

UQ Spatial Ecology Lab
www.uq.edu.au/spatialecology/

*Interests in Coral Triangle conservation science
and planning: People and projects*

αεδα

The Applied Environmental
Decision Analysis hub
www.aeda.edu.au

I. Development of, and training in, marine reserve design tools (Marxan and Marxan with zoning) and conservation resource allocation methods. Professional exchange opportunities exist for conservation managers, technical experts, academics, and students.

Lead researchers: **Professor Hugh Possingham, Mr Matt Watts, Ms Carissa Klein, Dr Kerrie Wilson, Mr Dan Segan and Ms Lindsay Kircher**



Funding and collaborators: TNC (Indonesia), AEDA (DEWHA), contracts

Project Description: **Marxan is the most widely used marine conservation planning tool in the world**

<http://www.uq.edu.au/marxan/>, <http://en.wikipedia.org/wiki/Marxan>. It was used to inform the rezoning of the Great Barrier Reef and is **now used in over 80 countries to build marine and terrestrial systems of protected areas**. Marxan is changing the face of much of the planet's surface.

We run regular training courses

<http://www.uq.edu.au/marxan/index.html?page=77690> on Marxan that have included people from Coral Triangle countries. New ideas and methods (see other projects, below) are being progressively included into Marxan, and tested on case studies, some in the Coral Triangle (see links, above). In particular Marxan can now do multiple-use zoning, incorporate asymmetric connectivity and accommodate the possibility of catastrophes like coral bleaching in how it sets conservation priorities.

The Australian government used Marxan to inform the rezoning of the Great Barrier Reef – the largest systematically designed network of marine reserves in the world. The Australian government is now using Marxan to inform its rezoning of ALL of Australia's commonwealth waters.



Recent publications:

Numerous journal articles: see <http://www.uq.edu.au/marxan/index.html?page=80365>

Oxford University Press book, coming late 2009: Moilanen, A., Wilson, K.A. and Possingham, H.P. **Spatial conservation prioritisation: Quantitative methods and computational tools**.

II. Focusing regional marine conservation: merging seascape genetics and biophysical modeling within a graph-theoretic framework *and* Coral reef connectivity & conservation: an empirical and theoretical synthesis

Lead researcher: **Dr Eric Treml (WWF Fuller Fellow)**

Funding and collaborators: WWF (US, Australia, and Indonesia), ARC Discovery, ARC Federation Fellowship, Dr Cynthia Riginos (UQ, Lead CI on Discovery grant), Professor Hugh Possingham, and NSF-PIRE grant with: Dr Patrick Halpin (Duke University), Dr Paul Barber (UCLA), Dr Kent Carpenter (ODU)



Project Description: Marine population connectivity, via larval dispersal, is critical for population persistence and is a key factor influencing how a species might cope with global climate change. However, identifying the patterns in marine population connectivity poses one of the greatest challenges in marine ecology. Although several studies in population genetics have discovered a general scale of population connectivity, little progress has been made in identifying the spatial structure of this connectivity. The objectives of this research are to:

- 1) Identify the probable dispersal routes and spatial population structure for several marine species throughout the biodiversity hotspots of the Coral Triangle.
- 2) Develop new graph-theoretic and metapopulation approaches for quantifying marine connectivity and network resilience.
- 3) Integrate these connectivity estimates into marine conservation planning.

Exploiting new techniques in population genetics, biophysical modeling, and graph theory, this work tests the hypothesis that the spatial structure of marine populations is determined by the location and strength of connectivity. Dispersal probabilities will be derived for multiple species throughout the Coral Triangle using a spatially-explicit biophysical modeling approach. These probabilities will incorporate high-resolution hydrodynamics, pelagic larval duration, larval behavior, mortality, and settlement probability. The resultant spatial structure, including persistent dispersal corridors and barriers, will be uncovered using clustering and connectivity algorithms from graph theory. Independent estimates of population connectivity will be made using mitochondrial DNA sequences from 8 - 10 coral reef species collected at 10 - 15 locations throughout the study area. Population subdivision and gene flow will be estimated using both classic and coalescent population genetic methods. The correlation between the biophysical connectivity predictions and the observed population genetic structure will be tested. Finally, the spatial structure of the marine population connectivity will be integrated into siting algorithms for the design of marine reserve networks.

