



Peace Through Governance

# Challenges and benefits to biodiversity and ecosystem services of rapidly expanding cage aquaculture in Lake Victoria

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# Overlapping uses: fish farming and wild fisheries in Lake Victoria



## Cage farming is growing rapidly



*...a farmer who had started with **3 cages in late 2013, now [2016] has over 350 cages in the lake.** Several new cages are popping up every other day,...*

*~ John Okechi, KMFRI, Feb. 2016*

## Ecosystem services impacted by cages

Water quality and quantity: –

Local food security: + or –

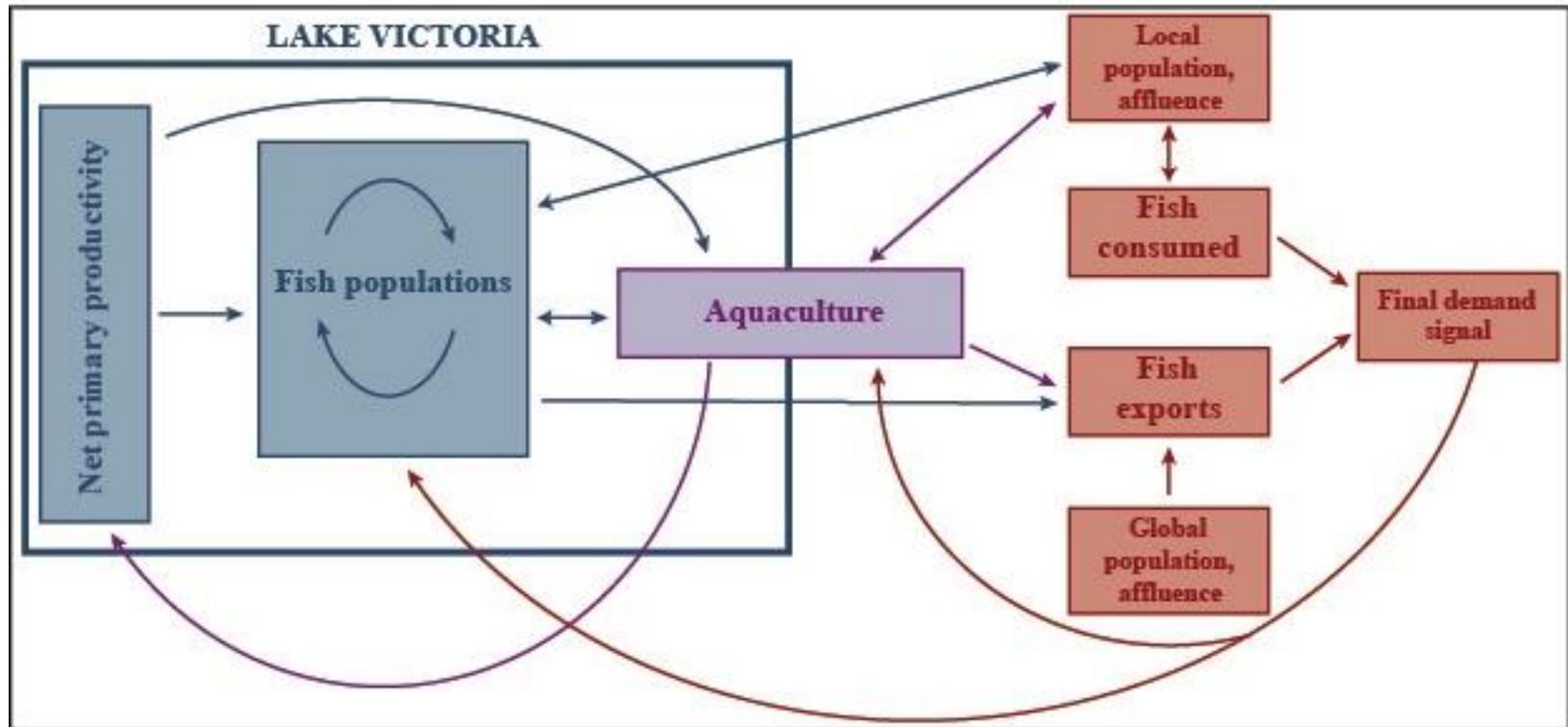
Global fish supply: + or –

Income in fishing communities: + or –

Economic security for women: + or –



# Predicting the impacts of cage culture: a coupled human & natural systems approach (CHANS)





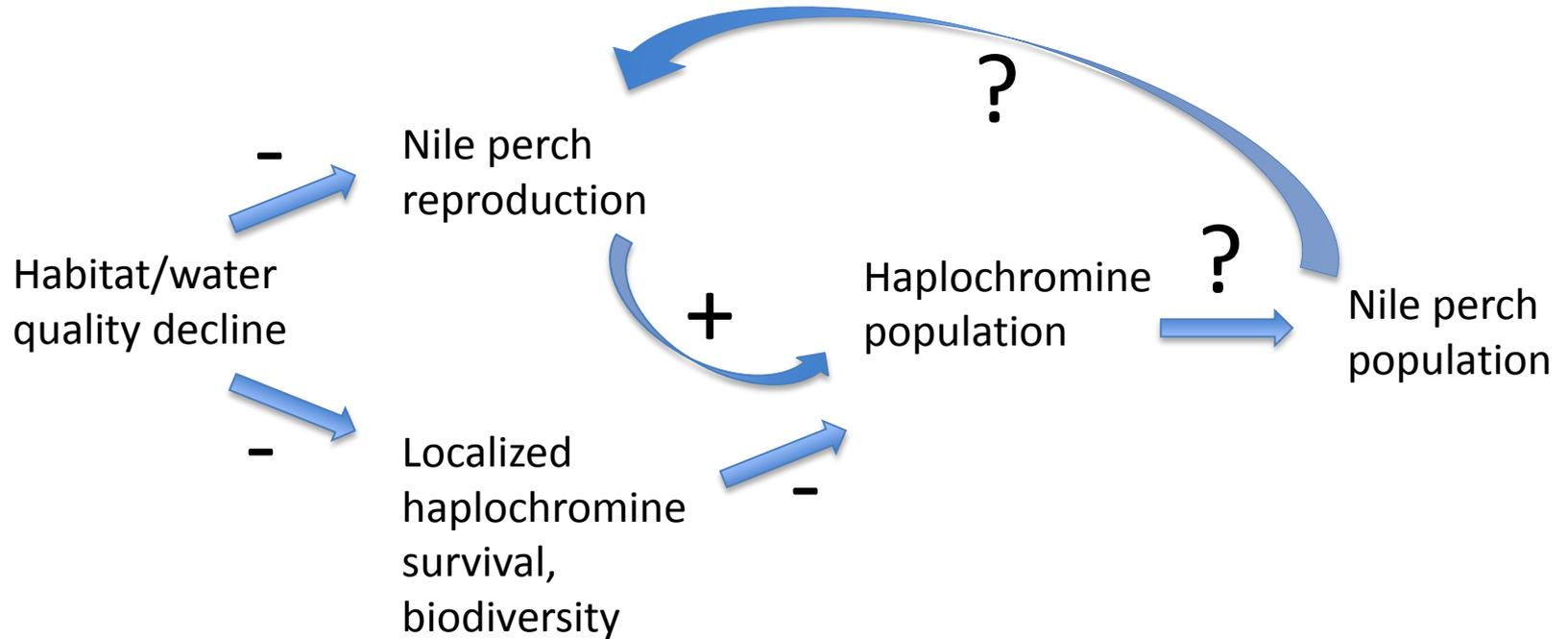
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## Key aspects of CHANS

