doi: 10.1111/j.1442-8903.2011.00573.x

Research challenges to improve the management and conservation of subtropical reefs to tackle climate change threats

(Findings of a workshop conducted in Coffs Harbour, Australia on 13 September 2010)

Key words: *climate change*, *connectivity*, *decision support*, *marginal coral reefs*, *marine conservation*, *subtropical reefs*.

Summary

This paper reports on a workshop conducted in Australia in 2010, entitled 'Management, Conservation, and Scientific Challenges on Subtropical Reefs under Climate Change'. The workshop brought together 26 experts actively involved in the science and management of subtropical reefs. Its primary aim was to identify the areas of research that need to be most urgently addressed to improve the decision-making framework for managers of subtropical reefs. The main findings of the workshop were a sustainable subtropical reefs declaration that highlights seven research priorities for subtropical reefs. These are to (i) conduct research and management activities across local government, state and bioregion borders; (ii) understand natural variability of environmental conditions; (iii) quantify socio-economic factors and ecosystem services; (iv) benchmark cross-realm connectivity; (v) know marine population connectivity; (vi) habitat mapping and ecological research; and (v) determine refugia. These findings are hoped to form a basis for focussing research efforts, leveraging funds and assisting managers with allocation of resources.

Introduction

Subtropical reefs are naturally dynamic ecological systems encompassing a unique blend of species with both tropical and temperate ranges (Harriott *et al.* 1999). Despite their resilience to short-term environmental extremes, subtropical transitional regions are threatened with major environmental and biological shifts from climate change in the long term, such as establishment of invading tropical species (Figueira & Booth 2010). Although protection of reef ecosystems from other stressors, such as fishing and habitat destruction, is currently considered the most promising way to ensure their persistence under climate change (McLeod *et al.* 2009; Hughes *et al.* 2010), considerable knowledge gaps presently obviate informed conservation decisions and best-practice management. These knowledge gaps mostly relate to the existing dynamics of patterns and processes on reefs, likely trajectories of change associated with climate change and relevant socio-economic impacts.

To examine these questions, a workshop entitled 'Management, Conservation, and Scientific Challenges on Subtropical Reefs under Climate Change' was held in Coffs Harbour, Australia on 13 September 2010. The workshop brought together scientists, managers and communicators working on subtropical reefs to discuss ongoing research and identify important knowledge gaps relevant to the short-term and medium-term decisions faced by fisheries and marine park managers.

Identification of Main Challenges

The workshop started with short introductions of research and management groups and major projects, followed by the identification and discussion of critical questions for research and management of subtropical reefs under climate change. Each speaker proposed up to three important research priorities that, from their perspective, are critical to adapt management efforts of subtropical reefs to future challenges.

These research priorities were documented and evaluated in the subsequent discussion, which acknowledged that while there is considerable information on the processes and likely impacts of climate change on tropical coral reefs and temperate rocky reefs, very little is known for subtropical reefs, which form a transition zone between temperate and tropical bio-geographic provinces in terms of species, environmental conditions and seasonal variation (Harriott *et al.* 1999; Schleyer *et al.* 2008). Climate change-induced alterations in environmental parameters are likely to redefine the characteristics of subtropical communities, partly by range shifts of tropical and temperate species, but also through changing habitats and trophic interactions (Schleyer *et al.* 2008; Munday *et al.* 2009). Indeed, increasing water temperatures have already led to a poleward shift in the establishment of viable populations of some tropical fish species along the subtropical east Australian coast (Figueira & Booth 2010). Climate change generates the need to both re-evaluate existing conservation efforts and to generate new conservation strategies to incorporate the dynamics of future changes into management strategies to facilitate persistence (Araújo 2009). The present dynamics of processes on subtropical reefs, and their transformations associated with climate change are largely unknown and are an urgent research priority (Munday *et al.* 2009).

In Australia, subtropical reefs are threatened not only by climate change, but also by rapid population growth and

the associated expansion in coastal development and human use of marine resources (Smith *et al.* 2008). As in other regions of the world, the economic viability of these communities is dependent on the maintenance of natural marine environmental processes for tourism, recreation, human health and aesthetic values as well as for their extractive uses. Adaptation of management strategies to anticipate climate-driven ecological change is crucial to protect against impacts of the growing population, whilst still providing resources for livelihood activities in a truly sustainable way.

Identification of Seven Priorities for Research and Management Action

Many of the issues identified at the workshop related to the lack of data and the missing institutional links at a regional level. The workshop participants identified the following seven research and management priority areas that should be targeted urgently to improve the management and conservation of subtropical reefs.

Research and management activities across local government, state and bioregion borders

The purpose of much research is to provide information to resource managers and politicians who make decisions about where, how and when to invest conservation dollars to maintain marine biodiversity and productivity and the associated benefits to humans (Wilson *et al.* 2007). Managers and researchers must communicate with each other in participation with key stakeholders, and straddle political and administrative boundaries to allow an integrated regional approach to conserving and managing subtropical reefs along the spatial gradients relevant to climate change. To tackle climate change, research and management need to focus on understanding patterns and processes required to maintain natural ecosystems and connectivity (McLeod *et al.* 2009), rather than fragment these through superimposition of artificial boundaries.