Recent publications:

Bode, M., K. Burrage, and H. P. Possingham. 2008. Using complex network metrics to predict the persistence of metapopulations with asymmetric connectivity patterns. *Ecological Modelling* 214:201-209.

Treml, E., P. Halpin, D. Urban, and L. Pratson. 2008. Modeling population connectivity by ocean currents, a graph-theoretic approach for marine conservation. *Landscape Ecology* 23:19-36.

III. Marine conservation planning for persistent coral reef communities: Incorporating connectivity and resilience



Lead Researcher: **Dr Maria Beger (ARC funded PDF)**

Funding and collaborators: TNC, ARC Linkage, Dr Alison Green, Professor Hugh Possingham, Dr Eric Treml, Dr Eddie Game, Dr Ken Anthony, Ms Zoe Richards, Ms Carissa Klein

Project Description: This project develops theory and examples of how information on coral reef connectivity and resilience can be accommodated in marine reserve system design systematically. Developing such a theory is the first step in achieving the long-term survival of the world's coral reefs and the sustaining the humans that depend on those reefs. Once we have a new method for designing resilient and connected coral reef reserve systems we will answer the question: How much better is a coral reef reserve system that considers connectivity and resilience compared to one that ignores these processes? This will allow us to recommend what information is necessary, beneficial and economical to collect when marine reserves are planned and implemented with a limited budget. The general problem will be approached by sequentially achieving three specific objectives:

1. *A taxonomy of connectivity for marine reserve system design: different patterns require different conservation actions.*
2. *Conserving resilient coral reefs: A trick to mitigate climate change?*
3. *The role of dispersal connectivity for the resilience of coral reef communities: incorporating processes promoting persistence of these communities into conservation planning.*

We will advance the theory and methods for marine conservation planning by incorporating the concepts of resilience and dispersal connectivity using novel modelling and simulation approaches. This research will assure that future marine reserve networks maximise the persistence of coral reef communities and biodiversity on a global and national scale. There are two project parts pertinent to the Coral Triangle:

- (a) Conservation and management of resilient connected reefs in the Sulu Sea, Philippines: Collaborators include Terence Dacles (GTZ Philippines), Zoe Richards (JCU-COE), Eric Treml (UQ), Carissa Klein (UQ). Gap analysis for marine management in the Sulu Sea, attempting to avoid user conflict with zoned management.
- (b) Resilience of reefs in Kalimantan, Java, Indonesia: Collaborators include Ken Anthony (UQ-CMS), Eddie Game (UQ/ TNC). Community-based management for resilient reefs, choosing actions that maximize biodiversity benefit for reef health, with a strong collaboration with local stakeholders

Recent publications:

- Beger, M., Jacobson, D., Pinca, S., Richards, Z.T., Hess, D., Harris, F., Page, C., Peterson, E.L., and Baker, N. (2008). The State of Coral Reef Ecosystems of the Marshall Islands. In *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*, J.E. Waddell and A. Clarke, eds. (NOAA), pp. 330-361.
- Beger, M., and H. P. Possingham. (2008). Environmental factors that influence the distribution of coral reef fishes: modelling occurrence data for broad-scale conservation and management. *Marine Ecology Progress Series* 361: 1-13.
- Richards, Z.T., Beger, M., Pinca, S., and Wallace, C.C. (2008). Bikini Atoll coral biodiversity resilience five decades after nuclear testing. *Marine Pollution Bulletin* 56, 503-515.
- Beger M., McKenna S.A. and Possingham H.P. (2007). Effectiveness of surrogate taxa in the design of coral reef reserve systems in the Indo-Pacific. *Conservation Biology* 21: 1584–1593

