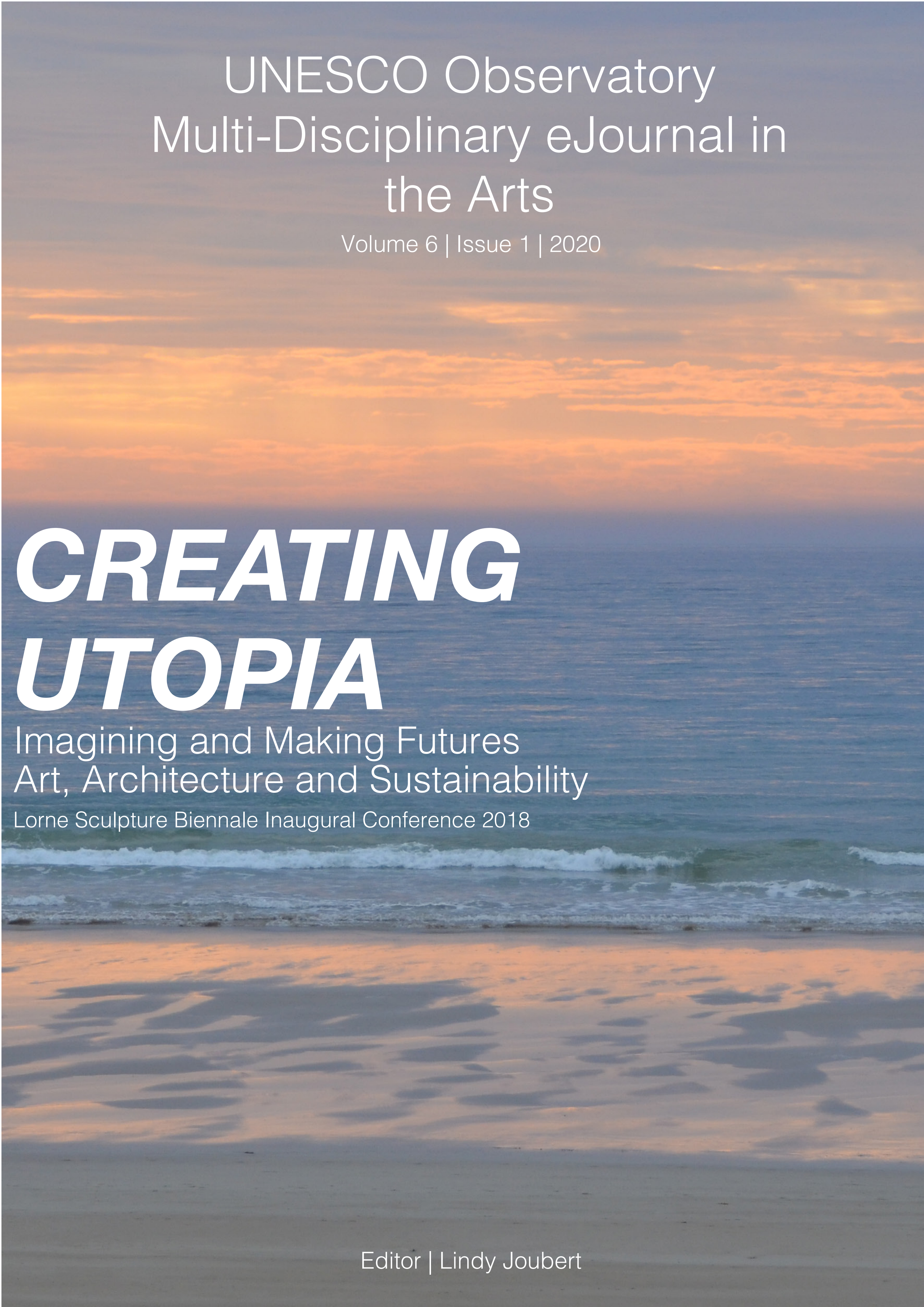

UNESCO Observatory Multi-Disciplinary eJournal in the Arts

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

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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.

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COVER IMAGE

Leon Walker
Photography at
The Lorne Sculpture
Biennale 2018

THEME

The inaugural conference, 'Creating Utopia Imagining and Making Futures: Art, Architecture and Sustainability' was held at Qdos Gallery, Lorne in March as part of The Lorne Sculpture Biennale (LSB) for 2018, under the Biennale's curatorial theme of 'Landfall, Nature + Humanity + Art'.

