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Editorial

Seagrass meadows in a globally changing environment

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ABSTRACT

Seagrass meadows are valuable ecosystem service providers that are now being lost globally at an unprecedented rate, with water quality and other localised stressors putting their future viability in doubt. It is therefore critical that we learn more about the interactions between seagrass meadows and future environmental change in the anthropocene. This needs to be with particular reference to the consequences of poor water quality on ecosystem resilience and the effects of change on trophic interactions within the food web. Understanding and predicting the response of seagrass meadows to future environmental change requires an understanding of the natural long-term drivers of change and how these are currently influenced by anthropogenic stress. Conservation management of coastal and marine ecosystems now and in the future requires increased knowledge of how seagrass meadows respond to environmental change, and how they can be managed to be resilient to these changes. Finding solutions to such issues also requires recognising people as part of the social–ecological system. This special issue aims to further enhance this knowledge by bringing together global expertise across this field. The special issues considers issues such as ecosystem service delivery of seagrass meadows, the drivers of long-term seagrass change and the socio-economic consequences of environmental change to seagrass.

Scientific concern for the health of our coastal marine environments against a background of anthropogenic pressures and global climate change is wide spread (Grech et al., 2012; Hoegh-Guldberg et al., 2007; Waycott et al., 2009). In engaging with the issues involved it is easy to focus on the global media discussion of the future of iconic species and habitats; threats to polar bears, whales, melting ice sheets and bleaching coral reefs. Other systems, such as seagrass meadows, that are integral to and underpin the health and productivity of marine coastal ecosystems receive less public attention yet are of similar importance (Duarte et al., 2008).

Seagrass meadows are often the dominant primary producers in coastal areas, playing a key role in trophodynamics, habitat provision, substrate stability and biogeochemical cycling (Green and Short, 2003) and are considered one of the most productive of the Earth's ecosystems (Costanza et al., 1997; Duarte and Chiscano, 1999). Seagrass meadows globally are closely linked with high fisheries production, principally due to their value as a critical nursery habitat in all regions of the world (Coles et al., 1993; Jackson et al., 2001; Unsworth et al., 2008), as well as their direct value for fisheries exploitation (Unsworth and Cullen, 2010). In tropical areas, direct herbivory of seagrasses from dugong, sea turtles and parrotfish is common (Lanyon et al., 1989; Unsworth et al., 2007) and many tropical seagrass species have high primary production rates providing a substantial proportion of the primary productivity for associated ecosystems (Kaldy and Dunton, 2000; Mateo et al., 2006).

Seagrass meadows can be highly dynamic, changing as a result of both natural and anthropogenic influences. There are a variety of factors that influence seagrass meadow biomass, area and species composition, including: physical disturbance, herbivory, intraspecific competition, nutrients pollution and sediment laden flood waters (Klumpp et al., 1993; Rasheed and Unsworth, 2011; Rasheed, 2004; Rose et al., 1999; Udy et al., 1999).

The shallow estuarine and coastal distribution of seagrasses and their proximity to anthropogenic impacts has led to widespread losses (Waycott et al., 2009). Almost 14% of all seagrass species are now considered at risk of extinction (Short et al., 2011). A number of environmental parameters determine whether seagrass meadows will occur along any coastline. These include the natural biophysical parameters that regulate the physiological activity and morphology of seagrasses (such as temperature, salinity, waves, currents, depth, substrate, day length, light, nutrients, water currents, wave action, epiphytes and diseases), the availability of seeds and vegetative fragments and the anthropogenic inputs that impact plant resources (such as excess nutrients and sediment loading). Combinations of these parameters will permit, encourage or prevent seagrass meadows thriving.

Direct impacts on seagrass (e.g. removal of plants during dredging) cause immediate and quantifiable seagrass loss. Indirect impacts (e.g. overfishing of predators, which can cascade down the food web or nutrient enrichment) can be potentially widespread and chronic. Both classes of loss are important, however indirect impacts may be less obvious because the decline in seagrass meadows can be slow (sometimes years or decades) and difficult to quantify. This slow loss of seagrass may go unnoticed against a shifting baseline through time. Global climate change will exacerbate these impacts (see Plate 1), especially for meadows that

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lack ecological resilience; a major challenge to those scientists providing coastal management advice or modeling future trajectories.

