A changing climate for tropical marine conservation?

Richard K.F. Unsworth[1,2], Len J McKenzie[3], Lina M. Nordlund[4], Leanne C. Cullen-Unsworth[2,5]

[1]Seagrass Ecosystem Research Group, College of Science, Wallace Building, Swansea University SA2 8PP, UK

[2]Project Seagrass, 33 Park Place, Cardiff, CF10 3BA, UK

[3] Centre for Tropical Water & Aquatic Ecosystem Research, James Cook University, Cairns, Australia

[4]Department of Ecology, Environment and Plant Sciences, Stockholm University, SE-106 91 Stockholm, Sweden

[5]Sustainable Places Research Institute, Cardiff University, 33 Park Place, Cardiff, CF10 3BA, UK

Corresponding author: r.k.f.unsworth@swansea.ac.uk

Summary

Tropical coral reefs are threatened and in decline, with their future highly uncertain. With increasing rates of climate change and increasing global temperatures, people looking to coral reefs for food and income, may increasingly have to rely on resources from other habitats. Efforts to protect and conserve the coral reefs we have left are critical, for a suite of economic, ecological, cultural and intrinsic reasons, but there is also an urgent need to take heed of the future scenarios from coral reefs and broaden the focus of tropical marine conservation. Here we argue that seagrasses especially are becoming ever more important for people and planet as coral reef health declines, but these systems are also globally under increasing anthropogenic threat. We need to both increase and reprioritize our conservation efforts and use our limited conservation resources in a more targeted manner, in order to attain sustainable systems. For seagrass, practicable conservation opportunities exist to develop sustainable ways to respond to increased resource use. Targeted action now could restore and protect seagrass meadows to maintain the suite of ecosystem services they provide in to the future.

Introduction

Seagrass meadows are of fundamental importance to humanity, they support global fisheries production, play a vital role in our global carbon cycle and act as important bio-filters in our coastal ecosystems[1-3]. Seagrass meadows are globally expansive but are subject to growing levels of degradation, principally due to local water quality and physical disturbance problems [4]. In the tropics there is increasing evidence that a widespread lack of management of these systems is exacerbating these problems (e.g. in Indonesia)[5]. Tropical seagrasses remain in the media, research and conservation funding shadow of their more illustrious neighbours, coral reefs (Figure 1). This is typically the result of their apparent charisma problem (typically perceived as uncharismatic species they often lack conservation interest)[6].

Tropical coral reefs are threatened and in decline, with their future highly uncertain. With increasing rates of climate change and increasing global temperatures, people looking to coral reefs for food and income, may increasingly have to rely on other nearby habitats such as seagrass meadows. Efforts to protect and conserve the coral reefs we have left are critical, for a suite of economic, ecological, cultural and intrinsic reasons, but there is also an urgent need to broaden the focus of tropical marine conservation. Here we argue that tropical seagrasses are becoming ever more important for people and planet, and that increasing resources need to be put into supporting their long-term conservation.

Global decline of Coral Reefs

Coral reefs are undergoing widespread decline[7]. The resources they supply are also in decline as these ecosystems become increasingly dominated by low complexity corals, sponges, algal communities or mobile rubble that harbour lower and less diverse faunal assemblages[8]. A coral reef disaster is unfolding in front of us and the full consequences

53 are far from being realised. Climate induced impacts on Coral reefs are so severe as to
54 necessitate risk planning initiatives to determine reef locations globally that, in the absence
55 of other impacts, are likely to have a heightened chance of surviving projected climate
56 changes[9].
57 Coral reef conservation is possible and researchers have recently argued the case for the
58 value of local management in improving reef resilience[10]. But the effectiveness of reef
59 conservation is diminishing with every bleaching event[7]. Dire predictions and calls for
60 action over the last few decades have unfortunately largely failed to lead to positive
61 change[11-14]. Critically we are now seeing increasing evidence of negative reef accretion
62 rates in places previously considered pristine[15]. Coral reef loss is a global problem now
63 being increasingly driven by a changing climate and consequential declines in coral reef
64 productivity are likely to have profound impacts upon associated coral reef fisheries[16].
65 Given the poor recovery of many reef systems following climate[14] and other impacts,
66 scientists have grappled with the response to restore coral reefs using active
67 intervention[17]. But we now know that reef restoration is also unlikely to be economically
68 viable at any meaningful scale[18]. Even so, increasing levels of funding continue to support
69 ever more desperate reef restoration and preservation projects[19].
70 We shouldn't give up on coral reef conservation, as glimmers of hope do exist[20] and our
71 understanding of the benefits of local management for reef resilience increase[10]. But
72 given the unfolding coral reef disaster, it is time the tropical marine conservation
73 community broadened its focus and became more realistic about the future. Here we argue
74 that governments, NGO's and communities should both broaden and reprioritise strategies
75 to protect tropical marine resources and look towards the concept of future reefs and
76 alternative ecosystems that are also in trouble but are not beyond saving.

