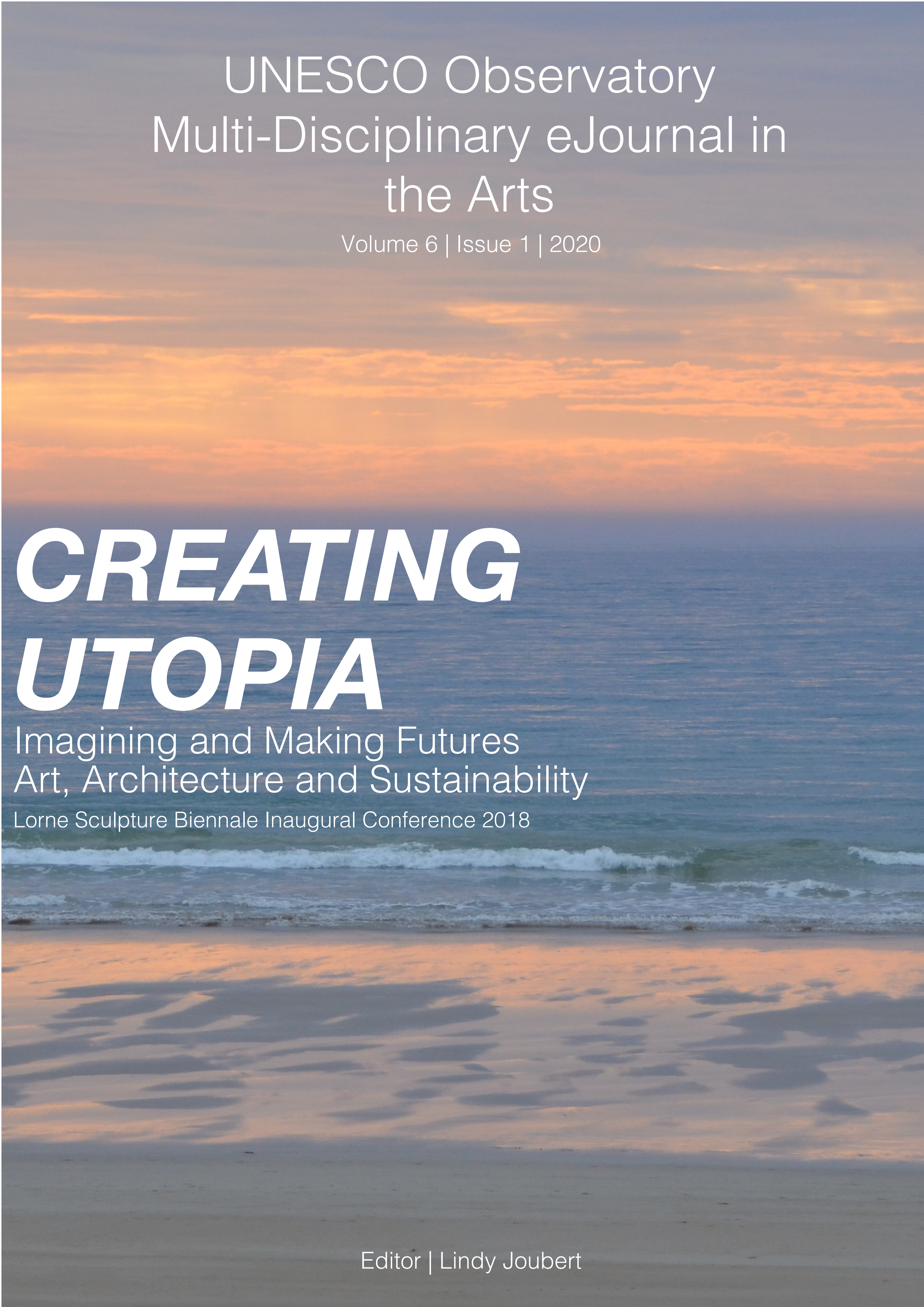


UNESCO Observatory Multi-Disciplinary eJournal in the Arts

Volume 6 | Issue 1 | 2020

CREATING UTOPIA

Imagining and Making Futures
Art, Architecture and Sustainability

Lorne Sculpture Biennale Inaugural Conference 2018

Editor | Lindy Joubert

UNESCO Observatory Multi-Disciplinary eJournal in the Arts

Volume 6 l Issue 1 l 2020

ABOUT THE E-JOURNAL

The UNESCO Observatory refereed e-journal that promotes multidisciplinary research in the Arts and Education and arose out of a recognised need for knowledge sharing in the field. The publication of diverse arts and cultural experiences within a multi-disciplinary context informs the development of future initiatives in this expanding field. There are many instances where the arts work successfully in collaboration with formerly non-traditional partners such as the sciences and health care, and this peer-reviewed journal aims to publish examples of excellence. Valuable contributions from international researchers are providing evidence of the impact of the arts on individuals, groups and organisations across all sectors of society. The UNESCO Observatory refereed e-journal is a clearing house of research which can be used to support advocacy processes; to improve practice; influence policy making, and benefit the integration of the arts in formal and non-formal educational systems across communities, regions and countries.

ISSN 1835 - 2776
Published in Australia
Published by
The Graduate School of Education

The University of Melbourne, Parkville,
Victoria 3010

COVER IMAGE

Leon Walker
Photography at
The Lorne Sculpture
Biennale 2018

EDITOR'S LETTER

The sixth Lorne Sculpture Biennale, March 2018, was a vibrant festival celebrating the best of Australian and international sculpture. The stunning Lorne foreshore became a picturesque pedestal for a curated landscape of sculptures, presented alongside an exciting program of events devoted to pressing global issues of nature and endangerment, under the distinguished curation and visionary direction of Lara Nicholls, curator at the NGA Canberra. The inaugural conference, Creating Utopia Imagining and Making Futures: Art, Architecture and Sustainability was held at Qdos Gallery, Lorne, as part of the Biennale's curatorial theme of 'Landfall, Nature + Humanity + Art'. Keynote and invited speakers – conservationists, visual artists, architects and academics – reflected on issues and processes of social and environmental degradation, transformation and regeneration. The presentations came from a diverse and thought-provoking range of viewpoints offering innovative, and well researched future directions to the world's mounting problems.

