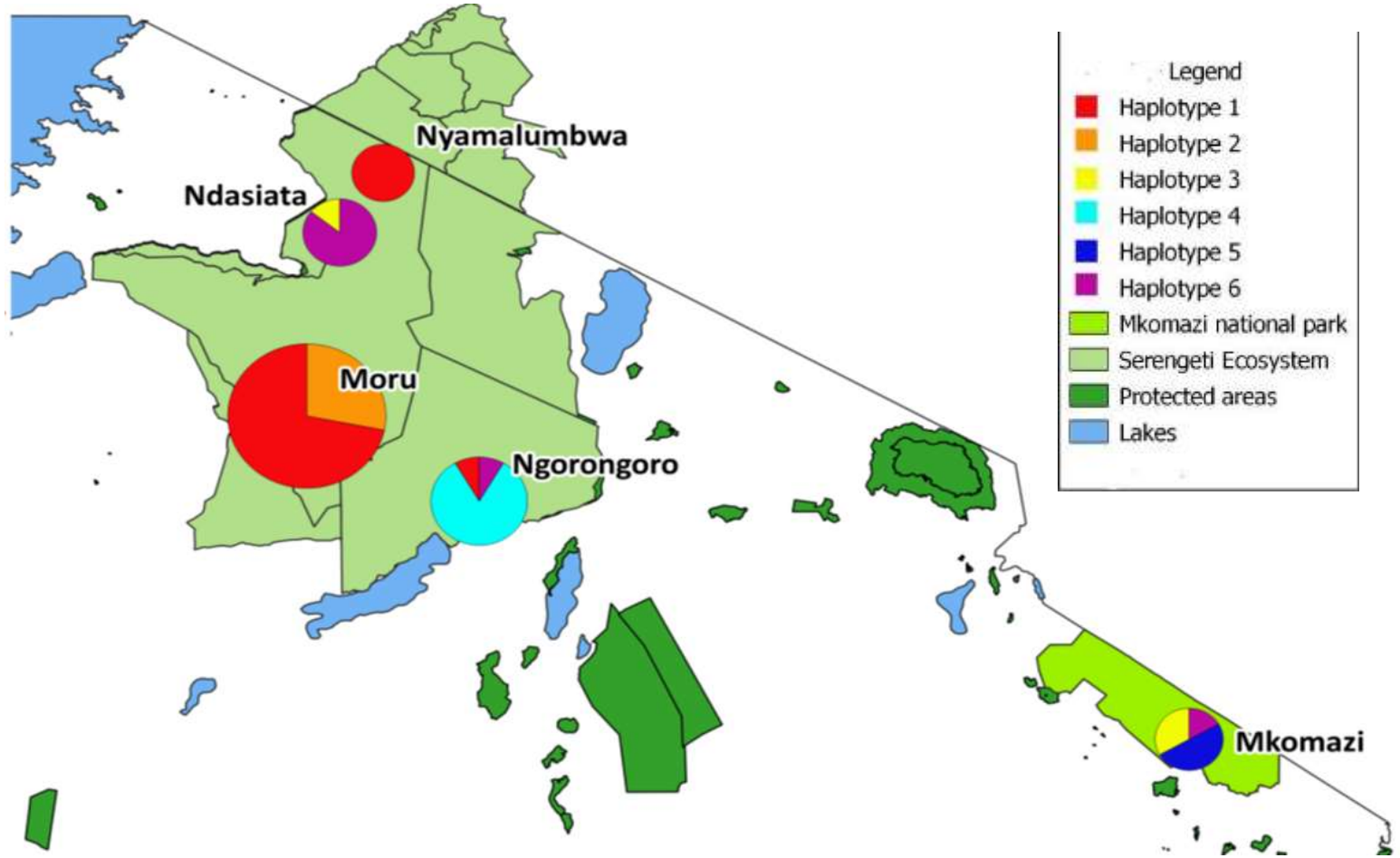
Moru population (native) **mean kinship 0.24**

- **3 founders**



Relationship	Kinship coefficient
Individual-self	0.5
full sister / full brother	**0.25**
mother / father / daughter / son	**0.25**
grandmother / grandfather / granddaughter / grandson	0.125
aunt / uncle / niece / nephew	0.125
first cousin	0.0625
half-sister / half-brother	0.125

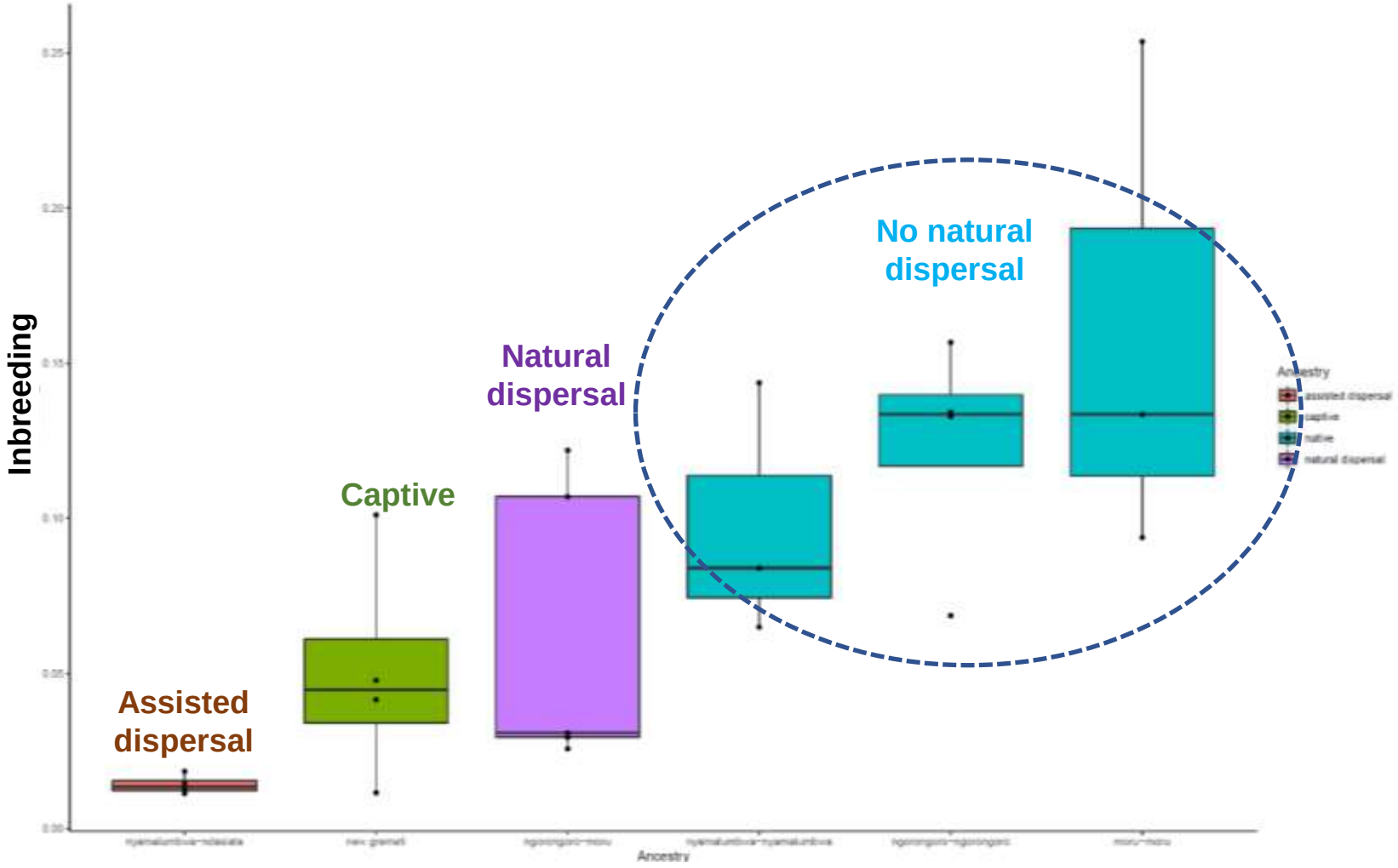
Rhino conservation – more connectiveity than expected



	Rhino Population	Total_samples_collected
1	Moru	38
2	Ndasiata	10
3	Nyamalumbwa	8
4	Grumeti	11
5	Ngorongoro	20
6	Mkomazi	20
7	Maasai Mara	30
	Total	**137**

Ronald Mellya: 2285780M@student.gla.ac.uk
Barbara Mable Barbara.Mable@glasgow.ac.uk
Anubhab Khan Anubhab.Khan@glasgow.ac.uk
Mellya, PhD, continuing

Rhino conservation – natural dispersal as good as captive breeding for reducing inbreeding



- Natural dispersal is equally effective for maintaining genetic diversity as captive breeding
- Populations that cannot disperse have very high inbreeding

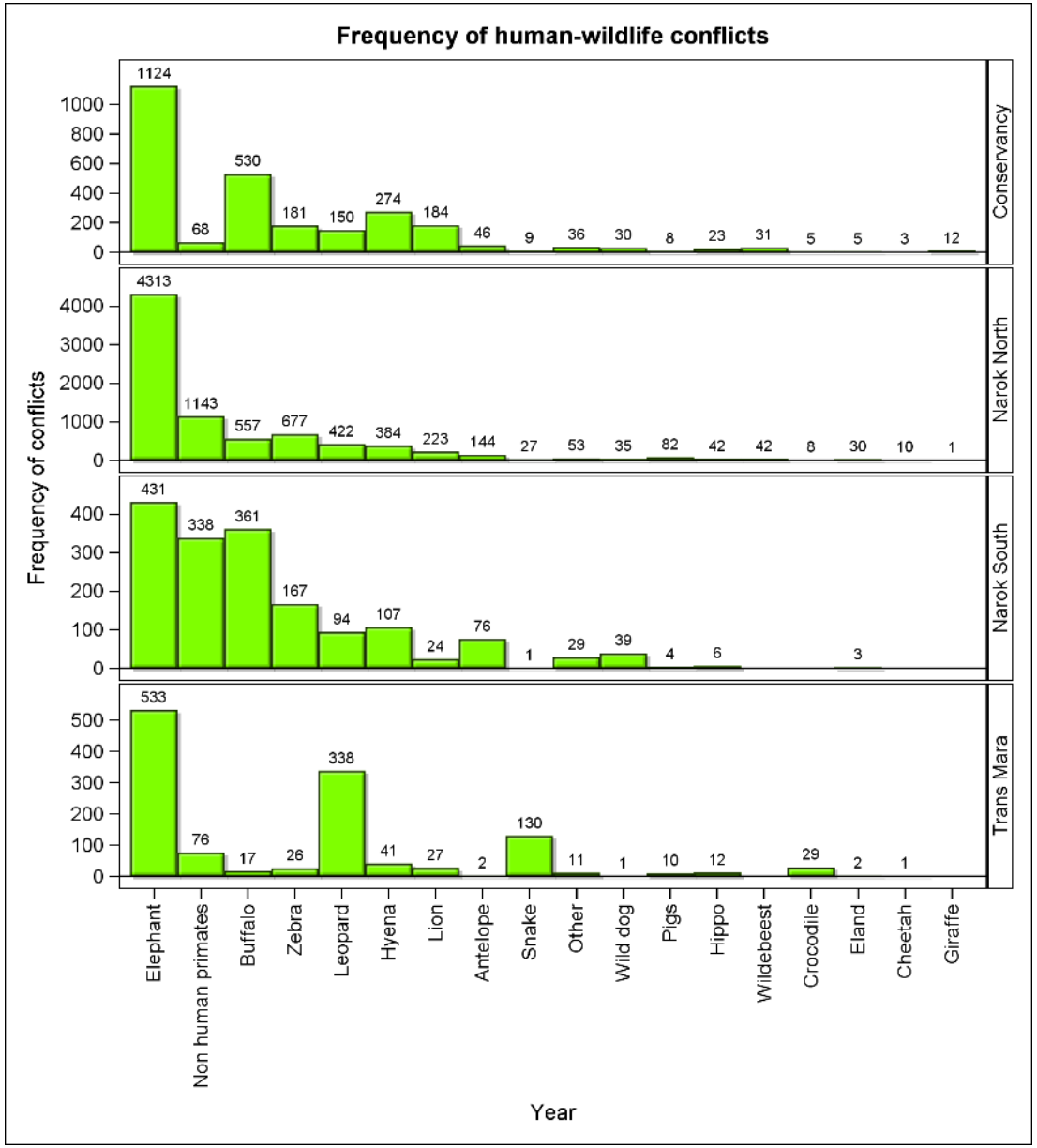
Ronald Mellya: 2285780M@student.gla.ac.uk
Barbara Mable Barbara.Mable@glasgow.ac.uk
Anubhab Khan Anubhab.Khan@glasgow.ac.uk
Mellya, PhD, continuing

Suggested recommendations for consideration

- Wildlife are displaced by intensive human activity therefore, improve techniques for managing the boundaries
- Maintain connectivity and corridors of natural populations and seasonal ranges
- Revise protection for wet and dry season ranges as well as refugia for extreme events given current change in human population and climate

Human-wildlife conflict

Human-wildlife conflict & co-existence – Narok

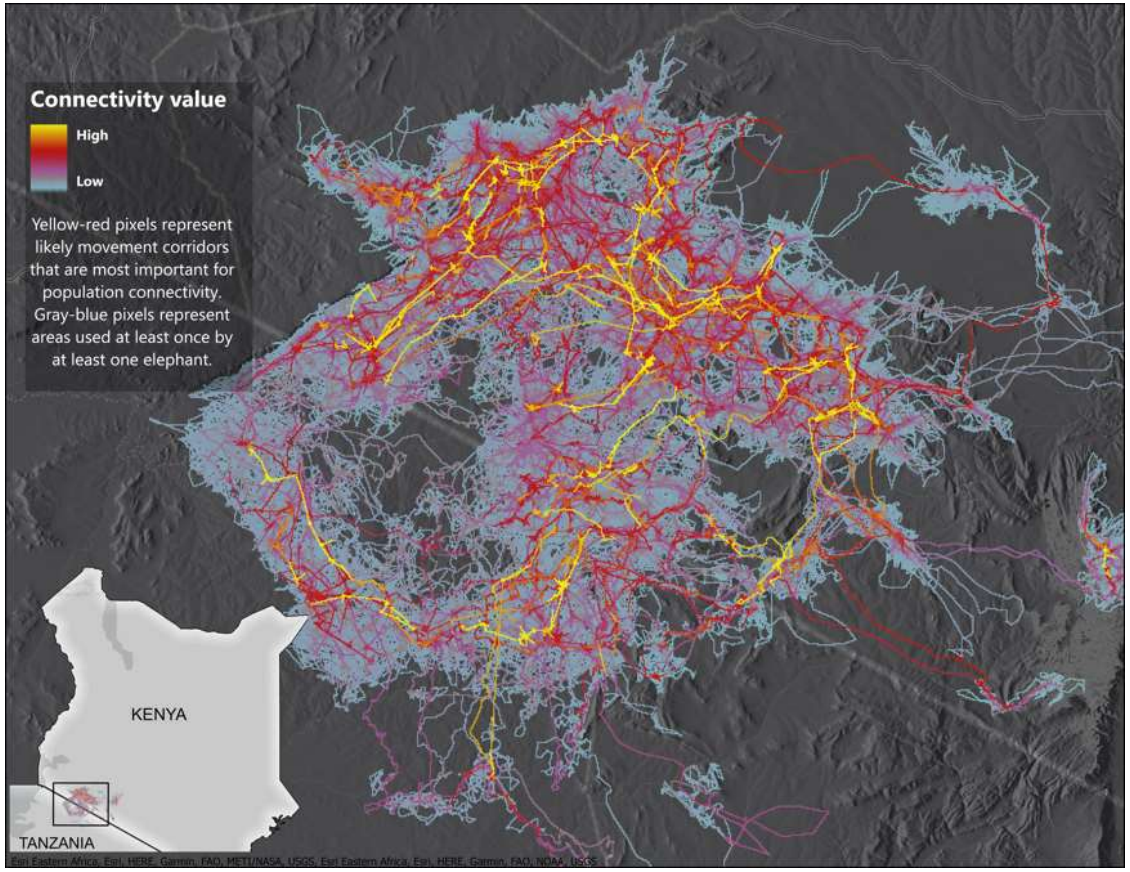


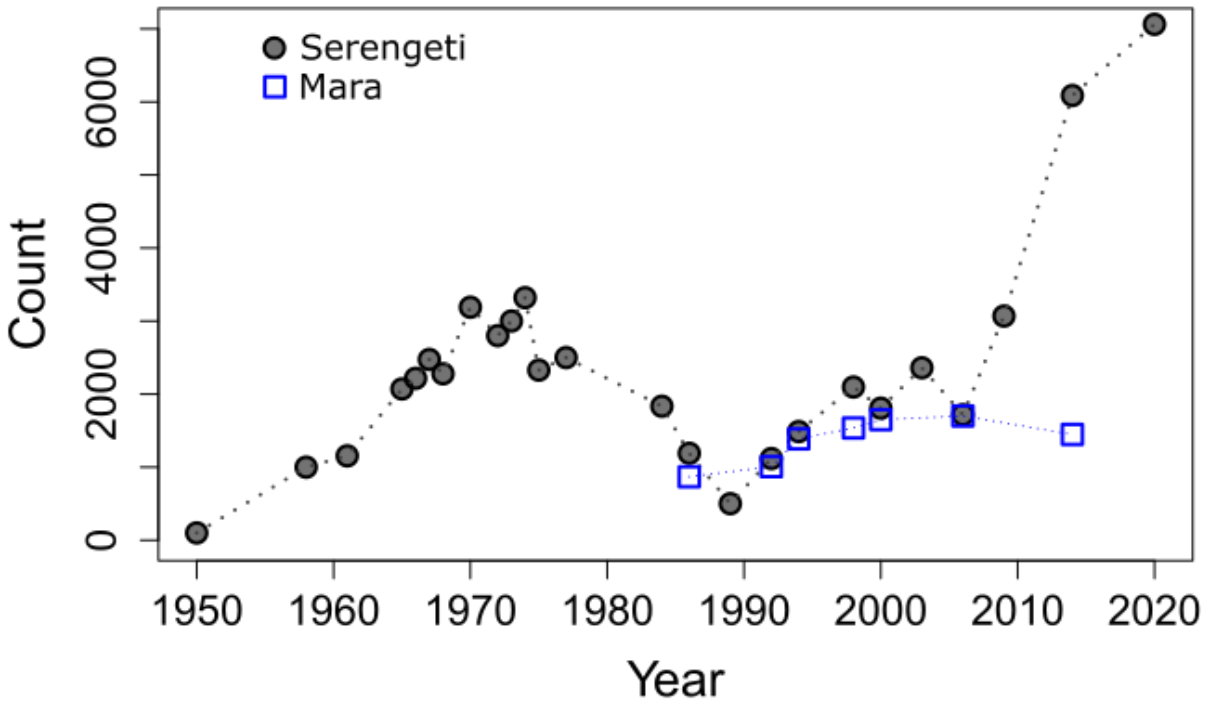
Elephant – greatest frequency of human-wildlife conflict