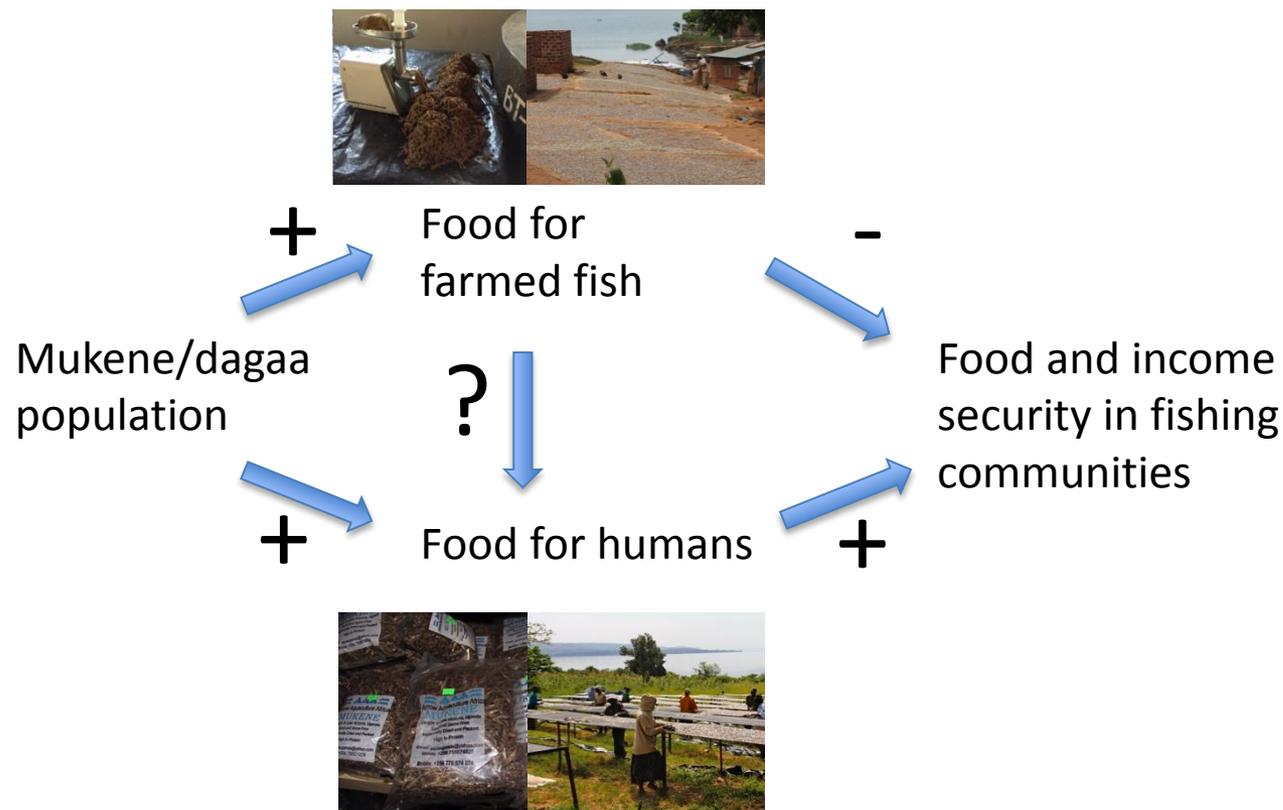
- Delays and time lags in response variables
- Feedbacks
- Critical tipping points and nonlinearities
- Scale and aggregation effects
- Unanticipated consequences and surprises

See: Liu et al (2007) Complexity of coupled human and natural systems. *Science* 317: 1513.

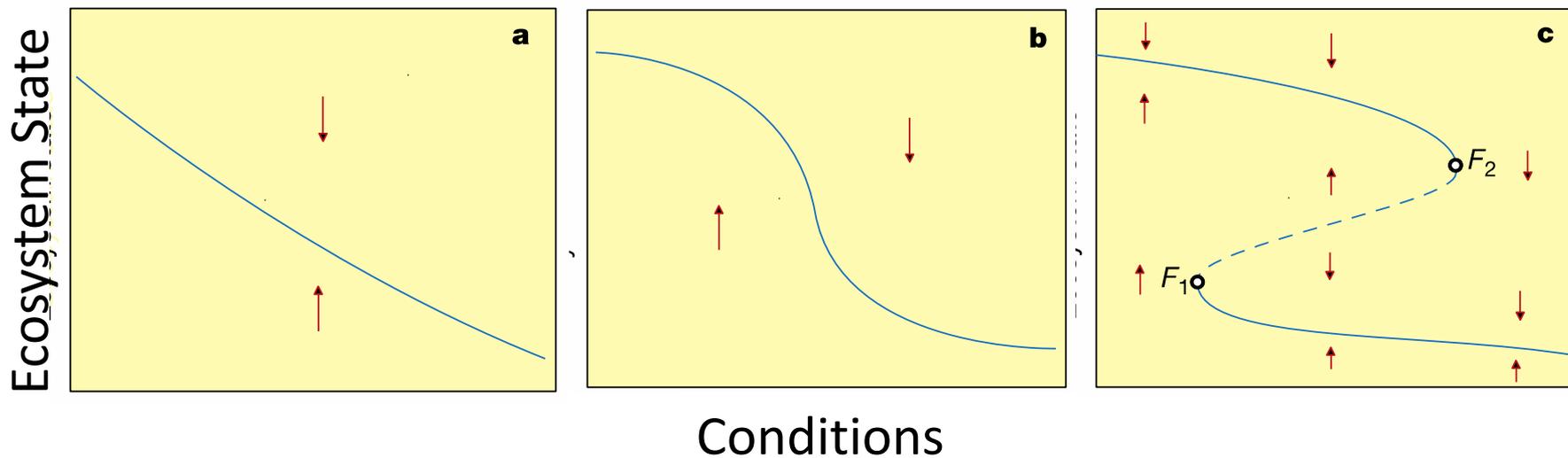
# Example: delays, feedbacks in fish populations