Creating Utopia examined the green revolution – greater than the industrial revolution and happening faster than the digital revolution. The speakers were introduced by the inimitable Design Professor, Chris Ryan, whose elegant and thoughtful comments to each presenter added a distinctive contribution. Mona Doctor-Pingel, an architect from Auroville, India delivered her keynote address, 'Journeying to Oneness through architecture in Auroville, South India', discussing the natural and built landscapes found in the unique, social utopia that is Auroville, with an emphasis on experimental building techniques using local materials and craft principles, inspired by biology. I would like to thank all the presenters for their valuable contributions and this issue, volume 6, issue 1 of the 'UNESCO journal, multi-disciplinary research in the arts' www.unescoejournal.com is testament to their important research and life's work.

The conference was considered by all who attended to be a wonderful success. Inspired by the beautiful setting amidst the gum trees and singing birds surrounding the Qdos Gallery. Sincere thanks to all who attended, the excellent list of speakers, the team - Graeme Wilkie OAM for his overall, tireless support; Lara Nicholls the LSB curator for her helpful ideas and professionalism; Gillian Oliver for the superb food; Laurel Guymer, the behind the scenes angel of 'La Perouse' at Lorne who managed the bookings and accommodation and our diligent rapporteur, Jeremy Laing. The excellent Deakin intern student managed all computer glitches, problems and presentation hurdles. A very sincere thankyou to Evelyn Firstenberg who generously and professionally edited all the conference papers and most importantly, a very special thankyou to Seraphina Nicholls who has tirelessly and superbly designed and managed the collation and publication of this special issue. These people and others, the LSB committee and particularly Deakin University who gave generously for the LSB Education Program, enabled the 'Creating Utopia' conference to make a significant contribution to issues relating to climate change, environmental and global futures and the
role of the arts and sustainable planning.

Lindy Joubert

Immediate-Past President Lorne Sculpture Biennale
www.lornesculpture.com
Founding Director, UNESCO Observatory Multi-Disciplinary Research in the Arts
Editor-in-Chief UNESCO Observatory ejournal - http://www.unescoejournal.com
Vice President, World Craft Council Asia Pacific Region, South Pacific
Senior Fellow, Faculty of Architecture, Building and Planning
The University of Melbourne
Email: lindyaj@unimelb.edu.au
Mobile: +61 (0)425 788 581

Feeding the World Without Killing the Planet: Where can Australian seaweed fit in?

Dr. Alecia Bellgrove
Deakin University

ABSTRACT

The world is under pressure and we humans are the major problem. Atmospheric carbon dioxide levels continue to soar and with that our climate is changing in unprecedented ways. Our freshwater resources are dwindling but our population continues to rise putting more and more demand on our earth to supply us with the food we need to survive. We have to look to alternative, sustainable ways to feed our global population without killing the very planet on which we depend. Part of the solution lies in the seaweeds that abound on our coastal margins. And with Australia being a global hotspot for seaweed biodiversity, with the longest continuous living culture of Indigenous Peoples that have lived from and with nature for millennia, we are well placed to be a part of this global nutrition solution that promises to reduce our impact on the earth.

ACKNOWLEDGEMENTS

We acknowledge the Gunditjmara and Gadubanud peoples, the traditional custodians of the lands and waters, of elders past and present, on which this work was conducted. Donna Squire, Mel Wells and Daniel Ierodiaconou are thanked for images. I thank industry partners Victorian Shellfish Hatchery, Kai Ho Tasmanian Sea Vegetables and Victorian Fisheries Authority, Deakin University and the Centre for Integrative Ecology for financial and in-kind support. Some of the work discussed in this paper was crowd-funded through the Deakin University – Pozible Research My World partnership, for which the many funders are thanked. I further acknowledge the contributions of my students and collaborators in helping realise the true potential of Australian seaweeds, and JB Pocklington for comments on the manuscript.

Introduction

We need to reimagine the way in which we feed our global population into the future. But first we need to overcome some prejudice. I'd like you to close your eyes and think about seaweeds for a second… You can open them now. I hazard a guess that many of you were thinking of the unsightly masses of seaweed washed up on our beautiful beaches; that perhaps gets in the way of a good game of beach cricket (Fig. 1a). Others might have been thinking about the horrible smell of this same seaweed, rotting in the summer sun and wafting in through your open windows when the wind finally changes to the south. You might also have been thinking about the slimy feeling of the seaweed brushing against your skin as you swim in the ocean (Fig 1b). Or perhaps fearing that you would get tangled in the seaweed and not be able to break free (Fig 1c).