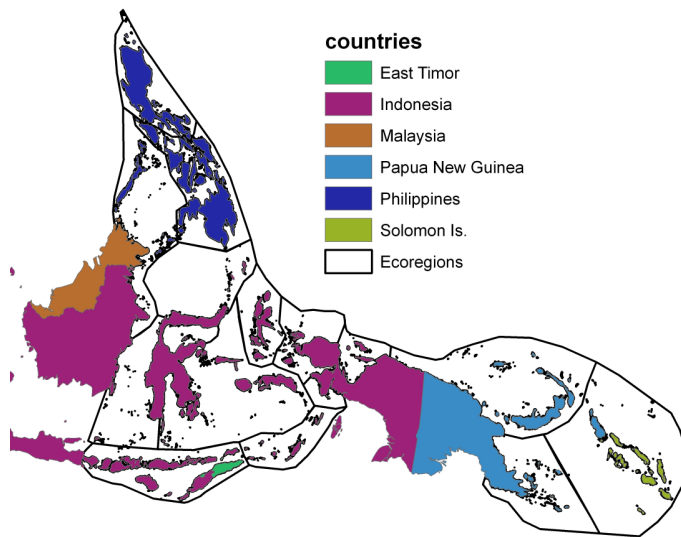
IV. Prioritizing Land- and Sea-based conservation investments to protect coral reefs in the Coral Triangle

Lead researcher: **Ms Carissa Klein (Postgraduate Scholar)**



Funding and collaborators: Dr Natalie Ban (JCU), Dr Ben Halpern (NCEAS), Dr Kerrie Wilson (UQ), Mr Stuart Kininmonth (AIMS), Dr Eddie Game (TNC), Mr Hedley Grantham (UQ), Dr Eric Treml (UQ), Dr Maria Beger (UQ), Dr Alison Green (TNC) and Professor Hugh Possingham (UQ)

Project Description: One of the most pressing issues facing the conservation community is how to allocate limited resources between regions identified as priorities for biodiversity conservation. We aim to develop an optimal investment plan for the Coral Triangle that reflects the relative return from investing in land and sea-based conservation actions in order to maximize the health of coral reefs. We will formulate how to optimally allocate conservation resources between regions (figure 1) in one of the world's most biologically diverse



marine environments, the Coral Triangle. The health of coral reefs is dependent upon anthropogenic threats occurring in the sea (e.g. fishing) and on the land (e.g. deforestation). Therefore, investments in both land- and sea-based management actions will contribute towards the protection of coral reefs. Conservation priority-setting schemes have not yet combined geographic priorities with a framework that can guide the allocation of funds between land and marine based management actions. Applying this framework will ensure investment in actions that provide the most cost-effective outcomes for coral reef conservation. This will help to minimize the misallocation of scarce conservation resources in a global biodiversity hotspot.

Recent publications:

- Klein, C., A. Chan, L. Kircher, A. Cundiff, Y. Hrovat, N. Gardner, A. Scholz, B. Kendall, and S. Airame. 2008. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. *Conservation Biology* 22:691-700.
- Klein, C., C. Steinback, A. Scholz, and H. Possingham. 2008. Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California. *Conservation Letters* 1:44-51.
- Klein, C., K. A. Wilson, M. Watts, J. Stein, S. Berry, J. Carwardine, D. M. Stafford Smith, B. Mackey, and H. Possingham. 2008, in press. Incorporating ecological and evolutionary processes into continental-scale conservation planning. *Ecological Applications*.

V. Conservation planning for resilient coral reefs.



Lead researcher: **Dr Eddie Game (TNC, formerly UQ)**

Collaborators: Dr Eve McDonald-Madden (UQ), Dr Scott Wooldridge (AIMS), Dr Marji Puotinen (Uni. of Woollongong), Mr Matt Watts (UQ), Dr Michael Bode (Uni. of Melbourne), Mr Hedley Grantham (UQ), Professor Hugh Possingham (UQ).

