Mechanistic indicators of coral reef resilience

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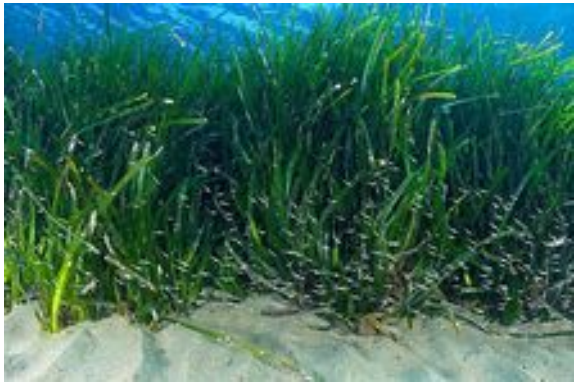
Ecological indicators of biogenic marine habitats

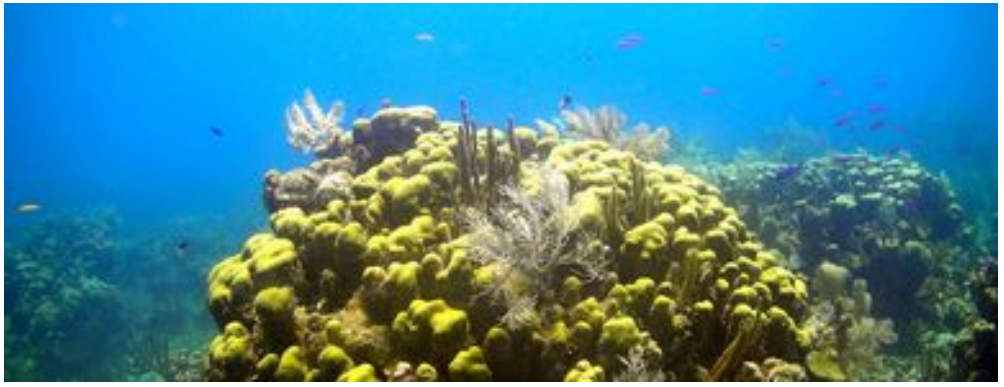
- **Fragile** and **complex** ecosystems

  feedbacks & regime shifts

- **Challenge** for the **interpretation** of ecological indicators

  state-based vs. mechanistic indicators

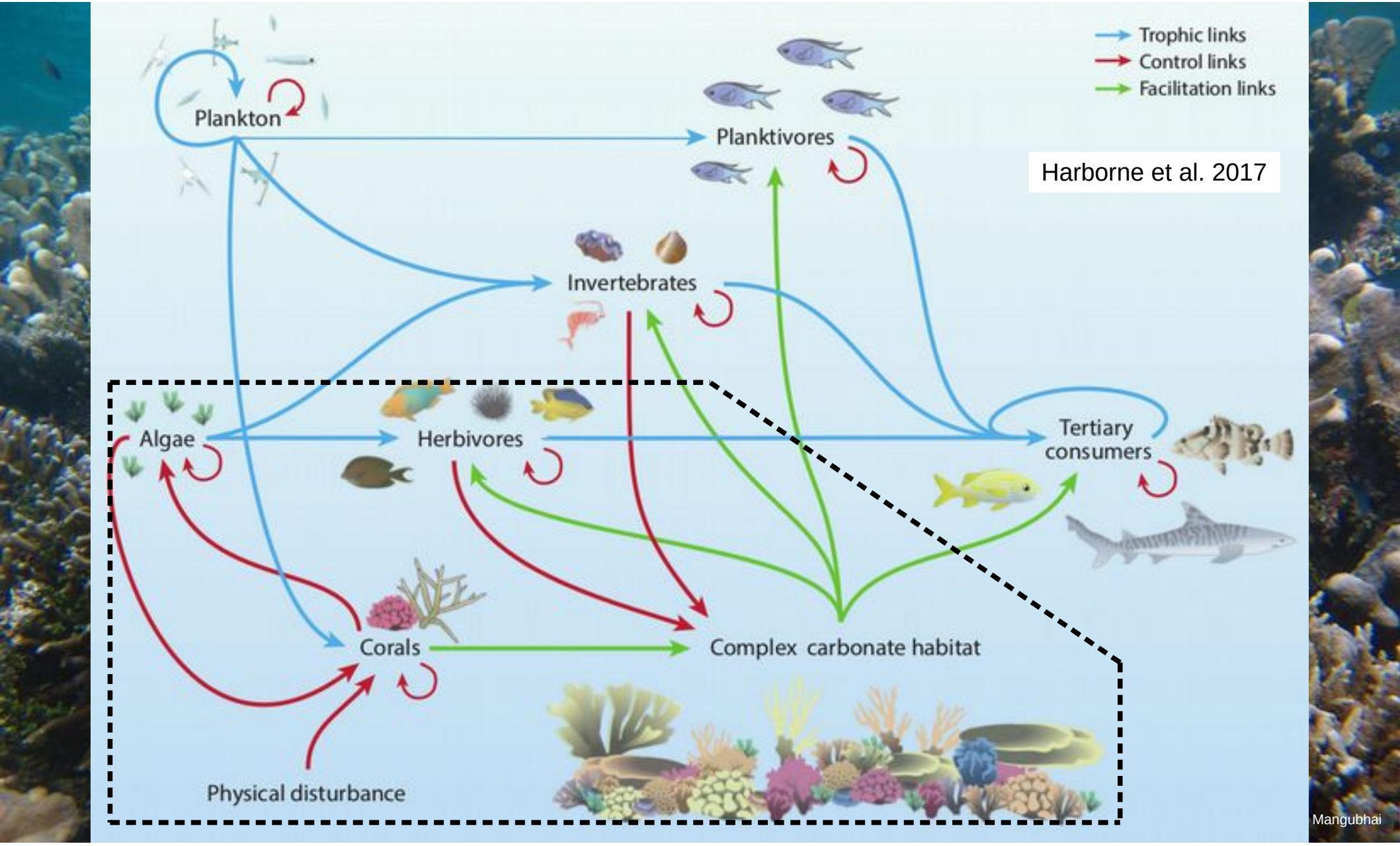


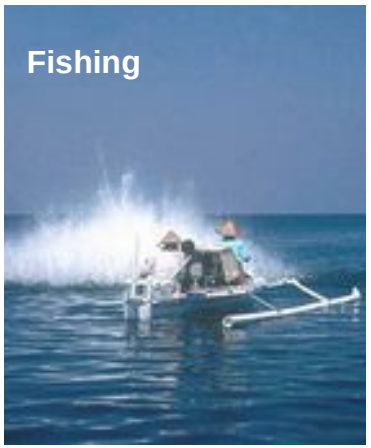

Tropical coral reef habitats

- Complex **hard structures** generated by reef-building corals
- Provision of habitat for highly-diverse communities
- Ecosystem services: fisheries, coastal protection