Broadening and rethinking conservation priorities

Poverty, over-population, coastal squeeze and increasing coastal infrastructure are placing increasing pressure on tropical marine resources. It is unfortunate that the focus of tropical marine conservation is largely on coral reefs, because other systems (e.g. seagrasses) are equally as important. Seagrass meadows support productive fisheries and are a largely underappreciated fisheries resource for many people[21]. Furthermore, as the productivity of coral reefs decreases, there is an increasing need for other habitats such as seagrass meadows to subsume the fisheries pressure present on reefs. This means that we need to broaden our focus from “just” coral reefs to an increasingly ecosystem based approach that includes seagrass ecosystems.

There are widespread concerns for all biota in an era of rapid change, and in fact coral reef loss may impact seagrass meadows in some localities[22]. There is also evidence that shallow water seagrasses can ‘burn’ under increasing temperatures and be negatively affected by rising sea levels[23, 24]. But overall, seagrasses are arguably better placed to deal with the stressors of high temperature, ocean acidification and to a lesser extent sea level rise[23, 25]. In the tropical seascape it is common for seagrass meadows to remain productive as corals rapidly change state. While doing so seagrass may actually support reef health[2]. There is also growing evidence of small scale buffering of ocean acidification by seagrass meadows in close proximity to coral reefs[26]. In addition, many key herbivores present on coral reefs utilise seagrass as an alternative grazing habitat, protecting fisheries on seagrass meadows adds to the functional role of coral reef fish assemblages. This means that conservation support for seagrass does not compete with but rather enhances coral reef conservation efforts.

It is also important to consider which conservation initiatives could be beneficial to several components of the seascape, even though it might not be the most effective measure for one specific ecosystem per se. For example, reducing land-based pollution will have positive impacts on both seagrass and coral reefs as well as other adjacent habitats, thus it is important in conservation to consider and argue for the cumulative benefits to the seascape. Depending on the in-water conditions, improving water quality might be the most important action for seagrass, an action that would also be very beneficial to other systems (e.g. corals). Importantly we need to prioritize actions to ecosystems that result in improved ecosystem services.

In a changing climate, are fisheries moving towards seagrass?

Seagrasses are ecosystems that provide global support for fisheries[27], including the direct provision of fishery grounds[21] (Figure 2). We hypothesise that this role for seagrass meadows will expand rapidly (and has already potentially done so) as coral reefs continue to degrade. There is growing evidence that as coral reefs degrade their ecosystem service value declines, particularly in terms of fisheries resources[8]; principally as they lose their three-dimensional complexity[28]. As hard corals become replaced by alternative dominant groups (e.g. corallimorphs, soft corals and sponges) and reef accretion decreases, fishers will arguably increasingly need to look elsewhere for resources. Seagrass ecosystems are one such alternative fisheries habitat that provide extensive often easily accessible shallow water fishing grounds[21]. When healthy, these seagrass systems contain an abundance of productive fish and invertebrate fauna[29] and even with limited fishing gear it is possible to exploit seagrass resources.

In countries such as Indonesia, Sri Lanka, Tanzania and the Philippines there is extensive evidence of high intensity seagrass fishing effort. Many of these localities are sites of now heavily degraded reefs. In parts of Indonesia where reef fisheries have rapidly declined, fishers target seagrass meadows[30]. There is also evidence of fishers working their way down the food chain, becoming ever more dependent on species that were once considered highly unappealing, which demonstrates unsustainable pressure on the seagrass resources available. Similar patterns are also being observed in the Philippines. In the Indo-Pacific region seagrasses compared to mangrove and coral reefs have been shown to be the most visited fishing grounds providing highest community benefits [31, 32]. Increasing reliance on seagrass meadows as a dominant fishery habitat is leading to the widespread use of ever more efficient and exploitative fishing techniques such as static fish fences[30] that lead to increased degradation of the food web.

