



Towards predictable science:
long time series, broad spatial scales, and expansive taxonomy

Graham Edgar



Discrepancies between field observations and conventional wisdom

- Marine protected areas
- Fisheries stock assessments
- Ecological modelling
- Heatwave impacts
- Population decline/loss of species



Extreme generalisation of results

ARTICLE

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

Net effects of life-history traits explain persistent differences in abundance among similar species

*11 coral species, Lizard Island reef crest

ARTICLE

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

Dispersal, kin aggregation, and the fitness consequences of not spreading sibling larvae

*1 bryozoan, shallow seagrass, Texas

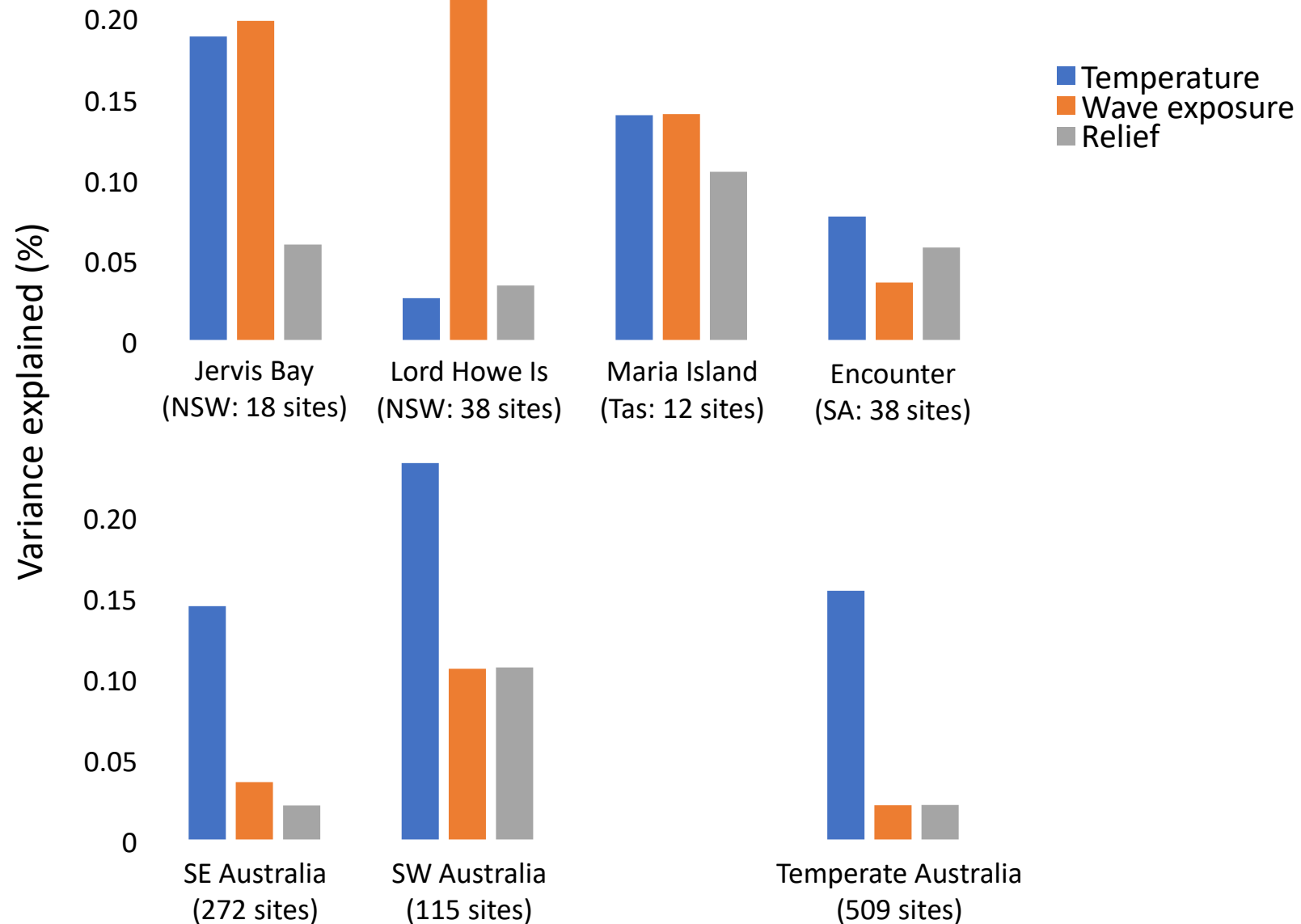
ARTICLE

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

The effects of dispersal, herbivory, and competition on plant community assembly

*51 prairie grass species, 1.6 ha plot, Iowa

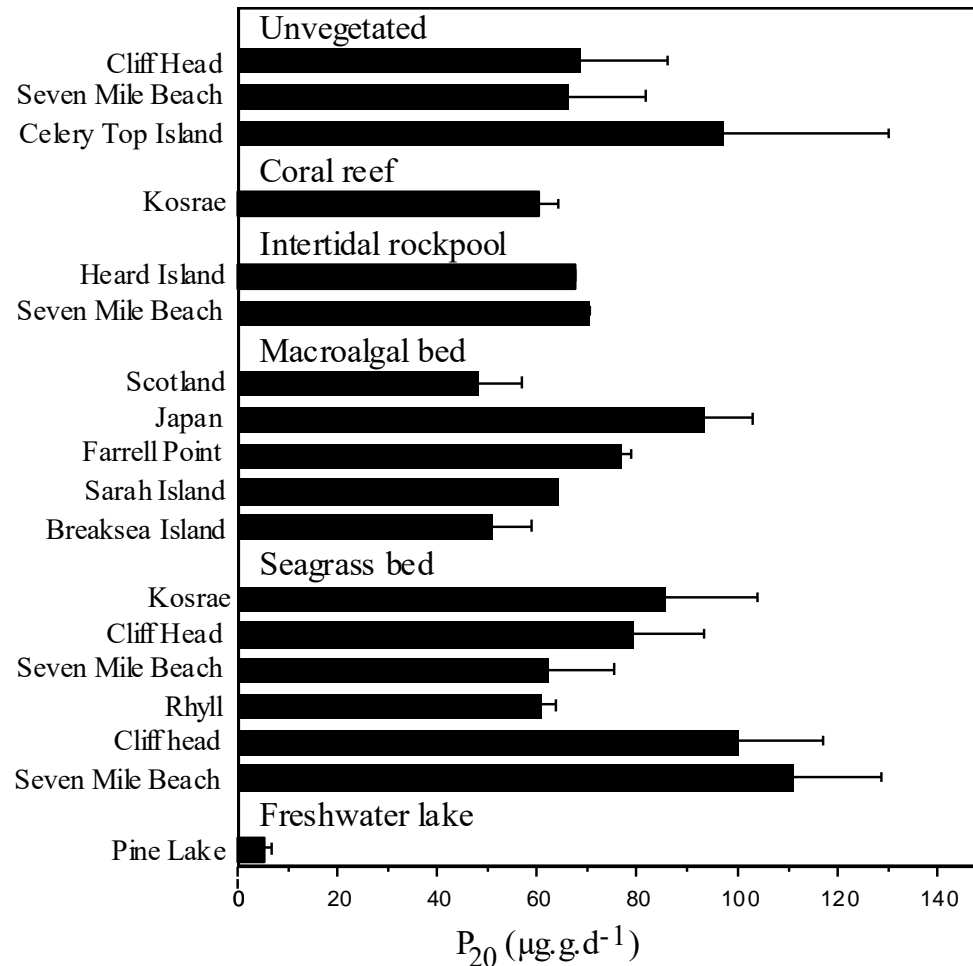
DISTLM –R² comparison for three covariates



Standardised
habitats



Secondary productivity at different locations



→ predictable total community metric, probably due to diffuse competition for resources (primary production)

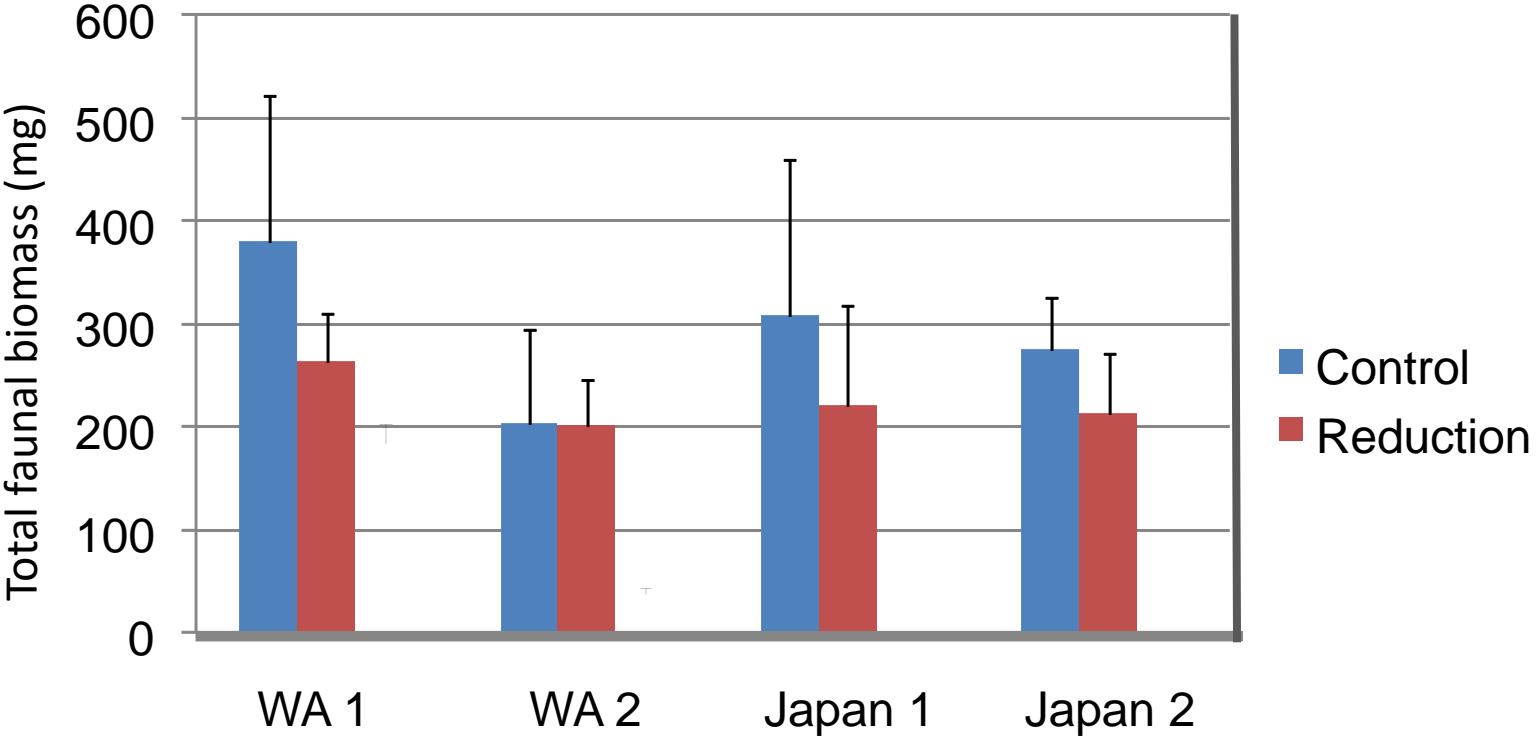
Edgar, G.J., 1993. Measurement of the carrying capacity of benthic habitats using a metabolic-rate based index. *Oecologia* 95, 115-121.

Microcosm experiments



Edgar, G.J., Aoki, M., 1993. Resource limitation and fish predation: their importance to mobile epifauna associated with Japanese Sargassum. *Oecologia* 95, 122-133.

