International Society for

Applied Phycology NEWSLETTER

ISSN 2208-3146

ISSUE 1-2019 July, 2019

Message from the President, Dr. Céline Rebours

Dear ISAP Members,

I am delighted to introduce this Newsletter as the first edition issue 1-2019. During the first part of this year, the MC members have been actively working on several topics.

With the secretary/treasurer of the ISAP, Valeria Montalescot, we have worked in establishing the new protocols that will be used for facilitating the management of the society in the international context and tail to the ISAPs by-laws. In February 2019, the ISAP was then registered as a foundation in the Netherlands.

Besides working on the legal and financial restructuring of the Society, we have also started to plan the new design for a new ISAP webpage. These new webpages will be tailored for membership management and facilitating the access to the Journal of Applied of Phycology. We are now well advanced into looking at different options and have a clear list of features. A working group with 7 of our EC members led by our secretary, Valeria Montalescot has now been created. I want to thank Leila Ktari, Fiona Moejes, Ionnis Tzovenis and Antoinette Kazbar to join the website team with Sasi Nayar, Rémi Nghiem-xuan and Alexandra Busnel.

Besides our webpages, I would like to remind you that we have a Facebook page and a LinkedIn group for ISAP. If you are not yet registered, I would like to invite you to register yourselves through the links that you will find on ISAP Website and at the end of this newsletter.

One of the objectives of ISAP is to support the organization of workshops and training programs in algal biotechnology for its members. The call for proposal for Training workshops is now opened with deadline **September 2nd, 2019**. For further information, please consult our webpage.

Please note that our **7th ISAP Congress** is to be held in **Cheba, Japan** from the **20th to the 25th of April 2020**. The site for abstracts submission will open in the following month and you will find more detailed information on this event under the ISAP 2020 conference webpage.

I would like to also remind you also that ISAP Members who are in good standing with their dues have free access to the electronic version of the Journal of Applied Phycology through the ISAP Website. If you are not yet a member, please do not hesitate to register in order to take advantage of this offer by Springer.

Finally, all ISAP members can actively participate in the activities of the society. We would appreciate your ideas, feedback on ISAP, news, and announcements of interest for ISAP Members. We would also be delighted to receive articles that could be published in our next Newsletter during winter 2019 or spring 2020. For the matters, please contact either the Editor of the Newsletter, Sasi Nayar or the ISAP Secretary/Treasurer, Valeria Montalescot. Their contact information's are given at the end of the newsletter.

With my warm regards

Céline Rebours

President, International Society for Applied Phycology

Message from the Editor, Sasi Nayar

Dear Colleagues,

It did not seem that long when we published the last issue of the newsletter towards the end of 2018. Time flies and before we realise, we are in the middle of the 'new year' proudly presenting you with the first issue of the newsletter for 2019. Whilst it is cold, wet and windy for some of us unfortunates in the Southern hemisphere, I am sure a good majority of you in the Northern hemisphere would be enjoying a great, long, warm, productive summer ahead!

The Editorial team is very pleased to bring you this issue of the newsletter. We have had an enthusiastic response to our request for articles, to the point that we have commenced collecting articles for the next issue. The response from the industry has also been encouraging. This gives the newsletter a great balance of commercial world realities complemented by the research that contributes to it. This is what our society is all about – applied phycology. If you want to contribute articles to the next issue, please do so before September in time for the end of the year issue. You will also find our newly drafted guidelines towards the end of the newsletter to make the submission and review process simpler.

First contribution in this newsletter is from the picturesque Emerald Isles in Ireland where González and Moejes provide us a very good and indepth snapshot of the state of play of the seaweed industry in Ireland followed by the applied phycology research undertaken at the Bantry Marine Research Station. Their research is focused on *Alaria esculenta* (aka Irish Wakame), an edible brown seaweed. The article illustrates the commercial potential of the seaweed with efforts undertaken in cultivating it on near-shore longlines and valorising the cultivated biomass. The second contribution is an industry snapshot from TNO in the Netherlands focusing on scaling-up of the seaweed biorefinery. This contribution includes a brief case study involving *Palmaria palmata* (Dulse) and the various biorefinery pathways that have been explored in conjunction with the production of biofuels. The third contribution is from the ENBIO project by Jubeau *et. al*. highlighting their experience in developing a project on circular economy in renewable energy. The project involves the production of *Arthospira platensis* on the West coast of Scotland adjacent to a wood-powered Combined Heat and Power (CHP) plant. Heat from the CHP plant is utilised by a local whisky distillery while the power was fed back into the grind. Instead of being wasted, because of limitations with the local grid, excess power generated, together with CO_2 from the distillery was utilised to operate the microalgal production system. The final article in this issue by Wang *et. al.* is the celebration of life and achievements of Professor C. K. Tseng, an acclaimed phycologist who contributed immensely towards the establishment of a seaweed industry in China and to our understanding of the life history of *Porphyra*. This article marks the 110th birth anniversary of Professor Tseng.

We hope you enjoy reading this issue of the newsletter that we have compiled. To conclude, I take this opportunity in thanking our hard-working colleagues from the Editorial team viz., Céline Rebours, Valeria Montalescot, Alexandra Busnel, Rémi Nghiem-Xuan and Sammy Boussiba for making this issue a reality. I look forward to your support for the next issue as well. Besides working on the newsletter Alexandra and Remi have been busy writing their thesis, defending it and publishing their research – a good example of multi-tasking! We wish them the very best.

Wishing all the very best until the next issue,

Sasi Nayar,

Editor of the ISAP Newsletter and Social media administrator

Seaweed: The Emerald Isle's untapped natural resource

SILVIA BLANCO GONZÁLEZ[1] AND FIONA WANJIKU MOEJES[1, 2]

[1]Bantry Marine Research Station Ltd. Gearhies, Bantry, Co. Cork, Ireland, P75 AX07
[2]Current address: Marine Programmes manager, Dahari, Mutsamudu, Anjouan, Comores
Contact: fiona.moejes@daharicomores.org