In 2012 many members of the international seagrass scientific community attended the 10th International Seagrass Biology Workshop in Brazil. This workshop series commenced in Japan around 20 years ago to stimulate global discussion on directions for seagrass research and to increase understanding of the services provided by healthy seagrass ecosystems (Coles et al., 2014). This conference series sponsored the compilation of a global seagrass methods book in 2001 (Short and Coles, 2001) development of the World Seagrass Association Inc. in 2002; an atlas of seagrass distribution in 2003 (Green and Short, 2003) along with development of a seagrass red list (Short et al., 2011), global monitoring programs and a seagrass research discussion list – the Seagrass Forum. At the 2012 ISBW meeting to stimulate ongoing initiatives and to build on this record it was proposed to invite the seagrass community to submit manuscripts to a special journal edition of the Marine Pollution Bulletin. The aim was to capture recent science results specifically in the areas of understanding change and resilience in a world whose climate has become less predictable. The emphasis would be on indirect impacts, trophic connections and the interaction of seagrass systems with climate change parameters in line with the philosophy of the Marine Pollution Bulletin. The fifteen manuscripts submitted range over a variety of topics associated with the title and theme of the edition – "Seagrass meadows in a globally changing environment".

Monitoring change in seagrass meadows at a global scale is a challenge in itself. The last 20 years has seen the development of number of programs responding to this resulting in three papers in the special edition that document long term regional and local changes in seagrass communities around the world from Europe (Potouroglou et al., 2014) to the Western Pacific including Australia (Short et al., 2014), and Singapore (Yaakub et al., 2014a, 2014b). Understanding what parameters are important for assessing seagrass in monitoring programs is critical to this effort; the papers by Christiaen et al. (2014) and Zhang et al. (2014) help answer some of these issues by examining the use of nitrogen isotopes and nitrogen ratios for understanding the influences of the urban and agricultural environment and signals in nearby seagrass meadows.

The data sets supporting these manuscripts include some of the most comprehensive to date and provide a much greater understanding of the long-term dynamics within these systems, including developing a greater understanding of the temporal dynamics of reproduction in *Zostera marina* (Potouroglou et al., 2014). Understanding changes in seagrass parameters through time and setting reference points for future analysis will be integral to our ability as seagrass scientists to provide advice on future coastal management.

At local and regional scales there is an increasing need to justify the protection of marine environments, and quantifying ecosystem services is a key means of providing that justification. Although it is often quoted that seagrasses provide high levels of these ecosystem services the data underpinning this is often geographically weak. This special issue provides three manuscripts that help to fill gaps about the importance of the seagrass ecosystem in terms of directly supporting food security and human well-being through supporting fisheries productivity and small scale fisheries. These