Project Description: Chronic anthropogenic disturbance has left many marine systems at risk of degrading into undesirable states. In many cases, ecosystem shifts are triggered by catastrophic disturbance events that are beyond the control of local management, such as coral bleaching or cyclones. Recognition of this risk has instigated what has been referred to as a new paradigm for marine stewardship; managing areas with the explicit goal of maintaining ecosystem resilience. Despite this, there has been little synthetic influence of resilience theory on marine conservation planning. The focuses of this research is on how to make good decisions regarding the selection of marine protected areas (MPAs) with the goal of maintaining resilient reef systems in the face of catastrophic disturbance events. There have been three main components to this research.

- 1) We formulated a new conservation planning problem that aims to minimize the probability of missing conservation targets as a result of catastrophic events. To illustrate this approach we tackled the problem of minimizing the impact of large-scale coral bleaching events on a reserve system for the Great Barrier Reef, Australia. We show that by considering the threat of catastrophic events as part of the reserve design problem it is possible to substantially improve the likely persistence of conservation features within reserve networks for a negligible increase in cost. In the case of the Great Barrier Reef, a 2% increase in overall reserve cost was enough to improve the long-run performance of our reserve network by 60
- 2) It is thought that recovery of marine habitats from uncontrollable disturbance may be faster in marine reserves than in unprotected habitats. But which marine habitats should be protected, those areas at greatest risk or those at least risk?. We applied solutions to this problem to a situation of cyclone disturbance of coral reefs on Australia's Great Barrier Reef. With regard to the risk of cyclone disturbance, the optimal reef to protect differed dramatically, depending on the expected speed of reef recovery of both protected and unprotected reefs. This work demonstrates that an adequate consideration of risk is fundamental to all conservation actions and can indicate surprising routes to conservation success.
- 3) Marine Protected Area networks are usually a system of static, permanently closed areas. There are, however, both social and ecological reasons to believe that the dynamic movement of protected areas may be preferable. On coral reefs, the periodic movement of protection may improve the resilience of the reef network and prevent unprotected reefs from undergoing phase-shifts to undesirable states. We establish a theoretical example to explore whether dynamic closures can promote the resilience of reefs systems. We discover that, at current levels of reservation (10-30%), the dynamic movement of this protection across all reefs in a system is unlikely to enhance resilience.

Recent publications:

Game, E. T., E. McDonald-Madden, M. L. Puotinen, and H. P. Possingham. 2008a. Should we protect the strong or the weak? Risk, resilience and the selection of marine protected areas. *Conservation Biology* in press.

Game, E. T., M. Watts, S. Wooldridge, and H. P. Possingham. 2008b. Planning for persistence in marine reserves: a question of catastrophic importance. *Ecological Applications* 18:670-680.

VI. Toward ecosystem-based management: multi-objective conservation planning for biodiversity conservation and sustainable fisheries in Raja Ampat, Papua.

Lead researcher: **Mr Hedley Grantham (UQ, recently submitted PhD)**

Funding and collaborators: TNC: Vera Agostini, Mike Beck, Jo Wilson; Professor Hugh Possingham (UQ)

Project Description: Raja Ampat is one of the most biodiverse marine regions in the world. Recent development of economic sectors such as fisheries, tourism, oil and gas are predicted to significantly impact the regions biodiversity. Given the considerable biodiversity and likely threats to the region, it is a global conservation priority. The governmental and non-governmental agencies operating within the region are co-ordinating to ensure that development is sustainable. Part of this is the recent delineation of a system of MPAs. The aim of the collaborative research between TNC Global Marine Initiative and Hugh Possingham's research group at the University of Queensland is to assist in the development of a zoning system for Raja Ampat MPA network. This will involve developing a decision support system and database to help facilitate the zoning process. This research will also potentially provide a model for the greater Coral Triangle and other similar geographies where The Nature Conservancy operates. We will focus on four particular areas 1) developing operational objectives, 2) gather, integrate and model existing datasets to represent and integrate information on biodiversity, fisheries, and people, 3) develop and explore the capability of a decision support system for MPA design and zoning, 4) Ensure there is adaptive feedback from practitioners and stakeholders to assist in the development of approaches. We also identify the necessity of capacity building workshops to guarantee tools have real-world application.