Ireland. The Emerald Isle. The land of 50 shades of green – and home to over 500 species of seaweed (Morrissey et *al.*, 2011). The Irish have been harvesting and utilizing this rich biomass for centuries with evidence of its use dating back to as early as the 12th century, where *Palmaria palmata* (Dulse or Dillisk or Duileasc in Irish) is described in an Irish poem (Figure 1)(Indergaard and Minsaas, 1991). The poem describes the work of monks, who amongst other duties, gathered and dried Dulse for distribution to the poor. Over time, the utilization of seaweed diversified. Most notably, the Irish began to utilize it as a fertilizer for the nutrient-poor soil found in the coastal farmlands where some types of brown seaweeds (e.g. *Ascophyllum nodosum* or Egg Wrack) were collected and placed on the land to rot into the soil before the new season's potatoes were sown. Around the mid-17th century, further uses were discovered for the large brown seaweeds found along the lower intertidal region. These seaweeds were collected and burnt in kilns to produce an ash called 'kelp', which was a source of potash (used in glazing pottery and making glass and soap) and latterly iodine (McErlean et *al*., 2002). Despite the dirtiness of the job, it was lucrative for a time. In fact, by the 18th century, the sale of kelp was the primary source of income for people in rural and remote parts of Ireland, particularly in the Aran Islands. The practice was so widespread, that the process gave the large brown seaweeds their generic name 'kelp' that is used today. Another alga with an important place in Irish history is *Chondrus crispus* or a very similar *Mastocarpus stellatus* (also known as Carrageen or Irish Moss), which was, and still is, prized for the gel that can be extracted from the dried seaweed. The use of Irish Moss in treating respiratory problems was first described in Ireland in 1810 and the name "carrageen," which in addition to its Irish language origins, may also stem from Carrigan Head in Co. Donegal, was first introduced around 1830. The relationship forged between Ireland and this seaweed was strengthened by the reliance on Irish Moss during Ireland's darkest hours – the potato famine that led to the Great Hunger (1846-1871) where it was one of the few sources of nutrition still available, at least to those living near the coast (Langan, 2019).

Seal ag buain duilisg do charraig,	A while gathering duileasc from the rock,
seal ag aclaidh,	a while fishing,
seal ag tabhairt bhídh do bhoctaibh,	a while giving food to the poor,
seal i gcaracair.	a while in a cell.
	Anon. probably 12th century

Figure 1: Poem with reference to Dulse (*Palmaria palmata*)

Fast-forward to 2019. As Irish consumer trends shift to traditional and natural products, seaweed is making a comeback with more and more seaweed-based products appearing in supermarkets and local market stalls. Worth over 23 million of Euro per year (Shannon and Abu-Ghannam, 2016), the sector is comprised of commodity products (high volume, low value; include animal feeds and plant supplements) and cosmetics products (low volume, high value; include therapy centres, seaweed baths and branded consumer products), as well as edible seaweeds (approximately 3 to 6 tonnes is consumed yearly in Ireland). The Irish seaweed industry utilises approximately 40,000 tonnes of seaweed biomass annually, the majority of which (over 95%) is made up of wild and mostly beach-cast *Ascophyllum nodosum*, used primarily as fertiliser or incorporated into livestock feed. Only 1% is processed into higher value compounds for pharma- and nutraceutical, cosmetics, and feed additives. This small percentage accounts for approximately 30% of the total commercial value (Walsh and Watson, 2011; Dring et *al.*, 2013; Walsh, 2016). With the domestic market largely saturated, there is a drive to increase the export market and Ireland currently exports its seaweed in bulk to 30 countries in South America, Europe, the Middle East and Asia. The European market includes the export of edible Irish kelp to Spain and France sold at 16€-19€/kg bulk dry. The sector employed approximately 185 full-time staff in 2011 (Morrissey et al., 2011).

Table 1: List of Irish seaweed industry players (compiled in 2017).

Name	Location	Sector	Number of employees
Arramara Teo	Connamara	Biotechnology/Alginate/Animal nutrition	10-50
Marigot Ltd	Carrigaline	Biotechnology	10-50
Oilean Glas Teoranta	Kilcar	Biotechnology	10-50
Brandon Bioscience	Tralee	Agronomic solution/ Plant care	10-50
BioAtlantis	Tralee	Biotechnology/Human nutraceuticals	1-10
CyberColloids Ltd.	Cork	Biotechnology/Hydrocolloids, focusing on food, nutrition and industrial applications.	1-10
Ocean Harvest Technology	Galway	Animal care/Animal nutrition	1-10
Kerry Healthcare	Kerry	Healthcare	1-10
Lotide Fine Foods Limited	Westport	Drying/Extraction	1-10
AlgAran	Donegal	Food/Cosmetic	1-10
Irish Seaweeds	Belfast	Food/Cosmetic	1-10
Sea Nymph	Galway	Agronomic solution	1-10
Rí Na Mara Irish Seaweed Cosmetics	An Spideal	Cosmetic	1-10

Globally, the seaweed bioeconomy is expected to rapidly increase to an estimated US$17.6 billion by 2021. In Ireland, the Sea Change Strategy stated that they aimed for the seaweed sector to reach a market size of €30 million by 2020 (Heffernan, 2006). However, wild seaweed stocks simply will not be able to fulfil the demand. Therefore, we must turn to cultivated or “farmed” seaweed. Ireland is working hard to meet the demand, and with less than six months to go to 2020, it hopes to support and expand the industry by granting numerous new licenses for seaweed farms totalling over 116 hectares (corresponding to approximately 145km of seaweed lines) at the end of 2018.

One of the first seaweed farms established in Ireland is based in the south-west of Ireland in Bantry Bay and is owned and run by the Bantry Marine Research Station (BMRS)(Figure 1). BMRS is a private company situated on the shores of Bantry and is focused on the delivery of marine bio-based products and processes. BMRS was incorporated in 2016 following a restructuring of the Daithi O’Murchu Marine Research Station Ltd (DOMMRS) which began its operations in 2005. Prior to that, it was in operation since 1991 as the University College Cork’s Aquaculture and Fisheries Development Centre. Working closely with Freddie O’Mahony from Cartron Point Shellfish Ltd and Lucy Watson from Ireland’s seafood development agency (Bord Iascaigh Mhara; BIM), BMRS began researching seaweed farming in 2004. It successfully developed cultivation protocols for cultivating *Saccharina latissima* on long-lines in Bantry Bay. This was followed by the development of methods for *Alaria esculenta* (Irish Wakame) and the first successful at-sea trial was achieved in 2014. *Alaria esculenta* is an edible brown seaweed that is high in calcium, B vitamins and trace metals. It is biologically and nutrionally identical to Japanese wakame, and is delicious in salads. There are very few natural sea forests of *Alaria.* At present, BMRS harvests over 10 tonnes of high quality *Alaria esculenta* from its long-lines in Bantry Bay annually.

Figure 2: Location of Bantry Marine Research Station (taken from https://www.worldatlas.com/webimage/countrys/europe/outline/ieout.htm)

To realise the potential of the seaweed biomass being cultivated at their sea site, BMRS began exploring the bioactive compounds present in *Alaria esculenta* in 2017 (Figure 3 and 4). Supported by BIM and the European Maritime and Fisheries Fund (EMFF), BMRS embarked on a three-year journey to identify seasonal variations of certain commercially valuable bioactive compounds present in *Alaria esculenta*. Generally, brown seaweeds (*Phaeophyta*) contain a number of bioactive compounds including polyphenols, carotenoids, polysaccharides, polyunsaturated fatty acids, and proteins (Balboa *et al.*, 2013). The compounds that BMRS is placing focus on are fucoxanthin, phlorotannins and fucans.