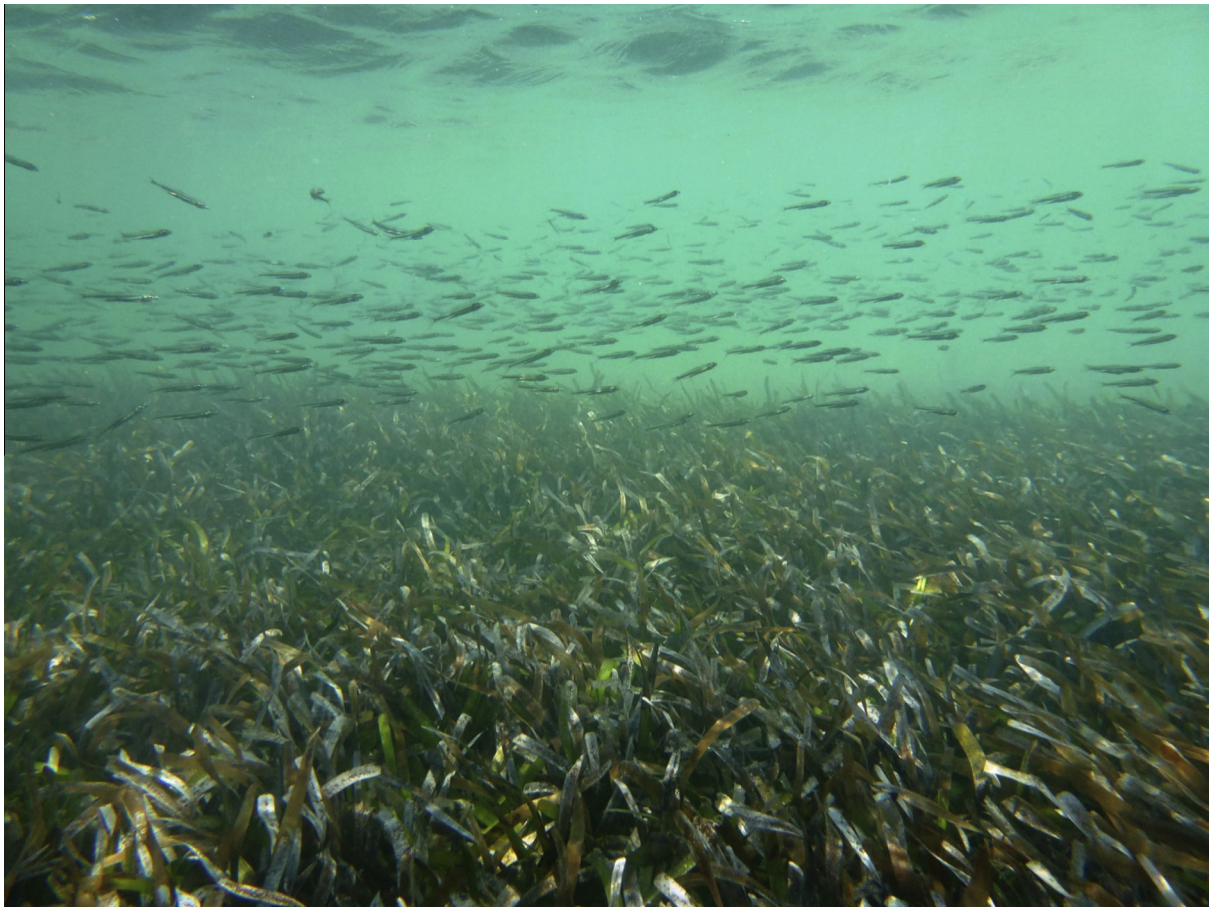

Plate 1. Seagrass meadows (*Thalassia testudinum*) in the Turks and Caicos Islands showing signs of widespread leaf 'burning' due to elevated sea surface temperatures in shallow waters. Such impacts are now seen globally and may increase as global temperatures rise.

include a global view of coupled social–ecological systems (Cullen-Unsworth et al., 2014) and analyses of the ecosystem service values of the seagrass meadows from very different systems in the United Kingdom (Bertelli and Unsworth, 2014) and eastern Africa (de la Torre-Castro et al., 2014). Increasing global interest now also focuses on a relatively newly appreciated ecosystem service provided by seagrass; its capacity to sequester carbon. The special issue includes a review of the modeling of the carbon sequestration capacity of seagrass meadows (Macreadie et al., 2014).

Climate change is a significant long-term threat to seagrass. Managing seagrasses for future resilience to climate change is about understanding current stressors and how they may change and about knowledge of temperature and ocean chemistry including developing greater knowledge of distribution limits, understanding ecosystem recovery and defining clear physical thresholds. Research in the special issue uses modeling to predict the upper limit of *Posidonia oceanica* distribution (Vacchi et al., 2014), develops knowledge of species light needs and how those needs interact with the environment (Yaakub et al., 2014a, 2014b; Kenworthy et al., 2014) and determines how deep water seagrasses recover from stress (Rasheed et al., 2014).

There exists increasing evidence of how climate related temperature changes may detrimentally affect seagrasses. Collier and Waycott (2014) investigate the temperatures and times which lead to plant mortality, but in addition and more worryingly for seagrass ecologists, demonstrate the synergistic effect of poor water quality. These complex and until now poorly understood interactions and the potential wider ecosystem effects are also investigated in the special issue study of how ocean acidification influences seagrass tolerance to herbivory (Garthwin et al., 2014).

As editors we appreciate the effort of the seagrass research community in undertaking the research that underpins this edition. The research adds significantly to our understanding of seagrass ecosystems. The issues developed here are global ones. Our world increasingly needs cooperation and linkages across regions and across disciplines if the predicted changes in our climate come to fruition. In putting this edition together we have all played a small but very important part in ensuring a science base for informed global decision making.

References

Bertelli, C.M., Unsworth, R.K.F., 2014. Protecting the hand that feeds us: seagrass (*Zostera marina*) serves as commercial juvenile fish habitat. Mar. Pollut. Bull. 83, 425–429.

