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Oceanographic factors, spatial context and the predictive modelling of fish species richness on coral reefs

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Predictive models of marine biodiversity are urgently needed to prioritize areas for conservation. The Prediction Project of the CERF Marine Biodiversity Hub aims to (i) examine the performance of statistical models to predict marine biodiversity patterns from habitat characteristics and (ii) deliver predictive maps of biodiversity patterns at large regional and national scales around Australia, including the Torres Strait.

1- The Torres Strait

- Shallow continental shelf (maximum depth 20–60 m)
- ~60,000 km^2 between Papua New Guinea and Australia
- Complex bathymetry, with ~ 800 islands and numerous reefs, shoals and submarine sand dunes.

2- Fish surveys

- Conducted in 1995/1996 by the CSIRO across 220 sites (Fig. 1)
- Underwater visual census of 197 fish species along 100m x 10m transects.
- Fish species richness (S) = total number of species recorded at each site.

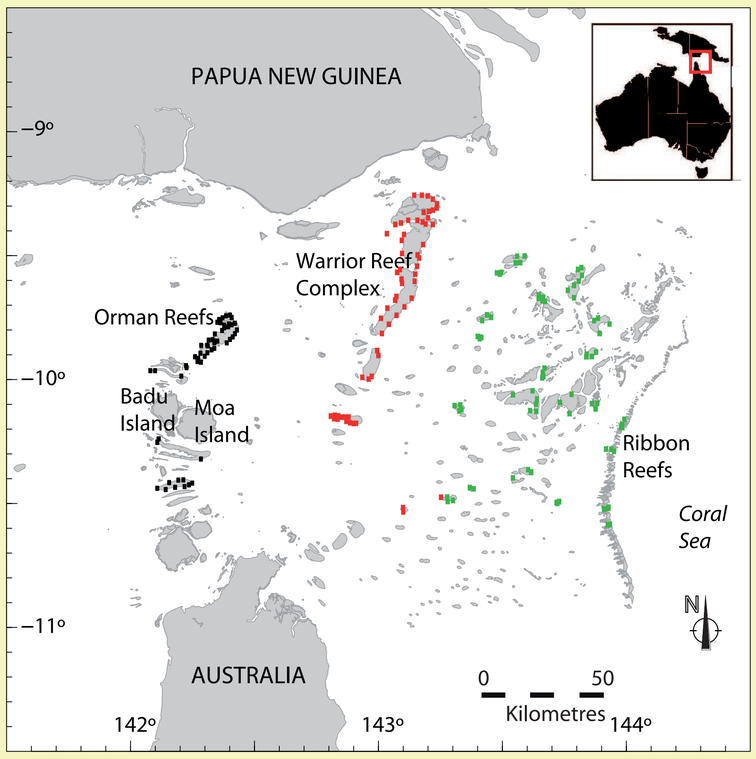

Figure 1 The Torres Strait, with sampled reefs represented in black (East), red (middle) or green (West).

3- Environmental variables

- 38 environmental variables collated across a 0.01° grid:
  - NO_3, PO_4, Si, temperature, salinity (annual mean levels and standard deviation; source: CSIRO Atlas of Regional Seas)
  - Chl a, light diffuse attenuation, sea surface temperature (source: SeaWIFS)
  - Depth and percent cover of carbonate sediments, gravel, sand and mud, wave exposure (source: Geoscience Australia)
- Spatial variables: longitude and latitude.

4- Analysis

- Variable-reduction procedure to minimize multicolinearity using Principal Component Analysis (PCA).
- Generalized Linear Model (GLM) comparisons to gauge the relative importance of oceanographic and spatial factors using Bayesian Information Criterion (BIC; Burnham & Anderson 2002)
- Spatial Generalized Linear Mixed-Effect Model (GLMM) to account for spatial autocorrelation in S using random effects (Diggle & Ribeiro 2007).

5- Selection of candidate predictors

- A total of 12 environmental variables selected (Fig. 2A)
- Same longitudinal gradient as observed with all environmental variables (Fig. 2B).