# Example: unanticipated consequences for food security

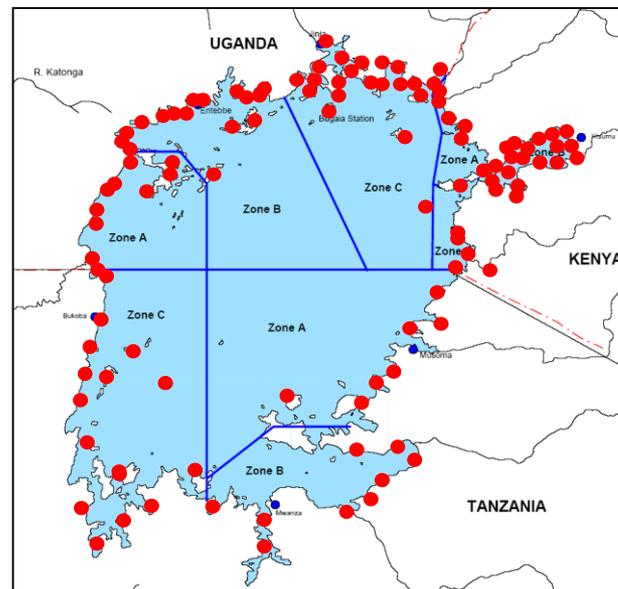
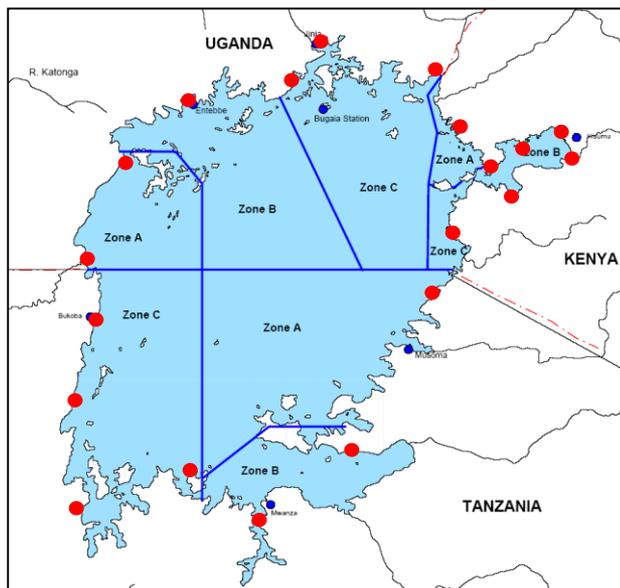


## Example: critical tipping points



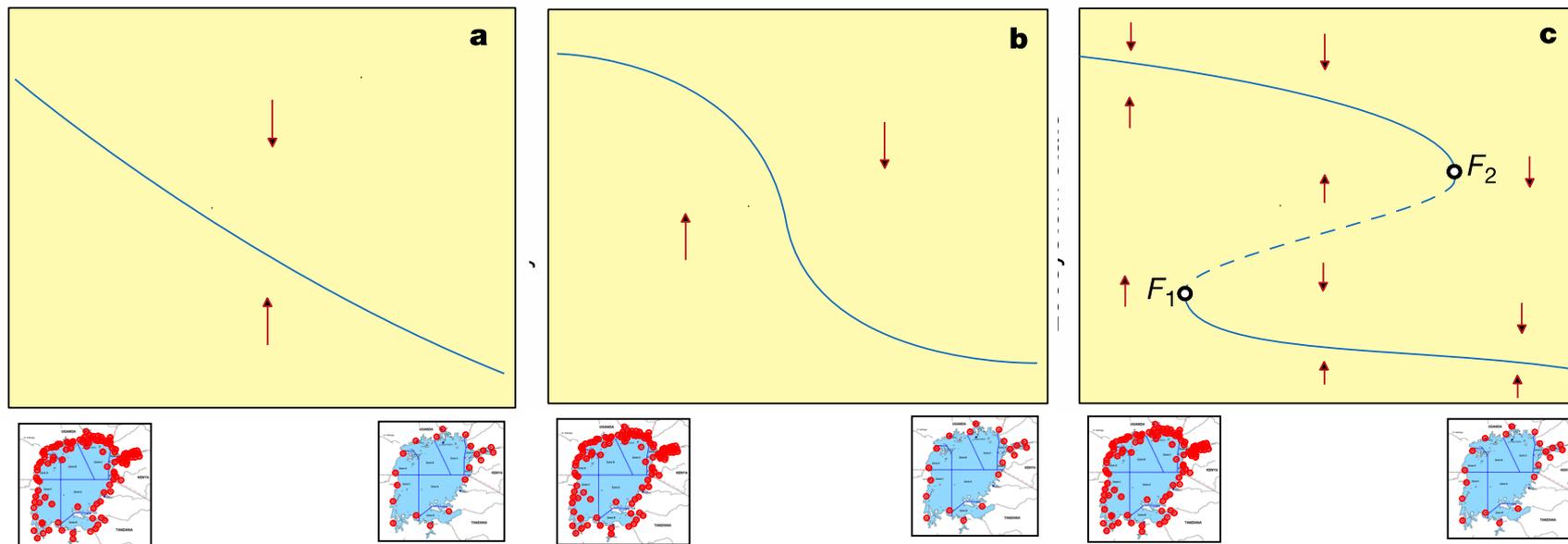
Scheffer et al. (2001) *Nature* 413: 591.

