70th British Phycological Society Winter Meeting Abstracts

Harnessing algal solutions towards a sustainable future

4th-7th January 2022

Presidential Address

Jason Hall-Spencer: An overview of shallow water CO2 seep studies worldwide

This presentation will cover some of the approaches that have been used to assess the effects of ocean acidification as well as other stressors using areas acidified by underwater volcanoes. A major advantage of such work is it shows which marine organisms can survive and what coastal habitats might look like in the coming years. These systems can also be used to assess effects on ecosystem services and how people might be affected by the consequences. As carbon dioxide levels increase this benefits some organisms but it causes an overall loss of marine biodiversity, both in temperate and in tropical systems. Key groups, like hard corals, sea urchins and coralline algae, are often lost and the diversity of fish and their reproduction are impacted. This talk will highlight the diverse methods used to quantify the abundance and diversity of biota along these natural gradients in carbonate chemistry, the use of settlement substrata, reciprocal transplants, physiological studies as well as molecular and 'omics approaches. The talk will present the results from kelp herbivory experiments from Agostini et al. (2021) and coralline algal molecular work by Pena et al. (2021) published in Global Change Biology – and set out opportunities in a newly funded project called 'ICONA' that provides an opportunity to replicate these studies worldwide.

Sustainable Food Systems

Cat Wilding: Seaweed Cultivation in South-West England – recent research highlights and emerging activities

The cultivation of macroalgae is an emerging field in the UK and across Europe. Sustainable cultivation has the potential to increase production, whilst simultaneously protecting natural seaweed populations, associated biodiversity and ecosystem services. Applications for cultivated seaweed biomass include human food, animal feed, biofuels, cosmetics, nutraceuticals, and bioactives, as well as potential for carbon sequestration and eutrophication management. However, commercialisation is held back by barriers including the high laboratory costs associated with traditional 'twining' seeding methods, biofouling impacts on product quality, and a limited number of species for which established protocols exist. Here, research on macroalgal cultivation is summarised with a focus on activities from the past five years in Cornwall and Devon. Trials exploring seeding method, seeding density, and biofouling community development of cultivated *Saccharina latissima* are outlined, along with initial work into Harmful Algal Bloom mitigation. Two recently completed reports, and the development of novel cultivation species are introduced, and future research directions discussed.

Jessica Adams: Composition variation in commercial red seaweeds through growth for alternative final products

Commercial red seaweeds *Kappaphycus alvarezii (cottonii)* and *Eucheuma denticulatum (spinosum)* are the main carrageenan-yielding cultivated species in the Philippines and other east Asian countries. Grown vegetatively, small pieces of mature seaweed are tied to ropes and placed back in the sea for an average of 45 days before being harvested and the ropes re-seeded with new pieces of seaweed. In a recent collaboration, seaweed farmers in the Philippines harvested seaweed throughout this growth period to ascertain how the composition of these seaweeds changes and if, by harvesting earlier due to adverse weather conditions or deteriorating seaweed (e.g. ice-ice disease prevalence) these 'juvenile' seaweeds could be more suited to alternative uses than the existing carrageenan industry. This presentation will report on the differences in composition found between the seaweeds through this growth time period from seaweeds grown in the cold water season (Feb-March 21) and the warm water season (May-June 21).

Kasper Brandt: Kelp gametophyte growth under different nitrate conditions and reduced salinity levels

There is increasing interest in European seaweed production for food, bioremediation and phycocolloid production. Selection of a suitable site to cultivate seaweeds is one of the most important decisions for the success of a seaweed farm, with nutrient concentrations being essential to maintain high growth rates. Estuaries could provide a suitable location for seaweed farms because of their increased nitrate concentrations due to runoff from terrestrial systems. However, the reduced salinity in estuaries can cause stress in kelps by disrupting their internal osmotic pressure. There has been limited research

on how reductions in salinity affect the growth of kelp gametophytes. In this study I tested the tolerance of the gametophytes of three key kelp species (*Laminaria digitata*, *L. hyperborea* and *Saccharina latissima*) to salinities and nitrate conditions typical for an estuary. Spores of these three species of kelp were released and settled on glass slips in a multifactorial experiment with 4 salinities (16, 22, 28, 34 ppt) and 2 nitrate concentrations (1.6 & 9.7 µM) (values representative of those in the Milford Haven Waterway), as well as a control with F/2 medium. Five replicates of gametophyte solutions per treatment were grown at 12 °C at an irradiation of 50 µmol m^{-2} s-1 with a photoperiod of 12L:12D. Settlement and germination were measured after one, and seven days respectively. Gametophyte growth was quantified by measuring their two-dimensional surface area under a microscope every 10 days for 30 days. Spore settlement remained high regardless of salinity and nitrate conditions, but germination rates were reduced in all species when salinity was at 16 ppt (6 to 23% compared to control germination rate). Growth rates of gametophytes were reduced in lower nitrate concentrations, as well as reduced salinities, but the effect of nitrate was much stronger. These results indicate that salinity is the main factor influencing the germination of spores in the species tested, but once a gametophyte has been attached to a substrate growth is mostly influenced by nutrient conditions. This means that estuaries could be suitable for kelp farming, but more research is needed into how fluctuations in salinity impact kelp growth.

Philip Kerrison: Lifecycle control of *Palmaria palmata*: Progress towards a contained seedstock for cultivation

The red macroalga *Palmaria palmata*, is a highly desired species for cultivation as a food across Europe; both in the sea and in land-based tanks. Kelp cultivation is becoming standardised with reliable methods in place, allowing a basis for continual refinement. In contrast, significant hurdles still exist regarding *P. palmata* which are hampering cultivation and research efforts. Hortimare is a supplier of high-quality seaweed seed for the cultivation industry, with a long-term view on the direction of the industry. We see great potential in the cultivation of red species such as *P. palmata*. Yet, *P. palmata*'s unique lifecycle makes seed supply and seedstock storage challenging; it also requires careful consideration on future breed strategies to address industry needs.