The sixth Lorne Sculpture Biennale 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.

Accompanying LSB 2018 was the inaugural two-day conference, 'Creating Utopia, Imagining and Making Futures: Art, Architecture and Sustainability'. Keynote and invited speakers – conservationists, visual artists, architects and academics – reflected on issues of environmental degradation, processes of social and environmental transformation and regeneration, from a diverse and thought-provoking range of viewpoints.

"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. Issues relating to climate change; facing uncertain global futures and protecting our planet by taking control, being prepared, and offering solutions for long-term impacts were the topics. The conference heard the voices of experts who offered innovative who offered innovative and well researched future directions to the world's mounting problems.

Invited Speakers included Mona Doctor-Pingel, an architect, based in Auroville, India since 1995. Her keynote address, 'Journeying to Oneness through architecture in Auroville, South India', discussed 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.

Esther Charlesworth, Professor in the School of Architecture and Design at RMIT University, the Academic Director of the new RMIT Master of Disaster, Design and Development degree [MoDDD], and the founding Director of Architects without Frontiers (AWF). Since 2002, AWF has undertaken over 42 health, education and social infrastructure projects in 12 countries for vulnerable communities. Esther spoke about the role Architects can play in improving the social and economic capacity of vulnerable people through design.

Janet Laurence is a Sydney-based artist who exhibits nationally and internationally. Her practice examines our relationship to the natural world, and has been exhibited widely, including as an Australian representative for the COP21/FIAC, Artists 4 Paris Climate 2015 exhibition, and an artist in residence at the Australian Museum.

Professor John Fien, based in Architecture and Urban Design at RMIT, spoke about the techniques and strategies for countering human harm of the environment based on design thinking and education for sustainable development.

Professor Ray Green, Landscape Architecture at the University of Melbourne presented his research on ‘The Changing character of Australian coastal settlements assessed through the eyes of local: A perceptual modelling approach’, exploring how ordinary people living in smaller Australian coastal communities conceptualize the “character” of the places they live and the changes they have noticed. In many such communities the valued ‘character’ of people’s towns and individual neighbourhoods is being lost, often as a result of replacement of older, vernacular forms of architecture with new buildings and changes to the natural landscape that do not fit into the local residents’ established images of their towns and neighbourhoods.

This issue, volume 6, issue 1 of the ‘UNESCO journal, multi-disciplinary research in the arts’ www.unescoejournal.com offers essays from a diverse range of authors and they are as follows:

Gabrielle Bates is a Sydney-based artist and writer exploring the intersections between place, politics and esoteric practice. Gabrielle has undertaken three residencies in Southeast Asia, and her art works have been selected for many competitive award exhibitions. A major survey of her paintings was held at Victoria University and she has produced 11 solo exhibitions.

Dr Greg Burgess, Melbourne-based Principal Designer at Gregory Burgess Architects, discussed architecture as a social, healing and ecological art. Burgess’ international reputation has been established through a significant award-winning body of work, which features housing, community, cultural (including Indigenous), educational, health, religious, commercial, exhibition design and urban design projects.

Dr. Alecia Bellgrove is a Senior Lecturer in Marine Biology and Ecology with Deakin’s School of Life and Environmental Sciences, and a marine ecologist with botanical and zoological training. Her research focuses on the role of habitat-forming seaweeds in ecological systems, their life history dynamics, and the impacts of anthropogenic disturbances such as sewage effluent and climate change. Her paper focussed on feeding the world with seaweed, without killing the planet. Although seaweed has many negative connotations, it plays a fairly major role in life here on earth - it is the primary producer of oxygen, it serves as the base for food webs and is a habitat provision. Seaweed she assured us can be the solution to many of our problems.

Dr. Ching-Yeh Hsu, Professor at the Department of Visual Arts, University of Taipei spoke about the role of visual art in creating utopia. Deeply rooting your art in nature creates a greater rapport and appreciation for nature itself, she maintains, while the use of abandoned material and junk for the creation of art is also a powerful way to express ideas for mutualism with the environment.

Jane and Peter Dyer, urban beekeepers based in middle-ring suburban Melbourne. Their apiary, Backyard Honey Pty Ltd, was seeded a decade ago with the idea of creating a micro-business that would work towards shifting negative perceptions about bees and help shape a sustainable future. Their paper provided an advocacy opportunity to actively explore the intersection of bees with art, architecture and landscape in a sustainable future.