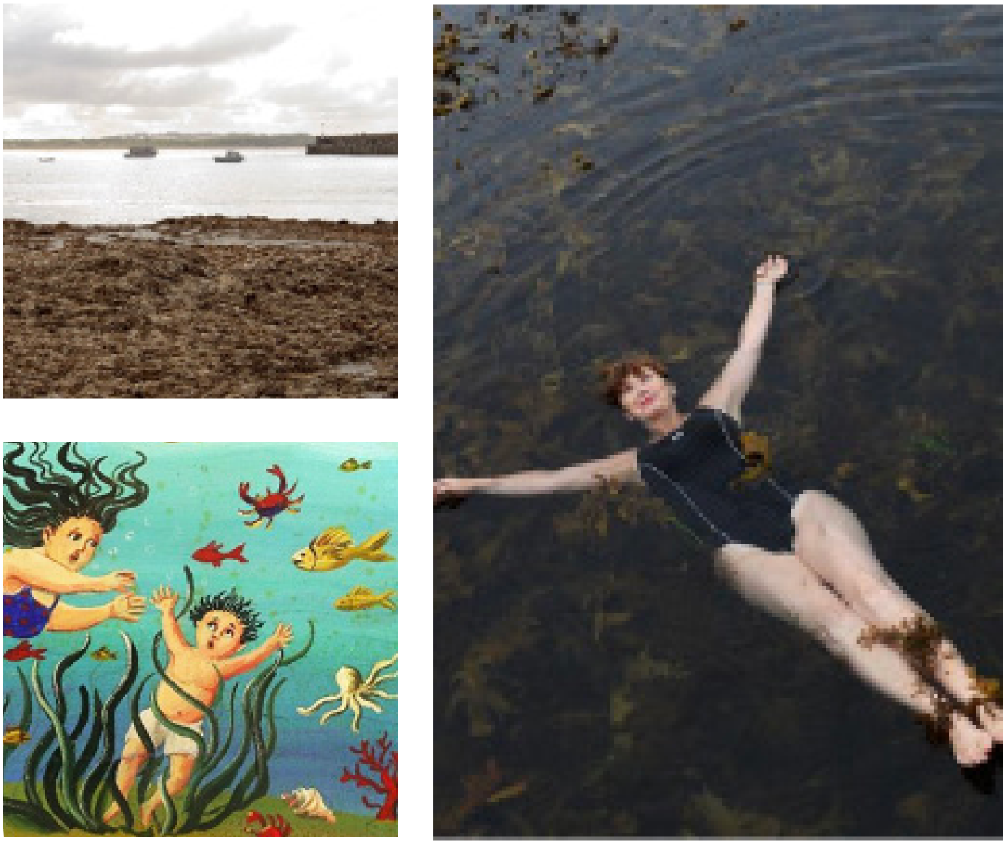


Figure 1
a (*Top left*).
Seaweed washed up on the beach at Lady Bay, Warrnambool
(Image Donna Squire);

b (*Right).*
Swimming in the slime
(Image Braden Fastier, Daily Telegraph https://www.dailytelegraph.com.au/newslocal/northern-beaches/the-peninsula-should-love-its-seaweed-like-people-in-the-tropics-care-for-coral-says-scientist/news-story/7f3047e3a848cb743ce63488223e4ad0);

c (*Bottom left)*
Tangled in the weed
(Image modified from Retablo by Selva Prieto Salazar; http://retablos.ru/en/tag/seaweed/)

Generally, for most Australians, and in fact many people in the west, the word 'seaweed' carries with it a plethora of negative connotations. Indeed, the very word we use in English to describe the macroscopic algae that line our coasts implies it's a bad thing: 'Sea-weed', where weeds are a nuisance, that don't belong and something to be gotten rid of. But if you look underwater (Fig. 2) and under the microscope (Fig. 3) they are truly beautiful (Fig 4)!

Seaweeds are also critically important to ecosystems. They are globally important primary producers with very high rates of primary productivity and growth, and significant biomass on coastal margins (Chung et al. 2011, Mann 1973), particularly in temperate regions (Cheshire et al. 1996, Connell and Irving 2008, Mann 1973). Seaweeds are thus globally important in both CO2 consumption and O2 generation, and in nutrient and carbon cycling (Hill et al. 2015). Moreover, because seaweeds are often the dominant space-holders in intertidal and shallow subtidal coastal regions on temperate coasts around the globe, they are important creators of complex three-dimensional habitats and modify resource availability (such as light, temperature and flow) for associated species (Sanchez-Moyano et al. 2001, Gosselin and Chia 1995, Kelaher et al. 2001, Schiel and Lilley 2011, Pocklington et al. 2017, Christie et al. 1998). As such, habitat-forming seaweeds have been shown to be important for biodiversity (Hily and Jean 1997, Fredriksen et al. 2005, Jenkins et al. 2004, Bertness et al. 1999, Bishop et al. 2012, Bishop et al. 2013, Schiel and Lilley 2011). Seaweeds are also at the base of many complex food webs in both marine (Steneck et al. 2002) and terrestrial systems, where seaweed wash up on the beach in storms can provide food for beach fauna, that then become food for seabirds or terrestrial predators for example (Ruiz-Delgado et al. 2014, Griffiths et al. 1983). These are just some examples of the ecosystem functions provided by healthy seaweed beds and forests.

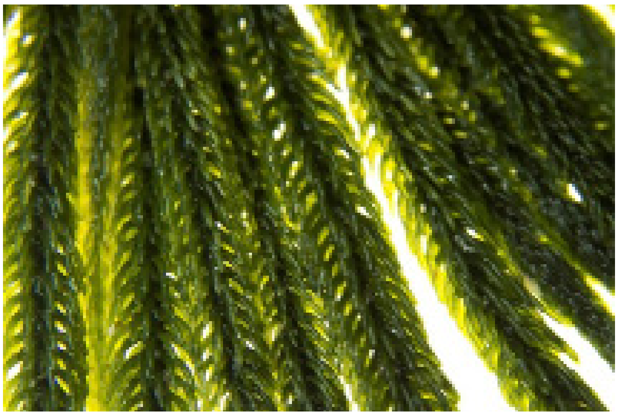
The Problem

Our world is in crisis and we humans are the major problem. Our planet is warming as atmospheric carbon dioxide levels continue to soar (IPCC 2014). Our freshwater resources are dwindling (Vörösmarty et al. 2000, UNESCO-WWAP 2012) but our population continues to rise (United Nations 2017) putting more and more demand on our earth to supply us with the food we need to survive. But at the same time, in developing nations the obesity epidemic is out of control (WHO 2016). We have to look to alternative, sustainable ways to feed and nourish our global population without killing the very planet on which we depend.