Figure 3: Harvesting of *Alaria esculenta* from near-shore long-lines in Bantry Bay with researcher Rémi Chausse (taken in 2017).

Fucoxanthin is a light-harvesting carotenoid found in the chloroplasts of brown seaweeds and diatoms. It is one of the most abundant carotenoids on Earth, contributing to more than 10% of the estimated total production of carotenoids in nature, and is responsible for the brown to yellow colour of brown seaweeds and diatoms (Matsuno, 2001; Hurd *et al.*, 2014). Research has shown fucoxanthin to act as an anti-oxidant, and as a chemo-preventive agent against obesity, cancer, inflammation, angiogenesis, and diabetes (Peng *et al.*, 2011). Global fucoxanthin production in 2015 reached 500 tonnes with an expected increase of at least 5.3% per annum between 2016 and 2021 (Joel, 2016). The total value of the carotenoid market rose from US$1.20 billion in 2010 to US$1.50 billion in 2014 (Ulrich, 2015). All the health benefits, coupled with a wholesale market price of around US$2,000 per gram (Kyndt and D'Silva, 2013), it is a no brainer why fucoxanthin is of serious commercial interest. And despite its recognition as a GRAS (Generally Recognised As Safe) compound by the European Food Safety Authority, Japan's Food for Specified Health Uses, and the US Food and Drug Administration, fucoxanthin remains underutilised in pharma- and nutraceutical, cosmetic, and feed/food industries

(Shannon and Abu-Ghannam, 2016). This is most likely due to the inefficient and costly extraction methods.

Figure 4: *Alaria esculenta* on long-lines (taken in 2013)

Phlorotannins are secondary metabolites found only in brown seaweeds (Shibata *et al.*, 2008). They are polyphenol compounds with one or more hydroxyl groups attached to a benzene ring (Sies, 2010). Research has shown phlorotannins to possess anti-bacterial, anti-oxidant, anti-fungal, anti-parasitic, anti-viral (including Human Immunodeficiency Virus; HIV), anti-diabetic, anti-inflammation as well as anti-allergic properties (Eom *et al.*, 2012). To date, only *Ecklonia cava*-derived phlorotannins are available on the market (SeaPolynol™).
Finally, fucans (or fucoidans) are a group of polysaccharides primarily composed of sulphated L-fucose commonly found in the cell walls of brown macroalgae, but not in any other algae or higher plants (Berteau and Mulloy, 2003). Although the major physiological purposes of fucans in macroalgae are not thoroughly understood, the presence of L-fucose as well as sulphate ester groups have a wide range of pharmacological and biomedicinal applications. The list of bioactivity of fucoidan for human and animal health is long, with fucans showing anticoagulant, antimicrobial, antiviral and anticancer properties (Chevolot *et al.*, 1999; Vera *et al.*, 2011).

Figure 5: A single 4-metre long blade of *Alaria esculenta* (taken in 2019)

Whilst the project is still on-going, some interesting results are coming to light. Initial data analysis has shown that the average yield of *Alaria esculenta* was 12kg of seaweed per 1m of line (Figure 5), and the highest quantity of fucoxanthin in our samples was 2.4g per 1m of line (or 2g per 1g of dried *Alaria esculenta* biomass). In-depth data analysis is still on-going and we hope to publish some lovely results soon.

Seaweed is making an appearance in a growing range of products – from soaps, shampoos and moisturisers; to smoothies, pesto and bread. Companies such as Wild Atlantic Seaweed Baths (http://wildatlanticseaweedbaths.com/) and WASi (seaweed pesto; https://www.wasi.ie/), and wonderfully successful seaweed cookbooks such as Prannie Rhatigan's 'Irish Seaweed Kitchen: the comprehensive guide to healthy everyday cooking with seaweeds' are helping to promote and broaden the use of seaweed locally in West Cork (Rhatigan, 2009). Such activities, coupled with research projects that are improving our understanding of the bioactives present in this untapped natural resource, is the key to stengthening the Irish seaweed industry.

REFERENCES

Balboa, E. M. *et al.* (2013) 'In vitro antioxidant properties of crude extracts and compounds from brown algae', *Food Chemistry*. Elsevier Ltd, 138(2–3), pp. 1764–1785. doi: 10.1016/j.foodchem.2012.11.026.

Berteau, O. and Mulloy, B. (2003) 'Sulfated fucans, fresh perspectives: structures, functions, and biological properties of sulfated fucans and an overview of enzymes active toward this class of polysaccharide', Glycobiology. Oxford University Press, 13(6), p. 29R–40R. doi: 10.1093/glycob/cwg058.

Chevolot, L. et al. (1999) 'Further data on the structure of brown seaweed fucans: relationships with anticoagulant activity', Carbohydrate Research, 319(1), pp. 154–165. doi: 10.1016/S0008-6215(99)00127-5.

Dring, M., Edwards, M. and Watson, L. (2013) Development and demonstration of viable hatchery and ongoing methodologies for seaweed species with identified commercial potential, Marine Institute Report no. 2009-3195. Dublin, Ireland.

Eom, S. H., Kim, Y. M. and Kim, S. K. (2012) 'Antimicrobial effect of phlorotannins from marine brown algae', Food and Chemical Toxicology. Elsevier Ltd, 50(9), pp. 3251–3255. doi: 10.1016/j.fct.2012.06.028.

Heffernan, P. (2006) Sea Change (2007–2013): A Marine Knowledge, Research & Innovation Strategy for Ireland. Oranmore.

Hurd, C. et al. (2014) Seaweed ecology and physiology. Cambridge: Cambridge University Press. Available at: https://books.google.com/books?hl=en&lr=&id=azPkAwAAQBAJ&oi=fnd&pg=PR13&dq=hurd+2014+seaweed&ots=53U4mK5Tr2&sig=_SN92IMS4r0JjtV5sE5iL_Cu_Qw (Accessed: 7 February 2017).

Indergaard, M. and Minsaas, J. (1991) 'Animal and human nutrition', in Guiry, M. D. and Blunden, G. (eds) Seaweed Resources in Europe: Uses and Potential. John Wiley & Sons.

Joel, J. (2016) Global fucoxanthin market 2016 industry trends, sales, supply, demand, analysis and forecast to 2021, Analysis and Forecast. New York. Available at: http://www.qyresearchgroup.com/market-analysis/global-fucoxanthin-market-2016-industry-trends-sales-supply.html (Accessed: 7 February 2017).

Kyndt, J. and D'Silva, A. (2013) Algae: coloring the future green. Moura Enterprises Publishing Division.

Langan, S. (2019) IC Health Month: Learn about the health benefits of Irish moss. Available at: https://www.irishcentral.com/culture/food-drink/health-benefits-irish-moss.