Their presentation, A BeeC's – changing our thinking to changing the world, was developed to highlight the following aspects: Why do we need bees? What do healthy bees need? They provided an overview of built environments that actively promote bees through art, landscape and architecture.

Adjunct Professor Anton Hassel from RMIT claims non-indigenous people living in Australia find themselves on an ancient land mass that is nearly, but not quite, familiar. It is a landscape with unique archetypal cadences, an ambient pulse that unsettles us, and against which our imported familiar architectures and garden-planting schemes act as a bulwark to its strangeness, keeping us émigrés to country.

Professor David Jones and his team, Mandy Nicholson, Glenn Romanis, Isobel Paton, Kate Gerritsen and Gareth Powell wrote 'Putting Wadawurrung meaning into the North Gardens Landscape of Ballarat'. The paper discusses creating the first Indigenous-inspired sculpture landscape in Australia. This paper, prepared by the Indigenous-rich consultant team in conjunction with the Wadawurrung (Wathaurung Aboriginal Corporation) and City of Ballarat, reviews the aspirations of the project together with these narratives and relationships in etching a design and master plan on the canvas.

Paula Llull spoke of Nature as being at the core of artistic creation. The inclusion in art of ideas like ecosystems, natural environment or extinction requires a medium that minimises the distance between the artwork and the spectator. She spoke of the work of Janet Laurence as one of the most remarkable contributions to this current. In particular, her installation Deep Breathing. Resuscitation for the Reef illustrates the commitment of the artist in communicating with feeling the threats such as global warming and its resulting acidification of oceans on particular natural environments.

Phillip B. Roös, Anne S. Wilson, and David S. Jones presented their research on 'The Biophilic Effect: Hidden living patterns within the dance of light''.

They challenged the notion of 'Healthy cities' and 'well-being' as being the most topical and misused words in our global society. They see them being used in discourses about new strategies and policies to create urban environments often masking a failing 'healthy economy'. This discourse, they claim, is the result of our human-made environments as a consequence of our Western quest for 'development', having 'economic renewal' as part of our global urbanisation. This quest appears to be casting aside our primal knowledge of living structures and systems, our important spiritual and innate affiliations to the natural world that we are part of, and thereby loss of biophilia.

Dr. Shoso Shimbo is a garden designer from the esteemed Japan Horticultural Society, specialising in Japanese gardens. He is a director of the International Society of Ikebana. His work in this field, and that as an environmental artist seeks to harness the life force of nature. His sculptural works have featured in some of the nation's major contemporary art exhibitions, and a new work 'Sea Snakes: Trash Vortexes' was a feature of LSB 2018.

Marcus Tatton's sculpture practice is an example of using recycled, natural materials. He works as a sculptor for over of thirty years in Tasmania, Marcus acknowledges that the purpose of his sculpture making is seeking enlightenment. Marcus lives in line with the Asian proverb "to seek enlightenment is to chop wood".

Dr. Rose Woodcock, from Deakin University, presented her research and investigations into a practice-led project 'Merri Creek to the MCG', featuring broken glass sourced from along the Merri Creek in Melbourne's north. The status and function of the glass is ambiguous but rich in possibilities, with the glass fragments connecting her practice with issues of soil sustainability. Rose drew upon aspects of Parmenides' poem on the nature of 'what is' to explore the workings of language, in particular how poetic language can open up otherwise tightly construed discourses.

In conclusion, the conference was a wonderful success in a beautiful setting amidst the gum trees and birds surrounding the atmospheric Qdos Gallery. All the papers were inspirational and left an indelible mark on the audience. 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 Universtiy intern student managed all computer glitches, problems and presentation hurdles.

Sincere thanks goes to Evelyn Firstenberg who generously and professionally edited all the conference papers. 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, environmen-

Lindy Joubert
Editor-in-chief

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).