Figure 2.
Underwater images of seaweeds show their true colour and vibrancy (Images: Mel Wells and Daniel Ierodiaconou)

The Solution

Seaweeds can be part of the solution. Seaweeds do not require freshwater to grow so their production does not compete with that of terrestrial food crops for dwindling water resources. Seaweeds uptake nutrients from the water column and draw down CO_2 during photosynthesis which means they can help mitigate coastal eutrophication (Fei 2004, Neori et al. 2004) and elevated atmospheric CO_2 (Sondak et al. 2017a, Sondak et al. 2017b). With ocean-based systems, seaweed aquaculture can have a very small land-use footprint and thus not compete with increasing demands for urban development, housing or terrestrial food production as our population soars towards 11.2 billion by 2100 (United Nations 2017). Most seaweeds have very fast growth rates (Mann 1973), with some species growing as much as 8%·day-1 (Wheeler and North 1981). Together this all means that large amounts of seaweed biomass can be produced annually for food with the addition of relatively few resources compared to land-based agriculture systems, whilst actually counteracting the negative impacts of other anthropogenic activities causing eutrophication and climate change.



Importantly, the seaweeds that can be produced by aquaculture are nutritionally rich in proteins and essential amino acids, dietary fibre, sulfated polysaccharides, phlorotannins, polyunsaturated fatty acids (PUFA), vitamins, minerals and pigments (Burtin 2003). As such, there are many health benefits that can be gained from regular consumption of seaweeds. Reports suggest many seaweeds can have anti-inflammatory, anti-cancer, anti-viral, anti-oxidant, anti-obesity and anti-diabetic effects (Wijesekara et al. 2010, Jung et al. 2012, Kim and Pangestuti 2011, Zubia et al. 2009); assist in the prevention and treatment of metabolic syndrome, cardiovascular disease and arthritis (Cornish et al. 2015, Kumar et al. 2015) and potentially protect the brain against Alzheimer's disease (Mohamed et al. 2012). Different species of seaweeds, however, can differ in their nutritional profiles and vary in space and time (Skrzypczyk et al. 2018) such that research that focusses on aquaculture practices that maximize the nutritional value of the seaweed products produced will be of great value in feeding the world into the future.

Figure 3 (*all*). Microscopic detail of seaweeds shows a beauty hidden from many (Images: Donna Squire)

The increasing recognition of the health benefits of seaweeds (Cornish et al. 2015) and the potential environmental benefits of farming seaweed (Duarte et al. 2017, Sondak et al. 2017a, Sondak et al. 2017b), along with the globalisation of sushi from beyond the shores of Japan, has led to a dramatic increase in the global production of seaweeds in the last decade.

Seaweed aquaculture now produces more than 30.1 Mt (wet weight) seaweed globally per year, valued at more than US$11.7 billion (FAO 2018).

But where can Australia fit in? Southern Australia is a hotspot of biodiversity of seaweeds with the highest regional species richness and levels of endemism (~60 %) of seaweeds globally (Phillips 2001 and Bryan Womersley's extensive works cited therein). Because our seaweed flora is so rich and our waters are so clean (Halpern et al. 2008) there is a huge opportunity for Australia to expand into the global market with novel, clean, green and "Australian Made" seaweeds (Skrzypczyk et al. 2018).

Asian countries, particularly Japan, China and Korea, are well known for their lengthy history of consuming seaweeds, with Asian seaweed recipes dating back as far as 600BE (Fig. 5; Chapman and Chapman 1980). Whilst Australia has little contemporary use of seaweeds, we are home to the richest diversity of Indigenous nations, with the longest continuous cultural history in the world, dating back at least 65,000 y (Clarkson et al. 2017). So we have a fantastic opportunity to value the traditional ecological knowledge of Indigenous seaweed use (Fig. 6; Thurstan et al. 2018) and partner with Indigenous Saltwater Peoples in the development of a vibrant and sustainable seaweed industry in Southern Australia.

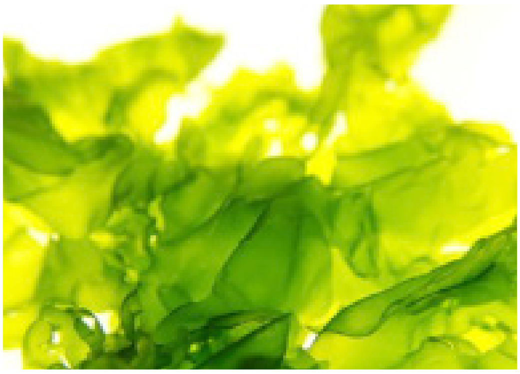


Figure 4 (*all*)
Temperate Australian seaweeds are diverse in colour, form and species and a wonder to behold
(Images: Donna Squire)

The Path: Would you like seaweed with that?

The unique seaweed flora of Australia offers many opportunities for emerging food and other products, but also poses significant challenges that will be best met by productive partnerships between industry, Indigenous communities, government organisations and researchers from a range of disciplines. In particular, research that addresses the following key knowledge gaps will pave the way for a viable and sustainable seaweed industry for Australia:

Figure 5.
Japanese women returning to shore with their harvest of seaweeds.
Woman Gathering Seaweed.
Ukiyo-e wood block print circa 1810 by Japanese artist Katsukawa Shunsen (Shunko II)

1. Palatability and nutritional benefits of native seaweeds

With all the diversity of seaweeds on our shores, which ones are actually good to eat? One of the first steps in exploring the Australian marine flora for edible seaweed products is to assess which species are palatable and nutritionally rich enough to warrant further investigation for aquaculture or wild-harvest potential. Some recent successes in this area have identified that a number of endemic Australian seaweeds compare favourably to commercially available Asian seaweeds with respect to both palatability assessed by consumer taste trials, and nutritional profiles (Skrzypczyk et al. 2018, Schmid et al. 2018), but we are only scraping the surface of the incredible diversity of seaweeds on our shores.