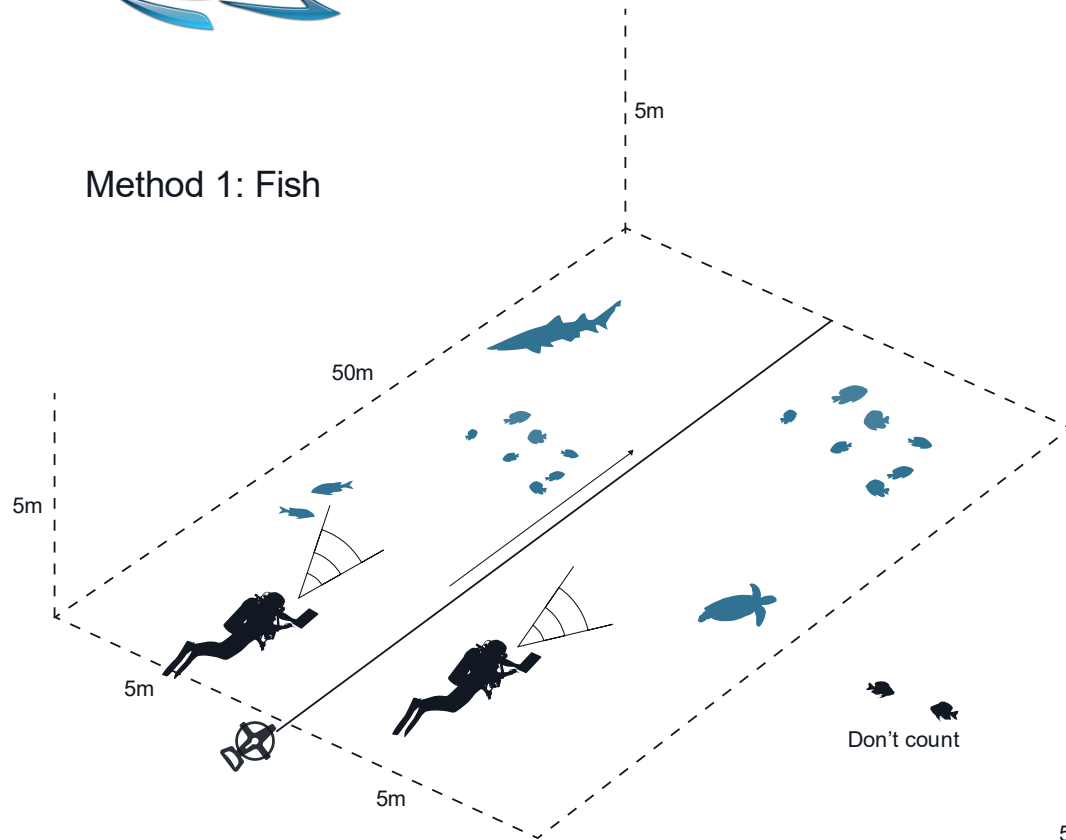
Regardless of changing initial starting conditions (ie defaunation), community metabolism quickly returns to constant level.



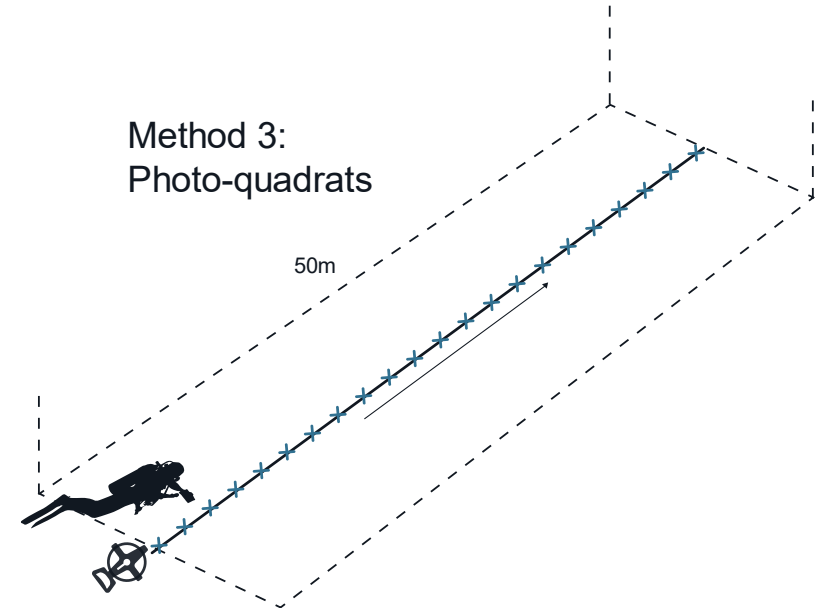


Reef Life Survey - Standardised survey methods

Method 1: Fish

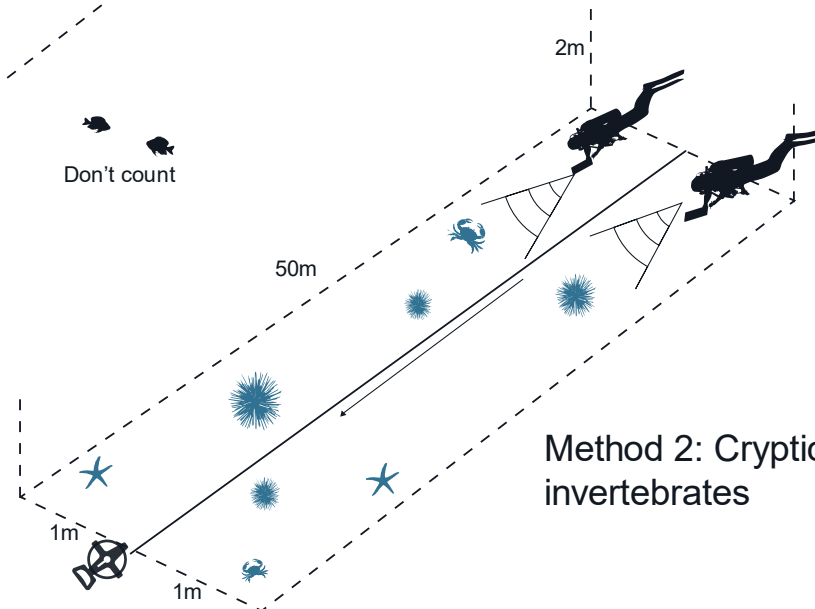


Method 3:
Photo-quadrats



Don't count

Method 2: Cryptic fish & invertebrates





Reef Life Survey



4,900
SPECIES



13,515
SURVEYS

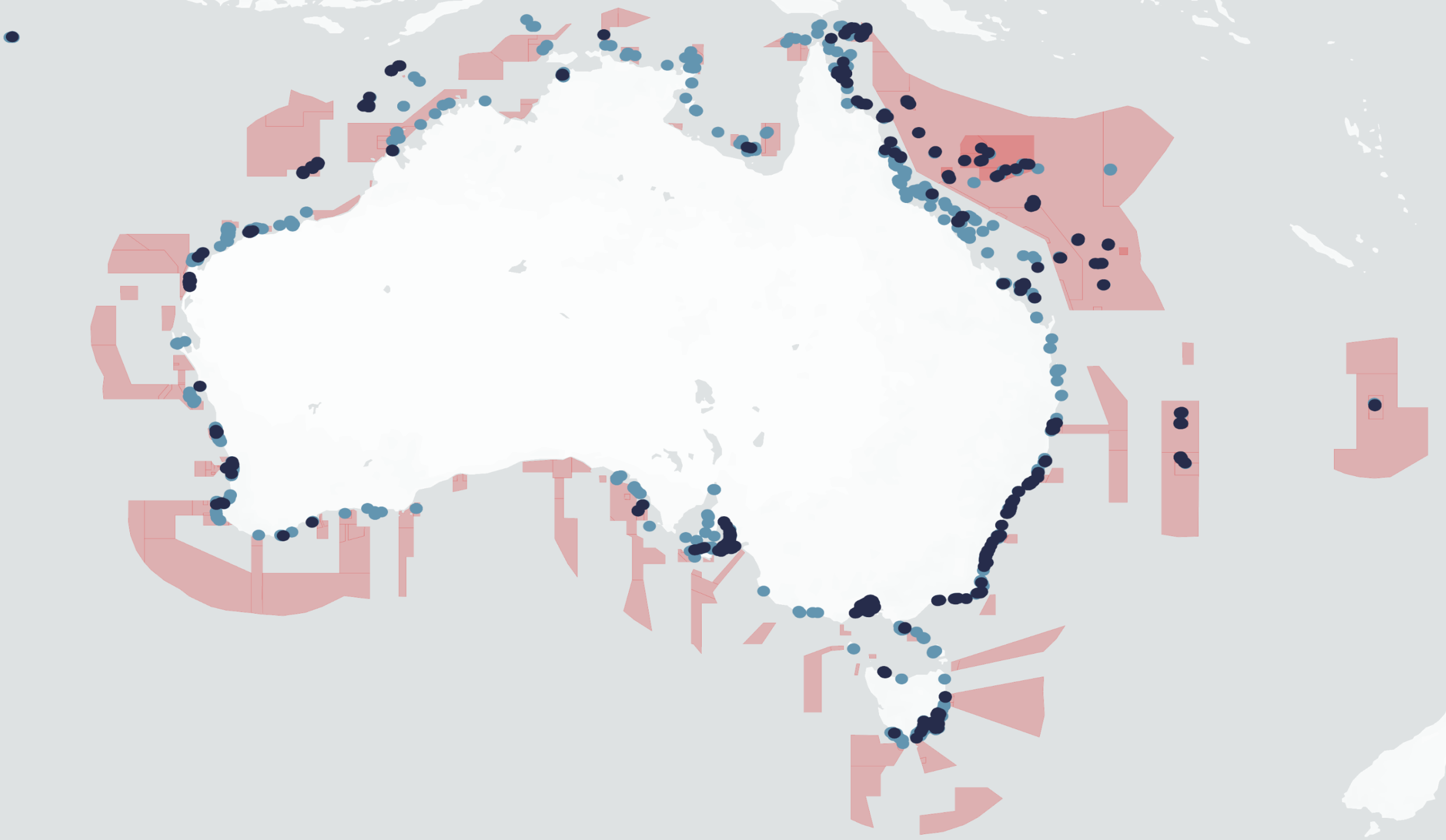


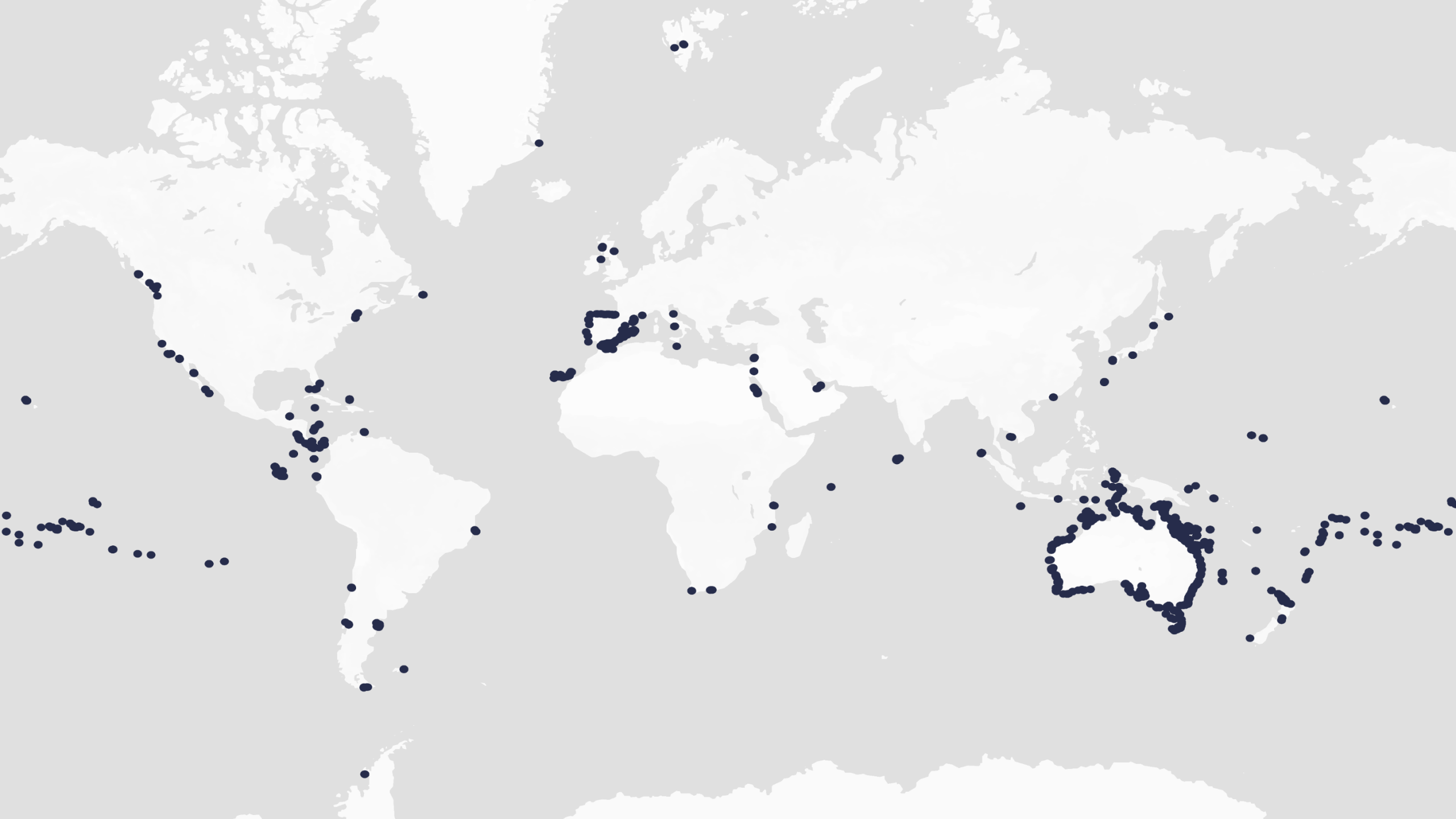
3,560
SITES



53
COUNTRIES







Reef Life Survey Data Portal

Get Data

Reef Life Survey (RLS) aims to improve biodiversity conservation and the sustainable management of marine resources by coordinating surveys of rocky and coral reefs using scientific methods, with the ultimate goal to improve coastal stewardship. Our activities depend on the skills of experienced and motivated recreational SCUBA divers, partnerships with management agencies and university researchers, and active input from the RLS Advisory Committee.