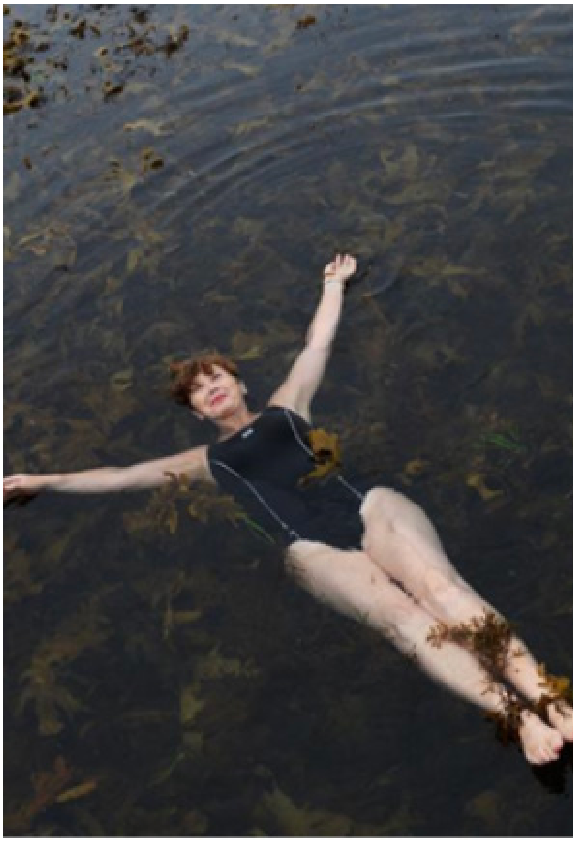


Figure 1
a (*Top left*).
Seaweed washed up on the beach at Lady Bay, Warrnambool
(Image Donna Squire);

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)!

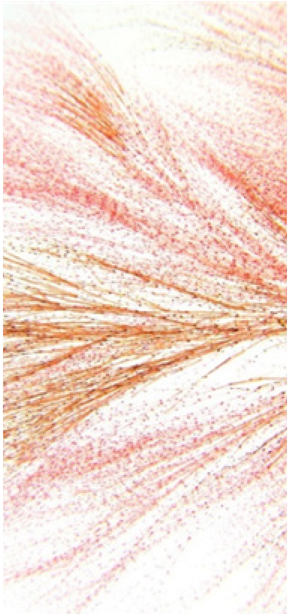
Seaweeds are also critically important to ecosystems. They are globally important primary producers with very high rates of primary productivity and growth, and significant biomass on coastal margins (Chung et al. 2011, Mann 1973), particularly in temperate regions (Cheshire et al. 1996, Connell and 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 CO2 during photosynthesis which means they can help mitigate coastal eutrophication (Fei 2004, Neori et al. 2004) and elevated atmospheric CO2 (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.

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

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.

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.

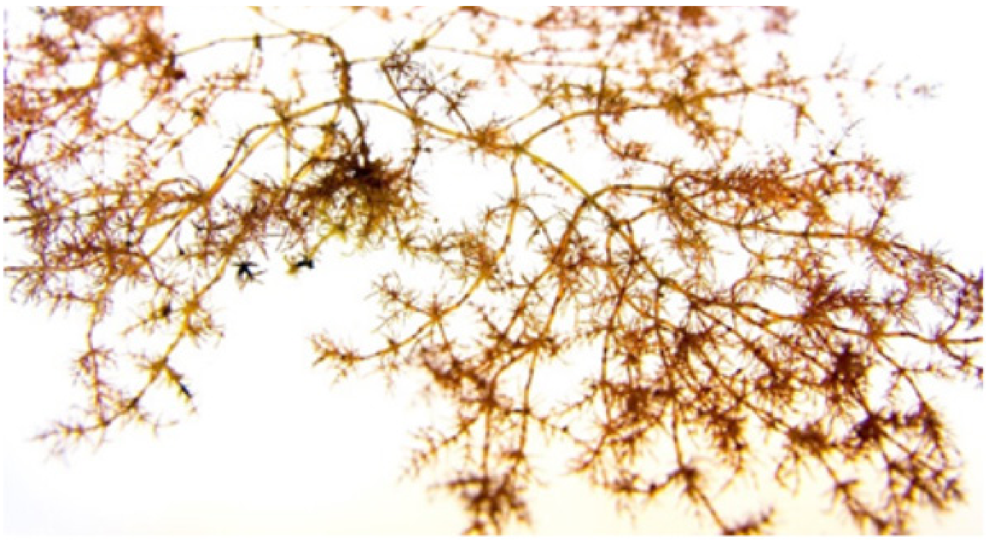


Figure 4 (*all)*
Temperate Australian seaweeds are diverse in colour, form and species and a wonder to behold
(Images: Donna Squire)

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 CO2 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. CO2 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.

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