2. Potential contamination in both wild populations and ‘grow out’ sites

Seaweeds are known to be good nutritional sources of essential minerals that are often less abundant in terrestrial vegetables, particularly those grown on old, weathered soils as in Australia (Naidu and Rengasamy 1993, MacArtain et al. 2007). This is partly because seaweeds are bathed in mineral-rich seawater and partly because the abundant matrix components of seaweed cell walls are composed of primarily polyanionic polysaccharides (Kloareg and Quatrano 1988) that have a high affinity for metal binding (Davis et al. 2003). Although many minerals are beneficial for health in trace amounts, they can become toxic in high doses.

In particular, the levels of arsenic, cadmium, lead, mercury and tin in food are regulated in Australia.

Figure 6
a. (*Left)*
Indigenous Australian water carrier
(© Trustees of the British Museum) made from
b. (*Right)*
Bull kelp
(Durvillaea potatorum)
(Image: Mel Wells)

A key global marketing advantage for Australian seaweeds is the well-established global image of 'clean and green' Australian-made products developed from strong agriculture and existing aquaculture industries and strict environmental protection regulations (Australian Trade and Investment Commision 2017). By global standards, Australian waters are amongst the cleanest of populated continents (Halpern et al. 2008). Ensuring that this 'clean and green' Australian-made image is maintained by carefully examining any potential sources of contamination and/or species specific propensities to accumulate contaminants will guide aquaculture, commercial wild harvest, and foraging to ensure public safety. Moreover this research should guide the development of safe food standards for Australian seaweeds. Work is currently underway to address this knowledge gap for a suite of Australian seaweeds with potential as emerging food products (Skrzypczyk et al. unpublished data) and methods for cost-effective toxicity testing by industry are under-development (Winberg 2017).

3. Suitable species for culture and method development

The high levels of endemism of Australian seaweeds (Phillips 2001) and the fact that commonly cultured seaweeds from Asia are not native to Australian waters, means that the Australian seaweed flora needs to be explored for species that are not only tasty and nutritious, but also suitable for sustainable aquaculture. Understanding of the life cycles, growth requirements, and growth rates can inform development of suitable methods for domesticating the hatchery stages of seaweeds of interest. At present, aquaculture methods are being developed for a few species of laminarian (Sanderson et al. unpublished data) and fucoid (Cumming et al. in prep) Australian kelps in southern Australia and sea lettuce (Ulva species) in NSW and QLD (Winberg unpublished data, Praeger and de Nys 2017, Praeger and de Nys 2018). This is an area that is set to develop rapidly with increasing interest from industry.

4. What can we learn from Indigenous uses of seaweeds?

Whilst our contemporary understanding of the palatability and potential uses of Australian seaweeds is in its infancy, there is much to be learned by valuing the traditional ecological knowledge of the longest continuous cultural history in the world, dating back 65,000 years (Clarkson et al. 2017).

In a recent archival assessment we found records of seaweed use by Aboriginal Australians for a variety of purposes including: cultural activities, ceremonial activities, medicinal uses, clothing, cultural history, food, fishing, shelter and domestic uses (Thurstan et al. 2018). We are currently expanding our understanding of the significance of seaweeds to Indigenous Australians by collecting oral histories of seaweed uses across temperate, southeastern Australia (Brittain et al. unpublished data).

5. Bioremediation by seaweed aquaculture

One of the key problems with fed-fish aquaculture is the addition of nutrients to the water body from both uneaten food and faeces. Typically marine systems are nitrogen limited so additions of nitrogenous wastes can have significant environmental impacts. As seaweeds photosynthesise they uptake nutrients, particularly nitrogen and phosphorous, from the water body and as such have the potential to negate the effects of fed-fish aquaculture. This is the premise of integrated multitrophic aquaculture (IMTA). IMTA combines fed aquaculture species (e.g. fin fish, abalone) with extractive species (e.g. seaweeds), where the wastes from the fed species fertilise the extractive species and the co-cultured species can both provide valuable crops. IMTA can provide both nutrient and carbon offsets to fish and shellfish farmers. Algal production is key to successful IMTA. While taking up dissolved inorganic nutrients (nitrogen and phosphorous) and atmospheric CO2, the produced algal biomass is a renewable feed to cultivated species, as well as a sea-vegetable product in its own right (Chopin et al. 2001). Understanding which Australian species are best suited to IMTA and the nitrogen and carbon uptake dynamics of each species are key to maximising the bioremediation potential of IMTA.

6. Viability and sustainability of wild-harvested seaweed

Aquaculture production can provide a large amount of seaweed biomass with minimal environmental impact if carefully planned. However, domestication of seaweeds for aquaculture can be challenging and as such may not be feasible for all species of interest. In such cases, and where initial limitations in demand may deter investment in aquaculture systems, wild-harvest may be a realistic alternative. Indeed there are viable wild-harvested seaweed fisheries in many parts of the world with 0.8 Mt harvested globally each year (FAO 2018). However, given that we know seaweeds play important roles in coastal ecosystems, it is imperative that wild harvesting is informed by an understanding of the reproductive and regenerative biology of the target seaweeds, and the direct and indirect interactions of those species with other organisms in the system. For most Australians seaweeds this information is severely lacking.

7. End-use markets

Whilst there is demonstrable potential for new food products from Australian seaweeds (Skrzypczyk et al. 2018, Thurstan et al. 2018, Winberg 2017), the development of a viable seaweed industry will depend on either rapid consumer acceptance and associated demand or, perhaps more realistically, a diversity of end-use products and increasing market demand for each. Sustainable aquaculture production of Australian seaweeds grown in clean ocean waters has the potential to supply diverse markets with a range of products in addition to food, including but not limited to high-value nutraceuticals and pharmaceuticals, innovative natural fibres, animal feeds and biofuels, but each should be built on a foundation of evidence-based research.

