# Vulnerability and adaptability: predicting the effects of climate change on Africa's inland fisheries

Dr. Elizabeth Nyboer
NaFIRRI Weekly Seminar
March 7, 2019

# Fresh waters are predicted to be among the most vulnerable to climate change

Alterations due to climate change

Selection pressure on freshwater species

Alterations due to climate change

↘

Selection pressure on freshwater species

↙

Ectotherms must escape or adapt

Alterations due to climate change

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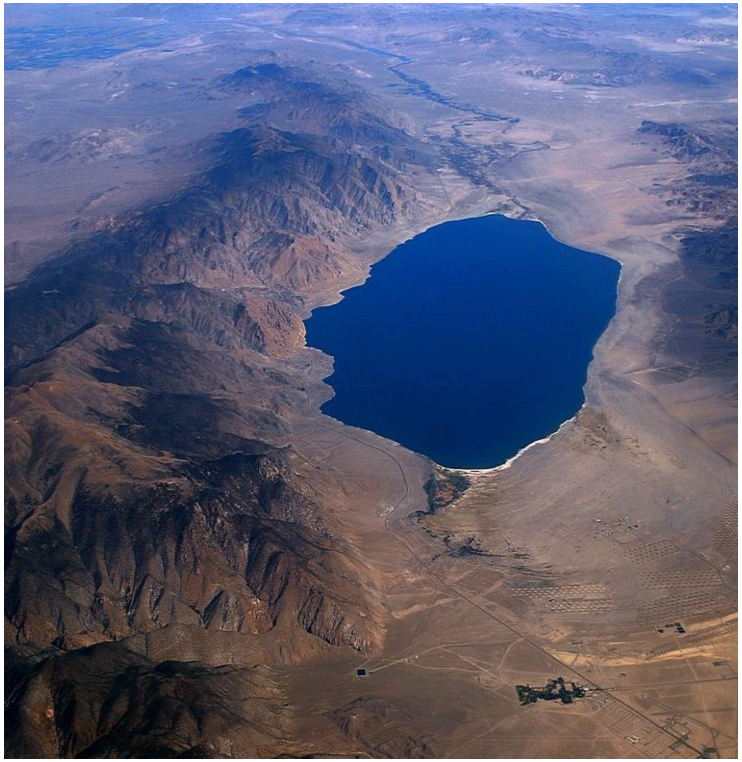

Alterations due to climate change

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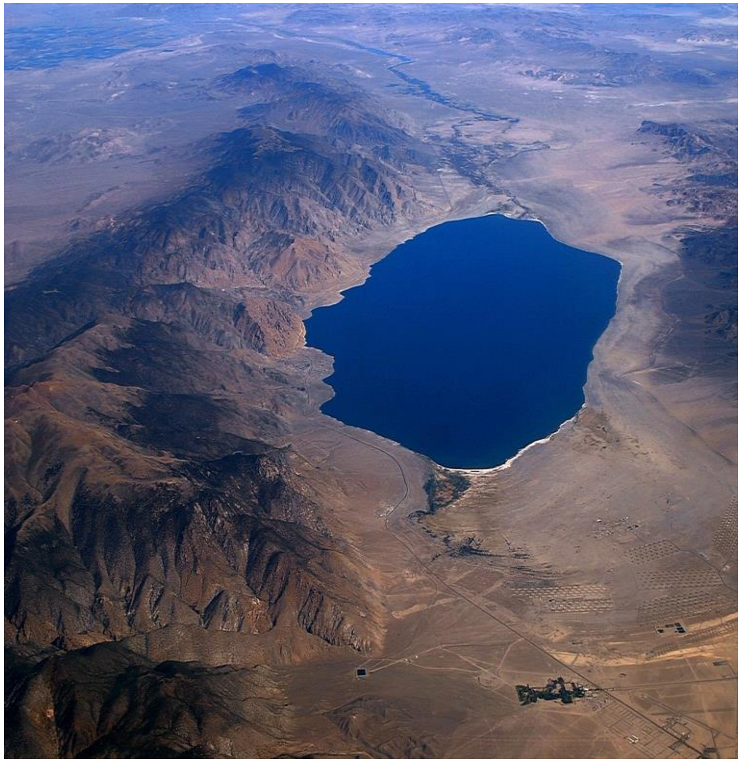
Genetic adaptation
Phenotypic plasticity



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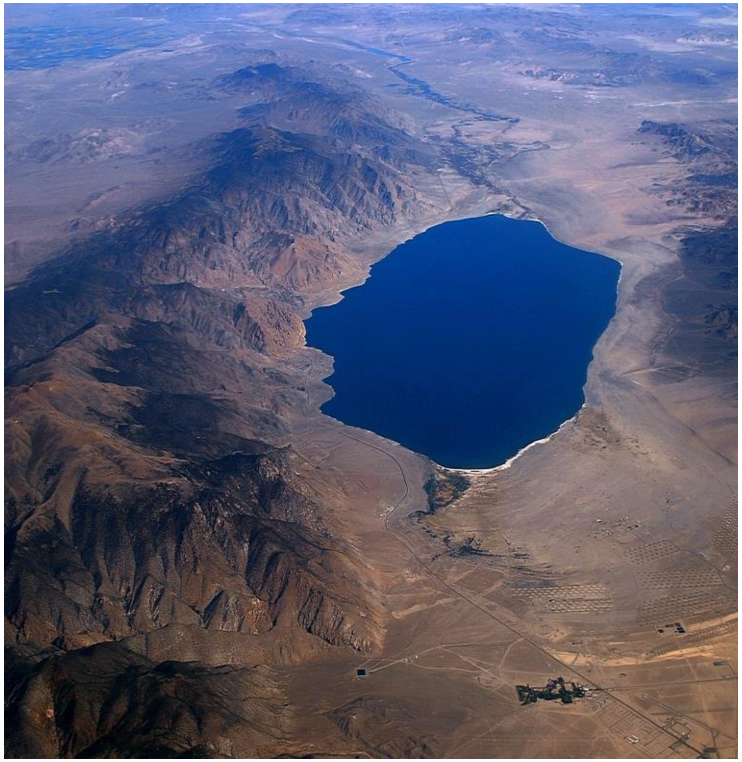
Species traits
Behavioural
Genetic
Ecological
Physiological



Alterations due to climate change

Human use (fishing pressure)

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population shrinkage

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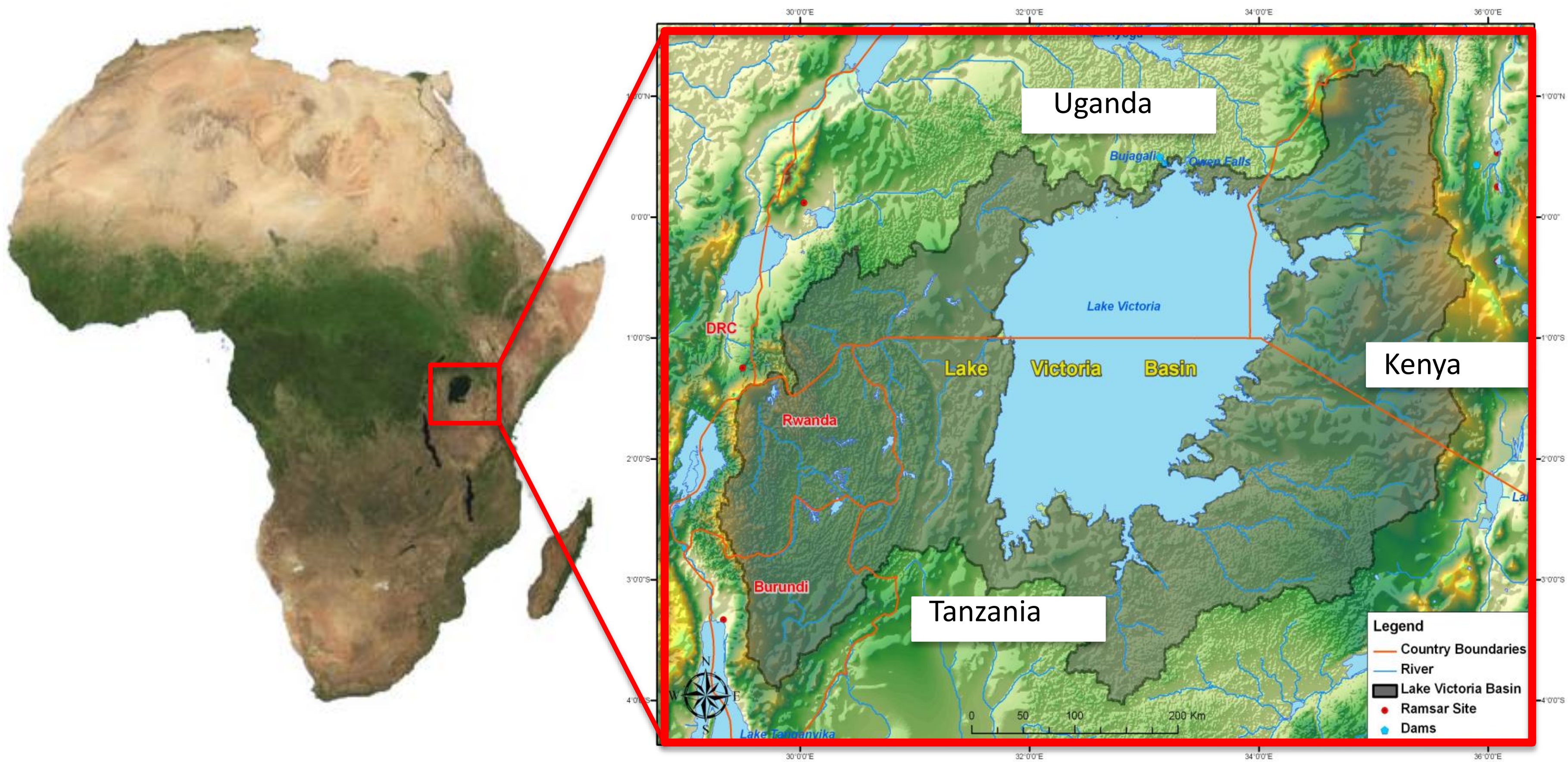
Species traits
Behavioural
Genetic
Ecological
Physiological

The future of heavily exploited fisheries will depend on the adaptive capacity of both the **fish species** and the **human communities** that rely on them.



Uganda
Kenya
Tanzania
DRC
Rwanda
Burundi
Lake Victoria
Lake Victoria Basin
Bujagali
Owen Falls
Lake Tanganyika
Legend
Country Boundaries
River
Lake Victoria Basin
Ramsar Site
Dams
0 50 100 200 Km

Chapter 1

Chapters 2 & 3

Chapter 4

## Chapter 1

Trait-based climate change vulnerability assessment (CCVA) of African freshwater fishes.

## Chapters 2 & 3

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Determine the adaptive capacity of fishing communities to projected changes in the LVB fishery

# **Chapter 1** Trait-based climate change vulnerability assessment (CCVA) of African freshwater fish

**Conservation challenge:** how to assess the potential risks to biodiversity posed by climate change

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**Trait-based vulnerability assessments**

- Estimates of relative vulnerabilities of a taxonomic group based on scores in broad trait categories

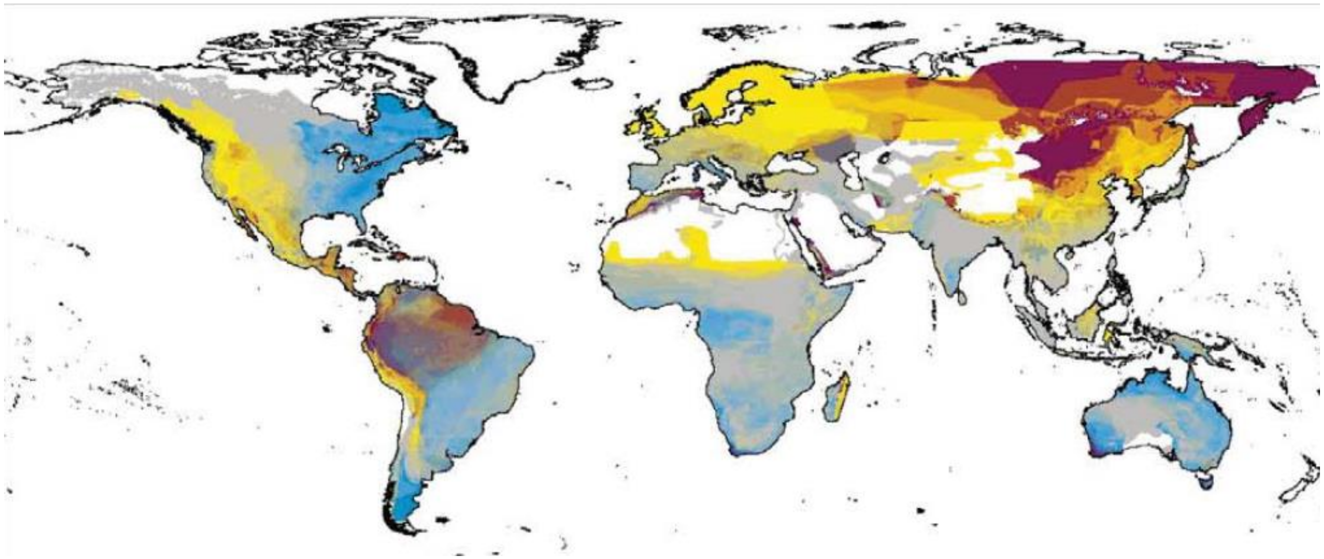
**Conservation challenge:** how to assess the potential risks to biodiversity posed by climate change

**Trait-based vulnerability assessments**

- Estimates of relative vulnerabilities of a taxonomic group based on scores in broad trait categories

- Relatively rapid and straightforward to perform
- Take species traits into account
- Cover large number of species and large geographic ranges

# Spatial visualization to highlight hotspots for conservation focus



e.g., concentrations of highly vulnerable amphibian species

Foden et al., 2013, PLOS One

~ 3300 described species in 95 families





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15 endemic families in sub-Saharan Africa;  e.g. Cichlidae









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High numbers of basal and archaic families; e.g. Polypterus species



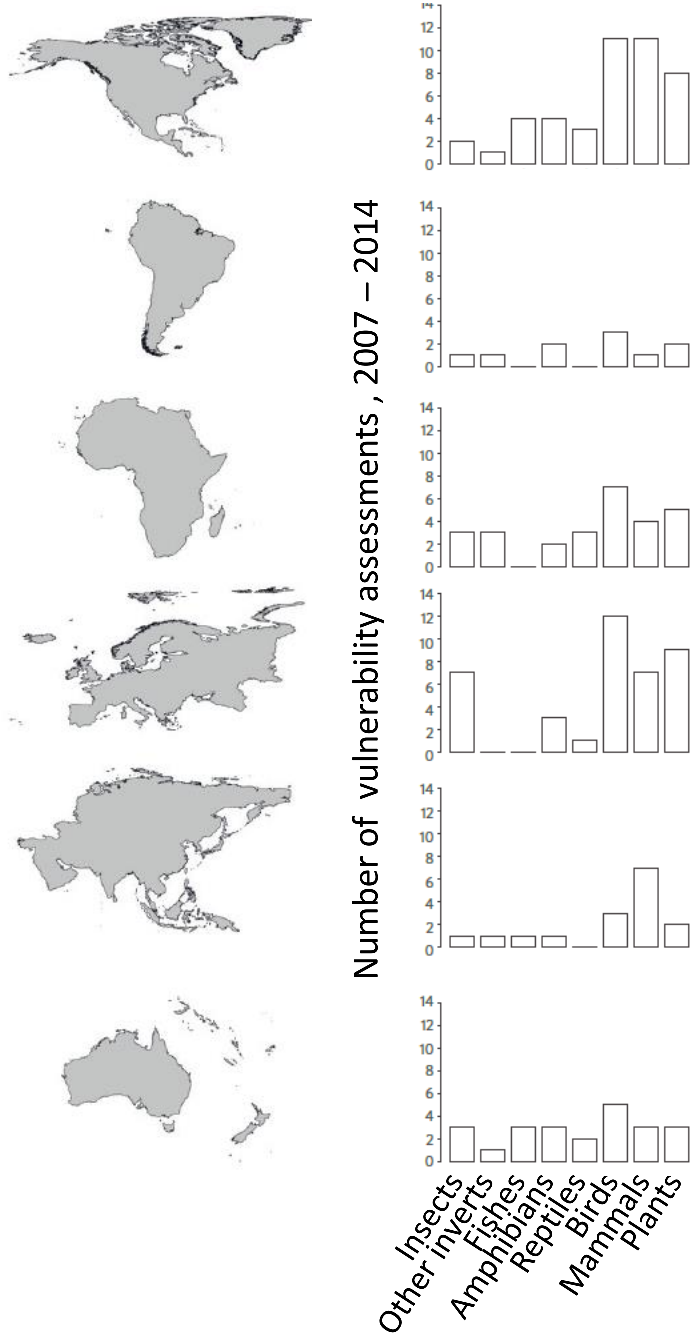




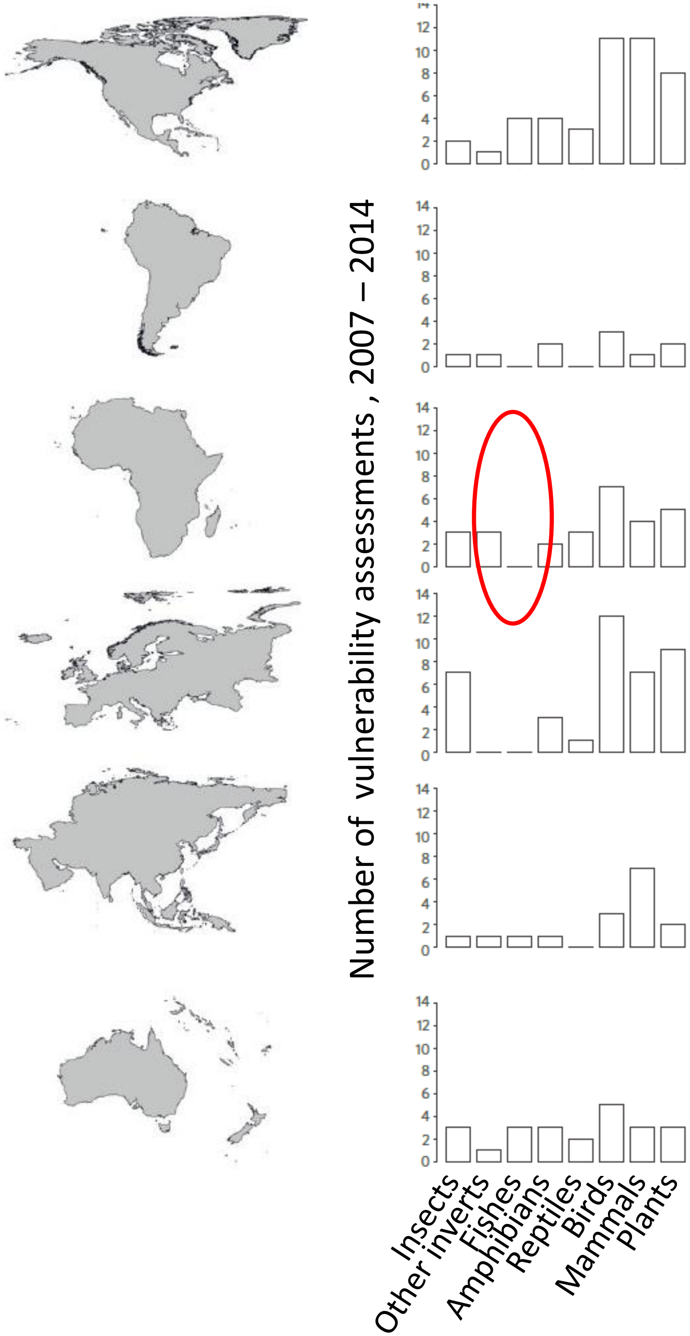





~ 3300 described species in 95 families
15 endemic families in sub-Saharan Africa;  e.g. Cichlidae
High numbers of basal and archaic families; e.g. Polypterus species
Major source of food security and economic stability




Pacifici et al., 2015,
Nature Climate Change




Pacifici et al., 2015,
Nature Climate Change

## Objectives

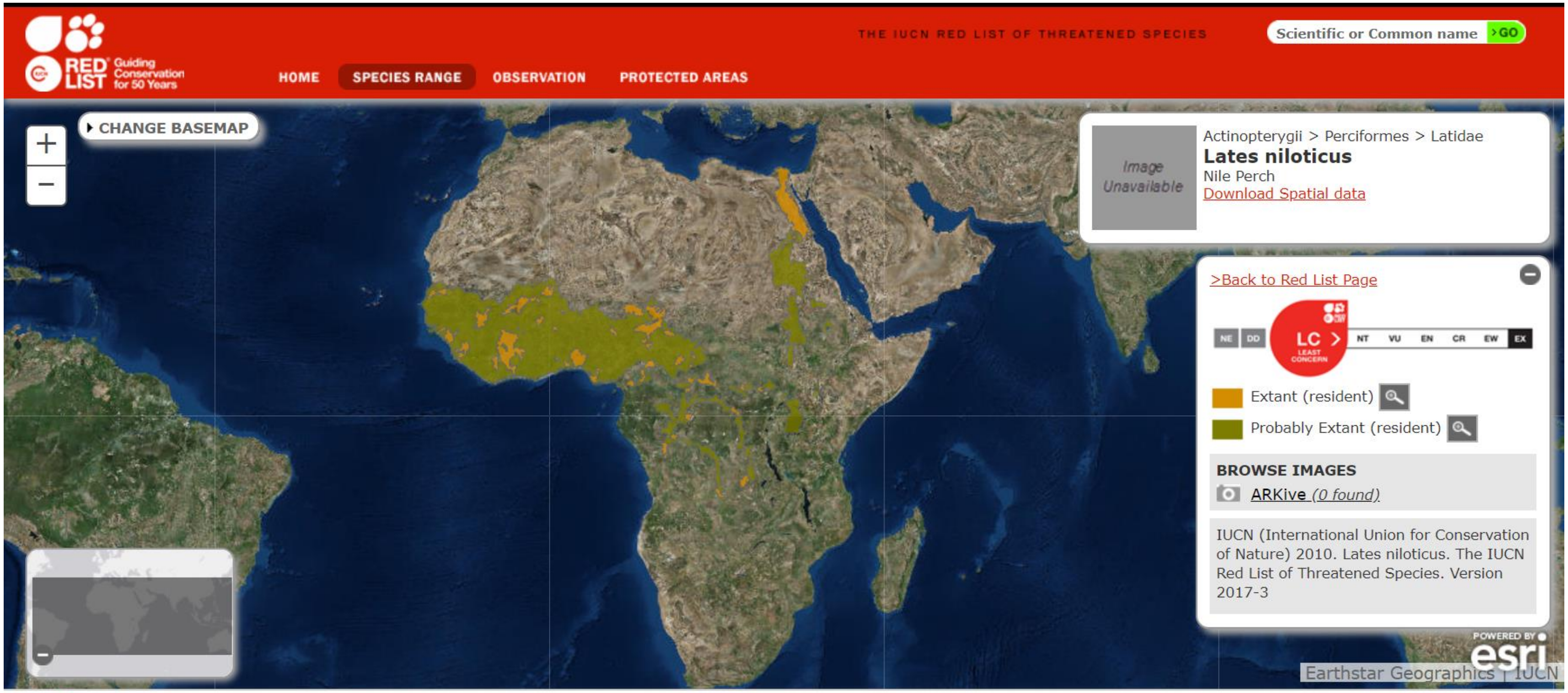
Identify species and regions likely to be affected by climate change

Determine where areas of climate change vulnerability coincide with areas of high conservation value

2 major indices

A. **Vulnerability to climate change**

B. **Conservation value**




- Species distributions from IUCN redlist spatial data download
- > 3000 species ranges

## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

(i) Sensitivity

(ii) Low adaptive capacity

(iii) Exposure

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- a species inability to avoid negative impacts of climate change though dispersal/micro-evolutionary change

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## A. Vulnerability to Climate Change

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(i) Sensitivity

- lack of potential for species to persist *in situ*

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(iii) Exposure

- how much a species physical environment will change

## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

(i) Sensitivity

(ii) Low adaptive capacity

} Based on ecological, physiological, and life-history traits

Fishbase
IUCN redlist
Literature Review

## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

(i) Sensitivity – relying on predictable seasonal cues for life cycle

(ii) Low adaptive capacity

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## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