Joseph Ogutu: jogutu@uni-hohenheim.de
Mukeka et al 2019

Human-wildlife conflict & co-existence - elephant

Mara Elephant Project (tracks 2011-2020)

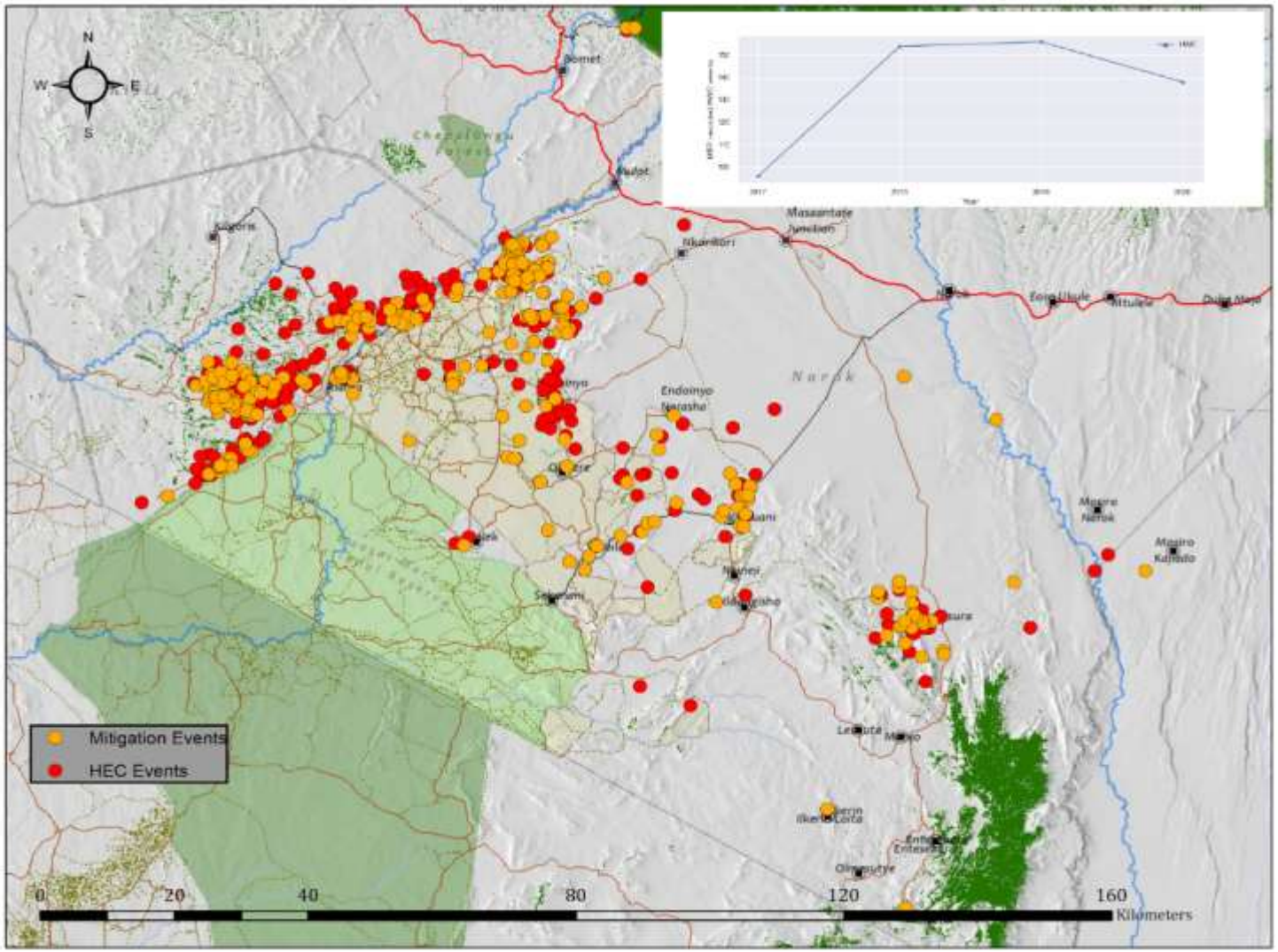




- there is a large trans-boundary movement of elephant with frequent movement in Ke and Tz (Data credit MEP, KWS, WWF).

Jake Wall: Jake@maraelephantproject.org
Tom Morrison:Thomas.Morrison@glasgow.ac.uk
Edward Kohi: edward.kohi@tawiri.or.tz
Morrison et al, 2018

Human-wildlife conflict & co-existence - elephant

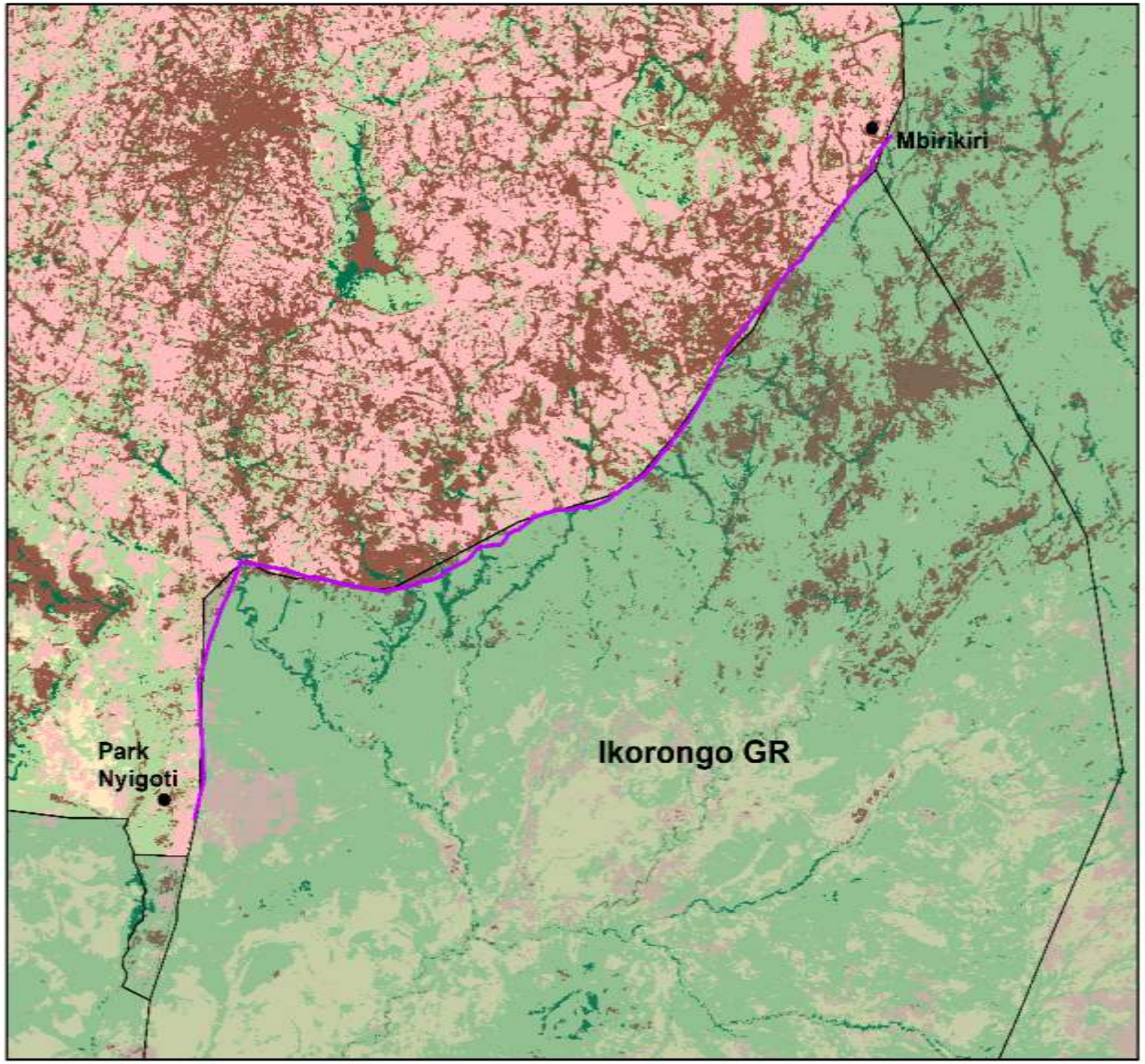


630 Human Elephant Conflict (HEC) events (red) and 388 HEC mitigations by MEP rangers (orange) since 2016.

Most conflict is occurring outside of protected areas especially on the western boundary of the conservancies and the Triangle.

Jake Wall: Jake@maraelephantproject.org

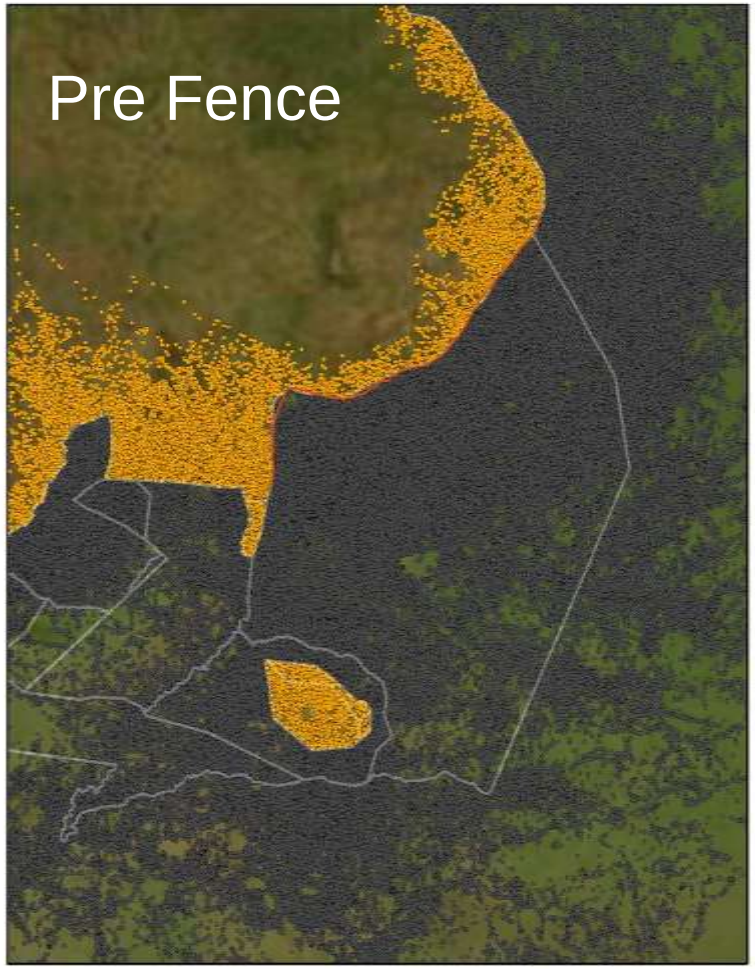
Human-wildlife conflict & co-existence – Experimental Fence

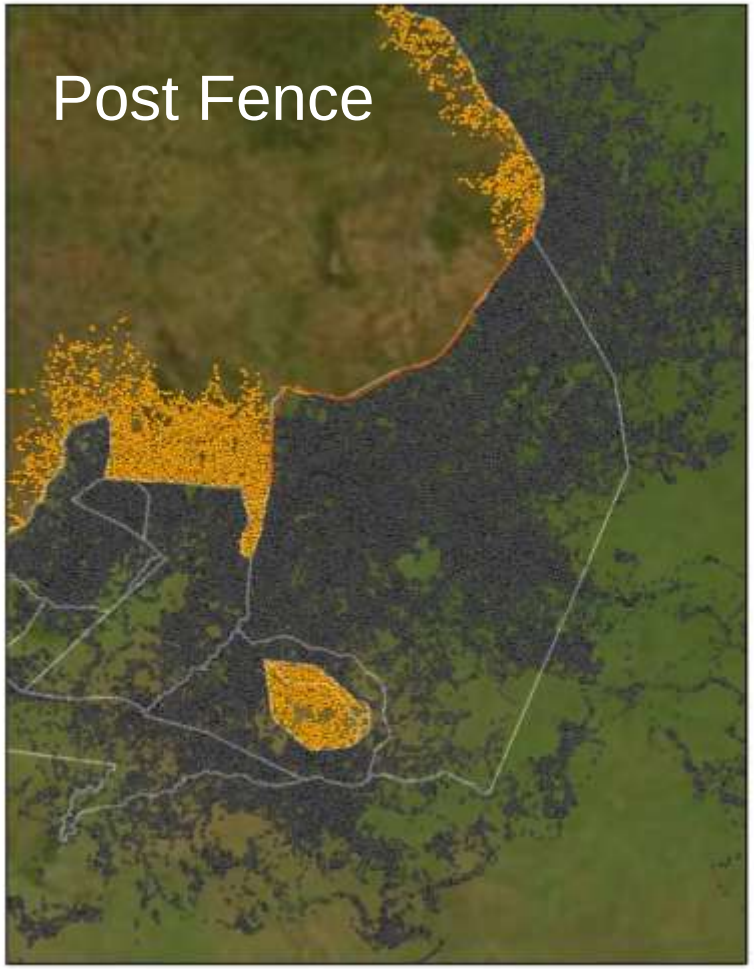


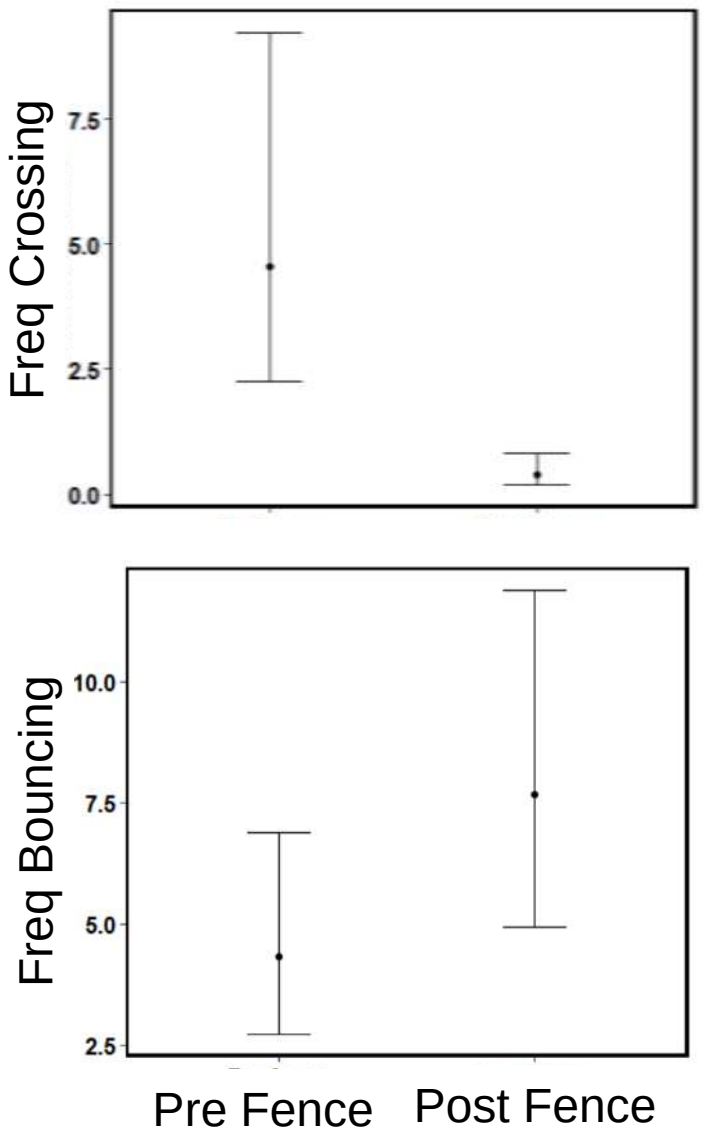
- 33km electric fence along hard boundary of Ikorongo Game Reserve (Mbirikiri to Park Nyigoti)
- Completed in March 2020
- Elephant short fence design
- Construction cost = $16,291 / km (materials, road, labor, road construction)
- Maintenance cost for 33km: capital expenditure ~$7k and operational expenditure ~ $13k / year