8. Understanding carbon mitigation and sequestration potential of seaweeds

A walk along most beaches in Australia will eventually involve stepping over masses of seaweed, ripped from the reefs by storms and other hydrodynamic processes. Seaweed solutions to climate change can come through the long-term sequestration potential and protection of natural seaweed forests that 'donate' carbon to coastal and deep-sea carbon sinks (known as blue carbon sinks) via such dislodged seaweed biomass (Hill et al. 2015, Trevathan-Tackett et al. 2015, Krause-Jensen and Duarte 2016). In addition to donating biomass to blue carbon sinks, seaweed aquaculture farms can also mitigate CO_2 through avoided carbon emissions from the burning of fossil fuels, as seaweeds are used for biofuels, organic fertilisers and soil conditioners, or less carbon-intensive forms of food production for example (Duarte et al. 2017, Sondak et al. 2017a, Sondak et al. 2017b). Understanding the rates and significance of seaweed-derived carbon deposition to blue carbon sinks (Hill et al. 2015) and the carbon budgets of seaweed aquaculture (i.e. CO_2 emissions from seaweed farming vs amount of carbon sequestered or emissions mitigated) are important areas of further research.

9. Climate proofing seaweed aquaculture investments

Temperate Australian coastal waters are warming at an unprecedented rate and this warming is already having negative effects on some seaweed species leading to deforestation of kelps in particular (Johnson et al. 2011). Moreover increasing extreme warming events are having documented devastating impacts on seaweed-dominated ecosystems (Wernberg et al. 2016). In the face of such negative effects of ocean warming, it is essential that we understand the adaptive capacity of seaweeds with aquaculture potential and investigate methods of temperature-resistant strain selection to future proof the investments in a developing seaweed aquaculture industry.

Conclusions

Seaweeds should be part of our global food security future. Increasing production of seaweeds through sustainably managed aquaculture, alongside the creation of products and markets that lead to greater public acceptance and consumption of a diverse suite of seaweeds by people in western cultures, should lead to both improvements in environmental and health outcomes. Australia has an important role to play, with huge potential for a seaweed industry based on best-practice sustainable production of unique native Australian seaweeds that can be cultured in our clean oceanic waters. This industry could be guided by Indigenous Australians' knowledge of our unique seaweed flora, leveraging training and business opportunities for coastal Aboriginal communities. But the research challenges and environmental responsibilities to realise this potential should not be overlooked and will involve effective partnerships with, and investment by, both government and industry.

REFERENCES

Australian Trade and Investment Commision, 2017. Why Australia. Benchmark Report 2017. Canberra: Australain Government.

Bertness, M.D., Leonard, G.H., Levine, J.M., Schmidt, P.R. and Ingraham, A.O., 1999. Testing the relative contribution of positive and negative interactions in rocky intertidal communities. Ecology, 80(8), 2711-26.

Bishop, M.J., Byers, J.E., Marcek, B.J. and Gribben, P.E., 2012. Density-dependent facilitation cascades determine epifaunal community structure in temperate Australian mangroves. Ecology, 93(6), 1388-401.

Bishop, M.J., Fraser, J. and Gribben, P.E., 2013. Morphological traits and density of foundation species modulate a facilitation cascade in Australian mangroves. Ecology, 94(9), 1927-36.

Burtin, P., 2003. Nutritional value of seaweeds. Electronic Journal of Environmental, Agricultural and Food Chemistry, 2(4).

Chapman, V.J. and Chapman, D. 1980. Seaweeds and their uses. Dordrecht: Springer Netherlands.

Cheshire, A.C., Westphalen, G., Wenden, A., Scriven, L.J. and Rowland, B.C., 1996. Photosynthesis and respiration of phaeophycean-dominated macroalgal communities in summer and winter. Aquatic Botany, 55(3), 159-70.

Chopin, T., Buschmann, A.H., Halling, C., Troell, M., Kautsky, N., Neori, A., Kraemer, G.P., Zertuche-Gonzalez, J.A., Yarish, C. and Neefus, C., 2001. Integrating seaweeds into marine aquaculture systems: A key toward sustainability. Journal of Phycology, 37(6), 975-86.

Christie, H., Fredriksen, S. and Rinde, E., 1998. Regrowth of kelp and colonization of epiphyte and fauna community after kelp trawling at the coast of Norway. Hydrobiologia, 375-76, 49-58.

Chung, I.K., Beardall, J., Mehta, S., Sahoo, D. and Stojkovic, S., 2011. Using marine macroalgae for carbon sequestration: a critical appraisal. Journal of Applied Phycology, 23(5), 877-86.

Clarkson, C., Jacobs, Z., Marwick, B., Fullagar, R., Wallis, L., Smith, M., Roberts, R.G., Hayes, E., Lowe, K., Carah, X., Florin, S.A., McNeil, J., Cox, D., Arnold, L.J., Hua, Q., Huntley, J., Brand, H.E.A., Manne, T., Fairbairn, A., Shulmeister, J., Lyle, L., Salinas, M., Page, M., Connell, K., Park, G., Norman, K., Murphy, T. and Pardoe, C., 2017. Human occupation of northern Australia by 65,000 years ago. Nature, 547(7663), 306-10.

Connell, S.D. and Irving, A.D., 2008. Integrating ecology with biogeography using landscape characteristics: a case study of subtidal habitat across continental Australia. Journal of Biogeography, 35(9), 1608-21.

Cornish, M.L., Critchley, A.T. and Mouritsen, O.G., 2015. A role for dietary macroalgae in the amelioration of certain risk factors associated with cardiovascular disease. Phycologia, 54(6), 649-66.