Matsuno, T. (2001) 'Aquatic animal carotenoids', Fisheries Science, 67(5), pp. 771–783. Available at: http://onlinelibrary.wiley.com/doi/10.1046/j.1444-2906.2001.00323.x/pdf (Accessed: 29 October 2015).

McErlean, Thomas, McConkey, R. and Forsythe, W. (2002) Strangford Lough: An Archaeological Survey of the Maritime Cultural Landscape. Blackstaff Press.

Morrissey, K., O'Donoghue, C. and Hynes, S. (2011) 'Quantifying the value of multi-sectoral marine commercial activity in Ireland', Marine Policy, 35(5), pp. 721–727.

Peng, J. et al. (2011) 'Fucoxanthin, a marine carotenoid present in brown seaweeds and diatoms: Metabolism and bioactivities relevant to human health', Marine Drugs, 9(10), pp. 1806–1828. doi: 10.3390/md9101806.

Rhatigan, P. (2009) Irish Seaweed Kitchen : The Comprehensive Guide to Healthy Everyday Cooking with Seaweeds. Co. Down: Booklink.

Shannon, E. and Abu-Ghannam, N. (2016) 'Optimisation of fucoxanthin extraction from Irish seaweeds by response surface methodology', Journal of Applied Phycology. Journal of Applied Phycology, pp. 1–10. doi: 10.1007/s10811-016-0983-4.

Shibata, T. et al. (2008) 'Antioxidant activities of phlorotannins isolated from Japanese Laminariaceae', Journal of Applied Phycology, 20(5), pp. 705–711. doi: 10.1007/s10811-007-9254-8.

Sies, H. (2010) 'Polyphenols and health: Update and perspectives', Achives of Biochemistry and Biophysics, 501(1), pp. 2–5.

Ulrich, M. (2015) The Global Market for Carotenoids - Report Code FOD025E, BCC Research. Available at: http://www.bccresearch.com/market-research/food-and-beverage/carotenoids-global-market-report-fod025e.html (Accessed: 7 February 2017).

Vera, J. et al. (2011) 'Seaweed Polysaccharides and Derived Oligosaccharides Stimulate Defense Responses and Protection Against Pathogens in Plants', Marine Drugs. Molecular Diversity Preservation International, 9(12), pp. 2514–2525. doi: 10.3390/md9122514.

Walsh, M. (2016) Seaweed Production in Ireland 2016. Galway, Ireland.

Walsh, M. and Watson, L. (2011) A market analysis towards the further development of seaweed aquaculture in Ireland. Galway, Ireland.

Scaling up your seaweed biorefinery concepts

JAAP WILLEM VAN HAL[1], PHD

[1]Innovation Manager Biorefinery, ECN part of TNO, The Netherlands.

Contact: biorefinery@tno.nl

An essential part of scaling up a sustainable novel seaweed biorefinery process is to perform each and every key processing step under realistic conditions. Furthermore, by producing at scale samples of the key intermediates of the envisioned process, prototypes of intended sustainable products can thus be produced with the actual realistic intermediates at hand.

The ECN part of TNO Biorefinery Team, has opened a new seaweed processing facility (Figure 1). The new scale-up facility offers entire processing chain for the conversion of seaweed into products such as carbohydrates, platform chemicals, plant stimulants, fibers or proteins. The facility can process up to 50 kg of wet seaweed per day to demonstrate the batch production of key intermediates and products. This facility is intended to accelerate the development of novel seaweed-based products and processes.

The case study below highlights the production of more than 100 L of concentrated desalted sugar syrup

Figure 1: Impression of the ECN part of TNO seaweed processing lab (Photo TNO).

from the red seaweed *Palmaria palmata* (Dulse) as part of the H2020 project, MacroFuels. Dulse is a high xylose-containing red seaweed that contains little or no other ionic polymeric recalcitrant carbohydrates. Xylose is the precursor for the chemical building block furfural, which is seen as one of the key intermediates to the transition to sustainable aromatic intermediates. Routes to and from those intermediates are being developed in the Biorizon program, which paves the way to profitable bio-based aromatics.

Furfural can be converted to various advanced biofuels among which is the reductive etherification of fuel alcohols to highly effective tetrahydrofuran-based fuel additives. An effective route to liberate most of the xylose in a form suitable for conversion to furfural as well as a substrate for fermentative conversions was developed under MacroFuels. Xylose containing syrups were effectively processed in the seaweed laboratory, where the salt concentration was reduced to levels suitable for fermentation while simultaneously reaching sugar concentration of over 60 g L^{-1}. These processing steps were executed at a scale of 50 kg wet weight of seaweed in several batches and processing stages. Upon purification, the process yielded more than 100 L of desalted syrup suitable for fermentation.

Figure 2: Inspecting the seaweed (Photo TNO, top left); Loading the extractor (Photo Agnes Kappert, top right); Distilling the fuel component (Photo Agnes Kappert, bottom left). Running the membrane unit (Photo Agnes Kappert, bottom right);

The conversion of xylose syrup to furfural was effectively scaled up from 100 mL to 20 L scale using a batch bi-phasic reaction system yielding furfural in an extractive phase. The use of a bi-phasic system prevents further reaction of the formed furfural to unwanted condensation products. Essential differences were found in the amenability of seaweed-derived syrups obtained at either small or large scale, demonstrating that syrup purification is an essential element of thermo-catalytic conversion routes (figure 2). Detailed results were presented at the ISS2019 as well as EUBCE 2019. For further information on the results contact the author.

Link to the video : <https://www.youtube.com/watch?v=Yb9JApeb7Bw&feature=youtu.be>
Link to the brochure : https://mailing.tno.nl/ct/m8/k1/D8yf3cBhVG2ldRusK_2XeuEInzMg5PSkutCCzPf4rdbpARg8gx8MiG7qYkVy-EEx/JPRnX7DjrCtQhZp

Production of microalgae in a circular economy approach using renewable energy – ENBIO project

SÉBASTIEN JUBEAU[1], LAURENCE EVANS[1], INMACULADA TOCINO MARQUEZ[1], LAURENCE MURRAY[1], LYNDA MITCHELL[2], CAROLE SHELLCOCK[2], EAMONN COUGHLAN[3], WILLIAM KELLY[3], DOUGLAS MCKENZIE[1].

