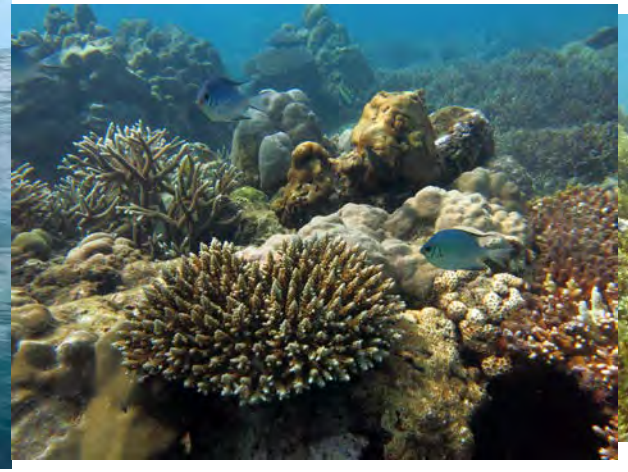
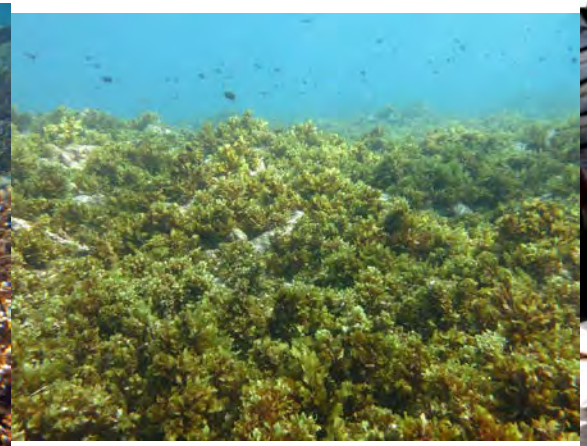
Productive instability of coral reef fisheries after climate-driven regime shifts

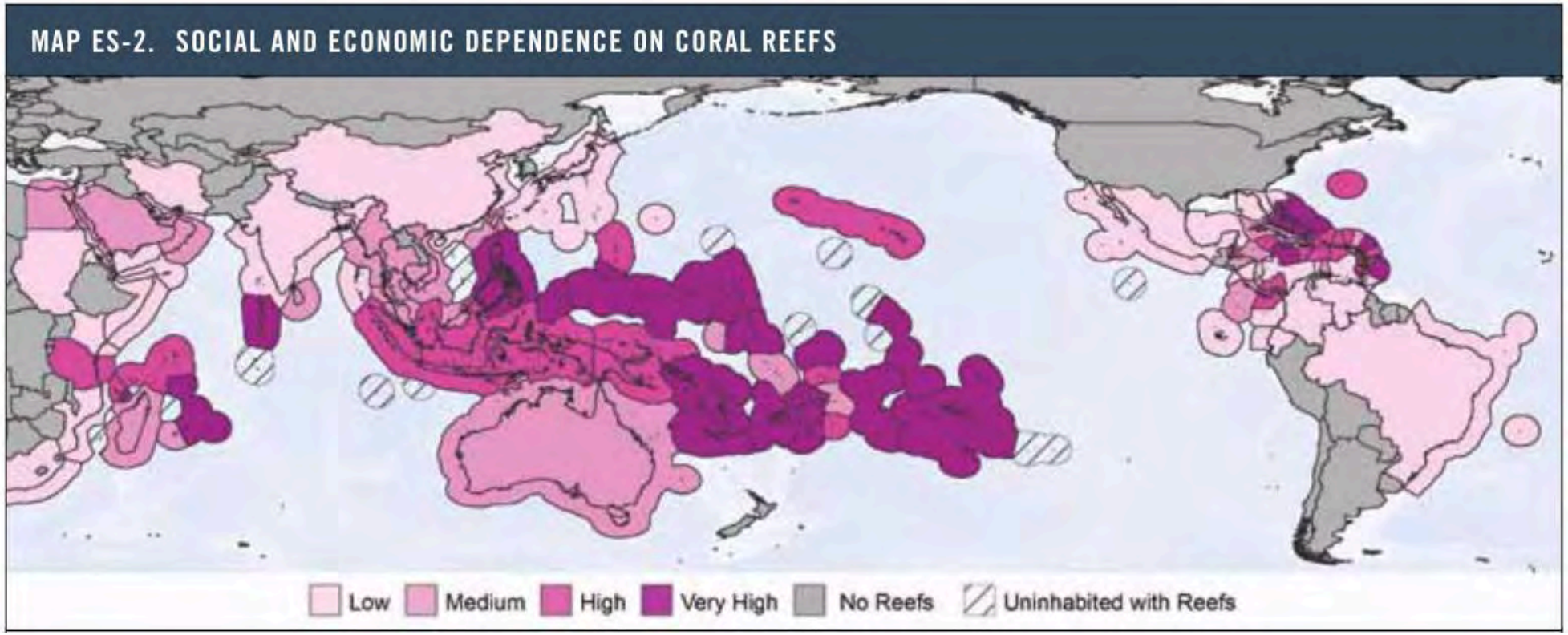

James Robinson, Shaun Wilson, Jan Robinson, Calvin Gerry, Juliette Lucas, Cindy Assan, Rodney Govinden, Simon Jennings, Nick Graham

Lancaster University

james.robinson@lancaster.ac.uk | @jamespwr

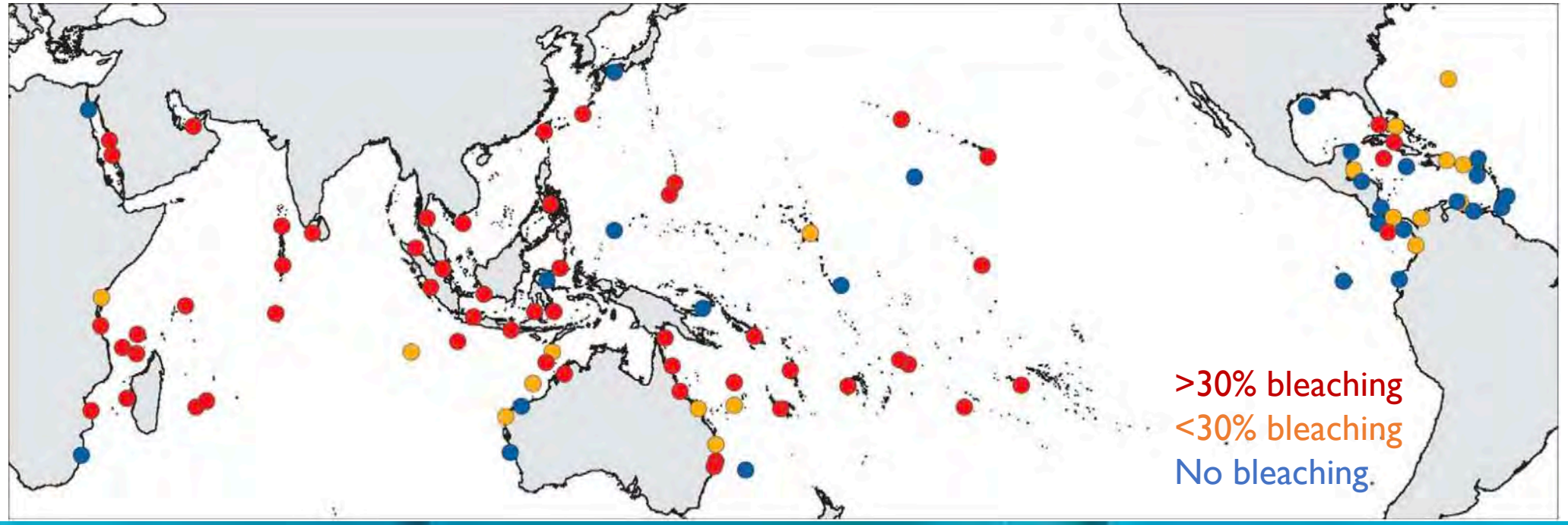
SEYCHELLES FISHING AUTHORITY

Coral reefs provide food & employment for >1 billion people



Reefs at Risk Revisited 2011

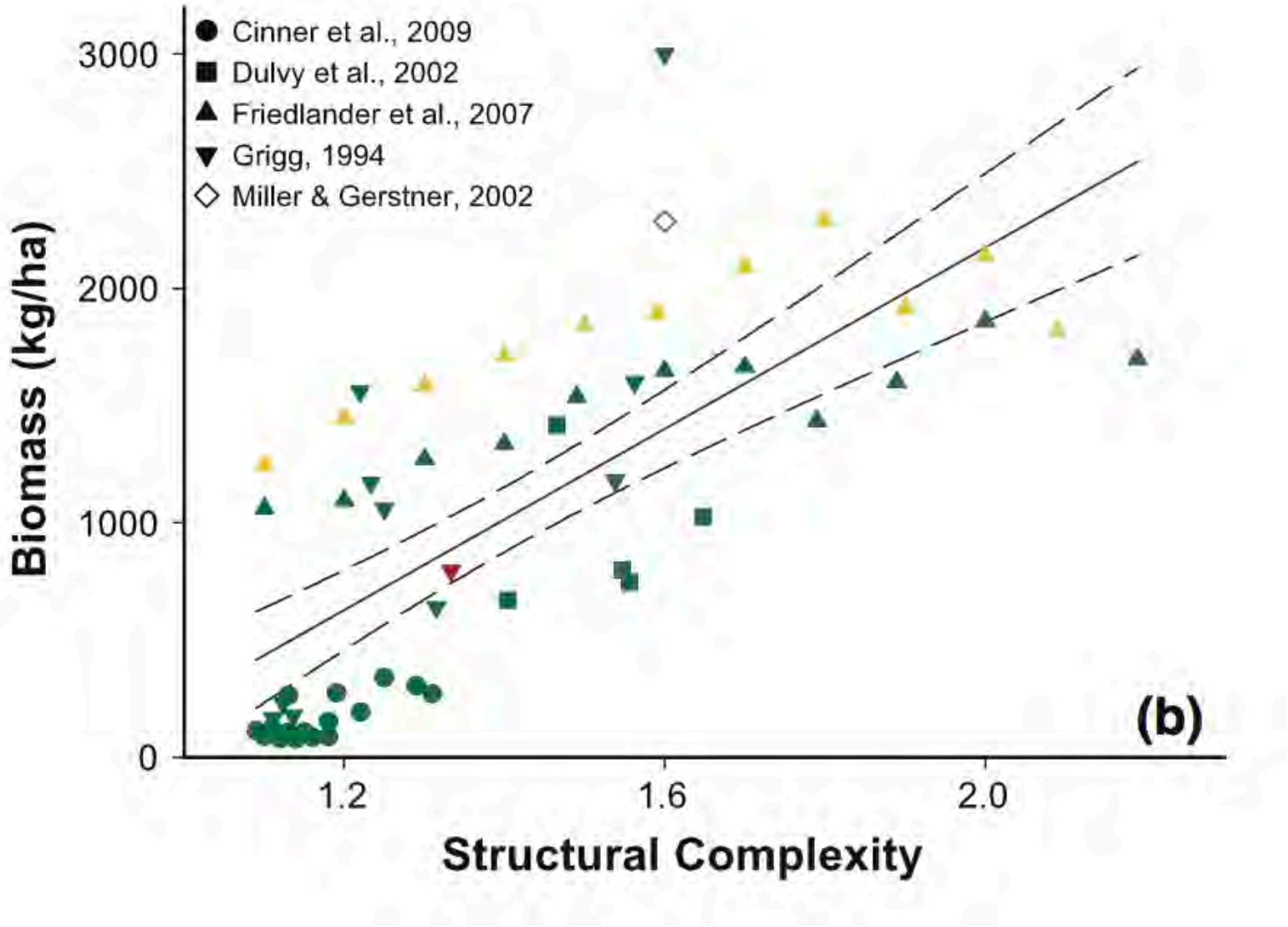
Coral reefs for food & employment…under recurrent bleaching events



Hughes et al. 2018 *Science*

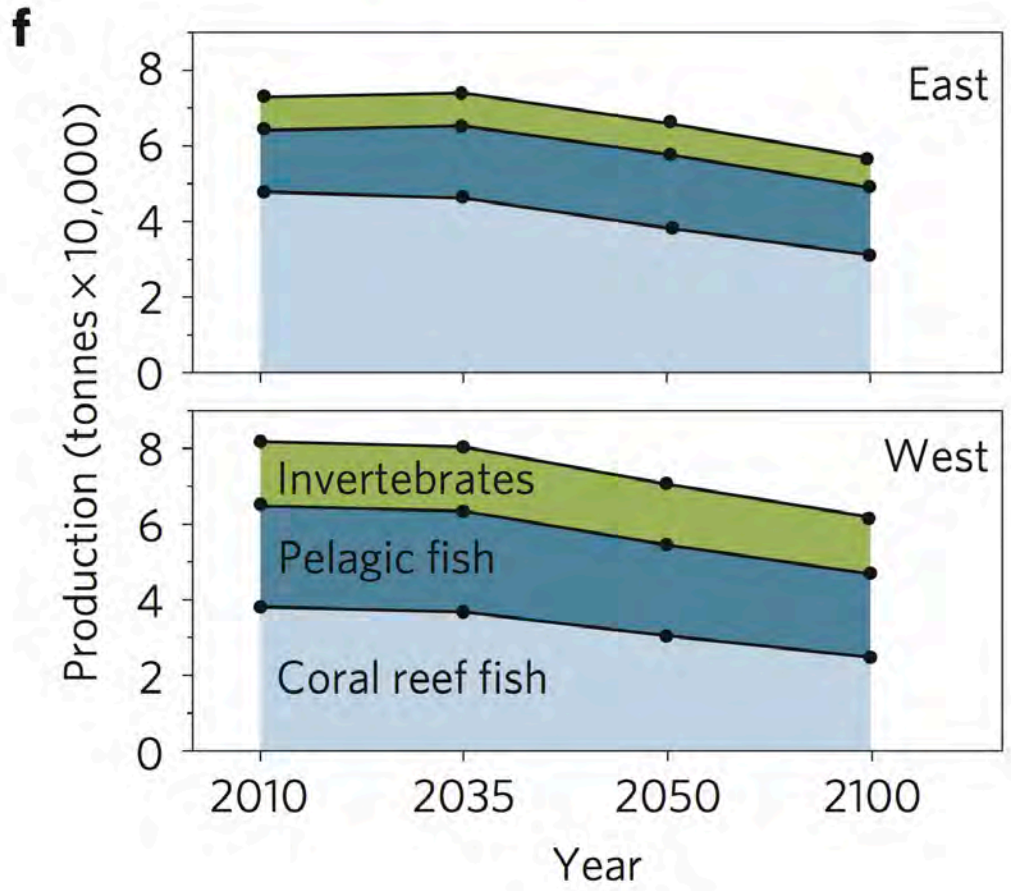
Coral reefs for food & employment…under recurrent bleaching events