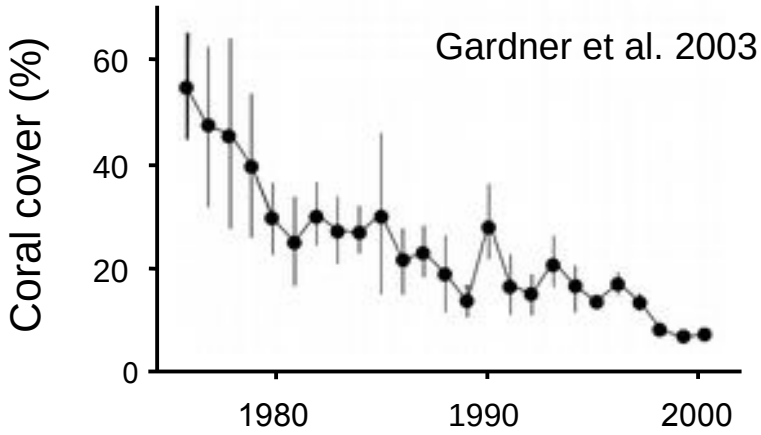
Functional relationships

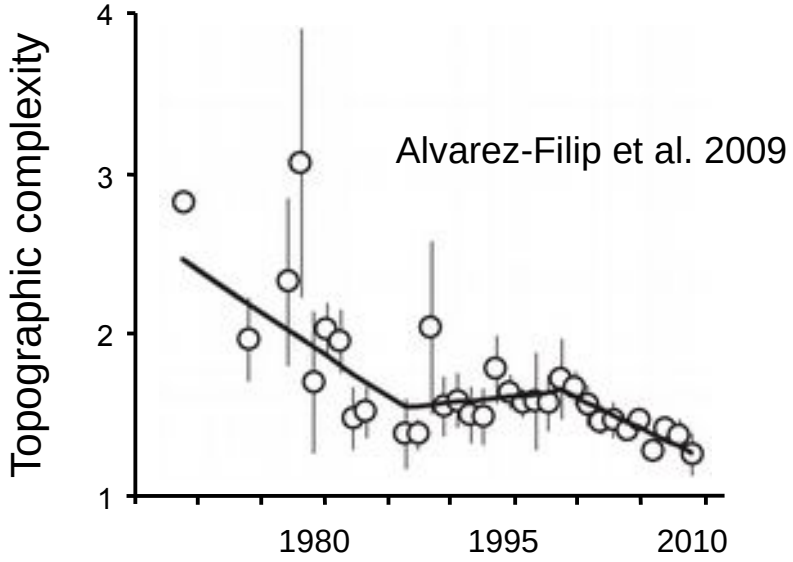


Disturbances of coral reef habitats



Global coral decline in the Caribbean region

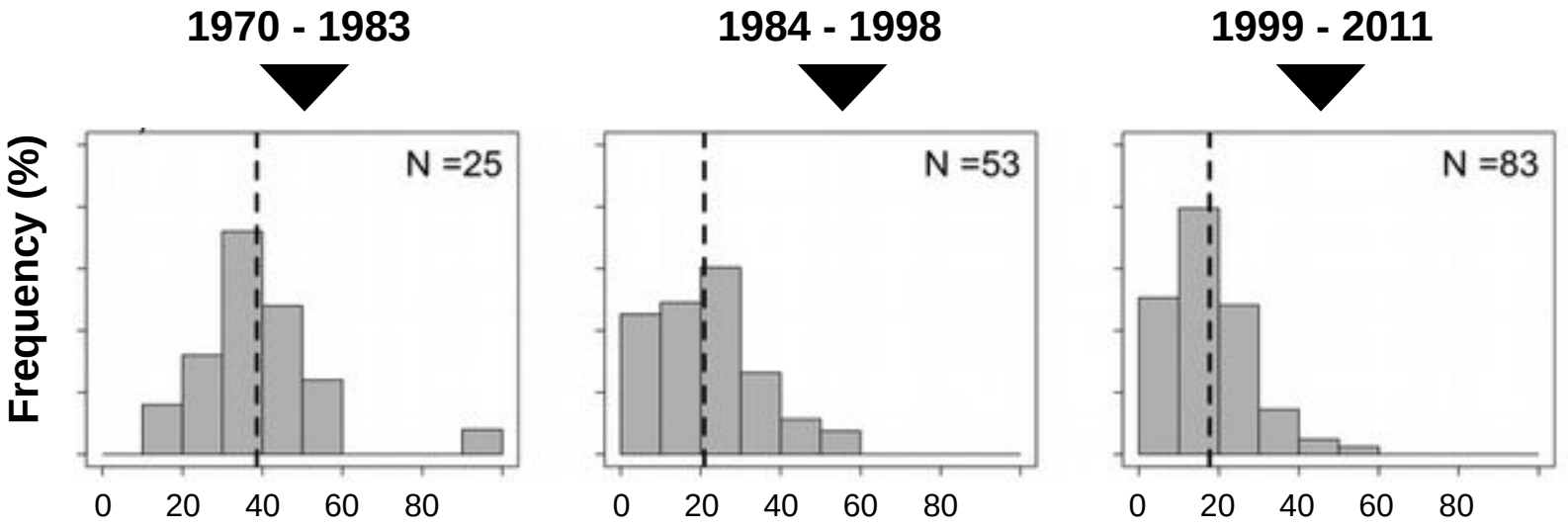


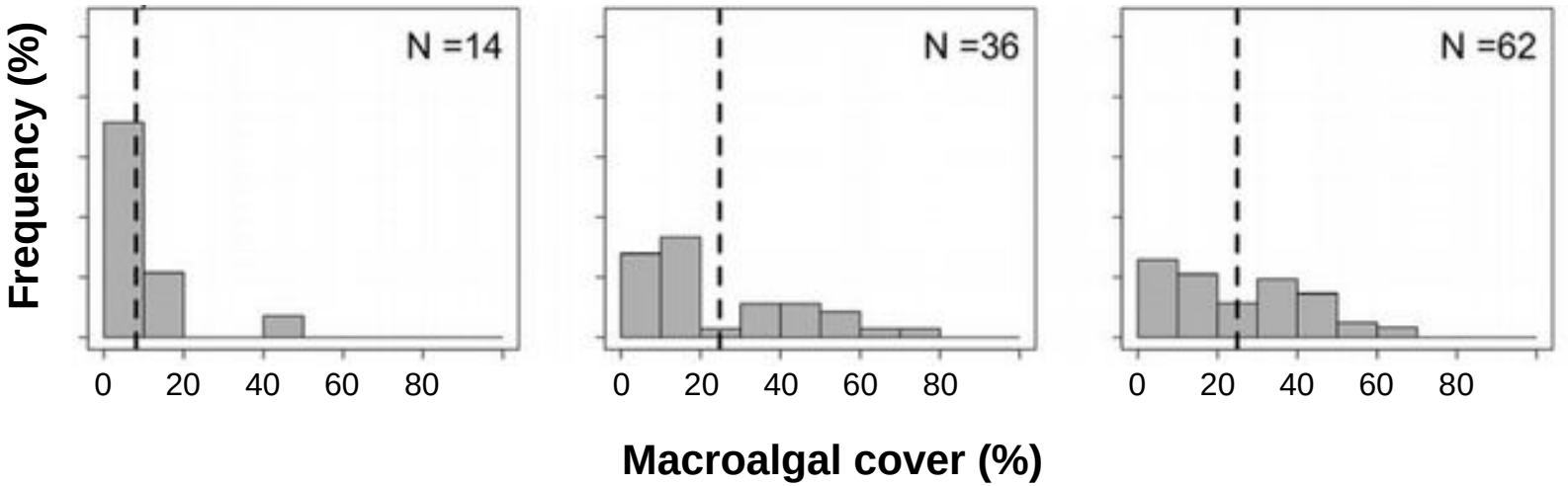


Coral-algal phase shifts

Jackson et al. 2014

Coral-algal phase shifts





Jackson et al. 2014

Modelling coral-algal phase shifts

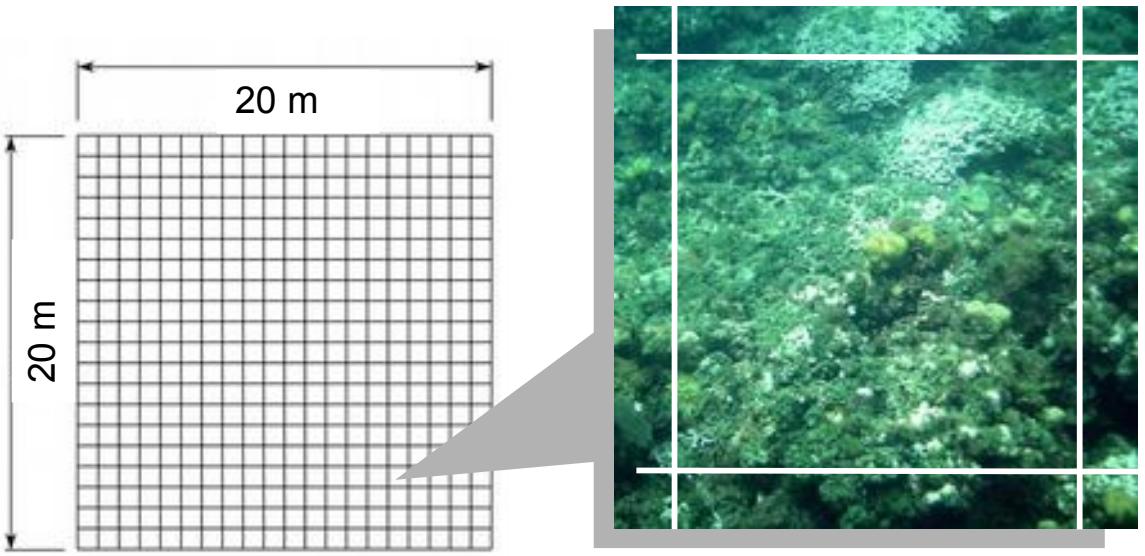
An individual-based model (Mumby et al. 2007)