In this presentation, we will first discuss specific research challenges that must be overcome to convert *P. palmata* cultivation from a wild seed-reliant, linear and unreliable process, into a dependable, closed-loop commercial activity. We will then outline the progress by Hortimare's dedicated red seaweed team towards addressing specific challenges regarding: controlled fertility induction, tissue propagation, bio-control and life stage identification. Hortimare welcomes opportunities to discuss collaboration.

Pippa Moore: The impacts and recovery of *Lessonia trabeculata* to kelp harvesting in Chile

Kelp harvesting is an important industry in Chile with 288,000 dry tons of kelp harvest per year, valued at US$90M and directly employing over 13,000 people, most of which make a subsistence living. Since 2003, there has been an increase in the wild harvest of the subtidal kelp *Lessonia trabeculata*. Anecdotal evidence suggests increased harvesting has led to persistent barren patches while surveys of harvested and non-harvested areas along the mid-coast of Chile suggest a juvenilsation of the kelp forest, which kelp heights shorter and holdfast diameters smaller. Given that larger holdfasts support a greater richness, abundance and biomass of macroinvertebrates and that a reduction in 3-D habitat is likely to reduce habitat complexity, this juvenilisation is likely to have community wide impacts; although these remain to be studied. To understand the recovery dynamics of harvested areas we set up 3 x 4m diameter clearance areas using a nested design incorporating upwelling intensity and management regime (managed kelp harvesting versus open access areas). Rates of recovery seem to be linked with levels of management with ongoing experiments looking at different harvesting strategies to inform an ecosystem-based approach to the management of this important fishery.

Sara Barrento: The first IMTA farm at sea in Wales – from idea to reality

The concept of Integrated Multi Trophic Aquaculture (IMTA) was first published in 2004. IMTA is a farming system concept that moves away from the monoculture production mind-set to an integrated system where different trophic species are farmed in proximity. Many experimental sites were set at sea or in land-based systems, but the take on from well-established big aquaculture companies on this multi-species farming system is still insignificant. In this presentation we will showcase the first IMTA farm system established in Wales, its challenges and strategies to stay afloat in a changing environment. IMTA involves the production of more than one species from a different trophic level, where usually primary producers (e.g. seaweeds) are key to uptake the nutrients excreted from filter feeders (e.g bivalves) or fed species (e.g. fish). Setting up an IMTA system involves a diverse skill set and knowledge. It all starts with the business plan, getting the license, buying the equipment, deploying the equipment at sea, getting the seeds, seeding the ropes, the cages, monitoring the different crops, and then marketing and selling. Car Y Mor, the first Welsh IMTA farm, was set up as a community benefit society, having 115 shareholders and aiming to increase an equal shareholder. The farm is set up to produces kelps, scallops, oysters and mussels but not fish. We will explore the factors that are playing a positive impact: trading with local fishermen to diversify the species on offer to include crabs and lobsters, partnering up with local companies, dispelling fears of invasive species, engaging different generations and capitalizing

on everyone's unique skills, uniquely available because it's a Community Benefit Society.

Sophie Corrigan: Understanding the development and diversity of successional epibiont fouling communities on the cultivated kelp *Saccharina latissima*

Seaweed aquaculture is one of the fastest growing marine industries and promises to contribute towards future food and energy security, sustainable livelihoods, and ecosystem services including habitat provisioning. Habitat provisioning is important for promoting biodiversity in coastal oceans, which will likely have spill-over benefits to other marine industries including commercial fisheries. The habitat value of seaweed farms has largely remained unquantified, and evidence surrounding seaweed farm biodiversity currently relates to biofouling or pest species, rather than highlighting the benefits these colonising species, or epibionts, may have for contributing to healthy ecosystem development. We monitored the development and diversity of successional epibiont fouling communities on the cultivated kelp *Saccharina latissima* from a farm in southwest UK, and compared its epibiont assemblages to neighbouring wild kelp populations. We found an increase in epibiont abundance and diversity on cultivated kelps over and beyond the course of the growing season, reaching an average of >6000 individuals per kelp in August 2020. Assemblages on cultivated kelps were dominated by amphipods, bivalves and bryozoans, which, despite their important roles in bioremediation and provisioning of food for higher trophic species, currently dictate the duration of the harvesting season, due to their detrimental effects on crop quality. Wild kelps hosted fewer epibionts, but had a higher species diversity, due to a lower abundance of amphipods. Further work investigates how macroalgal farms may be designed to maximise their habitat value potential, while optimising crop yield for farmers as a leading example of sustainable ecosystem-based aquaculture.

Jessica Knoop: Evaluating the harvesting impact on *Porphyra dioica* in South Wales

Demand in locally sourced seaweed biomass is increasing in Europe following the recognition of seaweeds as a healthy and environmentally friendly food source. As cultivation is still an emerging sector in Europe and currently limited to a few species, harvesting pressure is rising on wild seaweed populations with limited information available about possible impacts and sustainable yields. Therefore, we studied the effect of hand-harvesting on a *Porphyra dioica* population in South Wales, commonly exploited for laverbread production. Twelve control and twelve treatment permanent 1 m^2 quadrats were deployed in spring 2017 at Frainslake Beach (Pembrokeshire). In each quadrat, percentage cover of *Porphyra* as well as benthic flora and fauna visible to the eye, *Porphyra* maximum length, recruits and reproductive state were assessed on a monthly basis, followed by removal of *Porphyra* larger than 5 cm from treatment plots, mimicking current hand-harvesting techniques. Harvesting only impacted upon *Porphyra* thallus length, resulting in 64% smaller thalli compared to unharvested plots during summer while percentage cover was not affected. We observed strong seasonal effects on *Porphyra* cover and yield with highest cover of 60% and yield (over 80 g DW m^{-2}) observed in late spring and summer. Furthermore, disturbance events caused by dynamic sand deposits, which covered most of the experimental area during summer and autumn, were the predominant driver of *Porphyra* abundance. These results suggest that the opportunistic life strategy of *Porphyra* results in high resilience against disturbances. Therefore, hand-harvesting appears to have a minimal impact on *Porphyra* cover and yield.