[1] Xanthella, Malin House, European Marine Science Park, Dunstaffnage, Oban, PA371SZ, Scotland
[2] ALIenergy, Malin House, European Marine Science Park, Dunstaffnage, Oban, PA371SZ, Scotland
[3] Ardnamurchan Estate, Mingary Steading, Kilchoan, Acharacle PH36 4LH, Scotland
Contact: sebastien@xanthella.co.uk

Context

Microalgae are photosynthetic organisms that can be used for many applications including food supplements, aquaculture feed and bio-stimulants. Although some microalgae can be grown heterotrophically, the industrial production of microalgae is currently undertaken autotrophically using natural sun light, except for some very high value strains, in order to reduce manufacturing cost. This means production occurs mostly in places with strong solar irradiation like Hawaii, Israel, China, Spain or Portugal. Scotland is not one of these places as the solar potential during summer or winter is quite low. Therefore, Scotland doesn't seem to be a good place to autotrophically produce microalgae. Nevertheless, Scotland has other resources that can be used to grow microalgae. Indeed, with abundant water and wind, Scotland can produce vast amounts of cheap renewable energy (Figure 1) that can be transformed into artificial light. Scotland also has a large number of distilleries that produce almost pure CO_2 through the fermentation process - a carbon source essential for autotrophic microalgae production.

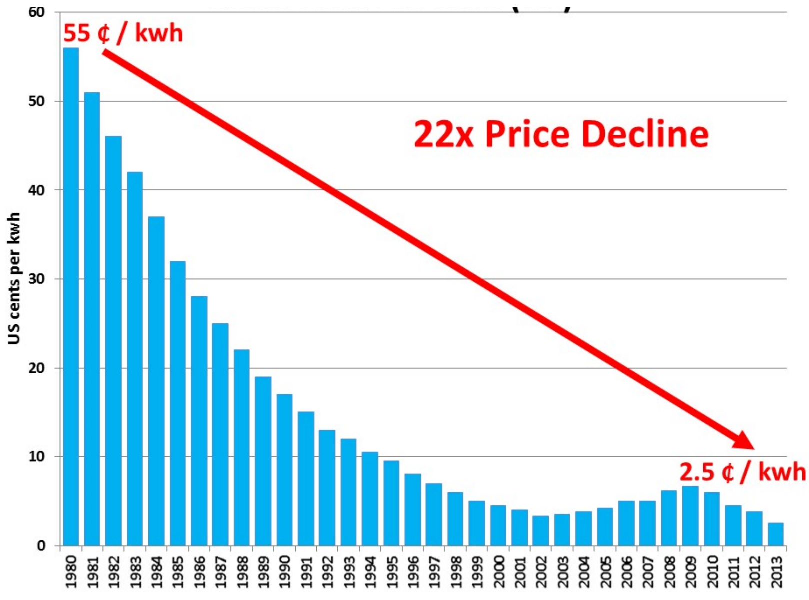

Figure 1: Evolution of the wind cost per kWh in United States.

The objective of the ENBIO project, funded by Zero Waste Scotland, is to assess the economic reliability of microalgae production in Scotland in a circular economy approach using local resources. Many of the areas with high potential for renewable energy production are rural and suffer from grid constraints and curtailment that prevent the development of large sustainable energy production projects. Electricity grid constraints can be overcome by using the renewable energy at source, to generate revenue and to offset costs. The ENBIO project will use locally available renewable energy to power newly developed photobioreactors (***Pandora PBR**^{TM}*), with submerged LED light tiles, to grow microalgae whilst also providing demand side management and grid balancing services. Capture of CO_2 from the distillery fermentation process will also be assessed.

Pandora PBR™

The main factor affecting productivity in a photobioreactor is the ratio of illuminated surface/volume (S/V). The microalgae production systems using natural sunlight, like raceways ponds or tubular PBR, have a huge footprint and a low S/V ratio because they need to get as much light as possible from only one source, the sun. When using artificial light, you can drastically reduce the footprint of the system and increase the S/V ratio by having multiple light sources. The *Pandora PBR™* has been designed in order to have a small footprint (around $1m^2$) but high productivity ($8m^2$ illuminated area for a culture volume of $1m^3$). The PBR consists of a GRP tank with internal and submerged light tiles that provide light directly to the algae (Figure 2). The light tiles are composed of numerous white LEDs that can provide up to 1000µmol of photons/m^2/s. One of the advantages of the LEDs is that they can be turned off and on very quickly and can respond rapidly to the variation in the renewable energy production.

Figure 2: Inside views of a Pandora PBR™.

Another advantage of the LED is their cost and their efficiency. In the past few years, the production costs of LEDs have dramatically decreased whilst their efficiency has increased (Figure 3), in turn reducing the PBR manufacturing cost substantially.

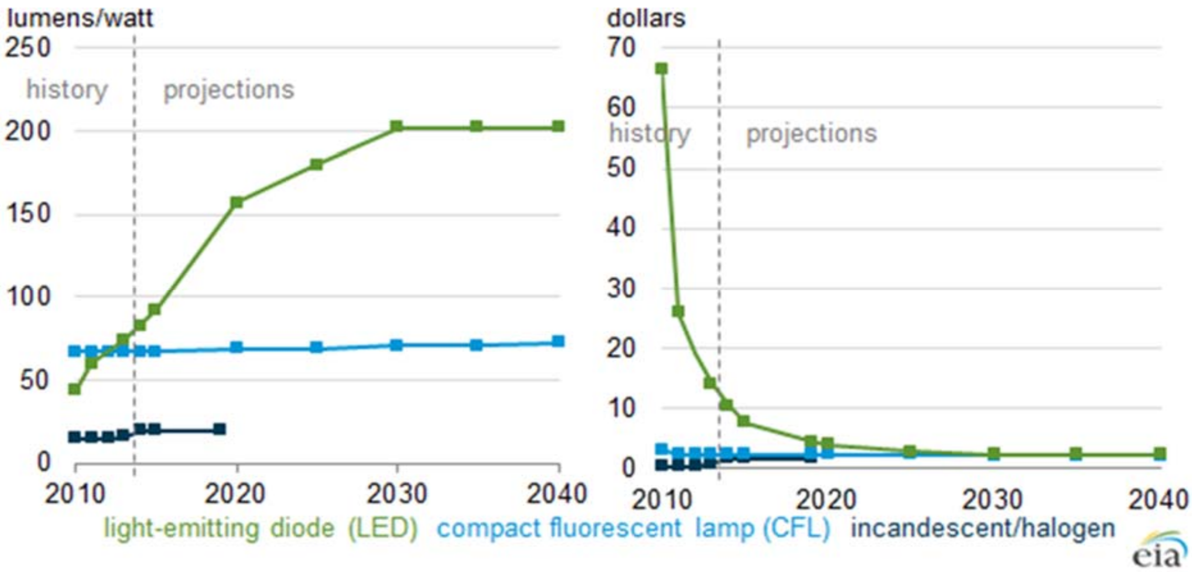

Figure 3: Average light efficiency (light output per energy consumed) and cost per bulb.

The Pandora PBR™ is food grade in order to be able to target microalgae production for various applications. The culture conditions such as light, pH and temperature are fully controlled in order to provide the best growing conditions to the algae and to adjust the parameters according to the renewable energy production.