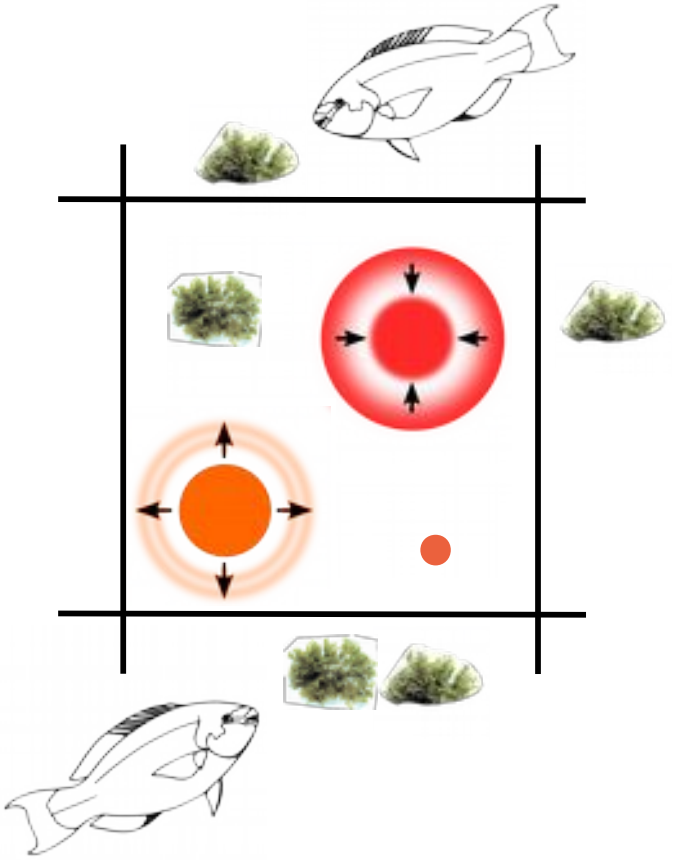
→ spatial grid: portion of a virtual reef

→ coral colonies with demographics (recruitment, growth, mortality)