Tropical marine and fisheries management is mostly focussed on the needs of biodiversity protection for species of conservation concern (e.g. hard corals). There remains limited consideration of the needs of coastal communities and their livelihoods, or the threats of unsustainable fishing practice on other supporting habitats. But biodiversity and human livelihoods are not mutually exclusive[33]. As we enter further an era dominated by an increasing presence of degraded reefs we risk exacerbating the long-term failures of most tropical marine fisheries management by chasing an unachievable goal of coral reef conservation for ecosystem service provision.

The case for seagrass conservation

Conservation funding for tropical seagrass meadows is highly limited and seagrass research effort is minimal relative to other ecosystems such as coral reefs and mangroves. In

addition, in many parts of the world, governance and management of seagrass ecosystems is virtually absent. We argue that seagrass conservation needs to be improved in order to not only increase seagrass viability but also to be prepared for the increasing reliance of fishers on these habitats. It is no longer sufficient for Marine Protected Area management plans to include seagrass as a 'tick box exercise' if that, instead seagrass management needs to be included strategically using best practice science to enhance fisheries productivity. In many parts of the world the overriding problem for coastal ecosystems such as seagrass is catchment degradation, and as such conservation of seagrass doesn't always need to be the focus. Ridge to reef conservation programmes can target wider-scale issues of catchment degradation and poor water quality and act as a platform for broader initiatives that include seagrass.

Seagrass meadows are under increasing stress from local and regional impacts associated with degraded water quality, physical disturbance, and the breakdown of food webs[4, 5]. Global loss of seagrass has been large-scale and continues to be rapid [5]. But the drivers of seagrass loss are largely manageable and threats can be reduced with targeted efforts[34]. There is increasing success seen in seagrass restoration[35], as well as a growing number of examples of catchment management leading to long-term seagrass recovery[36] (see Figure 3). But seagrass restoration is expensive and historically many large projects have resulted in failure. However, the last decade has seen a step change in the restoration techniques being used and as a result there are now many examples of successful projects conducted at viable cost[35]. This has included recent tropical seagrass restoration that has significantly benefitted from taking a multi-species approach[37], and in some circumstances restoration can now be conducted very cheaply through the large-scale dispersal of seeds[38].

Regardless, the most efficient and feasible conservation strategy is to preserve what

widespread productive seagrass meadows we have rather than having to rebuild or recreate something that has been lost.

Humanity cannot afford to allow the integrity of yet another marine ecosystem to be compromised by short sighted management of our planetary resources. Maintaining essential ecosystem services is critical. The time is right for major conservation donors, government regulators and conservation stakeholders to reprioritise their efforts to consider from where ecosystem services now and in the future will arise. In fact there is growing evidence for how fisheries management regimes globally need to respond to changing climate and develop adaptive policy targets[39].

There are some coral reef conservation 'bright spots' that indicate the potential for some coral reef survival[20]. But in order for our tropical seas to continue to be able to support fisheries and people we urgently need to focus on protecting ecosystems and biodiversity that provide the most critical ecosystem services while having the capacity to remain intact in a future climate. Seagrass meadows are one of those ecosystems and their conservation is paramount for the continued livelihoods and food security of many hundreds of millions of people. The time is right for global conservation efforts to conserve seagrass ecosystems.

Figure 1. The mean (±SD) global media coverage (as measured by Altmetric) of the 10 top research articles listed by Altmetric for seagrass, coral reefs and mangroves (search conducted using dimensions.ie).

Figure 2. When healthy and well managed, seagrass meadows can support highly productive fish assemblages of high commercial and subsidence importance. Left: Turks and Caicos Islands, Right: Green Island Australia. Photos: R Unsworth.

Figure 3. Predicted changing resilience, ecosystem service provision, global coverage and cost-benefit of conservation (the benefits of conservation action summed, and then the costs associated with taking that action subtracted) for seagrass and coral reef ecosystems throughout the 21st century as a consequence of a changing climate. With declining reef three-dimensional structure and increasing record-breaking marine heatwave events by the 2040's it expected that between 70 and 90% of all coral reefs will have been lost[9]. By this time many seagrass meadows will also be negatively impacted by a changing climate, but these will be a small fraction of the global extent of seagrass (and a small proportion of those in tropical seas). Therefore seagrass meadows will continue to provide ecosystem services and the cost-benefit of seagrass conservation will remain relatively high. Photos: R Unsworth.