Sergio Trevi: The benefits of microalgae replacement in fish nutrition: a meta-analysis

Use of microalgae in fish nutrition can relieve pressure on wild fish stocks, but there is no systematic quantitative evaluation of microalgae benefits. We conducted a meta-analysis on the nutritional benefits of *Spirulina* and *Schizochytrium* as replacements of fishmeal and fish or plant oil, respectively. We reviewed 50 peer-reviewed studies involving 26 finfish species and 144 control vs microalgae replacement comparisons. Inclusion of *Spirulina* in the fish diet significantly improved growth compared to controls (SMD = 1.21; 95% CI =0.71-1.70), while inclusion of *Schizochytrium* maintained the content of omega-3 PUFA of the fish fillet compared to fish fed on fish or plant oils (SMD = 0.62; 95% CI = -0.51-1.76). Benefits were apparent at replacement levels as low as 0.025% in the case of *Spirulina* and 10% in the case of *Schizochytrium* oil. Dose-dependent effects were found for *Spirulina* replacement on growth, but not for *Schizochytrium* on omega-3 fillet content. Subgroup analysis and meta-regression revealed that ~24-27% of variation in effect sizes can be accounted by variation between fish families, the rest likely reflecting variation in experimental conditions. Overall, the evidence indicates that *Spirulina* and *Schizochytrium* replacement in aquafeeds can be used to improve fish growth and maintain fillet quality, respectively, but considerable uncertainty exists on the predicted responses. To reduce uncertainty and facilitate the transition towards more sustainable aquafeeds, we recommend that feeding trials using microalgae are conducted under commercially relevant conditions and that greater care is taken to report full results to account for sources of heterogeneity.

Alla Silkina: ALG-AD project and experimental assessment of optimal growth of *Scenedesmus sp.* and *Chlorella sp.* under photoautotrophic, heterotrophic and mixotrophic conditions for improved waste remediation

The ALG-AD INTERREG Northwest Europe project is developing algal technology to convert excess nitrogen pro-

duced from the anaerobic digestion of food and farm waste to produce protein fraction for animal feed, specifically for pigs and fish. The ALG-AD project (2018-2021) will be presented, including progresses to date, successes and challenges. The circular bioeconomy approach will also be demonstrated, by using microalgae and their potential for wastewater treatment and nutrient recovery. Cultivation and harvesting of microalgae are expensive processes, mainly due to low biomass concentration, and photoautotrophic culture growth. Mixo- and heterotrophic cultivations could represent a solution, as they can increase biomass production by up to 2-4 times. As part of the ALG-AD project, this novel approach was investigated, for two microalgal species and in a two-steps cultivation system. Biomass productivity as well as bioremediation performances were assessed and demonstrated, with the overall aim to use waste nutrients for algal growth and utilise the produced biomass for an array of applications. Results showed an improved productivity by implementing a mixotrophic and heterotrophic feeding regime, hence contributing to better performances in terms of waste remediation. The approach used as part of this study, demonstrates potential for commercial applications, as it can lower production costs, and brings additional value and markets for the AD and wastewater industries

Diane Purcell-Meyerink: Does location matter to the nutritional content of wild harvested Giant Kelp?

Macrocystis pyrifera commonly called the giant kelp is one of the fastest growing seaweeds globally and can grow up to 60cm per day with an individual plant reaching 55m. It is a positively buoyant species enabling the creation of kelp forests - a critical ecosystem in the ocean. At present, kelp forests are under significant threat due to increasing ocean temperatures, and in particular marine heatwaves (MHW), which are occurring more frequently. Indeed, *Macrocystis pyrifera* is a threatened ecological community in Australia since 2012. It is a native species to both New Zealand and Australia and is found on the west coast of the US, South America, and South Africa.

Macrocystis pyrifera is not commercially globally cultivated seaweed unlike *Laminaria digitata*. The protein content of *Macrocystis pyrifera* ranges from 9-17% of the dry mass and depends on location and environmental factors including the season of harvest. Protein sourced from seaweed can contain all essential amino acids, and the protein profile of seaweeds is similar to egg protein. Initial nutritional analysis using AOAC standard protocols of wild harvested fronds of *Macrocystis pyrifera* from Tory Channel, South Island, New Zealand, found 12.2% dry weight (DW) crude protein. *Macrocystis pyrifera* harvested from Tower Bay, Tasmania, Australia contained only 6.5 % protein based on DW. Total fat values were similar at both sites with 1.9% DW from New Zealand, and 1.2% and 1.4% DW from Australia. *Macrocystis pyrifera* usually has <2% fat content year-round therefore these values are in the expected range. Interestingly, total polysaccharides varied between sites with the New Zealand kelp found to contain 21.6 mg / 100 g polysaccharides and the Australian samples 21.8mg / 100g, and 35.3 mg / 100 g, respectively. *Macrocystis pyrifera* adult plants were sampled at the same time of year in both locations. Previous studies have found higher growth rates for this species on wave-exposed sites, that can impact positively nutrient uptake specifically in low nitrogen environments. This data suggests that wave-exposed locations are worth investigating for aquaculture-based seaweed farms, to enable optimal conditions for seaweed production and quality, within a changing climate.