# Example: How many cages can Lake Victoria hold?



# Where will cages tip the balance?

Eutrophication



# Impacts on biodiversity: what is known

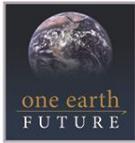
## Eutrophication:

- Localized N and P effects to within 50 m of cages

## Changes to biodiversity:

- Reversals in cladoceran, rotifer relative abundances
- Changes in diatom community
- Loss of diversity in zoobenthic taxa

## Introduced species effects (disease, genetics)



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# Impacts on biodiversity: what is not known

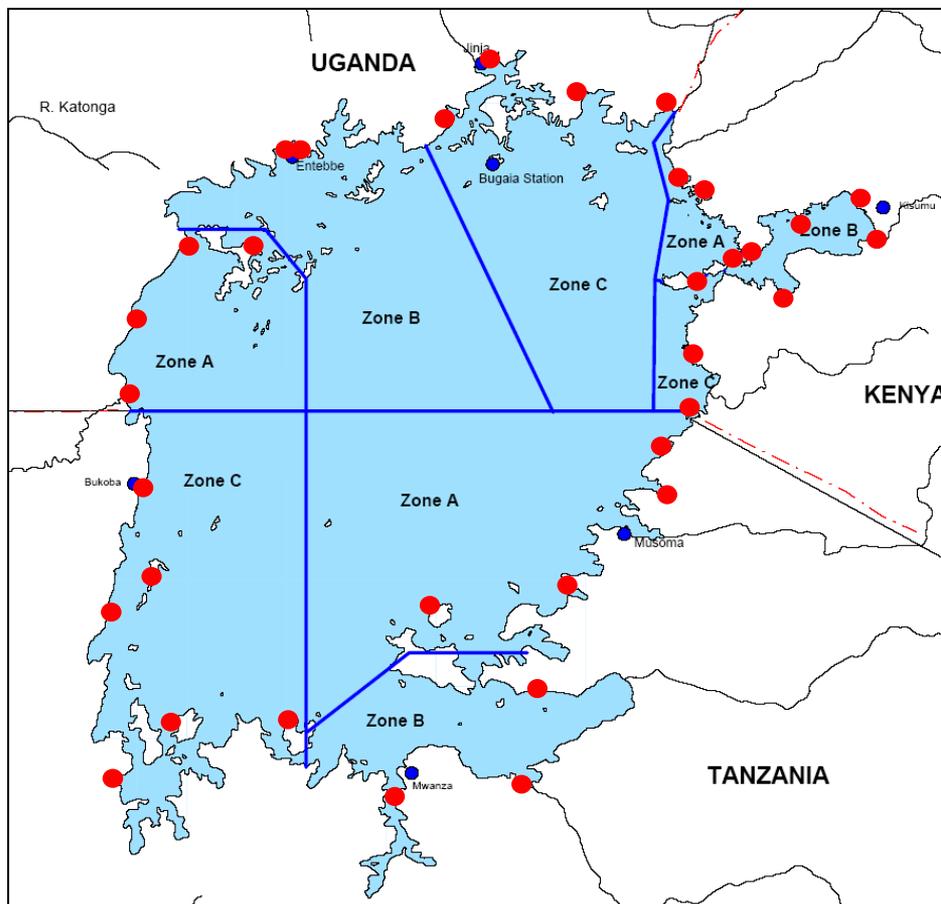
## Spillover effects on fish community:

- Changes in community metrics (evenness, richness)
- Effects on local vs total population sizes

## Long-term positive effects of effort displacement?

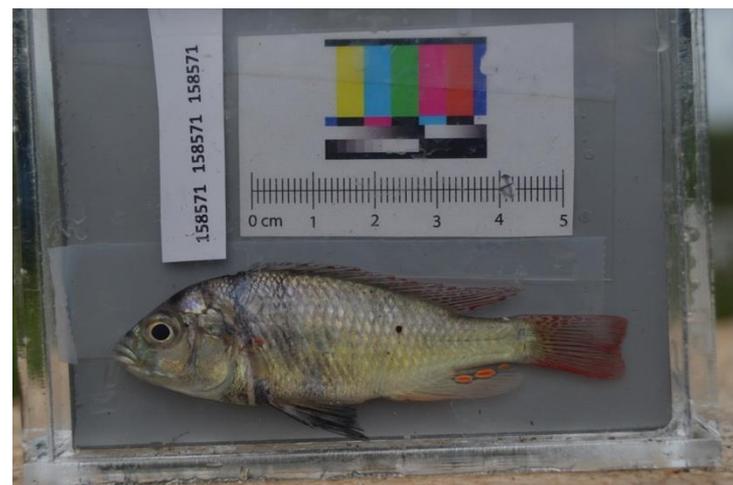
- Reduced pressure on wild fisheries
- Changes in markets and preferences (local and global)

# Approach: On-going gillnet and trawl surveys in Lake Victoria



Map credit:  
Ole Seehausen

# Biodiversity assessment: cage versus non-cage sites



# Approach: Multiscale Integrated Model of Ecosystem Services (MIMES)



Contents lists available at [ScienceDirect](#)

Ecosystem Services

journal homepage: [www.elsevier.com/locate/ecoser](http://www.elsevier.com/locate/ecoser)



The Multiscale Integrated Model of Ecosystem Services (MIMES): Simulating the interactions of coupled human and natural systems