→ algal patches

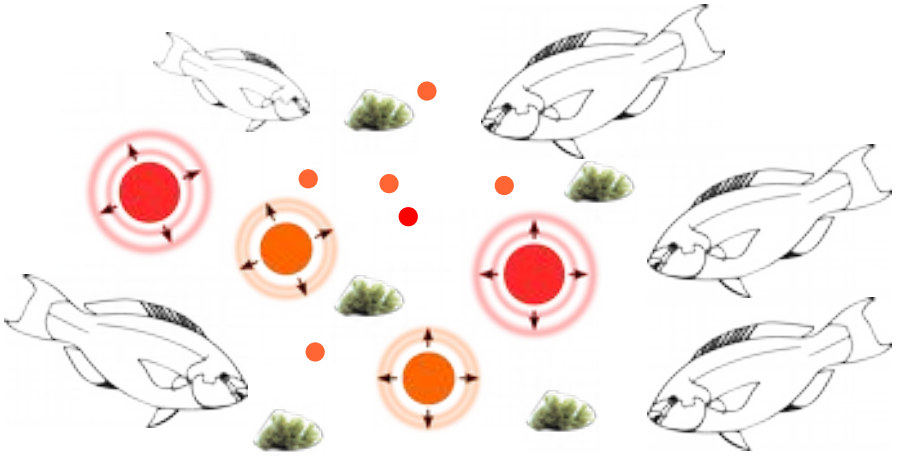
→ spatially-explicit grazing

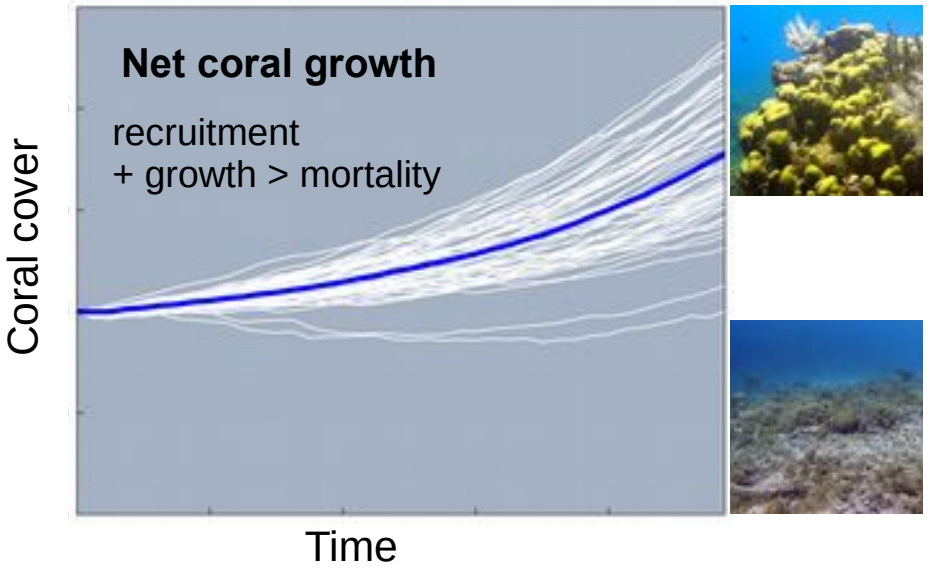




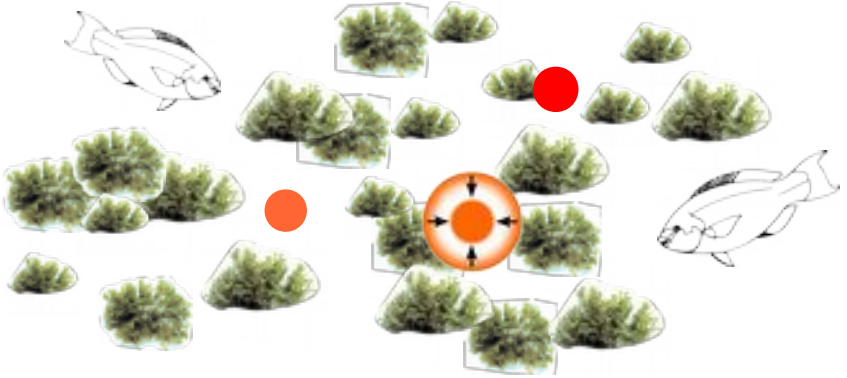
Simulating coral reef trajectories

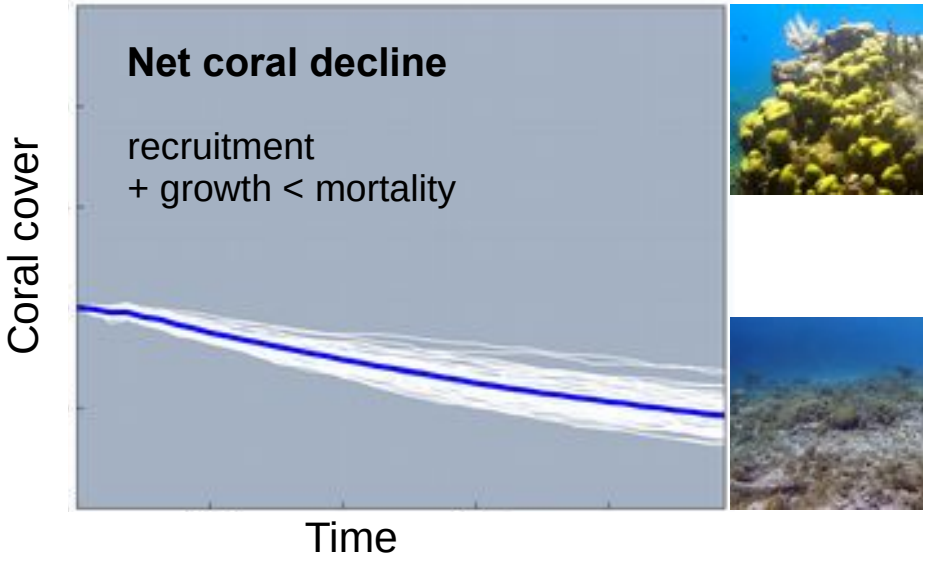
Full grazing





Deficient grazing

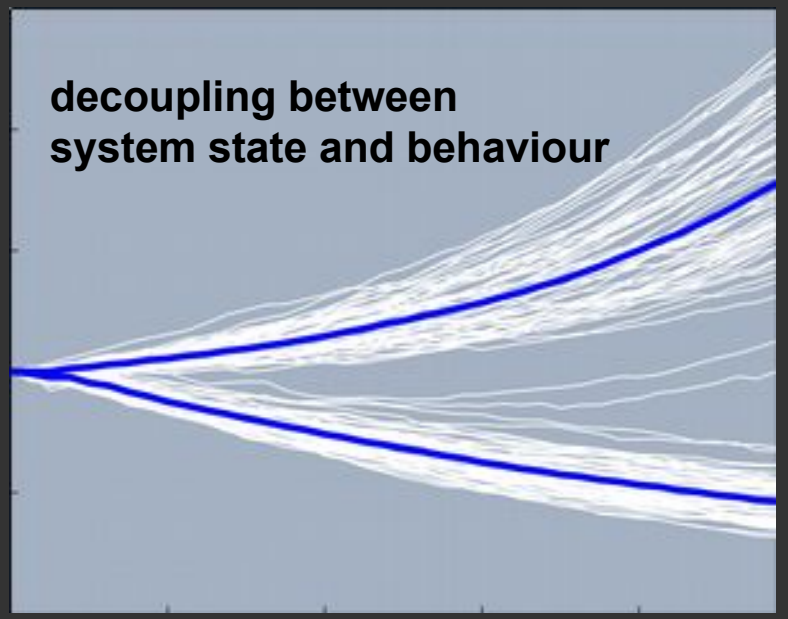




Implications for reef monitoring and indicators

- Coral cover
- Algal cover
- Fish density

= State-based indicators



- **Need to assess trends, not just snapshots**
- **Complement with mechanistic indicators**

McClanahan et al. 2013
Mumby et al. 2014
Flower et al. 2017
Maynard et al. 2017

- density of coral juveniles	- turf canopy height	- fish species biomass
- coral trait compostion	- algal growth rates	- grazing rates
- water clarity	- nutrient concentrations	- sediment loads (turf)

Persistence of the reef physical structure ?

Corals:

contribution to reef accretion varies

Parrotfish:

efficient grazers but also bioeroders

Levels of coral cover / grazing that maintain functional habitats?

Global Change Biology

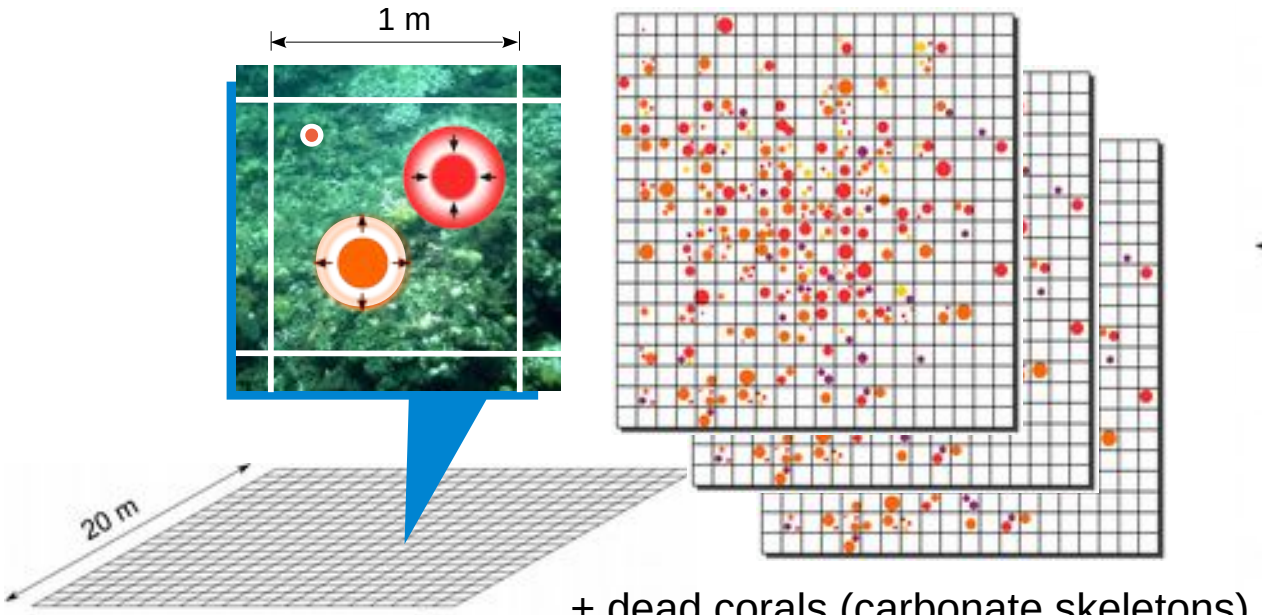
celebrating 20 years

Global Change Biology (2015) **21**, 223–235, doi: 10.1111/gcb.12698

The dynamics of architectural complexity on coral reefs under climate change

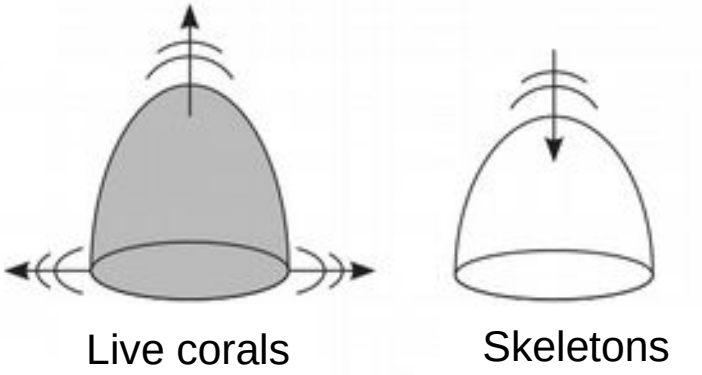
YVES-MARIE BOZEC[1,2], LORENZO ALVAREZ-FILIP[3] and PETER J. MUMBY[1,2]

Modelling reef accretion and erosion



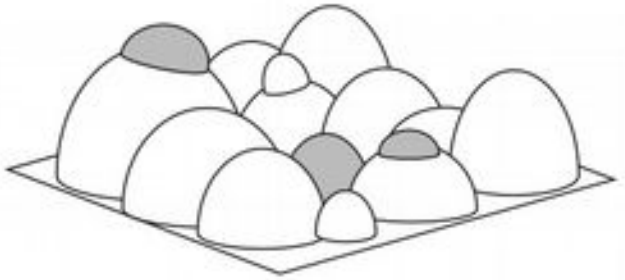
+ dead corals (carbonate skeletons)

Assign a shape (dome-like)