Blue Carbon and Kelp Ecology

Cristina Galobart: Community composition and functional diversity across brown macroalgal forests

In coastal marine environments, large brown seaweeds can create complex habitats which are often described as macroalgal forests. Even though these habitats can be dominated by different structural species that exhibit different growth forms and life strategies, these forests are usually major contributors to primary production and support a wide array of ecosystem functions and services. However, human induced stressors, such as habitat destruction and climate change, have altered the structure, distribution and functioning of these forests. These stressors sometimes drive the replacement of the structural species or even the regional extinction of the species and the habitats they underpin, especially when distribution shifts to track optimal conditions and climatic refugees are unavailable. Improved understanding of the biodiversity but also the functionality of macroalgal forests characterized by different species is key to better predict future responses to environmental change. Here, we studied three different macroalgal forests dominated by: *Laminaria hyperborea* (SW England), *Saccorhiza polyschides* (N Portugal) and *Laminaria rodriguezii* (E Spain), representative of geographic regions with contrasting oceanic conditions. Considering the current species composition and abundances on each forest, we analysed and compared species and functional diversity. Preliminary results show that while species richness and biodiversity indices are similar across regions, functional diversity is markedly higher in Mediterranean *L. rodriguezii* forests. In the context of climate change, both *L. hyperborea* and *S. polyschides* forests are widely distributed and can shift their distributions poleward, whereas *L. rodriguezii* forests are likely constrained to the Mediterranean Sea, with limited range shift potential. Thus, the loss of these forests would translate into the loss of a unique and specific functional diversity, which has major implications for conservation and management of these biologically rich habitats.

Dan Smale: Quantifying the production, export and fate of kelp detritus within the context of Blue Carbon ecosystem services

Kelp forests are widely distributed across the world's coastlines, where they typically support high levels of biodiversity and productivity. Although their high rates of productivity and detritus release are expected to lead to substantial export of carbon, few studies have actually quantified rates of export, likely transport pathways and the immediate fate of detritus. We addressed this in eight subtidal kelp forests (*Laminaria hyperborea*) spanning the length (9° of latitude) of the United Kingdom (UK). Specifically, we quantified detritus production, retention/export from source and adjacent habitats, and in situ decomposition rates. Detritus released via both dislodgment of whole plants and 'May-cast' shedding of old growth was highly variable between sites with greatest values recorded in our colder, northern sites. This was attributable to greater plant size biomass in northern regions, rather than plant density or dislodgement rates. On average, the annual production of kelp detritus was 4706 ± 700 g FW m^{-2} yr^{-1} or 301 g C m^{-2} yr^{-1}. Low retention of detritus within the kelp forest and adjacent sedimentary habitats indicated very high rates of export (>98% across the study). A litterbag experiment showed detritus may take >4 months to decompose, suggesting great potential for long distance transport. Given the wide distribution and substantial standing stock of these forests, exported organic matter may contribute to long-term carbon storage, if it reaches sink habitats. Further work has combined molecular techniques, particle tracking models and laboratory experiments to identify likely transport pathways and potential coastal sink habitats amenable to management actions. The results of both studies are discussed within the context of the contribution of kelp forests to Blue Carbon ecosystem services.

Kathryn E. Smith: Impacts of marine heatwaves on Californian kelp forests

Kelp forests play an important role in maintaining biodiversity and ecosystem functioning along >25% of the world's coastlines. They support a diverse range of species and significantly contribute to carbon assimilation and transfer. These ecosystems are, however, currently under threat from climatic extremes, which are becoming increasingly common against a global background trend of gradual warming. Here, we investigate the impacts of marine heatwaves (MHWs; periods of anomalously warm water) on biodiversity in kelp forests along the Californian coast. Using ten years of species assemblage data collected by Reef Check California, a citizen science program, we explore how 'the blob', a large marine heatwave that was present in the Northeast Pacific Ocean between 2014 and 2016, impacted kelp forests along 800 km of Californian coast. We found that species composition varied significantly from before the MHW event to after the MHW event. In almost all regions, the change was characterized by a decrease in diversity, driven in particular by shifts in kelp and urchin abundance. We discuss the implications of MHWs on kelp forests and the ecosystem services they provide.

Nathan King: Consistent hierarchical structuring of the kelp microbiome over large spatial scales

Kelps, large brown macroalgae predominantly of the order Laminariales, are distributed along ~25% of the world's coastlines and the forests they form represent some of the most productive and diverse ecosystems on Earth. As with other marine habitat-formers, the microbial community associated with kelp species is now recognised as being fundamental for host, and, in turn, wider ecosystem functioning. However, given that there are thousands of bacteria-host associations, determining which relationships are important remains a major challenge. Here, we characterised the associated bacteria microbiome of two habitat-forming kelp species, *Laminaria hyperborea* and *Saccharina latissima*, from eight sites (two sites nested within four study regions) spanning 9°of latitude in the northeast Atlantic. We found no difference in diversity or community structure between the two kelp species but there was evidence of regional structuring and considerable variation at the individual level. Individuals from within the same sites shared very few Amplicon Sequence Variants (ASVs) and tended to support only a very small proportion of overall bacterial diversity associated with wider kelp microbiome. However, consistent characteristics between individuals were observed, with the kelp microbiome aligning with a recently simplified framework for corals. Here, individual microbiomes consisted of three community layers i) a small "core" (80% prevalence and ≤ 0.1% relative abundance) of 8 -11 ASVs that comprised 25 and 32% of sample abundances for *L. hyperborea* and *S. latissima*, respectively ii) a "resident" component dominated by four classes (Planctomycetes, Gammaproteobacteria, Alphaproteobacteria and Bacteroidia) that comprised ~ 84.3% of overall abundance and iii) an "environmentally responsive" component of rare and transient ASVs from 47 other classes that made up very little contribution to overall abundance but the majority of taxonomic diversity. Overall, we demonstrate the spatially consistent features of kelp microbiomes across large spatial scales, and across environmental gradients, simplifying this seemingly dynamic and complex relationship.