RLS data are freely available to the public for non-profit purposes, so not only managers, but also groups such as local dive clubs or schools may use these data to look at changes over time in their own local reefs. By making data freely available and through public outputs, RLS aims to raise broader community awareness of the status of Australia's marine biodiversity and associated conservation issues.

The Reef Life Survey Data Portal is hosted and maintained by the Institute for Marine and Antarctic Studies at the University of Tasmania, Australia.



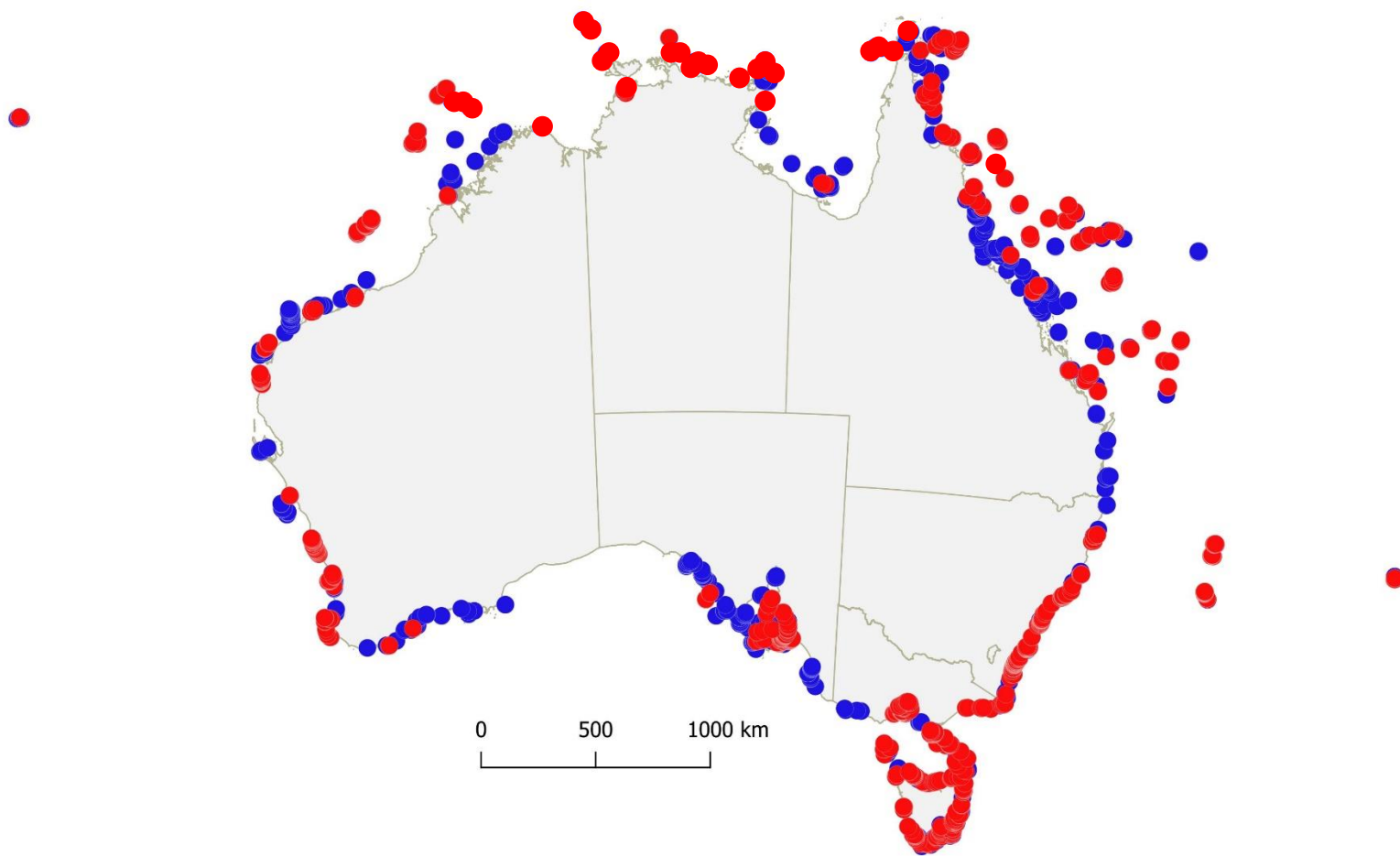
This project is supported by the Australian National Data Service (ANDS). ANDS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy Program.

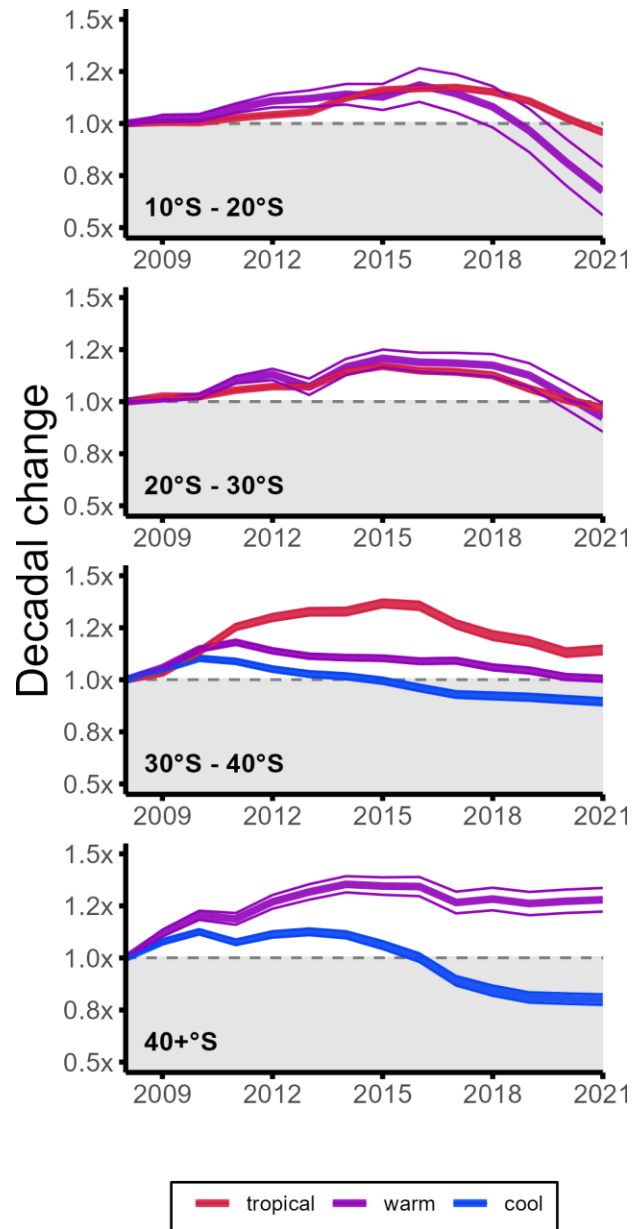
The Reef Life Survey Data Portal is also supported by the following organisations:



Australian sites surveyed by RLS and ATRC scientists and volunteers.

Sites with repeated surveys in red.

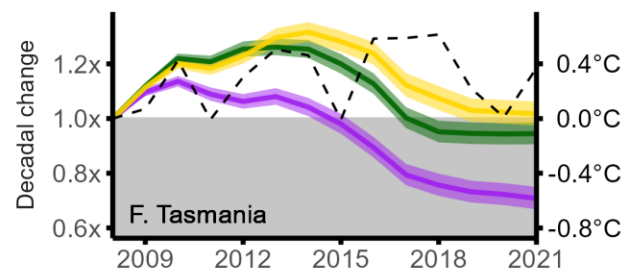
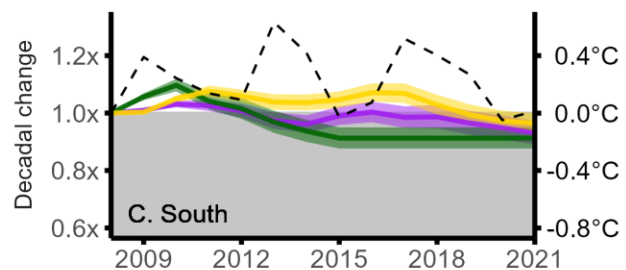
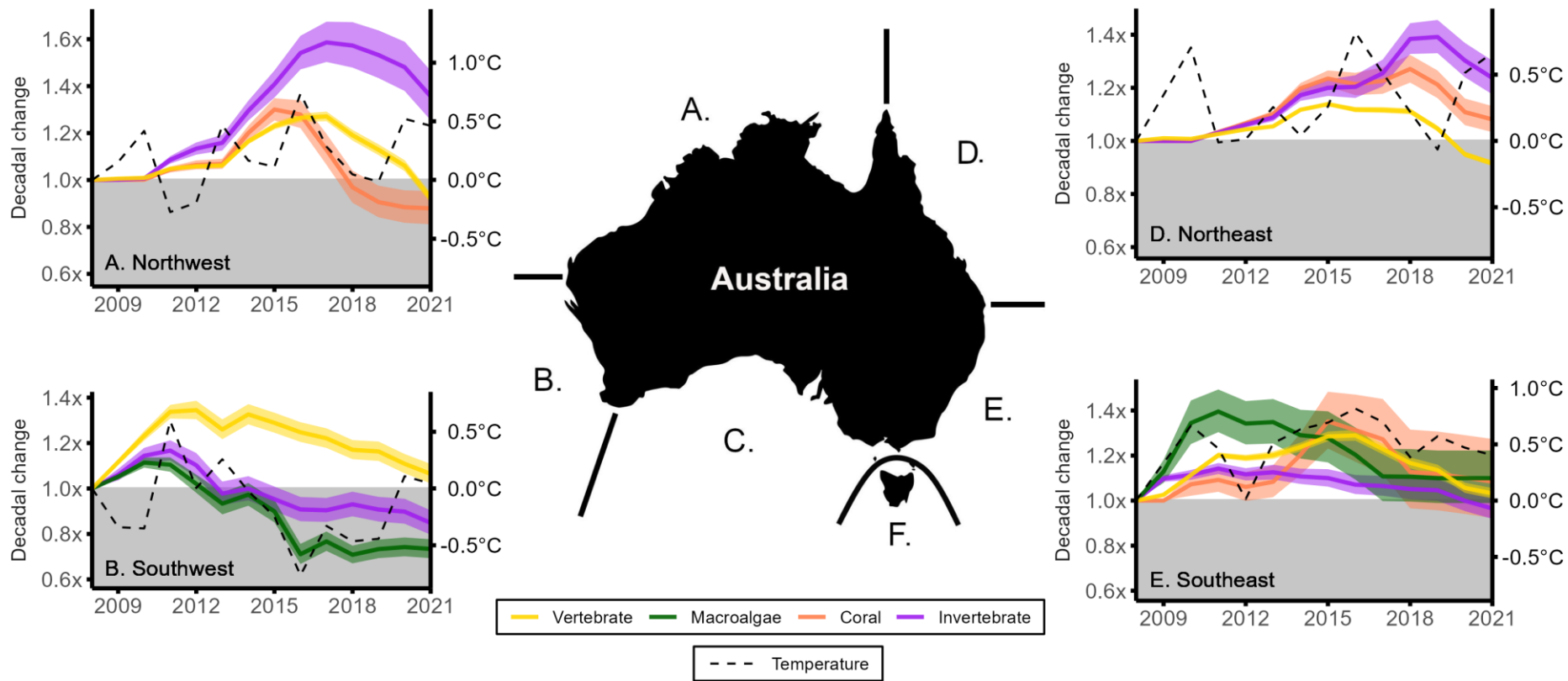