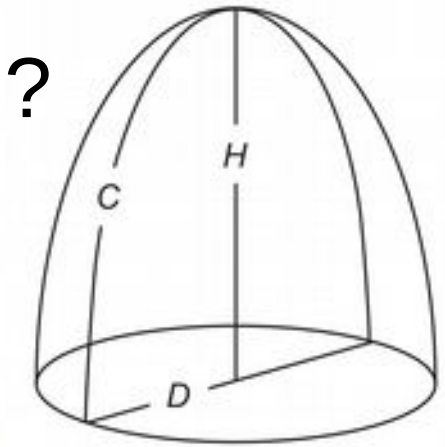
Live corals

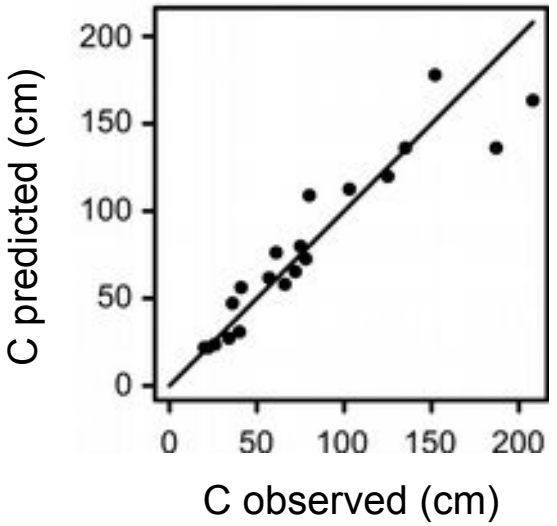
Skeletons



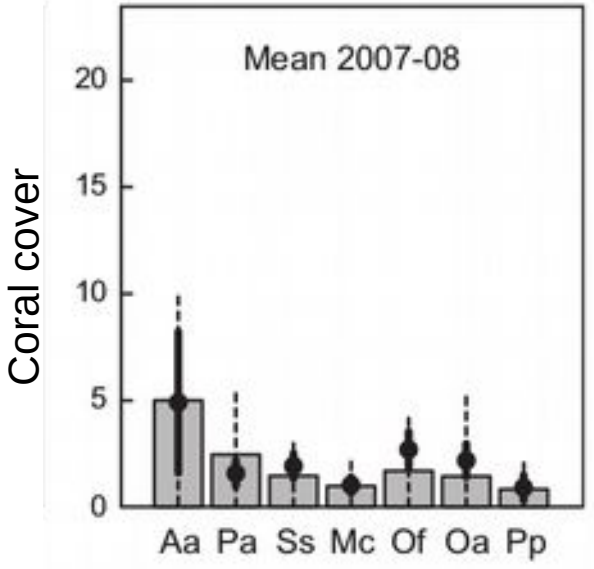
Structural complexity = deformation of the reef surface

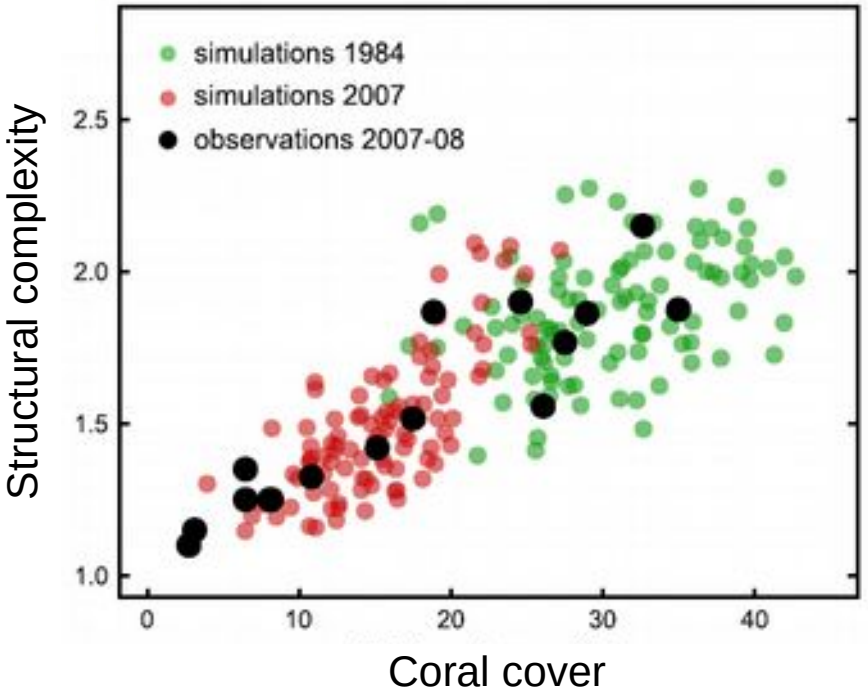
Model parameterisation and testing





Montastrea annularis



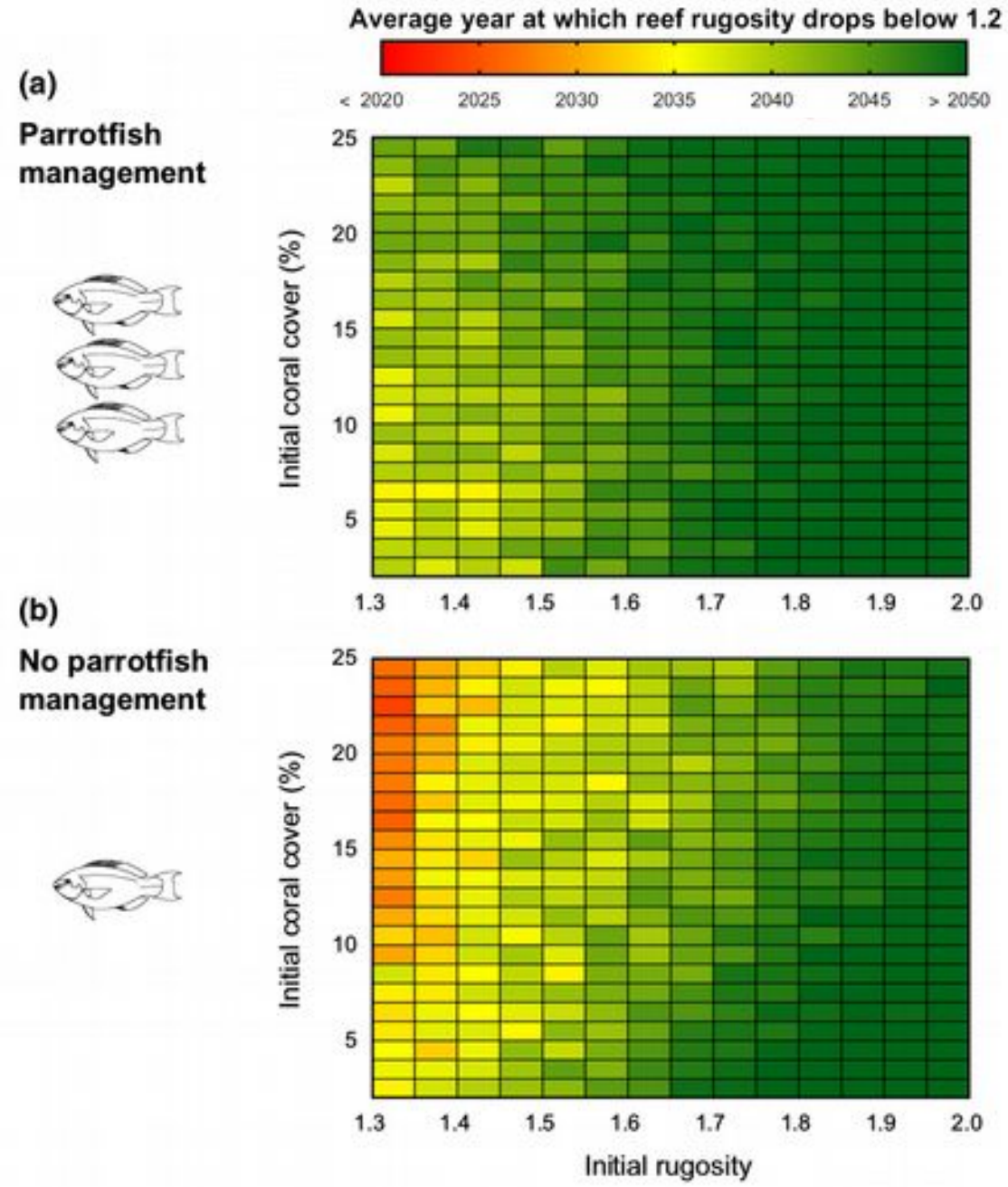


Forecasting the future of structural complexity

Simulation of different scenarios

- coral cover
- structural complexity
- global warming
- local management (herbivores)

Importance of managing herbivores for habitat persistence



Ecosystem impact of fishing on coral habitats?

Parrotfish:

Dominant herbivore in the Caribbean but also an important catch



Maximum level of fishing that maintain functional habitats?