Davis, T.A., Volesky, B. and Mucci, A., 2003. A review of the biochemistry of heavy metal biosorption by brown algae. Water Research, 37(18), 4311-30.
Duarte, C.M., Wu, J., Xiao, X., Bruhn, A. and Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation? Frontiers in Marine Science, 4(100).

FAO, 2018. FAO yearbook. Fisheries and Aquaculture statistics 2016. Rome: Food and Agriculture Organization of the United Nations.

Fei, X., 2004. Solving the coastal eutrophication problem by large scale seaweed cultivation. Dordrecht: Springer Netherlands.

Fredriksen, S., Christie, H. and Saethre, B.A., 2005. Species richness in macroalgae and macrofauna assemblages on Fucus serratus L. (Phaeophyceae) and Zostera marina L. (Angiospermae) in Skagerrak, Norway. Marine Biology Research, 1(1), 2-19.

Gosselin, L.A. and Chia, F., 1995. Distribution and dispersal of early juvenile snails: effectiveness of intertidal microhabitats as refuges and food sources. Marine Ecology Progress Series, 128, 213-23.

Griffiths, C.L., Stanton-Dozey, J. and Koop, K., 1983. Kelp wrack and flow of energy through a sandy beach ecosystem. In: A. McLachlan and T. Erasmus, eds., Sandy Beaches as Ecosystems. The Hague: Dr W Junk.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R., 2008. A global map of human impact on marine ecosystems. Science, 319(5865), 948-52.

Hill, R., Bellgrove, A., Macreadie, P.I., Petrou, K., Beardall, J., Steven, A. and Ralph, P.J., 2015. Can macroalgae contribute to blue carbon? An Australian perspective. Limnology and Oceanography, 60, 1689-706.

Hily, C. and Jean, F., 1997. Macrobenthic biodiversity in intertidal habitats of the Iroise biosphere reserve (Brittany, France). Journal of the Marine Biological Association of the United Kingdom, 77(2), 311-23.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change In: R.K. Pachauri and L.A. Meyer, eds. Geneva, Switzerland: IPCC.

Jenkins, S.R., Norton, T.A. and Hawkins, S.J., 2004. Long term effects of Ascophyllum nodosum canopy removal on mid shore community structure. Journal of the Marine Biological Association of the United Kingdom, 84, 327-29.

Johnson, C.R., Banks, S.C., Barrett, N.S., Cazassus, F., Dunstan, P.K., Edgar, G.J., Frusher, S.D., Gardner, C., Haddon, M., Helidoniotis, F., Hill, K.L., Holbrook, N.J., Hosie, G.W., Last, P.R., Ling, S.D., Melbourne-Thomas, J., Miller, K., Pecl, G.T., Richardson, A.J., Ridgway, K.R., Rintoul, S.R., Ritz, D.A., Ross, D.J., Sanderson, J.C., Shepherd, S.A., Slotvvinski, A., Swadling, K.M. and Taw, N., 2011. Climate change cascades: Shifts in oceanography, species' ranges and subtidal marine community dynamics in eastern Tasmania. Journal of Experimental Marine Biology and Ecology, 400(1-2), 17-32.

Jung, H.A., Islam, M.N., Lee, C.M., Jeong, H.O., Chung, H.Y., Woo, H.C. and Choi, J.S., 2012. Promising antidiabetic potential of fucoxanthin isolated from the edible brown algae Eisenia bicyclis and Undaria pinnatifida. Fisheries Science, 78(6), 1321-29.

Kelaher, B.P., Chapman, M.G. and Underwood, A.J., 2001. Spatial patterns of diverse macrofaunal assemblages in coralline turf and their associations with environmental variables. Journal of the Marine Biological Association of the United Kingdom, 81(6), 917-30.

Kim, S.-K. and Pangestuti, R., 2011. Potential role of marine algae on female health, beauty, and longevity. Advances in Food and Nutrition Research, 64, 41-55.

Kloareg, B. and Quatrano, R.S., 1988. Structure of the cell walls of marine algae and ecophysiological functions of the matrix polysaccharides. Oceanography and Marine Biology, 26, 259-315.

Krause-Jensen, D. and Duarte, C.M., 2016. Substantial role of macroalgae in marine carbon sequestration. Nature Geosci, 9(10), 737-42.

Kumar, S., Magnusson, M., Ward, L., Paul, N. and Brown, L., 2015. Seaweed supplements normalise metabolic, cardiovascular and liver responses in high-carbohydrate, high-fat fed rats. Marine Drugs, 13(2), 788.

MacArtain, P., Gill, C.I.R., Brooks, M., Campbell, R. and Rowland, I.R., 2007. Nutritional value of edible seaweeds. Nutrition Reviews, 65(12), 535-43.

Mann, K.H., 1973. Seaweeds - their productivity and strategy for growth. Science, 182(4116), 975-81.

Mohamed, S., Hashim, S.N. and Rahman, H.A., 2012. Seaweeds: A sustainable functional food for complementary and alternative therapy. Trends in Food Science & Technology, 23(2), 83-96.

Naidu, R. and Rengasamy, P., 1993. Ion interactions and constraints to plant nutrition in Australian sodic soils. Soil Research, 31(6), 801-19.

Neori, A., Chopin, T., Troell, M., Buschmann, A.H., Kraemer, G.P., Halling, C., Shpigel, M. and Yarish, C., 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. Aquaculture, 231(1), 361-91.

Phillips, J.A., 2001. Marine macroalgal biodiversity hotspots: why is there high species richness and endemism in southern Australian marine benthic flora? Biodiversity and Conservation, 10, 1555-77.