1,058 common shallow reef species
 1,642 sites around Australia
 2008-2021

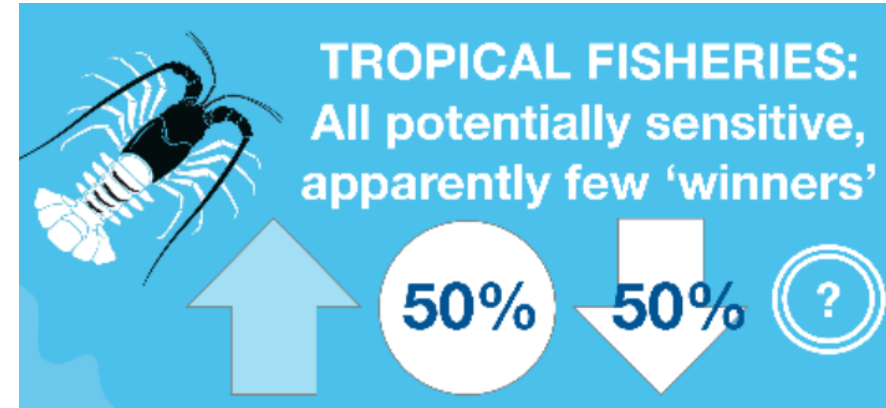
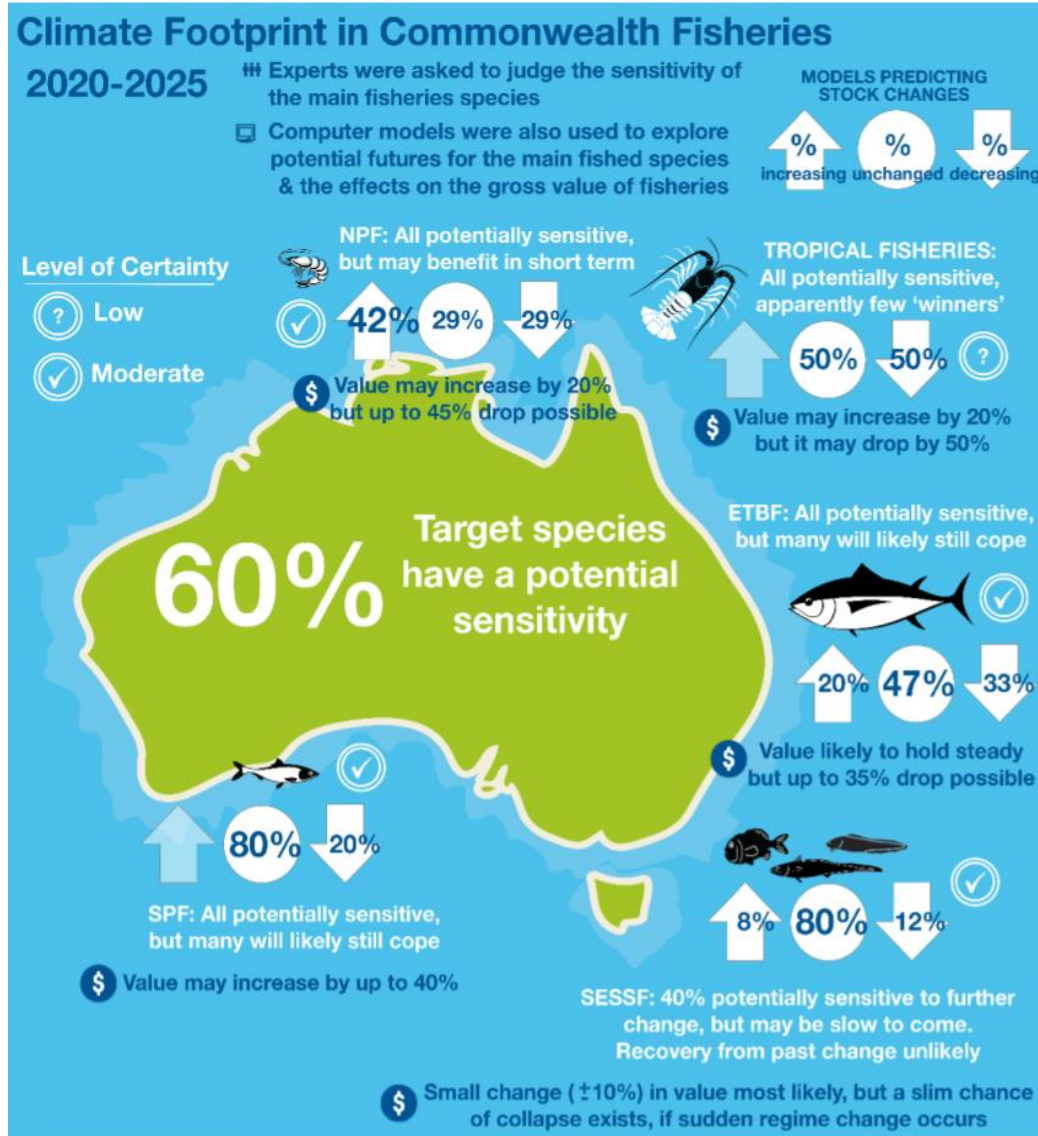
Impacts concentrated in temperate zone

- Greatest observed population decline
- Greatest predicted temp increase
- Extreme endemism (72% vs 8%)
- Climate trap
- Low public interest

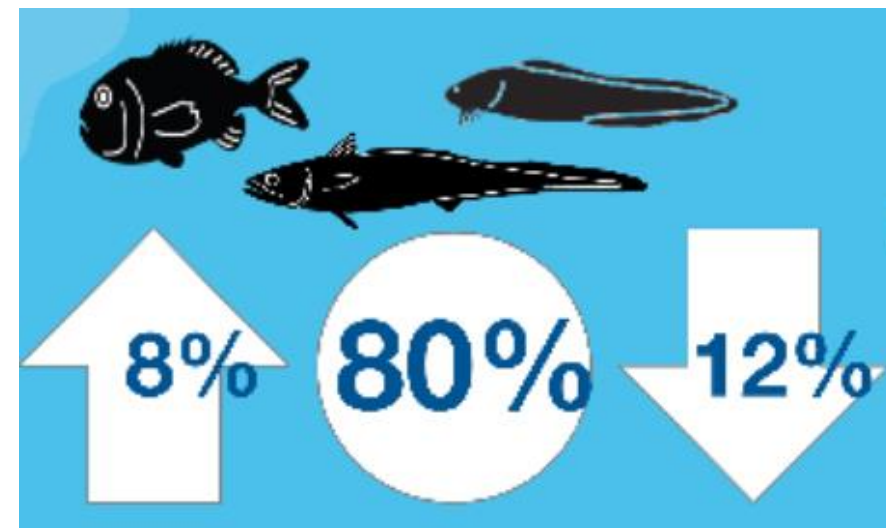


Australian fisheries stocks under climate change

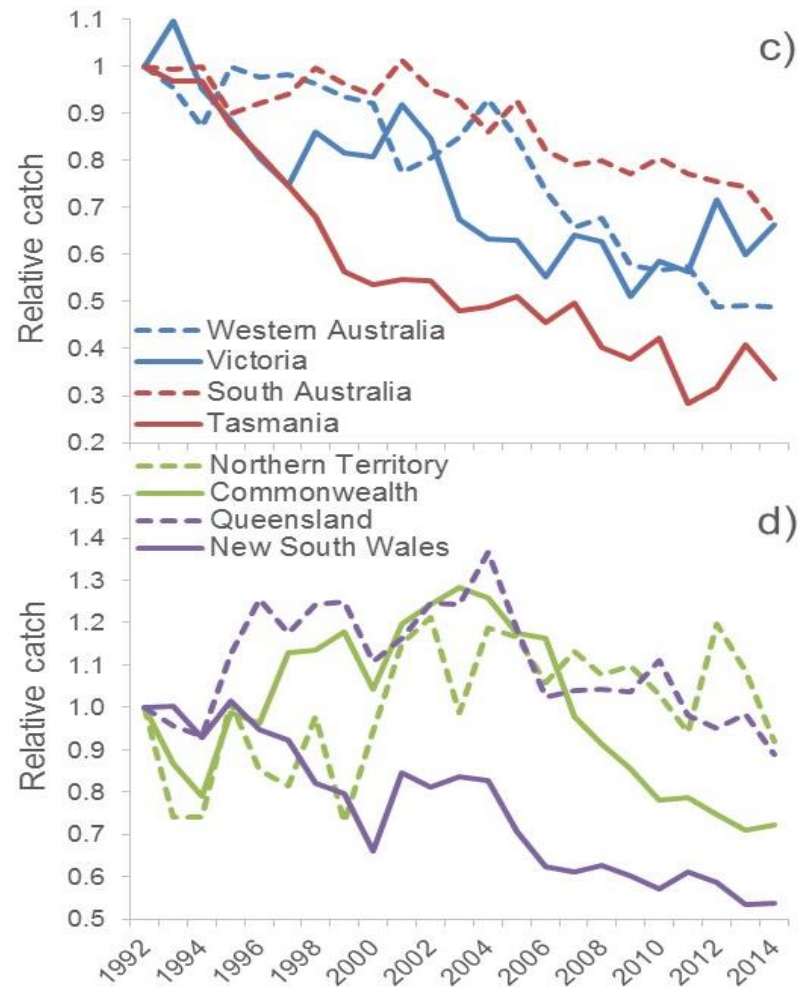
CSIRO OCEANS & ATMOSPHERE FACT SHEET



<https://www.csiro.au/~media/OnA/Files/Climate-projections-Australian-fisheries-factsheet.pdf>



Australian fishery catches



Trends in 213 stocks reported by ABARES 1992-2014

LETTER

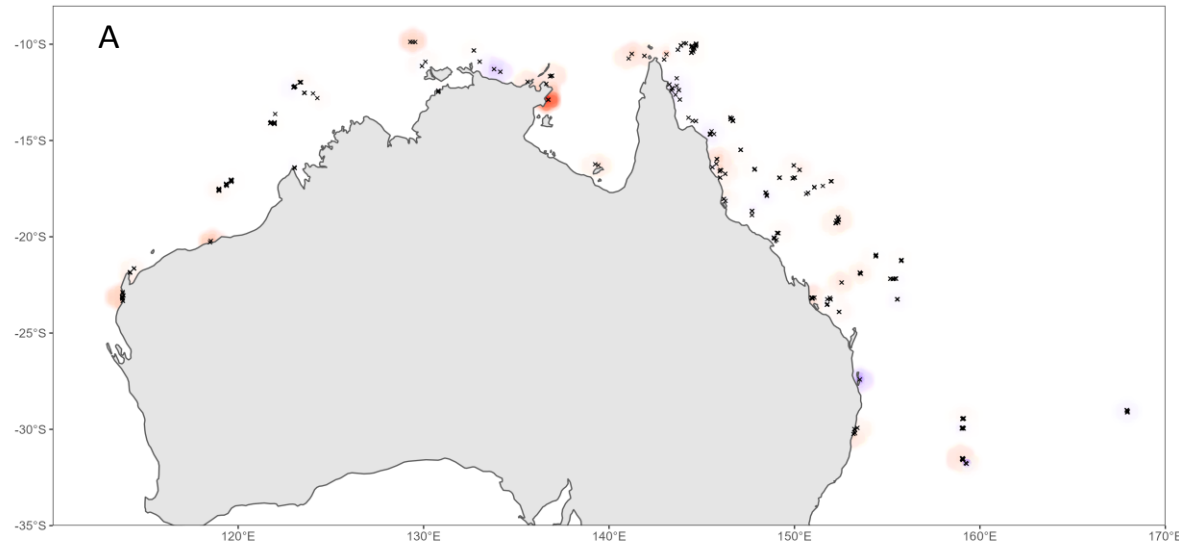
<https://doi.org/10.1038/s41586-018-0041-2>

Global warming transforms coral reef assemblages

Terry P. Hughes^{1*}, James T. Kerry¹, Andrew H. Baird¹, Sean R. Connolly^{1,2}, Andreas Dietzel¹, C. Mark Eakin³, Scott F. Heron^{3,4,5}, Andrew S. Hoey¹, Mia O. Hoogenboom^{1,2}, Gang Liu^{3,4}, Michael J. McWilliam¹, Rachel J. Pears⁶, Morgan S. Pratchett¹, William J. Skirving^{3,4}, Jessica S. Stella⁶ & Gergely Torda^{1,7}

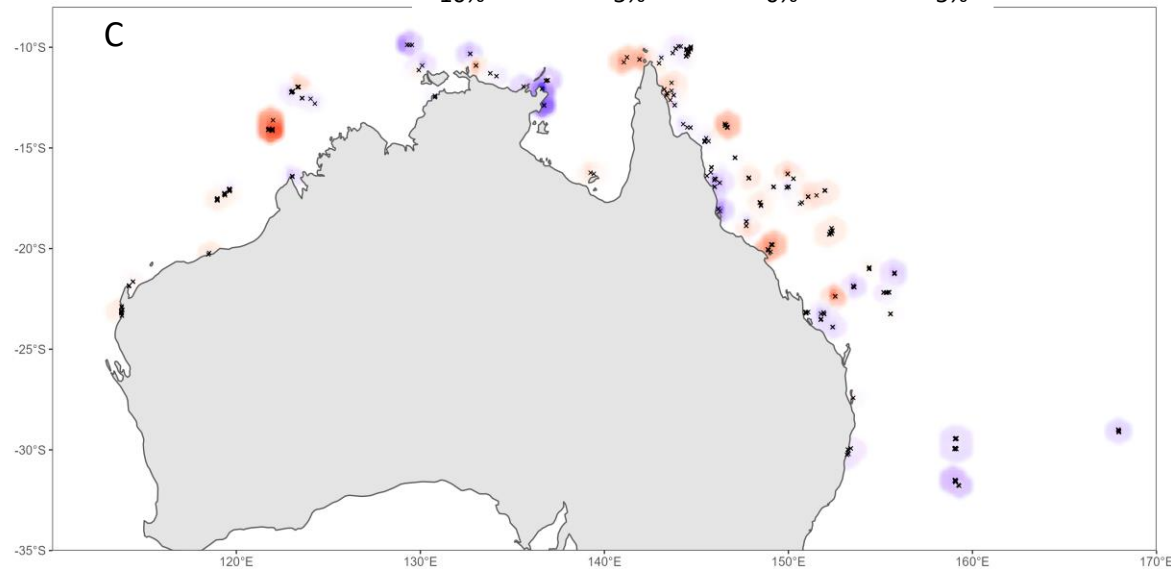
“...More broadly, throughout the entire Great Barrier Reef, including the southern third, in which the heat exposure was minimal (Fig. 1b), the cover of corals declined by 30.0% between March and November 2016.”