Kristen Snyder KristenS@grumetifund.org

Human-wildlife conflict & co-existence – Experimental Fence







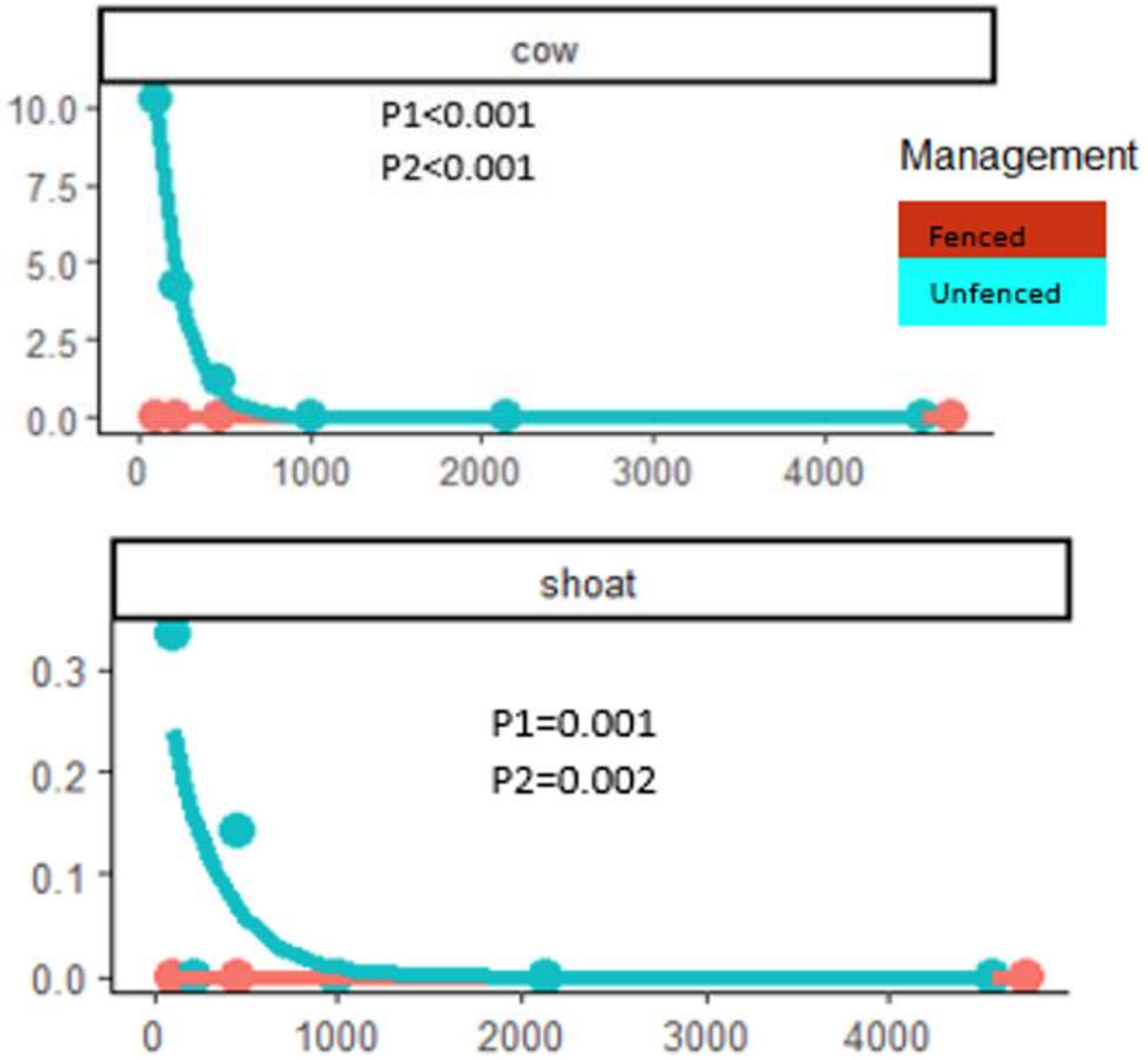
Movement of GPS collared elephant (yellow points are located outside the protected area, grey points are located inside the protected area)

Kristen Snyder KristenS@grumetifund.org

Human-wildlife conflict & co-existence – Experimental Fence

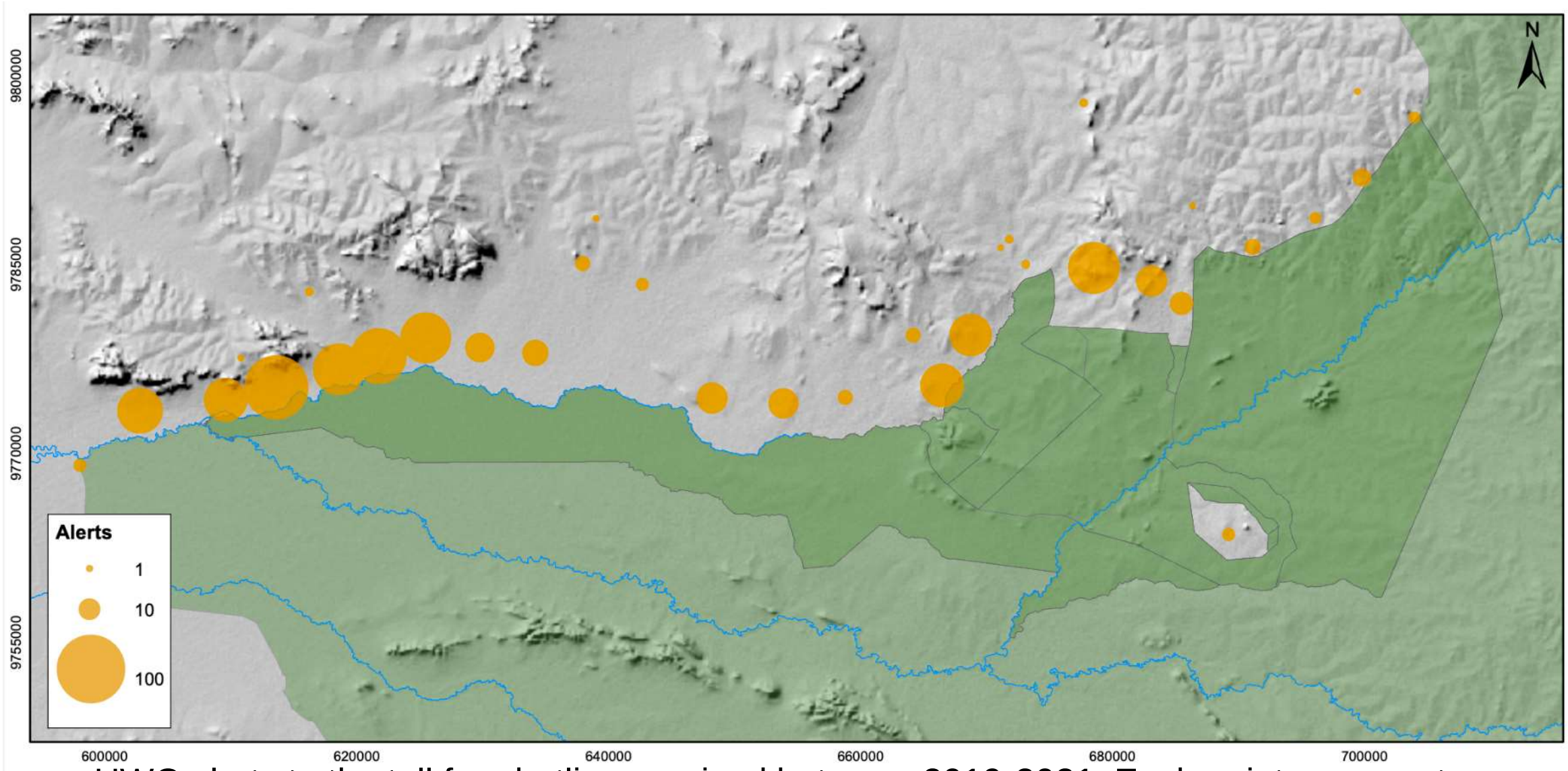
- Fence-related mortalities comprised 13% of all those recorded between Apr 1, 2020 – Dec 1, 2021.
- All fence related mortalities were of wildebeest, two due directly from electrocution and 27 indirectly from people using the fence as a hunting feature

	Cause	Total
Human-induced	Snare	65
	Panga	66
	Other	23
	Euthanized	5
	Roadkill	20
	Fence	29
Unknown	Unknown	9
Total		**217**



Kristen Snyder KristenS@grumetifund.org

Human-wildlife conflict & co-existence – Experimental Fence

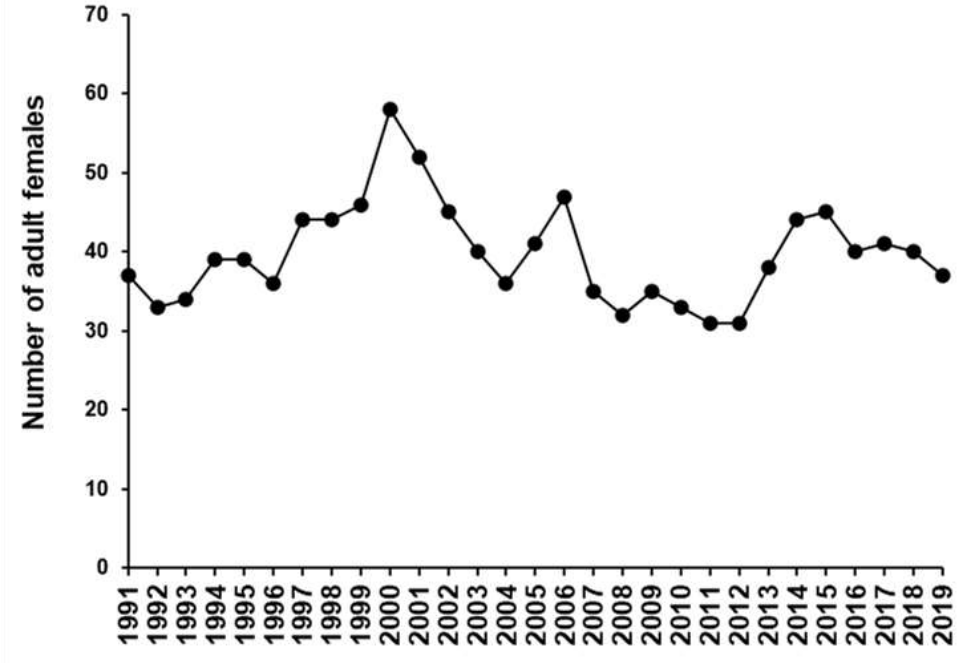


HWC alerts to the toll free hotline received between 2019-2021. Each point represents one village.

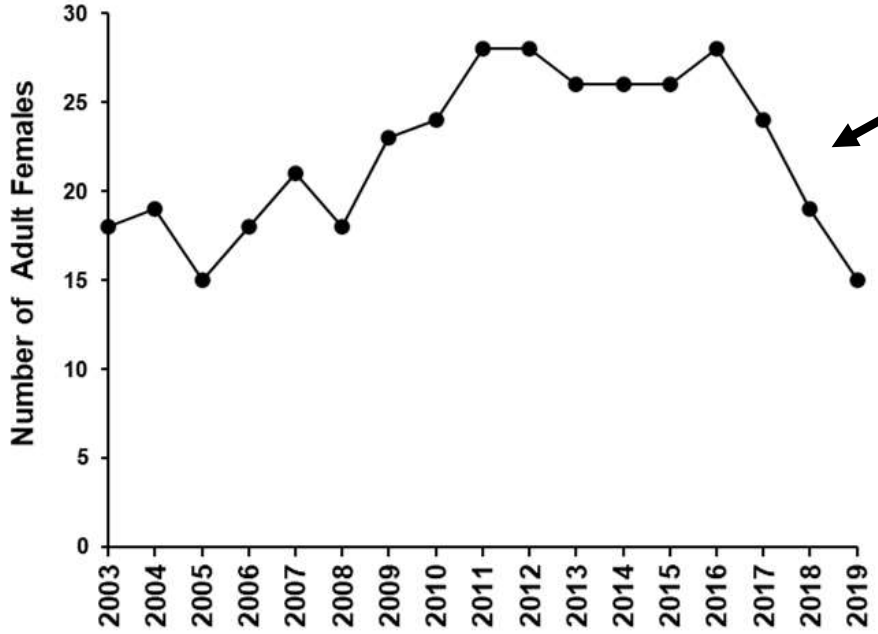
Kristen Snyder KristenS@grumetifund.org

Human-wildlife conflict & co-existence - Cheetah

Serengeti Plains



SNP/NCA Border



Evidence suggests this decline is due to mortality at the park edges and not reduced recruitment

Sarah Durant: Sarah.Durant@ioz.ac.uk

Niedzialek et al, in prep
Durant et al 2004

Human-wildlife conflict & co-existence - Lions

Lions attack the most valued livestock

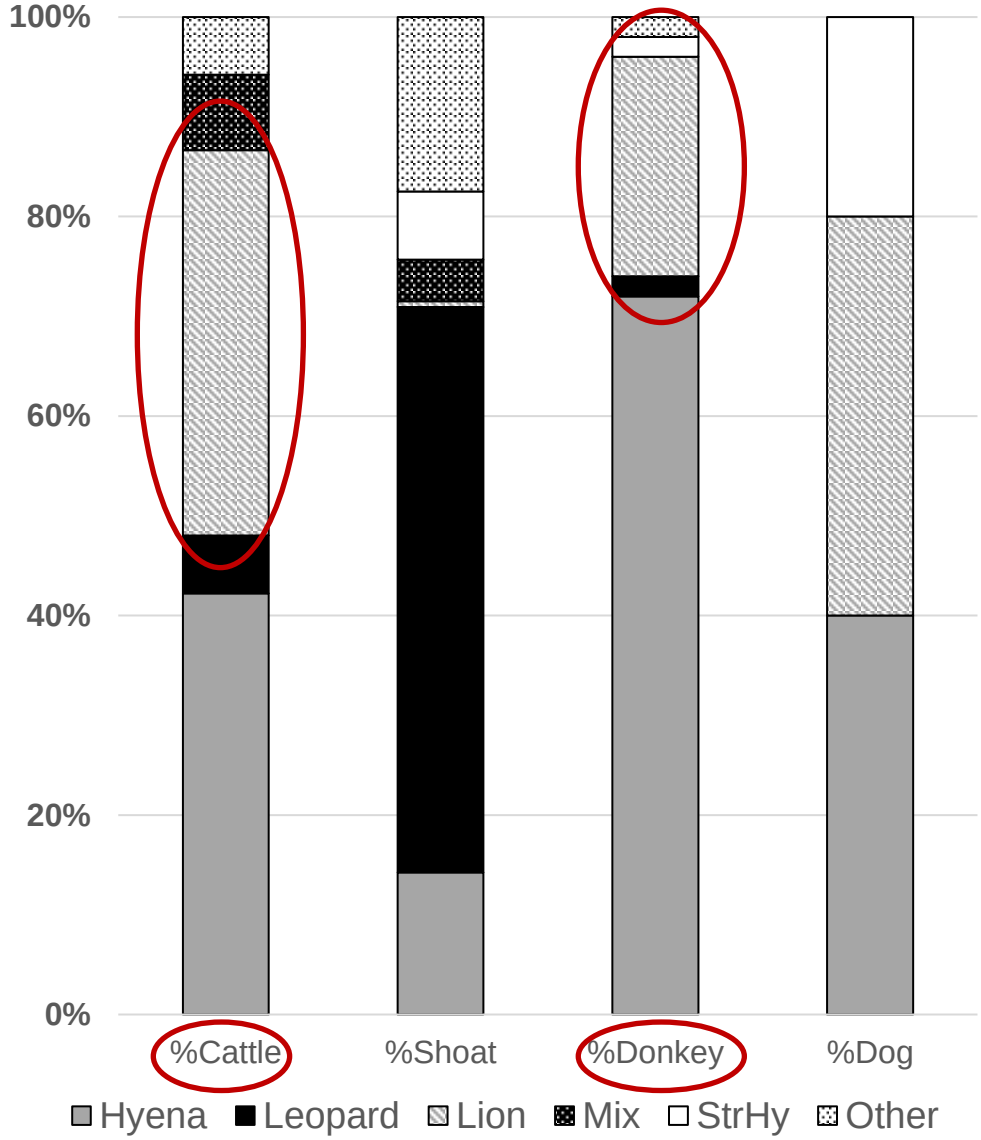
Attacking predators

1. Leopard 31%
2. Hyena 30%
3. **Lion 18%**
4. Mixed 5%
5. Striped Hyena 4%
6. Other 11%

Area: 5 villages, ca 2000km2.