Graham & Nash 2012 *Coral Reefs*



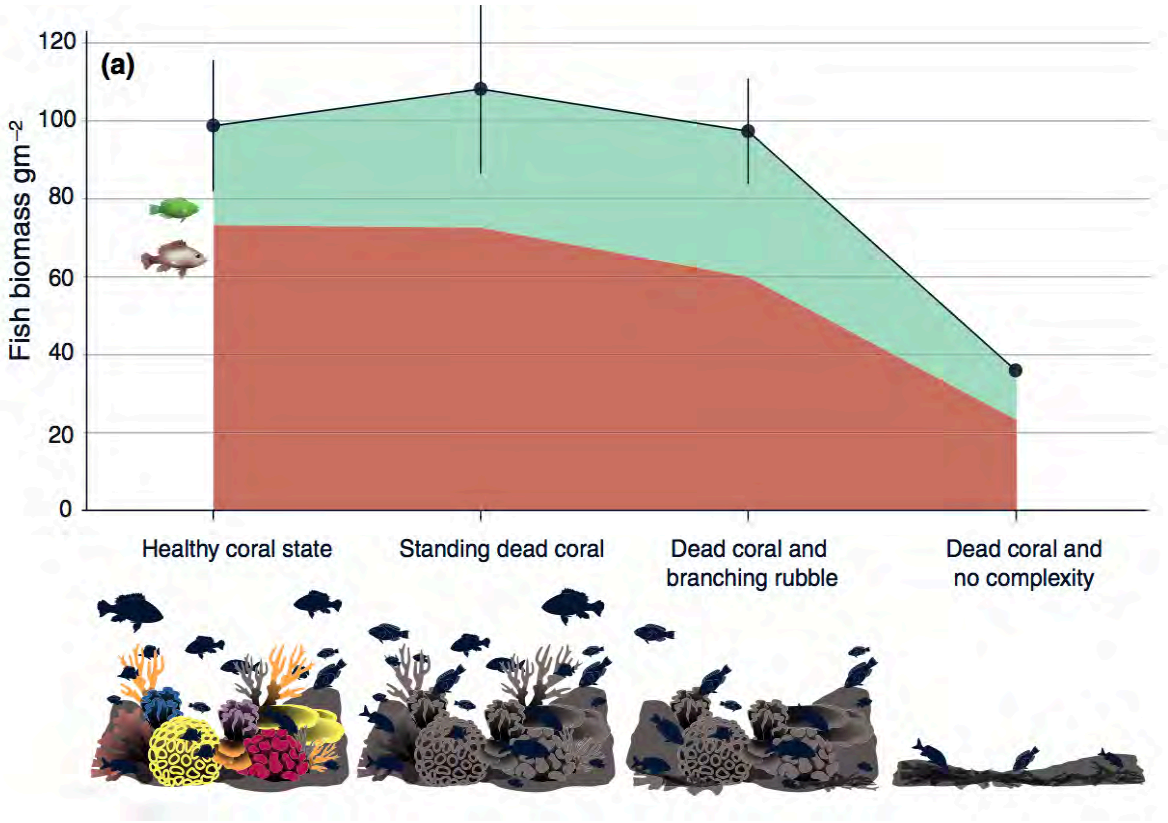
Bleaching impacts on fisheries: models indicate productivity declines

Climate envelope models:



Bell et al. 2013 *Nat. Clim. Change*

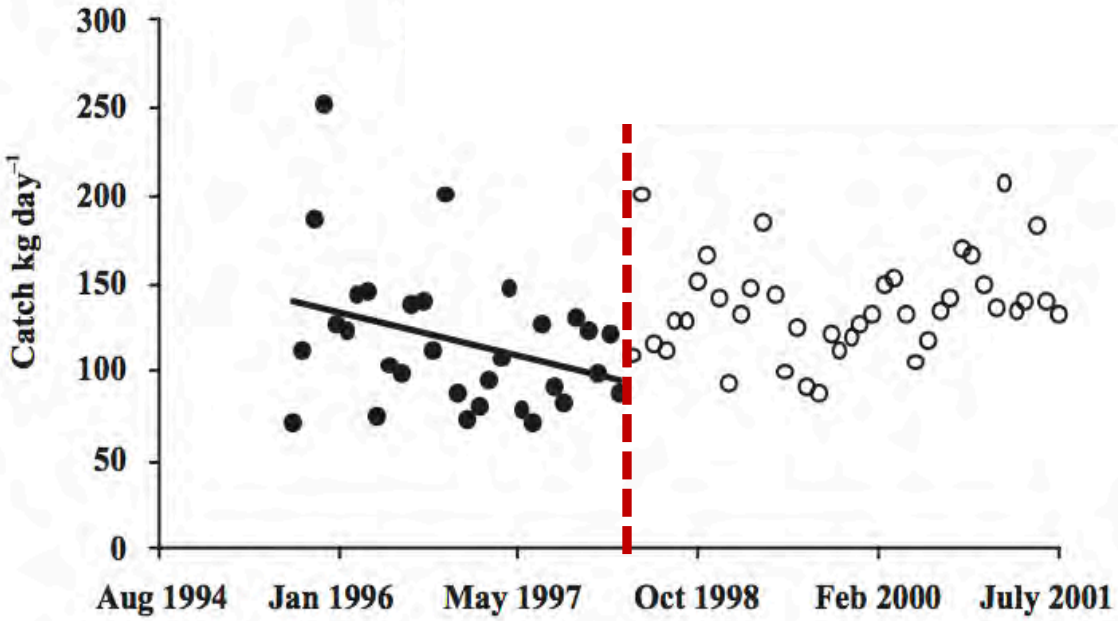
Food web models:



Rogers et al. 2017 *J. Appl. Ecol.*

Bleaching impacts on fisheries: empirical expectations

Fisheries data:

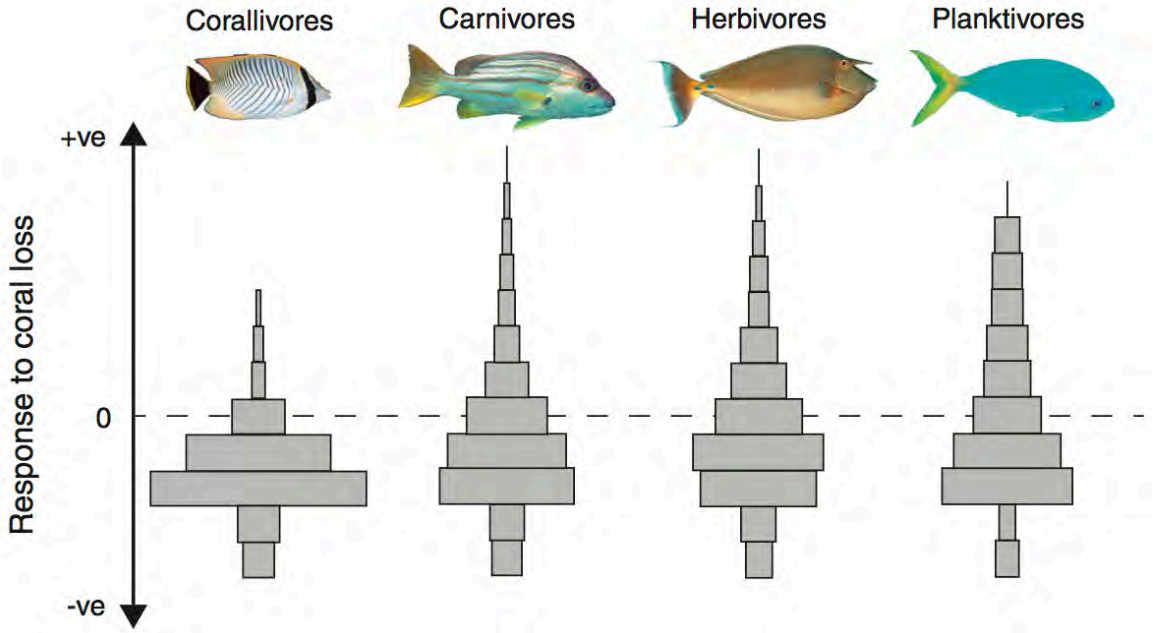


McClanahan et al. 2002 *Ambio*

No immediate impacts…

but long-term datasets are rare

Underwater observations:

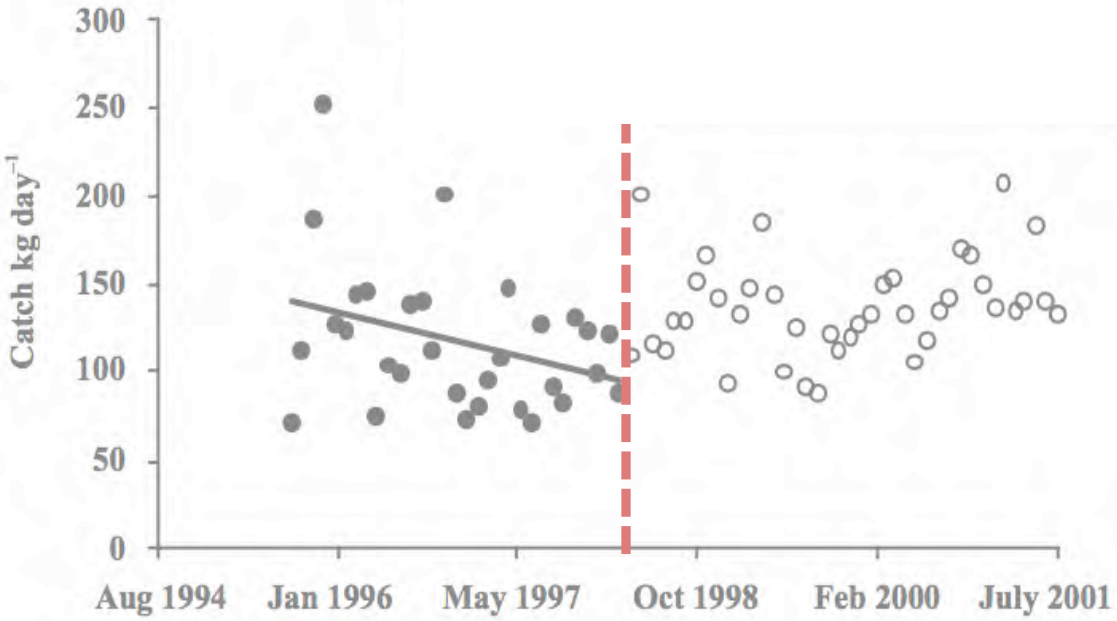


Pratchett et al. 2014 *Curr. Op. Env. Sust.*

High response diversity to habitat disturbances

Bleaching impacts on fisheries: empirical expectations

Fisheries data:



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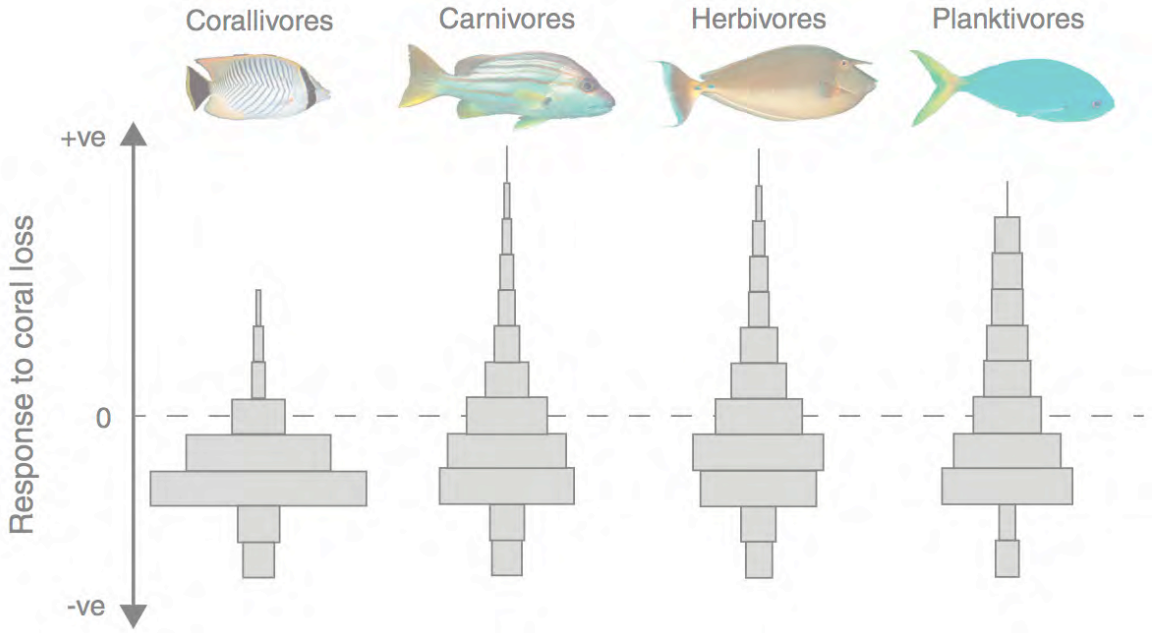
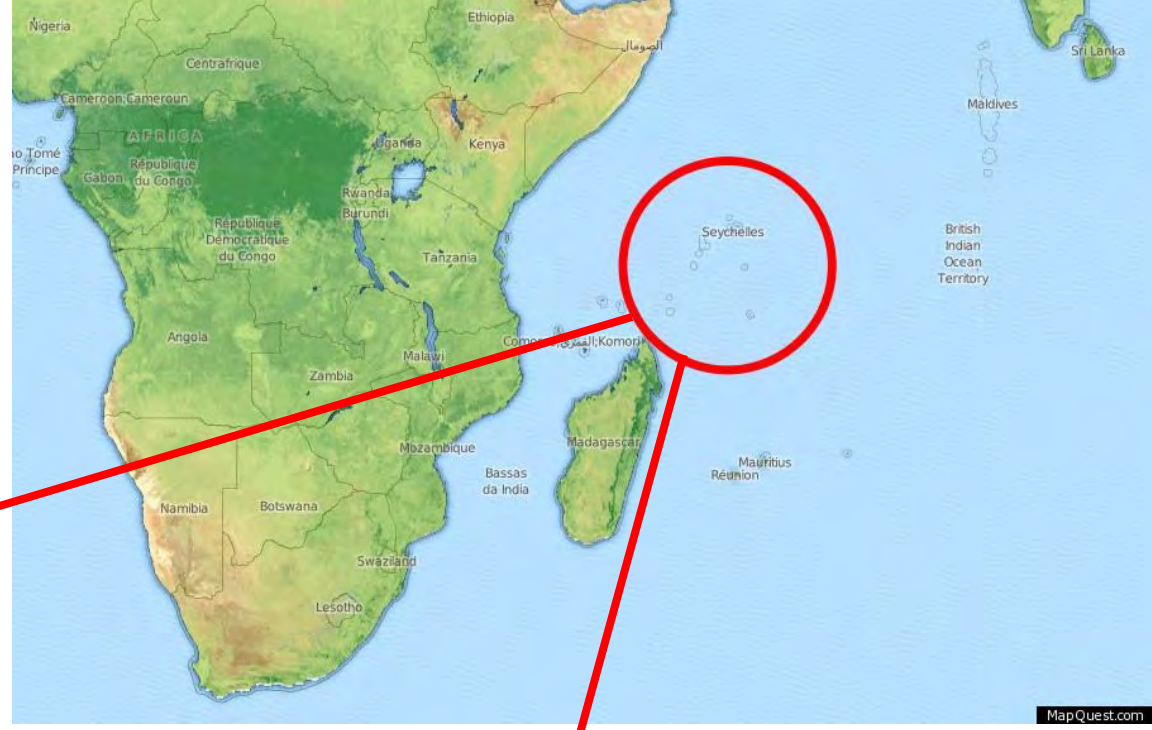


Pratchett et al. 2014 *Curr. Op. Env. Sust.*

How has coral bleaching impacted reef fisheries?

Seychelles: model system for understanding bleaching impacts on fisheries



Long-term monitoring of reef-associated fisheries

Photo cred: Nick Graham

1998 El Nino: >90% coral mortality, phase shifts, benthic recovery

Landings dataset

Fishery-dependent
Daily catch records
Stratified by inner Seychelles regions
Species group, biomass
Gear type + number (= fishing effort)
1994 - 2016

Photo cred: Tim Daw

Target species

Target species

Siganid sp.
Rabbitfish

Lethrinid sp.
Emperors

Mixed sp.
Parrotfish, goatfish

Landings dataset

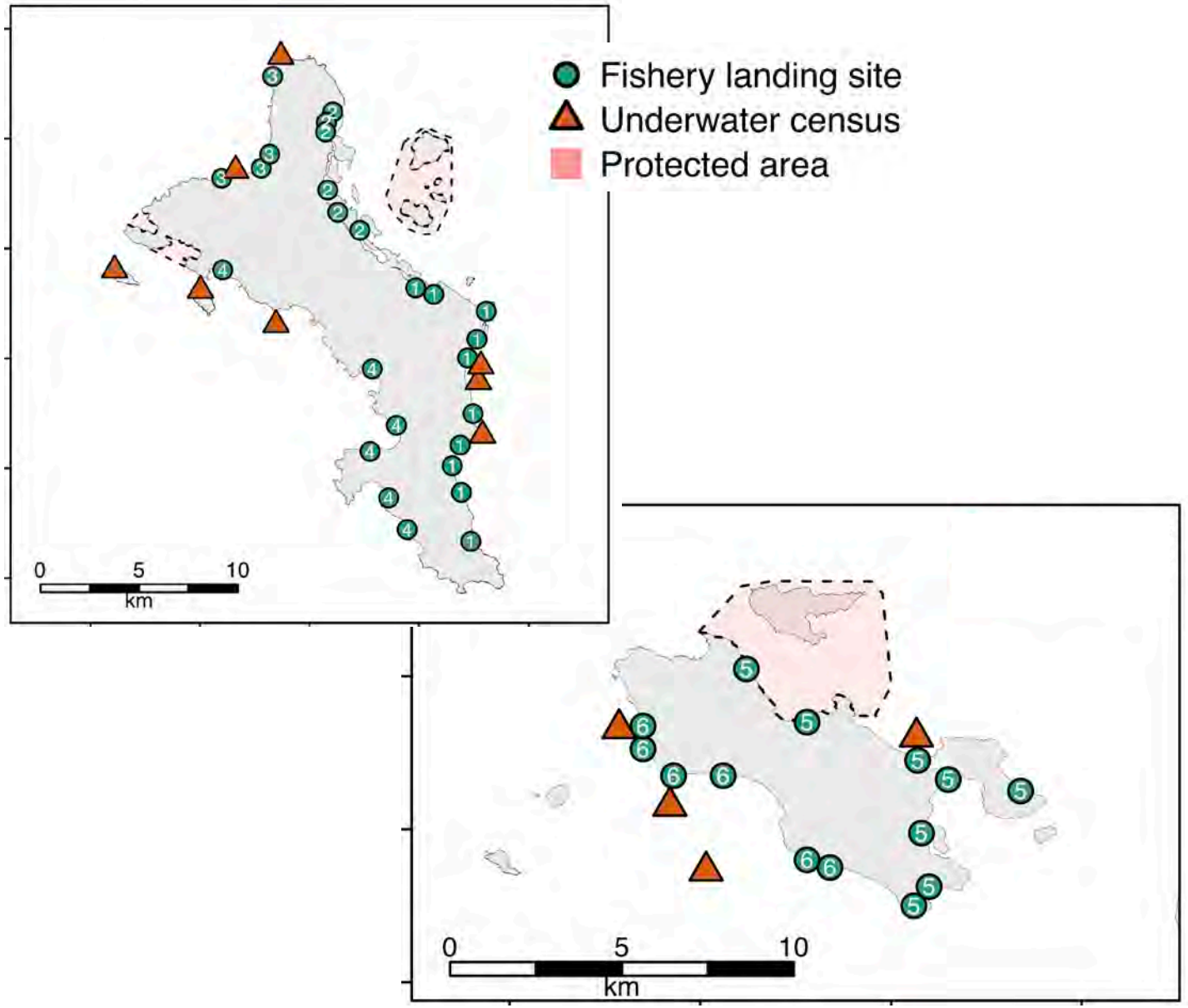
Fishery-dependent
Daily catch records
Stratified by inner Seychelles regions
Species group, biomass
Gear type + number (= fishing effort)
1994 - 2016

Underwater dataset

Fishery-independent
Scuba observations
Stratified by reef habitat types
Fish abundance, biomass
Benthic habitat composition
1994, 2005, 2008, 2011, 2014

Photo cred: Nick Graham

How did a climate-driven coral mortality event impact reef-associated fisheries?



Trap fishery catches:

- CPUE and CV of CPUE
- Yield
- Fishing effort

Underwater surveys:

- Biomass, size, habitat associations
- Benthic habitat composition

Statistical models:

- Time-series GAMs
- Multivariate dispersion

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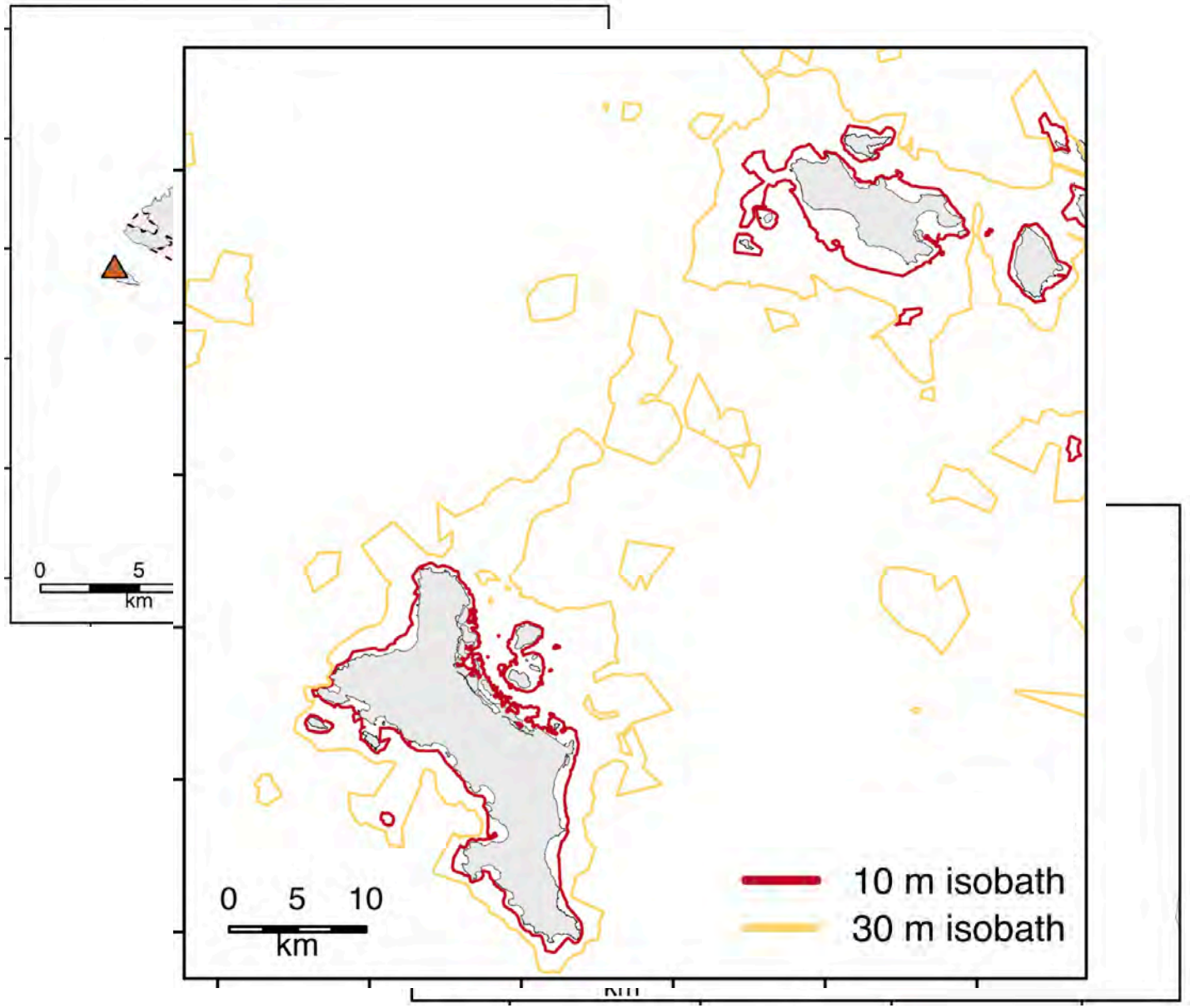