Decadal analysis of changing coral cover



Absolute change in coral cover

-10% -5% 0% 5%



Absolute change in coral richness

-5 0 5

- 514 sites surveyed on at least two occasions between 2010 and 2021:
- Total cover initial surveys 22.2%
 - Total cover most recent surveys 22.2%





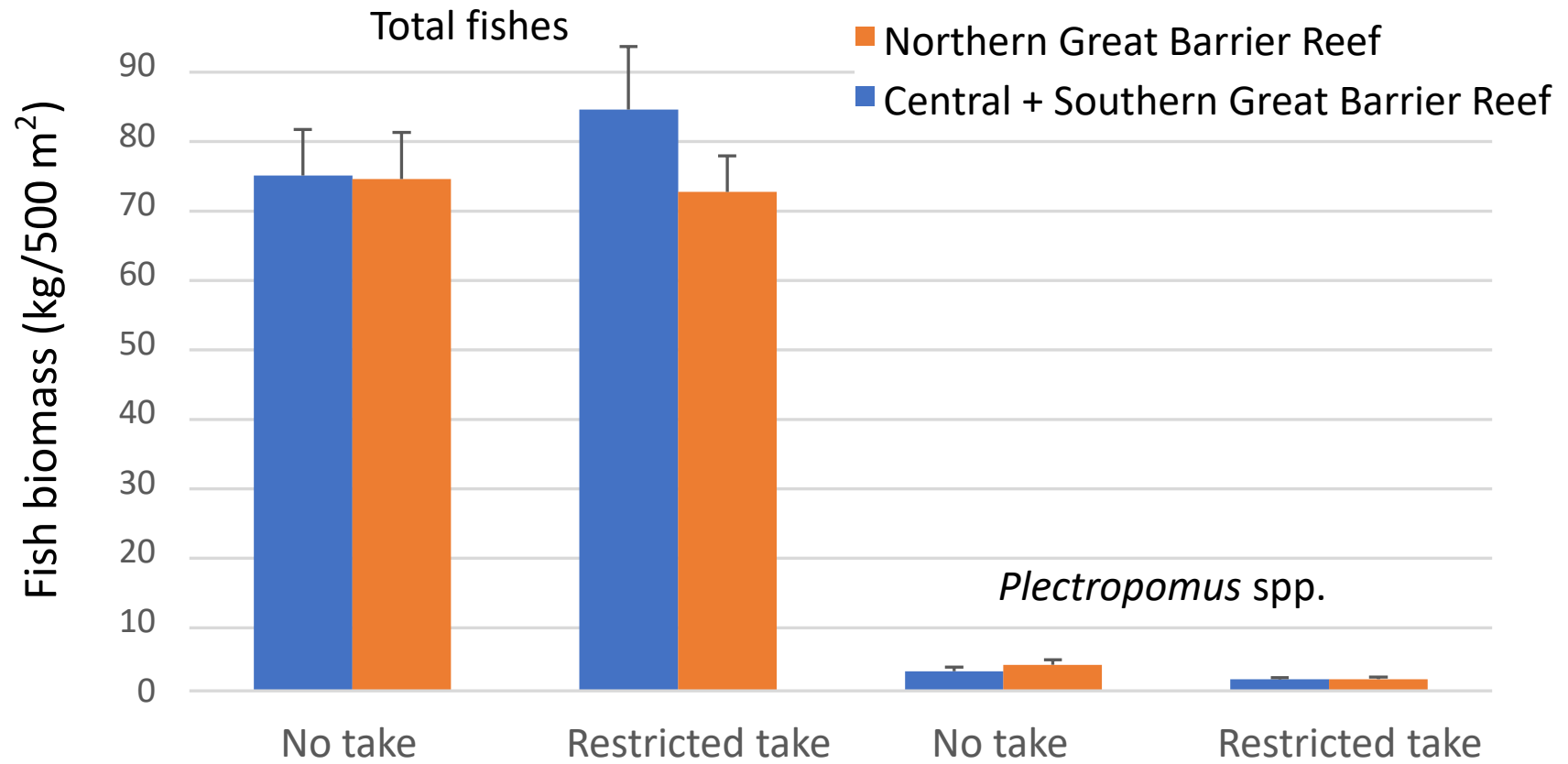
Global warming and recurrent mass bleaching of corals

Terry P. Hughes¹, James T. Kerry¹, Mariana Álvarez-Noriega^{1,2}, Jorge G. Álvarez-Romero¹, Kristen D. Anderson¹, Andrew H. Baird¹, Russell C. Babcock³, Maria Beger⁴, David R. Bellwood^{1,2}, Ray Berkelmans⁵, Tom C. Bridge^{1,6}, Ian R. Butler⁷, Maria Byrne⁸, Neal E. Cantin⁹, Steeve Comeau¹⁰, Sean R. Connolly^{1,2}, Graeme S. Cumming¹, Steven J. Dalton¹¹, Guillermo Diaz-Pulido¹², C. Mark Eakin¹³, Will F. Figueira¹⁴, James P. Gilmour¹⁵, Hugo B. Harrison¹, Scott F. Heron^{13,16,17}, Andrew S. Hoey¹, Jean-Paul A. Hobbs¹⁸, Mia O. Hoogenboom^{1,2}, Emma V. Kennedy¹², Chao-yang Kuo¹, Janice M. Lough^{1,9}, Ryan J. Lowe¹⁰, Gang Liu^{13,16}, Malcolm T. McCulloch¹⁰, Hamish A. Malcolm¹¹, Michael J. McWilliam¹, John M. Pandolfi⁷, Rachel J. Pears¹⁹, Morgan S. Pratchett¹, Verena Schoepf¹⁰, Tristan Simpson²⁰, William J. Skirving^{13,16}, Brigitte Sommer⁷, Gergely Torda^{1,9}, David R. Wachenfeld¹⁹, Bette L. Willis^{1,2} & Shaun K. Wilson²¹

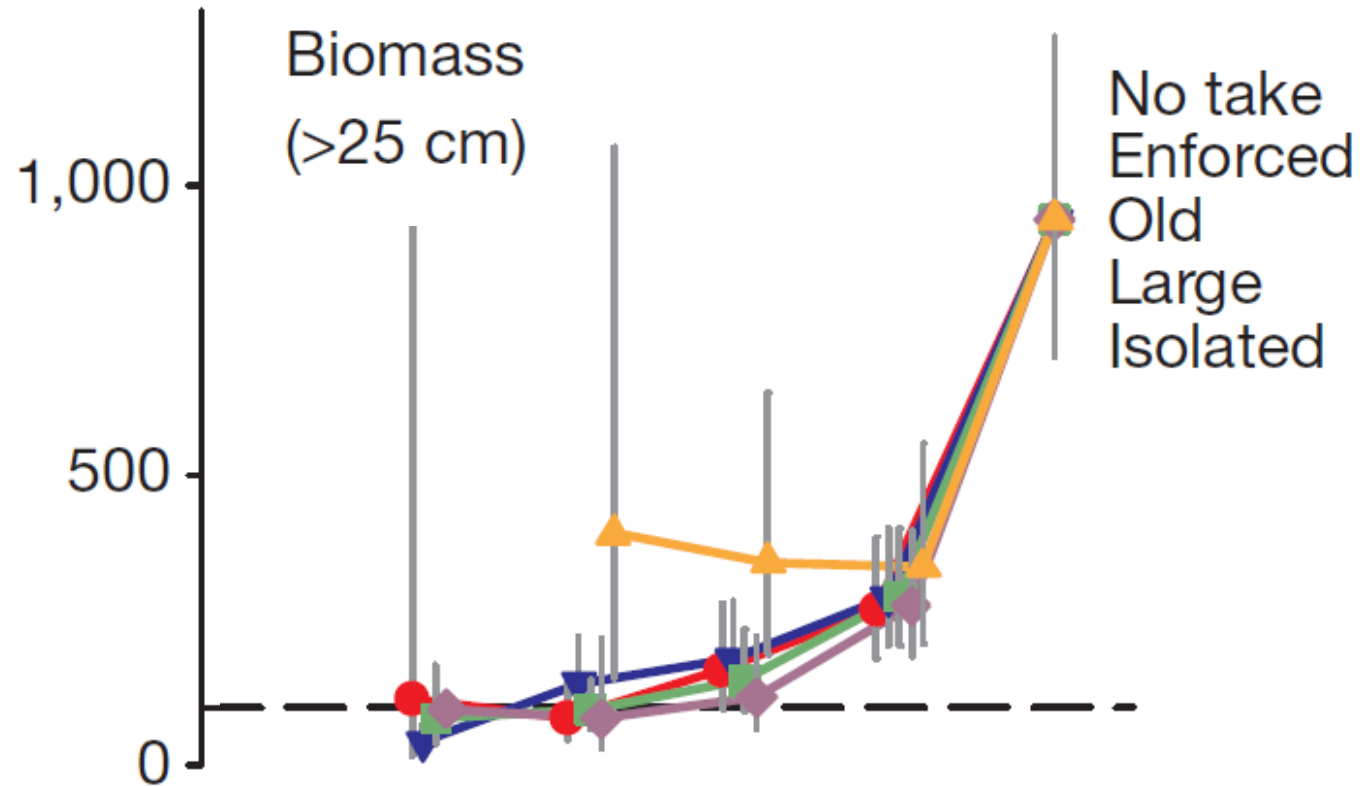
During 2015–2016, record temperatures triggered a pan-tropical episode of coral bleaching, the third global-scale event since mass bleaching was first documented in the 1980s. Here we examine how and why the severity of recurrent major bleaching events has varied at multiple scales, using aerial and underwater surveys of Australian reefs combined with satellite-derived sea surface temperatures. The distinctive geographic footprints of recurrent bleaching on the Great Barrier Reef in 1998, 2002 and 2016 were determined by the spatial pattern of sea temperatures in each year. Water quality and fishing pressure had minimal effect on the unprecedented bleaching in 2016, suggesting that local protection of reefs affords little or no resistance to extreme heat. Similarly, past exposure to bleaching in 1998 and 2002 did not lessen the severity of bleaching in 2016. Consequently, immediate global action to curb future warming is essential to secure a future for coral reefs.

“... fishing pressure had minimal effect on the unprecedented bleaching in 2016, suggesting that local protection of reefs affords little or no resistance to extreme heat.”