(i) Sensitivity – relying on predictable seasonal cues for life cycle

(ii) Low adaptive capacity – low reproductive rates, small pops

Fishbase
IUCN redlist
Literature Review

## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

(i) Sensitivity

(ii) Low adaptive capacity

(iii) Exposure } Based on projected climate changes across the species range

WorldClim Global Climate Data

## A. Vulnerability to Climate Change

Assign each species a vulnerability score based on three contributing components

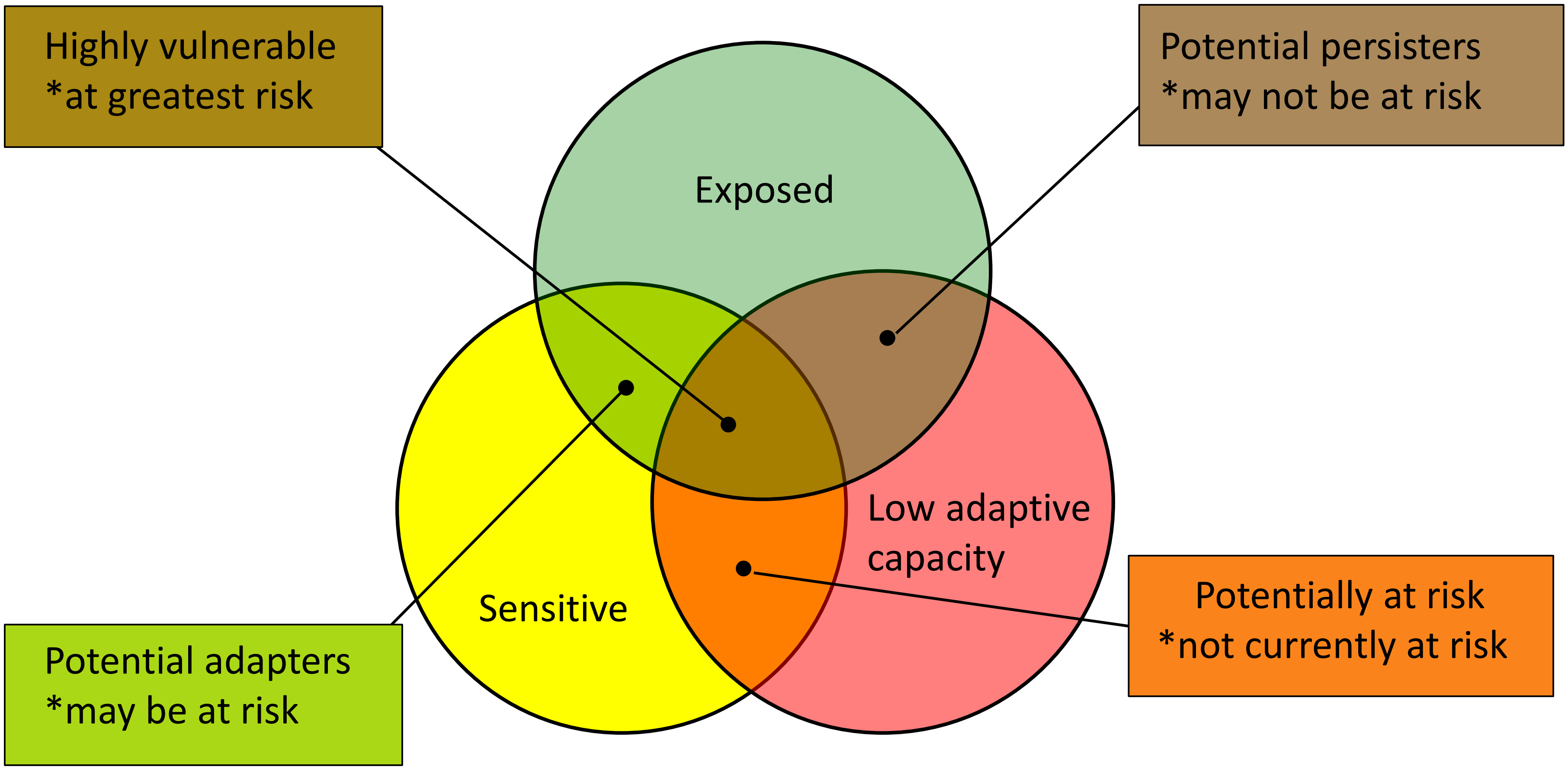
(i) Sensitivity

(ii) Low adaptive capacity

(iii) Exposure
- Δ temperature (average and variability)
- Δ precipitation (average and variability)

WorldClim Global Climate Data

# Scores in each category are combined to assign a vulnerability score



## B. Conservation value

Assign each species a conservation value score based on three contributing components

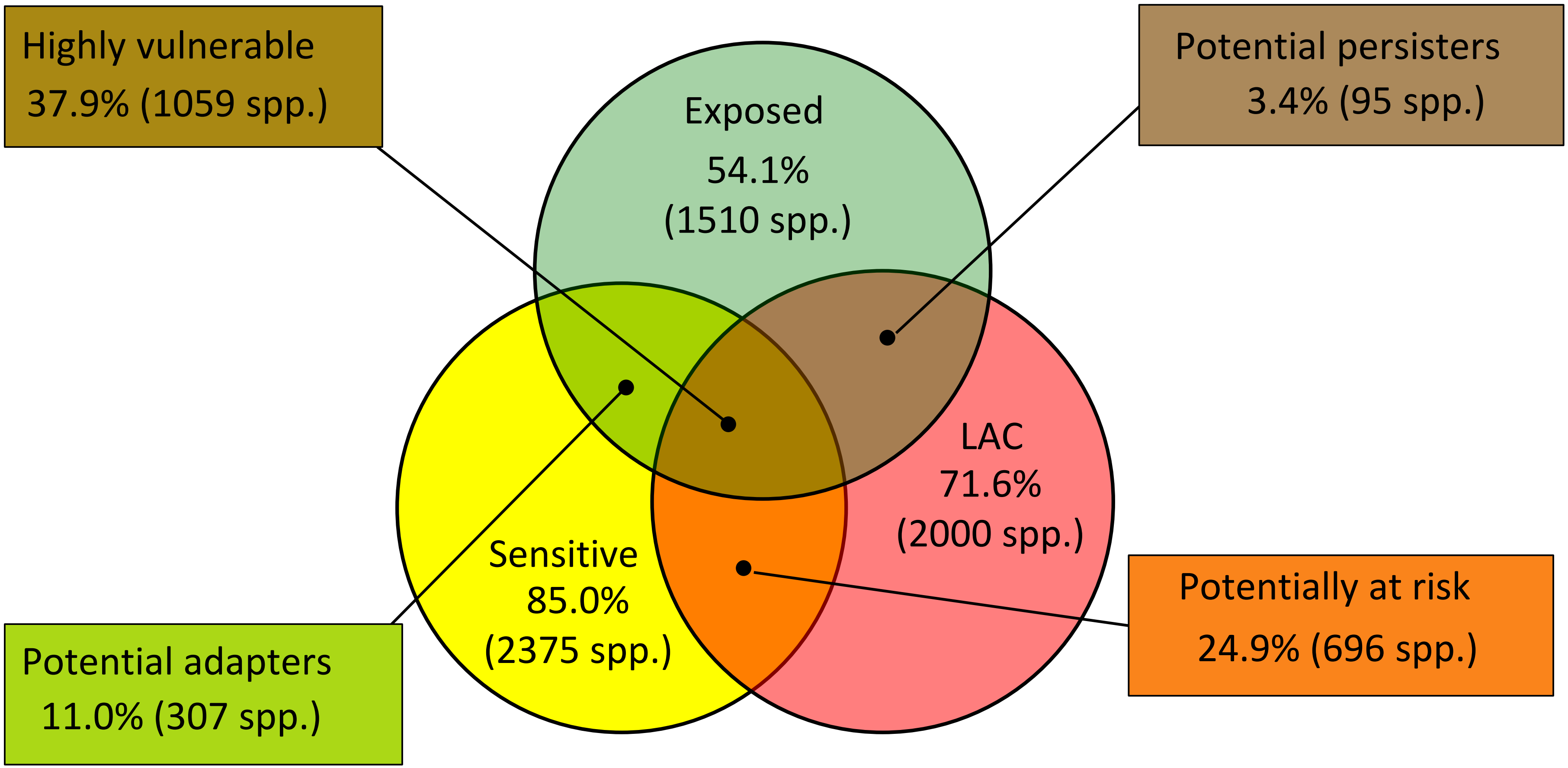
(i) Importance for human use (fishing, aquarium trade, etc.)

(ii) Endemism

(iii) Threat status (IUCN Red List)

Fishbase
IUCN redlist
Literature Review

2794 species (85% of the ~3300 described species)




High conservation value
61% (1714 spp.)

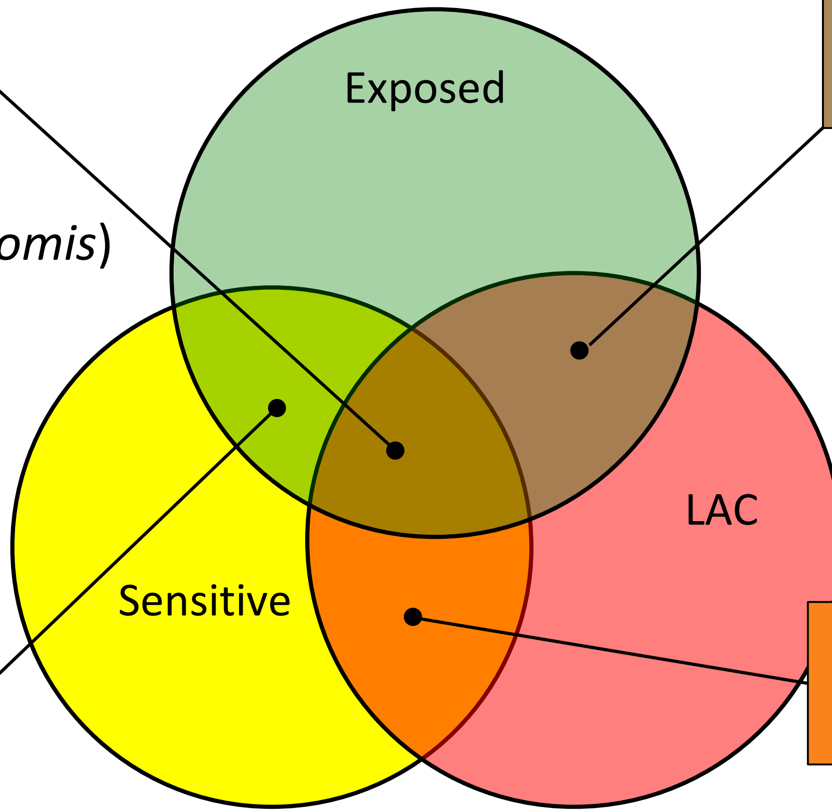
In revision for Biological Conservation

Highly vulnerable

Cichlids (Genus *Haplochromis*)

- Mouth brooder, low fecundity, restricted dispersal
- Specific habitat requirements, low temperature tolerance

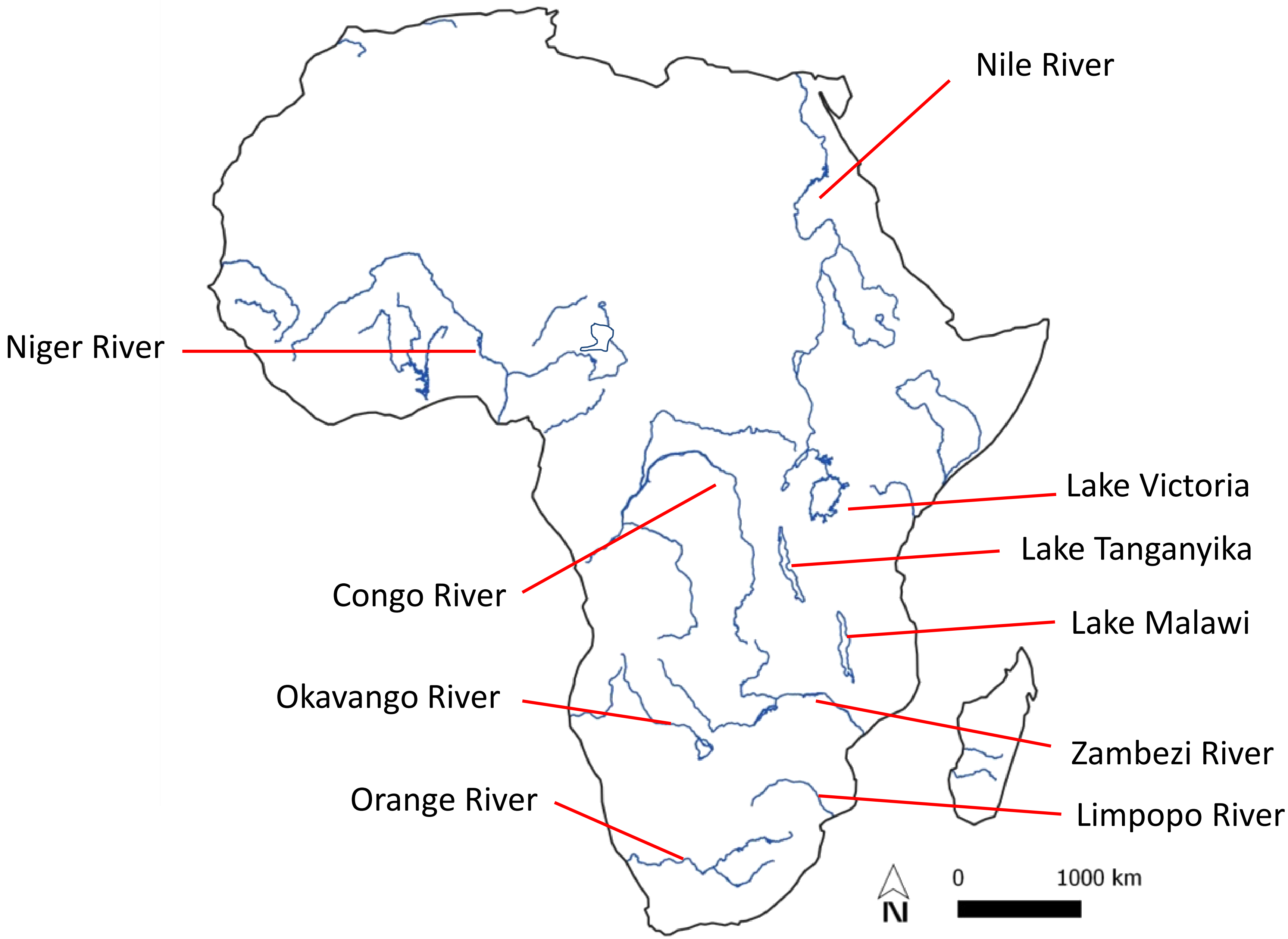
Potential persisters



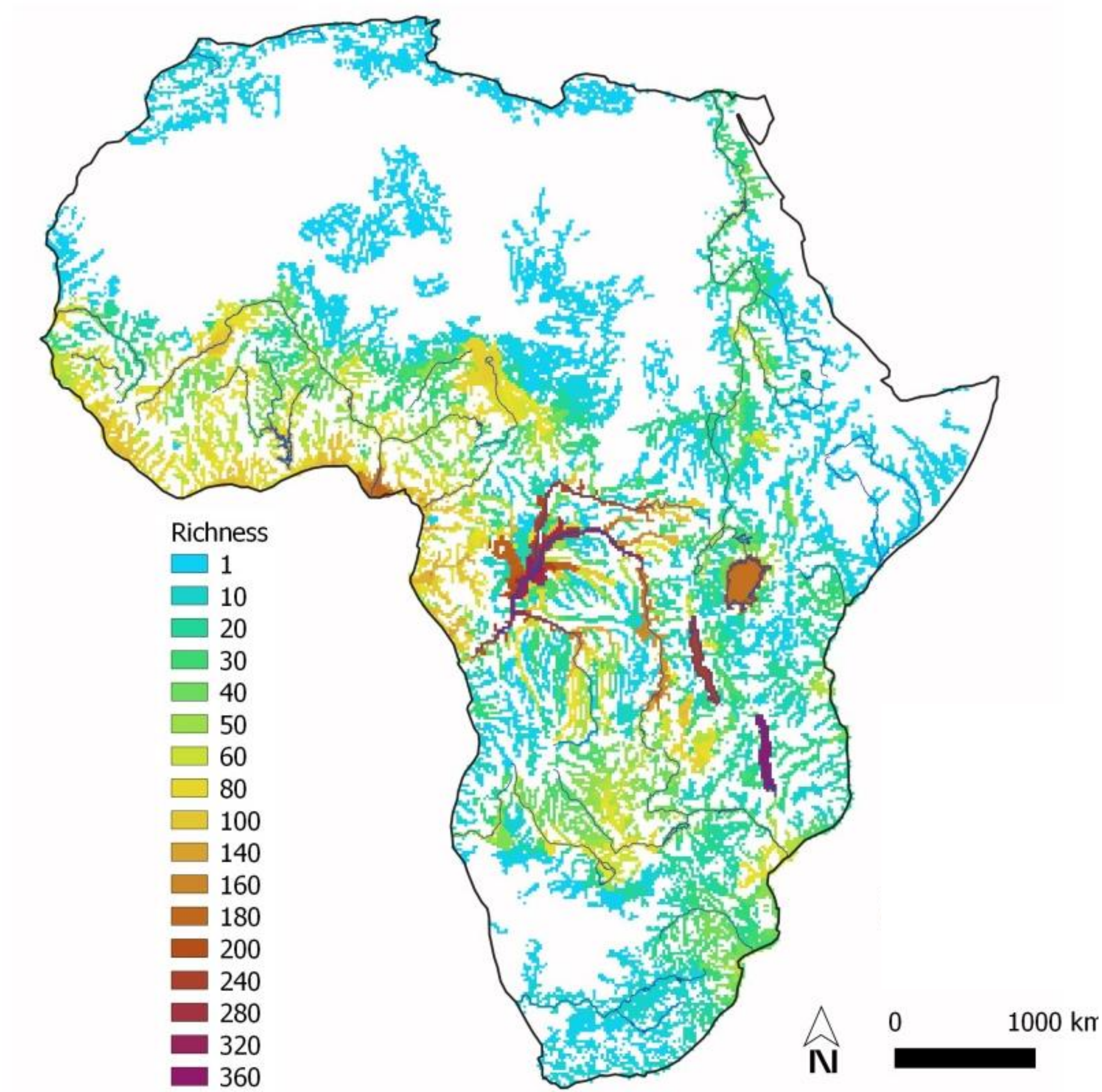

Potentially at risk

Potential adapters

High conservation value
61% (1714 spp.)


Nile River
Niger River
Lake Victoria
Lake Tanganyika
Congo River
Lake Malawi
Okavango River
Zambezi River
Orange River
Limpopo River
N
0
1000 km

# Species richness

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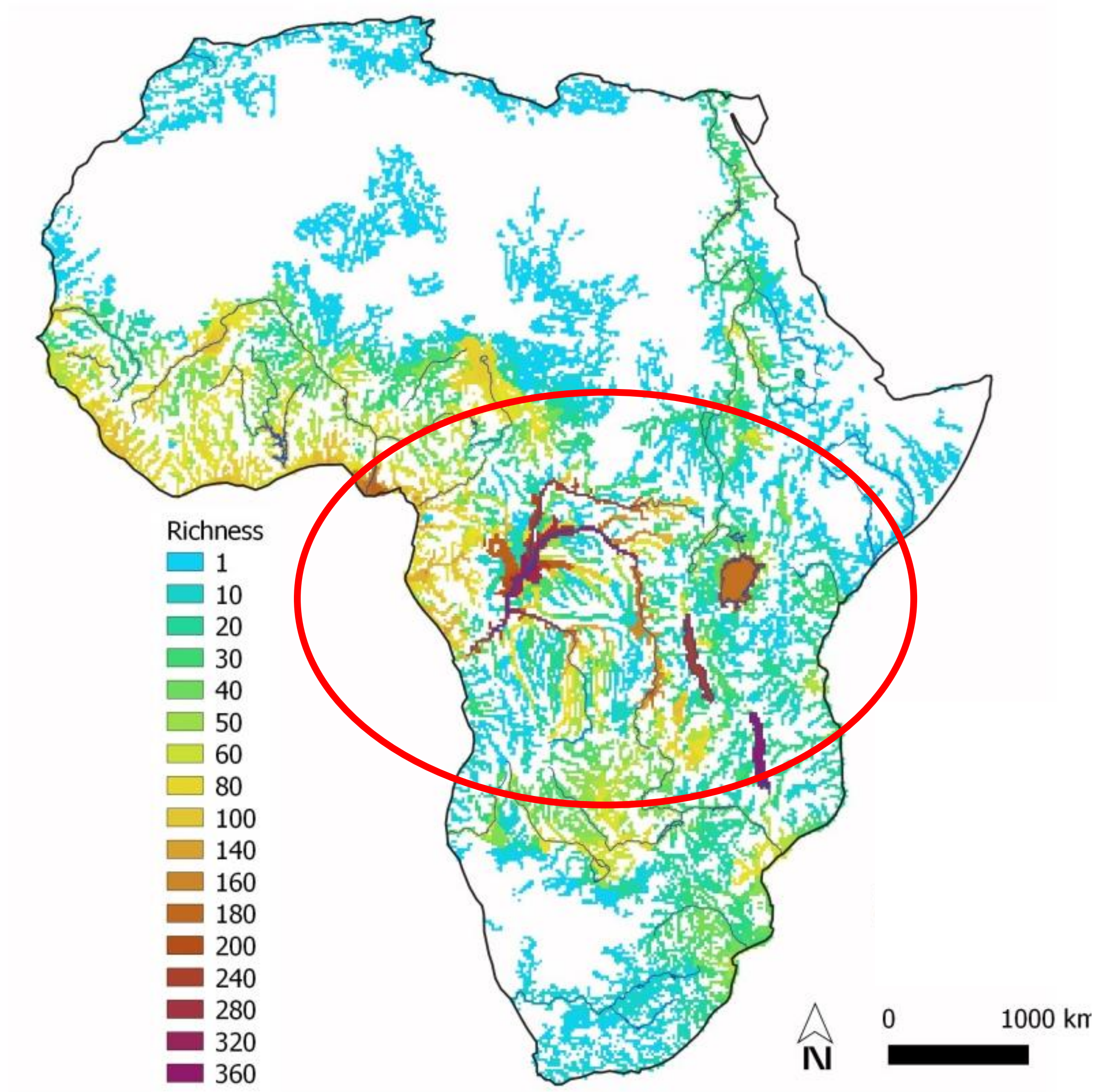


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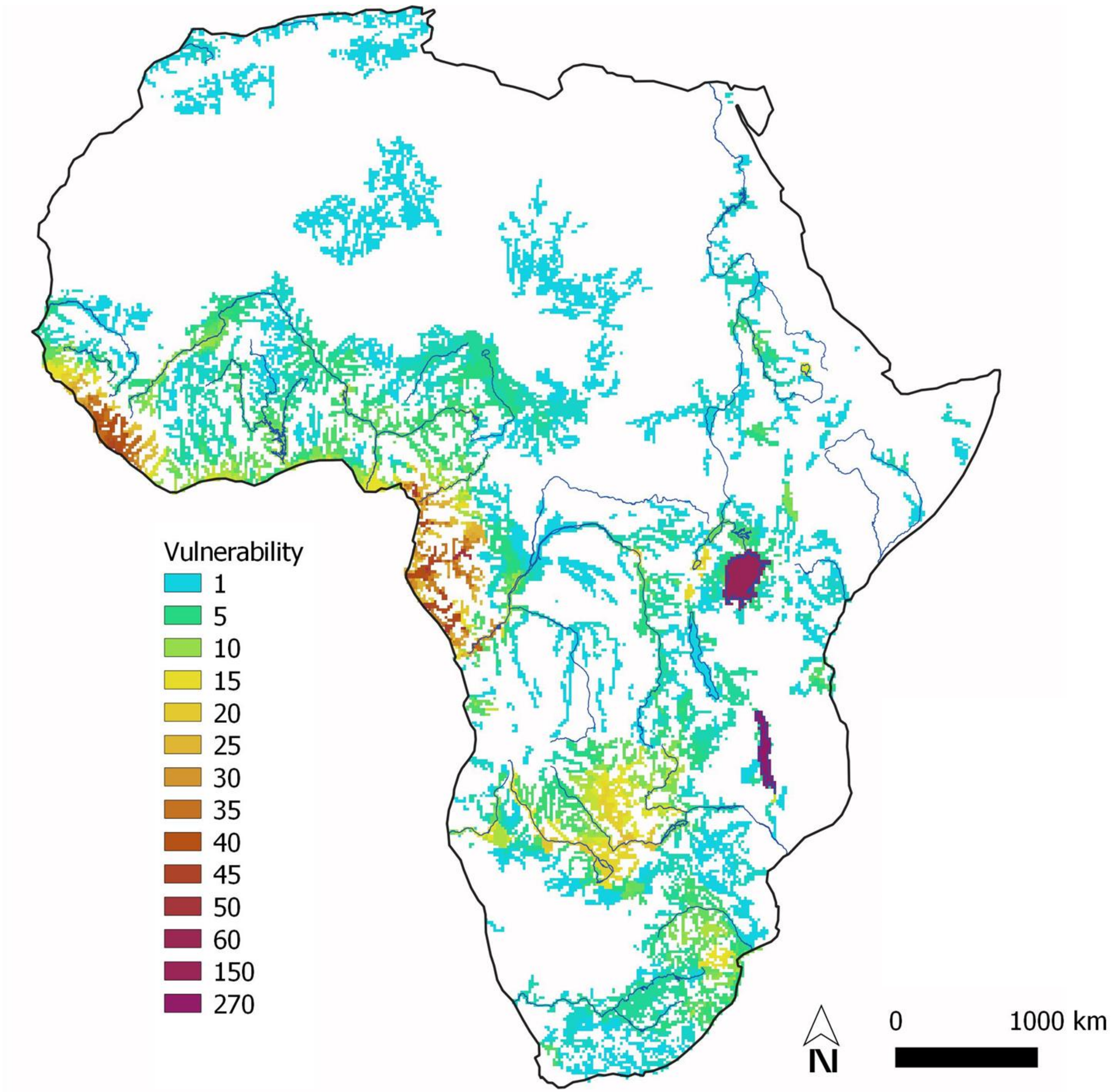
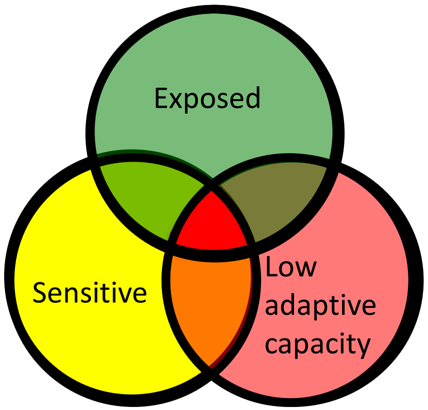
# Climate change vulnerability