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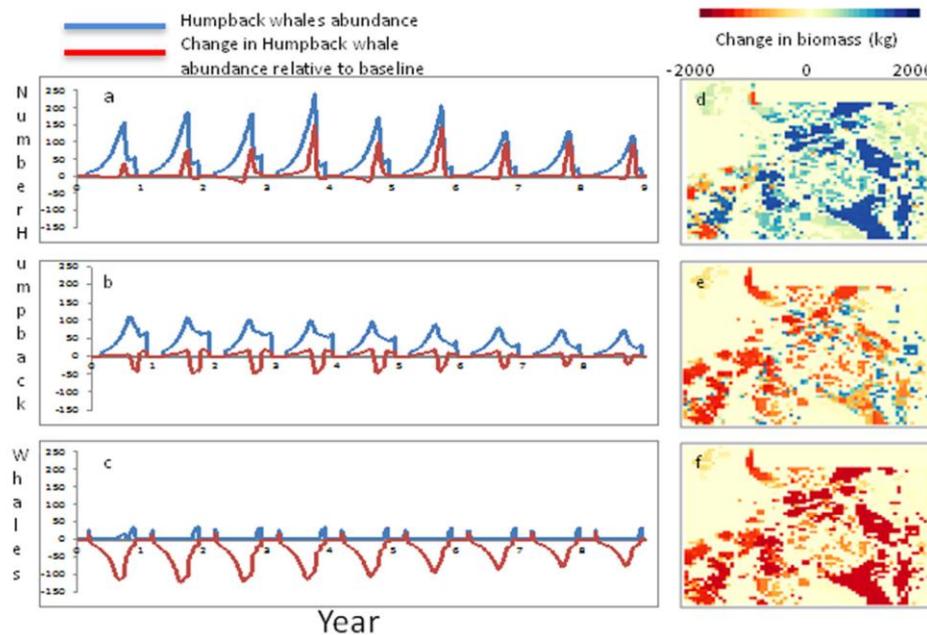
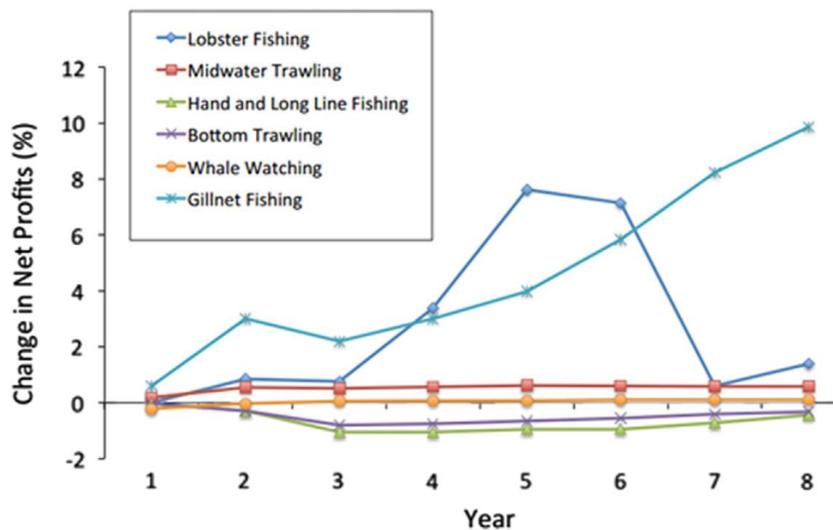
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<sup>b</sup> Gund Institute for Ecological Economics, University of Vermont, Burlington, VT 05405, United States

<sup>c</sup> Program on Coupled Human and Natural Systems, Pardee Institute for the Study of the Longer-Range Future, Boston University, Boston, MA 02215, United States

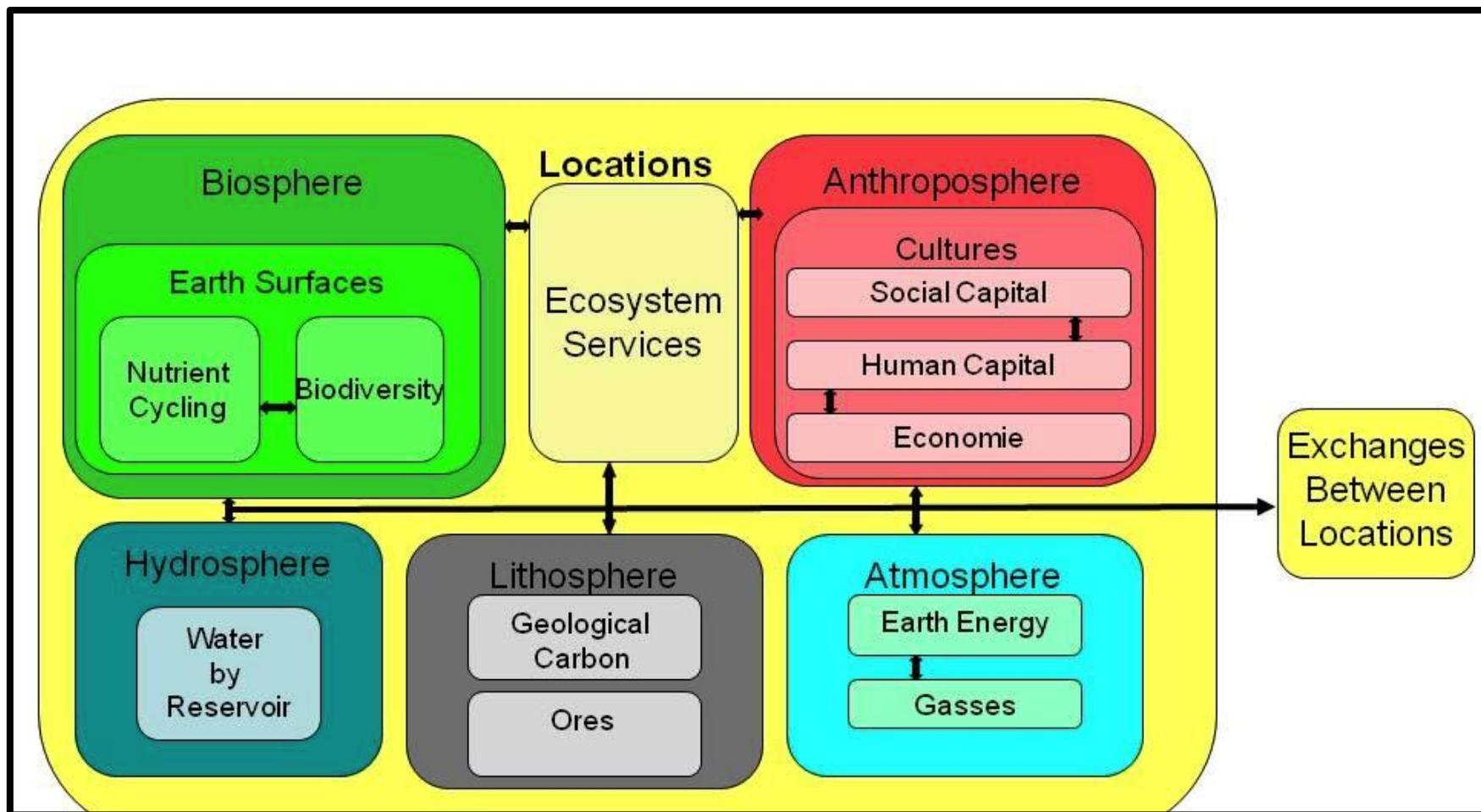
<sup>d</sup> Gordon and Betty Moore Center for Ecosystem Science and Economics, Conservation International 2011 Crystal Drive, Suite 500 Arlington, VA 22202, United States