Total reef fish biomass – Great Barrier Reef Marine Park



Variation in total biomass of large reef fishes: NEOLI

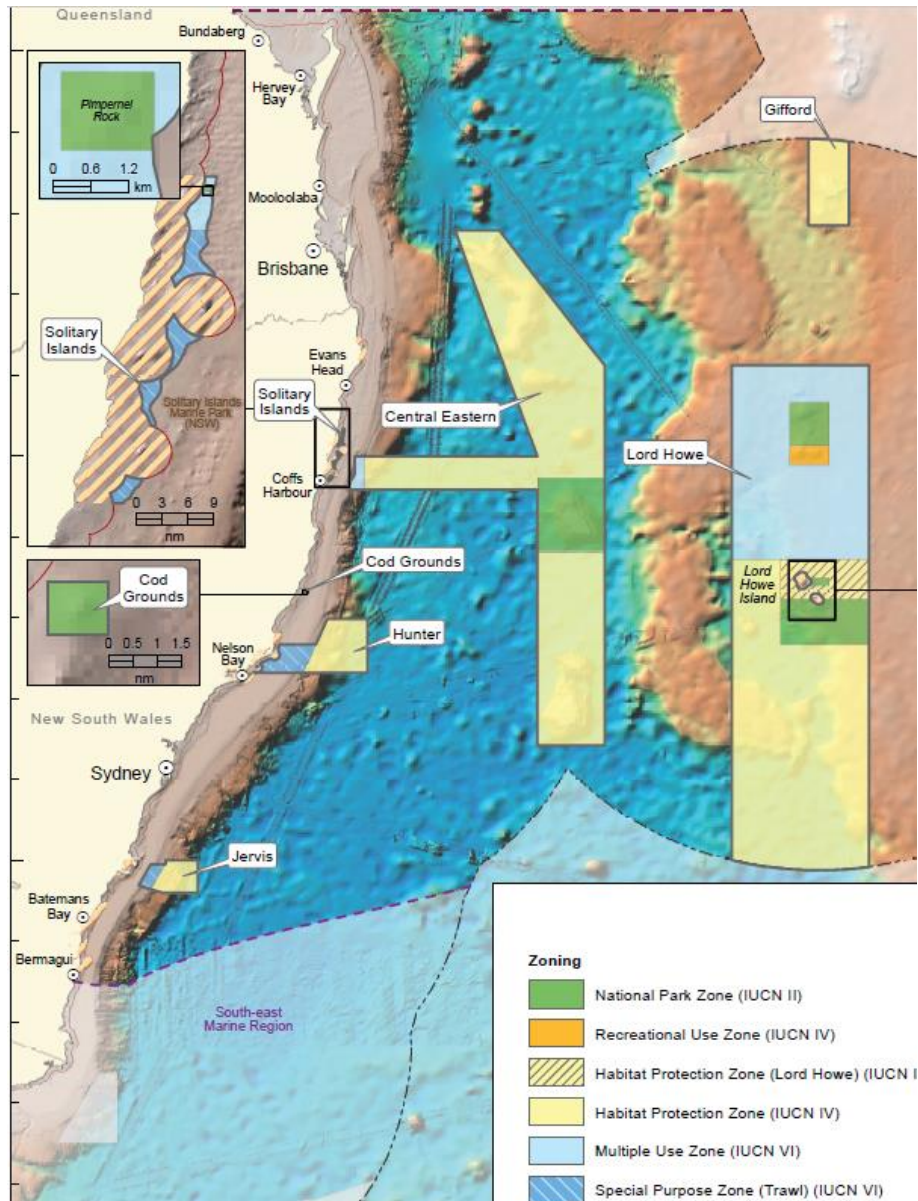


Only 9 of 87 MPAs investigated had 4 or 5 NEOLI features

=> Only ~10% of MPAs were demonstrably different to fished locations

Edgar, GJ et al (2014) Global conservation outcomes depend on marine protected areas with five key features. *Nature*, **506**, 216-220.

Temperate East Marine Parks Network

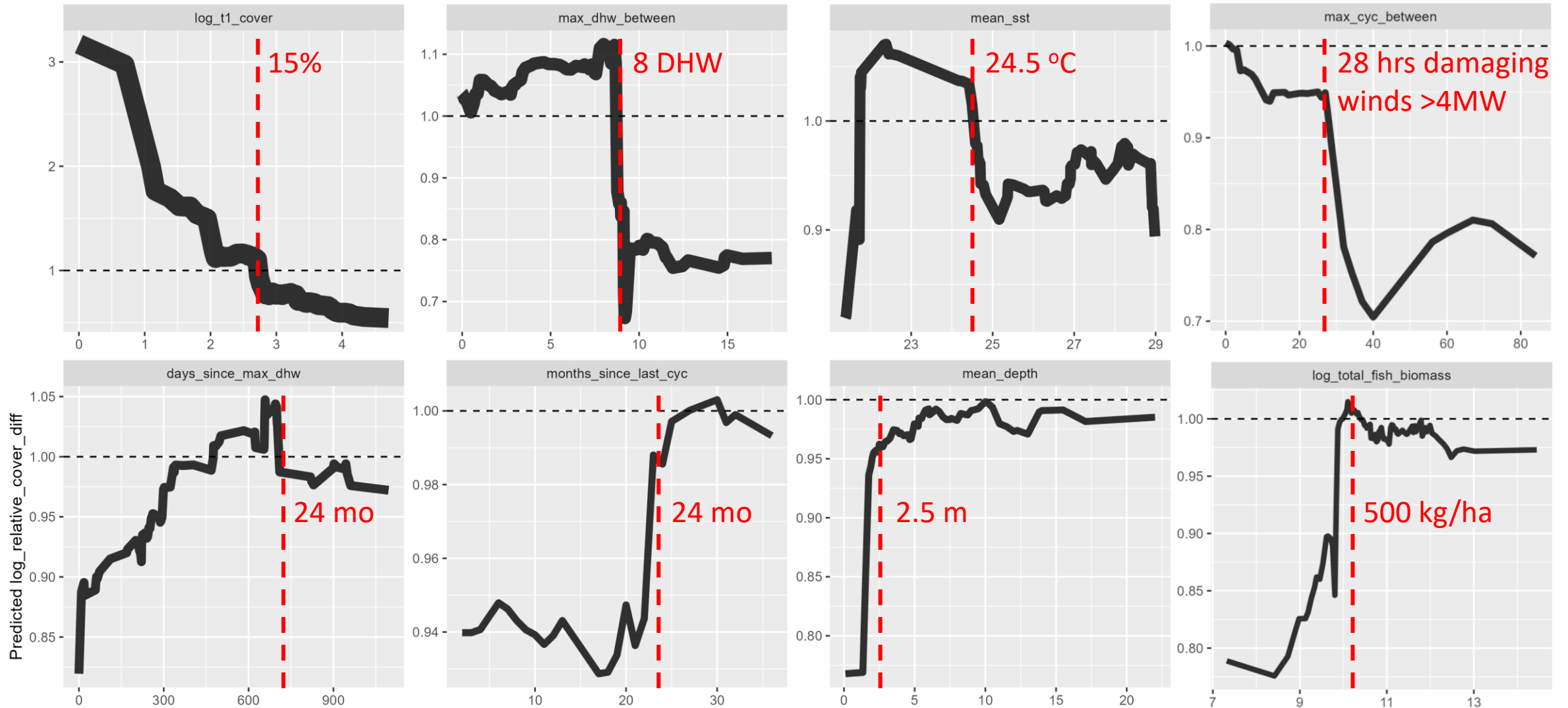


Continental shelf/slope
0.01% No-fishing

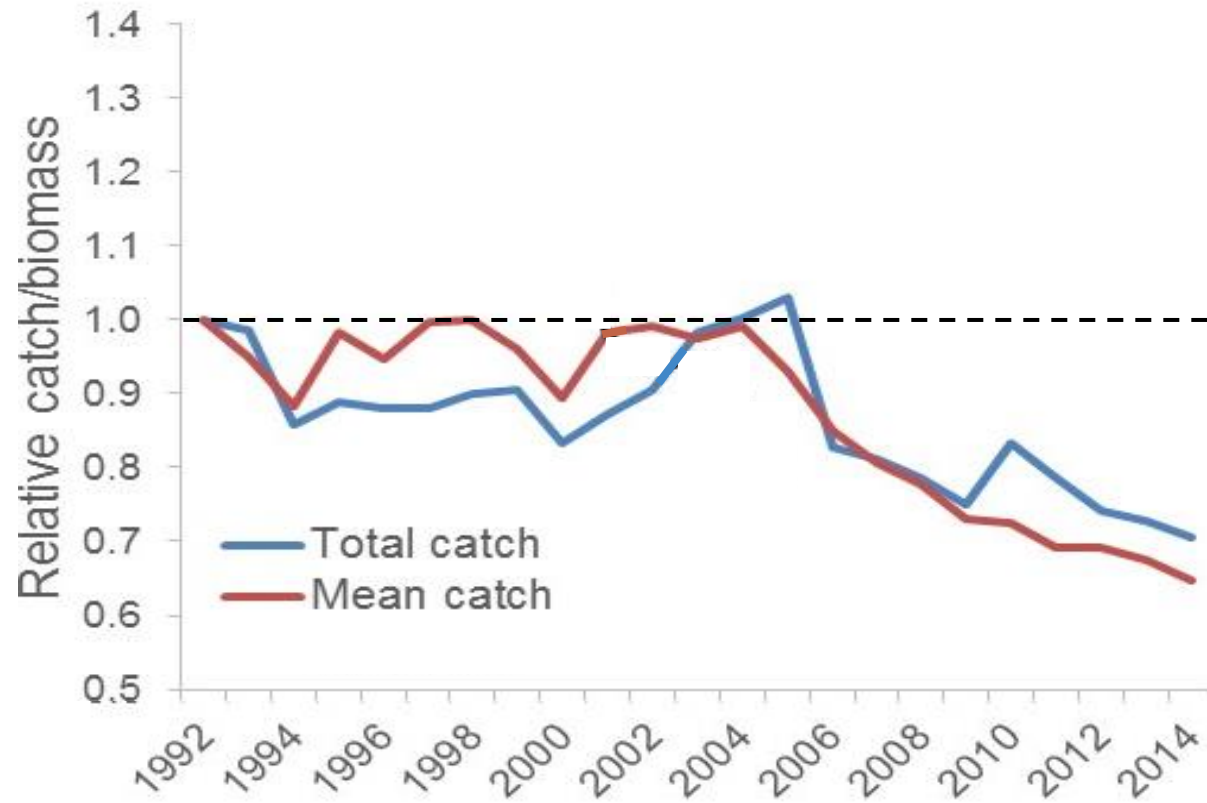
Specifically designed through 3 iterations to avoid any impact on fishing activity or petroleum exploration
=>business continues as usual, no environmental, science or economic benefits can be expected.