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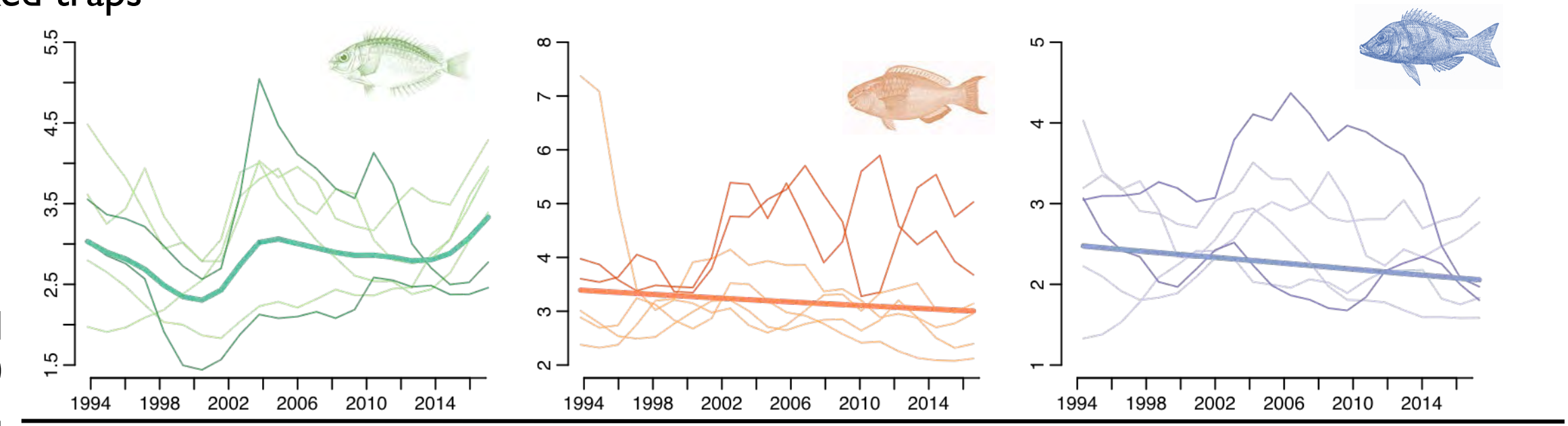
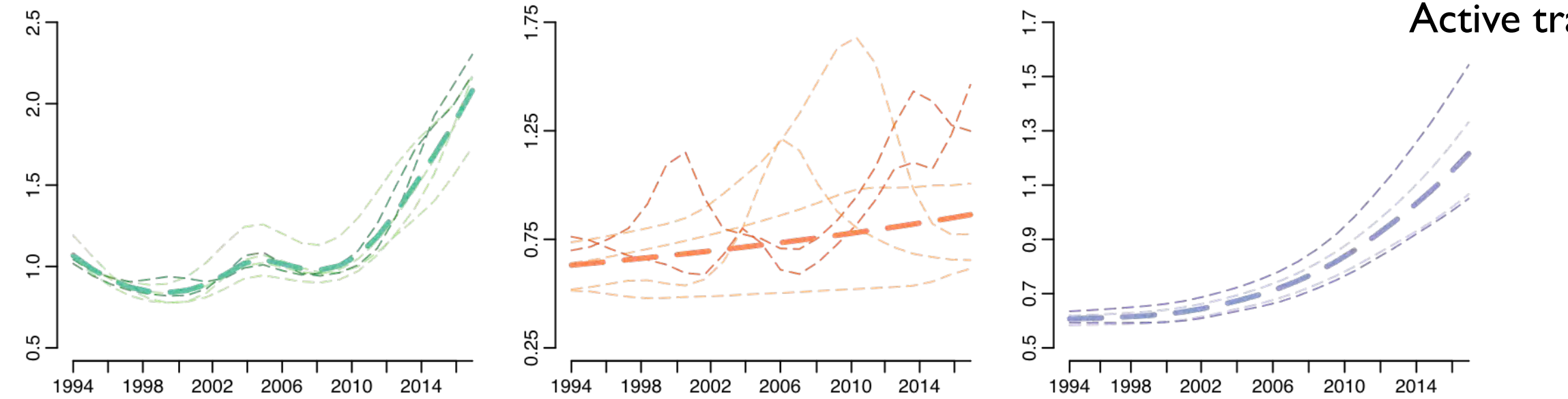
Mean CPUE remained stable or increased from 1994-2016

Fixed traps

CPUE



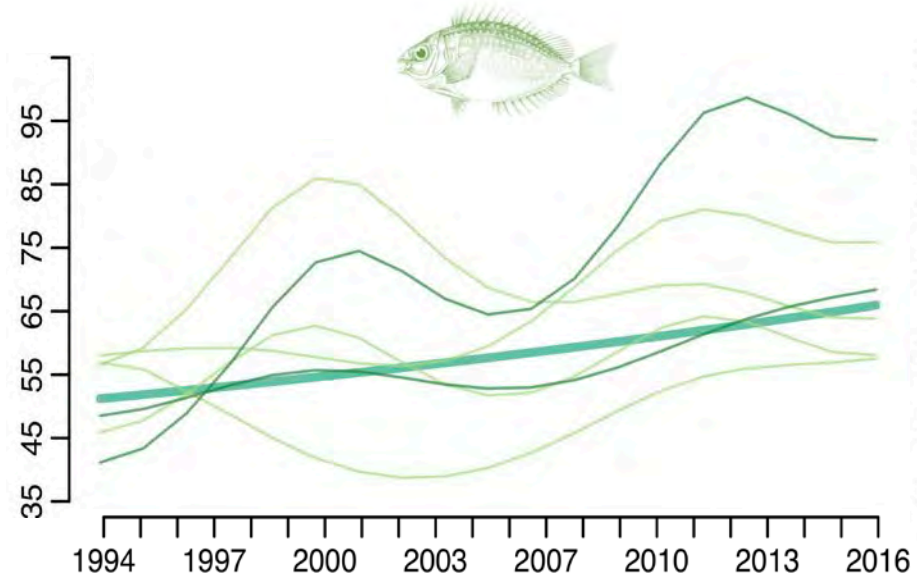
Active traps

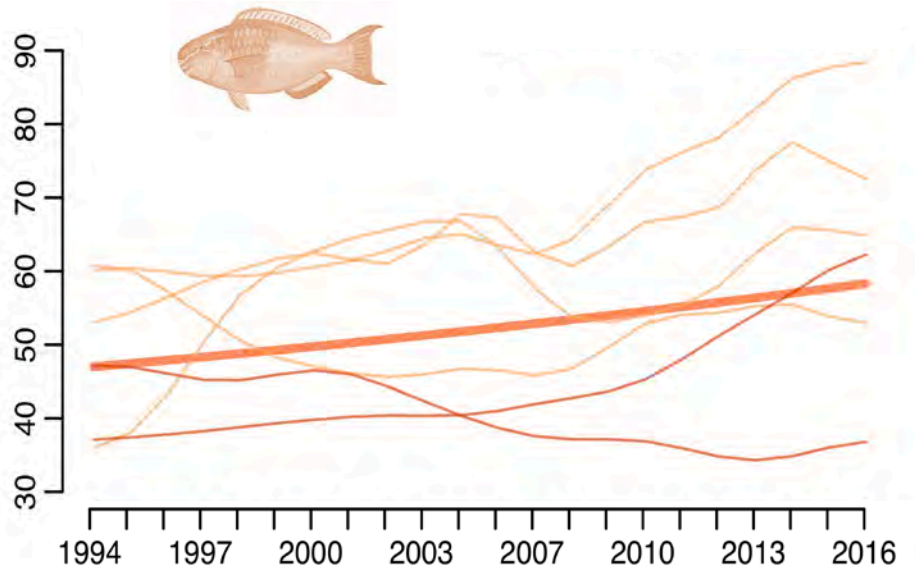


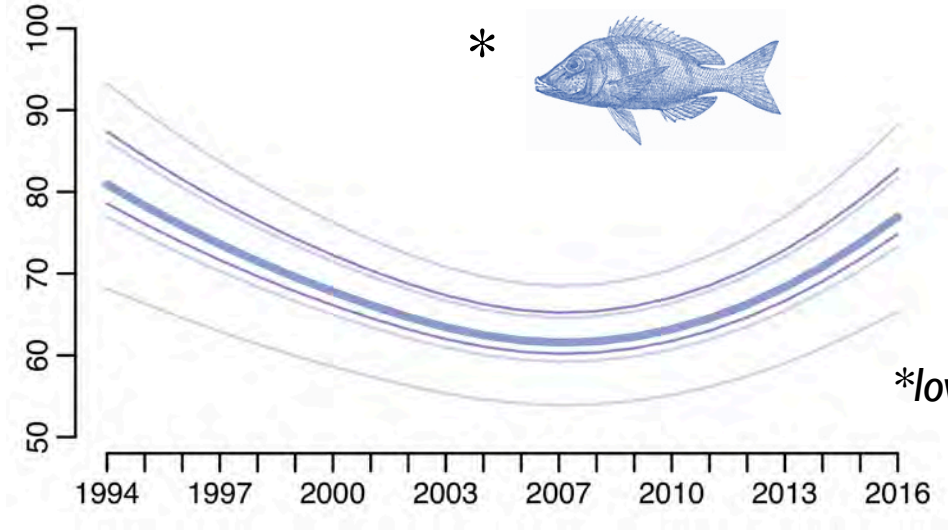
Catch variability increased steadily from 1994-2016:
so, after bleaching, fishers' catches are more variable in each month

CV - CPUE

(Monthly variation in catches)





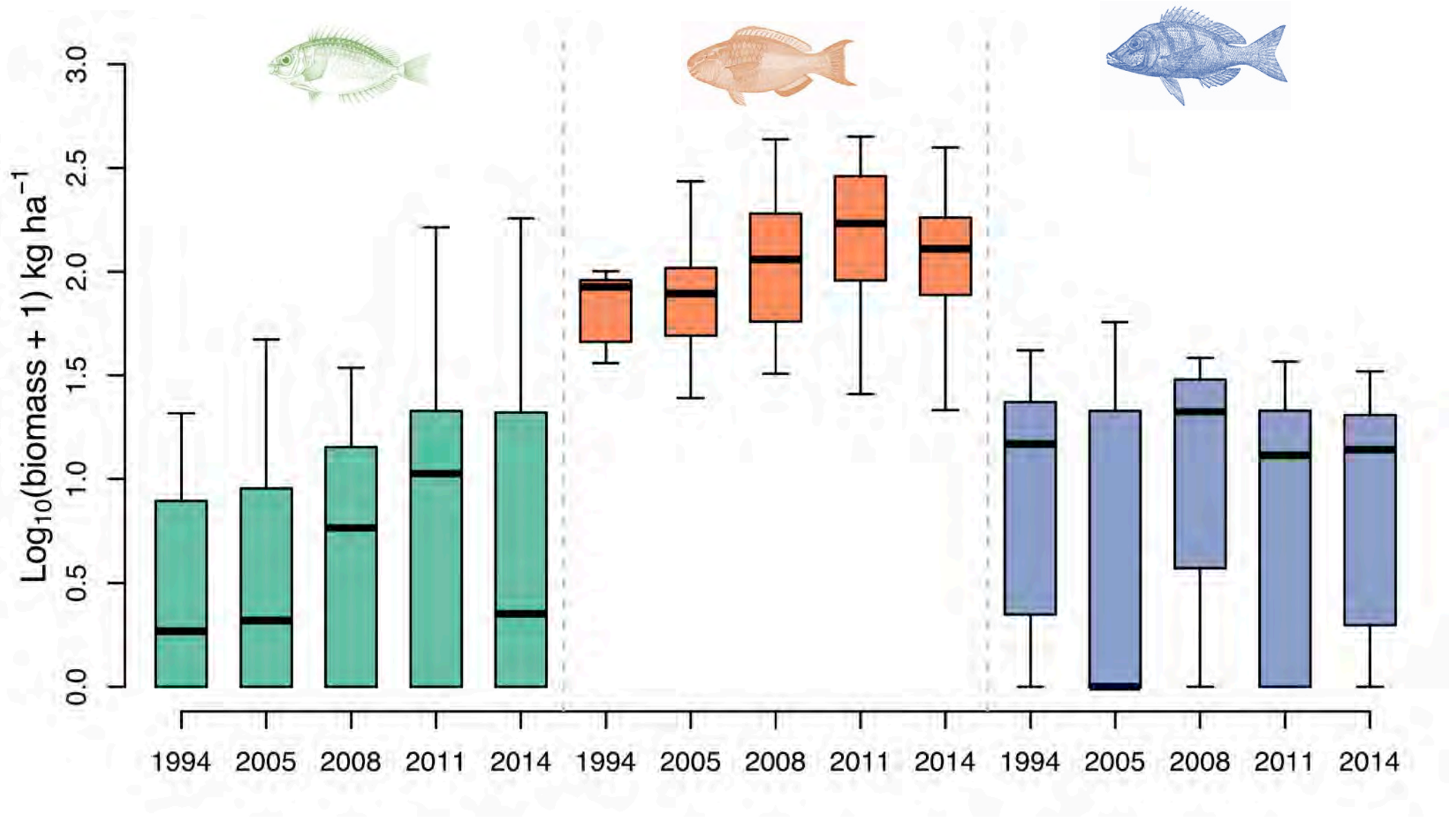


*low catch frequency = unreliable CV estimates

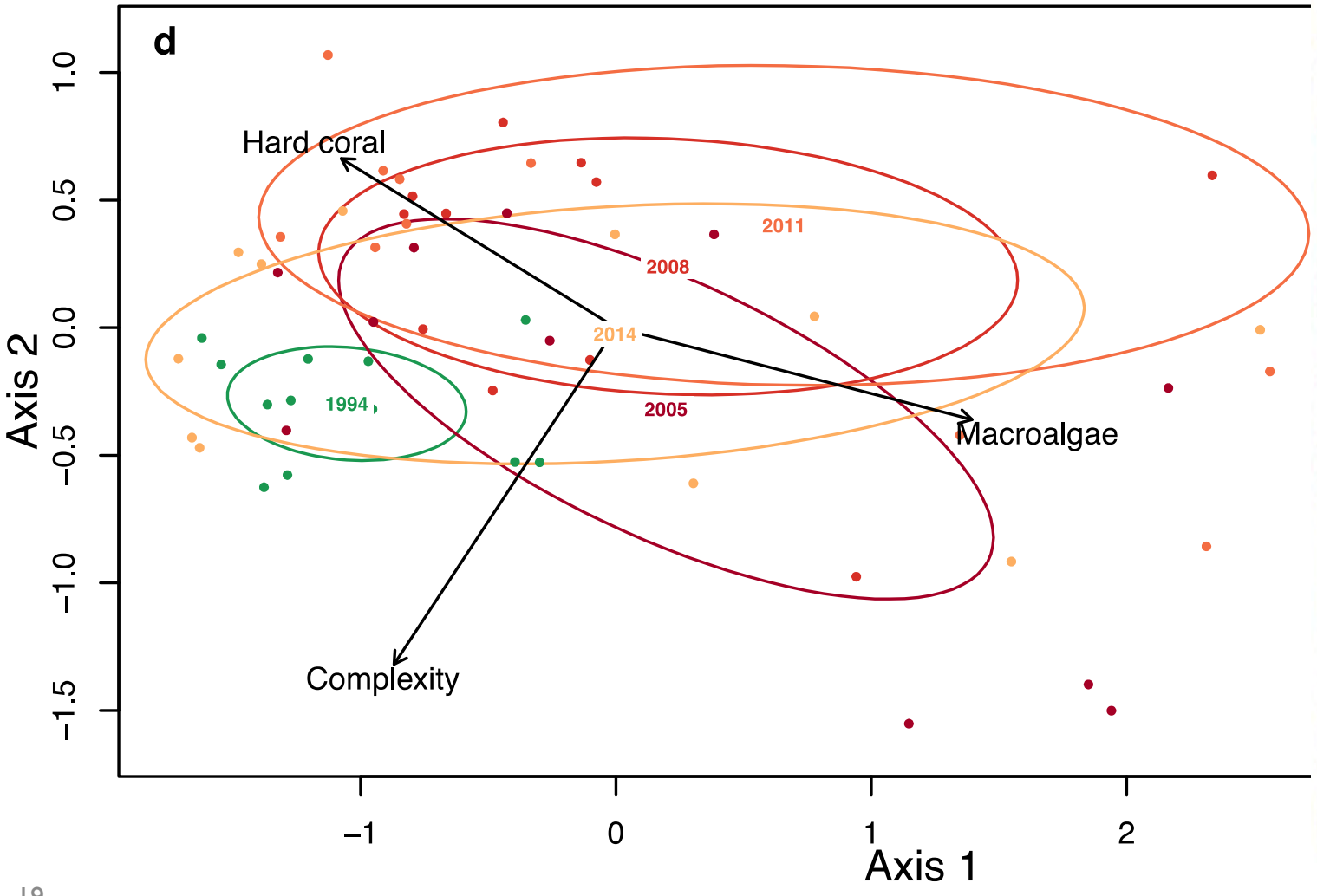
How did benthos and target fish assemblages change after bleaching?