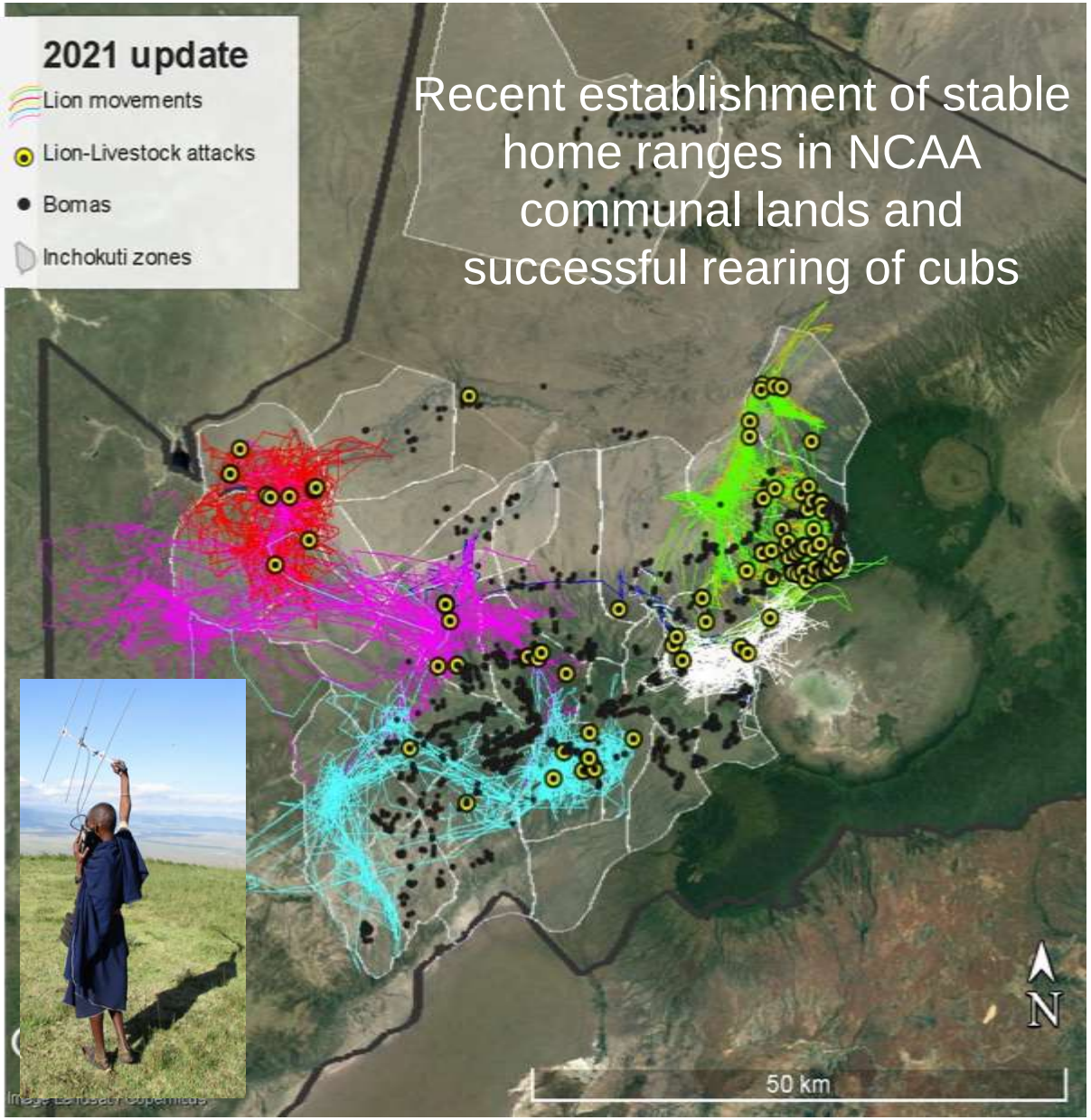
Total **677** attack events

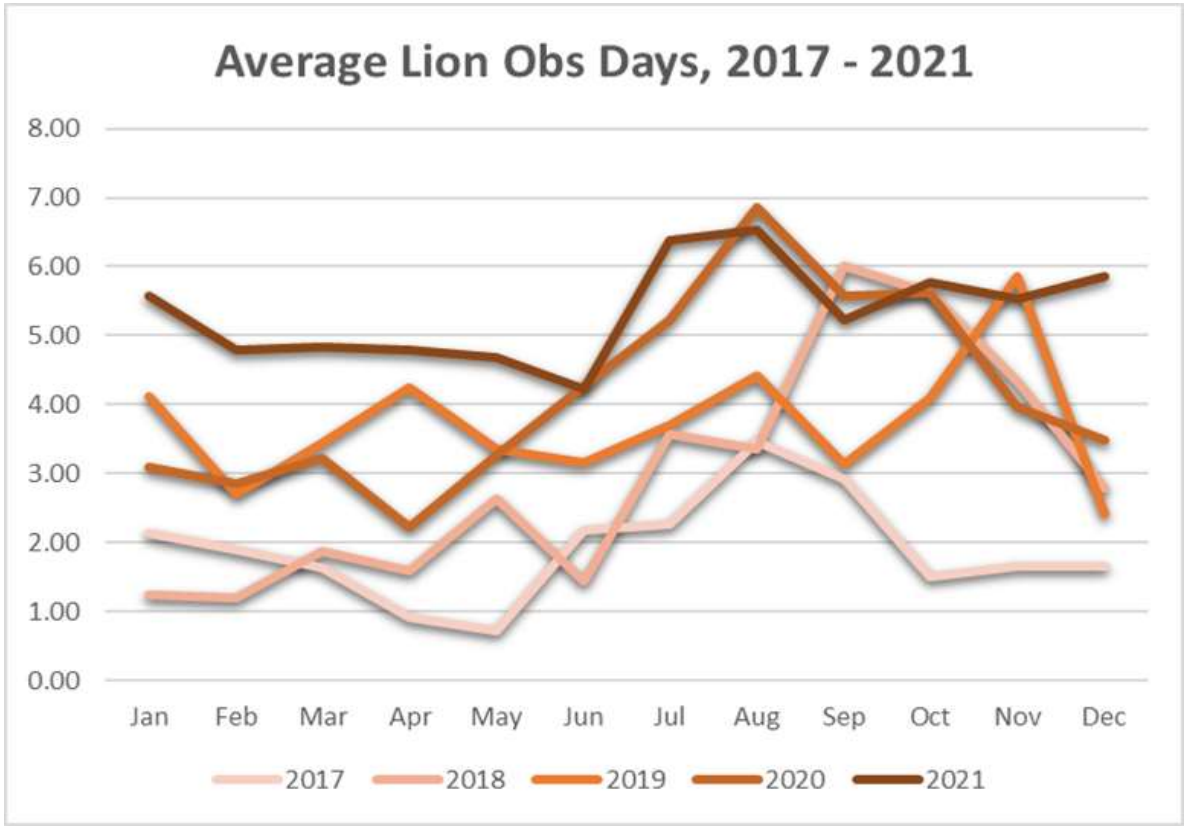
Total **1615** Livestock attacked



Ingela Jansson: ingela@kopelion.org

Human-wildlife conflict & co-existence - Lion





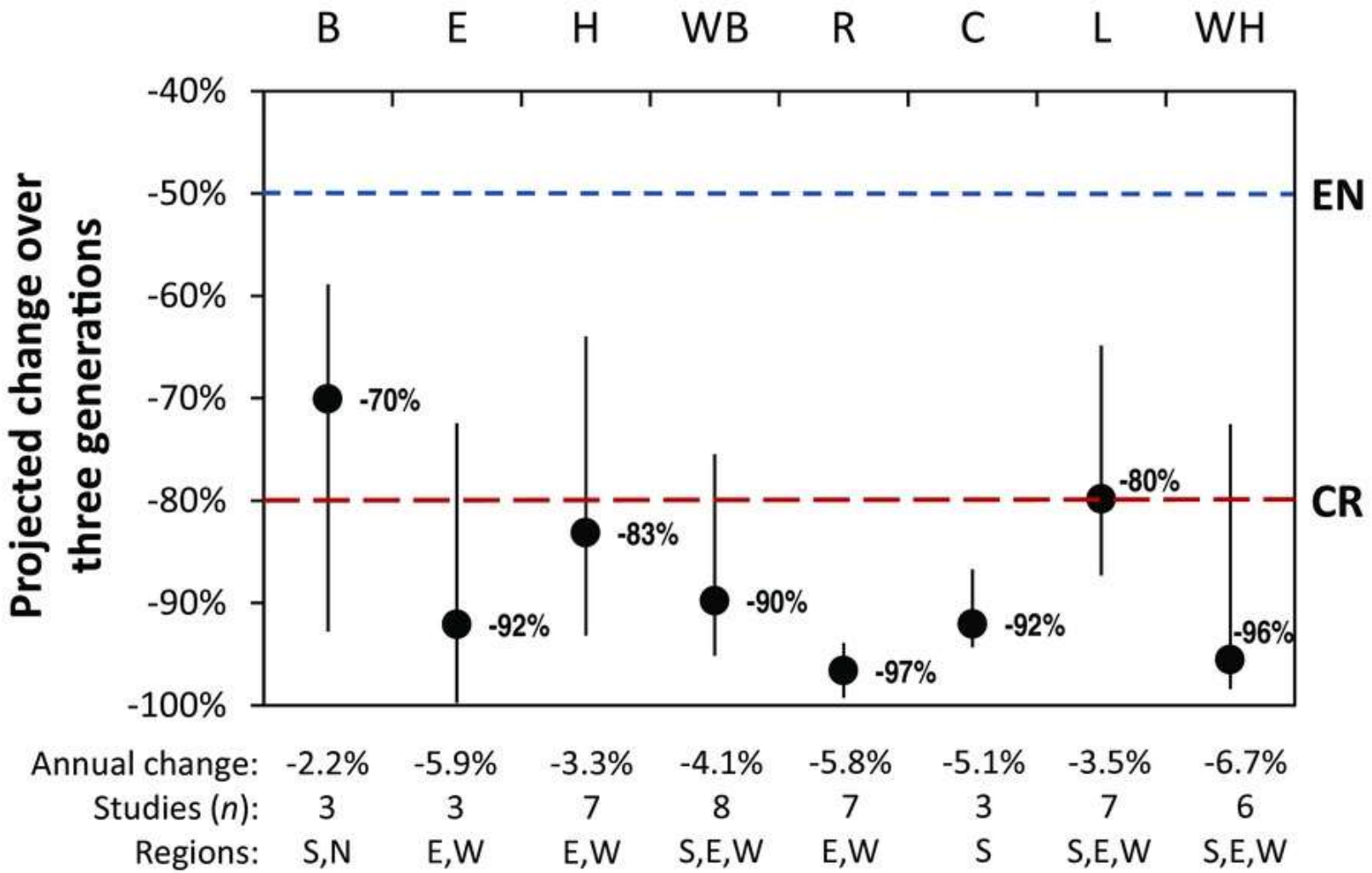
- Success: engaging with communities has led to increased pride and greater tolerance of lion conflict
- 12% annual increase in observations in multi-use areas

SLU

KOPE LION
Koroongoro People's Lion Initiative

Ingela Jansson: ingela@kopelion.org

Human-wildlife conflict & co-existence - Vultures

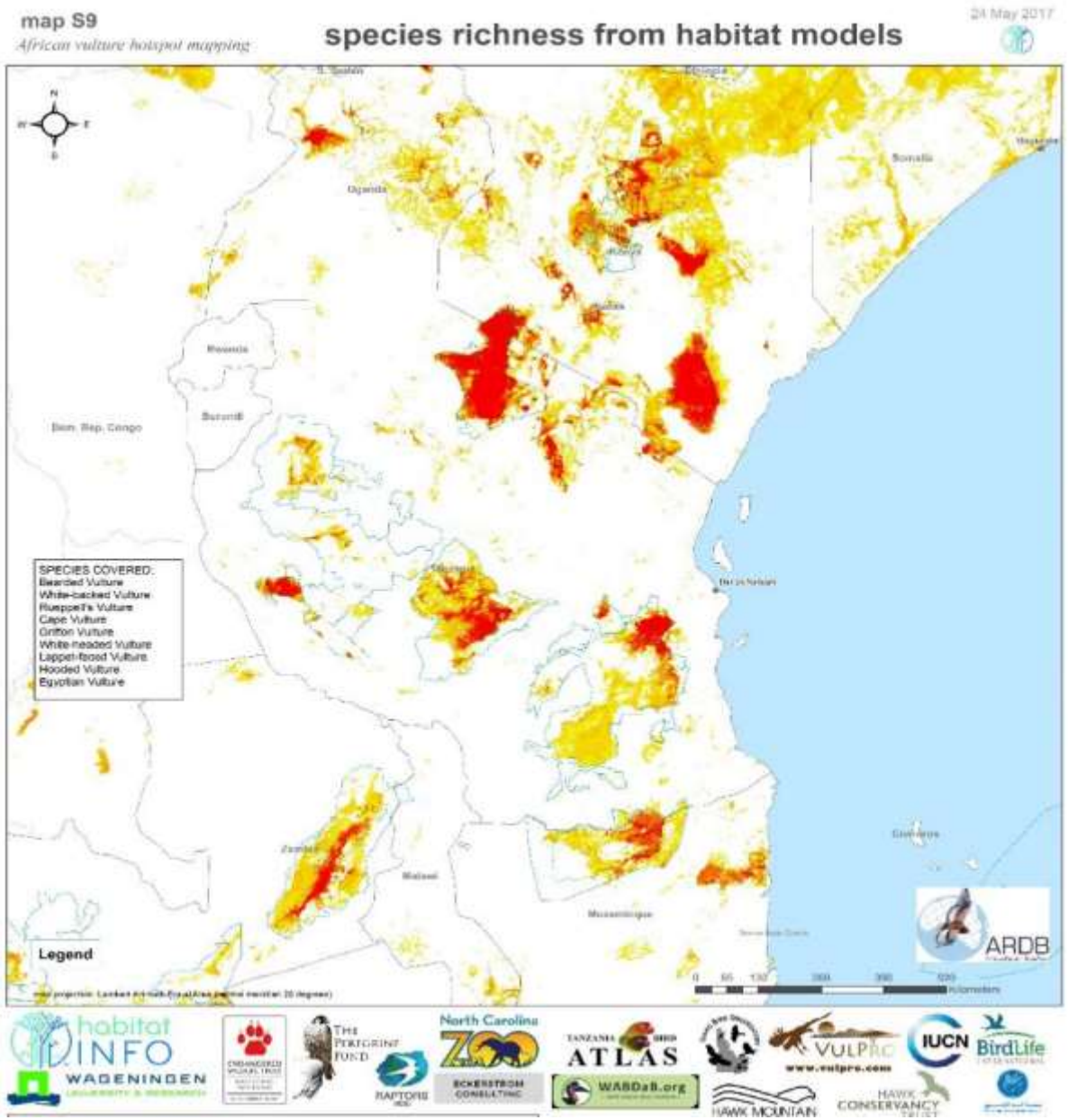


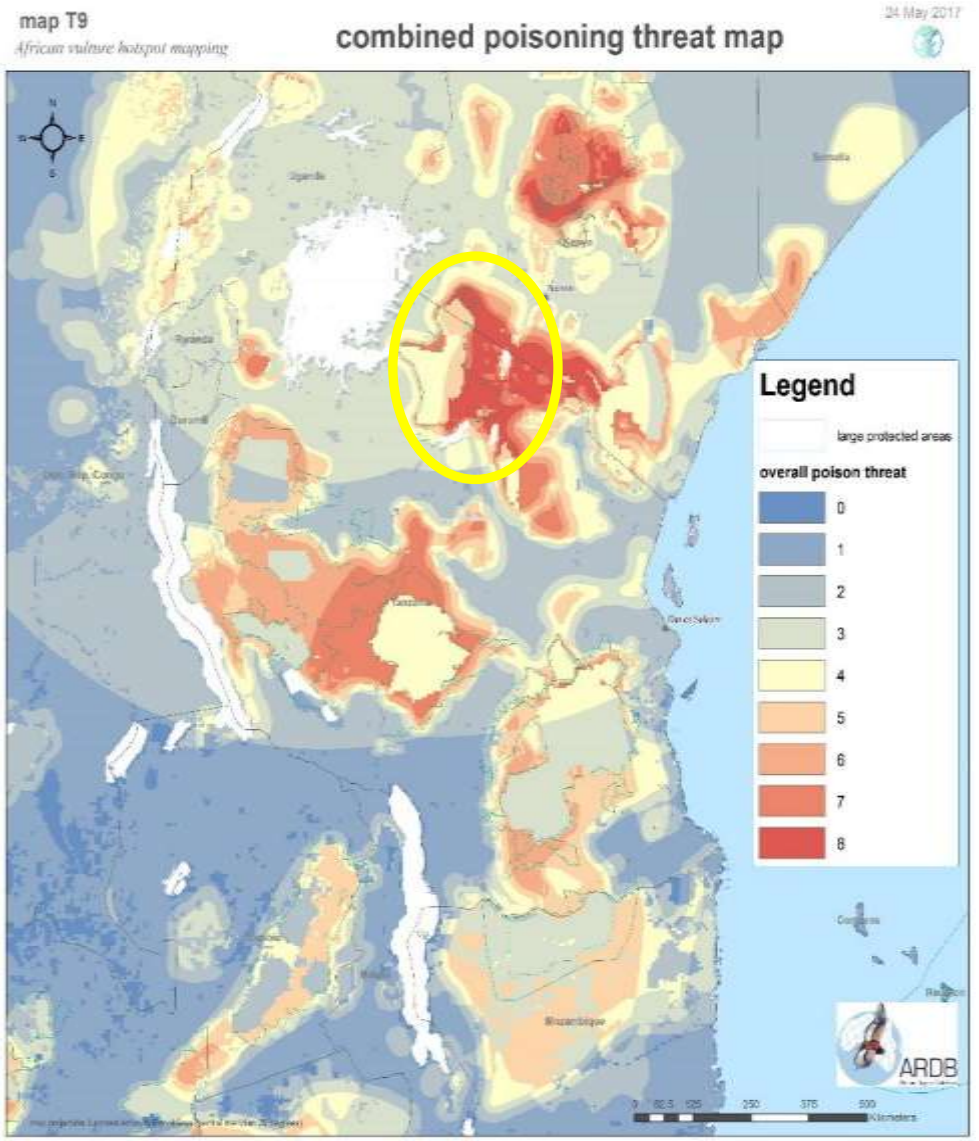
Drivers of decline:

- Retaliatory poisoning
- Trade

Ralph Buji: ralph.buij@gmail.com
Munir Virani: virani.munir@peregrinefund.org
Ogada et al, 2016