Random forest decadal analysis of potential drivers of changing coral cover

514 sites surveyed on at least two occasions



Australian fishery catches

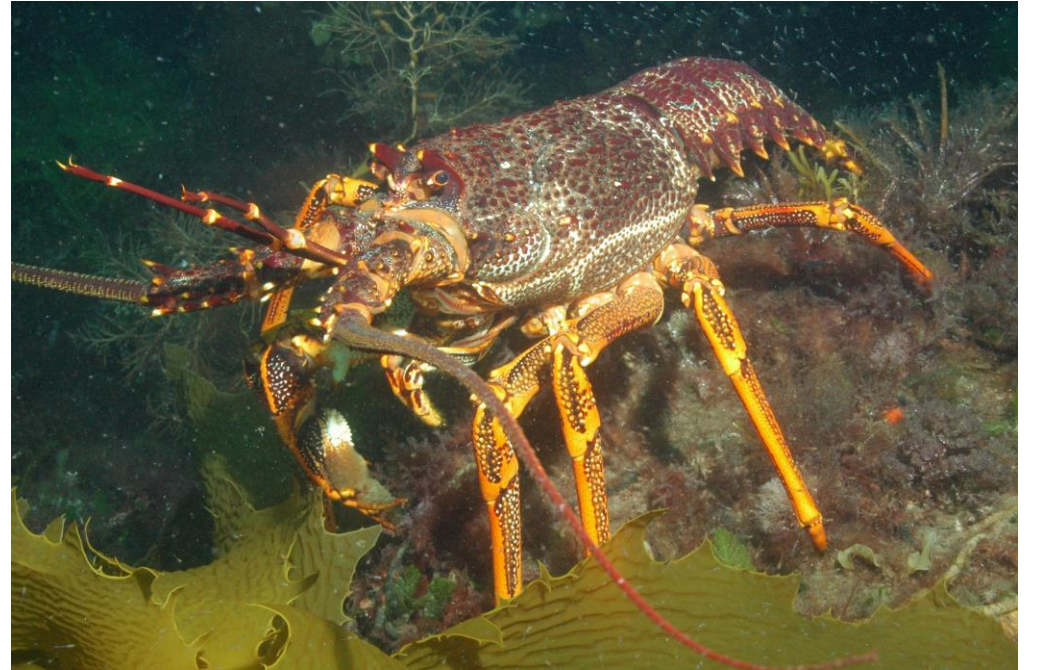


Trends in 213 stocks reported by ABARES 1992-2014

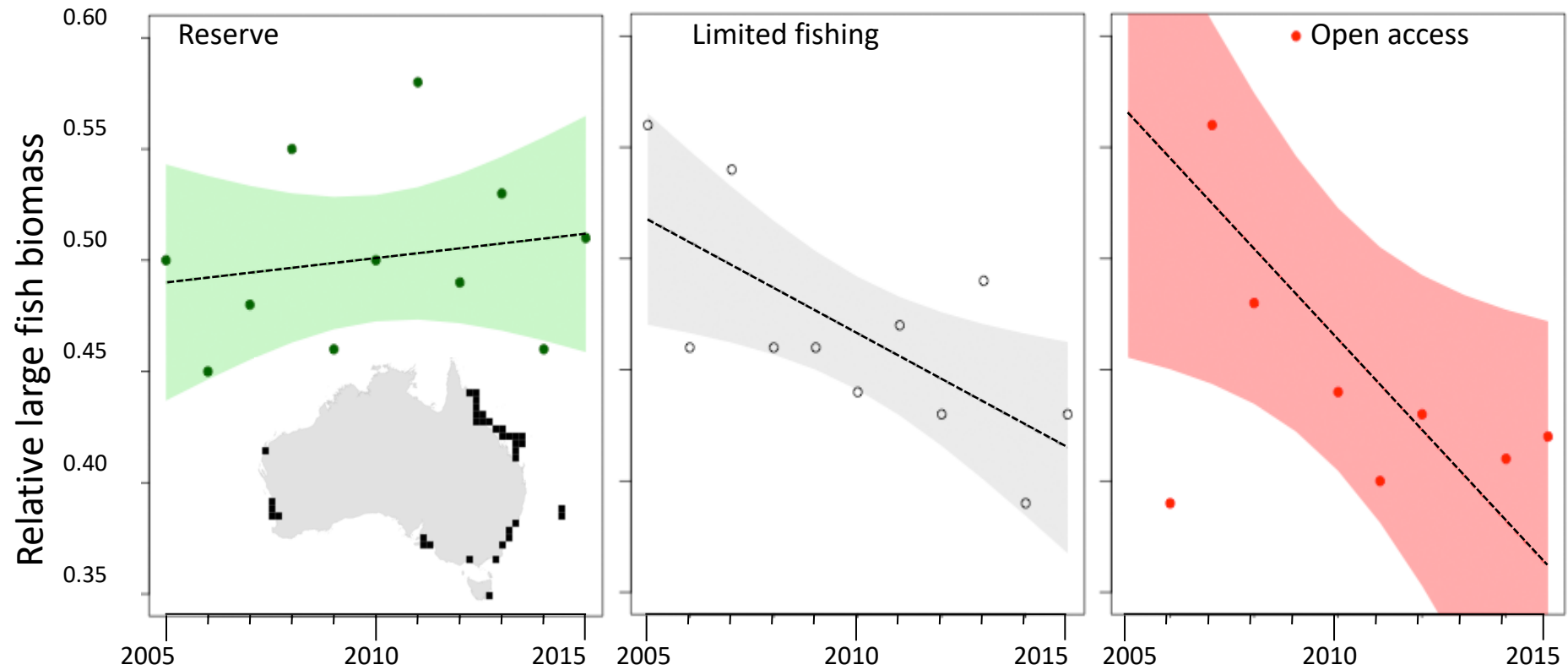
Competing hypotheses

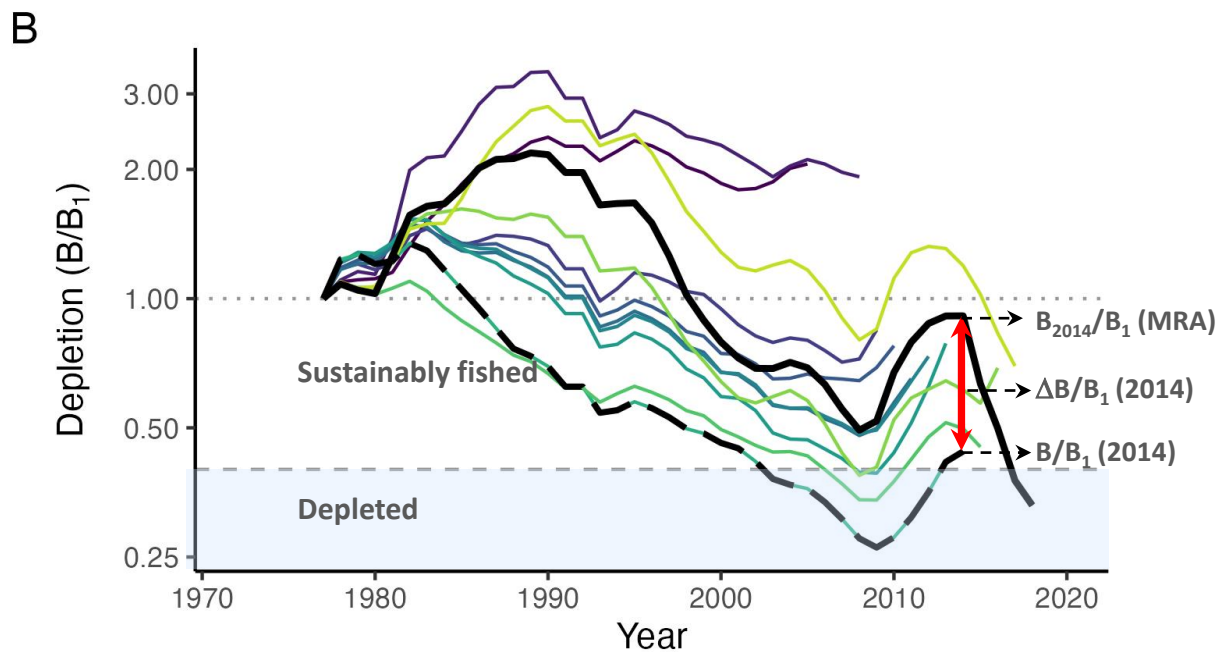
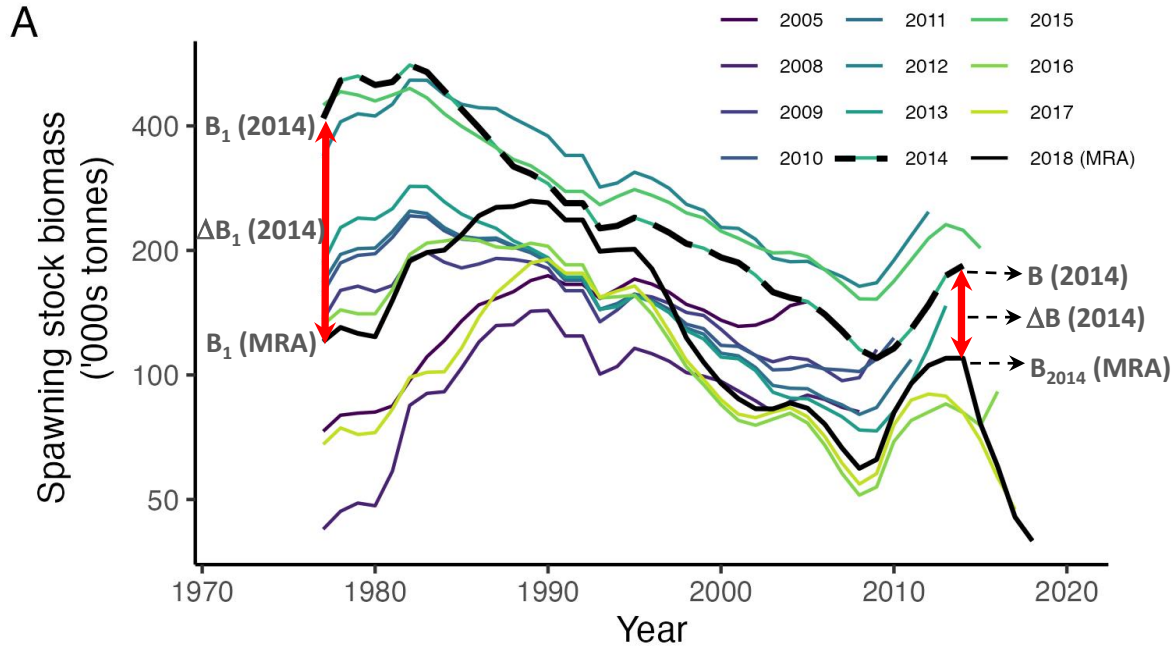
Declining fish catches are:

- Good => more conservative catch limits
=> more fish left in the sea
=> more precaution
- Bad => fish stocks are declining.



Trends in the total biomass of large fishes (≥ 20 cm in length) observed during underwater transects around Australia (ATRC, RLS and AIMS data)





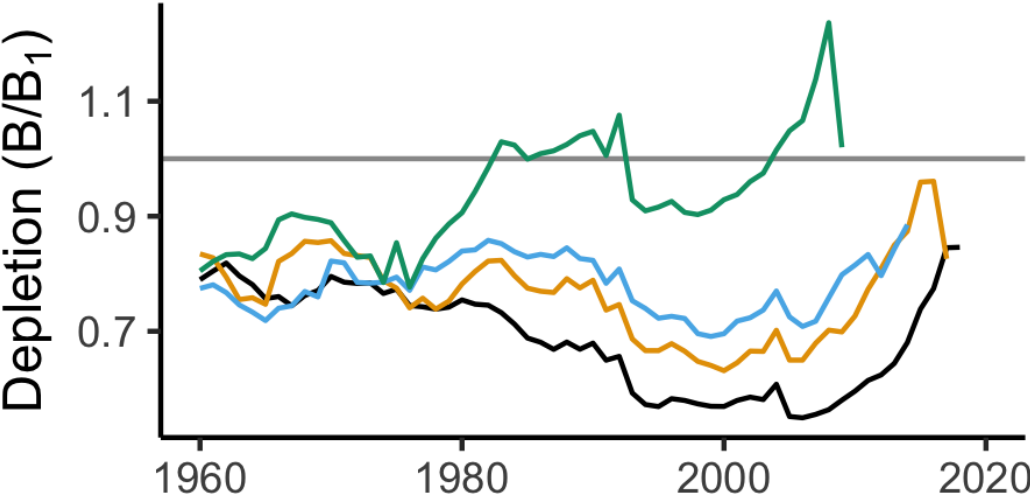
Retrospective analysis of 230 major fisheries worldwide

Hindcast trends in stock size and depletion for Pacific cod (Gulf of Alaska) starting from 1977, as published in stock assessments from 2005 to 2018 by the Alaska Fisheries Science Center. Stock models were re-run regularly with new data, providing differing estimates of stock size for past years.

Complex stock assessment models overstate sustainability of the world's fisheries

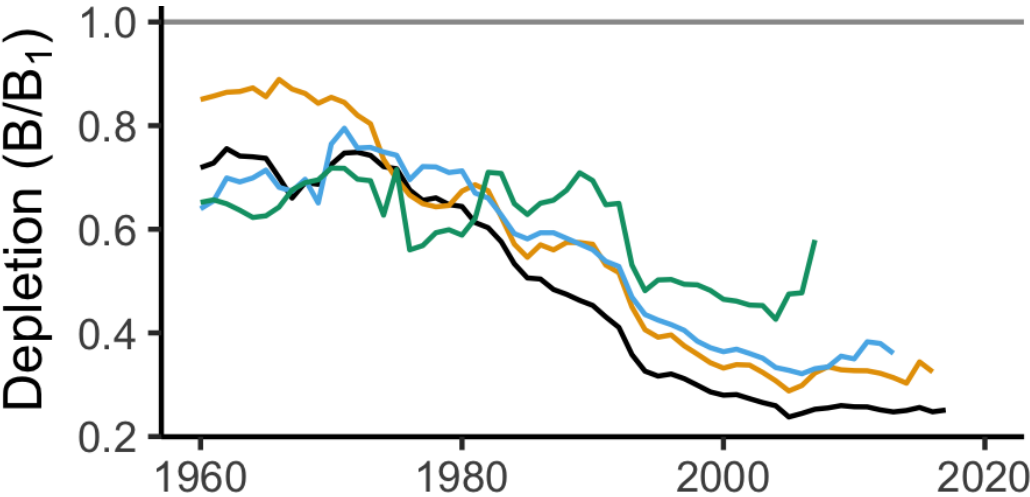
Edgar, G.J., Bates, A.E., Krueck, N.C., Baker, S.C., Stuart-Smith, R.D., Brown, C.J. in review

Retrospective analysis of 230 major fisheries worldwide



Assessment age

- MRA
- 1-3 yr old
- 4-8 yr old
- >8 yr old



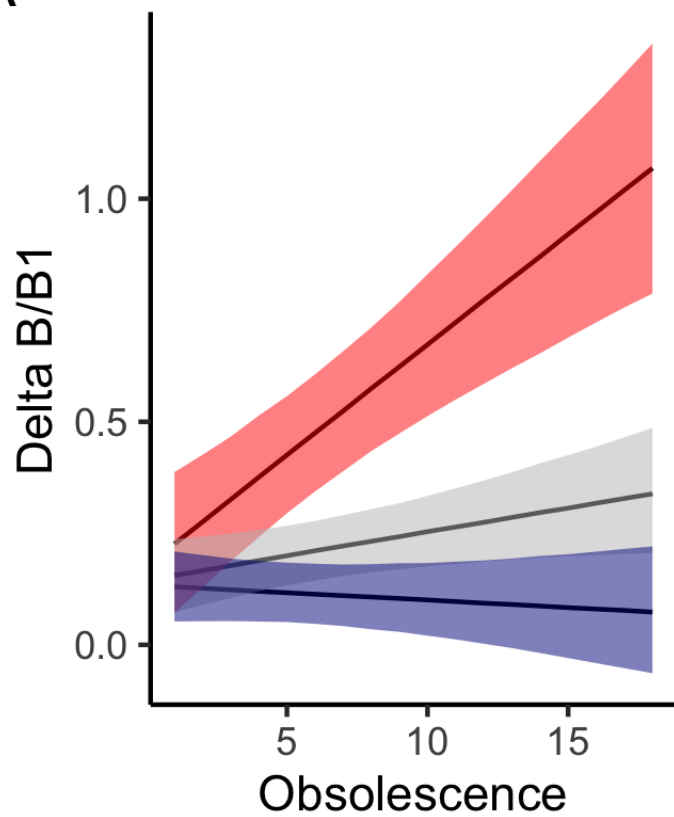
Retrospective analysis of 230 major fisheries worldwide

Stock estimates reported in a particular year are compared with subsequent hindcast estimates modelled with updated data.