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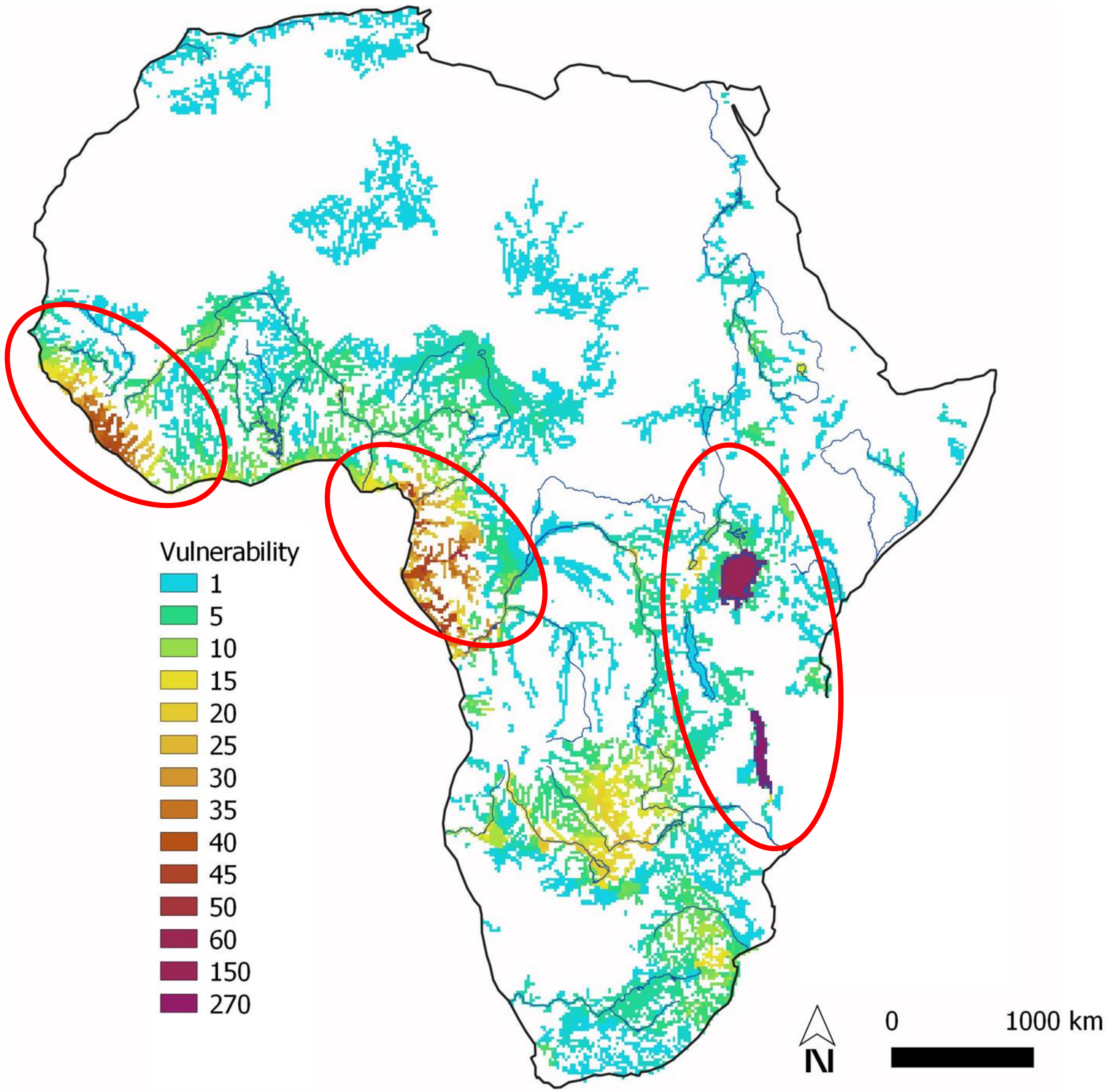
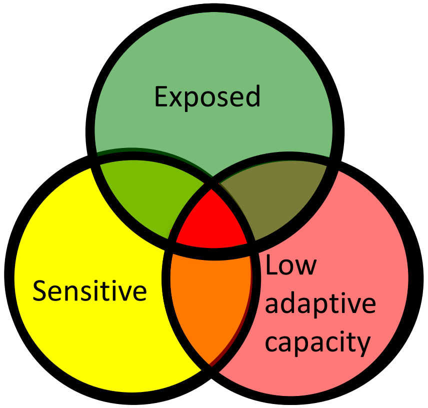
# Climate change vulnerability

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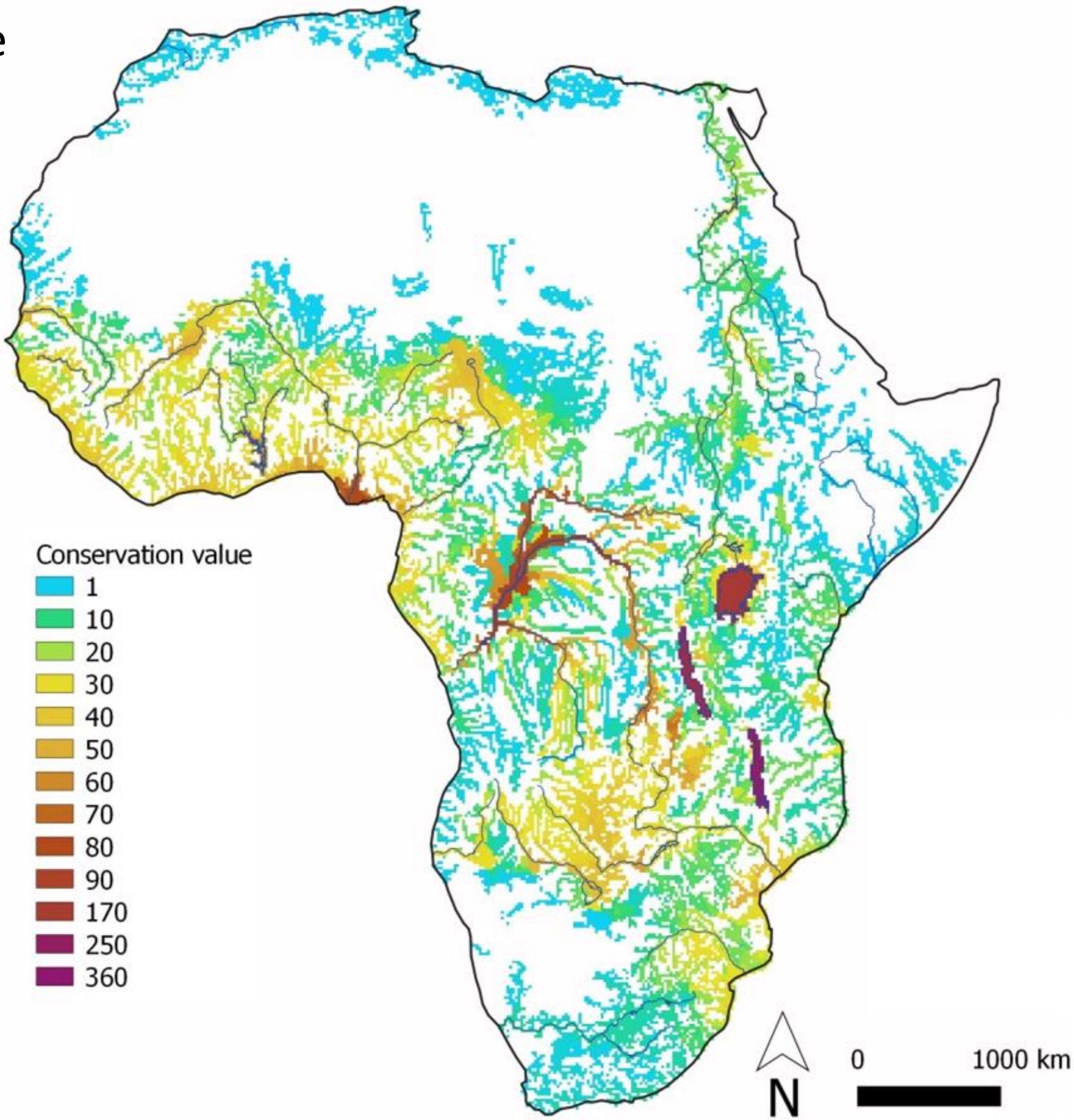
# Conservation value

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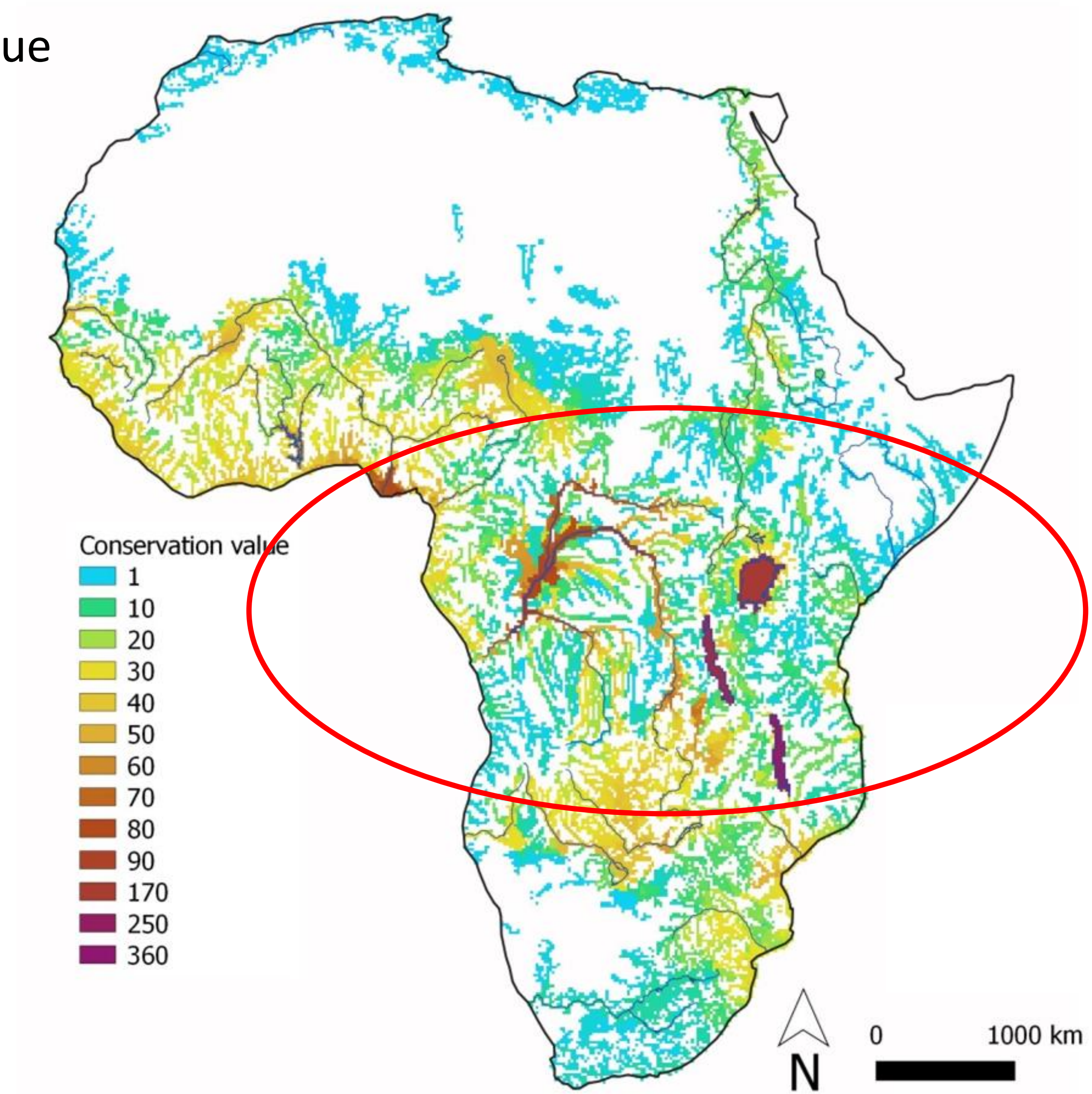


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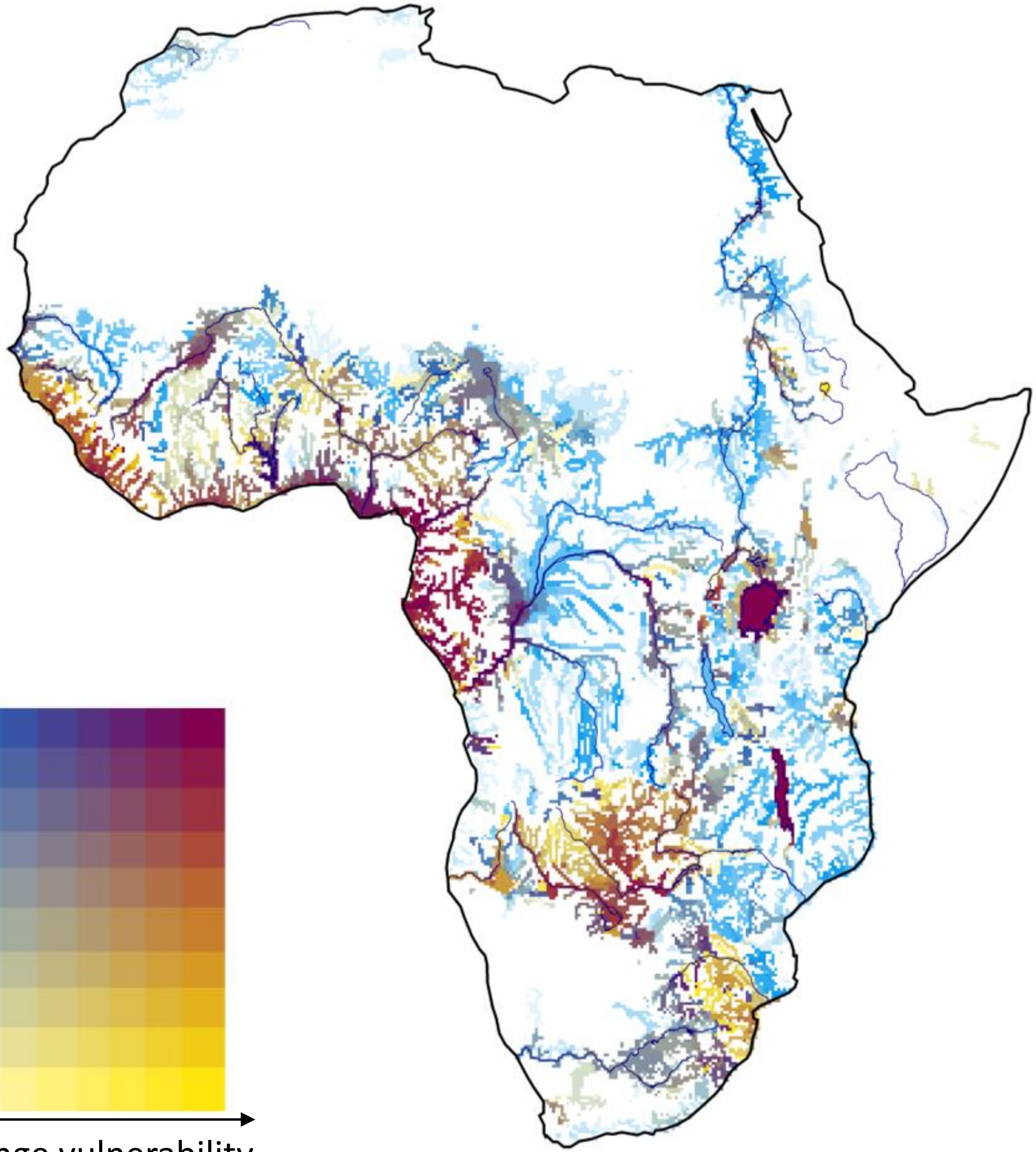
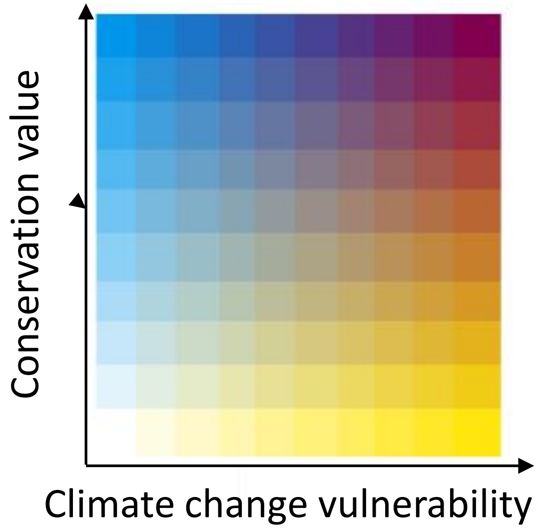
Conservation value
X
Climate change vulnerability






In revision for Biological Conservation

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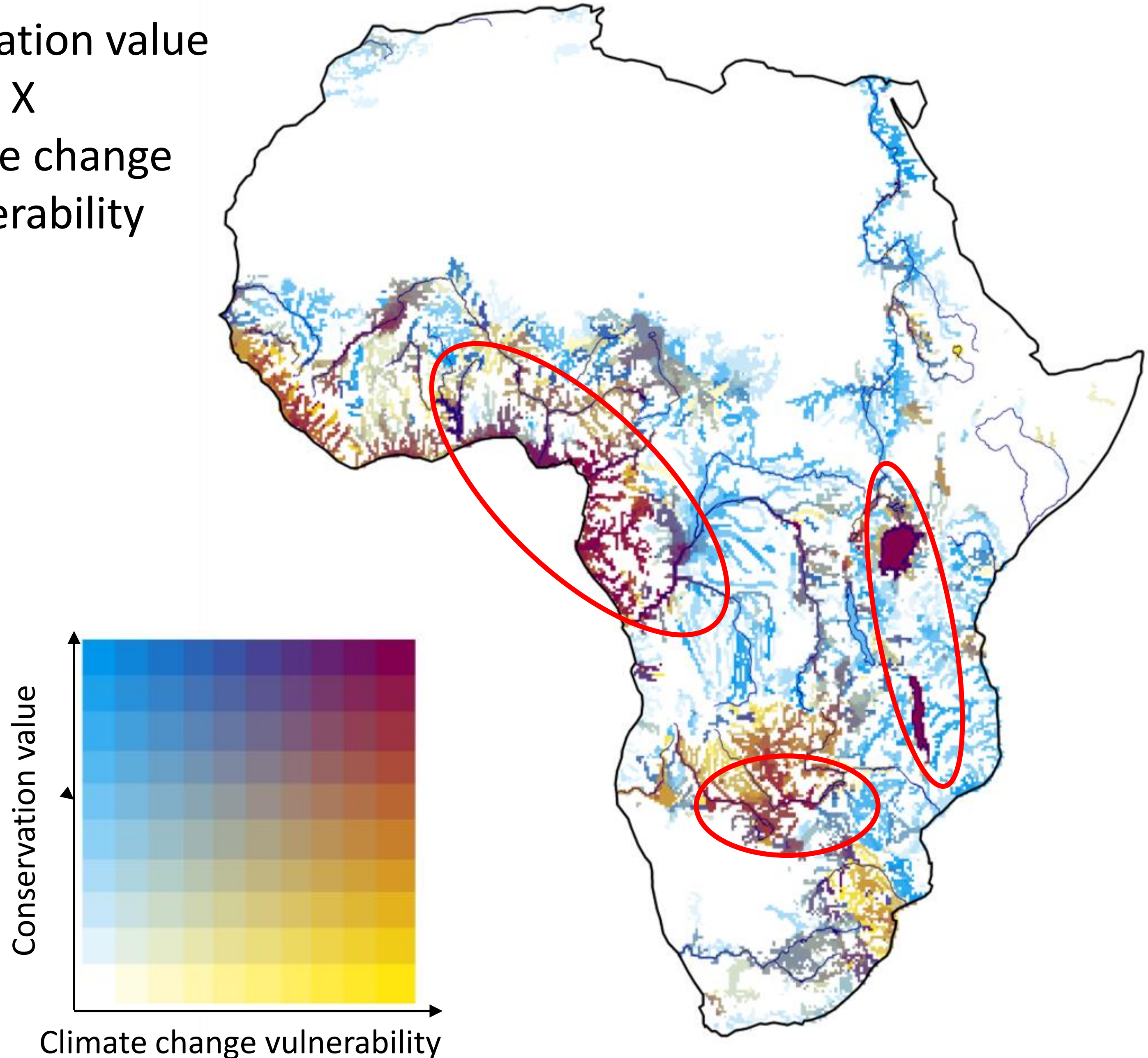


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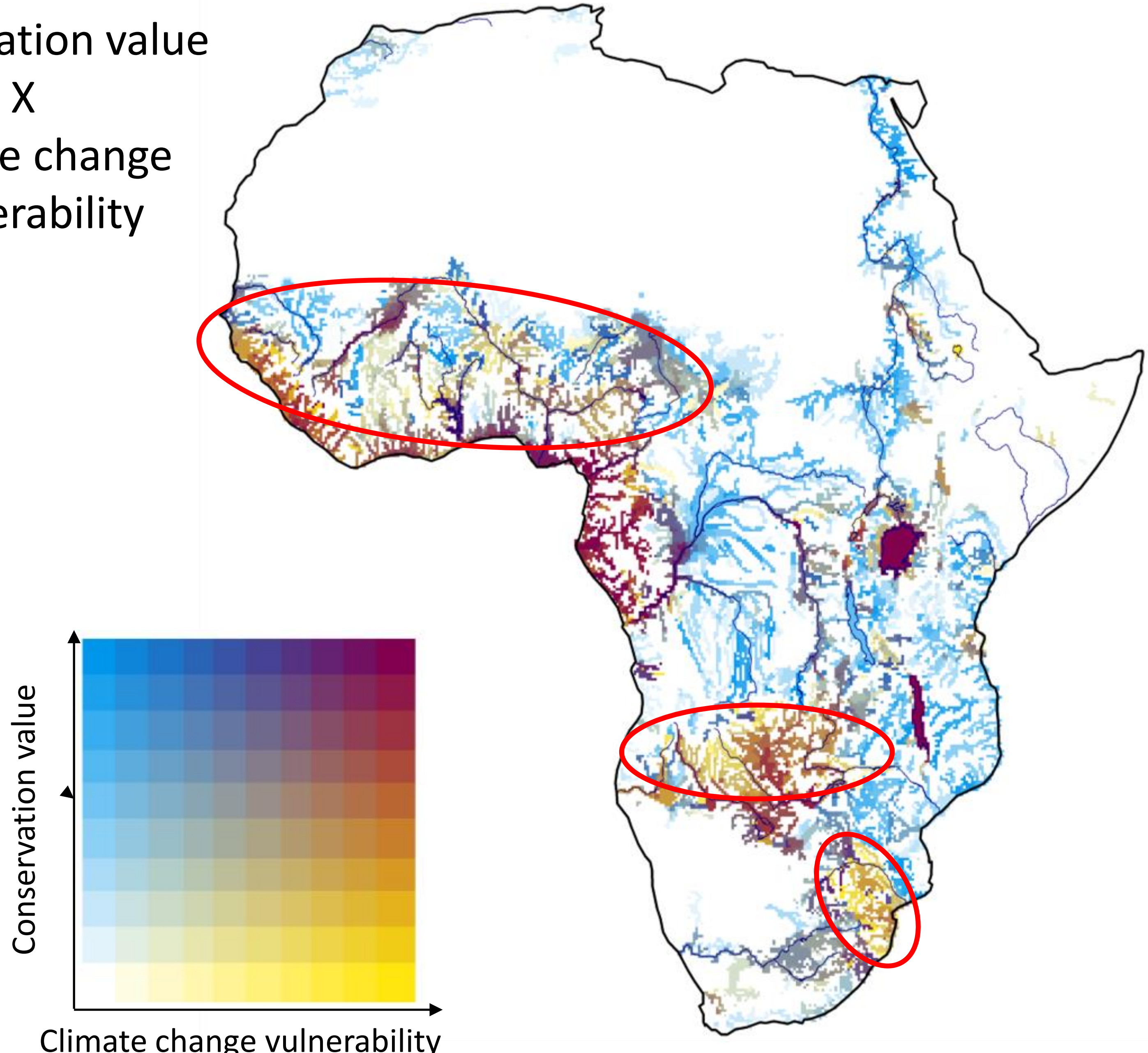