PNAS

Tradeoffs between fisheries harvest and the resilience of coral reefs

Yves-Marie Bozec[a,b,1], Shay O'Farrell[a,c], J. Henrich Bruggemann[d,e], Brian E. Luckhurst[f], and Peter J. Mumby[a,b,1]

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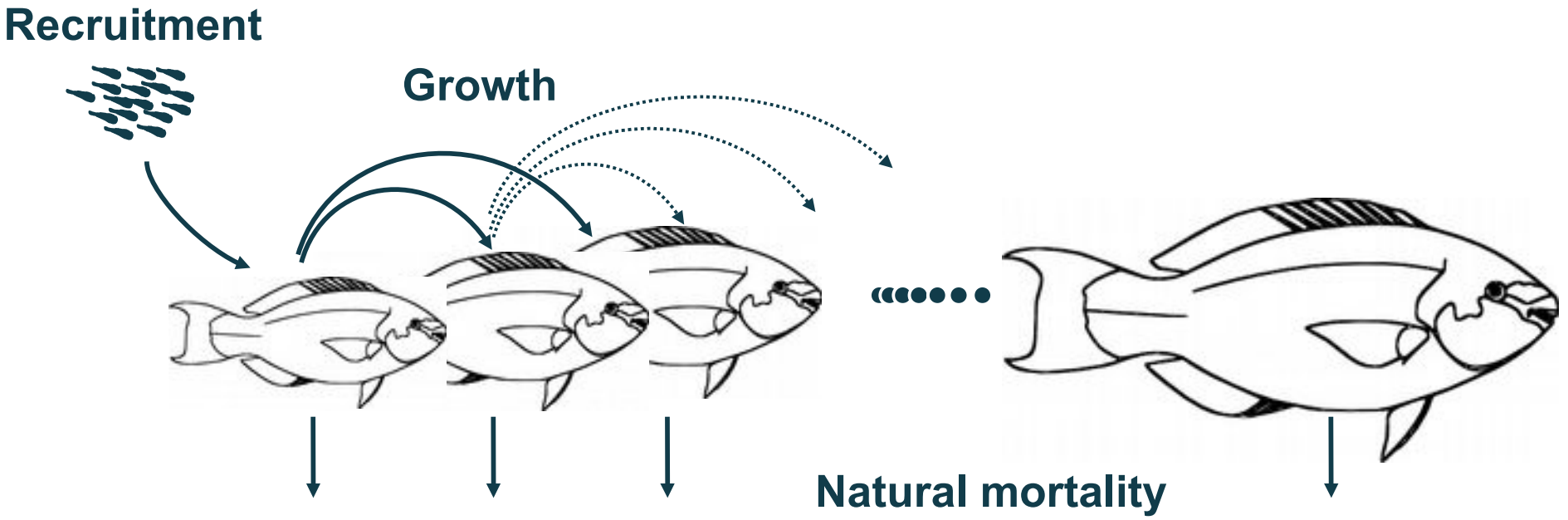
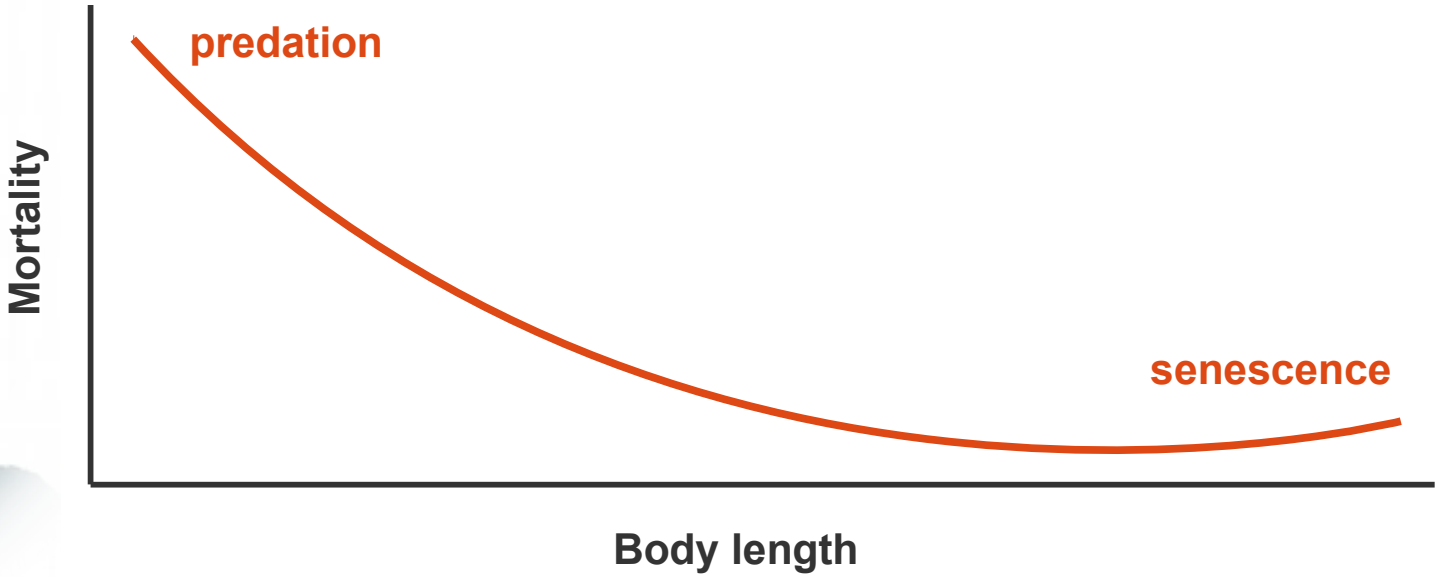
A simple demographic model of parrotfish



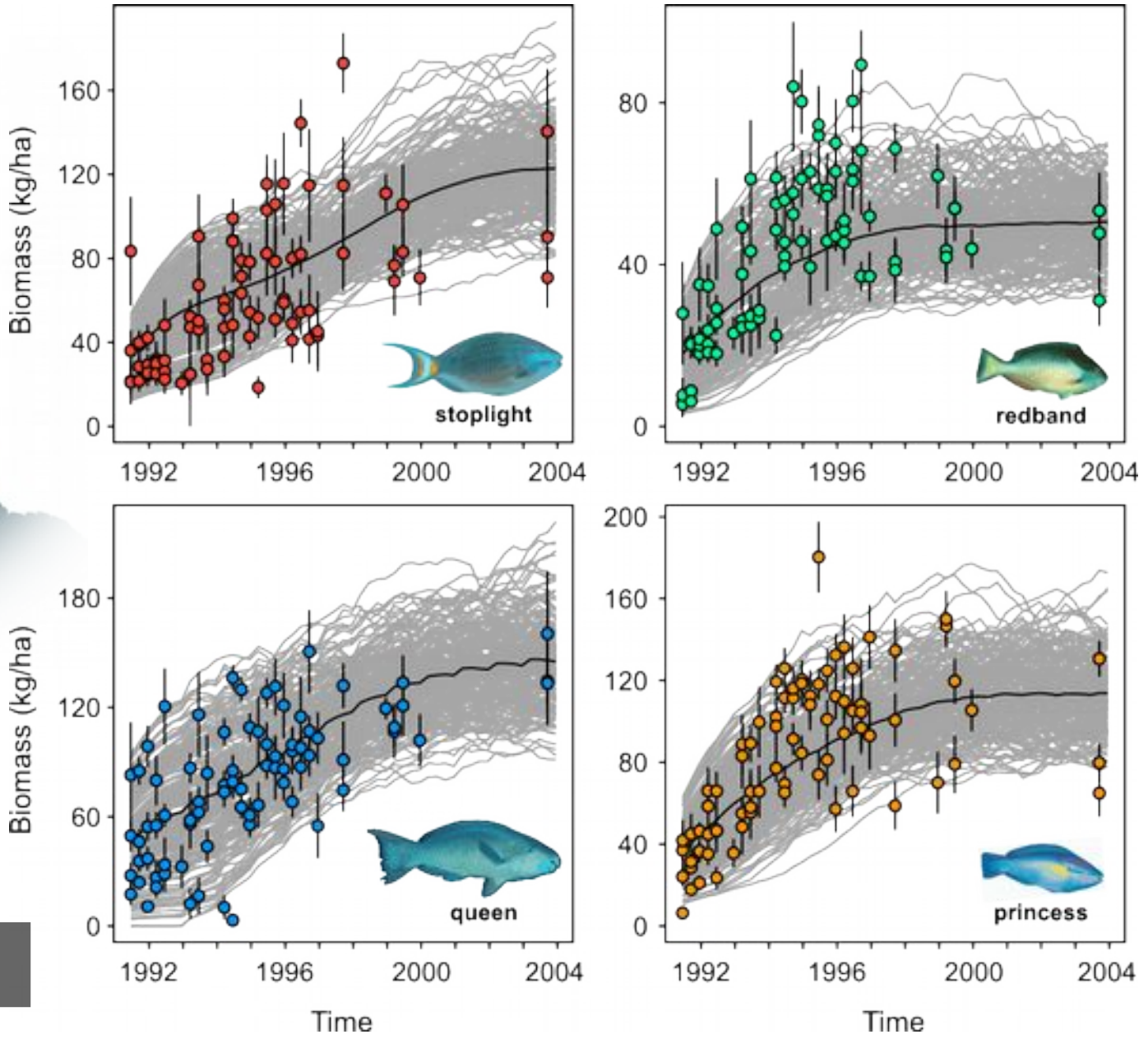


Model testing

5 parrotfish species

> 80% of parrotfish biomass

Populations recovering after banning fish traps (1990)