Hannah Earp: A synthesis of approaches, biases, successes and failures in marine forest restoration

Marine forests is a term commonly used for coastal marine habitats formed by dense stands of brown macroalgae, typically kelp and fucoids. These habitats are highly productive, offer habitat to numerous marine organisms and support a range of invaluable ecosystem services. Despite their importance, marine forests are declining in many regions around the world as a result of interacting global,

regional and local scale stressors. Consequently, interest in restoration as a tool to mitigate these declines and reinstate marine forests is growing. Recent reviews have provided insights into marine forest restoration, however for the most part, a synthesis of restoration success is lacking. We conducted a meta-analysis and quantitative review of published marine forest restoration efforts to examine: (1) how restoration affects the abundance and morphology of marine forest species and; (2) trends in marine forest restoration success. The meta-analysis of 25 studies revealed that restoration positively influences the abundance and morphology of marine forest species. The quantitative review of 63 studies demonstrated that taxa and restoration technique were important factors influencing restoration success and revealed a bias towards the monitoring and reporting of abundance and morphological response variables. The review also highlighted a lack of monitoring and/or reporting of environmental variables at restoration sites, and limited comparative research across environmental contexts and restored species. We show that successful marine forest restoration is possible at experimental scales, but that better reporting of restoration efforts would improve our understanding of where different restoration techniques could be applied. We argue that expanding the scope and duration of restoration experiments could enhance our understanding of restoration at the ecosystem level. The review will advance future marine forest restoration efforts and their reporting, allowing the preservation of these valuable ecosystems and their associated services.

General Phycology

Abigail Perrin: CyanoTag: High-throughput protein localisation in photosynthetic bacteria

Cyanobacteria are photosynthetic aquatic microorganisms that possess specialised CO_2-concentrating structures thought to be the sites of up to 20% of global CO_2 fixation. By combining fluorescent protein tagging, super-resolution microscopy, mass spectrometry and robotics we aim to understand the protein networks underpinning the efficiency of photosynthesis and other important processes in these understudied organisms.

Juliet Brodie: 'Operation Himantothallus': South Georgia seaweed diversity, environmental change and biogeographical considerations for the South Atlantic.

South Georgia is a remote subantarctic island in the southern Atlantic Ocean and seaweeds are a major component of its unique and charismatic marine biodiversity. Despite its isolated location, its biodiversity faces threats from climate change, invasive species, tourism and fishing activities. Consequent impacts on seaweeds can resonate throughout entire ecosystems. Whilst seaweed collections have been made from South Georgia over the last 150 years, there is no baseline for conservation management, nor a comprehensive taxonomic framework based on up-to-date approaches. In November 2021, we undertook an expedition to record and collect seaweeds from the intertidal and subtidal as part of a Darwin Plus funded project "Biodiversity discovery and the future of South Georgia's seaweed habitats". Preliminary observations show that red and brown seaweeds predominate. Dominant groups for the red algae include the Bangiales, Gigartinaceae and Delesseriaceae. For the brown algae, in addition to *Macrocystis pyrifera* forests (Laminariales), members of the Desmarestiales are conspicuous, notably the massive, habitat-forming *Himantothallus grandifolius*. There appear to be relatively few green algae, although we have added considerably to the list of known species. Subsequent molecular work will shed new light on the taxonomy of these seaweeds. Whilst many areas appear pristine, a resurvey of a shore transect undertaken at Husvik 30 years ago suggests ecological change. We attribute this to increasing temperatures and the impact of expanding fur seal populations occupying these shores in the breeding season. In this talk, we will report on our preliminary observations and consider these in relation to other regions in the South Atlantic, including the Falkland Islands where we have been undertaking similar studies over the last few years.

Hannah Kemp: Blooming blanket weed: managing nuisance algae in UK freshwater bodies

Across the UK, many standing freshwater ecosystems are experiencing increasingly frequent and widespread blooms of "blanket weed" algae, particularly genera such as *Cladophora*, *Ulva*, *Hydrodictyon* and *Spirogyra*. The formation of thick mats at the lake surface causes major ecological damage by harbouring pathogens and decreasing aquatic plant diversity. Blooms also reduce the amenity value of freshwater bodies because they are unsightly, prevent water-based activities and negatively impact conservation work. Currently the extent, cause and consequences of these blooms are largely unknown. Clumber Lake, a shallow water body within the National Trust property of Clumber Park (Nottinghamshire), receives nutrient-rich waters from the River Poulter and has had nuisance blanket weed blooms over recent decades. Ongoing limnological monitoring and bioassay experiments at this site aim to understand the causes of blanket weed growth and blooms to inform management. Blanket weed biomass in the Clumber Lake increased from April and peaked in June and July, followed by a rapid decline in August as the blanket weed began to decompose. Surface blooms in early summer were dominated by *Ulva sp.* as their tubular thalli fill with oxygen released from rapid photosynthesis making them buoyant. A combination of nutrient and bioassay experiments suggests that both phosphorus and nitrogen are rarely limiting to blanket weed growth, but that light availability is more likely to be the trigger for increased growth and subsequent blooms. Future controlled experiments at the mesocosm scale will investigate this hypothesis. These preliminary results indicate that abundant nutrients deriving from the River Poulter provide the ideal conditions for a high biomass of blanket weed to develop,

but that the timing of bloom occurrence is most likely modified by light availability. Therefore, nutrient control is likely to be the baseline requirement for a blanket weed control programme.

Michael Ross: CCAP: who we are, what we do, and our new expanded services

The Culture Collection of Algae and Protozoa (CCAP) is one of the most diverse biological resource centres for algae and protozoa, with nearly 3000 strains available and has a global customer base in both the academic and industrial sectors. CCAP offers a range of services to facilitate this community, including strain and media provision, cryopreservation, taxonomic and genomic studies, research engagement, and teaching/training workshops. As an International Depository Authority (IDA), we accept Patent and Confidential Depositions of algal material. During this presentation, we will provide an overview of CCAP and the core services we provide, discuss some of the main flagship research projects that we have been or are currently involved with. Finally, we will update the audience of our exciting recent updates, and the new and improved services that we can now offer.

In 2021, CCAP expanded and launched two new services to our repertoire. Firstly, to facilitate protistan research and continue the taxonomic curation of the collection, all nucleotide sequence data for CCAP strains generated by internally and externally has been collated and are freely accessible from the Bioinformatics Gateway. Secondly, with the cutting-edge equipment contained within the Algae Research, Innovation and Environmental Science (CCAP-ARIES) centre, we can cultivate and process much larger volumes of algae, and offer advanced biochemical and metabolomic screening, and genomic analyses.