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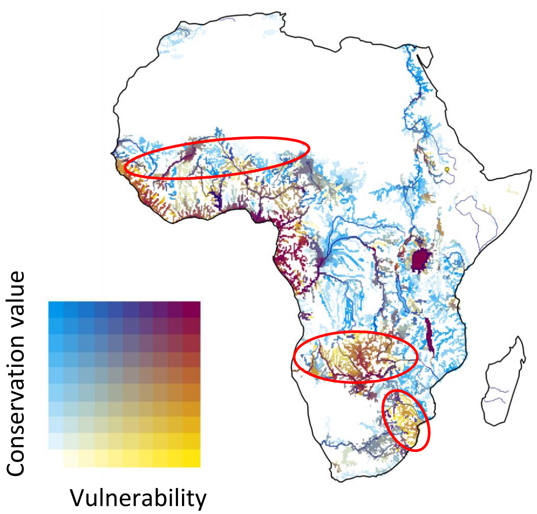
## Conclusions

- Highlights regions and species of greatest overall concern and where there are emerging risks due to climate change

- Direction for conservation effort



## Chapter 1

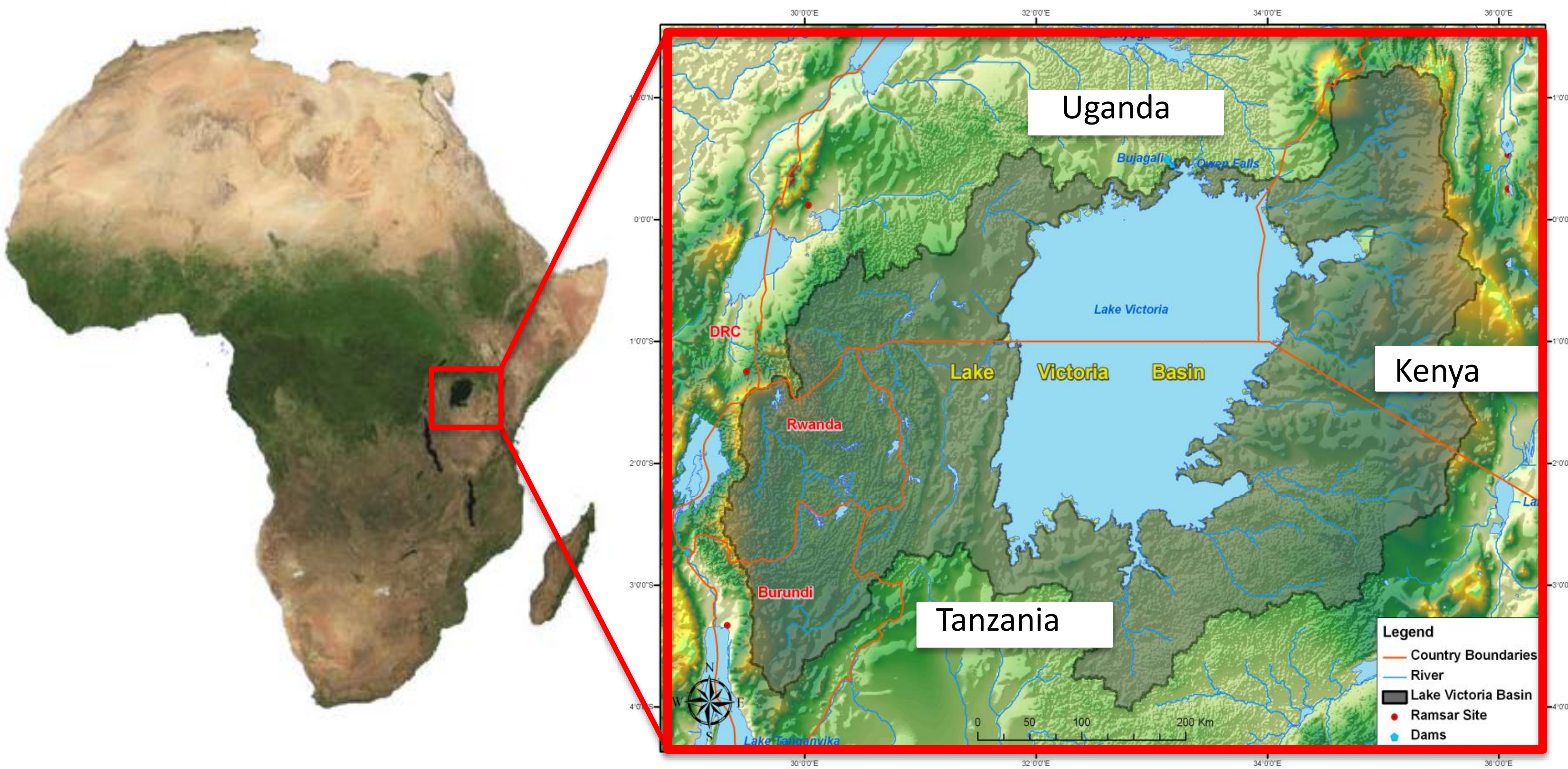

## Chapters 2 & 3

Testing the ability of Nile perch to modify their thermal tolerance limits upon exposure to heat stress

## Chapter 4

Determine the adaptive capacity of fishing communities to projected changes in the LVB fishery

# Study system - Lake Victoria basin (LVB)




- Africa's most important source of inland fisheries production
- High human population growth rate ( > 50 million by 2050 )
- Predict increases in temp ( 1 - 4°C ) and changes in seasonal patterns

## Study system – Nile perch (*Lates niloticus*)

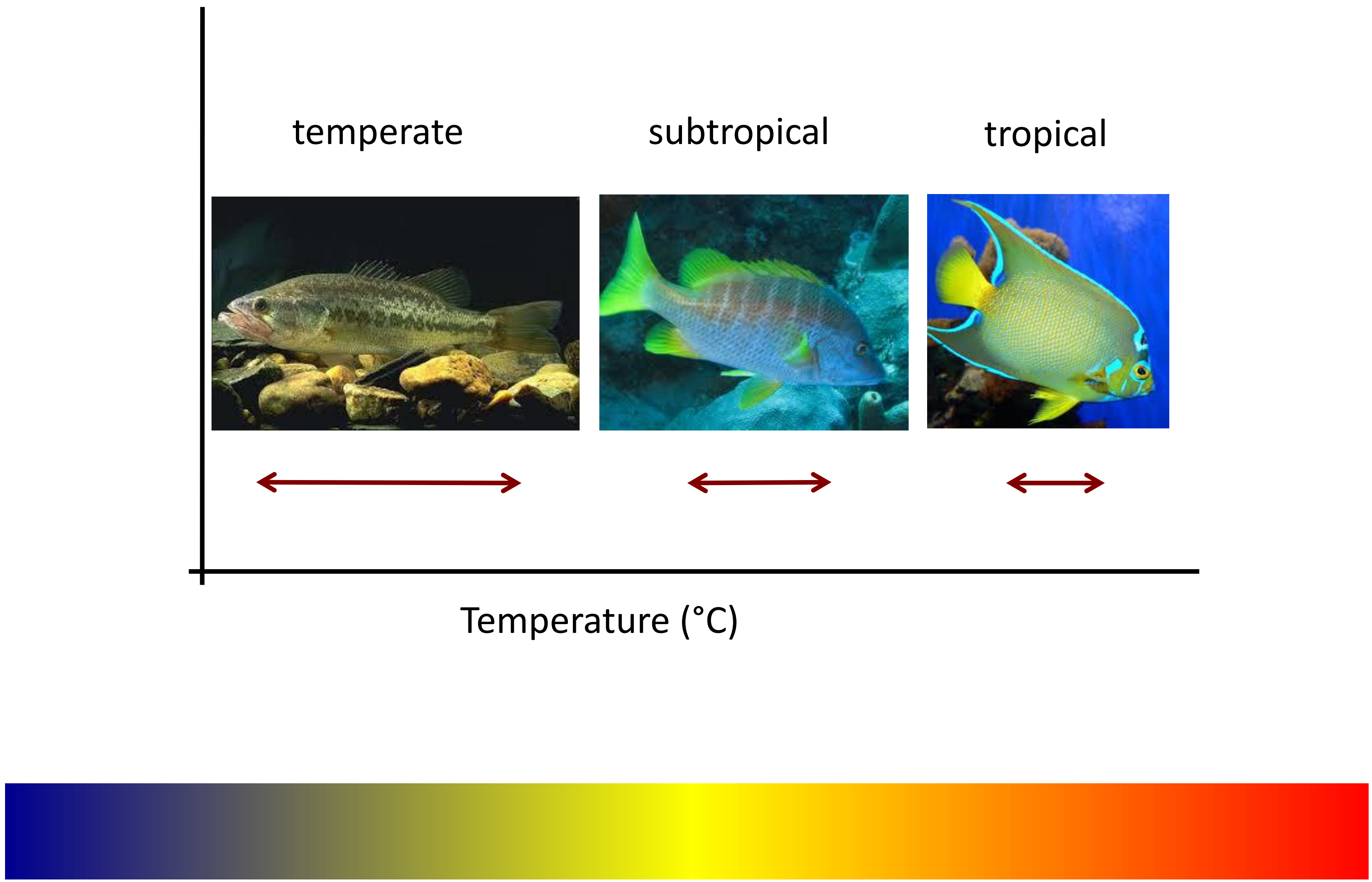
-One of the most important economic species in the Lake Victoria fishery

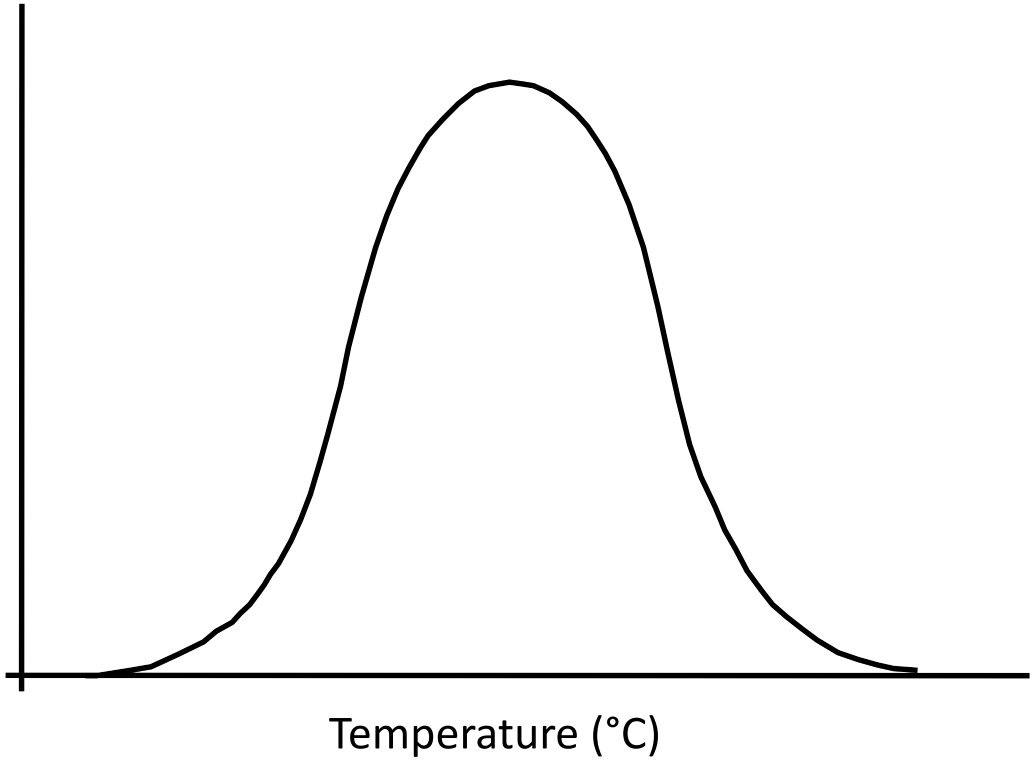
# Chapters 2 & 3 – Climate change and the metabolic performance of Nile perch in the Lake Victoria basin

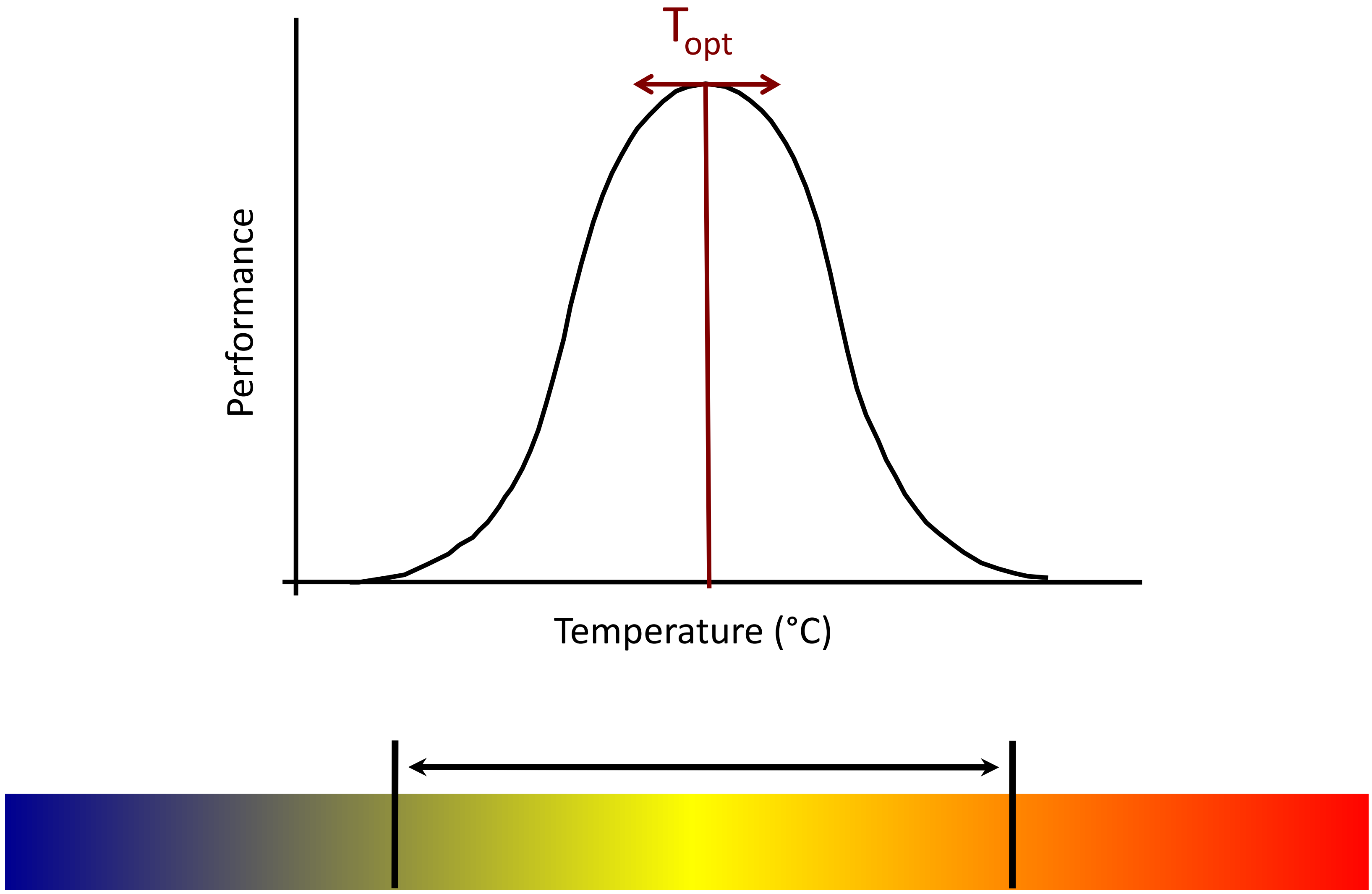
## Chapters 2 & 3 – Climate change and the metabolic performance of Nile perch in the Lake Victoria basin

Chapter 2 : Short term (3-day / 3-week) thermal acclimation

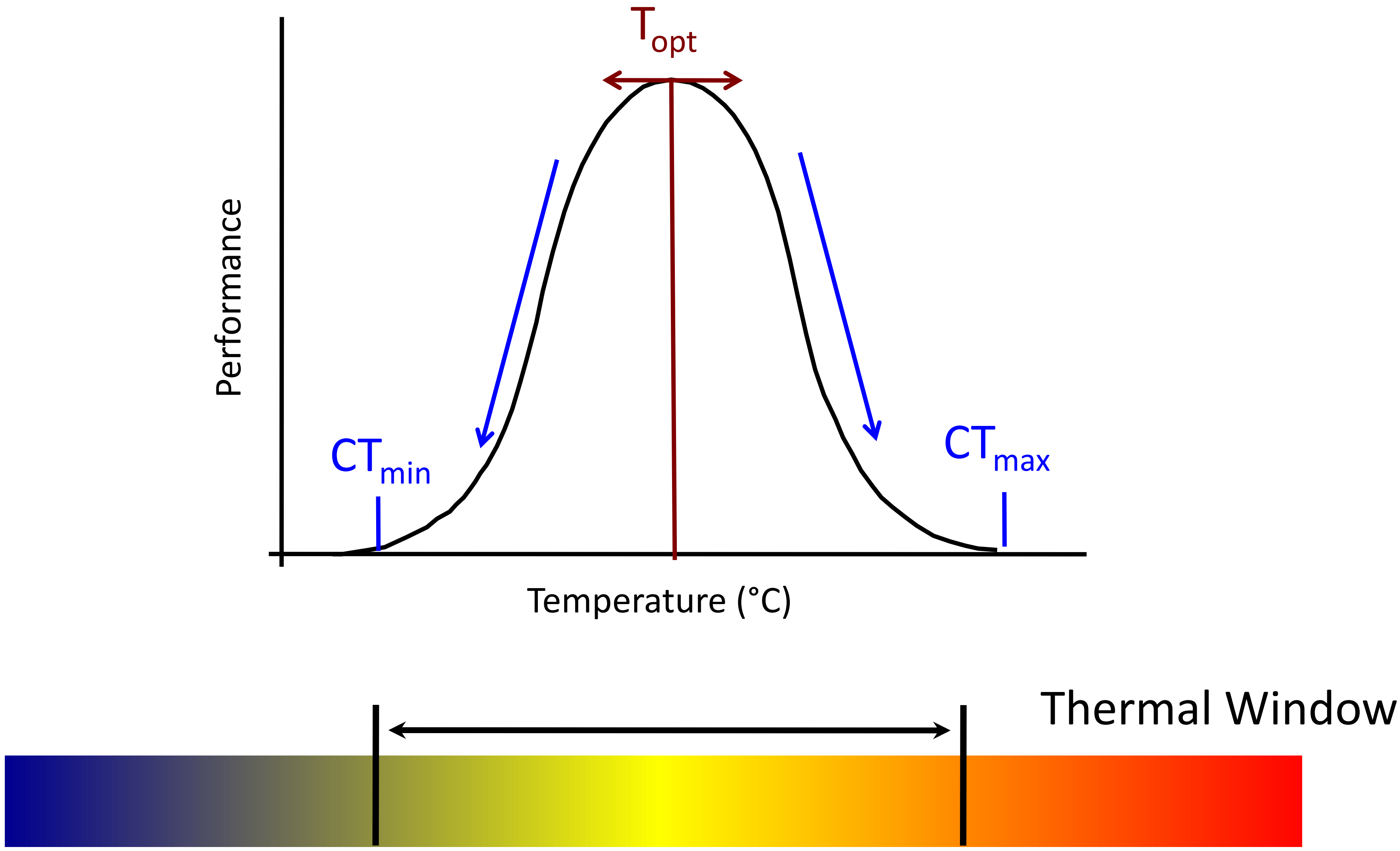
Chapter 3 : Long term (3-month) thermal acclimation


temperate
subtropical
tropical
Temperature (°C)

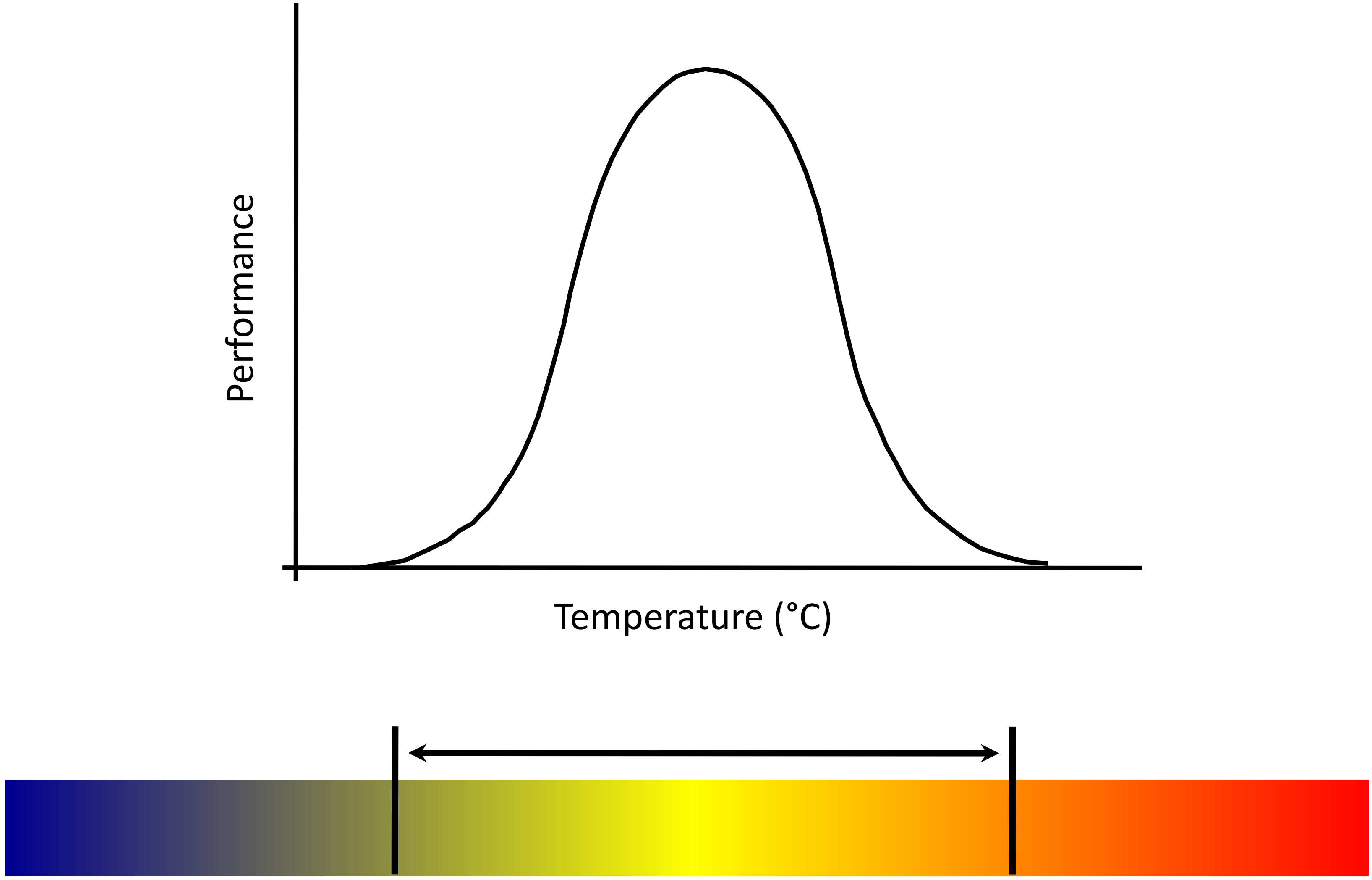

Temperature (°C)



$T_{opt}$
Performance
Temperature (°C)