Mara-Serengeti - key area for vulture conservation



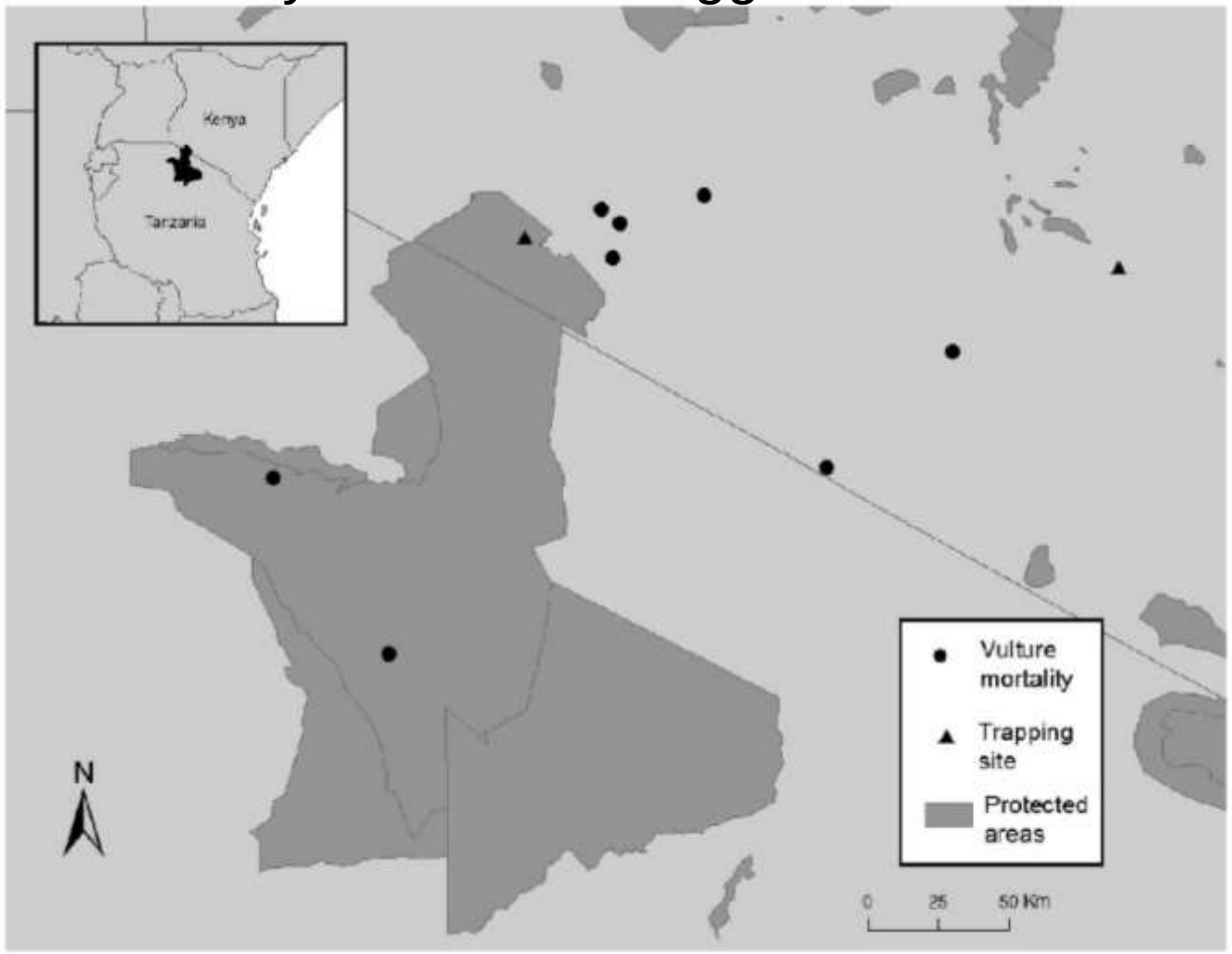


Best habitats are also the areas where poisoning is most prevalent

Ralph Buji: ralph.buij@gmail.com
Munir Virani: virani.munir@peregrinefund.org
Ogada et al, 2016

Human-wildlife conflict & co-existence - Vultures

Mortality locations of tagged GPS vultures



- Poisoning - major cause of death (furadan)
- Adult mortality – about 25-30%/year
- Most poisoning outside protected area especially during wet season (ie the time of highest human-wildlife conflict)

Actions:

- rapid poison response teams with proper training
- Tracking trade in vulture parts
- Vulture National Action Plans (TAWIRI)

Corinne Kendall: Corinne.Kendall@nczoo.org
Kendall and Virani 2012

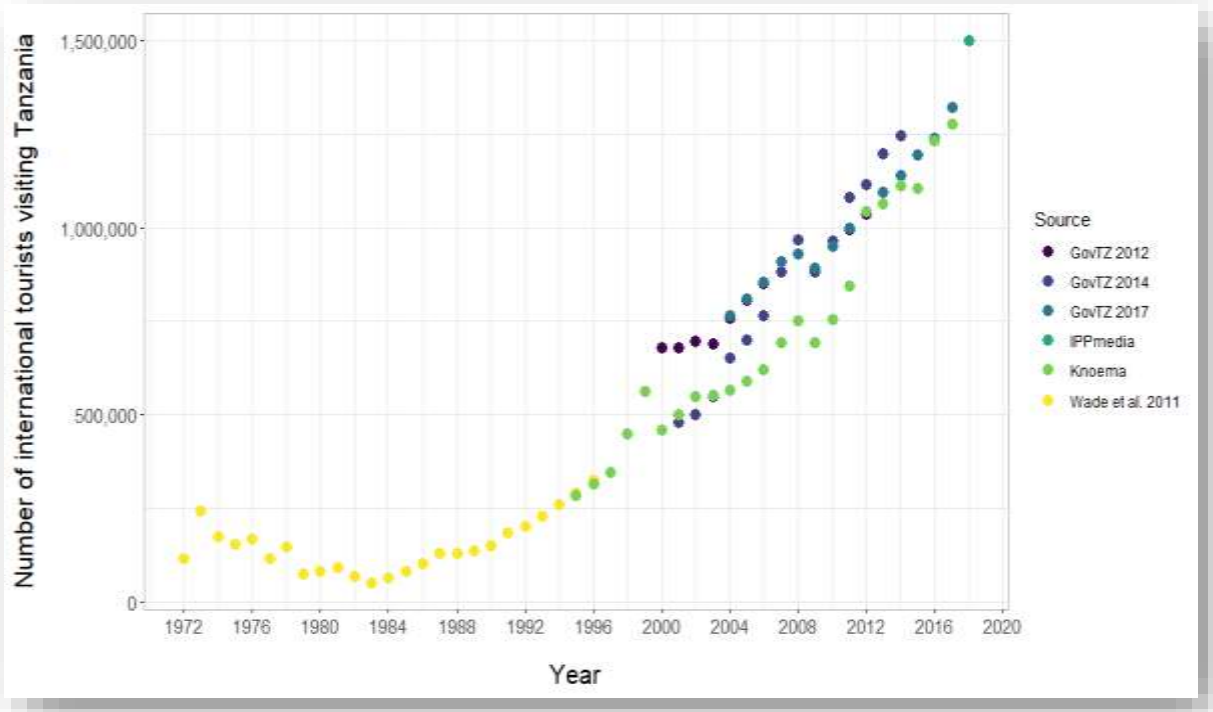
Suggested recommendations for consideration

- Engaging communities increases tolerance and enhances pride in the natural heritage
- Control of poisoning particularly beyond the core protected areas (vultures) is a national responsibility
  - scale of management must include the national level

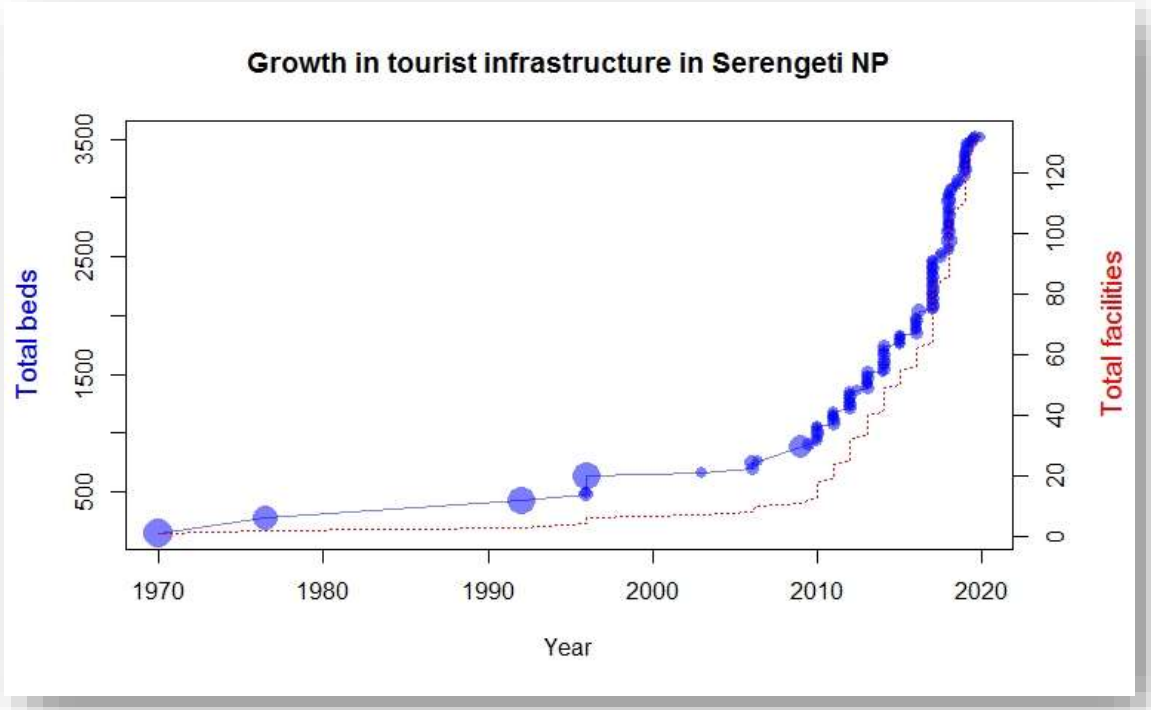

Tourism

Tourism infrastructure – Serengeti (Tz)

Number of tourists visiting Tz / year

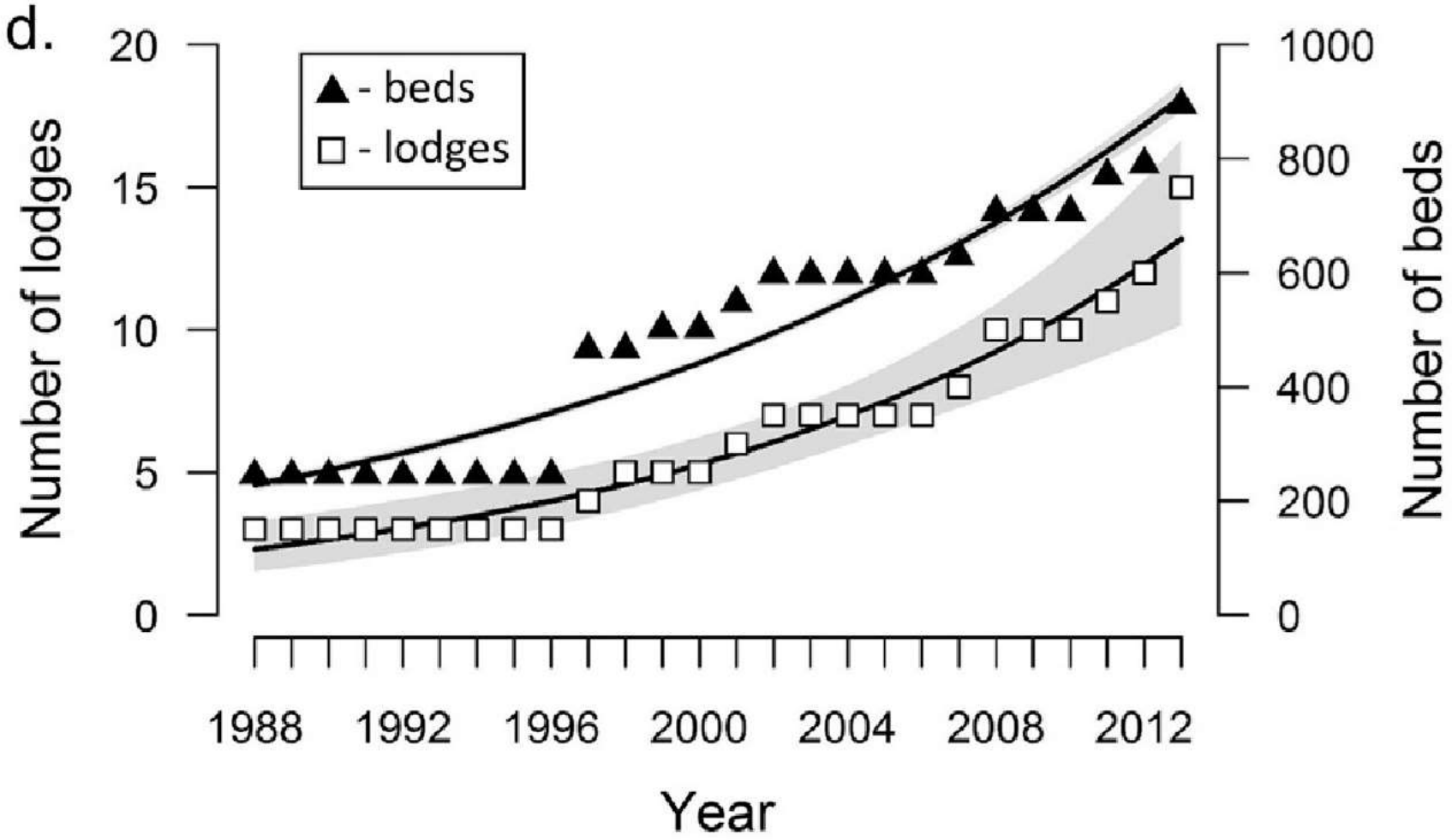


Tourist capacity in Serengeti / year



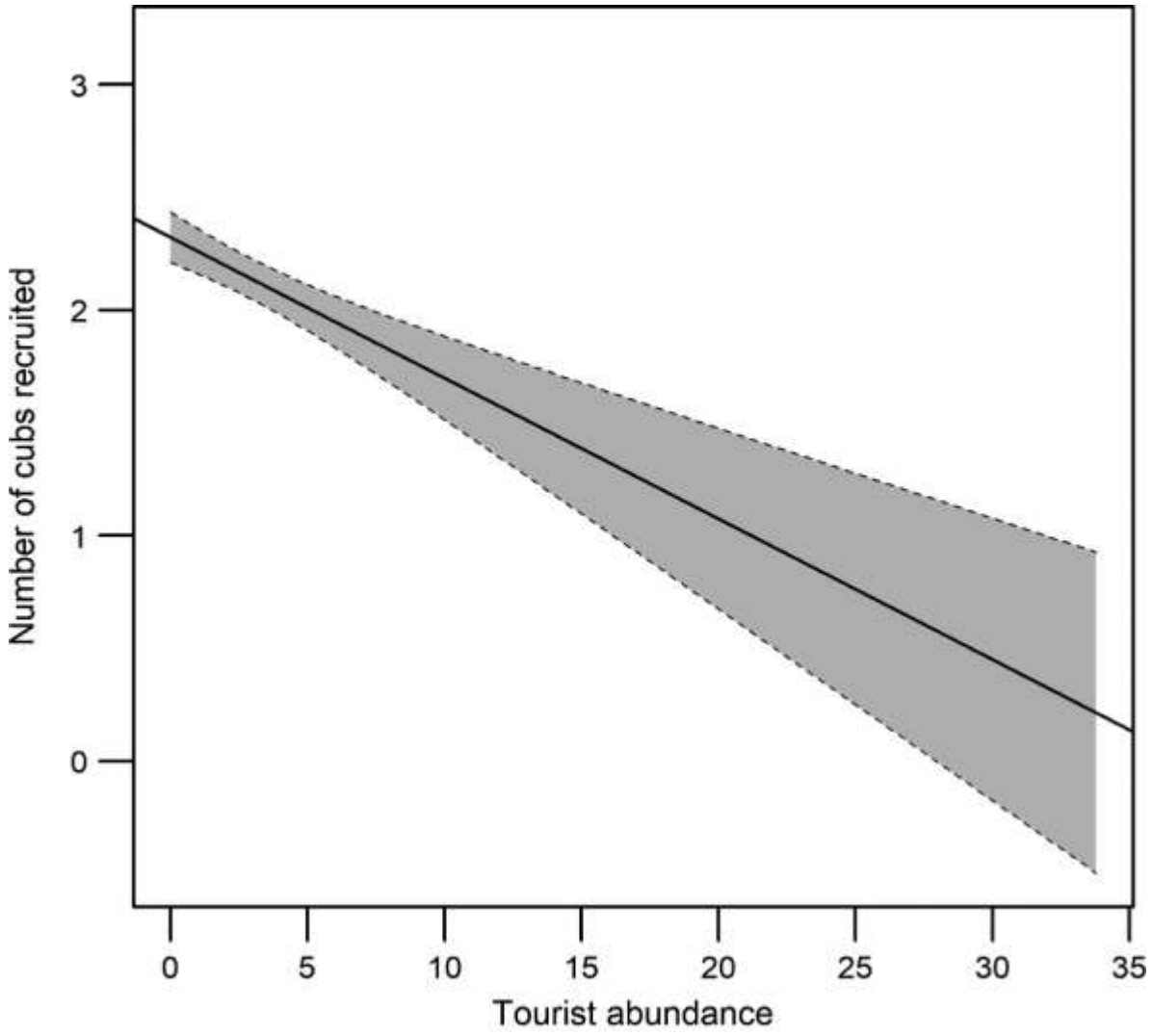
Tom Morrison: thomas.morrison@glasgow.ac.uk
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk
Larsen et al, 2020

Tourism infrastructure – Mara (Ke)