# MIMES as spatial planning tool



Boumans et al. 2015

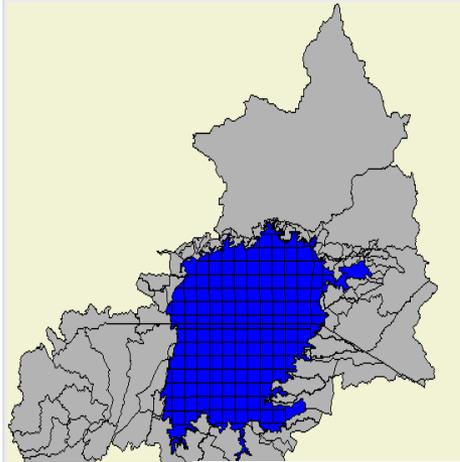
# MIMES structure: End to end systems model



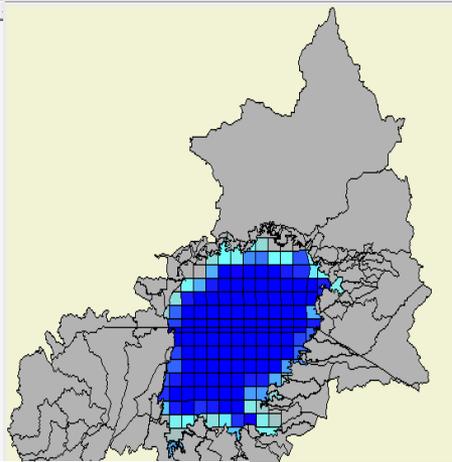


# GIS layers as input to MIMES

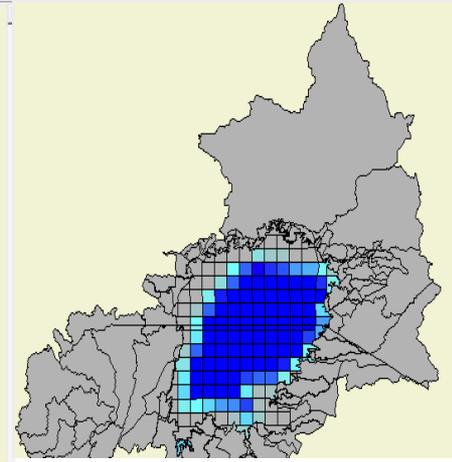
0 to -20 m



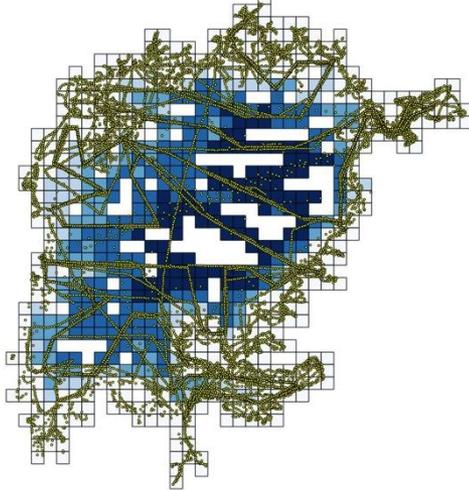
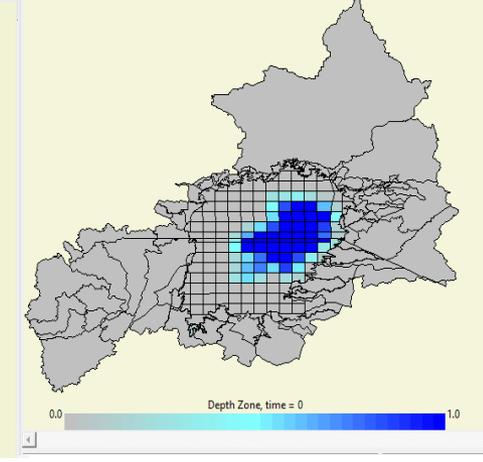
-20 to -40