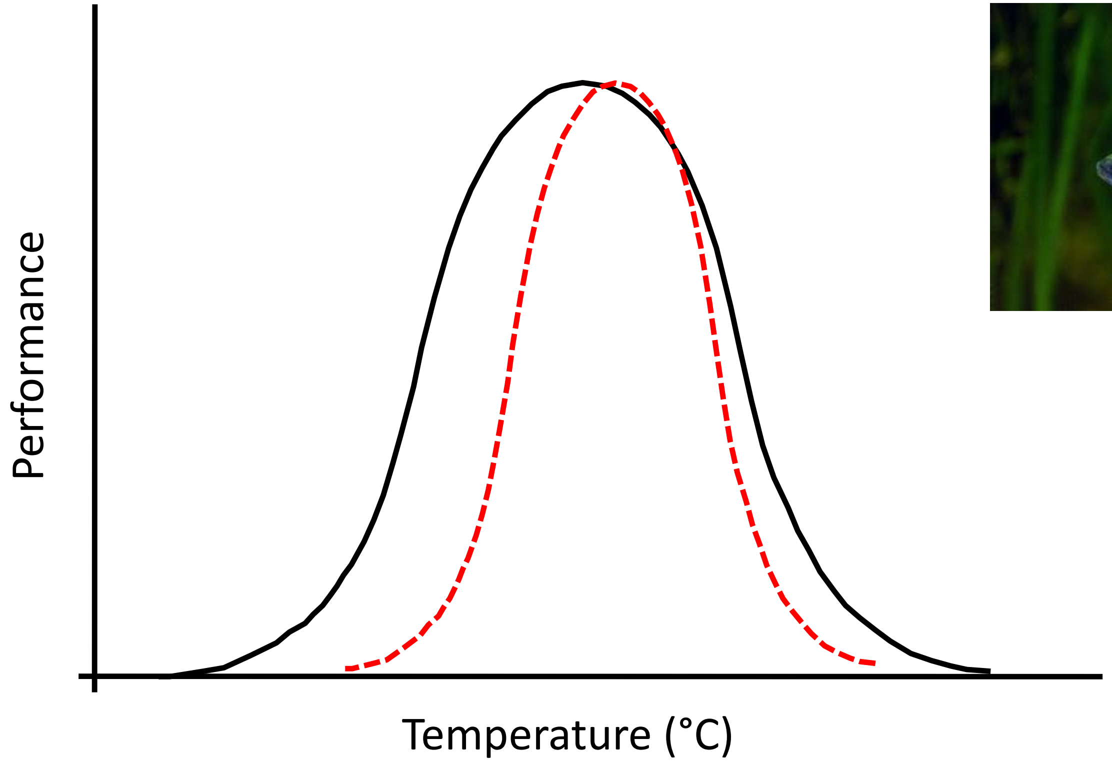

T
opt
Performance
CT
min
CT
max
Temperature (°C)
Thermal Window

# Adaptive background important in determining the thermal window



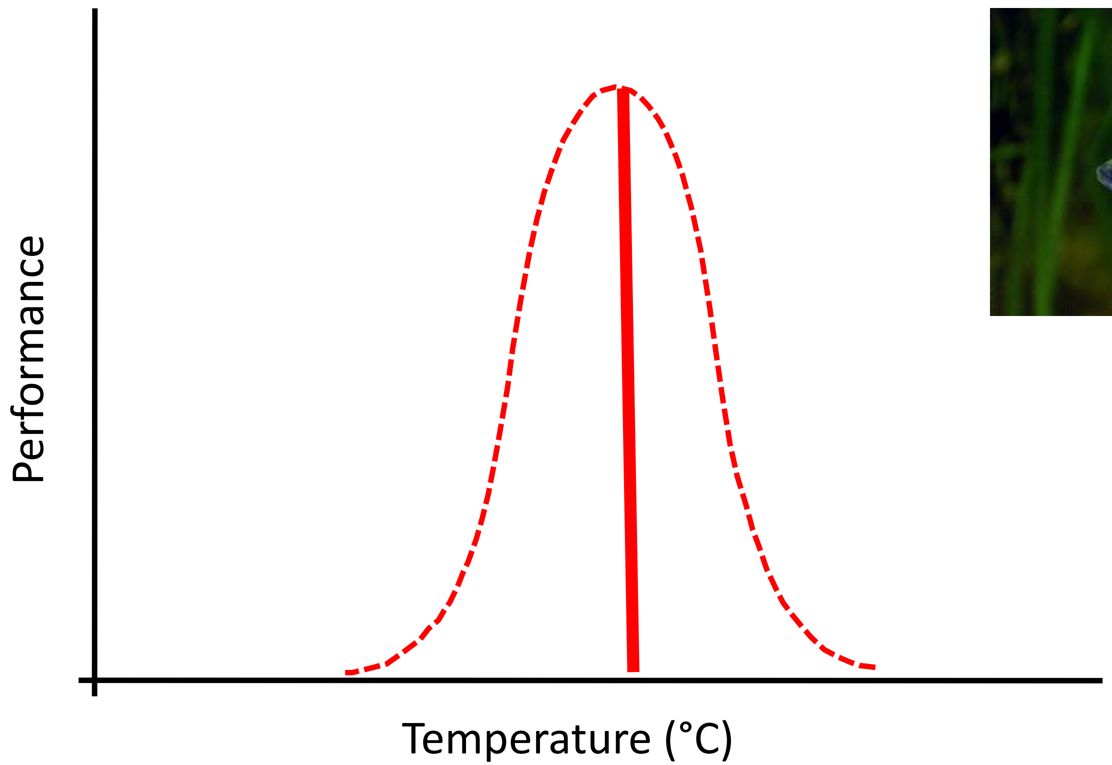
# Adaptive background important in determining the thermal window

- tropical species – thermo-stable environment

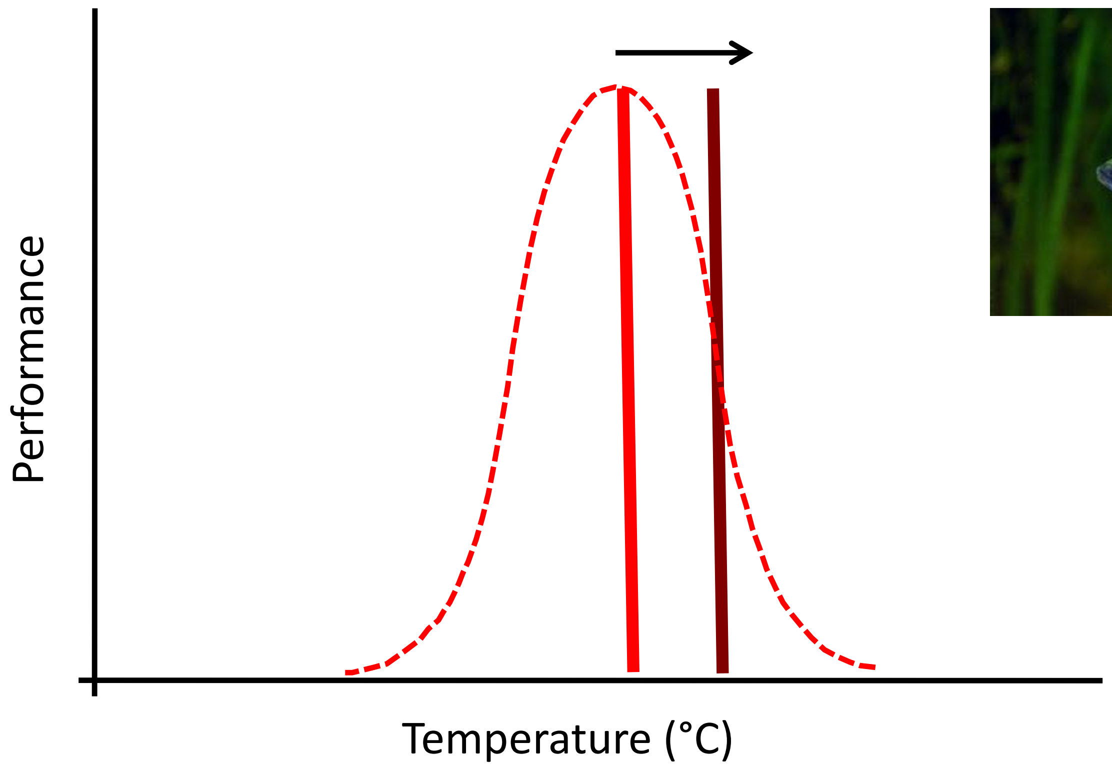



# Adaptive background important in determining the thermal window

- tropical species – live near upper thermal limit




# Small temperature increases = large negative performance consequences



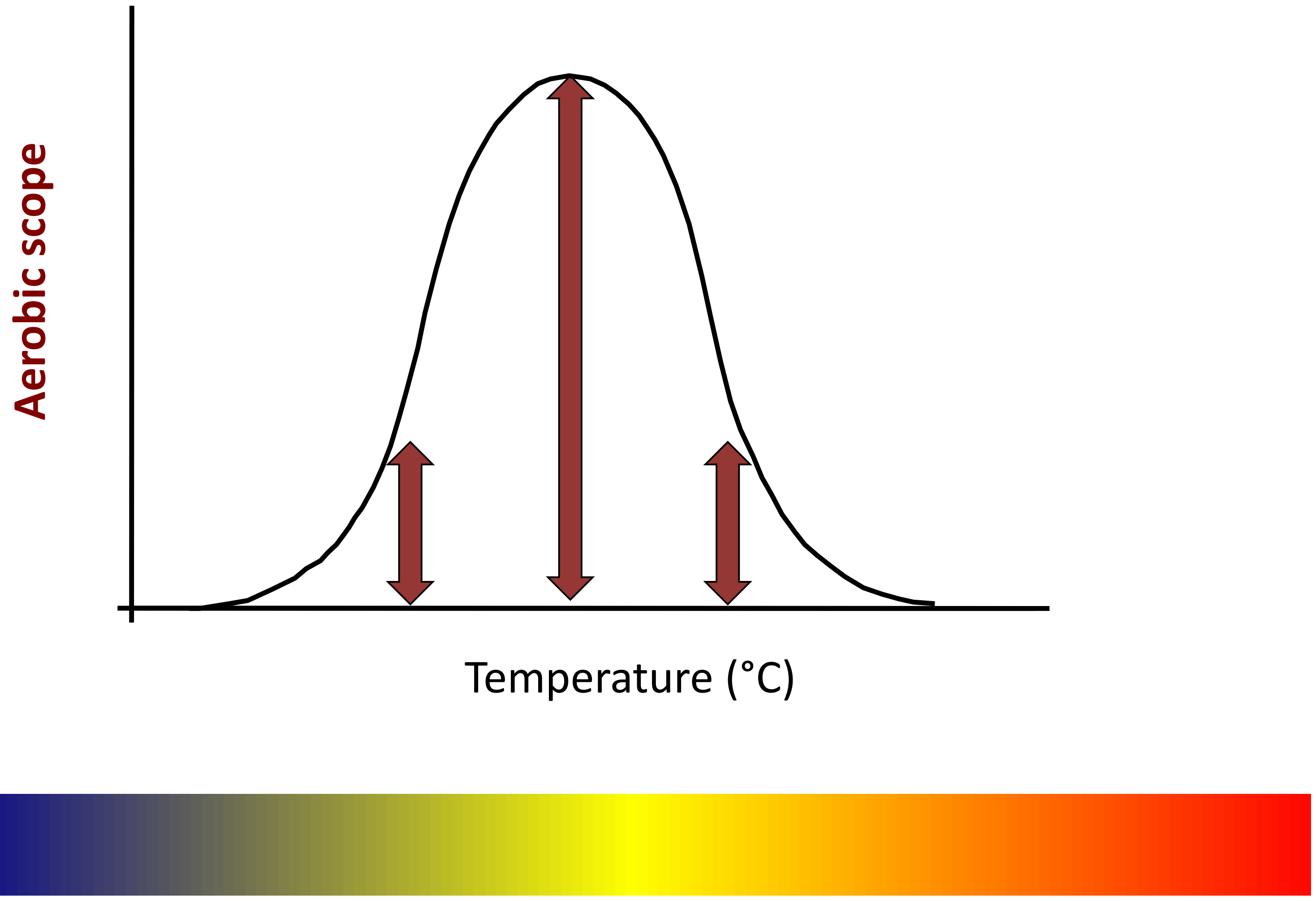

Maximum metabolic rate (MMR)

**Aerobic Scope**

Standard metabolic rate (SMR)

↑ aerobic scope = ↑ potential for activity over and above base survival

Aerobic scope is hypothesized to decrease at the upper and lower thermal limits



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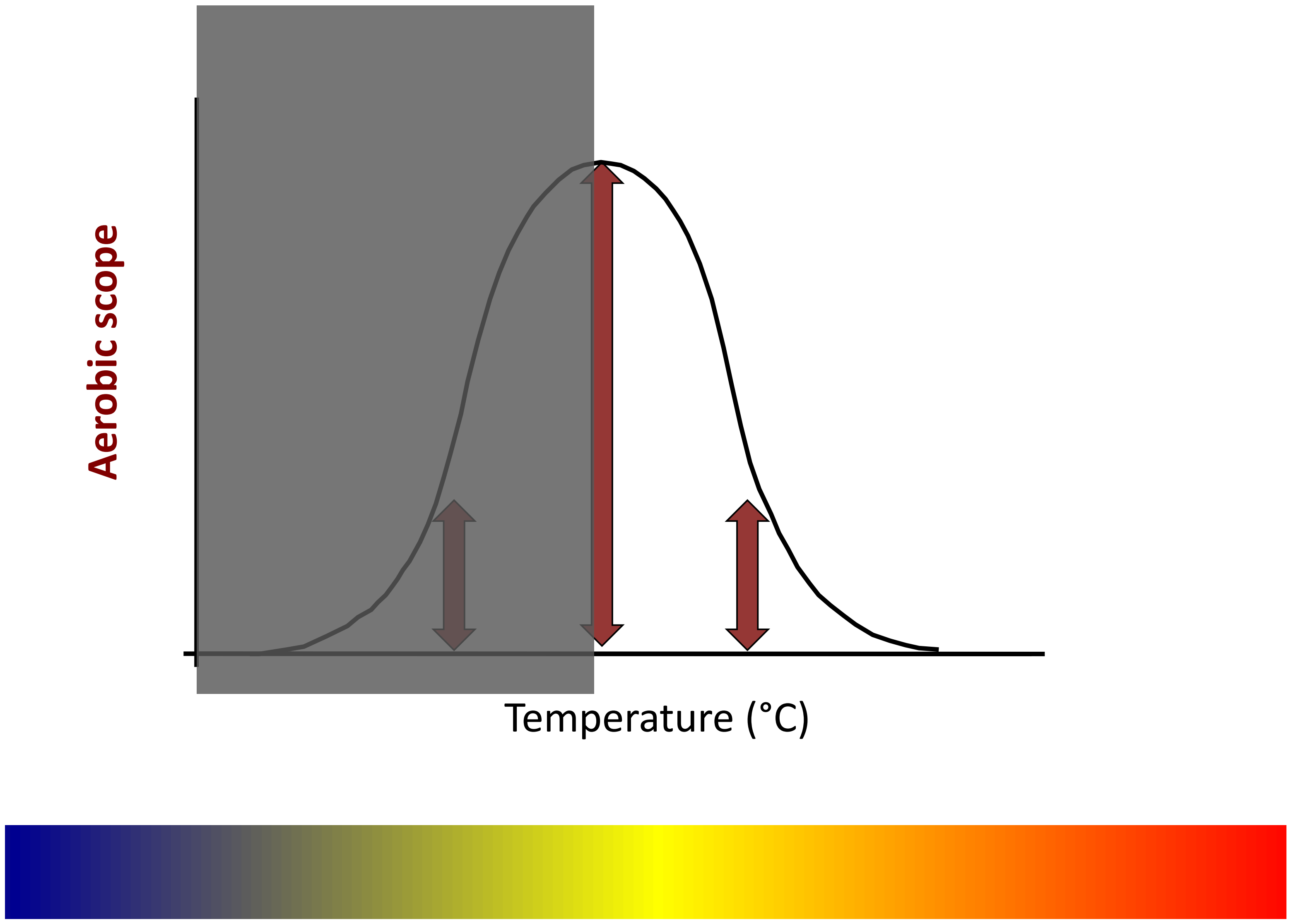

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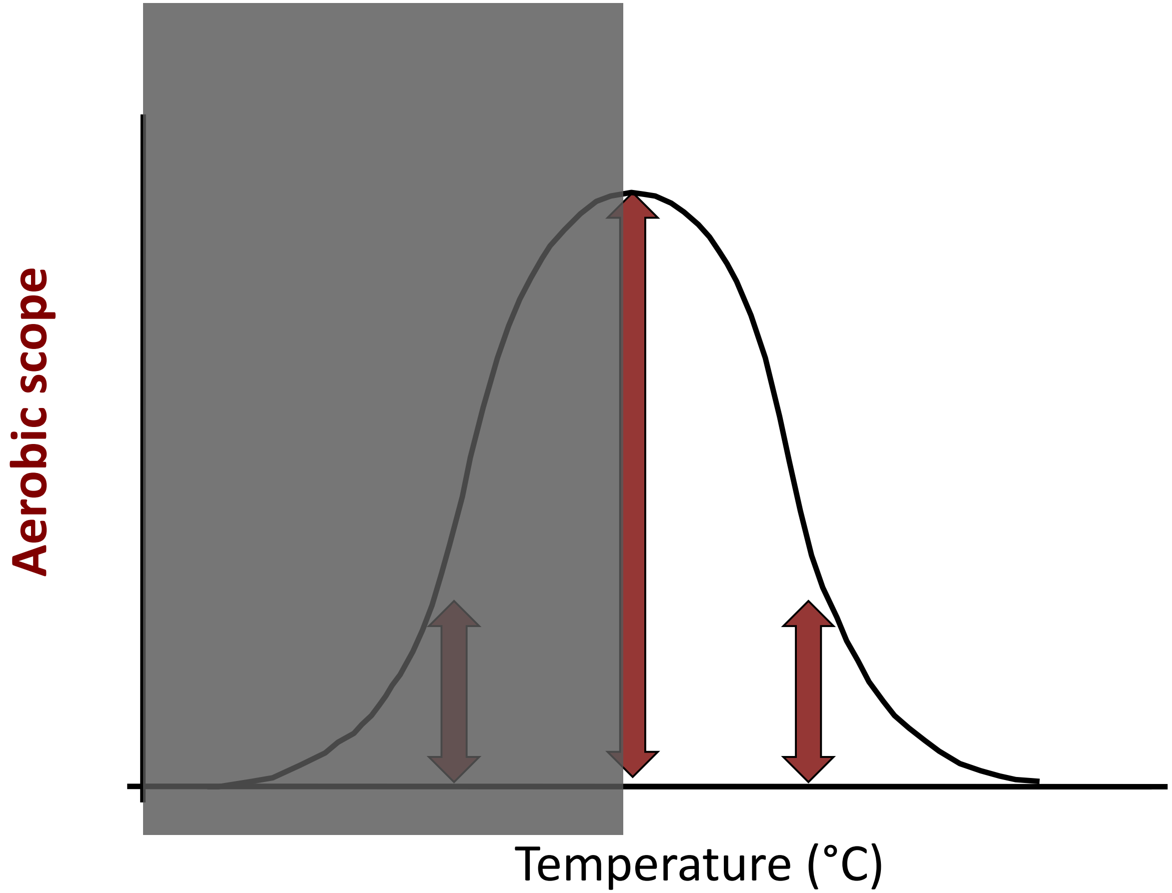
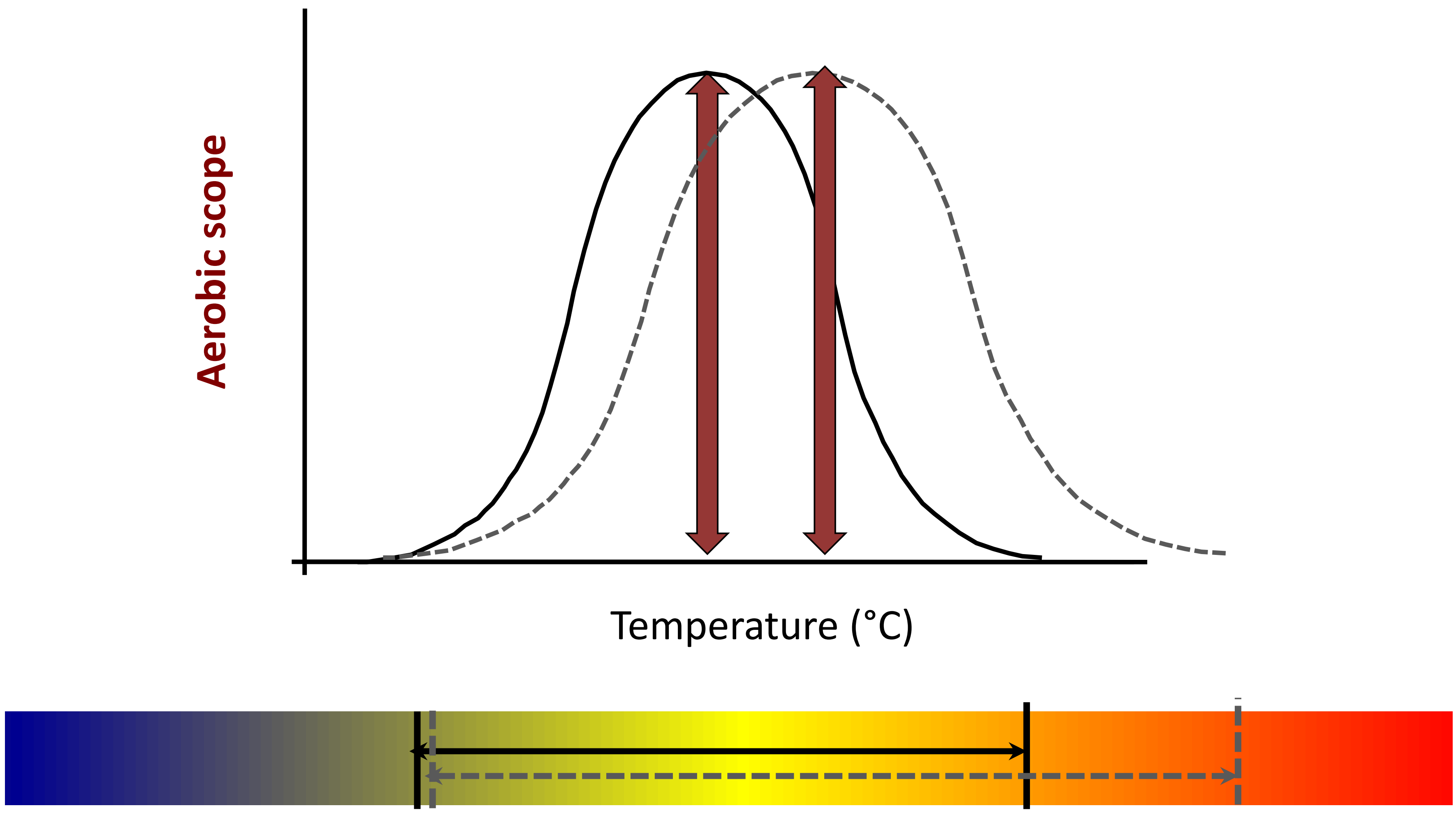
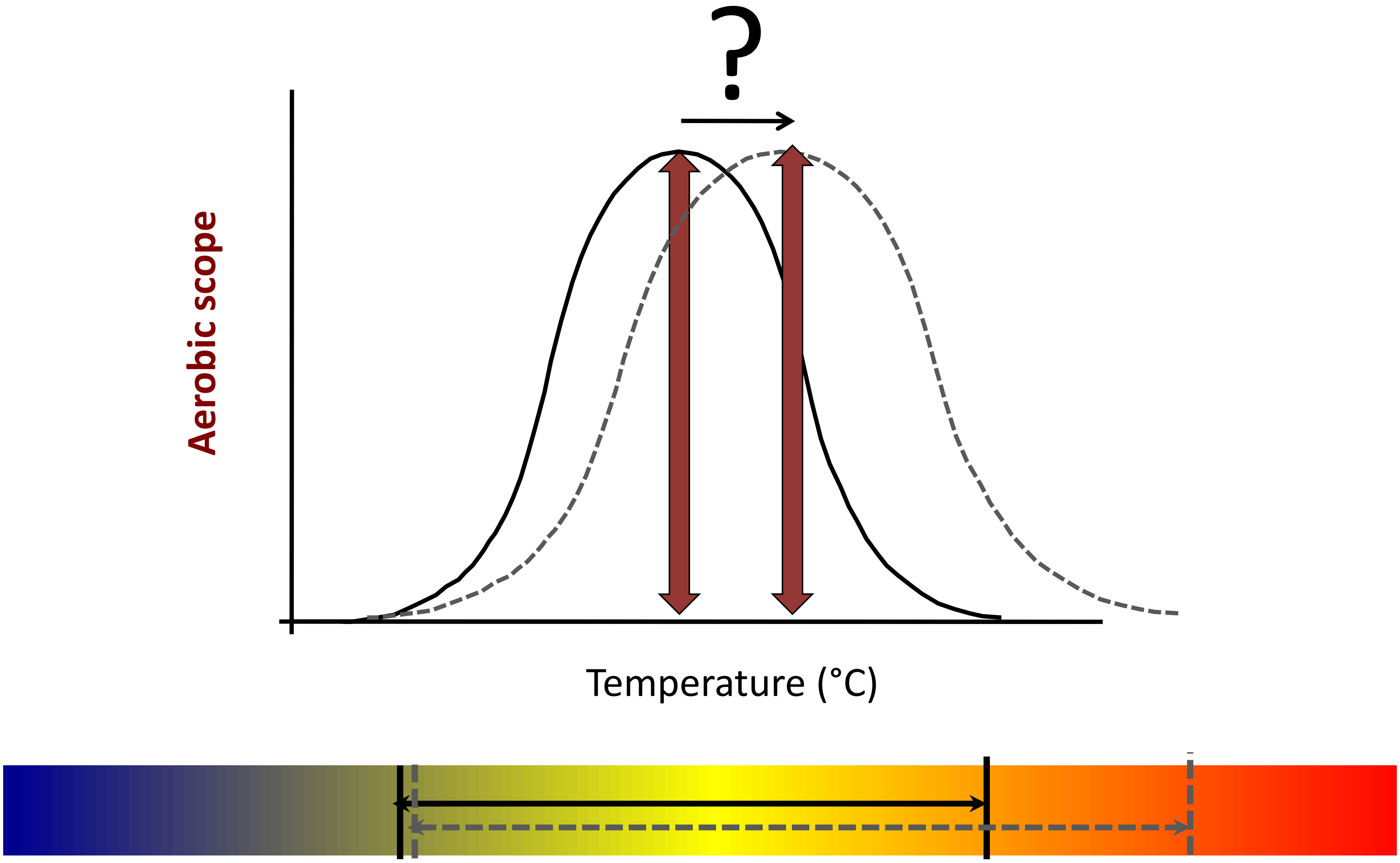



Reduced aerobic performance predicted to negatively affect growth / reproduction

# Thermal acclimation – adjust the width or peak of thermal optimum



# Determining acclimation potential can help to predict responses to warming



# **Chapter 2** Short term (3-day / 3-week) thermal acclimation

## **Chapter 2** Short term (3-day / 3-week) thermal acclimation

Objective

To understand how predicted warming will affect aerobic metabolic performance in Nile perch, and to compare responses across acclimation times.