Green et al, 2019

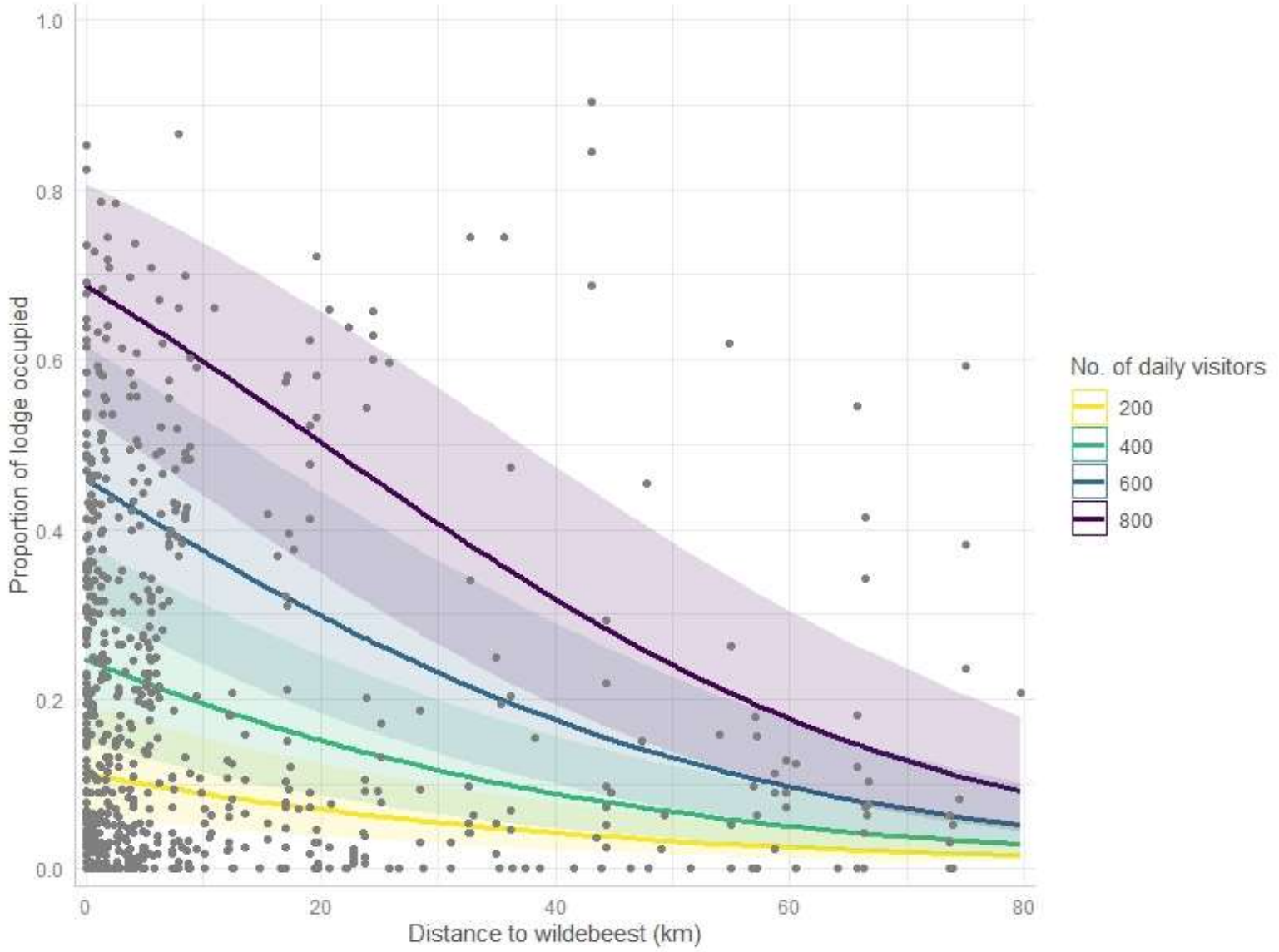
Mass tourism has negative effect on cheetah recruitment



- female cheetahs exposed to high tourist abundance on average raised 0.21 ± 0.72 cubs to independence compared to 2.32 ± 0.11 cubs in low tourism areas
- Neither lion nor spotted hyaena abundance had an impact on the number of cubs that were recruited

Femke Broekhuis: femke.broekhuis@gmail.com
Broekhuis et al 2017, 2018

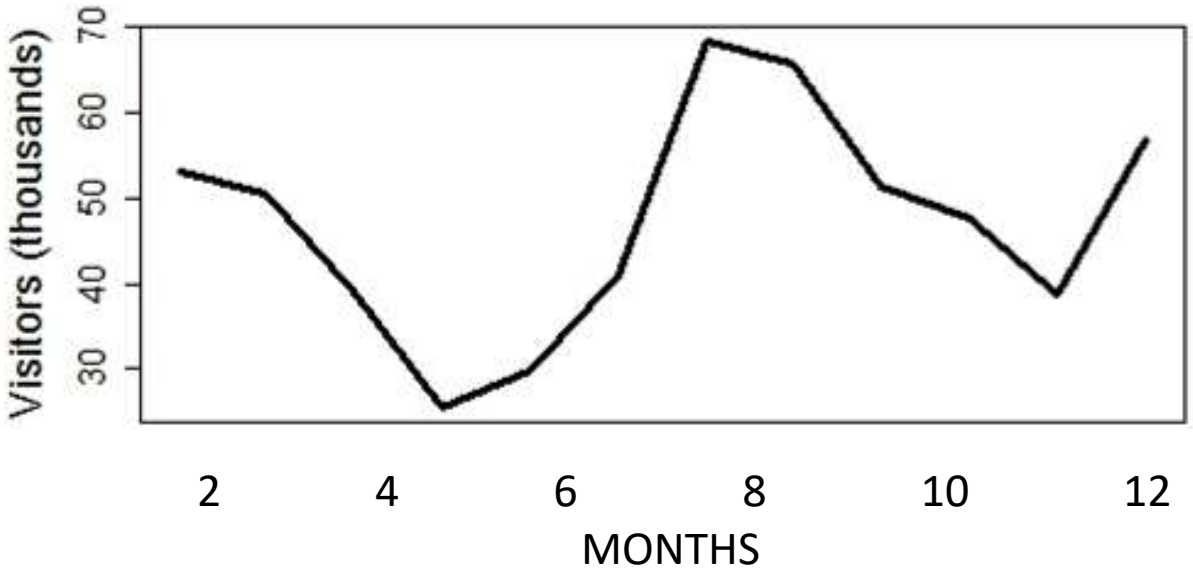
Wildebeest migration drives lodge occupancy



- Very large tourist demands for accommodation close to the migration places large economic incentives for building lodges in prime wildlife areas

Tom Morrison: thomas.morrison@glasgow.ac.uk
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk
Larsen et al, 2020

Non-equal distribution of tourism



- Seasonal cycles in tourism

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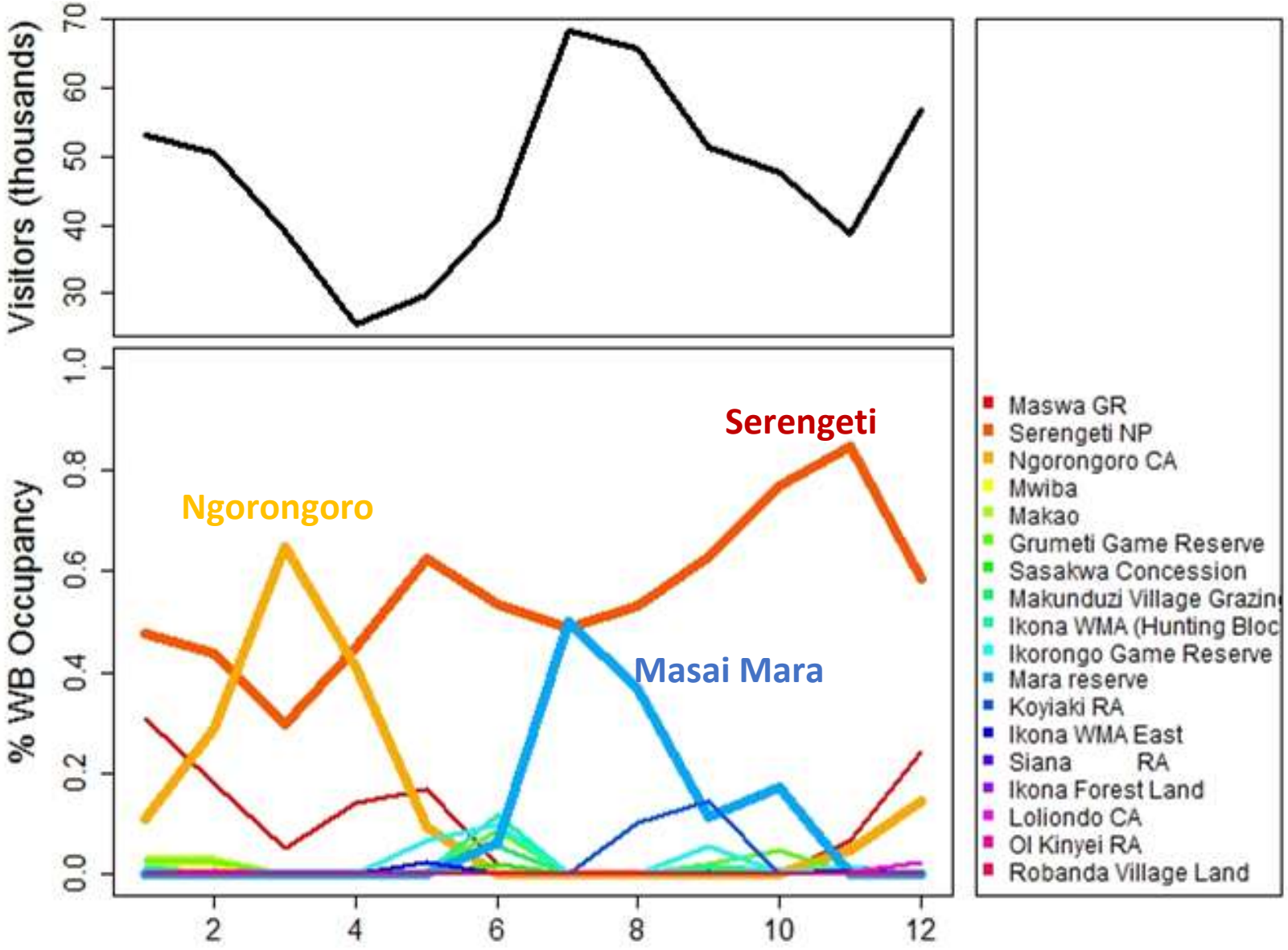
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk
Larsen et al, 2020

Non-equal distribution of tourism & revenue



- Seasonal cycles in tourism combined with seasonal cycles of migration result in spatial differences in how benefits accrue from tourism
- Peak tourism coincides with when wildebeest are in north Serengeti and Mara resulting in high revenues and greatest tourist pressure
- During low tourism season wildebeest are in NCAA and Maswa meaning these areas receive relatively little income from the migration, even though they are hugely important areas for wildebeest lifecycle (calving and recruitment)

Tom Morrison: thomas.morrison@glasgow.ac.uk
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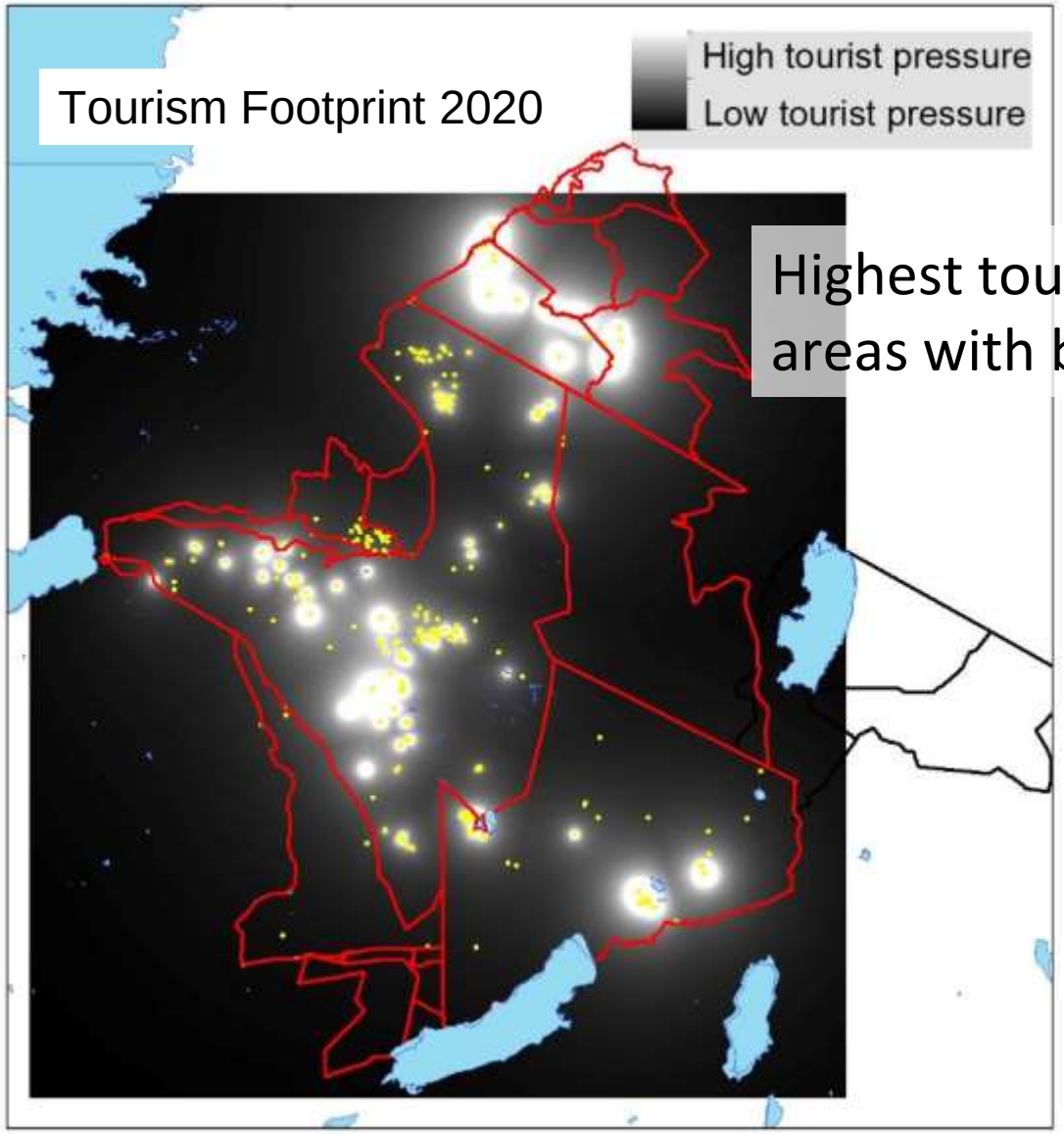
Larsen et al, 2020

Mass tourism effects wildebeest crossings

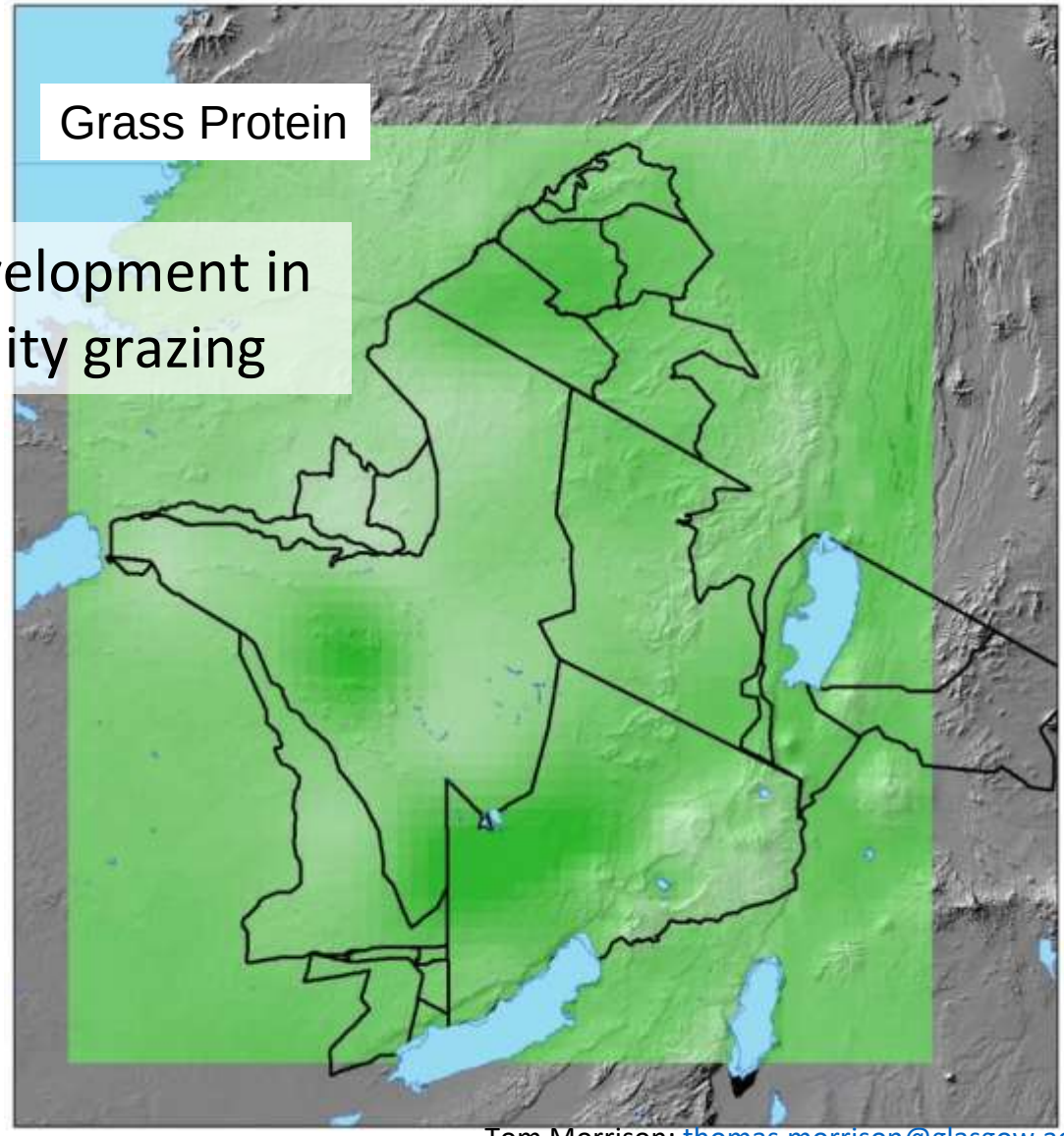
- Monitored 124 attempted and successful wildebeest river crossings in 2014-15
- Tourism presence influenced wildebeest behavior in 20% of river crossings