Underwater visual census: target group biomass

1994 - 2014



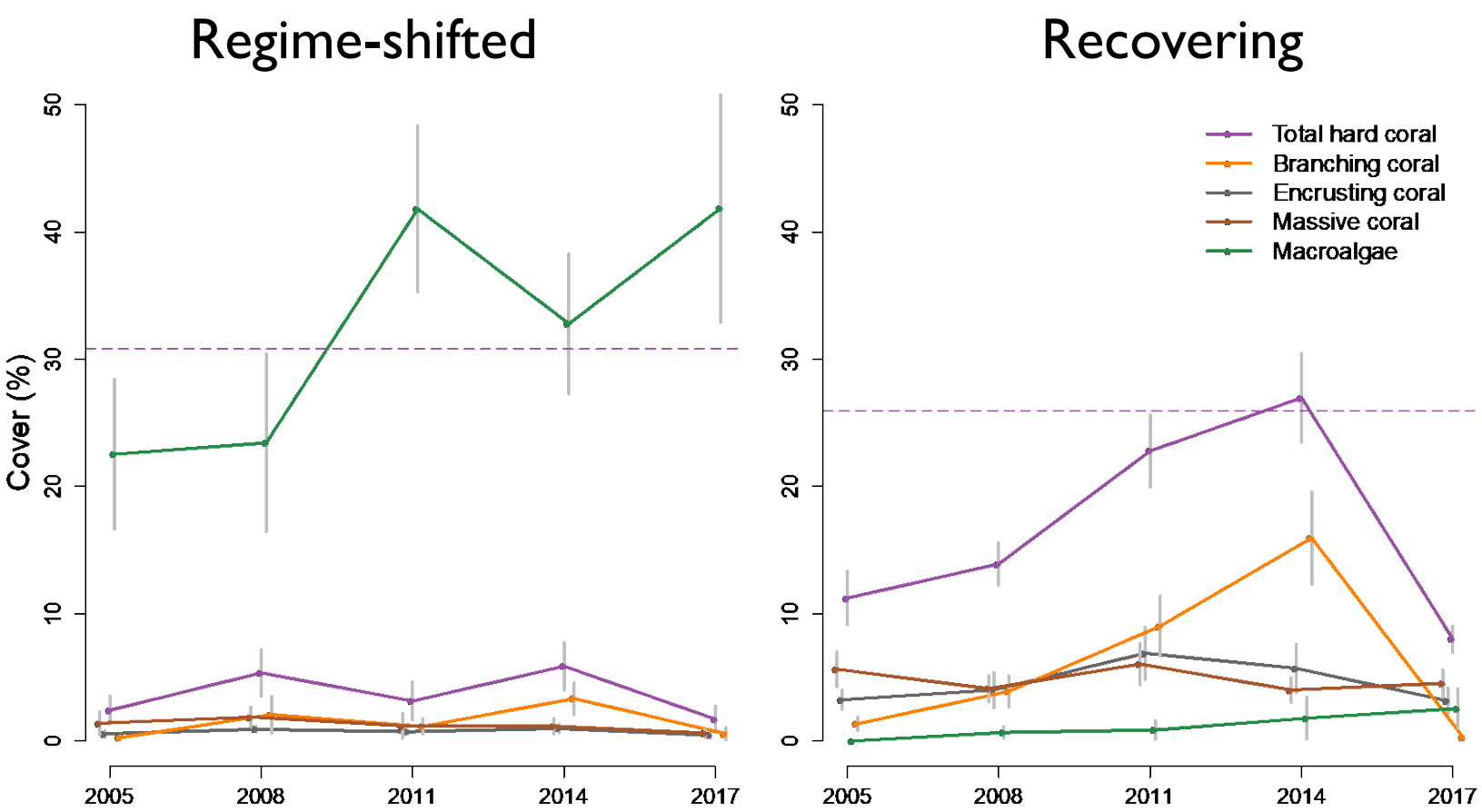
Differential bleaching response trajectories for reef benthos



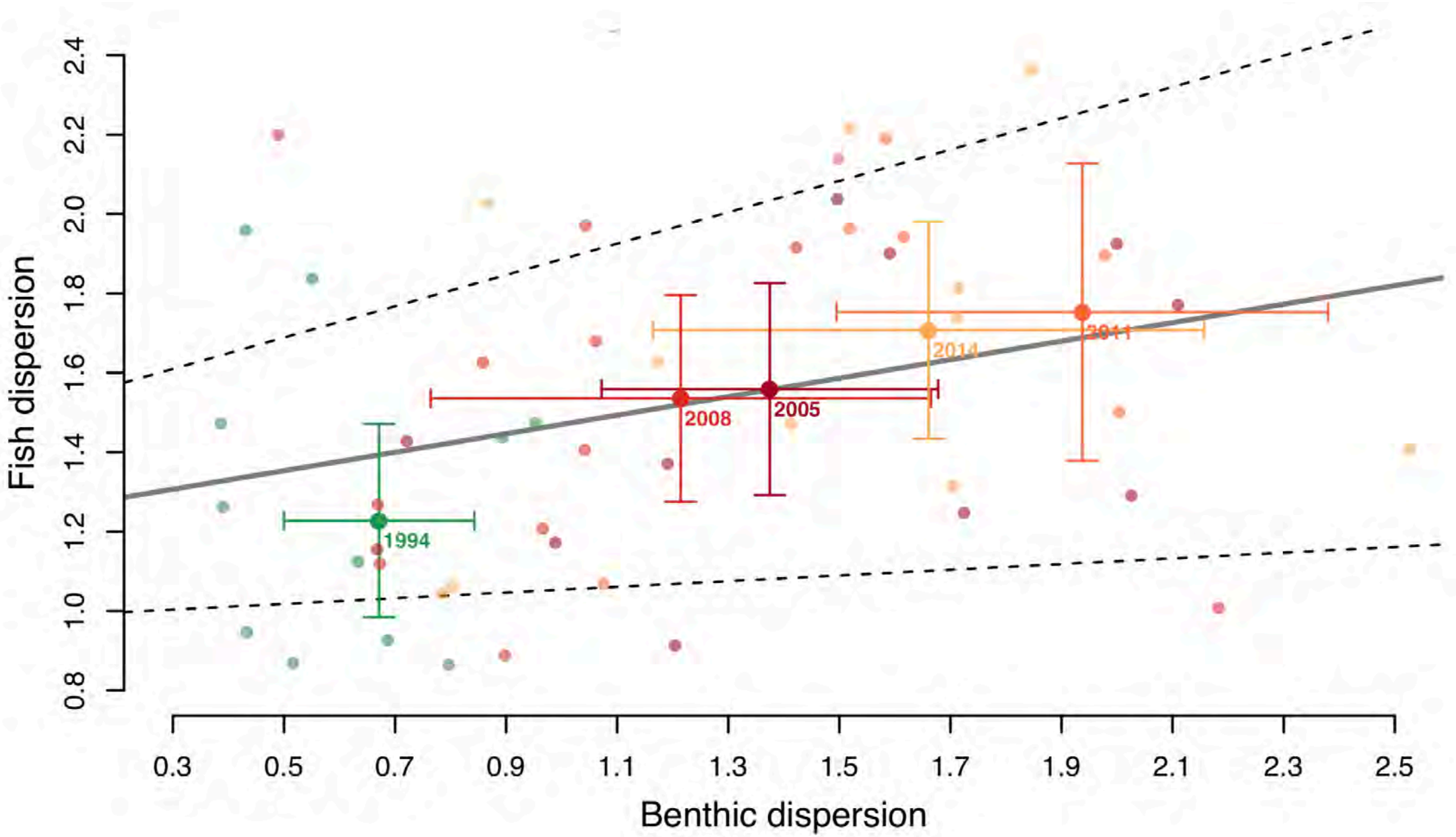
Recovering

Regime-shifted

Differential bleaching response trajectories for reef benthos

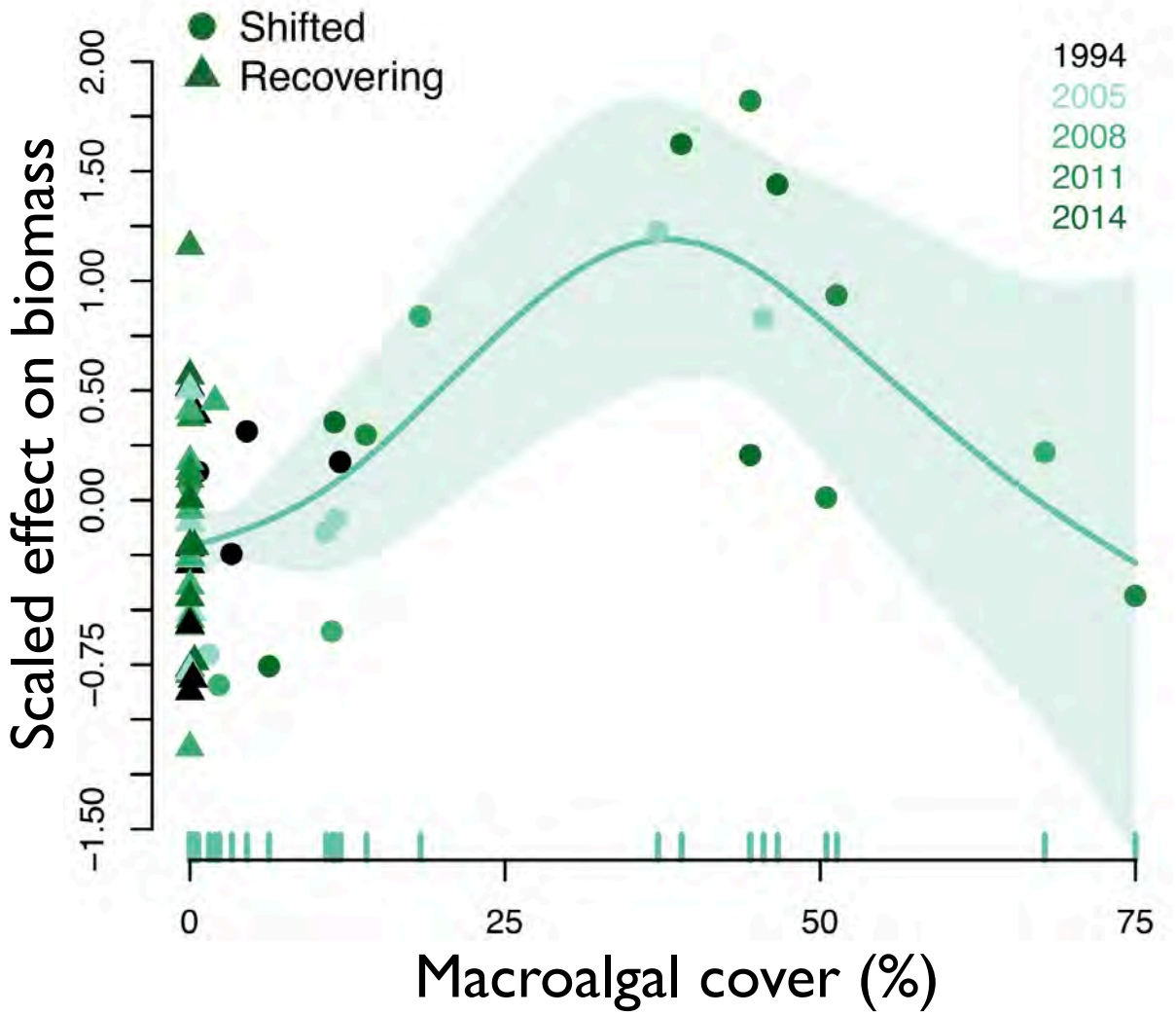


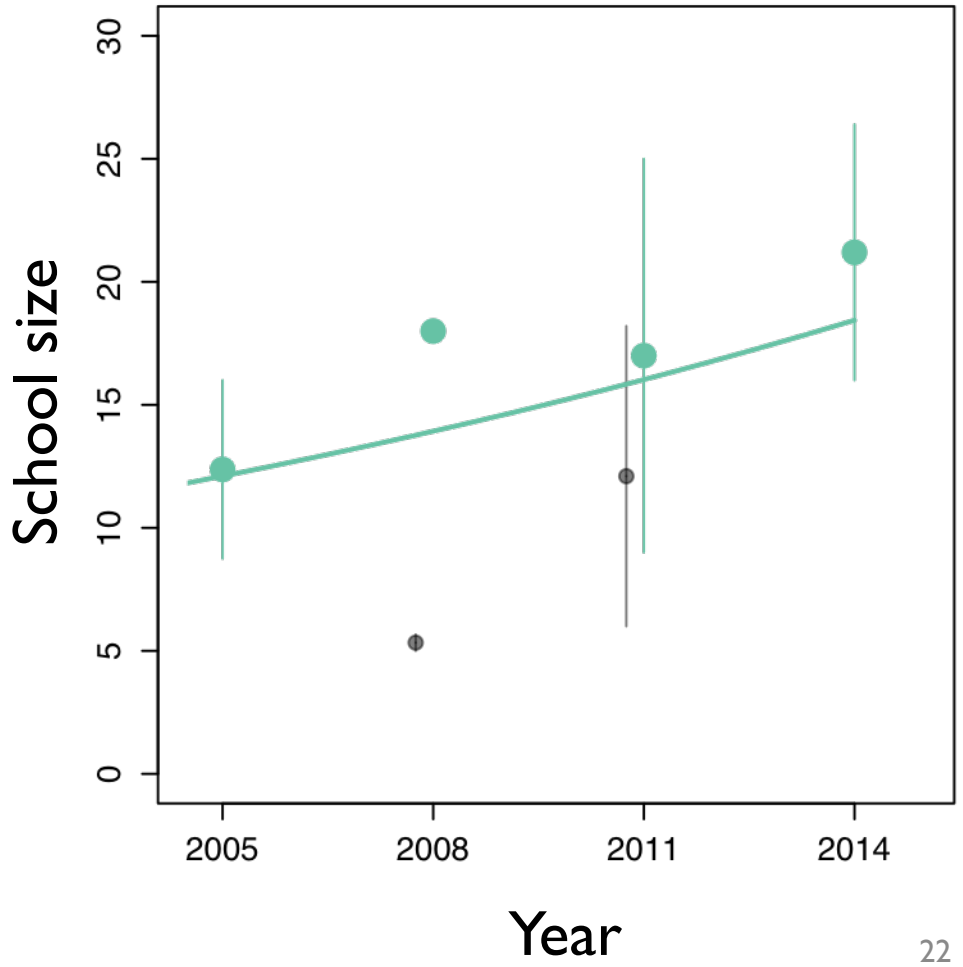
Greater spatial variability in benthic composition and target fish biomass