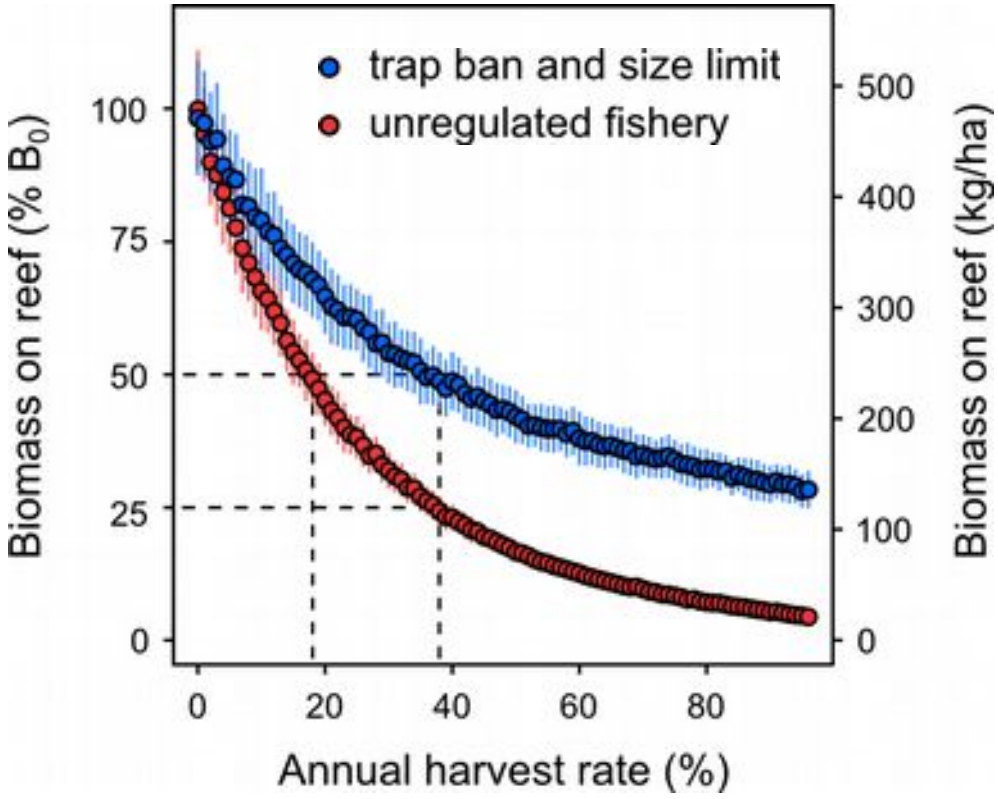


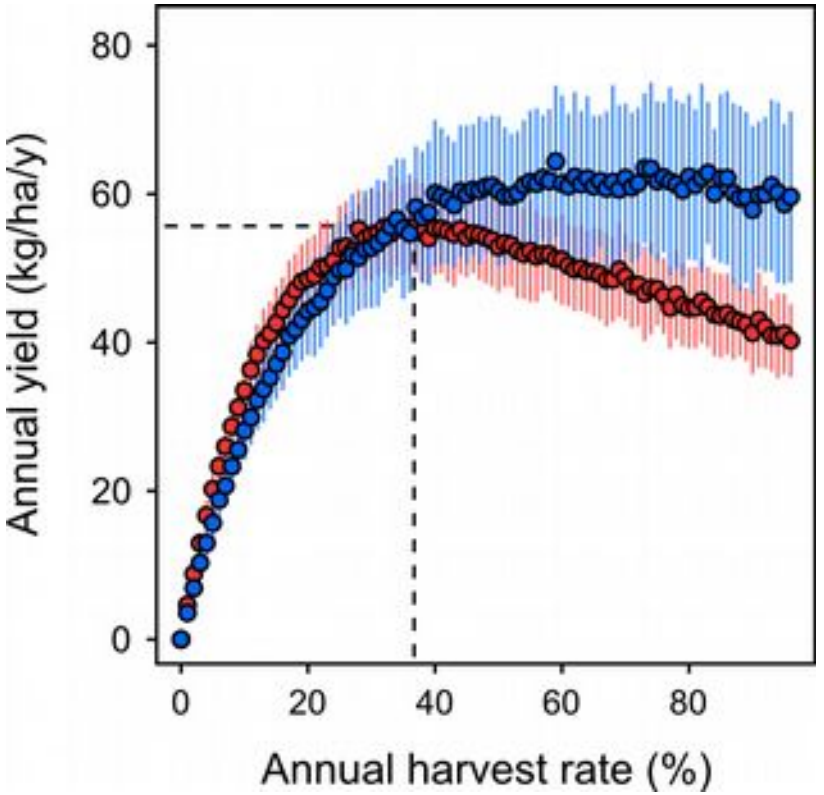
Exploring the impacts of fishing

Fishing mortality F + gear (length) selectivity

15 cm ~ unregulated fishery

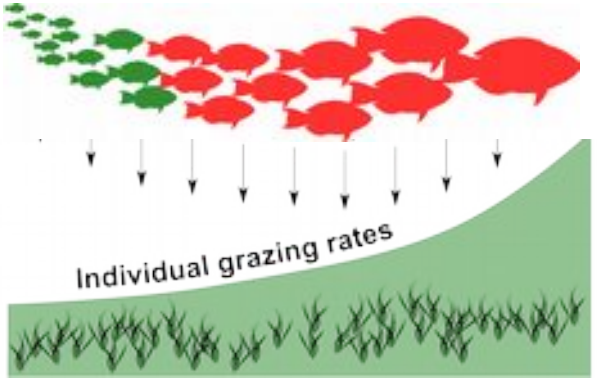
30 cm ~ trap ban + size limit



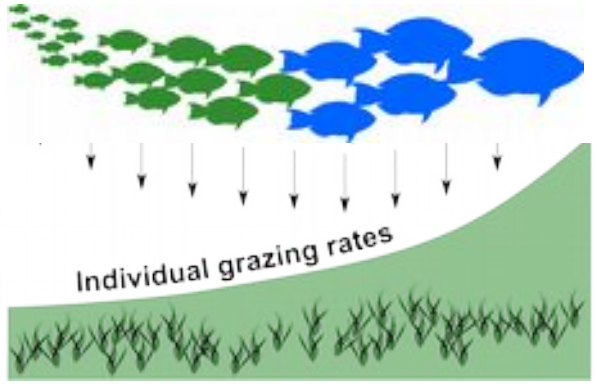


Simulating ecosystem impacts of fishing

15 cm (unregulated)

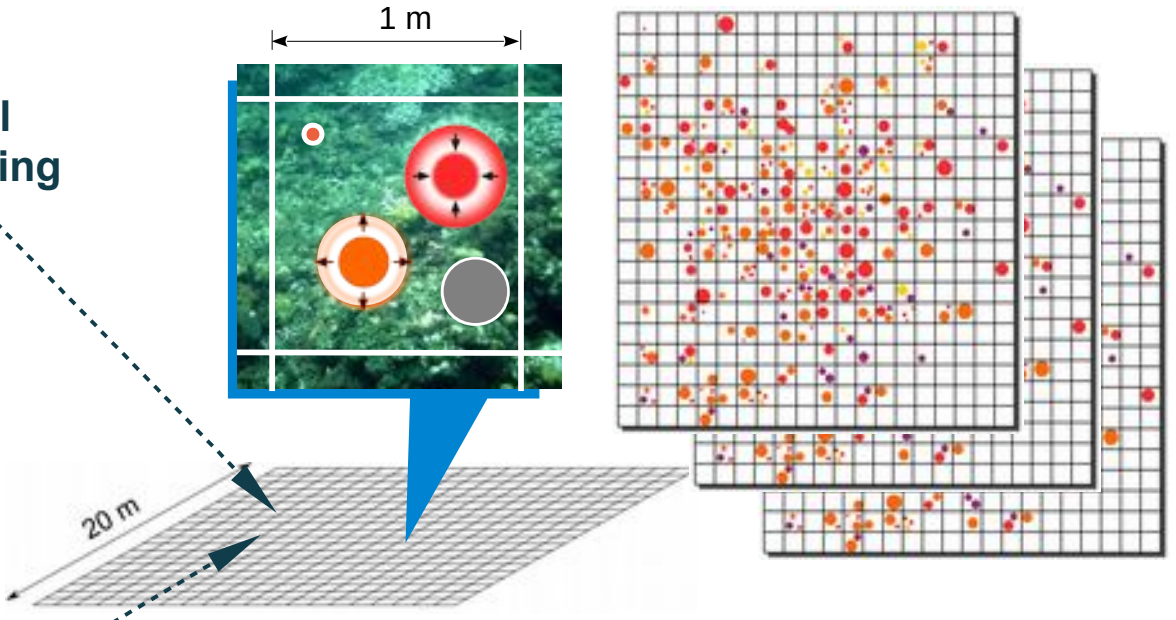


30 cm (trap ban + size limit)