Year	# Crossings Monitored	Mean # Vehicles at Bank (Min-Max)	# Crossings with Wildebeest Disturbed
2014	28	19 (0-77)	9 (32%)
2015	96	28 (0-81)	8 (8%)

Mass Tourism



Highest tourism development in areas with best quality grazing



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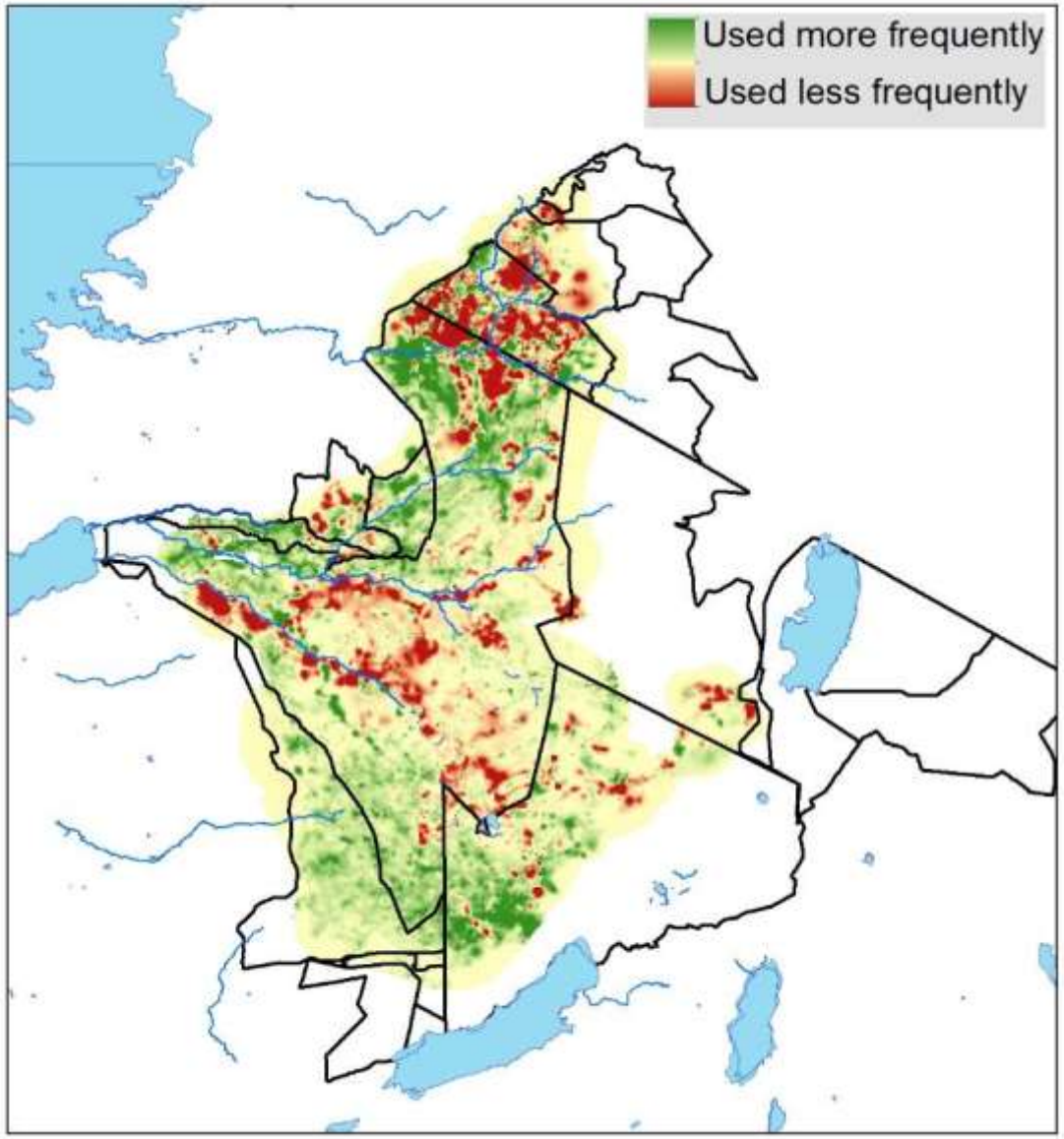
Morrison et al, in prep

Long term changes in migration



Large changes in wildebeest utilization over the last 20 years based on GPS collaring studies (1999-2007 versus 2008-2017)

35 days / year less in the Mara

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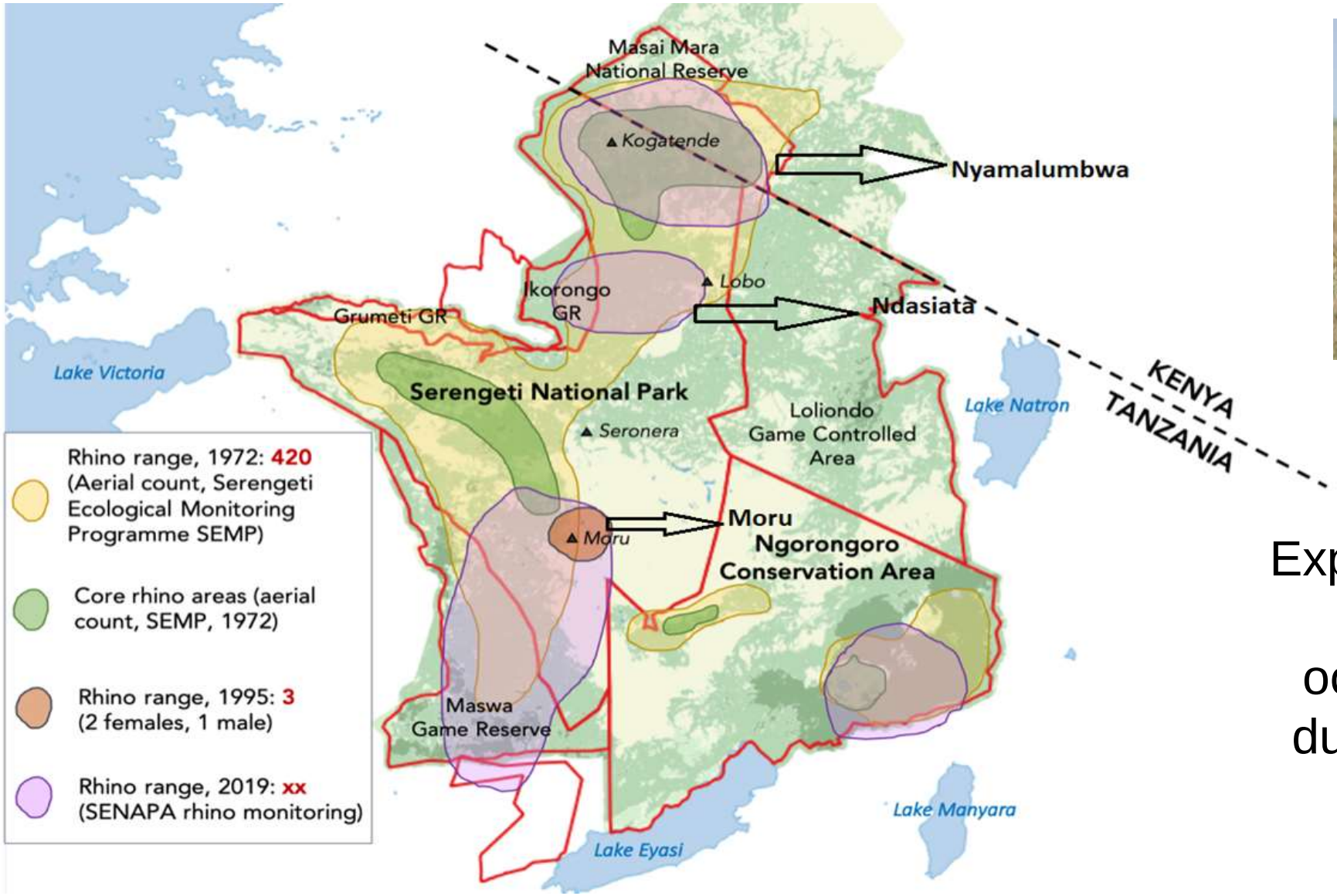
Grant Hopcraft: grant.hopcraft@glasgow.ac.uk
Morrison et al, in prep

Animal redistributions during COVID-19 Anthropause



Expansion of home ranges into previously high-occupancy tourist areas during COVID lock-down

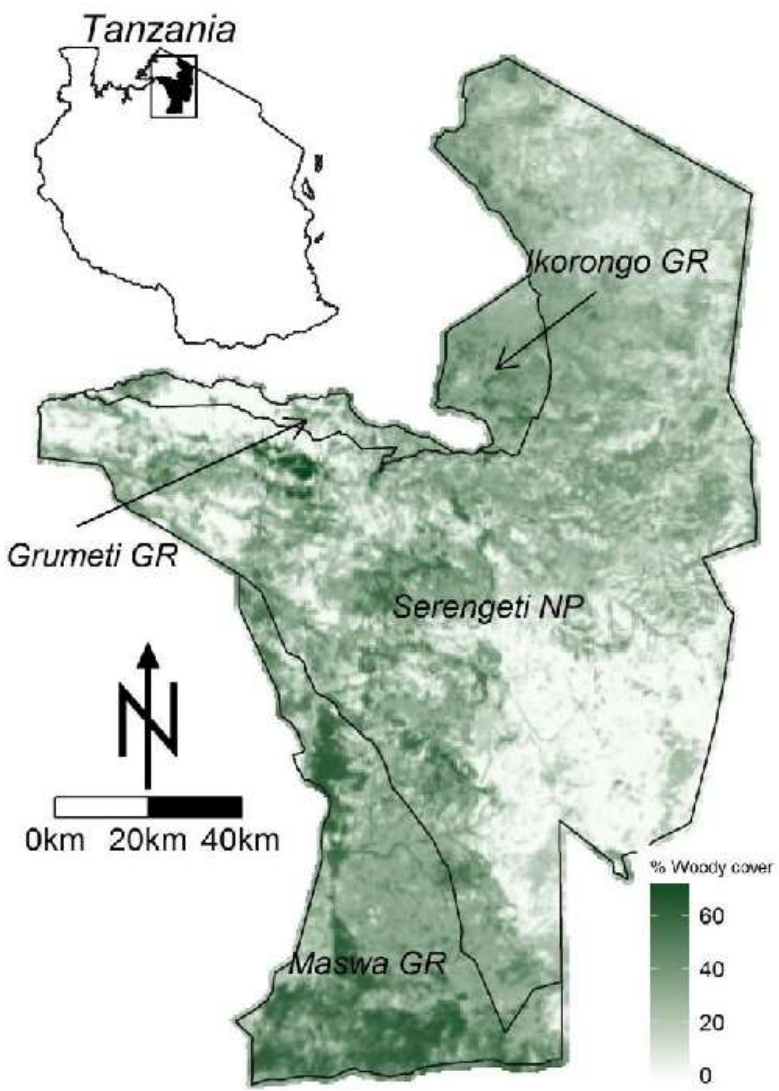
Ronald Mellya: 2285780M@student.gla.ac.uk
Mellya, PhD, continuing

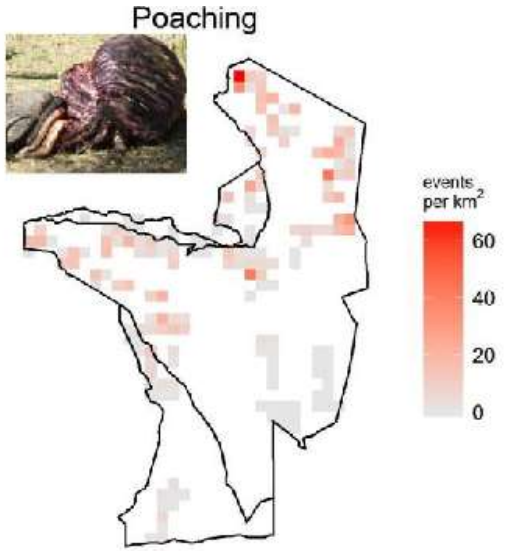
Suggested recommendations for consideration

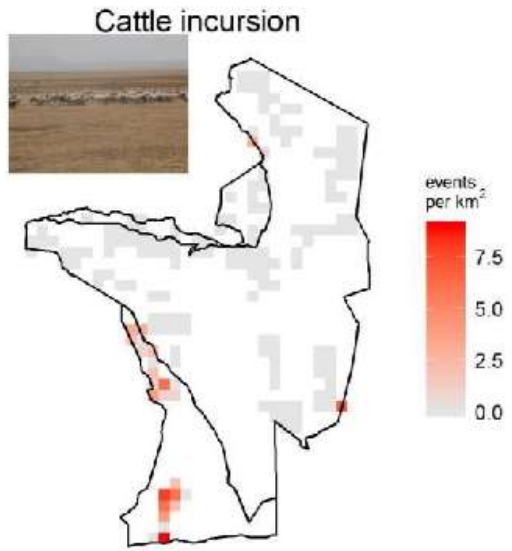
- Strategies for moving large permanent tourism infrastructure to the edges of the protected areas (not inside) – develop employment opportunities and provide a natural buffer to the park
- Stronger zoning and periods for tourism to protect ecologically sensitive locations (Mara river crossing, sensitive species (rhino, cheetah))
- Diversify tourist experience