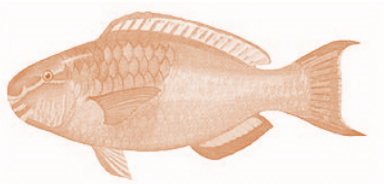
Connecting biomass to catches

1. Siganids: browsing herbivores recruit to regime-shifted reefs

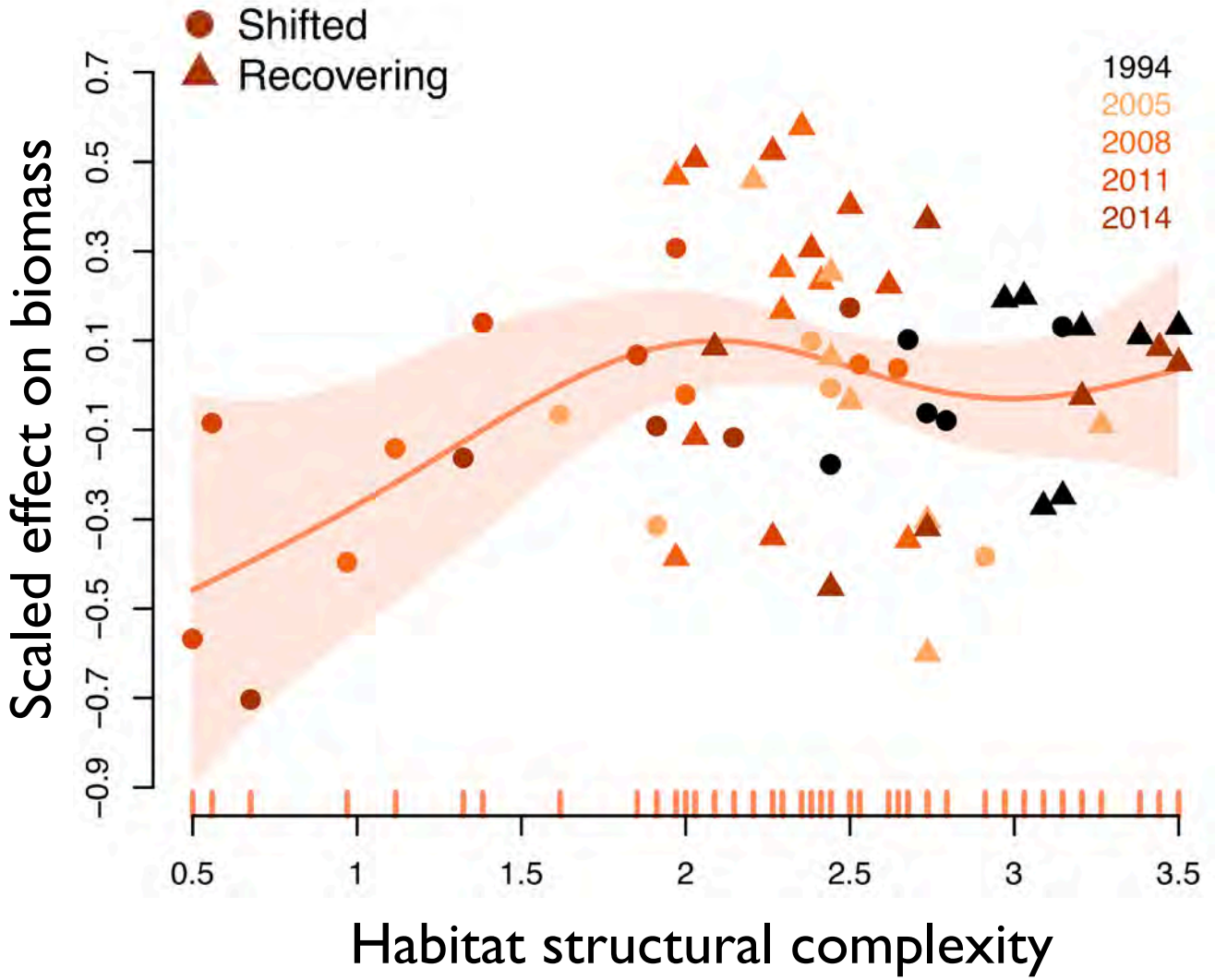




Connecting biomass to catches



2. Mixed species: variable *Scaridae* productivity on recovering reefs



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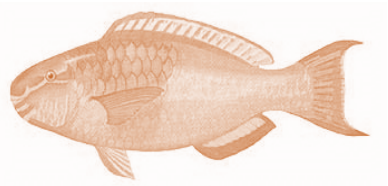

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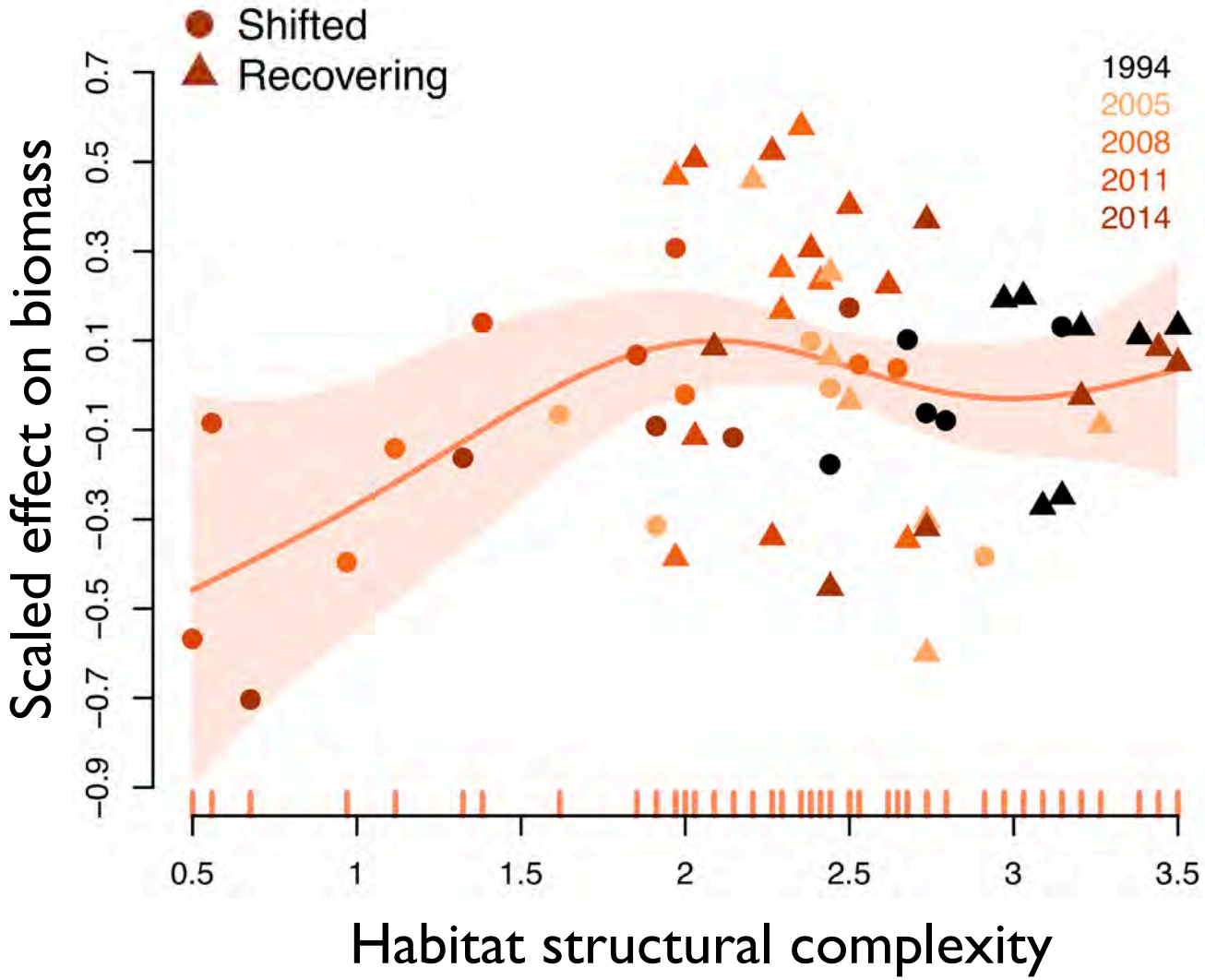
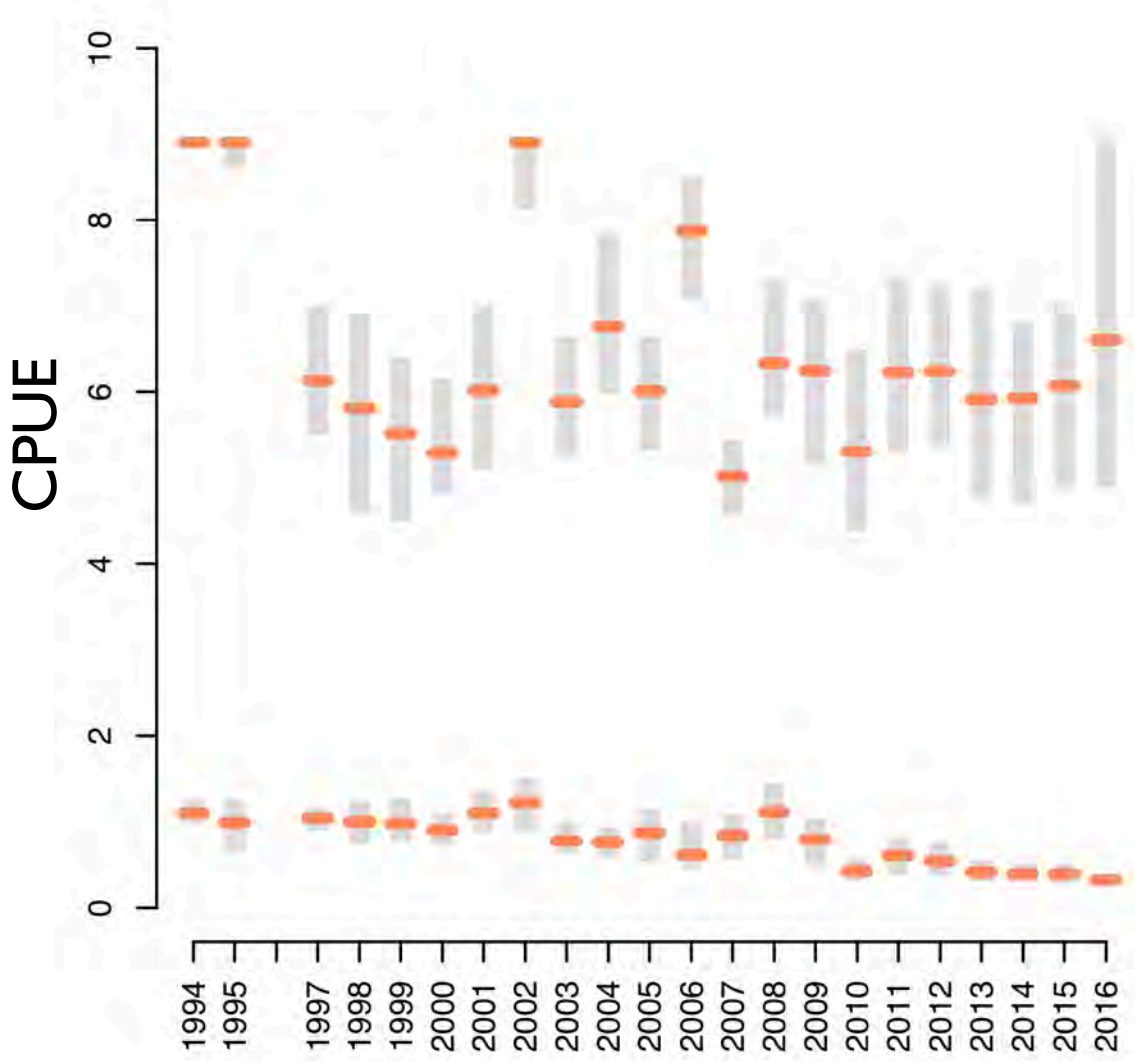
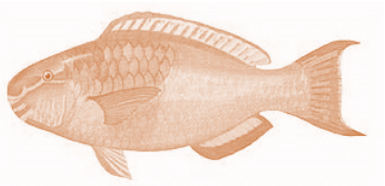