Pocklington, J.B., Jenkins, S.R., Bellgrove, A., Keough, M.J., O'Hara, T.D., Masterson-Algar, P.E. and Hawkins, S.J., 2017. Disturbance alters ecosystem engineering by a canopy-forming alga. Journal of the Marine Biological Association of the United Kingdom.

Praeger, C. and de Nys, R., 2017. Seeding filamentous Ulva tepida on free-floating surfaces: A novel cultivation method. Algal Research, 24, 81-88.

Praeger, C. and de Nys, R., 2018. Improvement of the seeding of filamentous Ulva tepida on free-floating surfaces. Algal Research, 30, 73-78.

Ruiz-Delgado, M.C., Vieira, J.V., Veloso, V.G., Reyes-Martinez, M.J., Sallorenzo, I.A., Borzone, C.A., Sanchez-Moyano, J.E. and Garcia Garcia, F.J., 2014. The role of wrack deposits for supralittoral arthropods: An example using Atlantic sandy beaches of Brazil and Spain. Estuarine Coastal and Shelf Science, 136, 61-71.

Sanchez-Moyano, J.E., Garcia-Adiego, E.M., Estacio, F.J. and Garcia-Gomez, J.C., 2001. Influence of the density of Caulerpa prolifera (Chlorophyta) on the composition of the macrofauna in a meadow in Algeciras Bay (southern Spain). Ciencias Marinas, 27(1), 47-71.

Schiel, D.R. and Lilley, S.A., 2011. Impacts and negative feedbacks in community recovery over eight years following removal of habitat-forming macroalgae. Journal of Experimental Marine Biology and Ecology, 407(1), 108-15.

Schmid, M., Kraft, L.G.K., van der Loos, L., Kraft, G.T., Virtue, P., Nichols, P.D. and Hurd, C.L., 2018. Southern Australian seaweeds: a promising resource for omega-3 fatty acids. Food Chemistry.

Skrzypczyk, V., Hermon, K., Norumbuena, F., Turchini, G., Keast, R. and Bellgrove, A., 2018. Is Australian seaweed worth eating? Nutritional and sensorial properties of wild-harvested Australian versus commercially-produced Japanese seaweeds. Journal of Applied Phycology.

Sondak, C.F.A., Ang, P.O., Beardall, J., Bellgrove, A., Boo, S.M., Gerung, G.S., Hepburn, C.D., Hong, D.D., Hu, Z., Kawai, H., Largo, D., Lee, J.A., Lim, P.-E., Mayakun, J., Nelson, W.A., Oak, J.H., Phang, S.-M., Sahoo, D., Peerapornpis, Y., Yang, Y. and Chung, I.K., 2017a. Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs). Journal of Applied Phycology, 29(5), 2363–73.

Sondak, C.F.A., Ang, P.O., Beardall, J., Bellgrove, A., Boo, S.M., Gerung, G.S., Hepburn, C.D., Hong, D.D., Hu, Z., Kawai, H., Largo, D., Lee, J.A., Lim, P.-E., Mayakun, J., Nelson, W.A., Oak, J.H., Phang, S.-M., Sahoo, D., Peerapornpis, Y., Yang, Y. and Chung, I.K., 2017b. Erratum to: Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs). Journal of Applied Phycology, 29(5), 2375–76.

Steneck, R.S., Graham, M.H., Bourque, B.J., Corbett, D., Erlandson, J.M., Estes, J.A. and Tegner, M.J., 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation, 29(4), 436-59.

Thurstan, R.H., Brittain, Z., Jones, D.S., Cameron, E., Dearnaley, J. and Bellgrove, A., 2018. Aboriginal uses of seaweeds in temperate Australia: an archival assessment. Journal of Applied Phycology.

Trevathan-Tackett, S.M., Kelleway, J.J., Macreadie, P.I., Beardall, J., Ralph, P. and Bellgrove, A., 2015. Comparison of marine macrophytes for their contributions to blue carbon sequestration. Ecology, 96(11), 3043-57.

UNESCO-WWAP, 2012. The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk. Paris: United Nations Educational Scientific and Cultural Organization - World Water Assessment Programme.

United Nations, 2017. World population prospects, the 2017 revision. Key Findings and Advance Tables. ESA/P/WP/248. New York: United Nations. Department of Economic and Social Affairs, Population Division.

Vörösmarty, C.J., Green, P., Salisbury, J. and Lammers, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science, 289(5477), 284-88.

Wernberg, T., Bennett, S., Babcock, R.C., de Bettignies, T., Cure, K., Depczynski, M., Dufois, F., Fromont, J., Fulton, C.J., Hovey, R.K., Harvey, E.S., Holmes, T.H., Kendrick, G.A., Radford, B., Santana-Garcon, J., Saunders, B.J., Smale, D.A., Thomsen, M.S., Tuckett, C.A., Tuya, F., Vanderklift, M.A. and Wilson, S., 2016. Climate-driven regime shift of a temperate marine ecosystem. Science, 353(6295), 169-72.

Wheeler, P.A. and North, W.J., 1981. Nitrogen supply, tissue composition and frond growth-rates for Macrocystis pyrifera off the coast of southern California. Marine Biology, 64(1), 59-69.

WHO, 2016. Overweight and obesity. Global Health Observatory. World Health Organisation.

Wijesekara, I., Yoon, N.Y. and Kim, S.K., 2010. Phlorotannins from Ecklonia cava (Phaeophyceae): biological activities and potential health benefits. BioFactors, 36(6), 408-14.

Winberg, P.C., 2017. Best practices for the emerging Australian Seaweed Industry: Seaweed quality control systems development Wagga Wagga: AgriFutures Australia.

Zubia, M., Fabre, M.S., Kerjean, V., Le Lann, K., Stiger-Pouvreau, V., Fauchon, M. and Deslandes, E., 2009. Antioxidant and antitumoural activities of some Phaeophyta from Brittany coasts. Food Chemistry, 116(3), 693-701.