Christiaen, B., Bernard, R.J., Mortazavi, B., Cebrian, J., Ortmann, A.C., 2014. The degree of urbanization across the globe is not reflected in the $\delta^{15}N$ of seagrass leaves. Mar. Pollut. Bull 83, 440–445.

Coles, R.G., Lee-Long, W.J., Watson, R.A., Derbyshire, K.J., 1993. Distribution of seagrasses, and their fish and penaid prawn communities, in Cairns Harbour, a tropical estuary, Northern Queensland, Australia. Aust. J. Mar. Freshw. Res. 44, 193–210.

Coles, R.G., Short, F., Fortes, M., Kuo, J., 2014. Twenty Years of Seagrass Networking and Advancing Seagrass Science: The International Seagrass Biology Workshop Series Pacific Conservation Biology.

Collier, C.J., Waycott, M., 2014. Temperature extremes reduce seagrass growth and induce mortality. Mar. Pollut. Bull. 83, 483–490.

Costanza, R., D'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Cullen-Unsworth, L.C., Nordlund, L.M., Paddock, J., Baker, S., McKenzie, L.J., Unsworth, R.K.F., 2014. Seagrass meadows globally as a coupled social–ecological system: implications for human wellbeing. Mar. Pollut. Bull. 83, 387–397.

de la Torre-Castro, M., Di Carlo, G., Jiddawi, N.S., 2014. Seagrass importance for a small-scale fishery in the tropics: the need for seascape management. Mar. Pollut. Bull. 83, 398–407.

Duarte, C.M., Chiscano, C.L., 1999. Seagrass biomass and production: a reassessment. Aquat. Bot. 65, 159–174.

Duarte, C.M., Dennison, W.C., Orth, R.J.W., Carruthers, T.J.B., 2008. The charisma of coastal ecosystems: addressing the imbalance. Estuaries Coasts 31, 233–238.

Garthwin, R.G., Poore, A.G.B., Vergés, A., 2014. Seagrass tolerance to herbivory under increased ocean temperatures. Mar. Pollut. Bull 83, 475–482.

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H., Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environ. Res. Lett. 7.

Green, E.P., Short, F.T., 2003. World Atlas of Seagrasses. University of California Press, Berkley, USA.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A., Hatziolos, M.E., 2007. Coral reefs under rapid climate change and ocean acidification. Science 318, 1737–1742.

Jackson, E.L., Rowden, A.A., Attrill, M.J., Bossey, S., Jones, M., 2001. The importance of seagrass beds as a habitat for fishery species. Oceanogr. Mar. Biol. 39, 269–304.

Kaldy, J.E., Dunton, K.H., 2000. Above- and below-ground production, biomass and reproductive ecology of *Thalassia testudinum* (turtle grass) in a subtropical coastal lagoon. Mar. Ecol. Prog. Ser. 193, 271–283.

Kenworthy, W.J., Gallegos, C.L., Costello, C., Field, D., di Carlo, G., 2014. Dependence of eelgrass (*Zostera marina*) light requirements on sediment organic matter in Massachusetts coastal bays: implications for remediation and restoration. Mar. Pollut. Bull 83, 446–457.

Klumpp, D.W., Salita-Espinosa, J.T., Fortes, M.D., 1993. Feeding ecology and trophic role of sea urchins in a tropical seagrass community. Aquat. Bot. 45, 205–229.

Lanyon, J., Limpus, C.J., Marsh, H., 1989. Dugongs and turtles: grazers in the seagrass system. In: Larkum, A.W.D., McComb, A.J., Shepherd, S.A. (Eds.), Biology of Seagrasses: A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier, New York, pp. 610–634.

Macreadie, P.I., Baird, M.E., Trevathan-Tackett, S.M., Larkum, A.W.D., Ralph, P.J., 2014. Quantifying and modelling the carbon sequestration capacity of seagrass meadows – a critical assessment. Mar. Pollut. Bull 83, 430–439.

Mateo, M.A., Cebrián, J., Dunton, K.H., Mutchler, T., 2006. Carbon Flux in Seagrass Ecosystems, Seagrasses: Biology, Ecology and Conservation. Springer, Dordrecht.

Potouroglou, M., Kenyon, E.J., Gall, A., Cook, K.J., Bull, J., 2014. The roles of flowering, overwinter survival and sea surface temperature in the long-term population dynamics of *Zostera marina* around the Isles of Scilly, UK. Mar. Pollut. Bull 83, 500–507.