References

1. Unsworth, R.K.F., Nordlund, L.M., and Cullen-Unsworth, L.C. (2018). Seagrass meadows support global fisheries production. Conservation Letters, e12566.
2. Lamb, J.B., van de Water, J.A.J.M., Bourne, D.G., Altier, C., Hein, M.Y., Fiorenza, E.A., Abu, N., Jompa, J., and Harvell, C.D. (2017). Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. Science *355*, 731-733.
3. Nordlund, L.M., Koch, E.W., Barbier, E.B., and Creed, J.C. (2016). Seagrass ecosystem services and their variability across genera and geographical regions. PLoS ONE *11*, e0163091.
4. Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R., et al. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences of the United States of America *106*, 12377-12381.
5. Unsworth, R.K.F., Jones, B.L., Ambo-Rappe, R., La Nafie, Y.A., Irawan, A., Hernawan, U.E., Moore, A.M., and Cullen-Unsworth, L.C. (2018). Indonesia's globally significant seagrass meadows are under widespread threat. Science of the Total Environment.
6. Duarte, C.M., Dennison, W.C., Orth, R.J.W., and Carruthers, T.J.B. (2008). The charisma of coastal ecosystems: Addressing the imbalance. Estuaries And Coasts *31*, 233-238.
7. Hughes, T.P., Anderson, K.D., Connolly, S.R., Heron, S.F., Kerry, J.T., Lough, J.M., Baird, A.H., Baum, J.K., Berumen, M.L., Bridge, T.C., et al. (2018). Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. Science *359*, 80-83.
8. Rogers, A., Blanchard, J.L., and Mumby, P.J. (2018). Fisheries productivity under progressive coral reef degradation. J. Appl. Ecol., n/a-n/a.
9. L., B.H., V., K.E., Maria, B., Allen, C.C., E., C.J., S., D.E., Mark, E.C., D., G.R., F., H.S., Nancy, K., et al. Risk-sensitive planning for conserving coral reefs under rapid climate change. Conservation Letters *0*, e12587.
10. Shaver, E.C., Burkepile, D.E., and Silliman, B.R. (2018). Local management actions can increase coral resilience to thermally-induced bleaching. Nature Ecology & Evolution *2*, 1075-1079.
11. Kennedy, Emma V., Perry, Chris T., Halloran, Paul R., Iglesias-Prieto, R., Schönberg, Christine H.L., Wisshak, M., Form, Armin U., Carricart-Ganivet, Juan P., Fine, M., Eakin, C.M., et al. (2013). Avoiding Coral Reef Functional Collapse Requires Local and Global Action. Current Biology *23*, 912-918.
12. Bellwood, D.R., Hughes, T.P., Folke, C., and Nystrom, M. (2004). Confronting the coral reef crisis. Nature *429*, 827-833.
13. Hodgson, G., Ogden, J.C., and Hughes, T.P. (1994). Coral Reef Catastrophe. Science *266*, 1930-1933.
14. Hughes, T.P., Kerry, J.T., Baird, A.H., Connolly, S.R., Dietzel, A., Eakin, C.M., Heron, S.F., Hoey, A.S., Hoogenboom, M.O., Liu, G., et al. (2018). Global warming transforms coral reef assemblages. Nature.
15. Perry, C.T., and Morgan, K.M. (2017). Bleaching drives collapse in reef carbonate budgets and reef growth potential on southern Maldives reefs. Scientific Reports *7*, 40581.
16. Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R., Zeller, D., and Pauly, D. (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology *16*, 24-35.
17. Jaap, W.C. (2000). Coral reef restoration. Ecol. Engin. *15*, 345-364.
18. Bayraktarov, E., Saunders, M.I., Abdullah, S., Mills, M., Beher, J., Possingham, H.P., Mumby, P.J., and Lovelock, C.E. (2016). The cost and feasibility of marine coastal restoration. Ecol. Applic. *26*, 1055-1074.