CCAP has been directly involved with numerous algal biotechnological screening projects (e.g., BioMara, ABACUS, DigestAlg) which have aimed at investigating algae for biofuels, food/feed, and high-value products, including pigments, to improve human and environmental health and sustainability.

CCAP has taken a key role in a wide range of international genome sequencing projects, to help answer fundamental questions in evolution and comparative genomics. One of CCAP's major commitments is to the UK Darwin Tree of Life (DToL), which aims to sequence representative genomes from most eukaryotic species resident in the British Isles. The extensive metadata and public accessibility of all genome-sequenced strains make this an extraordinary resource with which to understand the genomes of these key ecosystem players and will be critical in shaping the future study of biology, conservation, and biotechnology.

Alexander Bowles: Can adaptations of ice-inhabiting streptophyte algae illuminate the processes of plant terrestrialization?

Summer-time blooms of streptophyte 'glacier algae' that occur within the surface ice of glaciers and ice sheets have attracted significant recent attention because of their potential to drive biogeochemical cycling in these extreme cryo-environments, and to significantly enhance ice surface melt through impacts to albedo and energy absorbance. Yet, glacier algae may hold answers to even bigger questions surrounding the interplay between the biosphere and cryosphere. Taxonomically, Zygnematophycean glacier algae are amongst the closest living algal relatives to land plants and physiologically, they are adapted to life in aquatic surface ice environments that also present a host of terrestrial stressors (enhanced UV-radiation, temperature extremes, restricted access to nutrients and liquid water). Here, we present the rationale and early findings of the iDAPT (ice Dependent Adaptations for Plant Terrestrialization) project, which aims to investigate processes of early land plant evolution by studying the genomes and physiological adaptations of ice-inhabiting glacier algae. Due to their crucial phylogenetic position, the project is investigating whether the adaptations of extant glacier algae represent exaptations important for the transition of ancestral plants from water onto land around 500 million years ago. Initial analyses, which have leveraged the latest molecular data, resolve the early algal and land plant phylogeny including species from the rhodophytes, glaucophytes, chlorophytes and streptophytes. This provides a robust framework within which to understand the gain and loss of key genes, and therefore biological functions, shedding light on key adaptations of algae to glacial environments and algal exaptations for land plant terrestrialisation.

Katerina Kersting: Targeted Genome editing in the coccolithophore *Chrysotila carterae* with CRISPR/Cas ribonucleoproteins

Coccolithophores are an important group of unicellular marine algae characterized by the ability to decorate their cell surface with intricately shaped calcite scales known as coccoliths. Coccolithophores occur throughout the world's oceans. Coccoliths are found in marine deposits in vast numbers and are used as a sensitive indicator of environmental changes. In addition, the extraordinary morphology of coccoliths makes them very attractive for bioinspired material science research. Currently, molecular genetic studies in coccolithophores are limited to a descriptive level, due to the lack of tools for genetic manipulation. The aim of this study is to develop a CRISPR/Cas genome editing technique for the model coccolithophore species *Chrysotila carterae*. To this end, we have applied a DNA-free editing approach based on the delivery of in vitro preassembled CRISPR/Cas ribonucleoproteins (RNPs) via PEG-mediated transformation. Previously, PEG-mediated transformation of *C. carterae* had been shown only for

plasmid delivery. By optimizing the delivery parameters and the growth conditions, we demonstrated that successful biallelic knockout mutants can be obtained via co-delivery of RNPs targeting different genomic sites. Moreover, we identified an endogenous negative selectable marker gene, the targeting of which by genome editing allows selection of knockout mutants without the need for integration and/or expression of an antibiotic resistance gene. Development of CRISPR/Cas genome editing for *C. carterae* opens up new possibilities for addressing fundamental questions of coccolithophore biology by reverse genetic approaches and makes this species amenable to a range of synthetic biology applications.

Susana Londoño-Zuluaga: Bleaching responses of red seaweed holobiont to temperature, age, and geographical locations

Diseases can have severe consequences in natural systems, particularly when ecosystem engineers, such as habitat-forming seaweeds are involved. Seaweeds play a vital role in ecosystems as foundation species. Negative impacts can cascade throughout entire food webs due to, for example mass mortality of keystone species. Seaweeds maintain a close relationship with microbes and together with their associated bacteria they function as holobionts. Seaweed as the host provides various functions such as settlement substrata for microorganisms. In turn, microbes provide defences against pathogenic microbes, in addition to influencing the hosts health and morphology. Nevertheless, these seaweed host-microbe interactions are not always beneficial, and can be detrimental, for example, seaweeds can suffer from a variety of disease symptoms induced by opportunistic pathogens. Studies have emerged on seaweed interactions investigating the overall physiological and fitness response of seaweeds to biotic stressors, like pathogens. Nevertheless, knowledge on how different populations respond to pathogenic microbes is scarce.

In this present study, we aimed to investigate how the interaction of the invasive red seaweed *Agarophyton vermicullophylum* and the native red seaweed *Palmaria palmata*, with a known red algal pathogen, can vary among different populations. Using these two ecologically and economically important red seaweeds, we also compared host sensitivity towards the pathogen under two different temperature regimes. Additionally, as host age can affect the manifestation and pathophysiology of organisms, we tested how young and old algal tissue would respond to pathogen under the same conditions. We showed for the first time show that age affects pathogen resistance as younger tissue are more susceptible to disease compared to older tissues. Effect of temperature was found to be population dependent and was significantly more effective on native populations of *P. palmata*, as temperature increased. Finally, geographical locations were tested as a potential factor affecting the interactions between pathogen and host. In this study, we show a strong effect on the geographic latitudinal origin as it varies within the species and also in response to temperature tested. These results will provide a baseline for future research investigating dynamics of such host-pathogen interactions, as stressors affect ecology and the evolution of relationships, leading to disease susceptibility.

Benedikt Schrofner-Brunner: Does species sorting maximise ecosystem functioning of fucoid macroalgae?