Connecting biomass to catches



2. Mixed species: variable Scarid productivity on recovering reefs

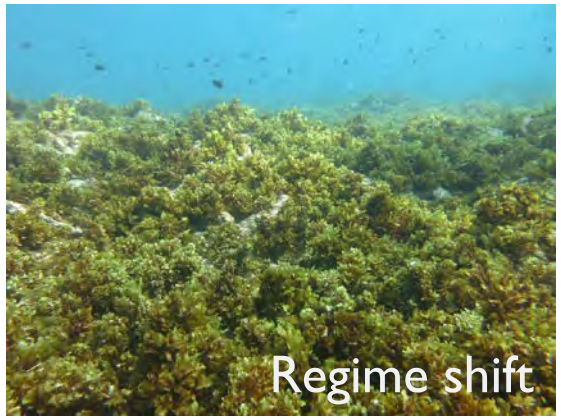
Shifted
Recovering
1994
2005
2008
2011
2014
Scaled effect on biomass
−0.9 −0.7 −0.5 −0.3 −0.1 0.1 0.3 0.5 0.7
0.5 1 1.5 2 2.5 3 3.5
Habitat structural complexity
CPUE
0 2 4 6 8 10
1994 1995 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Coral bleaching events: implications for fisheries

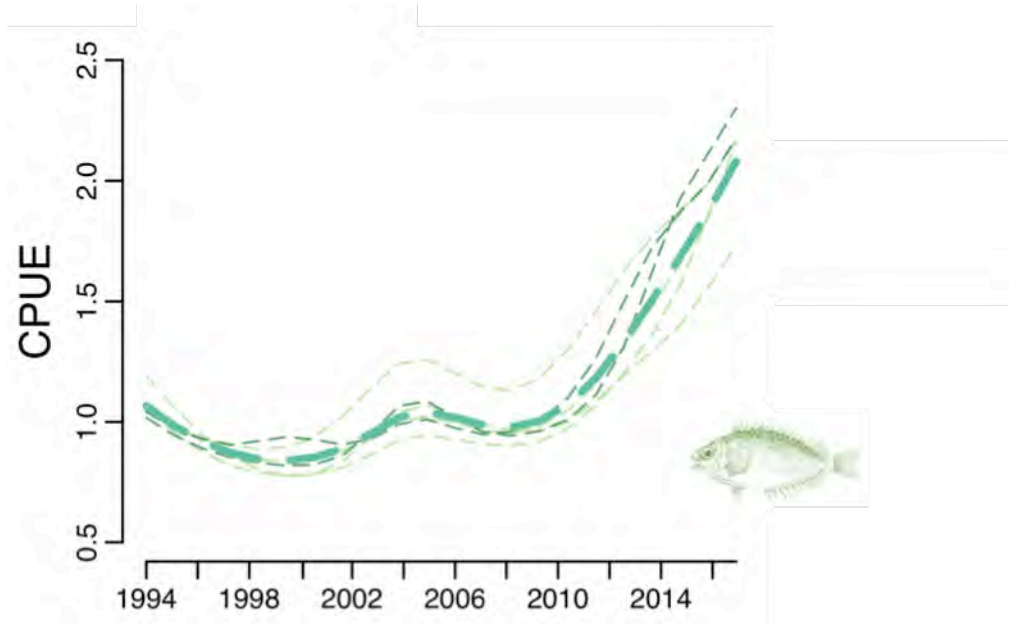
1. Low trophic levels resilient to habitat collapse

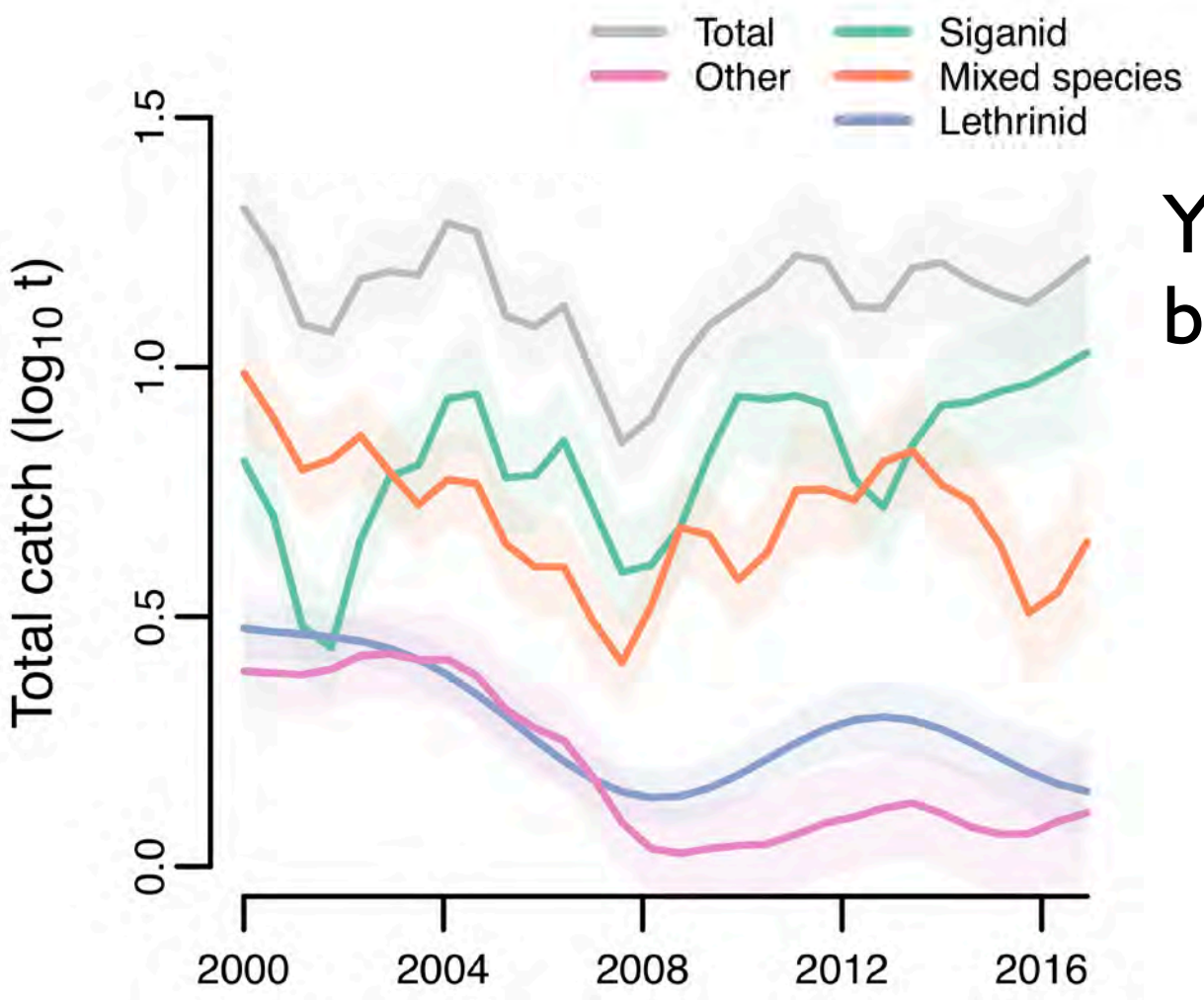
Herbivore response diversity + high productivity followed shift in algal resources:

= *CPUE and yields stable/increasing*



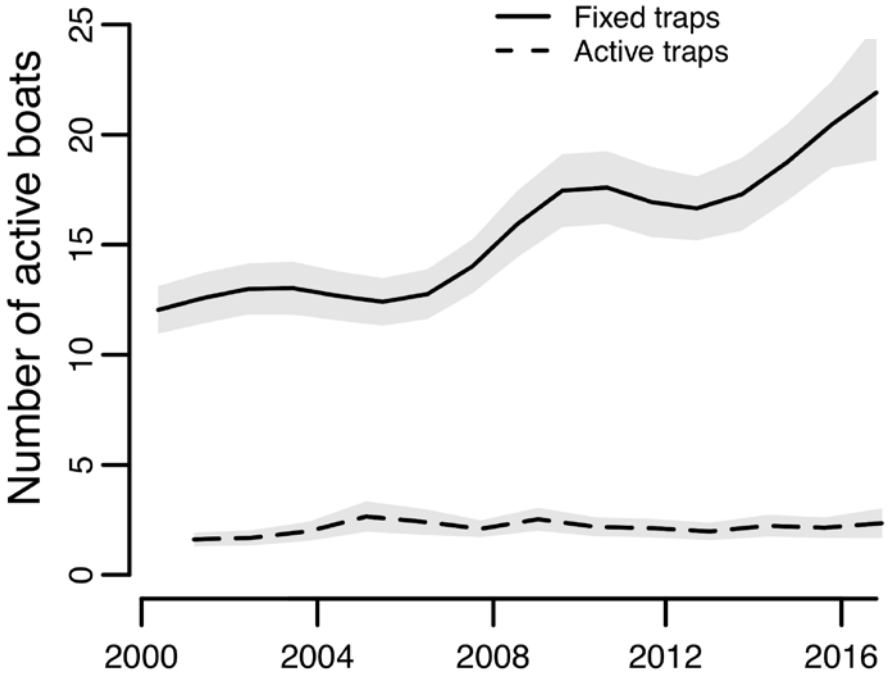
Siganid (rabbitfish) targeting by active traps





Yields maintained or increased after bleaching

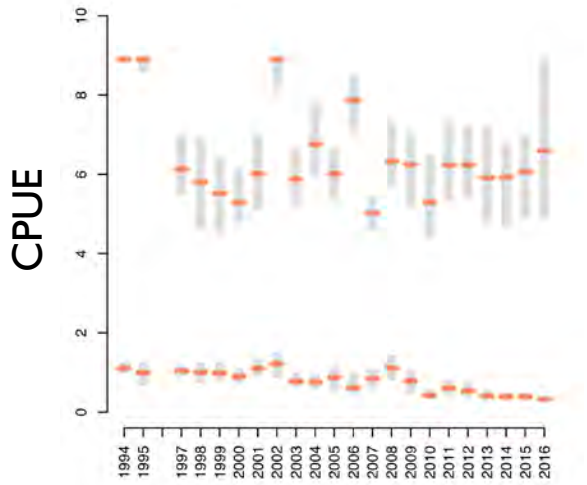
Linked to higher overall fishing effort (but not individual fisher effort i.e. traps or hours fishing)



2. Greater catch instability linked to benthic recovery trajectory

Spatial heterogeneity in target fish biomass

- High Scarid (parrotfish) biomass
- Poor quality 'recovering reefs' with low fish biomass
- Declining minimum catches



- Larger Siganid (rabbitfish) schools
- High biomass = heavily targeted

Future reef fisheries under recurrent bleaching

Increase monitoring efforts on resilient, fast-growing herbivores

Greater reliance on low trophic level species – need stock assessments

Examine how catch instability might impact livelihoods and market supply chains

Future reef fisheries under recurrent bleaching

Increase monitoring efforts on resilient, fast-growing herbivores

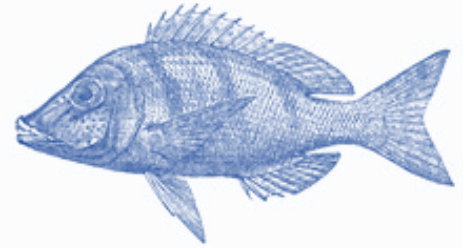
Greater reliance on low trophic level species – need stock assessments

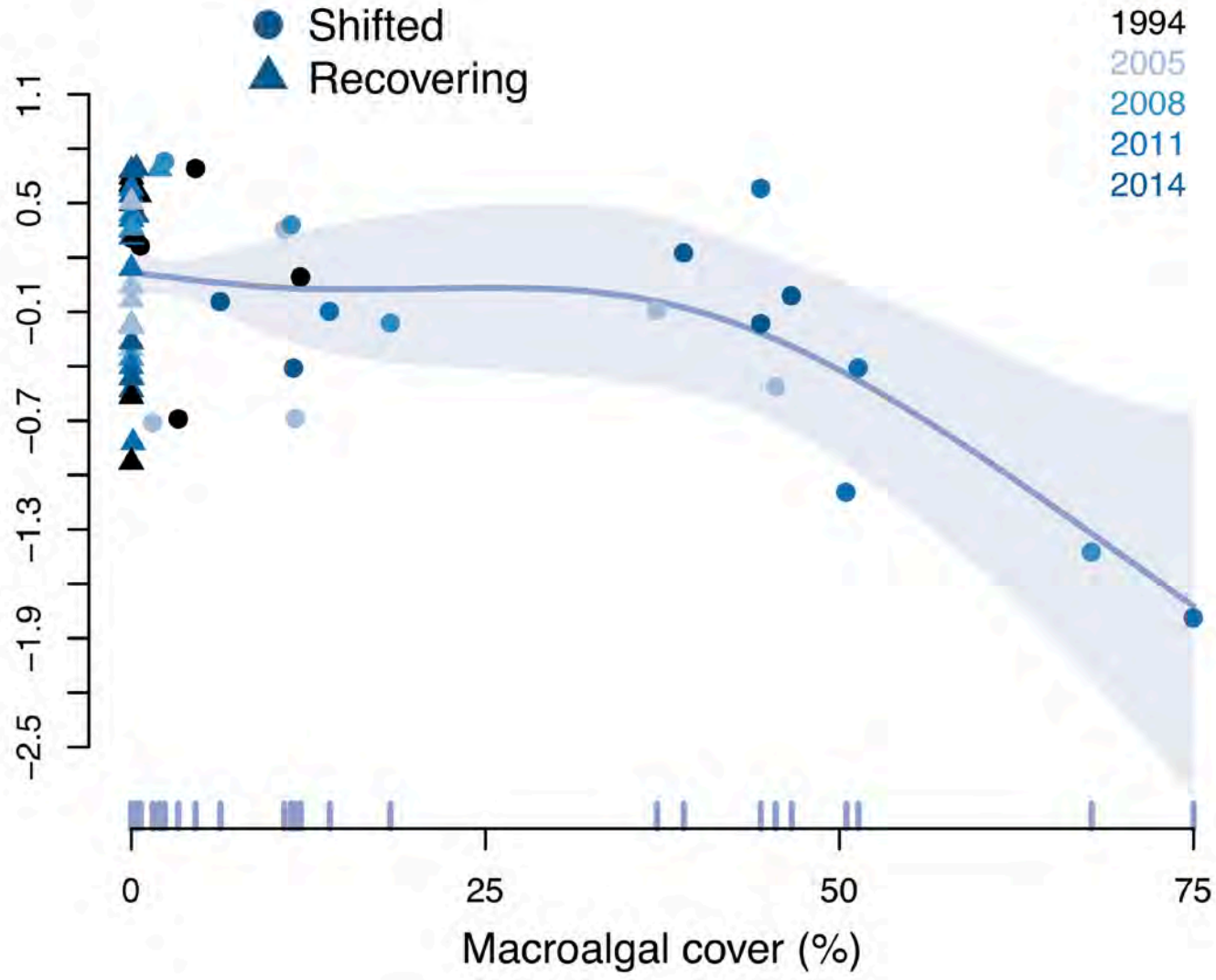
Examine how catch instability might impact livelihoods and market supply chains