# 3-day

Nile perch captured from Lake Victoria

# 3-day

Nile perch captured from Lake Victoria

27°C | 29°C | 31°C | 33°C | 35°C

3-day acclimation

## 3-day

Nile perch captured from Lake Victoria

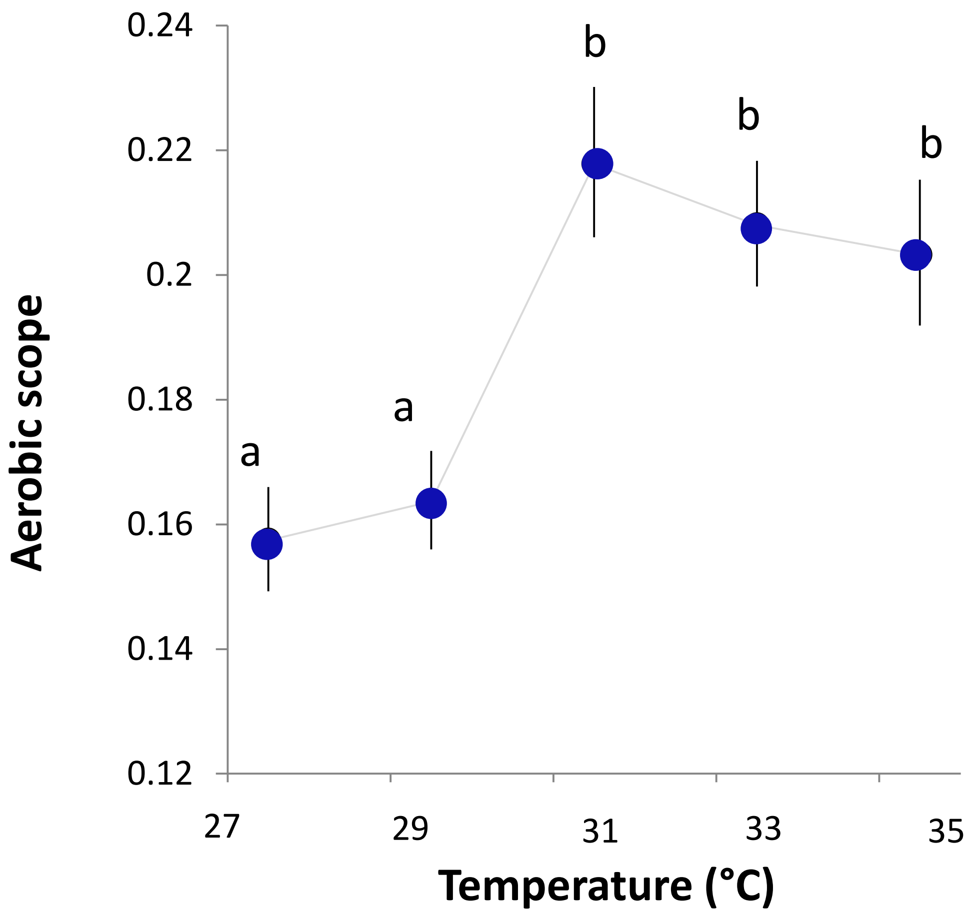
27°C | 29°C | 31°C | 33°C | 35°C

3-day acclimation

SMR, MMR, AS | SMR, MMR, AS | SMR, MMR, AS | SMR, MMR, AS | SMR, MMR, AS

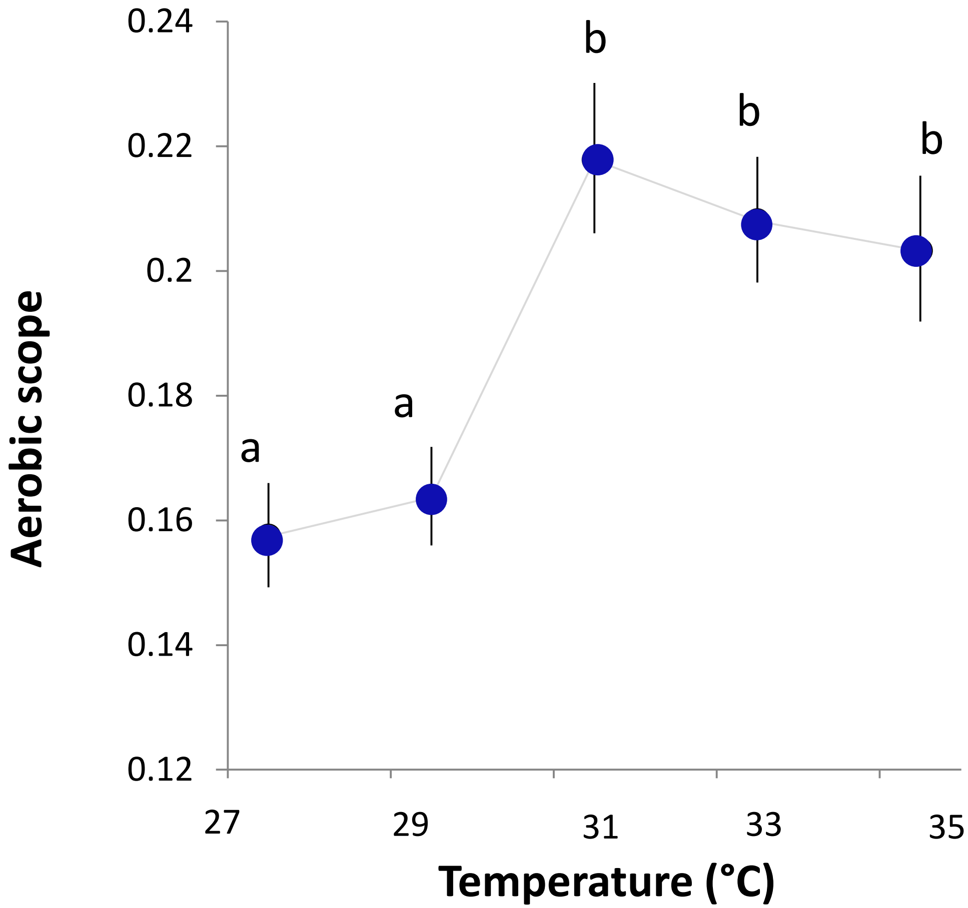
Respirometry

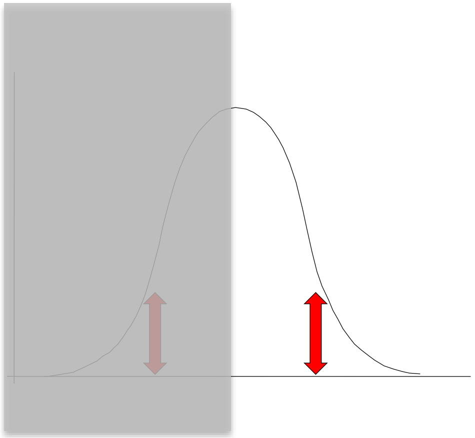
# 3-day – Aerobic scope




Nyboer & Chapman, 2017, JExpBiol

# 3-day – Aerobic scope



Maintenance of high aerobic scope at extreme high temperatures

# 3-week

Nile perch captured from Lake Victoria

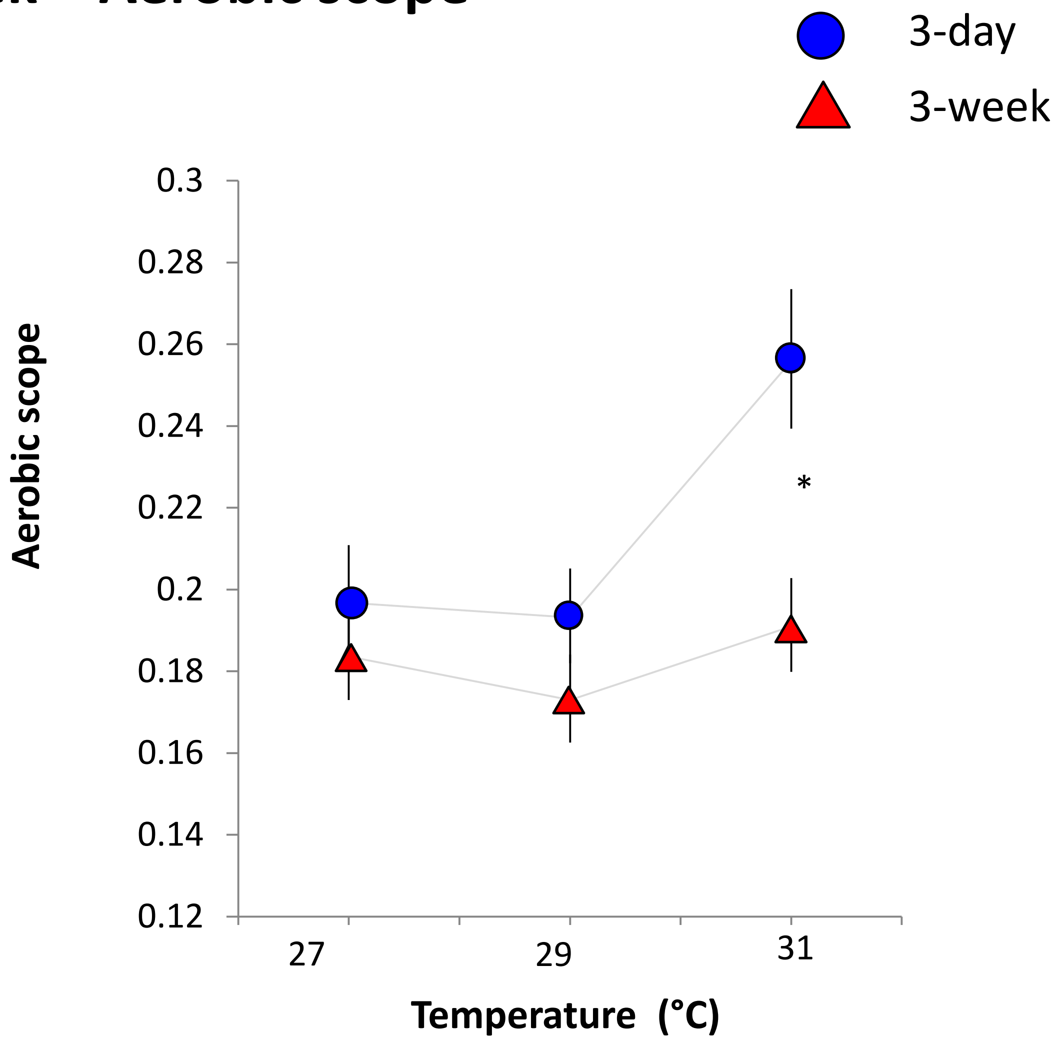
| 27°C | 29°C | 31°C |
|---|---|---|

3-week acclimation

| SMR, MMR, AS | SMR, MMR, AS | SMR, MMR, AS |
|---|---|---|

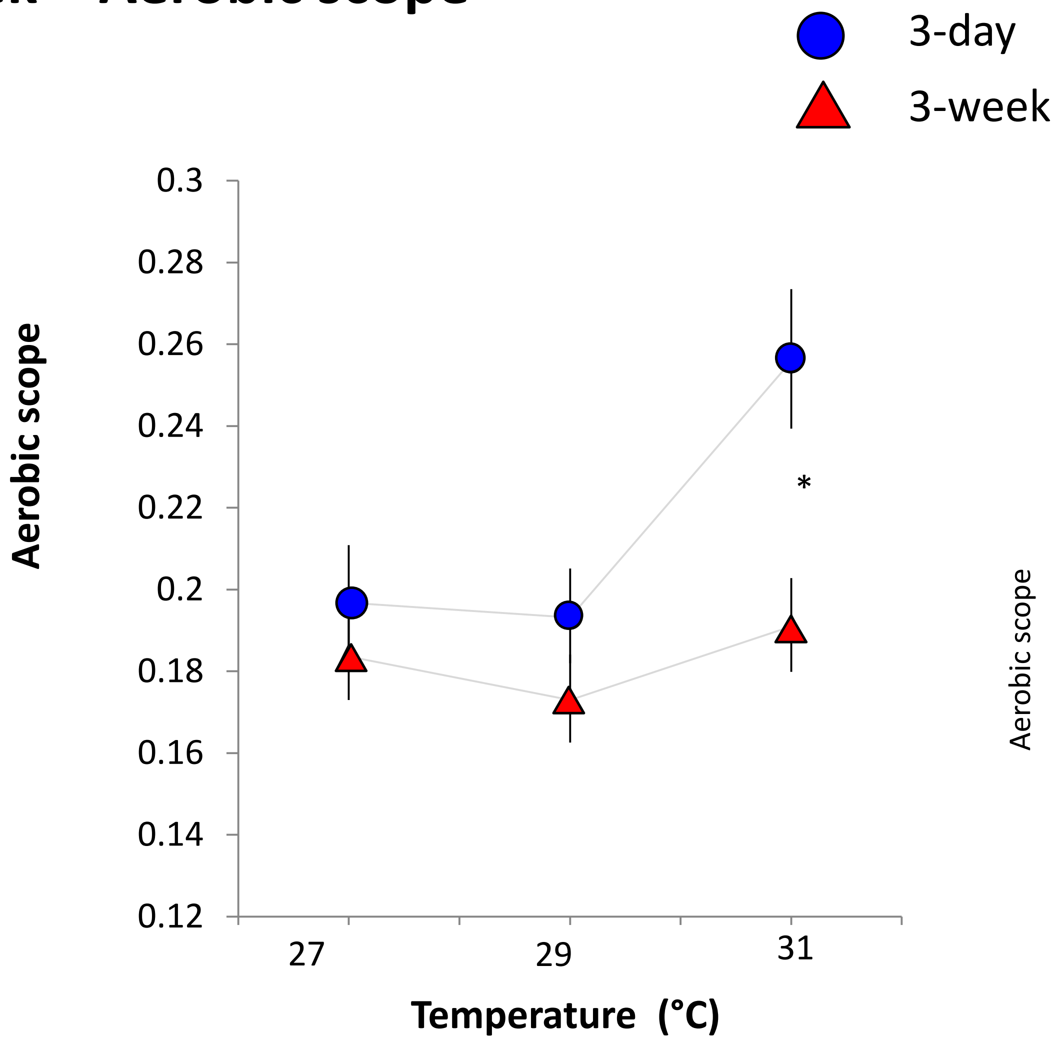
Respirometry

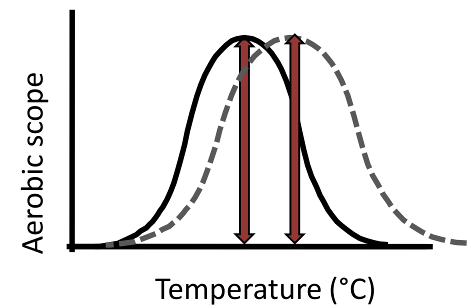
# 3-day vs. 3-week – Aerobic scope




Nyboer & Chapman, 2017, J. Exp. Biol.

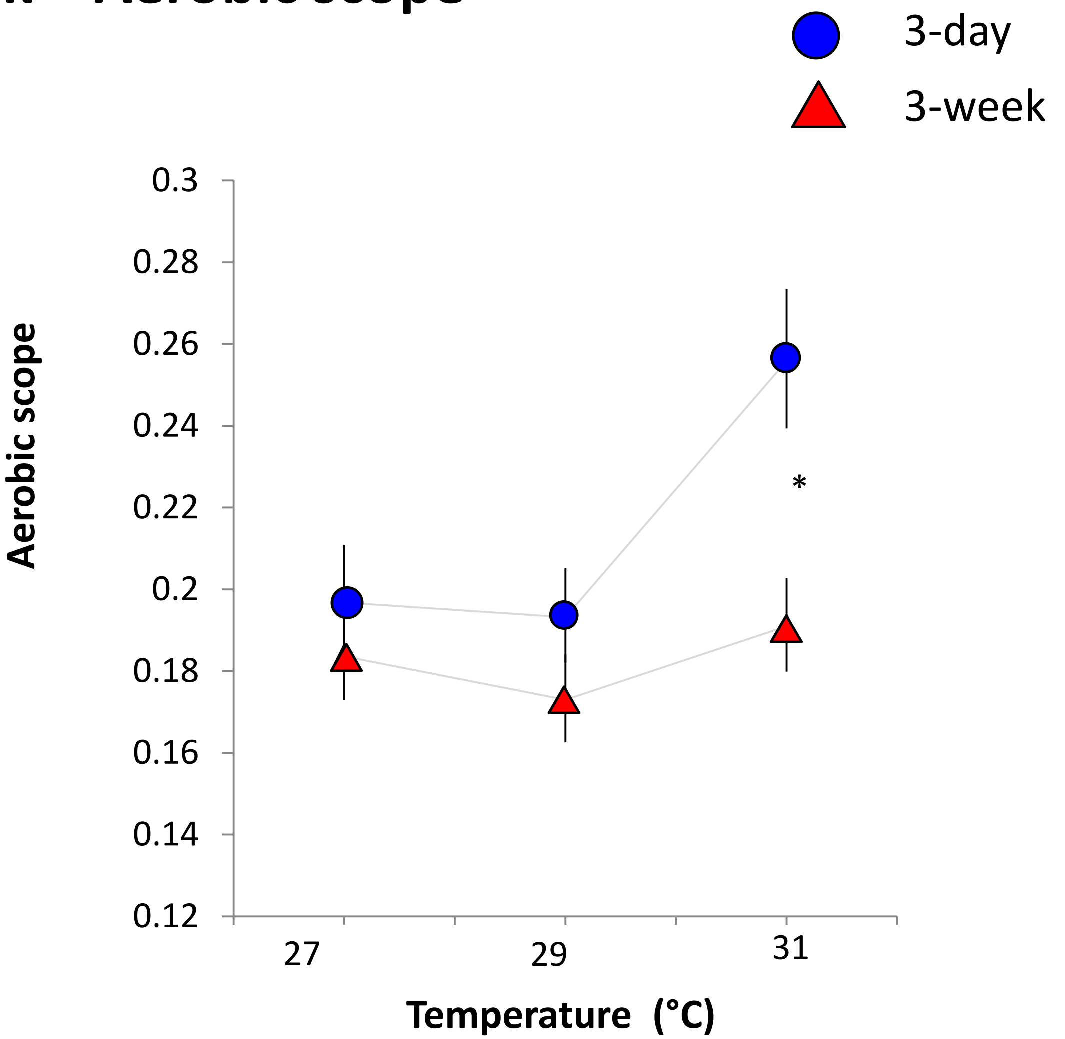
# 3-day vs. 3-week – Aerobic scope



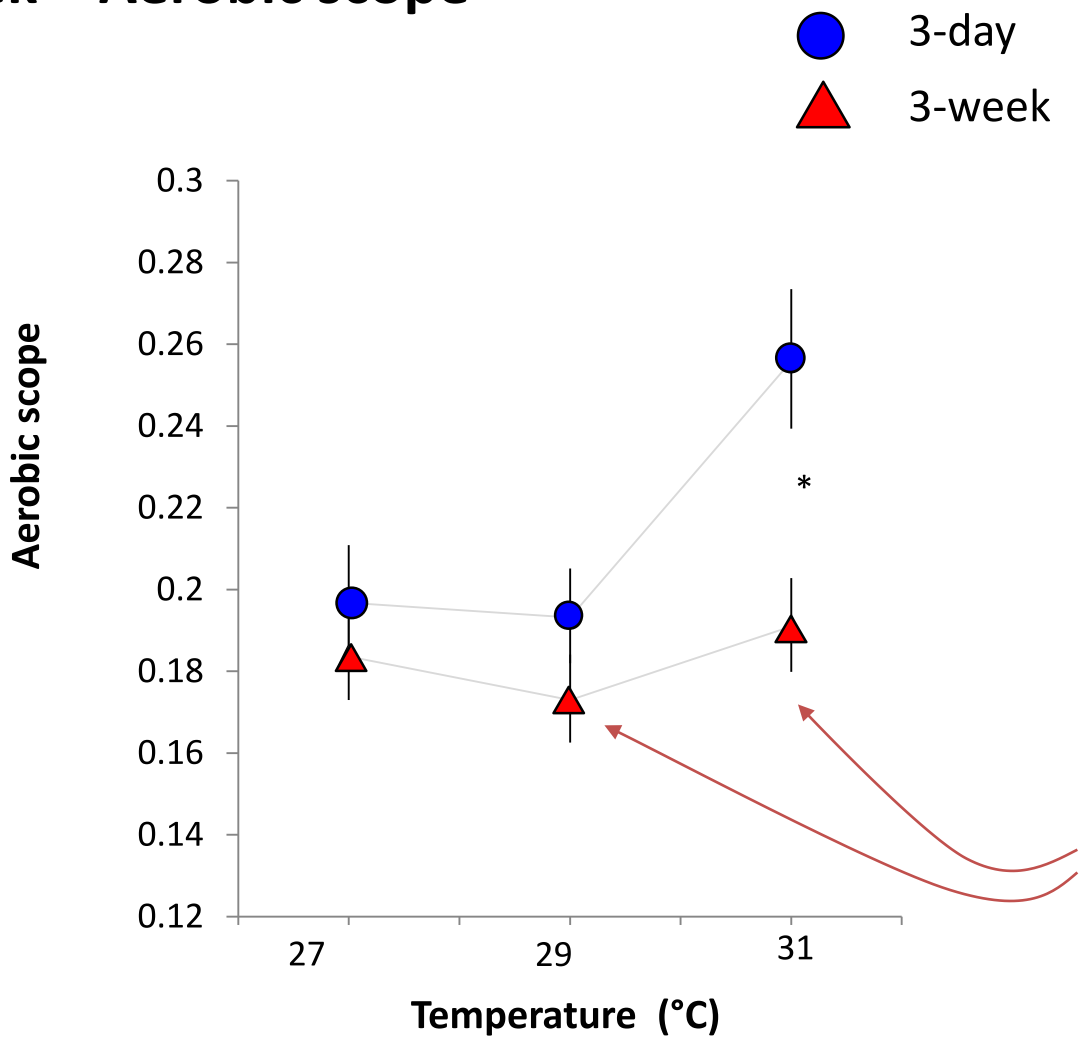

Nyboer & Chapman, 2017, J. Exp. Biol.

# 3-day vs. 3-week – Aerobic scope




Lack of aerobic compensation?

# 3-day vs. 3-week – Aerobic scope

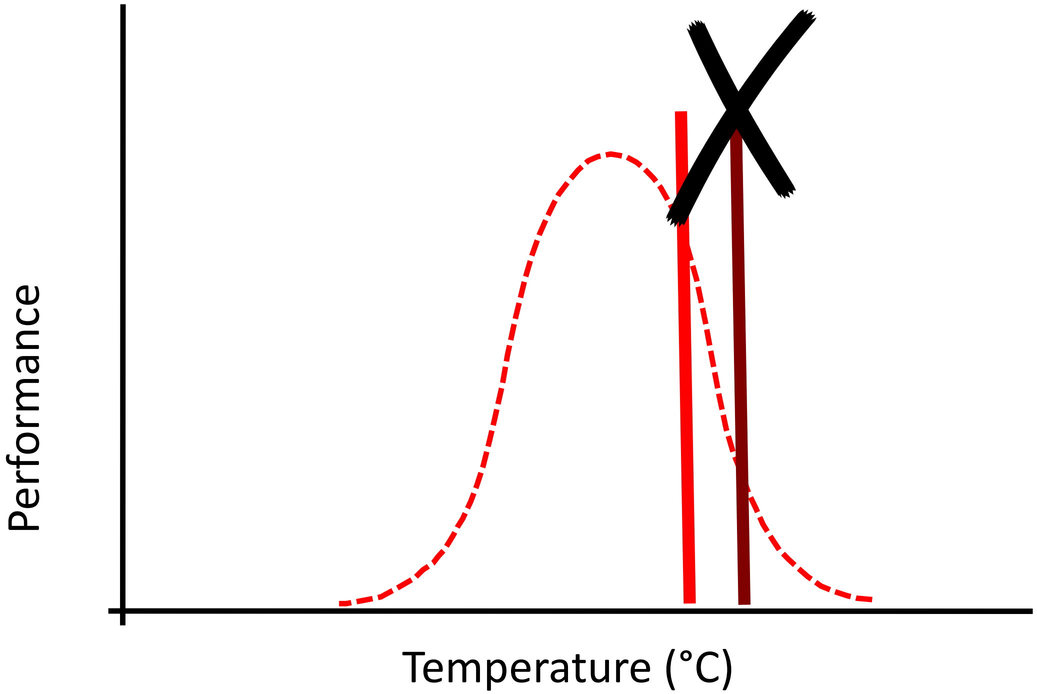



No reductions in growth or condition

Lack of aerobic compensation?