Implementation

Within ENBIO, a pilot site for integrated algal biomanufacturing is being established on the Ardnamurchan peninsula, West Coast of Scotland. The area has an abundance of biomass, which the local estate intended to use for renewable energy. However, progress was hindered due to grid constraints. The ENBIO model was applied to resolve issues whilst simultaneously creating multiple additional local benefits such as use of stranded timber resource; incorporation of waste streams; creation of new industry and jobs; production of valuable, quality-controlled end-products with provenance for many potential markets.

On the Ardnamurchan estate, local timber is used to power a 210kW woodfuel CHP plant. The heat generated is used to concentrate the pot ale from the local whisky distillery and to dry the draff to produce animal feed. The electricity generated at the same time is used to power the whole site and is partially fed back into the grid. Nevertheless, because of the grid constraints, a lot of electricity is lost. To overcome this loss of energy, the CHP plant has been connected to the microalgae plant. The surplus power will now be used to power the PBR.

Figure 4: Installation of 16 Pandora PBRTM in Ardnamurchan shed.

The microalgae production plant has been installed in a shed next to the CHP unit. Sixteen PBRs are being installed in on a two levels rack in order to minimise to global footprint of the system. Thanks to their design, the tanks can be easily moved by a forklift for cleaning or for maintenance (Figure 4).

Microalgae production and economic reliability

The strain selected for the validation of system productivity and for overall reliability of the system was *Arthrospira platensis* (Spirulina). The first trials performed at laboratory scale registered a productivity of 0.250g/L/day that could be achieved on site taking into account the labour force available on site to operate the production plant. The yearly production of the biomass will enable capture of CO_2 produced during the manufacturing of 1700 litres of whisky.

These results will be compared with productivity data obtained in Ardnamurchan by the end of August 2019. These productivity data will be integrated in a techno-economic model to assess the parameters affecting the economic reliability of microalgae production using renewable energy. If the results are encouraging, the consortium will transpose the model to other places in Scotland and elsewhere where renewable energy is available. This approach could change the microalgae production in a global landscape.

In Memory of Professor C. K. Tseng

GUANGCE WANG[1], XIUGENG FEI[1] AND CÉLINE REBOURS[2]

[1] Institute of Oceanology, Chinese Academy of Sciences,Qingdao 266071, China
[2] Møreforsking Ålesund AS, Norwegian Maritime Competence Centre, 6021, Ålesund, Norway
Contact: gcwang@qdio.ac.cn

June 18, 2019 marks the 110th anniversary of the birth of eminent phycologist Professor C. K. Tseng (1909-2005) (Figure 1). During his 76-year career in marine biology, Professor Tseng made groundbreaking contributions to research and development of algae, especially marine algae. In this article, we outline Professor Tseng's research career and highlight some of his contributions to applied phycology.

Figure 1: Portrait of Pr. C. K. Tseng.

Professor Tseng commenced his career in marine biological research in 1927 when he was a student of the Department of Botany at Amoy University. In 1942 he was awarded his doctoral degree by the University of Michigan. He published his first article entitled '*Gloiopeltis* and other economic marine algae in 1933. He then intensively researched macroalgae taxonomy and carried out extensive investigations into macroalgal resources, all the while nurturing future generations of Chinese phycologists. Together with his colleagues, he investigated macroalgae flora and phytogeography in China, resulting in discoveries of more than 100 new species, two new genera, one new family and a new record for a phylum (formerly Chlorophyta) (Figure 2).

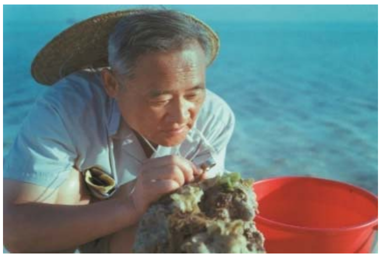

Figure 2: Professor C. K. Tseng sampling marine algae in Xisha Islands in 1979

In addition to furthering fundamental marine biology research, Professor Tseng's noteworthy contributions also included the development and establishment of a viable seaweed mariculture industry in China. This began with the cultivation of *Laminaria japonica* (now named *Saccharina japonica*) with innovative techniques, that included,

1. Enabling the growth of *Laminaria* in warmer open sea: The summer sporeling method, which acclimatizes the early developmental stages of temperate *Laminaria* to cold waters (10°C) followed by stimulating growth during the nursing stages in much warmer waters of about 20°C, before final transplantation in open sea.

2. Solving the problem of large-scale fertilization in oceanic cultures of *Laminaria* by using porous clay pots filled with nitrogen fertilizer suspended on cultivation rafts.

3. Extending commercial cultivation of *Laminaria* from cold temperate waters to the subtropics: Research by Professor Tseng and his colleagues not only allowed cultivation of cold water *Laminaria* in temperate waters of the Yellow Sea, but also in the subtropical waters of Zhejiang and Fujian provinces in the East China Sea.

Adoption of these methods brought about a production upsurge in *Laminaria*. Fujian Province has since become the main producing area of *Laminaria* in China, helping China attain the status as one of largest seaweed aquaculture producing countries in the world.

In 1952, Professor Tseng's research group and Professor Kurogi's group in Japan independently made a breakthrough in elucidating the complex life cycle of the purple laver *Porphyra*. Based on the pioneering work of K. M. Drew in 1949, the two research groups confirmed the origin of spores that developed into blades. They concluded that *Conchocelis rosu*, which Drew did not think to be a separate species, was in fact the shell-boring stage in the life cycle of *Porphyra* that forms and releases spores and finally develop into the leafy plant, resolving ambiguity on the origin of the *Porphyra* spores. Professor Tseng named these the 'conchospores'. With this discovery, Tseng, together with Drew and Kurogi, illustrated the life history of *Porphyra*. Based on these findings, Tseng and his colleagues further devised methods for both the semi-artificial collection of seedlings and the total-artificial collection of seedlings. These advances solved the production bottlenecks encountered in the cultivation of *Porphyra*. Professor Tseng's group, jointly with the efforts of other phycologists and industry departments, established a viable *Porphyra* farming industry in China.

Scientific breakthroughs in basic and applied phycological research by Professor Tseng and his colleagues provided the necessary enablers to pave the way forward for successful large-scale sea farming and sea ranching. Macroalgae production, coupled with integrated production of selected marine species, led to the upsurge in the production of shellfish, shrimp and fish (Figure 3). Today, *Laminaria* alone accounts for half the total Chinese aquaculture production, making China the top producer of seafood products in the world (FAO statistics, 2019).

Figure 3: A photograph of 90-year-old professor Tseng still at work

Professor Tseng paid close attention to the development and utilization of macroalgae resources around the world. During World War II, Japan, the main producer of agar in the world, cut back supply of agar. Professor Tseng, who was then working at the Scripps Institution of Oceanography, University of California San Diego began to investigate various marine algae for agar production. Professor Tseng identified *Gelidium* to be the best candidate species for agar production. He then applied study to the methods and practices of mariculture of *Gelidium* thereby preventing a short supply of agar in the USA. Shortly after the war, Professor Tseng returned home to China.