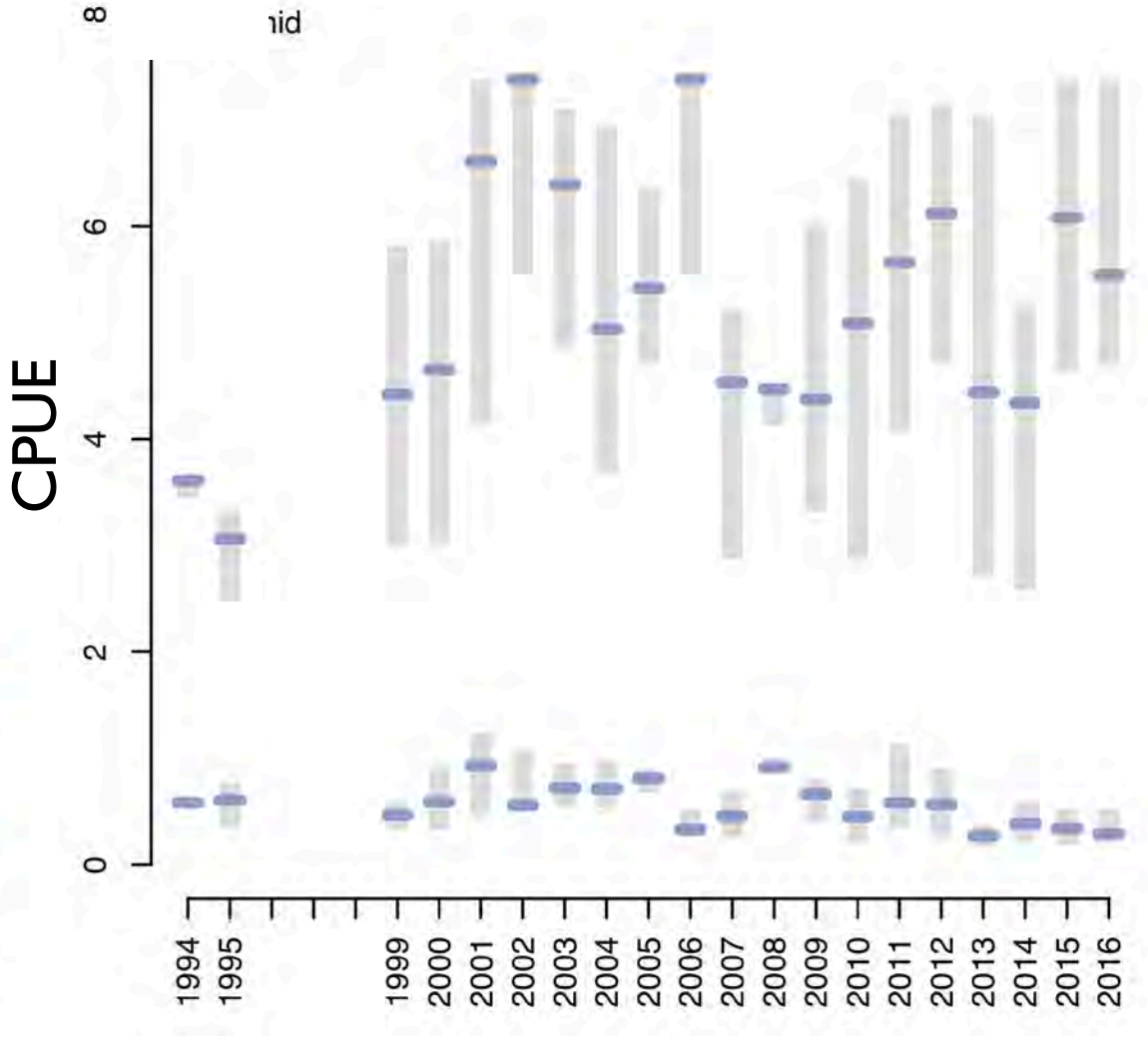
james.robinson@lancaster.ac.uk | @jamespwr

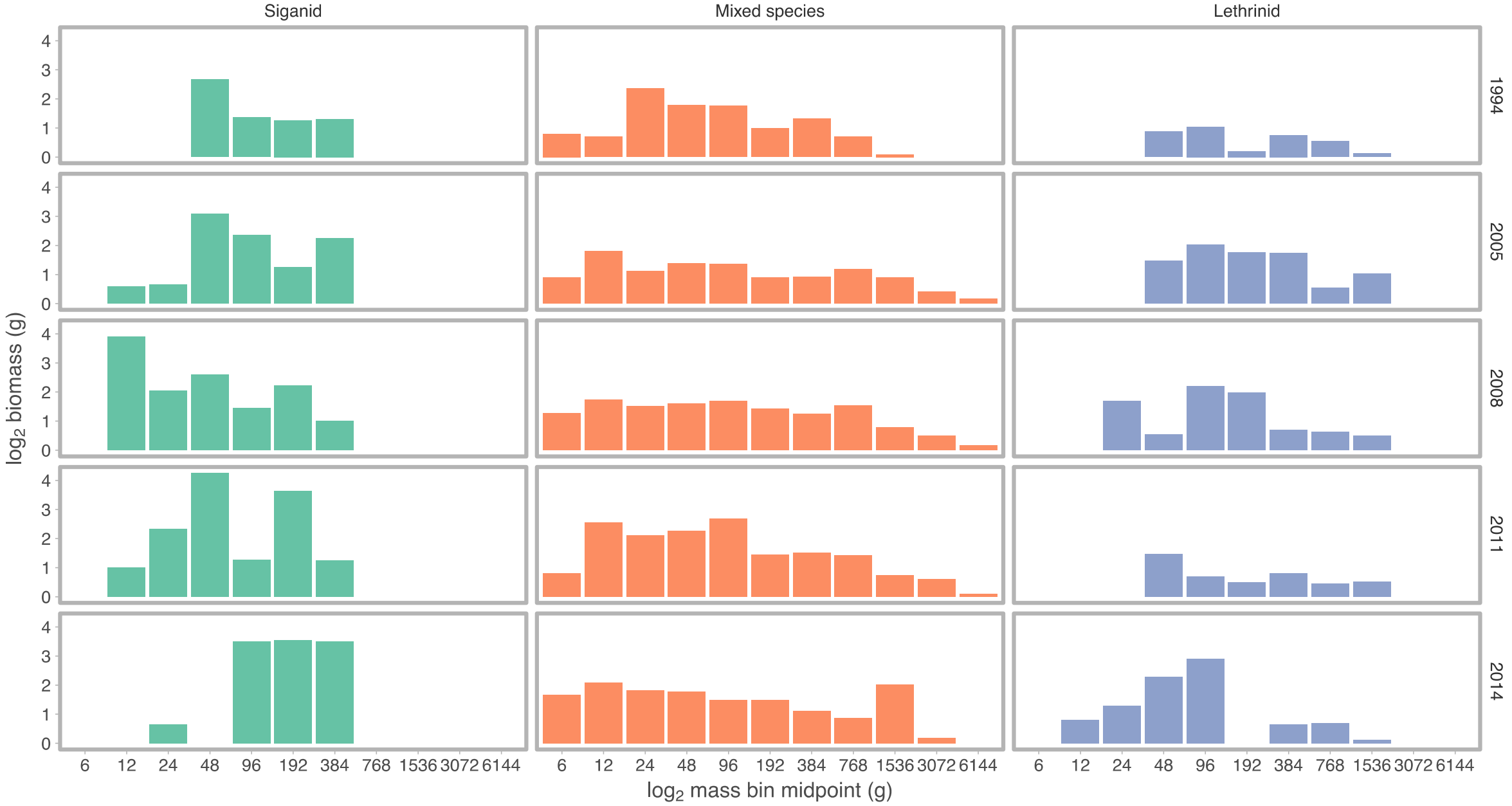
Questions?

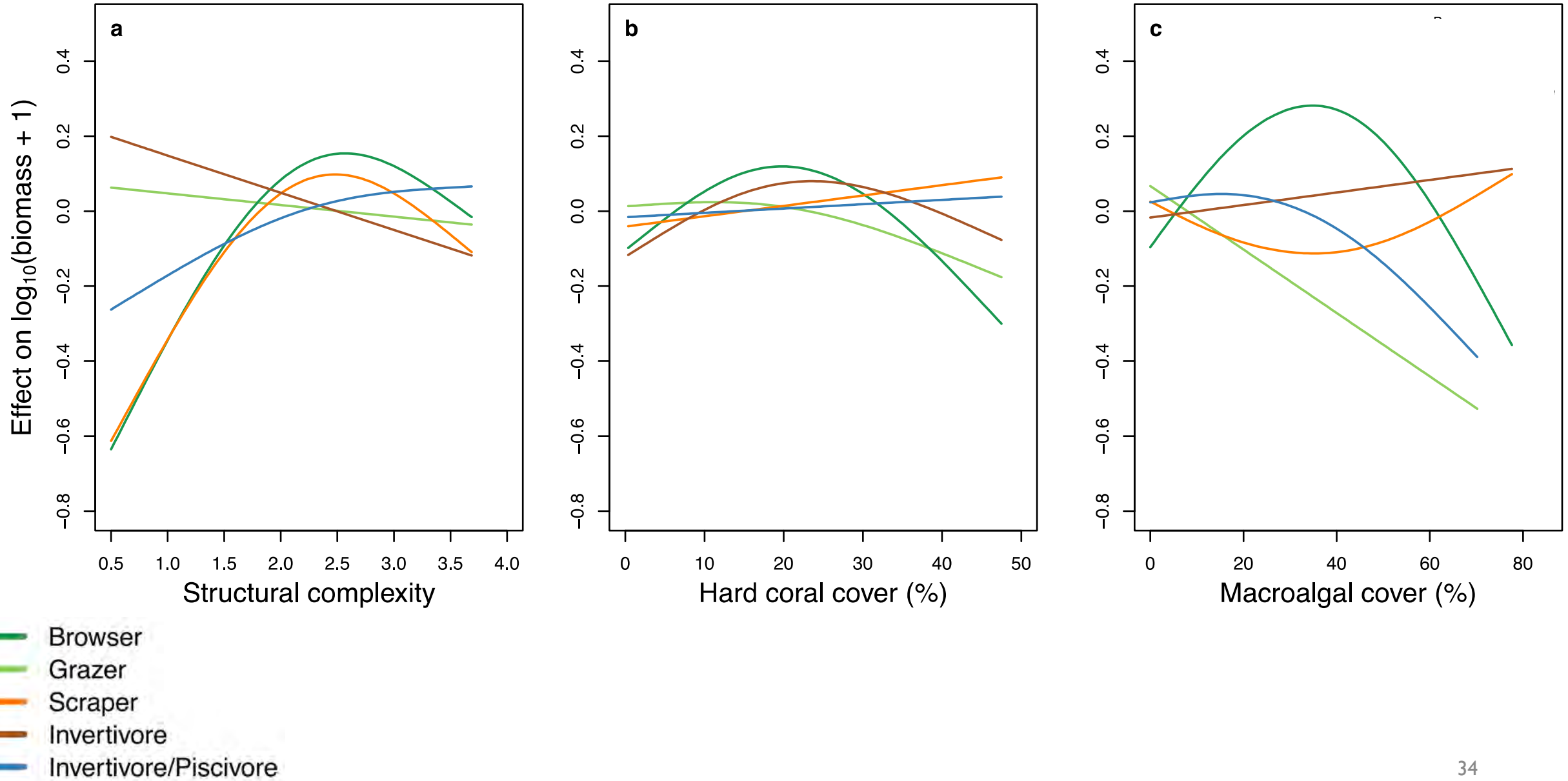
3. Lethrinid: reliant on both habitat types
difficult to sample with UVC
rarely caught in traps (10% of catches)








Siganid
Mixed species
Lethrinid
1994
2005
2008
2011
2014
log2 biomass (g)
0
1
2
3
4
6
12
24
48
96
192
384
768
1536
3072
6144
log2 mass bin midpoint (g)


a
b
c
Effect on log10(biomass + 1)
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Structural complexity
0
10
20
30
40
50
Hard coral cover (%)
0
20
40
60
80
Macroalgal cover (%)
Browser
Grazer
Scraper
Invertivore
Invertivore/Piscivore