Reduced costs of metabolism after acclimation

Nile perch have demonstrated thermal flexibility greater than what has been predicted for tropical species



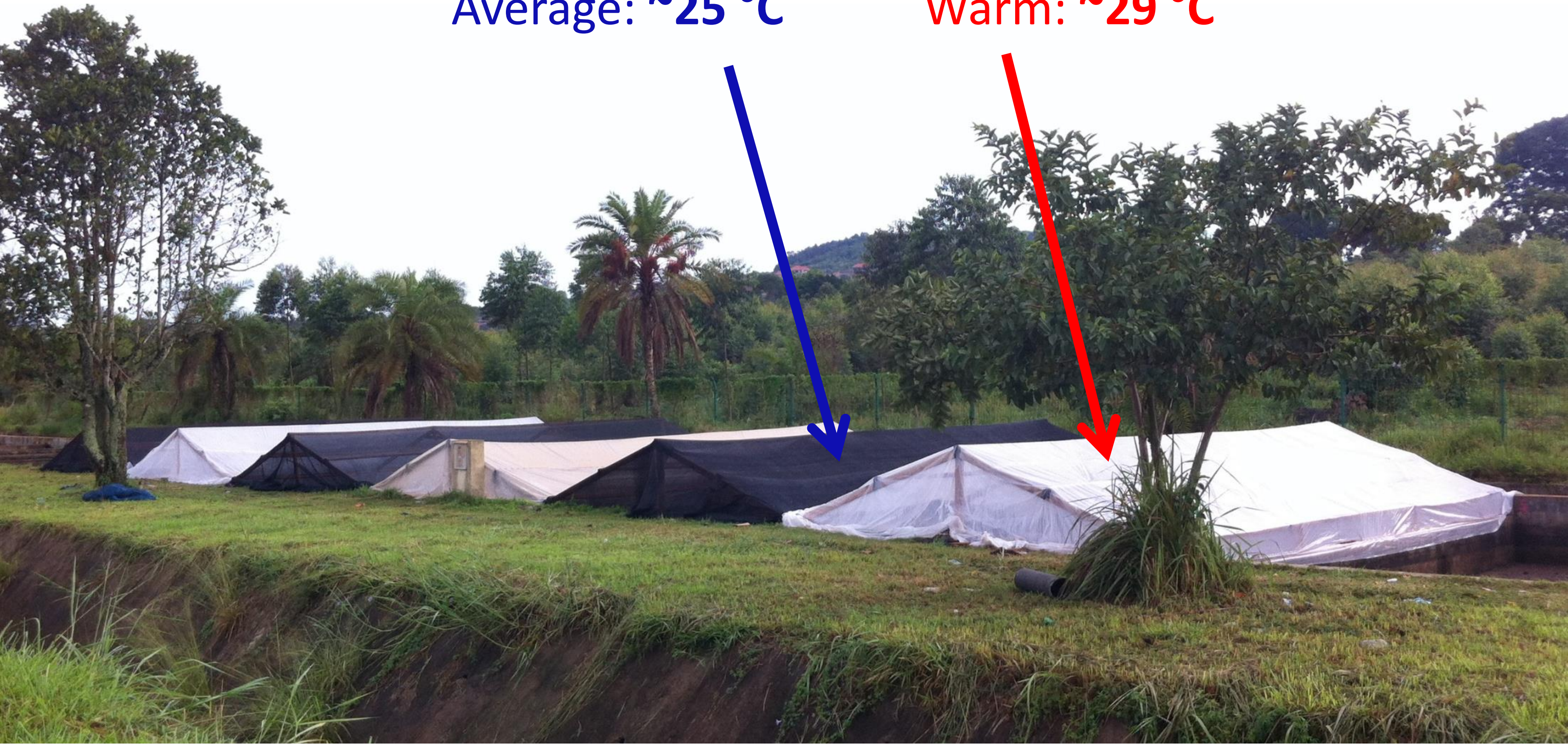
# **Chapter 3** Long term (3-month) thermal acclimation

# **Chapter 3** Long term (3-month) thermal acclimation

## Objective

To quantify thermal plasticity over ‘developmental’ timeframes, and determine whether there are fitness-related tradeoffs

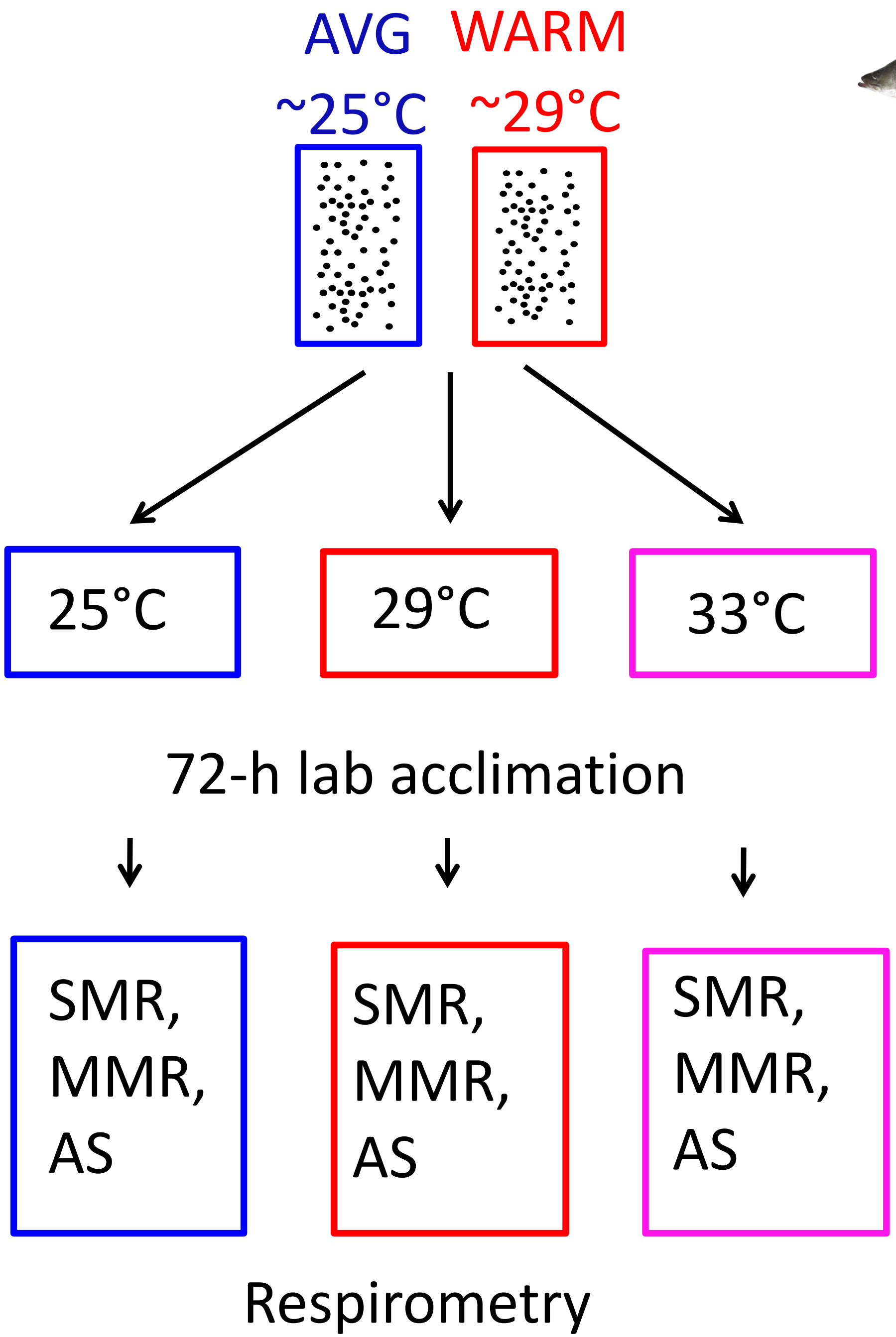
# 3-month rearing



Average: **~25 °C**

Warm: **~29 °C**

# Lab acclimation



# Physical trait measurements

**Size and condition**

Body mass

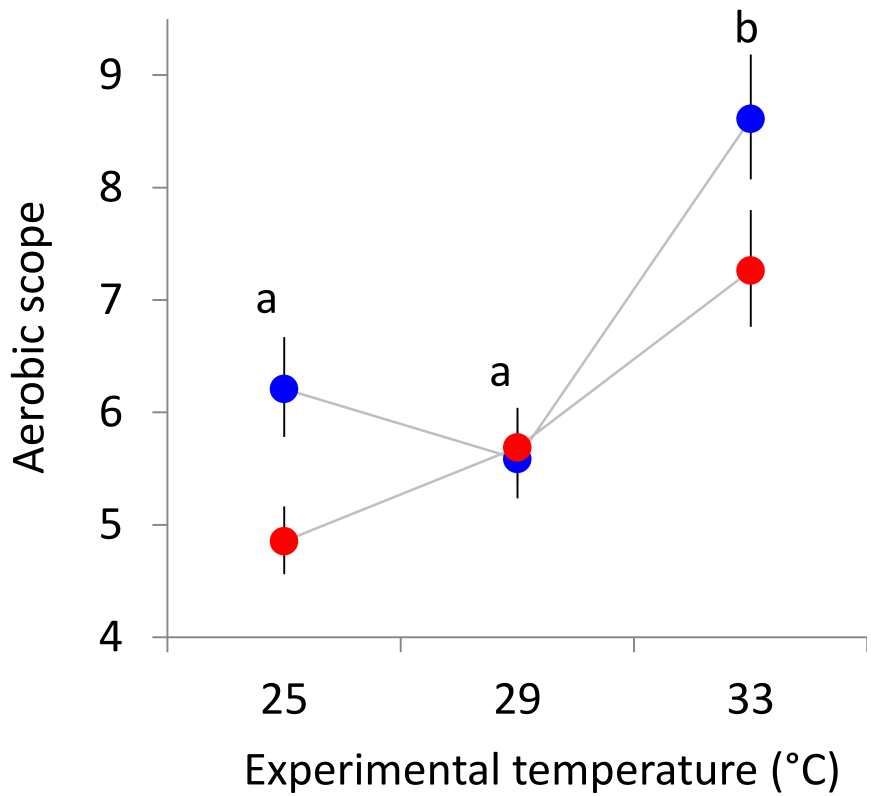
Body length

Condition (K)

# 3-months – Aerobic scope

● Average rearing temp. (~25°C)

● Warm rearing temp. (~29°C)

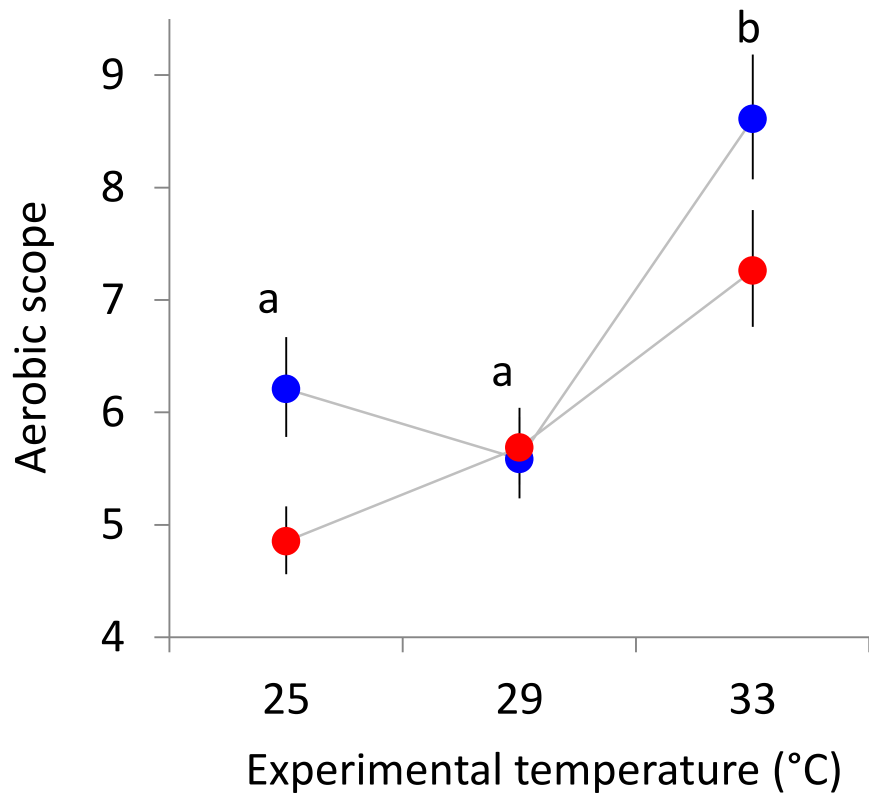



Nyboer & Chapman, 2018, J. Exp. Biol.

# 3-months – Aerobic scope

Average rearing temp. (~25°C)

Warm rearing temp. (~29°C)




**No difference in**

Body mass – ✗

Body length – ✗

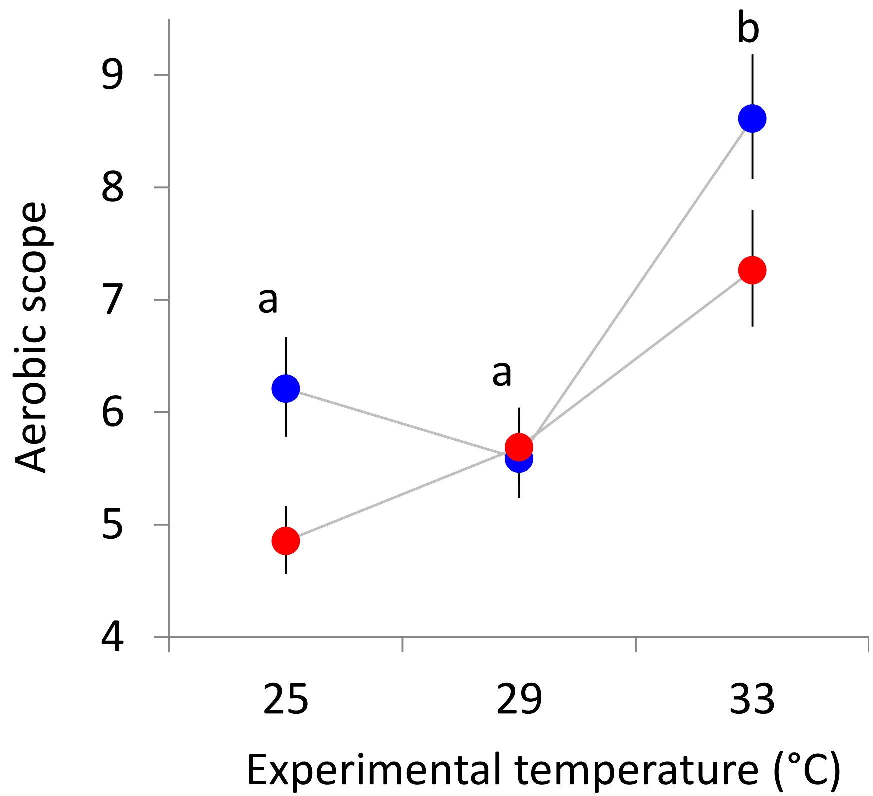
Condition (K) – ✗

Nyboer & Chapman, 2018, J. Exp. Biol.

# 3-months – Aerobic scope

● Average rearing temp. (~25°C)

● Warm rearing temp. (~29°C)




**No difference in**

Body mass – X

Body length – X

Condition (K) – X

- Lower aerobic scope in warm-reared fish not reflected in fitness-related traits

# Conclusion

Evidence for thermal plasticity over ‘developmental’ timeframes

Plastic changes in aerobic function follow the same pattern as in shorter acclimations.

**Chapter 4:** Adaptive capacity of fishing communities to climate variability and change in the Lake Victoria basin

# **Chapter 4:** Adaptive capacity of fishing communities to climate variability and change in the Lake Victoria basin

IDRC CRDI

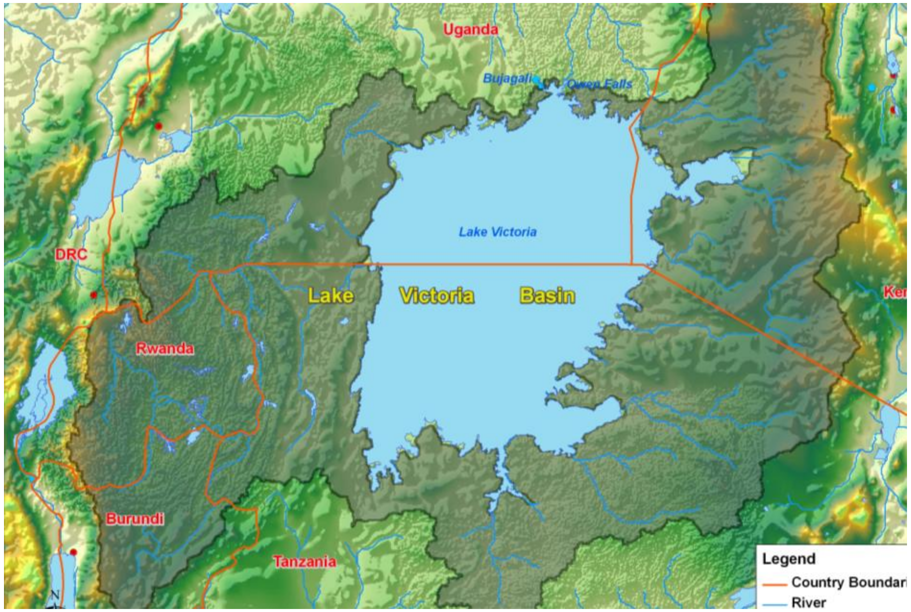
NAFIRRI

# Vulnerability of fishery-based social-ecological systems

Lake Victoria basin:

> 3 million people with 1° source of income and food security

> 30 million with essential source of protein




Emerging stressors due to climate change will require adaptive strategies

Adaptive capacity

↑

capital assets - *human, social, financial, physical, natural*

livelihood diversification options

Adaptive capacity

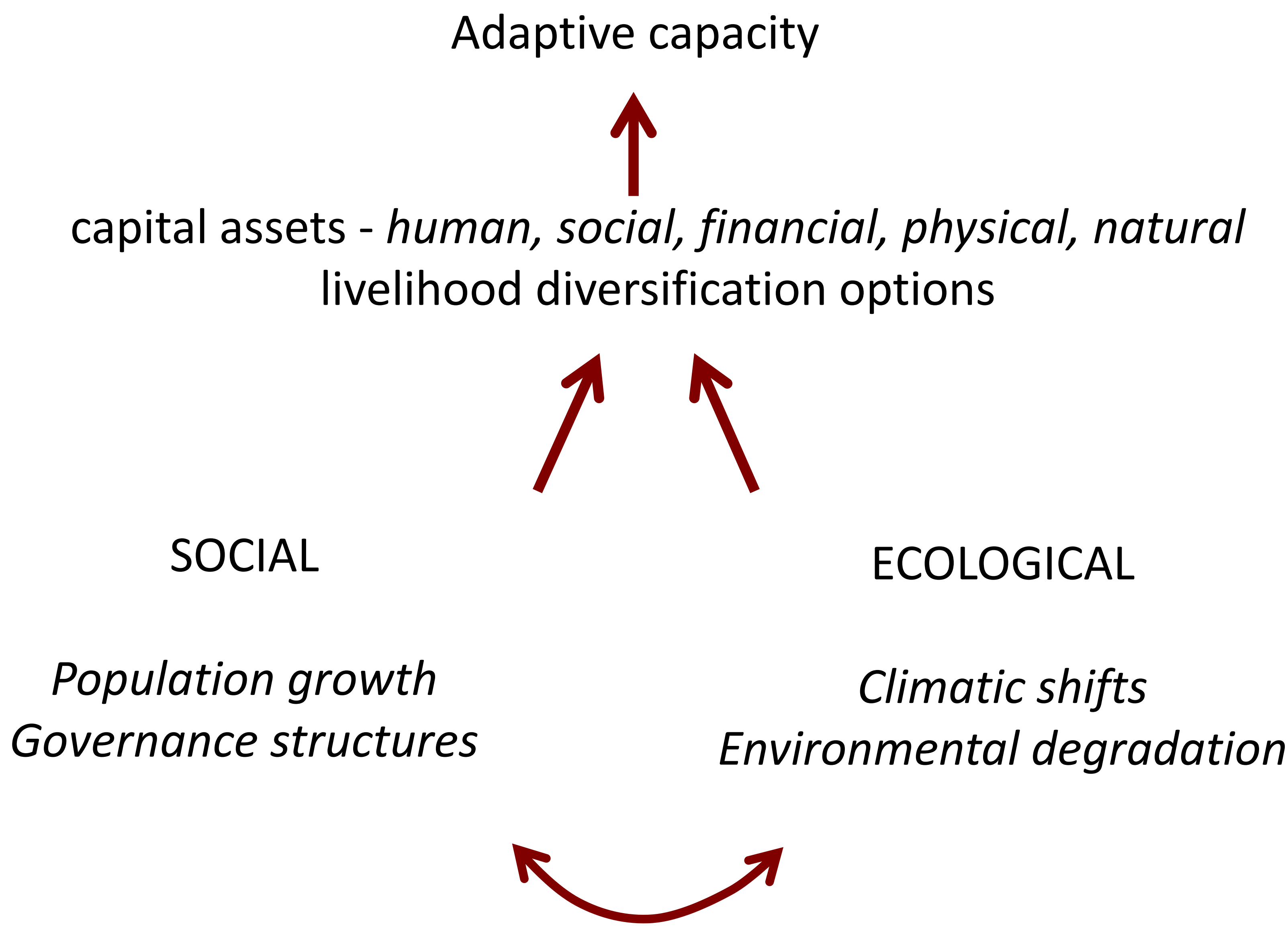
capital assets - *human, social, financial, physical, natural*
livelihood diversification options

SOCIAL

*Population growth*
*Governance structures*

ECOLOGICAL

*Climatic shifts*
*Environmental degradation*


Adaptive capacity
capital assets - *human, social, financial, physical, natural*
livelihood diversification options
SOCIAL
*Population growth*
*Governance structures*
ECOLOGICAL
*Climatic shifts*
*Environmental degradation*

# Objectives

To examine perceptions of how climate change affects fishery livelihoods

To assess adaptive capacity of fishing communities to environmental change

Household surveys

Focus group discussions

Key informant interviews

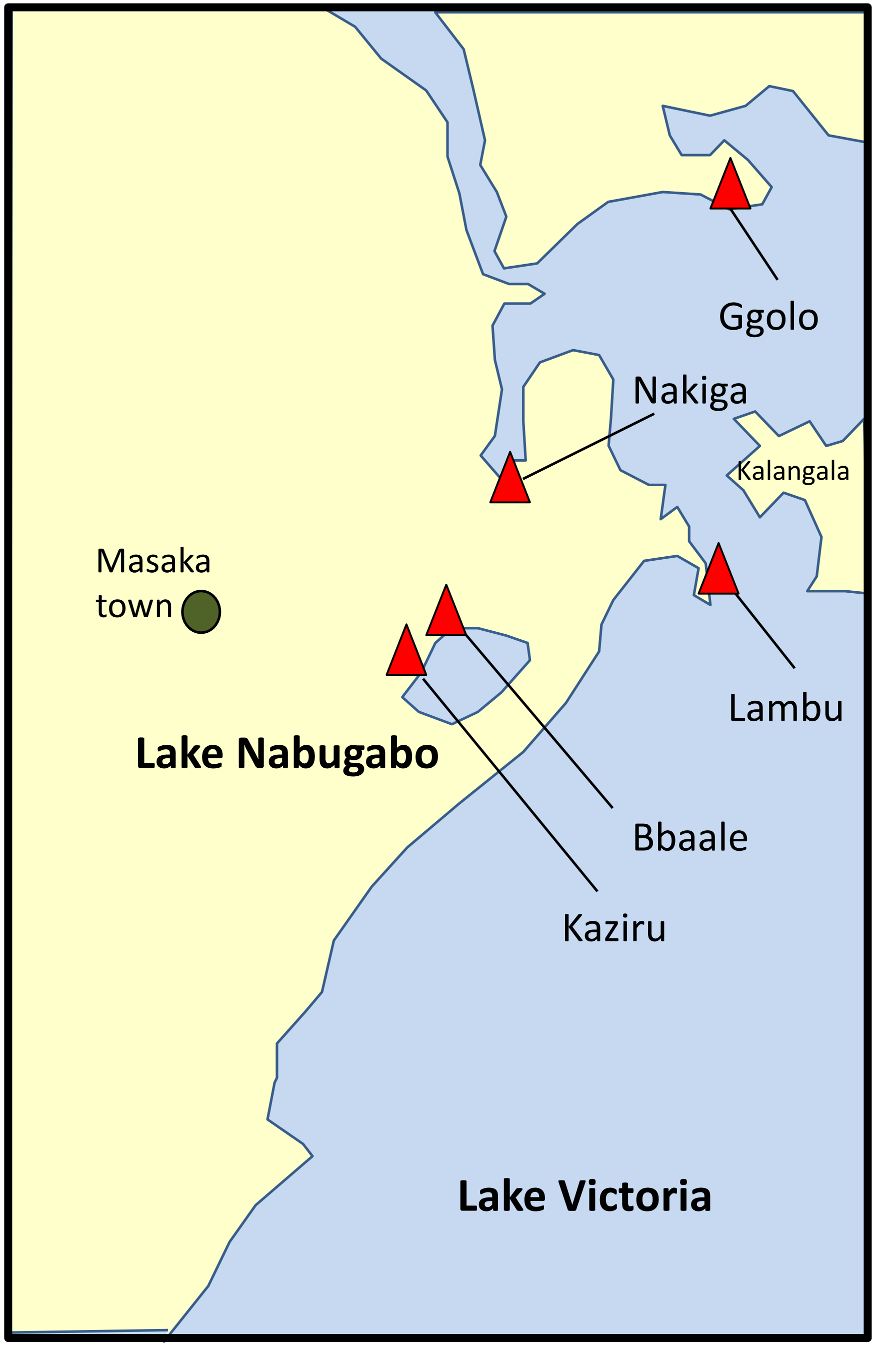
Household surveys

Focus group discussions

Key informant interviews

- Perceptions of impacts of climate change
- Livelihood diversification
- Adaptive practices
- Barriers to adaptation