19. Anthony, K., Bay, L.K., Costanza, R., Firn, J., Gunn, J., Harrison, P., Heyward, A., Lundgren, P., Mead, D., Moore, T., et al. (2017). New interventions are needed to save coral reefs. Nature Ecology & Evolution *1*, 1420-1422.
20. Cinner, J.E., Huchery, C., MacNeil, M.A., Graham, N.A.J., McClanahan, T.R., Maina, J., Maire, E., Kittinger, J.N., Hicks, C.C., Mora, C., et al. (2016). Bright spots among the world's coral reefs. Nature *535*, 416.
21. Nordlund, L.M., Cullen-Unsworth, L.C., Unsworth, R.K.F., and Gullstrom, M. (2018). Global significance of seagrass fishery activity. Fish and Fisheries *In Press*.
22. Saunders, M.I., Leon, J.X., Callaghan, D.P., Roelfsema, C.M., Hamylton, S., Brown, C.J., Baldock, T., Golshani, A., Phinn, S.R., Lovelock, C.E., et al. (2014). Interdependency of tropical marine ecosystems in response to climate change. Nature Clim. Change *4*, 724-729.
23. Short, F.T., and Neckles, H.A. (1999). The effects of global climate change on seagrasses. Aquat. Bot. *63*, 169-196.
24. Arias-Ortiz, A., Serrano, O., Masqué, P., Lavery, P.S., Mueller, U., Kendrick, G.A., Rozaimi, M., Esteban, A., Fourqurean, J.W., Marbà, N., et al. (2018). A marine heatwave drives massive losses from the world's largest seagrass carbon stocks. Nature Climate Change.
25. Koch, M., Bowes, G., Ross, C., and Zhang, X.-H. (2013). Climate change and ocean acidification effects on seagrasses and marine macroalgae. Global Change Biology *19*, 103-132.
26. Unsworth, R.K.F., Collier, C.J., Henderson, G.M., and McKenzie, L.J. (2012). Tropical seagrass meadows modify seawater carbon chemistry: implications for coral reefs impacted by ocean acidification. Environmental Research Letters *7*.
27. K.F., U.R., Mtwana, N.L., and C., C.U.L. Seagrass meadows support global fisheries production. Conservation Letters *0*, e12566.
28. Rogers, A., Blanchard, Julia L., and Mumby, Peter J. (2014). Vulnerability of Coral Reef Fisheries to a Loss of Structural Complexity. Current Biology *24*, 1000-1005.
29. Esteban, N., Unsworth, R.K.F., Gourlay, J.B.Q., and Hays, G.C. (2018). The discovery of deep-water seagrass meadows in a pristine Indian Ocean wilderness revealed by tracking green turtles. Mar. Poll. Bull.
30. Unsworth, R.K.F., Hinder, S.L., Bodger, O.G., and Cullen-Unsworth, L.C. (2014). Food supply depends on seagrass meadows in the coral triangle. Environmental Research Letters *9*, 094005.
31. de la Torre-Castro, M., Di Carlo, G., and Jiddawi, N.S. (2014). Seagrass importance for a small-scale fishery in the tropics: The need for seascape management. Mar. Poll. Bull. *83*, 398-407.
32. Unsworth, R.K.F., Cullen, L.C., Pretty, J.N., Smith, D.J., and Bell, J.J. (2010). Economic and subsistence values of the standing stocks of seagrass fisheries: Potential benefits of no-fishing marine protected area management. Ocean & Coastal Management *53*, 218-224.
33. Salomon, A.K., Gaichas, S.K., Jensen, O.P., Agostini, V.N., Sloan, N.A., Rice, J., McClanahan, T.R., Ruckelshaus, M.H., Levin, P.S., Dulvy, N.K., et al. (2011). Bridging the divide between fisheries and marine conservation science. Bull. Mar. Sci. *87*, 251-274.
34. Cullen-Unsworth, L.C., and Unsworth, R.K.F. (2016). Strategies to enhance the resilience of the world's seagrass meadows. Journal of Applied Ecology *53*, 967-972.
35. van Katwijk, M.M., Thorhaug, A., Marbà, N., Orth, R.J., Duarte, C.M., Kendrick, G.A., Althuizen, I.H.J., Balestri, E., Bernard, G., Cambridge, M.L., et al. (2016). Global analysis of seagrass restoration: the importance of large-scale planting. J. Appl. Ecol. *53*, 567-578.
36. Lefcheck, J.S., Orth, R.J., Dennison, W.C., Wilcox, D.J., Murphy, R.R., Keisman, J., Gurbisz, C., Hannam, M., Landry, J.B., Moore, K.A., et al. (2018). Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. Proceedings of the National Academy of Sciences.

310 37. Williams, S.L., Ambo-Rappe, R., Sur, C., Abbott, J.M., and Limbong, S.R. (2017). Species
311 richness accelerates marine ecosystem restoration in the Coral Triangle. Proceedings of the
312 National Academy of Sciences *114*, 11986-11991.
313 38. Marion, S.R., and Orth, R.J. (2010). Innovative Techniques for Large-scale Seagrass
314 Restoration Using Zostera marina (eelgrass) Seeds. Restoration Ecology *18*, 514-526.
315 39. Queirós, A.M., Fernandes, J., Genevier, L., and Lynam, C.P. Climate change alters fish
316 community size-structure, requiring adaptive policy targets. Fish and Fisheries *0*.

317