-40 to -60



-60 to -80

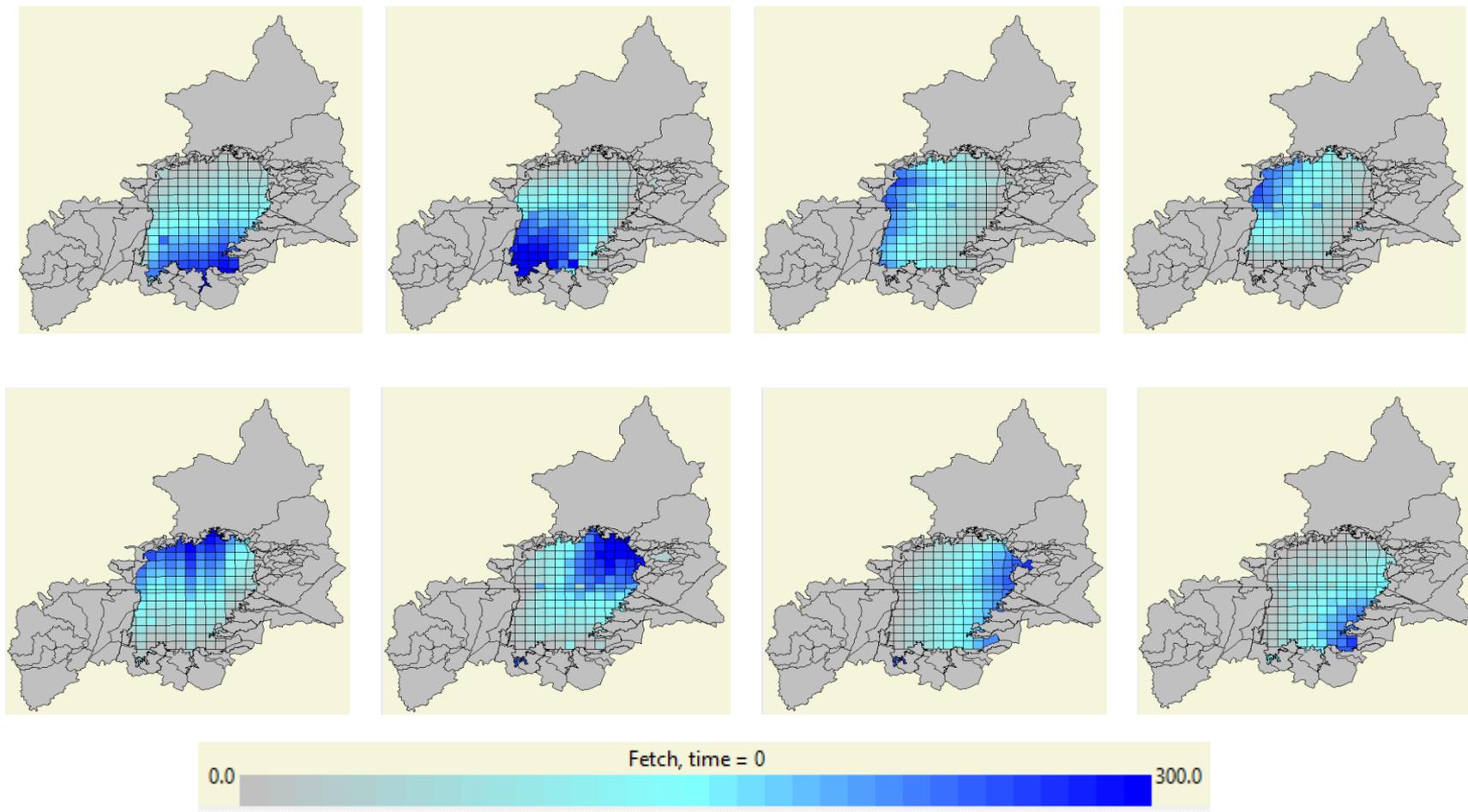


Silsbe, Greg (2015): Lake Victoria Shapefiles. figshare.

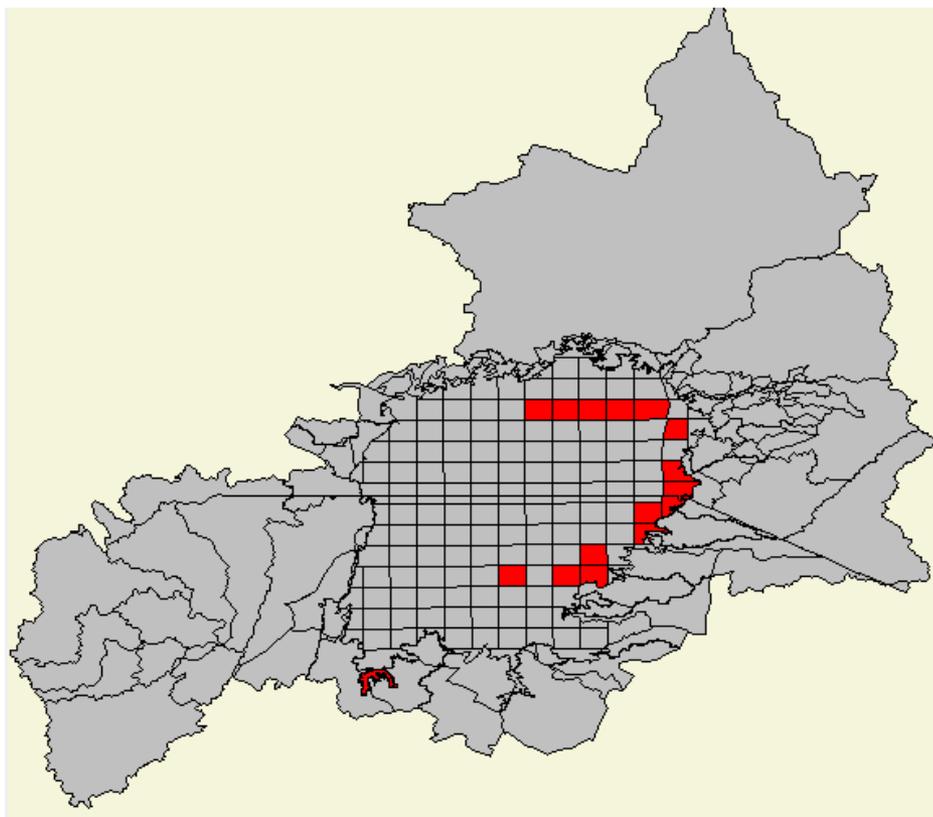
<https://dx.doi.org/10.6084/m9.figshare.1494839.v1>

Retrieved: 14 57, Jul 15, 2016 (GMT)