Natural variability of environmental conditions

Subtropical reefs are marginal habitats for both tropical and temperate organisms (e.g. reef corals and kelp). They experience high levels of natural spatial and temporal variability in environmental parameters that are poorly understood (Malcolm *et al.* in press 2010). Quantifying the dynamics in environmental parameters and the corresponding dynamics in biological characteristics and processes is crucial to detect, predict and adapt to climate change-related shifts in key ecosystem components. In particular, little is known of how the productivity of subtropical reef system may decline or improve with climate change and environmental perturbations (e.g. storms, floods).

Socio-economic factors and ecosystem services

Management decisions are often constrained by social, economic and political factors (Knight *et al.* 2009). Managers of subtropical marine environments require information on the extent and monetary value of human use practices including distribution, and rates of change of: recreational and commercial fishing catch and effort; tourism; commercial research; and other uses. Quantitative or even qualitative information on environmental values and associated values of ecosystem services is urgently required. Methods of incorporating this information into a transparent costbenefit-driven management decision-making framework are also needed.

Cross-realm connectivity

With increasing urban and rural development in subtropical catchments, there is a critical need to evaluate and quantify threats to marine habitats derived from terrestrial sources, and determine and implement mitigating management actions to safeguard water quality on subtropical reefs. Integrating cross-realm connectivity into management and conservation decision making is crucial (Beger *et al.* 2010). While good non-statutory examples of integrating and implementing management and science to reduce terrestrial impacts on coastal ecosystems exist (e.g. Healthy Waterways Partnership – http://www.healthywaterways.org), management models such as this need to be more widely adopted.

Marine population connectivity

There is an urgent need to understand the processes that are predicted to transform as a response to climate change, such as pathways of tropical 'invaders' and the role that Australia's subtropical reefs may play in providing refuge for tropical species. The southward flow of the major boundary current systems in Australia provides the opportunity for many species to shift from threatened tropical systems to subtropical (and even temperate) systems (Figueira & Booth 2010) (Fig. 1). A multi-disciplinary approach integrating near-shore hydrodynamics modelling, larval tracking models and genetics is required. Similarly, cross-shelf connectivity between estuarine, non-reefal, near-shore and offshore reef environments warrants investigation.

Habitat mapping and ecological research

The extent, distribution and structure of habitats and their species composition are still not fully understood in subtropical regions. These gaps need to be filled by continued broad-scale and fine-scale habitat mapping, modelling and ecological research in subtropical marine environments.

Refugia

Sites that are resistant to or better able to recover from disturbance are the key areas on which to focus strategic conservation or other management efforts, as these reefs will be the last refuges of biodiversity and other ecosystem values (Hughes *et al.* 2010). Targeted research is required

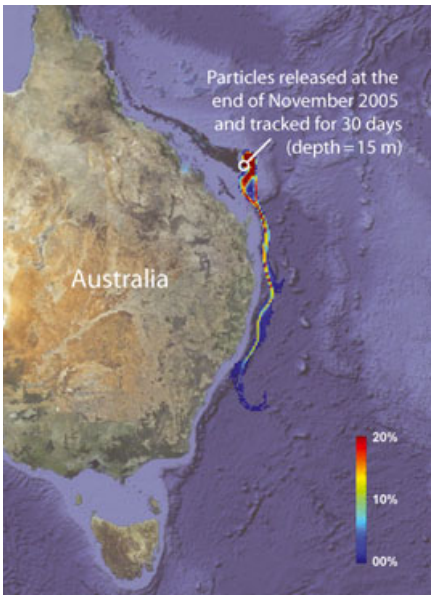

Figure 1. Percentages of larvae potentially arriving at subtropical reef locations from the southern Great Barrier Reef, from larval tracking model in Connie http://www.per.marine.csiro.au/aus-connie/quickGuide.html.

to better understand the ecosystem processes that underpin ecological resistance and resilience in Australia's subtropical coastal marine ecosystems.

Discussion of Uptake of Priorities by Managers and Researchers

Management decisions for subtropical reefs need improved data, as well as an improved benchmarking system that assesses outcomes and allows adaptations where required. Most of the above research priorities highlight gaps in knowledge that require targeted collection of new data or integration of existing datasets. The statement of research priorities is the first step to wide implementation of these research questions, enabling leverage of research funds, encouraging students to tackle relevant questions and guide managers in their investment of meagre resources. These research priorities are aimed at the wider research community, with dissemination via a website (http://www.susra.org), and directly to a network of managers and researchers via contact lists of the authors.

There is also an increasing need to ensure that research findings are effectively communicated and translated into management actions that maximise the likelihood of real conservation outcomes. To ensure the long-term persistence of dynamic marginal coral reefs and subtropical reefs and better understand possible reef futures in the face of climate change, we must integrate comprehensive and accurate ecological and socio-economic datasets, reef dynamics, current and modelled predictions of species distributions, and decision theory into a dynamic risk assessment and conservation decision-making framework (Araújo 2009). Such a framework must include the range of existing threats and mechanisms to evaluate how climate change may interact with and enhance these threats. This will ensure that conservation management actions are targeted at activities that continue to ensure subtropical reef resilience.

Acknowledgements

We thank Southern Cross University for hosting the workshop at the National Marine Science Centre, and the Australian Coral Reef Society for their support in organising this meeting. The Australian Research Council Centre of Excellence for Coral Reef Studies and the Commonwealth Research Facility for Applied Environmental Decision Analysis co-funded the workshop.

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