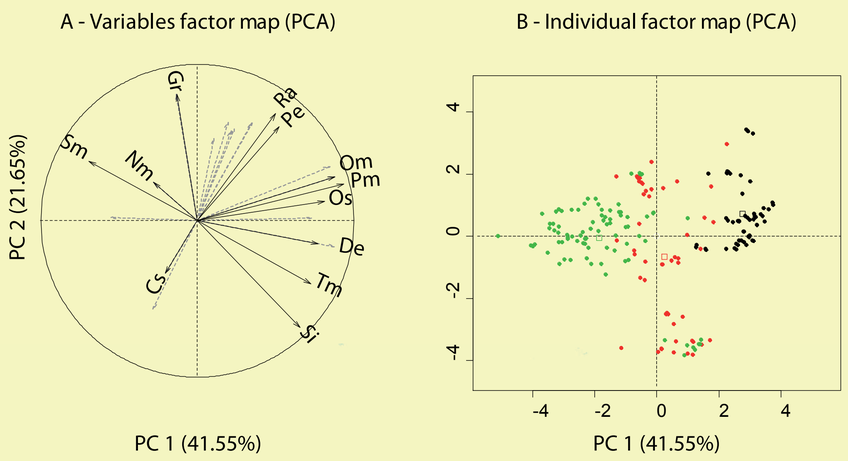

Figure 2 PCA of environmental variables. A: Candidate predictors (continuous labelled arrows) and other environmental variables of the data set (here illustrative, dotted arrows). B: Individuals factor map, with western sites in black, intermediate sites in red, and eastern sites in green.

6- GLM comparisons

- Most parsimonious model: all candidate predictors + spatial variables (83% deviance explained)
- Second most parsimonious model: spatial variables only (80% deviance explained)

7- Spatial GLMM

- Spatial autocorrelation in S observed at all distance classes (Fig. 3)
- Random effects with an exponential spatial structure.

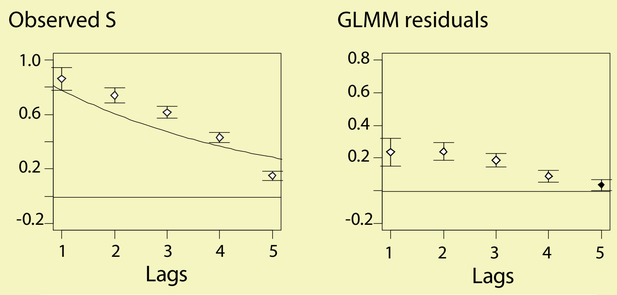

Figure 3 Spatial correlograms (1 lag ~ 20 km). The continuous line represents the exponential spatial structure assumed in the GLMM.

8- Predictive mapping of fish species richness

- Longitudinal gradient in S from western to eastern reefs (Fig. 4).
- Highest standard deviation on eastern and southern reefs.

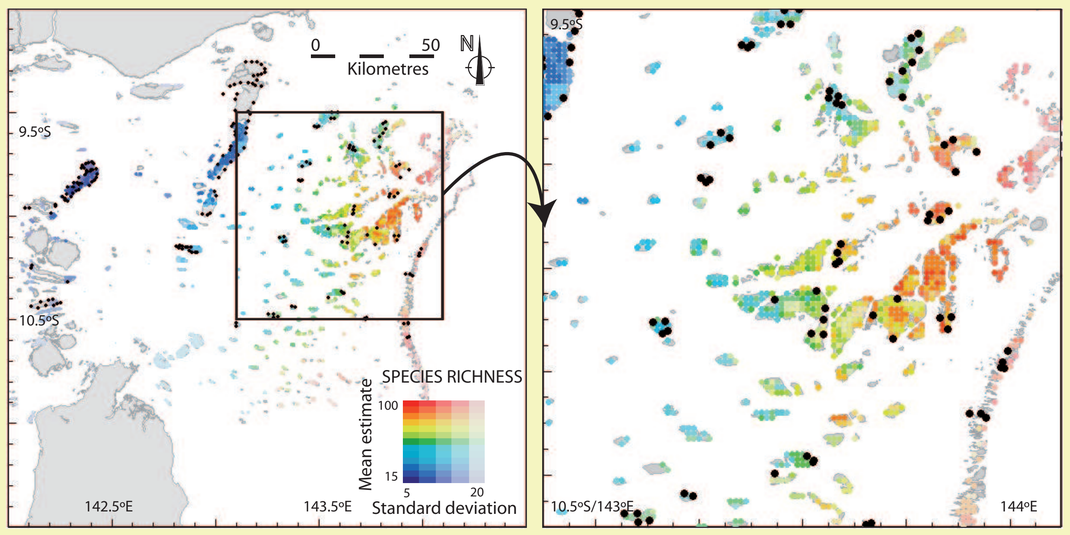

Figure 4 Spatial predictions of fish species richness across the Torres Strait

Conclusion

- Up to 80% of deviance explained in fish species richness, which could then be predicted in areas where only physical data were available.
- Importance of spatial context at a large scale (latitudinal and longitudinal gradients) and at a fine scale (spatial autocorrelation)

Acknowledgements

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References

Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information theoretic approach, 2nd ed. Springer-Verlag, New York.

Diggle PJ, Ribeiro PJJr (2007) Model-based geostatistics. Springer, New York.

MARINE BIODIVERSITY RESEARCH
Prediction and Management of Australia's Marine Biodiversity

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