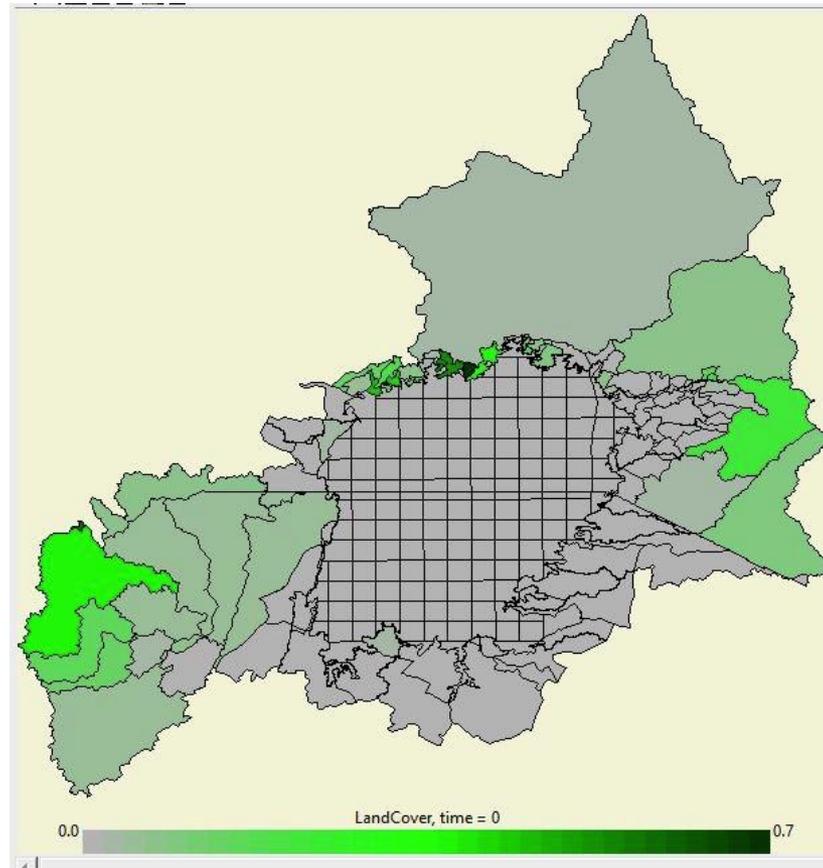
# Modeling fetch from wind direction data



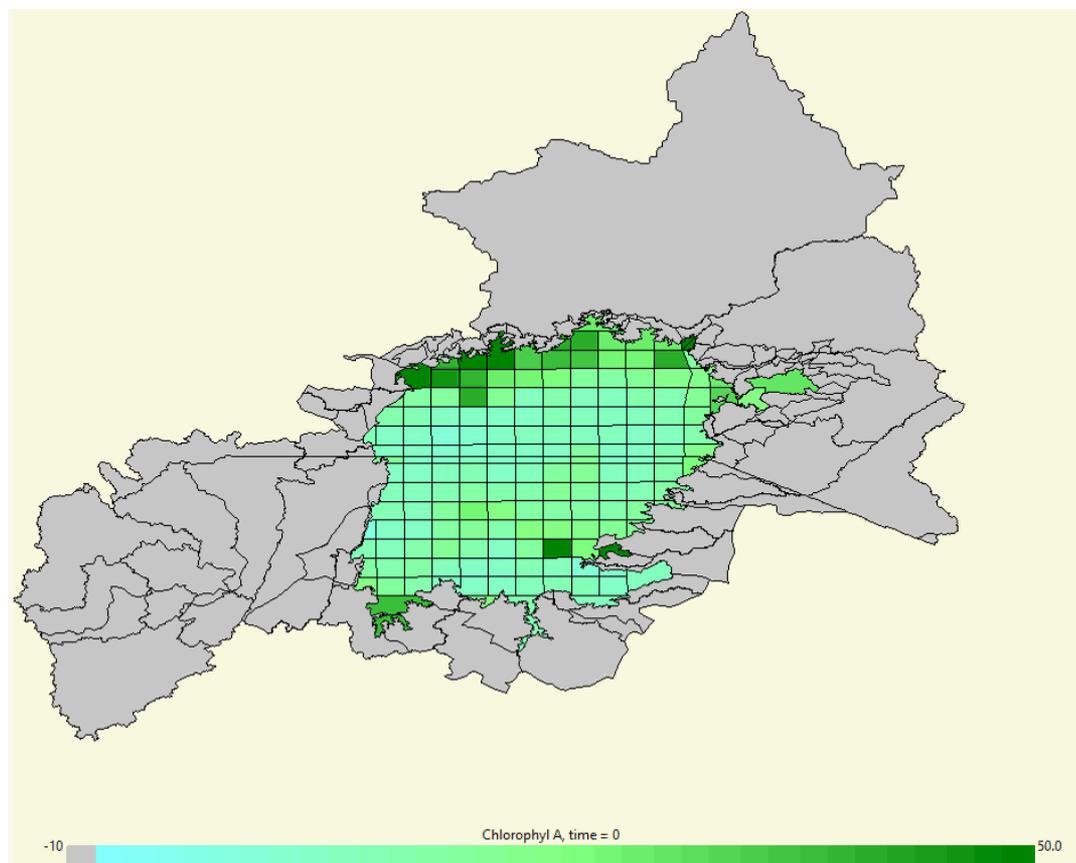
MIMES identifies areas of high likelihood anaerobic upwelling – bad for cages!



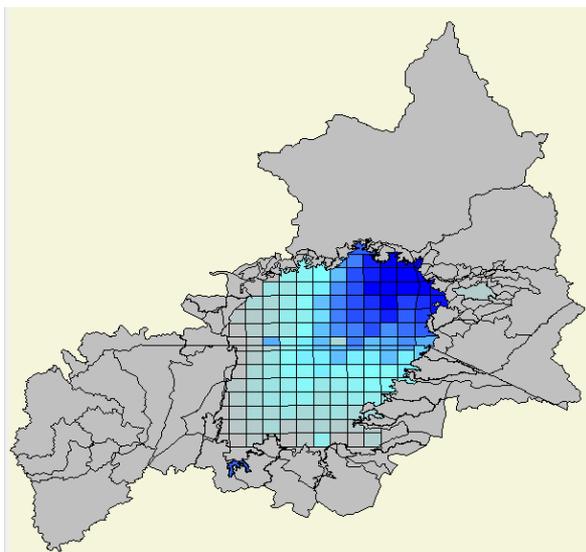
# Adding land cover...



# And chlorophyll



# SCALE



VS





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## Future work

- Add fishery data:
  - CAS catch and effort
  - Fish distributions from surveys
  - Gear distributions
- Add social factors
- Add economic factors
  - Transportation routes
  - Fish prices



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## Acknowledgements

- NSF Coupled Natural and Human Systems project grant
- NaFIRRI, KMFRI, TAFIRI, LVFO
- Robert Kayanda, Anthony Taabu Munyaho, William Ojwang, Magreth Musiba, Christopher Aura, John Okechi, Winnie Nkalubo, Lauren Chapman, Herbert Nakiyende, Monic Nsega, Sam Bbosa, Monica Owili, Ole Seehausen, Mary Kishe, Hillary Mrosso, Enock Mlaponi, Irit Altman, Matt Caddenhead, Stuart Hamilton, Karin Wedig, Cullen Hendrix, and many others