Rasheed, M.A., 2004. Recovery and succession in a multi-species tropical seagrass meadow following experimental disturbance: the role of sexual and asexual reproduction. J. Exp. Mar. Biol. Ecol. 310, 13–45.

Rasheed, M., Unsworth, R.K.F., 2011. Long-term climate-associated dynamics of a tropical seagrass meadow: implications for the future. Mar. Ecol. Prog. Ser. 422, 93–103.

Rasheed, M.A., McKenna, S.A., Carter, A.B., Coles, R.G., 2014. Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia. Mar. Pollut. Bull 83, 491–499.

Rose, C.D., Sharp, W.C., Kenworthy, W.J., Hunt, J.H., Lyons, W.G., Prager, E.J., Valentine, J.F., Hall, M.O., Whitfield, P.E., Fourqurean, J.W., 1999. Overgrazing of a large seagrass bed by the sea urchin *Lytechinus variegatus* in Outer Florida Bay. Mar. Ecol. Prog. Ser. 190, 211–222.

Short, F.T., Coles, R.G., 2001. Global Seagrass Research Methods. Elsevier Science, Amsterdam.

Short, F.T., Polidoro, B., Livingstone, S.R., Carpenter, K.E., Bandeira, S., Bujang, J.S., Calumpong, H.P., Carruthers, T.J.B., Coles, R.G., Dennison, W.C., Erftemeijer, P.L.A., Fortes, M.D., Freeman, A.S., Jagtap, T.G., Kamal, A.H.M., Kendrick, G.A., Judson Kenworthy, W., La Nafie, Y.A., Nasution, I.M., Orth, R.J., Prathep, A., Sanciangco, J.C., Tussenbroek, B.v., Vergara, S.G., Waycott, M., Zieman, J.C., 2011. Extinction risk assessment of the world's seagrass species. Biol. Conserv. 144, 1961–1971.

Short, F., Coles, R.G., Fortes, M.D., Victor, S., Isnain, I., Andrew, J., Seno, A., Salik, M., 2014. Monitoring in the Western Pacific region shows evidence of seagrass decline in line with global trends. Mar. Pollut. Bull 83, 408–416.

Udy, J.W., Dennison, W.C., Lee Long, W.J., McKenzie, L.J., 1999. Responses of seagrass to nutrients in the Great Barrier Reef, Australia. Mar. Ecol. Prog. Ser. 185, 257–271.

Unsworth, R.K.F., Cullen, L.C., 2010. Recognising the necessity for Indo-Pacific seagrass conservation. Conserv. Lett. 3, 63–73.

Unsworth, R.K.F., Taylor, J.D., Powell, A., Bell, J.J., Smith, D.J., 2007. The contribution of parrotfish (scarid) herbivory to seagrass ecosystem dynamics in the Indo-Pacific. Estuar. Coast. Shelf Sci. 74, 53–62.

Unsworth, R.K.F., De Leon, P.S., Garrard, S.L., Jompa, J., Smith, D.J., Bell, J.J., 2008. High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats. Mar. Ecol. Prog Ser. 353, 213–224.

Vacchi, M., Montefalcone, M., Schiaffino, C.F., Parravicini, V., Bianchi, C.N., Morri, C., Ferrari, M., 2014. Towards a predictive model to assess the natural position of the *Posidonia oceanica* seagrass meadows upper limit. Mar. Pollut. Bull 83, 458–466.

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., Kendrick, G.A., Kenworthy, W.J., Short, F.T., Williams, S.L., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proc. Natl. Acad. Sci. USA 106, 12377–12381.

Yaakub, S.M., Chen, E., Bouma, T.J., Erftemeijer, P.L.A., Todd, P.A., 2014a. Chronic light reduction reduces overall resilience to additional shading stress in the seagrass *Halophila ovalis*. Mar. Pollut. Bull 83, 467–474.

Yaakub, S.M., McKenzie, L.J., Erftemeijer, P., Bouma, T.J., Todd, P.A., 2014b. Courage under fire: seagrass persistence adjacent to a highly urbanised city–state. Mar. Pollut. Bull 83, 417–424.
Zhang, J., Huang, X., Jiang, Z., 2014. Physiological responses of the seagrass *Thalassia hemprichii* (Ehrenb.) Aschers as indicators of nutrient loading. Mar. Pollut. Bull 83, 508–515.

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