As early as 1954-1956 at the Institute of Oceanology, Chinese Academy of Sciences, Professor Tseng, together with his colleagues and students, successfully utilized a local seaweed *Sargassum confusum* as the raw material for extraction of alginates. The use of alginate eventually replaced the traditional use of starch as sizing material. In 1958, Professor Tseng and his colleagues successfully switched to using *Laminaria japonica* as a raw material for alginate production in the light of dwindling supplies of Sargassum. They further developed methodologies for comprehensive utilization of the biomass for the production of essential products such as iodine and mannitol, for applications in medicine, food and feed. They lowered the cost of alginate production and assisted with the establishment of China's first alginate production base in Qingdao City, Shandong. By the end of Professor Tseng's professional career, the first production base, in conjunction with 20 subsequently established factories, made alginate production in China the second highest in the world. As of 2003, the total alginate production amounted to 15,000 million tons, constituting about 40% of the total global production. China today exports about 80% of alginate produced to some 30 countries in the world (data from Seaweed Chemistry Research Center, Institute of Oceanology, CAS).

During the period of 1986-1991, Professor Tseng and his colleagues initiated a research project aimed at using microalgal feed to replace imported fish meal. They selected a special strain of *Spirulina* that could be cultivated in seawater and contained much higher protein and phycocyanin levels than freshwater strains. The research led by Professor Tseng helped to successfully establish a flourishing seawater *Spirulina* cultivation industry.

Many notable phycologists and marine scientists in China received their doctoral degrees under the guidance of Professor Tseng. He was also recognized internationally. He successfully promoted programs of scientific cooperation and exchange between China and other countries, such as the United States, Canada, United Kingdom, Japan, France and Germany. He also led and sponsored international meetings that were hosted in China, including the Sino-American Phycological Seminar, the 11th International Conference on Phycology, the 5th World Conference on Algae, and Sino-Japanese Algae Gene Engineering Symposium. Professor Tseng's efforts in international exchanges put a spotlight on the work of Chinese scientists resulting in international recognition. As far as honors from international scientific bodies go, Professor Tseng was elected Fellow of the Third World Academy of Sciences in 1985, President of the International Phycological Society in 1986 and Honorary Life Member of the World Aquaculture Society in 1991.

To further China's academic contributions worldwide, Professor Tseng established the publication of the English version of the Chinese Journal of Oceanology and Limnology (CJOL) in 1982. He served as its Editor-in-Chief from its inception to 2002. To expand the profile of the journal, he recruited well-known national and international scientists to join its editorial board. Professor Tseng's efforts over the years contributed to China being placed among the world's best in marine and limnological sciences.

The 110th birth anniversary of Prof Tseng was marked by a symposium at the Institute of Oceanology, Chinese Academy of Sciences on the 18th of June 2019. The symposium was followed by the unveiling of his bronze statue (Figure 4).

Figure 4: Symposium marking the 110th Birth anniversary of Prof. C. K. Tseng's on June 18, 2019 (left); Bronze statue of Professor C. K. Tseng at the Institute of Oceanology, Chinese Academy of Sciences (IOCAS). This photograph shows his relatives standing around the memorial (right).

News and Views

The 7th International Society for Applied Phycology congress will be held in Japan from the 20th to 24th April 2020.

Prof. Dr. Makoto M.Watanabe, Mitsuru Izumo and the ISAP Executive Committee are pleased to invite you to the next international applied phycology congress bearing the theme ‘The benefits of algae to all humankind’.

Prof. Dr. Makoto M. Watanabe
Co-chair of Local Organizing Committee of ISAP-7
Director of ABES, University of Tsukuba
Managing Director of AIIC Japan

Mitsuru Izumo
ISAP 2020 Local Organizing Committee
President of euglena Co., Ltd

This congress will be at the Makuhari Messe International Exhibition Hall in the outskirts of Tokyo.

The call for abstracts will be made soon. The organising committee look forward to receiving your abstracts and participation in the congress. For any further information, visit our webpage: https://isap2020-phycology.org/

Seaagriculture 2019: 8th International Seaweed Conference 'Seaweed Success Stories', 25 – 26th September 2019 in Ostend, Belgium

The conference gathers top speakers, who will share their know-how within seaweed for feed, food, offshore cultivation, biorefinery of seaweed and much more. Don't miss this unique opportunity to network with colleagues from all over Europe within industry and research. The two-day program will go into the many different applications of seaweed that exist now and will combine plenary sessions with interactive poster presentations, trade shows and debate sessions, among others.

Further information: https://seagriculture.eu/home/

The 10th Asia-Pacific Conference on Algal Biotechnology, 27 – 30th September 2019 in Nanchang, PR China

The theme of the conference is 'Accelerating Novel Algal Research and Sustainable Development for a Better Environment'. This conference aims to provide an open platform for communication and sharing of information in the field of Algal Biotechnology, so as to promote the cooperation among academic institutions, government organizations and industries.

Further information: http://apcab2019.csp.escience.cn/dct/page/1

Aquaculture Europe 19: Our future growing from water, 7 - 10th October 2019 in Berlin, Germany

The Aquaculture Europe events are all about communication with the sector. AE2019 will feature a special international trade exhibition, where German and international companies will present their latest products and services.

Further information: https://www.aquaeas.eu/uncategorised/402-welcome-to-aquaculture-europe-2019?fbclid=IwAR3mZelDeWfcUHk4Ee3_tMFHT3H9uPDczTC4omIqYb1N0GxcsCtOhcgHA6o

---

Nordic Seaweed Conference 2019, 9 – 10th October 2019 in Grenaa, Denmark

The topic of this year's conference will be 'Meeting the UN sustainability goals by Innovation in Macroalgae as a Bioresource'.

Further information : http://www.algecenterdanmark.dk/conferences/nordic-seaweed-conference-2018.aspx

---

EABA Spirulina workshop, 13-14th November 2019 in Montpellier, France

The European Algae Biomass Association (EABA) aims to promote a strong links between science, technology and business in the algae biomass sector. Many workshops have been organized. The following workshop will be held in the immediate future:

Further information: https://algaeurope.org/

AlgaEurope 2019, 3-5th December 2019 in Paris, France

A conference of relevance to European applied phycologists. AlgaEurope 2019 is a unique opportunity to learn and understand about bottlenecks in algae production as well as commercialization. One could expect to interact with over 300 key players from over 43 countries.

Further information: https://algaeurope.org/

International Society for Applied Phycology (ISAP) Newsletter Article Submission Guidelines

Contributing an article to the ISAP newsletter

Members or non-members of ISAP are welcome to contribute articles, news clips or announcements to the newsletter. We do particularly encourage undergraduate and graduate students to contribute.