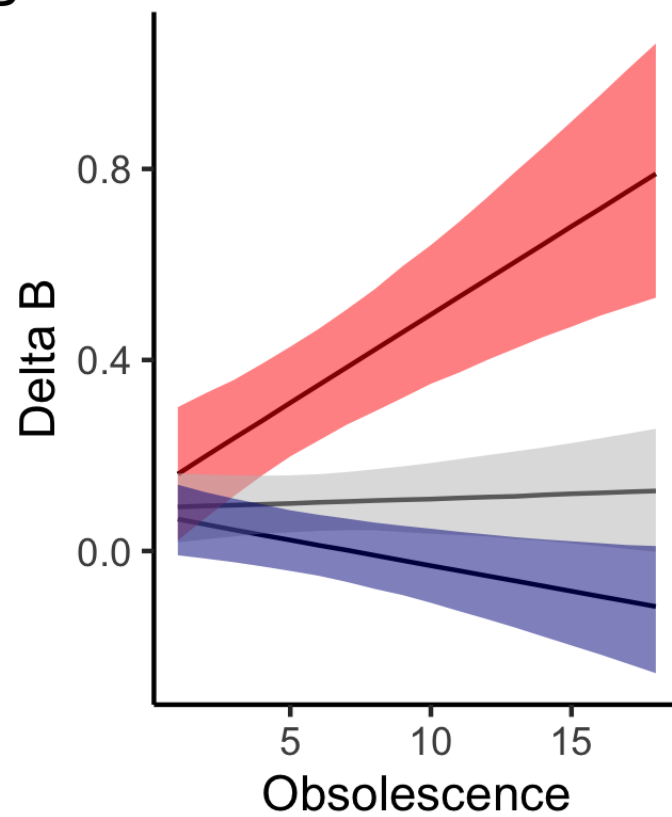
- Stock estimates oscillated greatly between sequential assessments, by $40\% \pm 2\%$ (SE) on average.
- Stocks were $17\% \pm 3\%$ (SE) more depleted than initially reported.
- Bias was extremely large for some stocks, by more than 1.5x for 21% of stocks, and more than 2x for 11% of stocks.
- $3.7\times$ (33 vs 9) and $1.7\times$ (53 vs 32), more assessed stocks have declined below $B/B_1 = 0.1$ and 0.2 reference points, respectively, than currently recognised

Retrospective analysis of 230 major fisheries worldwide

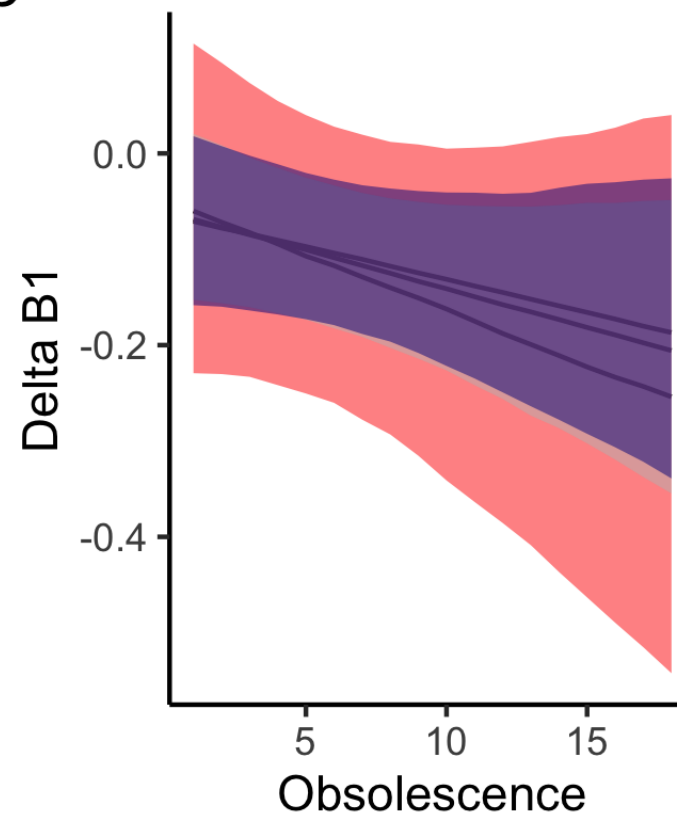
A



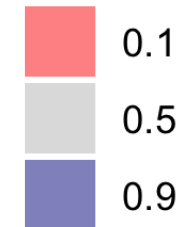
B



C



B/B1

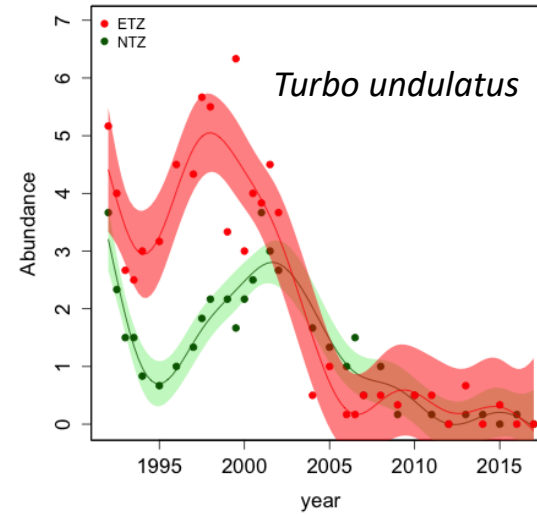
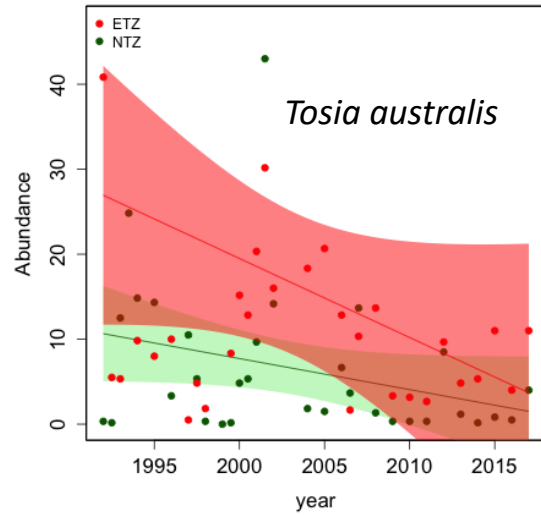
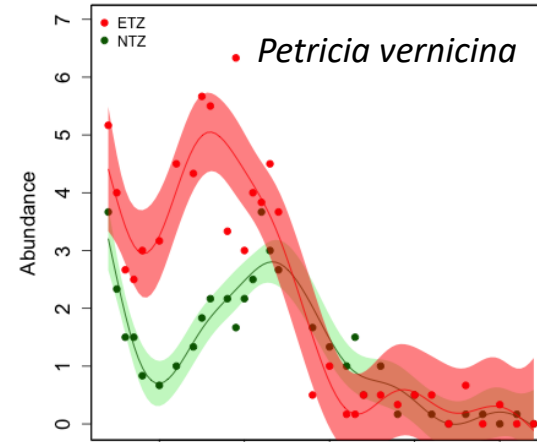
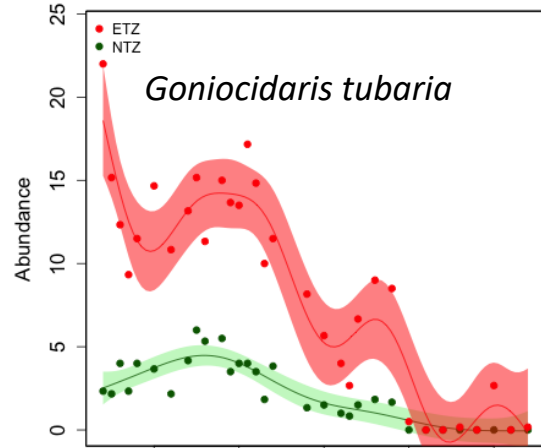


Issues affecting stock assessment models

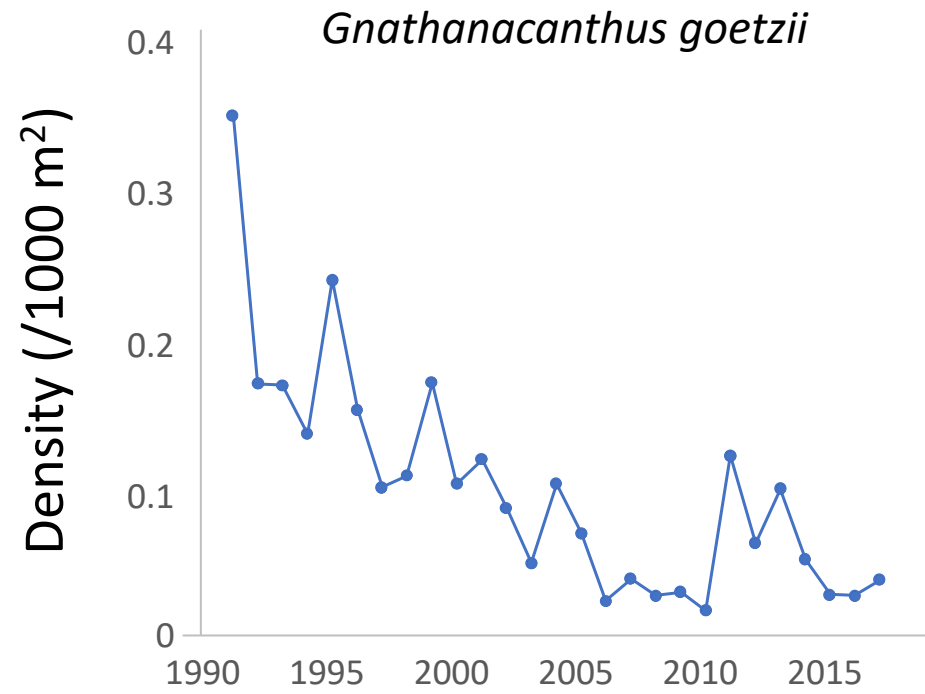
- No population trend information for most species, including bycatch
- Few high quality stock assessments
- Models extrapolated outside environmental bounds
- Interspecific interactions ignored
- Technological creep ignored
- Recreational and artisanal catch largely uncontrolled and ignored
- Little biological input
- Models rely on value judgments for parameterisation
- Models are opaque and cannot be independently reproduced
- Optimism when dealing with uncertainty

=> Extreme uncertainty, much more precaution needed

Population trends eastern Tasmania invertebrates



Population trends poorly known species



Global Ecosystem Monitoring Program

- Worldwide
- Long-term
- Multiple phyla
- Species-level
- Consistent, quantitative methods
- Online data distribution in near real time
- eDNA component

Thanks



- RLS volunteer divers
- RLS Advisory committee (including state and commonwealth parks management agencies)
- The Institute for Marine and Antarctic Studies, University of Tasmania
- The Ian Potter Foundation
- The Minderoo Foundation
- Parks Australia
- State Government Marine Environment Management Agencies
- The NESP Marine Biodiversity Hub
- The Integrated Marine Observing System



- Rick Stuart-Smith
- Neville Barrett
- Antonia Cooper
- Lizzi Oh
- UTAS students
- Scientific collaborators