Ecologists have extensively studied how species loss affects ecosystem functioning at local spatial scales with limited environmental heterogeneity. However, our knowledge about the functional consequences of changes in biodiversity at larger scales is still limited. Theory exploring how biodiversity affects ecosystem functioning at larger spatial scales predicts that biodiversity will maximise functioning when species respond asynchronously to environmental variation and species dominate at times or places where they are functioning the highest. These predictions have not been thoroughly tested in a natural system. To fill this gap, we employed the sharp zonation pattern of fucoid macroalgae on the Swedish west coast as a model system. In this system, it is commonly assumed that competition drives turnover in the lower shore regions, but different environmental tolerance is responsible for turnover on the upper shore where desiccation is common. We transplanted the four locally dominant macroalgae species across depth zones, where they occur and do not occur naturally, on five sites. As a measure of functioning, we used biomass production. We found that the highest functioning at each zone was not always performed by the naturally dominant species. Thus, species turnover might be more strongly driven by competition rather than environmental filtering, even in the upper shore. Hence, contrary to theoretical model predictions, the naturally observed pattern of species sorting has not maximised functioning (i.e. growth) compared to other species compositions. Our results show that critical predictions from theory regarding how biodiversity affects functioning at larger scales of space and time may not hold in fucoid algae at the west coast of Sweden. Other studies (e.g. Germain et al., 2018) have shown that many species can survive and function in different environmental conditions in absence of competition. Thus, species sorting may rather result from competition or other interspecific interactions than environmental filtering. This means that natural patterns of species turnover might not be used to argue for the importance of biodiversity at larger spatial scales.

Alex J Goodridge: Characterisation of 'phyco'-lignin in the cell wall of the green seaweed *Ulva linza*

The evolution of lignification in vascular plants conferred improved structural support, stress tolerance, and water transport, all of which likely contributed to improved fitness on land. Despite lignification being a land plant specific expansion, lignin-like phenolics are present in the cell

walls of red and green seaweeds (Martone et al., 2009; Gupta et al., 2013), despite both the Rhodophyte and Chlorophyte lineages lacking the genes required for lignin biosynthesis (the phenylpropanoid pathway). Here, I aim to characterise the function and structure of the lignin-like fraction of the green seaweed *Ulva*.

Changes in *Ulva linza* cell wall autofluorescence exposed to hypo- and hypersaline stress were quantified using confocal microscopy and image analysis software (Fiji). A lambda scan performed from 410-630 nm (ex 405 nm) demonstrated that the spectral properties of cell wall autofluorescence was comparable to that of known plant phenolics. Cell walls were then isolated and fractionated into pectin, hemicellulose, and □-cellulose fractions by a sequential extraction protocol for macroalgae to identify a candidate metabolite for the fluorophore observed during imaging. Fractions were assessed individually by Fourier transform infrared spectroscopy (FTIR) to identify lignin-like functional groups. The acetyl bromide soluble lignin (ABSL) method was also used to quantify phenolic content. Extractions were also performed on barley straw as a control, representing biomass known to have 'true' lignin. Cell wall autofluorescence was elevated following hyposaline stress relative to unstressed tissue (1.7X fold change, $p < 0.001$), but declined following hypersaline stress (0.5X fold change, $p < 0.001$). The autofluorescence data contradicted findings from the ABSL assay for hyposaline stress, where a non-significant decline in 'lignin' content was observed.

Cat Joniver: Ecological impacts of residual macroalgal blooms on estuarine birds in Milford Haven

Eutrophication, coupled with the reduction of herbivorous grazers from marine, coastal and estuarine ecosystems can cause unwanted macroalgal blooms globally. Opportunistic macroalgal blooms (predominately *Ulva spp*.) are increasingly becoming a problem in Milford Haven estuary in southern Wales, United Kingdom, where the waterbody has recently been classified as 'unfavourable status' in the European Union Water Framework Directive. Impacts of macroalgal blooms on estuarine systems can include smothering and loss of valuable habitat for infauna and foraging birds. This study used aerial data collected using a drone during summer 2020 to create a model which depicted average macroalgal biomass density at two survey sites. From this model algal density categories (ranging from low to high) were determined on which to base the bird surveys. Bird surveys were conducted during winter 2020/ 2021 to determine impacts that the residual macroalgal blooms had upon wintering birds. During these surveys the abundance and behaviour of coastal and wading birds were recorded in each algal density category. Results show that wading birds had a strong preference for areas where algal density was highest during summer months, particularly for passive behaviours and that algal densities were found to be significantly different at the two sites surveyed ($p < 0.001$). This study is of importance as macroalgal blooms are increasing globally and potentially creating favourable resting sites for wintering birds. This project is funded by the European Social Fund, GreenSeas Resources which is facilitated by KESS 2. Additional funding was awarded from BEERN Wales Biodiversity Partnership.

El Mahdi Bendif: Disentangling morphologic and genotypic complexity in extant coccolithophore

Gephyrocapsa huxleyi is a widely distributed bloom-forming coccolithophore that plays key roles in global marine carbon fluxes, largely due to the formation of its calcite platelets (coccoliths) covering the cell. This species is composed of morphotypes defined by their differing degrees of calcification and for which the evolutionary ecology remains unclear. Here, we conducted a multi-strain genomic survey across *G. huxleyi* to reconstruct evolutionary relationships between these morphotypes in relation to their habitats of isolation. While *G. huxleyi* has been considered a cosmopolitan species, our evolutionary genetic analyses demonstrated it has in fact evolved into 3 distinct lineages with a partial relationship to the current morphological delineation. The first divergence occurred before the onset of the last interglacial (~140 ka). Further diversifications followed rapidly during a period of high productivity coincident with the last ice-sheet expansion and established modern populations across environmental clines. These results provide the first comprehensive evidence for genetic divergence in *G. huxleyi*, shedding light on global process of micro-evolutionary radiation in marine phytoplankton throughout the Pleistocene/Holocene glacial cycles.