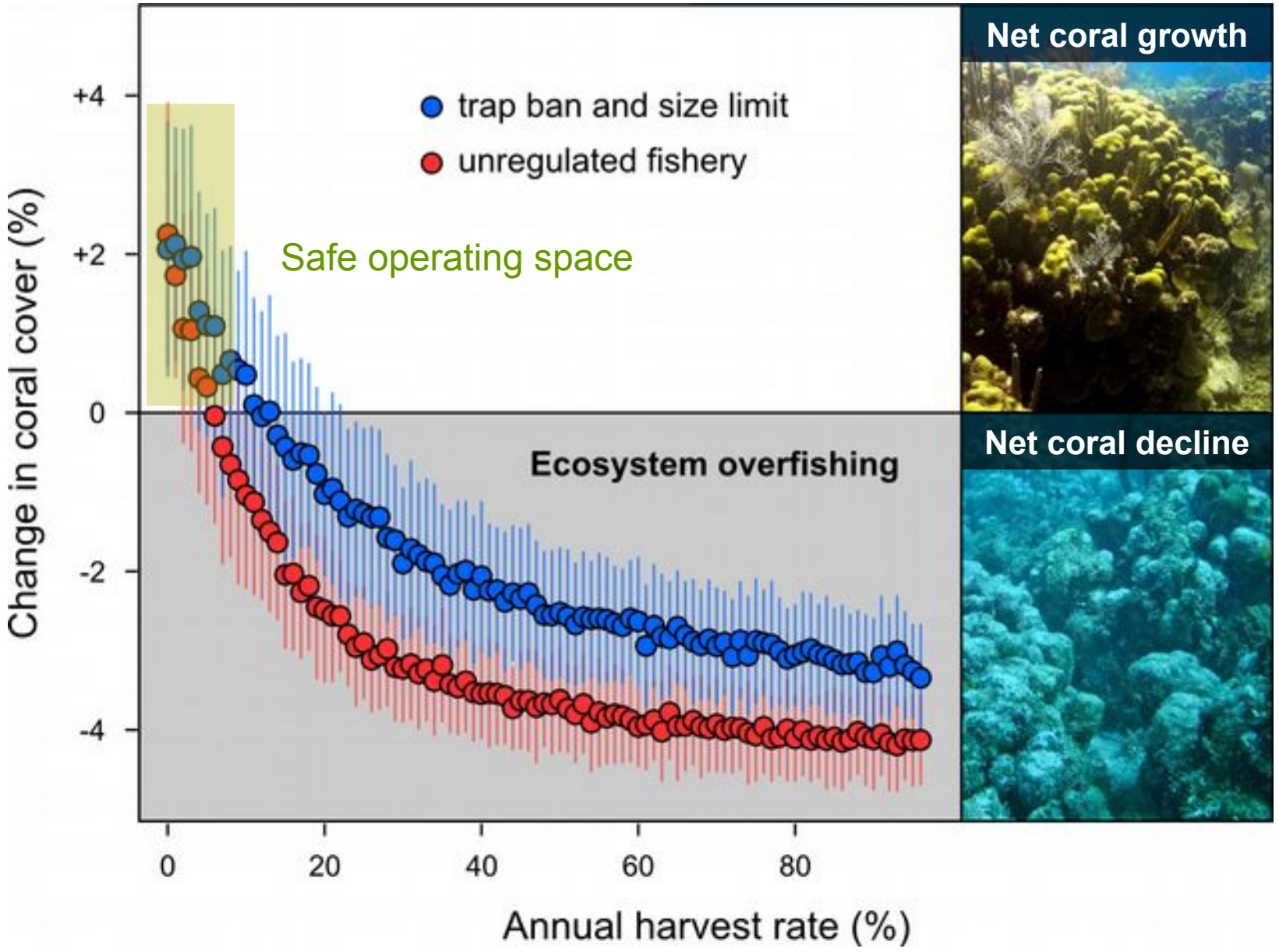
Total grazing

Total grazing



Impact on coral persistence ?

Impacts of fishing on coral persistence



Implications for monitoring and management

- **Indicators of ecosystem overfishing**
  - Parrotfish size distribution (~bites)
  - Parrotfish species composition
  - Parrotfish recruitment and mortality

- **Functional grazing sensitive to fishing → needs regulations**
  - Impose trap ban (where feasible)
  - Impose species / size limit (>30 cm)
  - Impose catch limit (10% of exploitable stock)



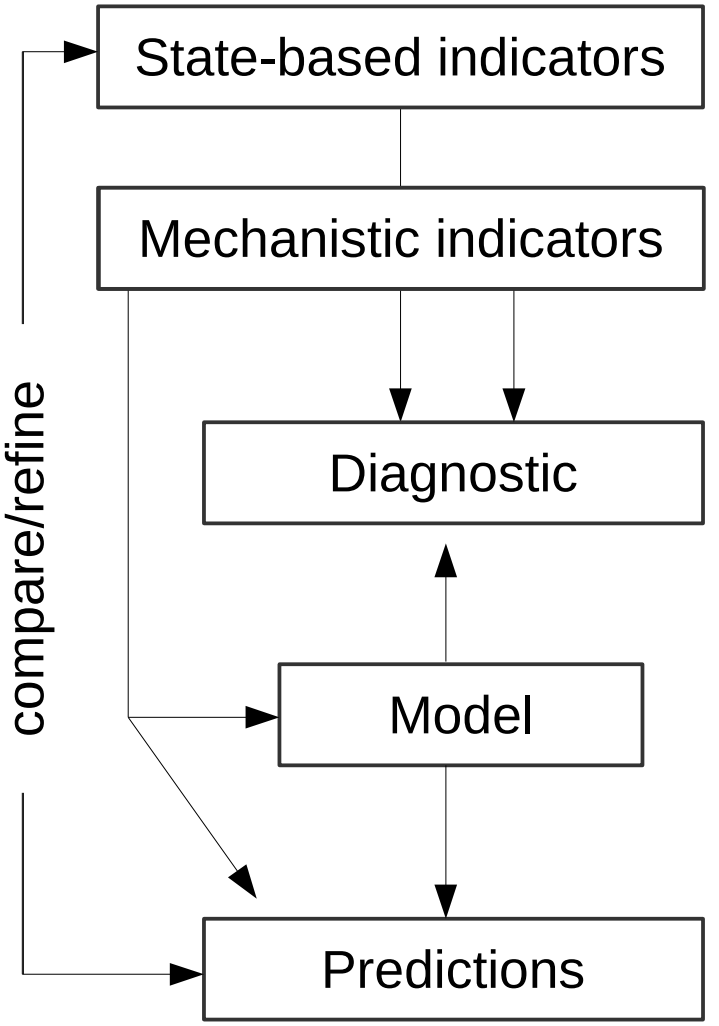
Summary

- **Mechanistic indicators**

  - Inform about system dynamics
  - Help predict system trajectory
  - Assessment can be time-consuming

- **Mechanistic models**

  - Explore possible trajectories
  - Help defining thresholds
  - Predictions confronted to monitoring



Aknowledgements

Prof. Peter J. Mumby (UQ), Carolina Castro-Sanguino (AIMS), George Roff (UQ)

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