# Study location



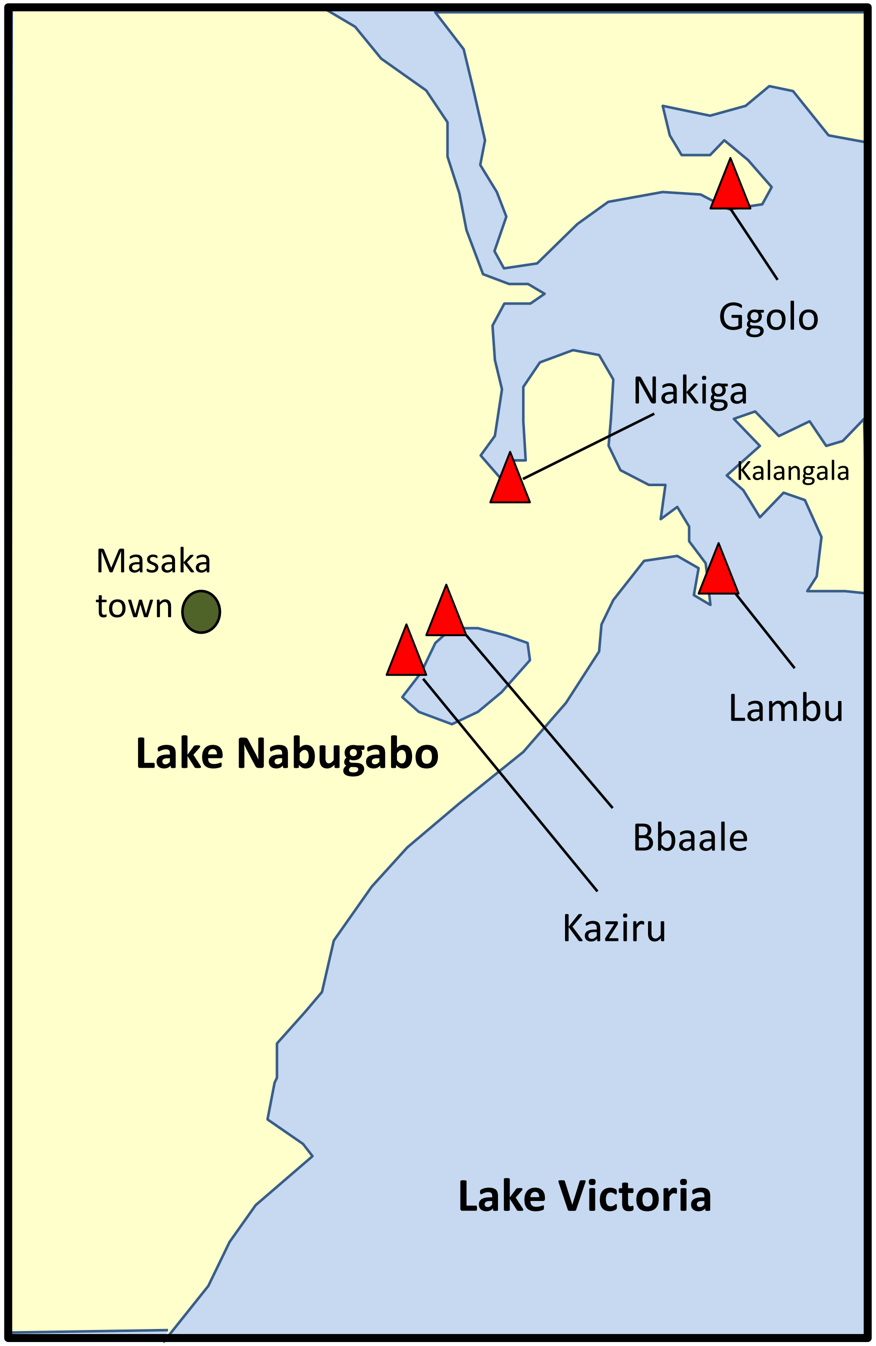
# Study location

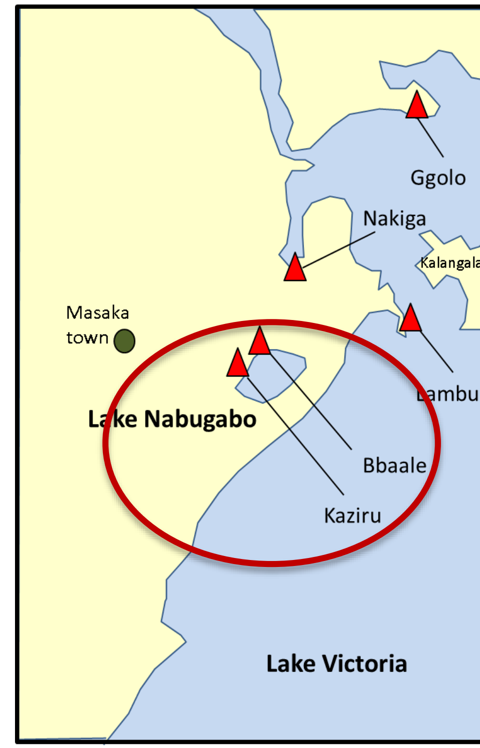
**Survey sample sizes (207 surveys)**

- Bbaale -> 23
- Kaziru -> 33
- Nakiga -> 33
- Ggolo -> 47
- Lambu-> 71

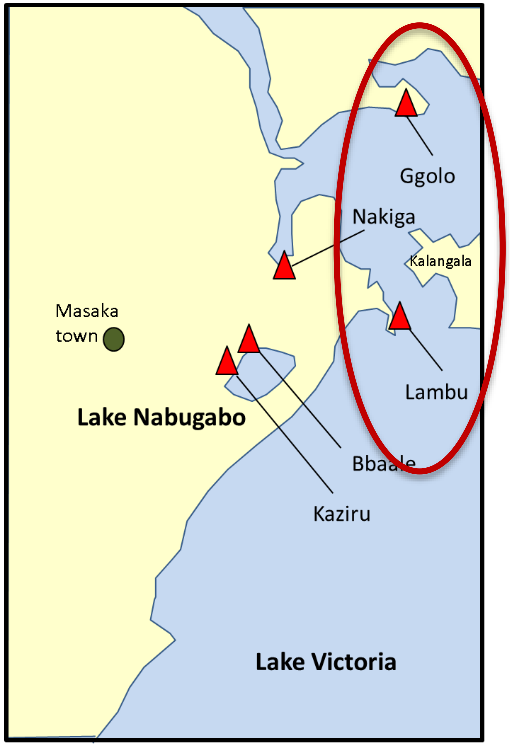
**Focus Group Discussions**

- Boat owners
- Boat crew
- Traders
- Women (trader-processors)




Ggolo
Nakiga
Kalangala
Masaka
town
Lambu
Lake Nabugabo
Bbaale
Kaziru
Lake Victoria

- Fewer fishers
- Small gears / smaller harvest
- Local markets
- Bicycle transportation

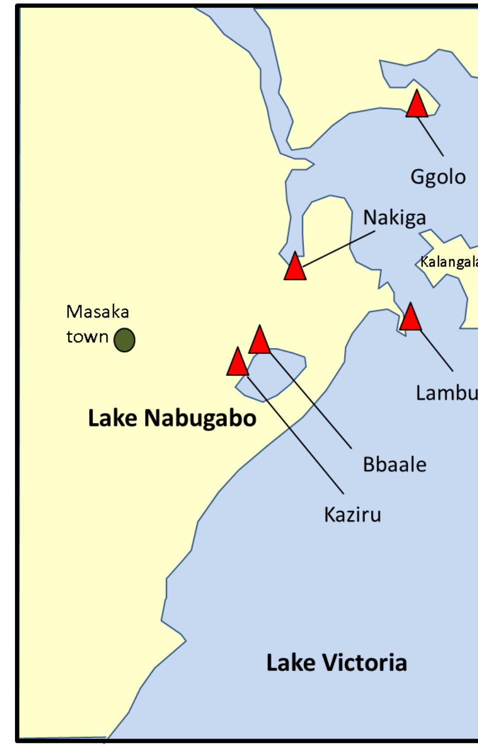

Ggolo
Nakiga
Kalangala
Masaka
town
Lambu
Lake Nabugabo
Bbaale
Kaziru
Lake Victoria




- Industrial scale, many fishers
- Larger gears / higher harvest rates
- Refrigerated trucks
- International markets

Less diversified, lower adaptive capacity

More diversified, higher adaptive capacity



# Perceptions of climate change

Decreased catch rate of Nile perch and Nile tilapia

Increased erratic weather (sudden storms)

Increased frequency floods and droughts

Droughts and floods in Bbaale and Lambu in 2016

# Perceptions of climate change

Decreased catch rate of Nile perch and Nile tilapia

Increased erratic weather (sudden storms)

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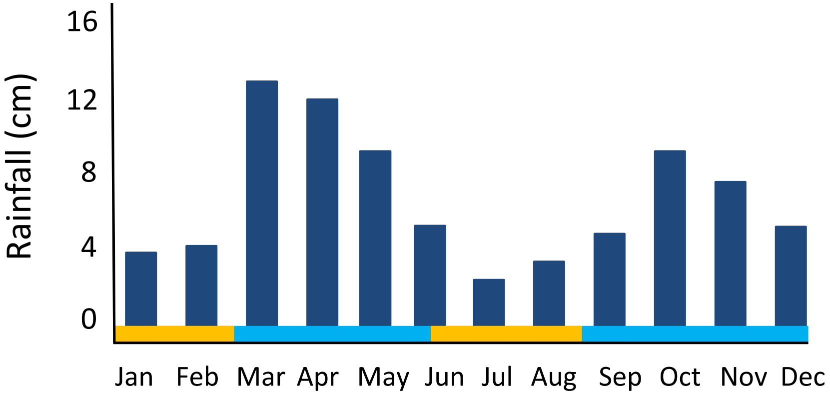


**Unpredictable timing of rainy and dry seasons**

# Perceptions of climate change

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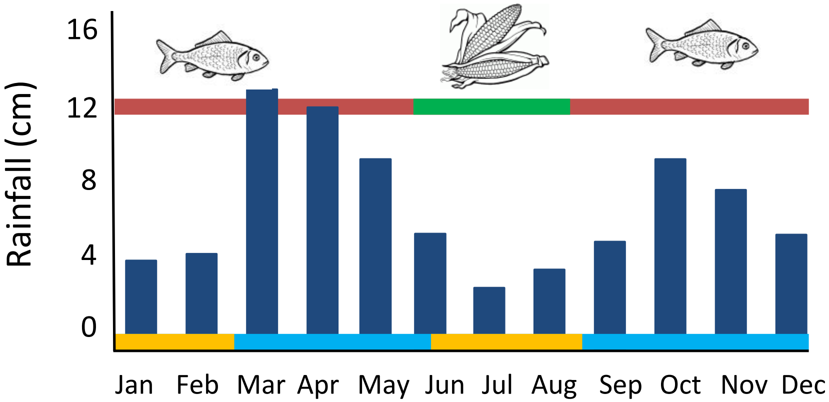

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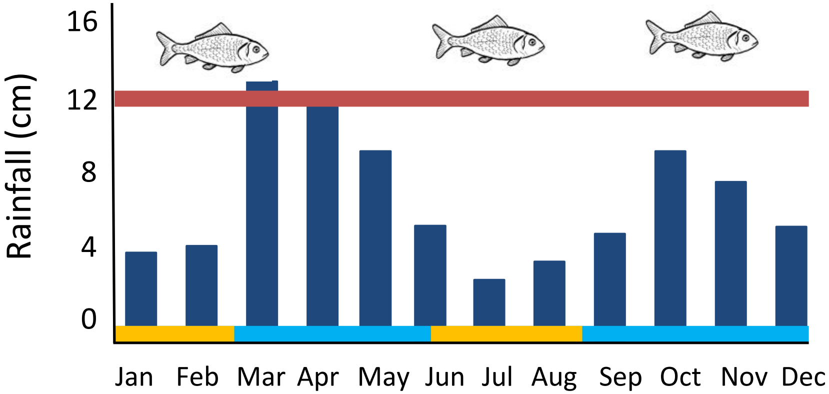



**Unpredictable timing of rainy and dry seasons**

## Effects on fishery-based livelihoods

These changes negatively affect livelihoods of fishery-dependent people

- -Changes in fish abundance
- -Reduced income
- -Food insecurity
- -Crop failure
- -Livestock death
- -Damage to infrastructure
- -Increased competition
- -Increased disease

## Vulnerable groups: women and youth

Both groups are marginalized, poor, and not diversified

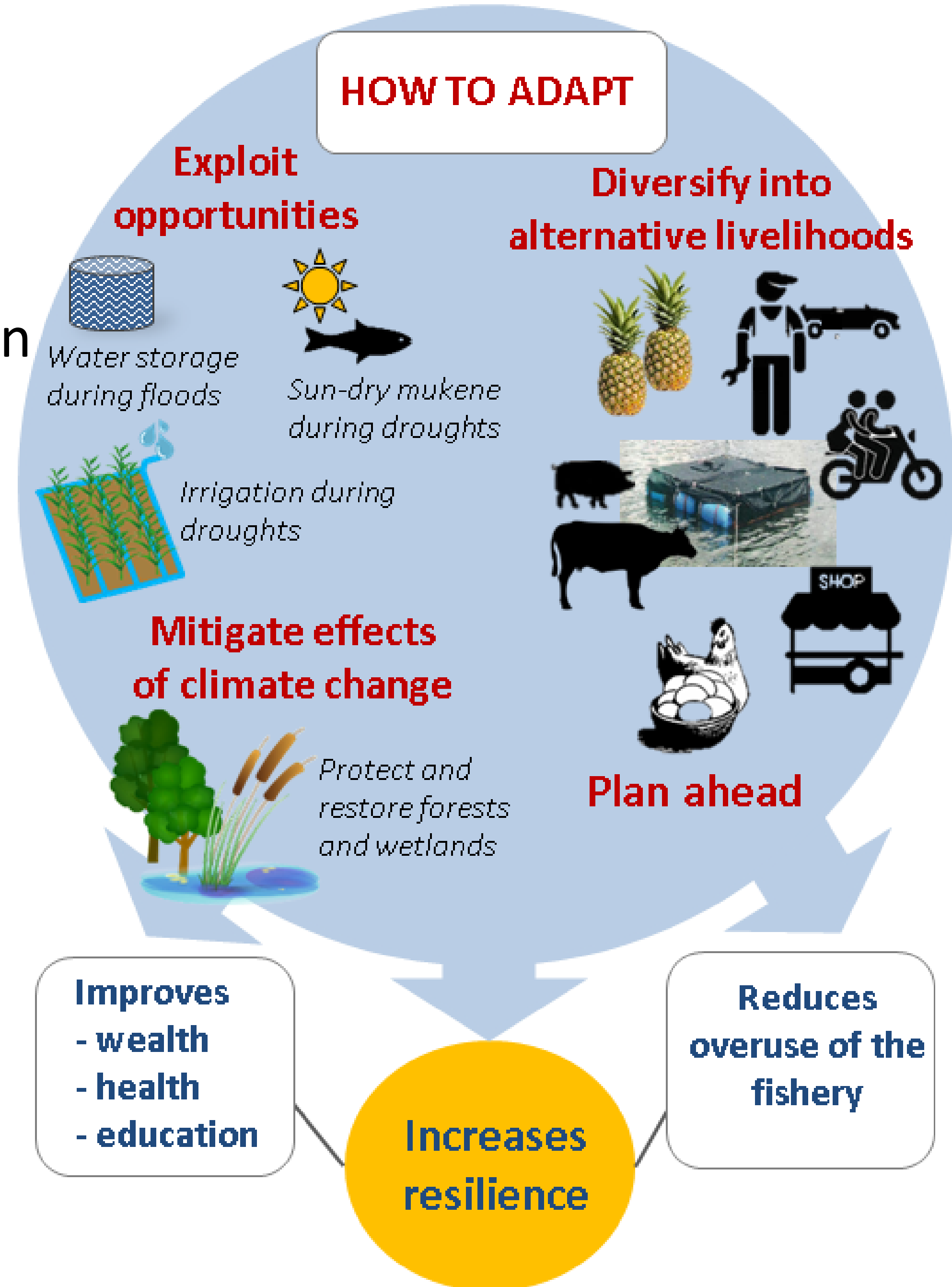
Youths are untrained, migratory, and lacking in community.

Women are unpaid or in low-paying jobs, are responsible for childcare, and have poor fish handling facilities.

# Fishers must develop adaptive strategies to maintain resilient livelihoods

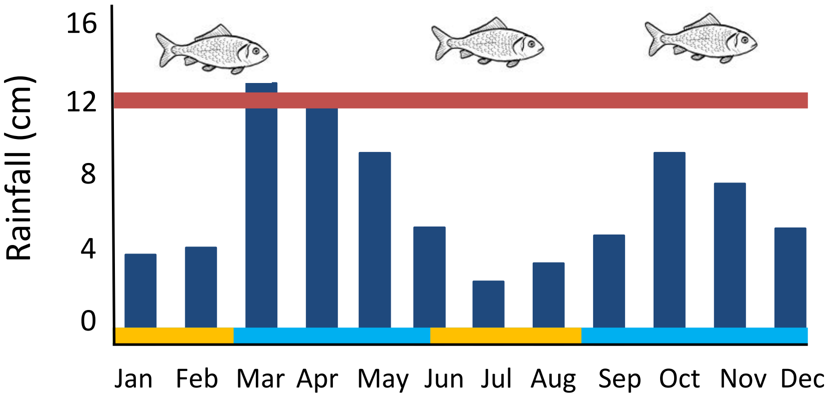
Adaptive capacity will depend on the ability of communities to:

- **Explore alternative livelihoods**
- **Mitigate effects of climate change**
- **Take advantage of opportunities**
- **Plan ahead for changes**



## Barriers to adaptation

-Poverty, lack of access to land
-Lack of  education or training
-Lack of trust within community
-Lack of motivation
-Unpredictable seasons



## Some recommendations


-Improve access to low-interest loans, provide access to land, improve post-harvest facilities, improve agricultural practices, facilitate group –based diversification

-Sensitization, training, and education for youths about HOW and WHY to diversify.

-Stay in one village to build community, make investments, and accumulate assets

-Build community cohesion to facilitate knowledge sharing, reduce risks of diversification, learn new skills.

-Develop within-home diversification options for women

-Improve knowledge sharing among fishers and governing bodies to avoid misunderstandings about management

-Develop a sense of community agency to increase fisher motivation to care for the fishery.

## Conclusions

Fishers are highly aware of impacts of climate change

Climate change may lead to heavier use of fish resources

Local-scale analysis can reveal different challenges and solutions among communities

# Data dissemination

**Plan to reach institutions, governing bodies, and the communities where the research was conducted**

- **NaFIRRI and LVFO** – distribute printed and electronic documents of all reaserch conducted, distribute data
- **MAAIF and the DiFR**– distribute technical reports and policy breif (focus on community adaptation)
- **Communitie**s – workshops, pamphlets, and an official report for the managers and leaders at the landing sites

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## Climate change in the Lake Victoria basin

Effects of climate change have already been noticed by fishing communities, including:

- Increased frequency of droughts / floods
- Increased erratic storm events
- Changes in wind patterns
- Unpredictable seasons

Other environmental changes include:

- Deforestation of wooded areas
- Destruction of wetland habitat
- Rapid human population growth

## Effects on fishery-based livelihoods

These changes negatively affect livelihoods of people who are dependent on fisheries.

- Changes in fish abundance
- Reduced income
- Food insecurity
- Crop failure
- livestock death
- Damage to infrastructure
- Increased competition
- Increased disease

**These effects will worsen as time goes on**

### Vulnerable groups: women and youth

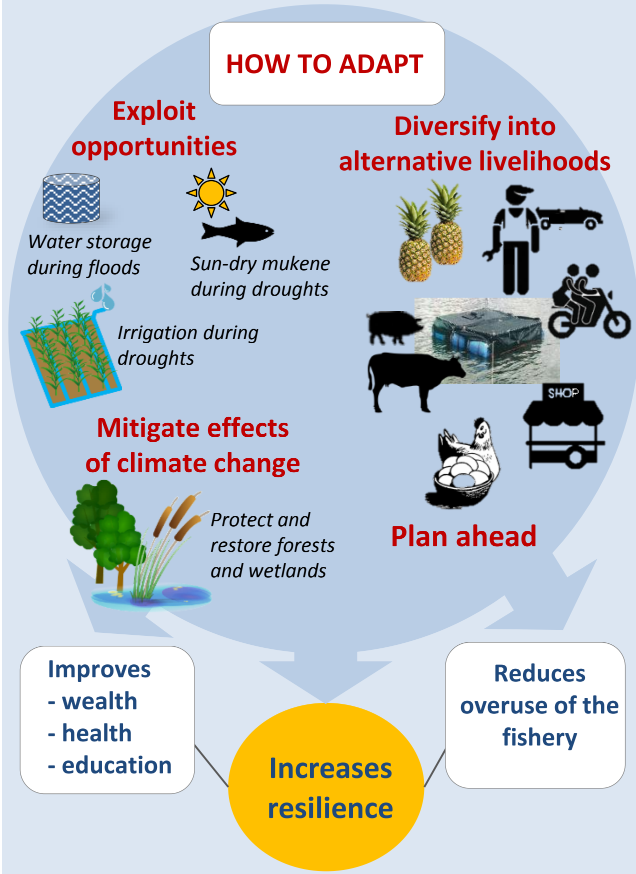
Both groups are marginalized, poor, and not diversified

Youths are untrained, migratory, and lacking in community

Women are unpaid or in low-paying jobs, are responsible for childcare, and have poor fish handling facilities

## Fishers must develop adaptive strategies to maintain resilient livelihoods

Adaptive capacity will depend on the ability of communities to plan ahead for changes, explore alternative livelihoods, or take advantage of opportunities arising from climate change.

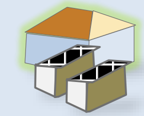



### Barriers to adaptation

- Poverty, lack of access to land
- Lack of education or training
- Lack of trust within community
- Lack of motivation
- Unpredictable seasons
- Lack of enforcement, poor governance

## Solutions for the future

- Improve access to low-interest loans or asset-based support to reduce financial risks of diversification.
- Promote saving culture and supply business training to ensure success of interventions.



- Improve post-harvest facilities to reduce losses and store products.
- Develop within-home diversification options for women

- Provide access to land for group-based agriculture or livestock projects
- Sensitization, training, and education for youths about HOW and WHY to diversify.

- Build community cohesion to facilitate knowledge sharing, reduce risks of diversification, learn new skills.
- Return to traditional agricultural practices (build trenches, cassava around edge, avoid chemicals, cultivate far from wetlands), AND use new innovations (small-scale irrigation).

- Stay in one village to build community, make investments, and accumulate assets

- Promote community agency thru better governance to increase motivation to care for the fishery.
- Improve knowledge sharing among fishers and governing bodies to avoid misunderstandings.

## Acknowledgements

**Lauren Chapman, Supervisor**

Assistants and collaborators (Montreal and Uganda)

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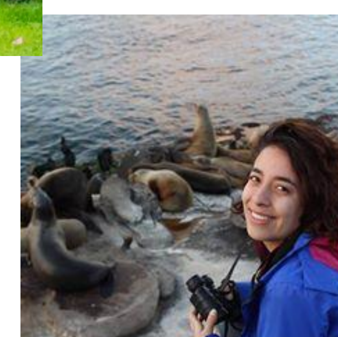

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Thank you!