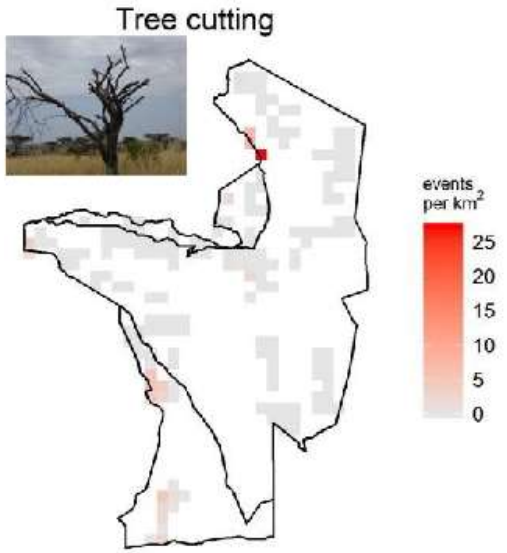

Poaching & illegal activity

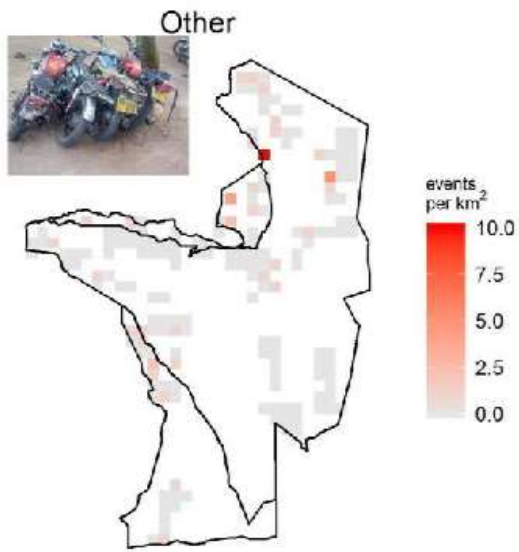
Poaching and illegal activity





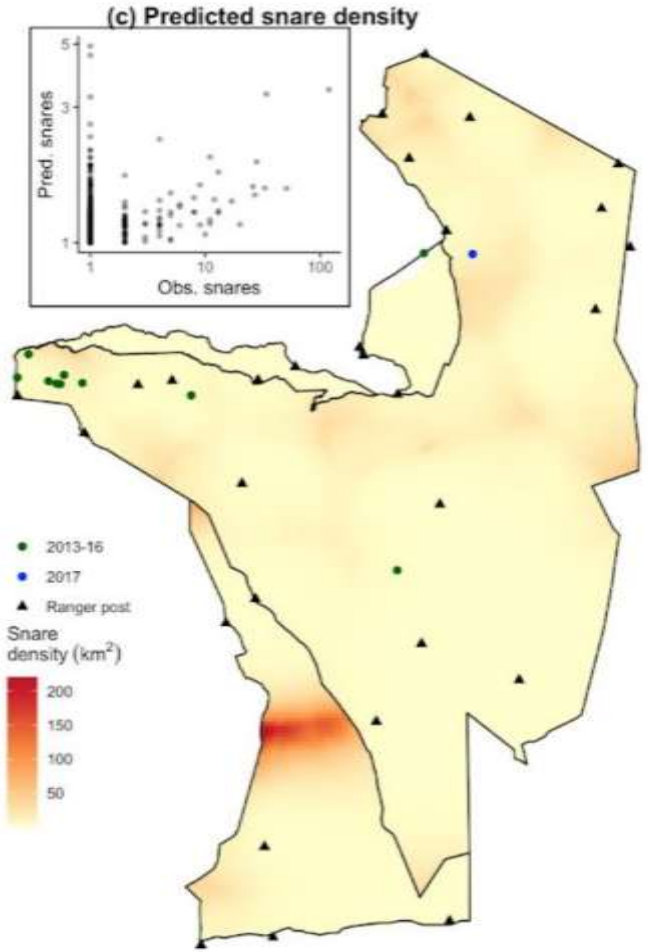




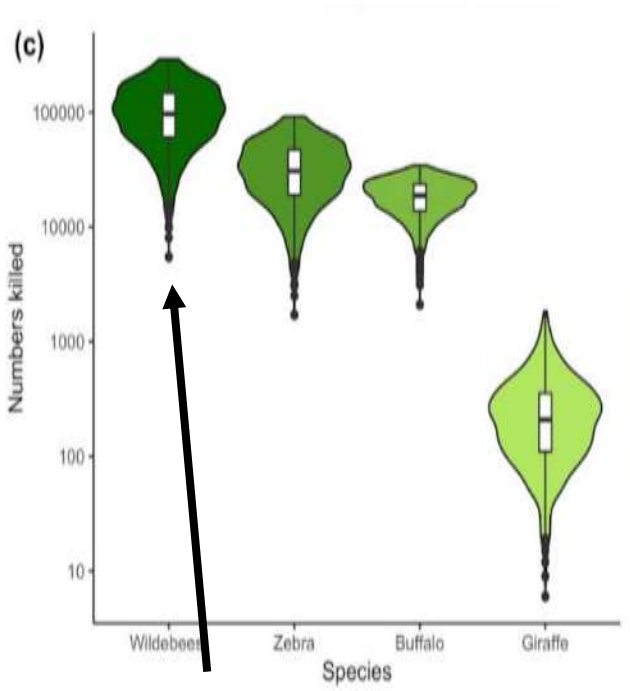


Alfan Rija: al.rija10@gmail.com
Rija PhD 2018

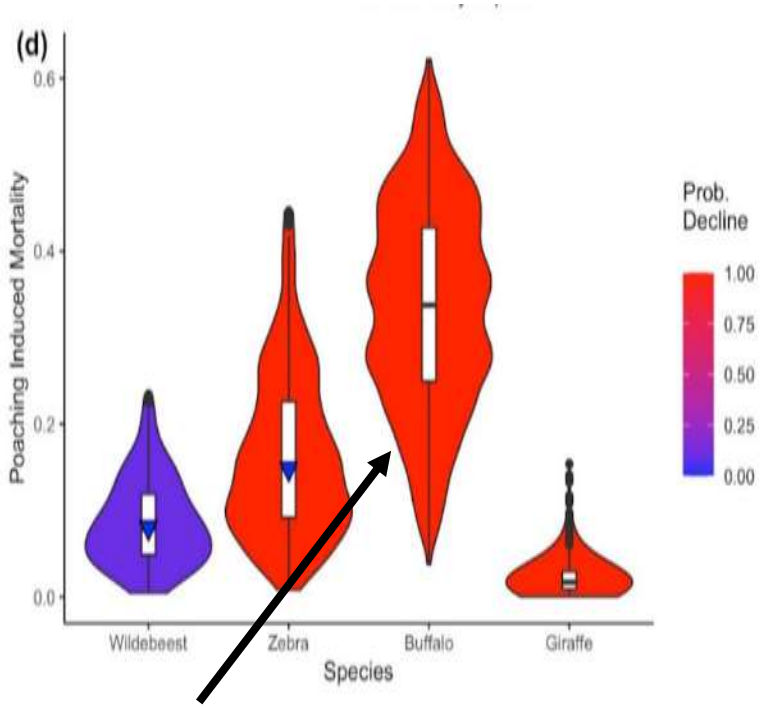
Poaching and illegal activity



Predicted Snare Density



Wildebeest have the highest offtake (up to 100,000 / year)



Greatest demographic impact is on buffalo

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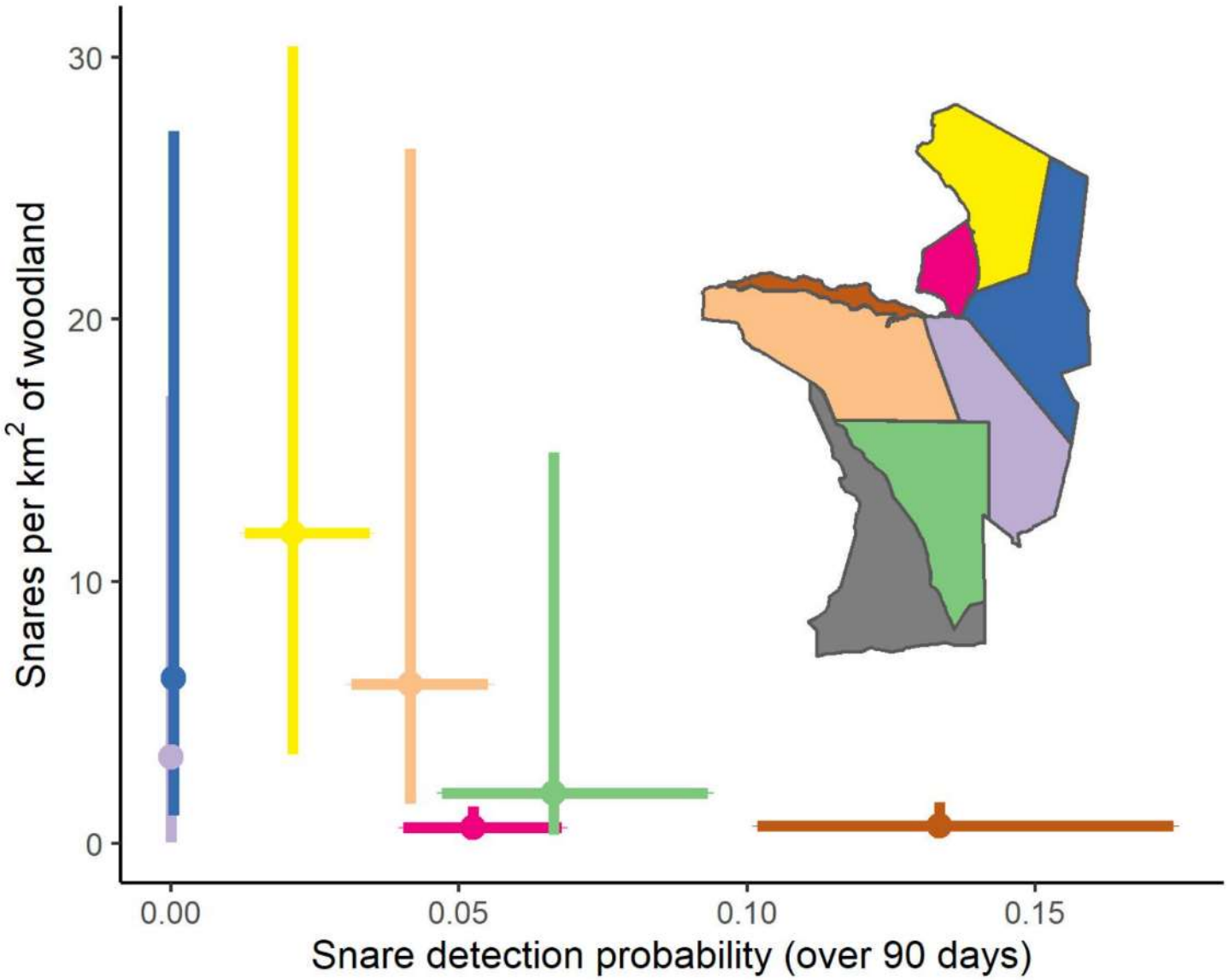
Rob Critchlow: rob.critchlow@york.ac.uk
Colin Beale: colin.beale@york.ac.uk
Rija et al, in prep.

Poaching and illegal activity



Suggested recommendations for consideration

- Improve the efficiency of current ranger patrols
- Shared intelligence between conservation areas between managers and researchers


Carbon credits &
Alternate sources of
income

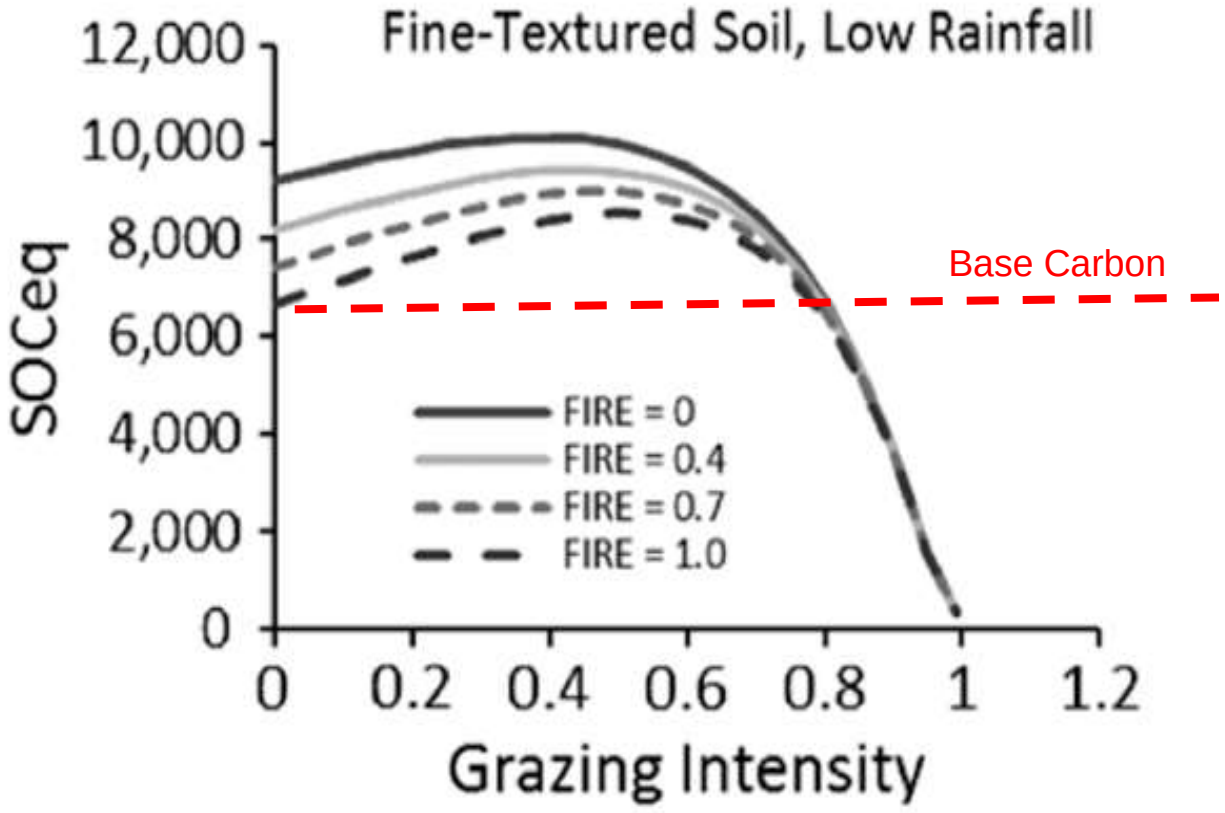
Soil carbon sequestration in savannas

$8/ton - Current value of carbon stock

Serengeti sequestering 700,000 tons / year = about $5.6M

Soil carbon sequestration rate depends on

- Soil type (ie % sand)
- Rainfall
- **Fires**
- Grazing intensity



Depends on managing fires in protected areas
Optimal burning rate is 4 fires / 10 years

Mark Ritchie: meritchi@syr.edu
REF PAPER

Soil carbon sequestration in savannas

$8/ton - Current value of carbon stock

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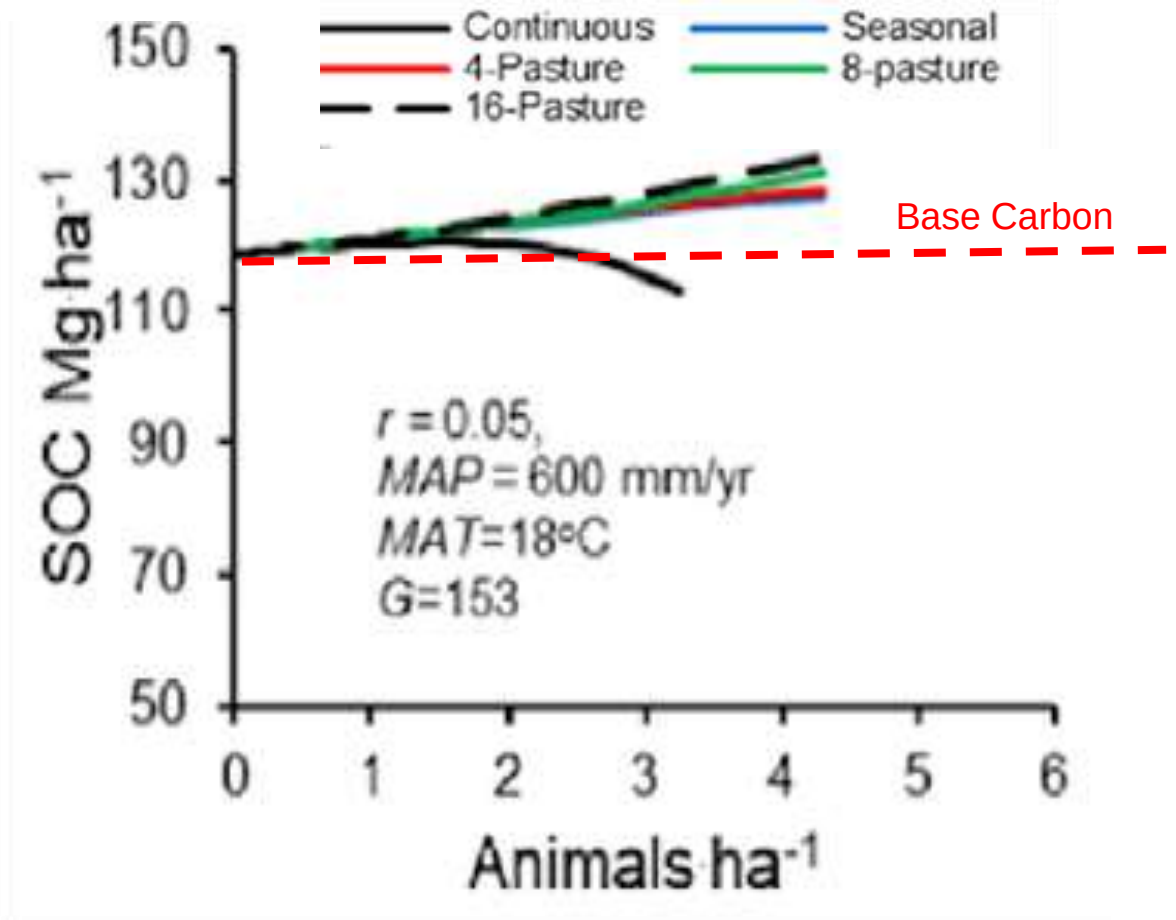


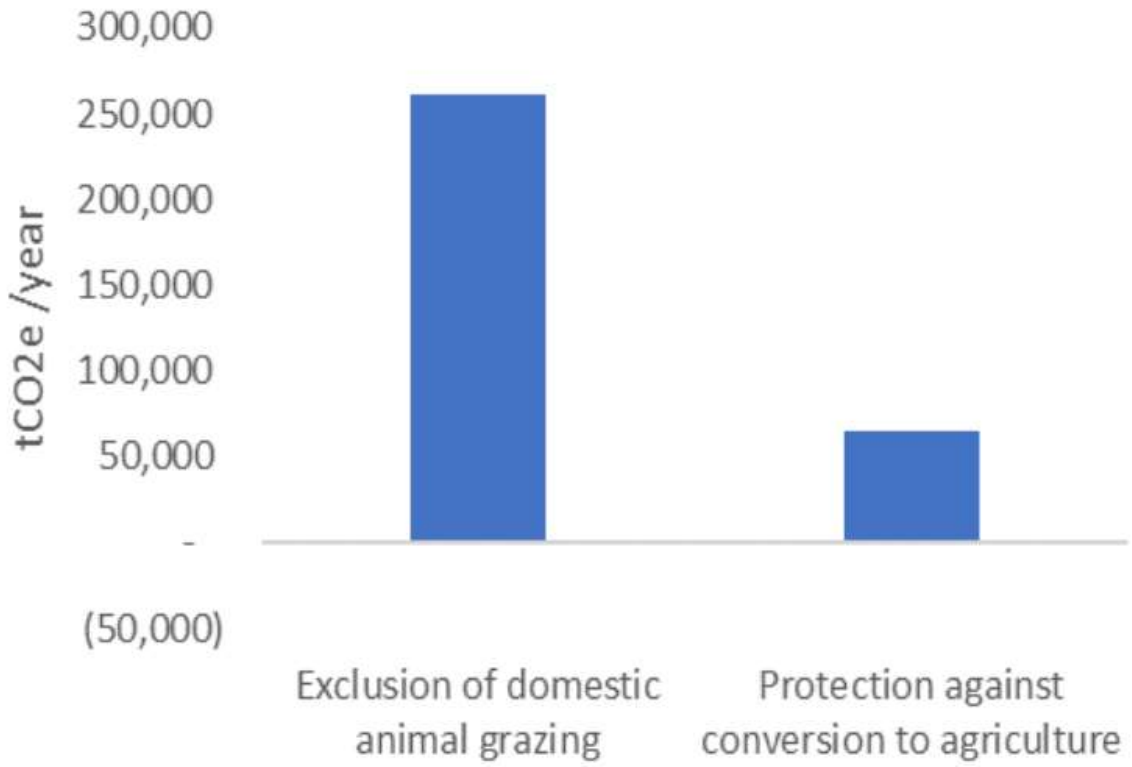
Only in pastoral areas but not protected areas
Optimal is 8 pasture rotation

Mark Ritchie: meritchi@syr.edu

REF PAPER

Soil carbon sequestration in savannas

- The exclusion of agriculture and domestic livestock equates to avoided emissions of 325,000 tCO2e per year.
- The ongoing protection of this landscape prevents significant emissions than if the area was degazetted, or even partially protected where livestock grazing is allowable.



Grumeti Fund
Kristen Snyder KristenS@grumetifund.org

Suggested recommendations for consideration

- Carbon credits could be an additional income source, but can be difficult to realize
- Risk of misuse to serve other purposes and beneficiaries such as agro-forestry

END