Past issues of the newsletter

Archives of the newsletter can be accessed on our website:
https://www.appliedphycologysoc.org/newsletters

Frequency of publication

Biannual.

The audience

The newsletter is read by about 600 members of the ISAP who are applied phycologists from universities, research institutes, industry, policy makers and other algae enthusiasts. It is also read by those who frequent our Facebook and LinkedIn in page where the newsletter is uploaded. The newsletter can also be accessed through National Library of Australia (NLA), as part of the agreement for the issue of the ISSN number.

Type of articles

We solicit and publish technical articles pertaining to applied phycology from any type of ecosystem. Each issue typically comprises two articles, one on microalgae and the other on macroalgae.

Other types of contributions may include announcements pertaining to conferences, workshops, symposia, training courses and events, project updates, book reviews as well as review of technology and services.

Article formatting

All submissions should be in **MS word (.doc or .docx) format typically of 250 – 2500 words**. Word files should be named with the surname (family name) of the corresponding author e.g., Camello.docx.

Please format your article in plain font ideally using **Times New Roman, font size 11**. Please bold titles and italicize sub-titles. Use appropriate symbol font for units. Please avoid the use of excessive space between characters or words. ISAP newsletter adopts metric unit of measurement. Scientific names should be in full, with genus and species in italics.

The manuscript should be organized as follows

- Title
- Author list with affiliation and corresponding author
- Summary or Abstract
- Main body of the manuscript
- Conclusions and/or recommendations
- Acknowledgments (optional)
- References
- Tables (optional)
- Figures (optional)
- Figure captions (optional)

Title
Typically **100 characters**, in bold.

Authors and affiliation
Each article should list all authors with their first name and middle name abbreviated. Superscripts may be used to indicate the institutional affiliation of the authors. An asterisk symbol is used to highlight the corresponding author and their contact email ID. For e.g.,

N.V. Thomas[1], K. R. Roman[2] and A. R. Camello[3*]
[1]Affliation of first author with institutional address
[2]Affliation of second author with institutional address
[3]Affiliation of third author with institutional address

*Corresponding author: camello.a@aad.gov.au

Summary or Abstract
A summary or abstract, typically **100-150 words** should summarize what the article is about and the salient findings.

Main body of the manuscript
The articles must be written in plain English with the broad objective of conveying technical information that can be understood by non-specialists and the general public. Technical jargon should be avoided. Figures and tables may be cited in the main body of the manuscript, but must not be embedded. Similarly, in-text citation of references must be adopted. In-text citations should follow the author-year format. For e.g., (Roberts and Emilio, 2003).

Conclusions / Recommendations
No more than 50 – 100 words with closing opinion with recommendations for further work.

References
Citations need not be extensive and may be restricted to pertinent reviews or those applicable to the subject matter. Only literature cited in the main body of the manuscript should appear in the reference list. The citations should be listed **alphabetically and chronologically**. The format adopted by the newsletter is as below:

Journal article
Thomas, P.A. and Oscar, M.A. 2005. Culture of *Nannochloropsis gaditana* in bubble column reactor. Journal of Applied Phycology 134: 31-38.

Book
Whatman, C.F. 2008. Pond water quality. CRC Press, Boca Raton, FL, USA. 455p.

Book chapter
Michaelis, M. 2008. Bacterioplankton in aquaculture ponds. 48 -52pp In: Pond water quality, Whatman, C.F. (Ed.). CRC Press, Boca Raton, FL, USA.

Report
Roman, H.G. and Pete, G.S. 2012. Seaweed cultivation in ponds. Report no. RD12/0208-1. Environmental Protection Authority, Canberra, ACT, Australia. 80p.

Tables
Small, concise tables that complement the data in the text are encouraged. Tables may be created using the word table tool. Tables must **be submitted separate to the main manuscript** and must contain the tile.

Photos / Figures / Images / Line art
Photos or image files should be of high resolution (typically >300dpi), in colour or Black and white (B&W) and should be supplied in **.jpg** or **.tiff** or **.png** format. Up to 15 figures or images can be included with each article. Image or photo files should be labelled with the surname (family name) of the corresponding author followed by the Figure number for e.g., **McTierFigure1.jpg**

Figures or photographs used in the manuscript should have in-text citation. Please do not embed photos or images into the main body of the manuscript. Figure legends or captions should be in word format with the description of each of the figure used. The photographs or figures used must be original and must have been taken by one of the co-authors. If not, the owner, the source of the photograph or figure must be acknowledged.

Copyrights and ownership

All materials submitted must belong to the authors. If not, contribution from other parties must be clearly acknowledged in the article. The corresponding author takes all responsibility pertaining to compliance with copyrights and permission to publish the material, when an article is submitted to the newsletter for publication.

Submitting an article

If the complete submission, that includes the manuscript, tables and figures, are <10Mb we encourage the corresponding author to attach the manuscript and the supporting files to an email message and email to the Editor at sasi.nayar@sa.gov.au If the files are too large to be communicated over email, please let the Editor know. We will then create a secure folder on OneDrive and share it with you for the files to be dropped and shared with the Editorial team.

ISAP Contacts and Officers

President: Dr. Céline Rebours
Møreforsking Ålesund AS
Postboks 5075, Larsgården, 6021 Ålesund, NORWAY
E-mail: celine.rebours@moreforsk.no
http://www.moreforsk.no/

Vice President (Outgoing President): Prof. Roberto De Philippis
Department of Agrifood Production and Environmental Sciences (DISPAA)
Florence University, Piazzale delle Cascine 24; I-50144 Firenze - ITALY
Tel: +39 0552755910
E-mail: roberto.dephilippis@unifi.it
http://www.dispaa.unifi.it/

Vice President (President-elect): Dr. Qiang Hu
Professor and Director
Center for Microalgal Biotechnology and Biofuels
Institute of Hydrobiology, Chinese Academy of Sciences
7# Donghu South Road, Wuchang District
Wuhan, Hubei 430072, China
Tel.: +86-138-1140-6745
E-mail : huqiang@ihb.ac.cn

Secretary/Treasurer: Dr. Valéria Montalescot
Project Manager for Global SeaweedSTAR
Scottish Association for Marine Science
Scottish Marine Institute
Oban, Argyll PA37 1QA, UK
Tel.: +44 1631 559205
E-mail: secretary@appliedphycologysoc.org

Editor, ISAP Newsletter &
Social media administrator: Dr. Sasi Nayar
Algal Production Group
South Australian Research and Development Institute - Aquatic Sciences
2 Hamra Avenue, West Beach, SA 5024, AUSTRALIA
Tel : +61 8 8429 0785
Fax : +61 8 8207 5415
E-mail : sasi.nayar@sa.gov.au
http://pir.sa.gov.au/research