Nora Salland: Winners and Losers in the Southwest: revisiting historical kelp sites

The southwest of UK and Ireland represents a biogeographic transition zone, where many warm-adapted Lusitanian species overlap with cold-adapted Boreal species. Indeed, several warm-water seaweed species are found towards their poleward range edges, whereas several cold-water species are found at their equatorward range edge. Recent ocean warming trends have affected the ecophysiological performance of some seaweed species, with implications for population structure and species' distributions. While anecdotal evidence suggests that warm-water kelps in SW England, like *Saccorhiza polyschides* and *Laminaria ochroleuca*, have increased in abundance and extent and, conversely, cold-water kelps such as Alaria esculenta have declined, robust empirical information is lacking. The absence of reliable information on temporal trends in kelp forest structure hinders conservation and management as well as restricting the understanding of climate change impacts. We conducted targeted surveys to address this knowledge gap and provide a robust assessment of temporal changes in kelp population structure and distribution in SW England.

Historical data was collated from open access data sets (MNCR, DASSH) and grey literature (theses), recorded between 1962 and 2016. A subset of historical sites were selected for resurvey, based on spatial coverage across the region, accessibility, water depth, level of wave exposure, confidence in data quality and a priori predictions. Surveys were conducted in low intertidal/shallow subtidal habitats, and the abundance (SACFOR scale, density, cover) and structure (biomass, morphology) of kelp populations was recorded. In summer 2021, 17 historical sites across Cornwall and Devon (incl. Lundy Island) were revisited. Preliminary results provide some support for climate-driven shifts in kelp forest structure. The warm-adapted opportunistic *S. polyschides* is thriving, while *L. ochroleuca* populations proliferated but perhaps less than expected. The cold-adapted A. esculenta has declined at some sites but seems stable at others, while *Saccharina latissima* populations have declined over time. Other cold-water kelps (*L. hyperborea* and *L. digitata*) seem relatively stable. The non-native kelp *Undaria pinnatifida* was common at some sites, however, no concerning spread of this species was evident within the scope of this survey. Future surveys resume in 2022 and will include further sites in Devon and Cornwall (incl. Isle of Scillys).

Veronica Farrugia Drakard: Artificial rockpools support similar seaweed assemblages across environmental contexts

Artificial structures are widespread features of coastal marine environments, but are generally poor surrogates of natural rocky shores as they support fewer species, leading to non-natural assemblages. Eco-engineering solutions that modify marine artificial structures may serve to ameliorate these differences and facilitate the establishment of more natural biotic assemblages. Water-retaining features in particular have been shown to positively impact diversity and ecosystem function when tested on concrete seawalls, but have not been widely tested in a range of environmental contexts. In this study, commercially-available artificial rockpools (Vertipools© by Artecology Ltd.) were deployed on concrete seawalls at 8 locations with differing environmental contexts. Locations were classified as 'estuarine' or 'marine' and as 'urban' or 'rural', with two locations selected for each combination of factors. Over a period of 18 months, regular samples were taken of cover and abundance of seaweeds and invertebrates and measurements were made of productivity and respiration. During that time, the pools were colonised by a total of 24 seaweed taxa, including *Fucus spp., Polysiphonia spp*., and *Ulva spp*. There were no differences in community structure, life-history composition (ephemeral v perennial), or morphological composition (crust v foliose v erect v turf) between environmental contexts. While there was considerable inter-site variability in productivity and respiration, overall these did not differ between environmental contexts. This suggests that Vertipools© will function similarly across a range of environmental conditions and are therefore widely applicable as an eco-engineering solution for the marine context.

Annesia L. Lamb: Bulk NGS Analysis Reveals Macroalgal Mat Species Composition in the South Coast of UK

As part of the Rapid Reduction of Nutrients in Transitional Waters (RaNTrans) project we have identified mat-forming macroalgae species in the southern UK and northern France. In Langstone Harbour and Holes Bay (Poole Harbour) we have identified the mat forming genera *Chaeteomorpha* and *Ulva* as being the high-density >200 g DW m^{-2} species. Bulk analysis of macroalgae using Next Generation Sequencing (NGS) can detect more single nucleotide polymorphisms (SNPs) than traditional DNA barcoding aiding identification of species in bulk samples thereby simplifying collection. However, NGS requires high quality biomass samples that are low in polysaccharides. Proposed management strategies for *Chaeteomorpha* (tubular) and *Ulva* (laminar) could be different based on morphology as well as the possible impacts on wading birds and macrofauna within and below the mats. The RaNTrans project will expand our understanding of the ecology of mat-forming macroalgae, examine the ecosystem impacts of commercial scale harvesting, and develop additional usages for macroalgal tissue.

Emily Broadwell: Investigating the photophysiology of supraglacial microalgae

The supraglacial region on the surface of glaciers and ice sheets is a high-light, low-temperature and oligotrophic environment that is home to a diverse assembly of microorganisms. Of these, Chlorophyte snow algae and Streptophyte glacial algae represent the major primary producers within this cryospheric landscape. Both groups form widespread algal blooms when liquid water and sunlight are available to drive photosynthesis during summer melt seasons. Recently, these blooms have been highlighted to have far-reaching consequences for both the physical and chemical characteristics of the supraglacial environment, for example, through impacts to ice surface albedo and melt, and the large-scale cycling of carbon and nutrients. Despite their potential importance, however, our understanding of the abilities of snow and glacier algae to dominate their dynamic supraglacial environments remains diminutive.

Here we report on recent efforts to examine the photophysiology responses of a range of snow algal species (*Chlamydomonas pulsatilla*, *Chloronomas pichinchae*, and *Raphidonema sempervirens*) relative to light, temperature and nutrient regimes. Each species was selected as cultures isolated from both Arctic and Antarctic environments. These were then cultured under high and low light intensities (50 and 500 µmol photons m^{-2} s^{-1}), a gradient of nitrogen concentrations in order to replicate what has been reported from the supraglacial environment, and a

temperature gradient. In order to assess the responses of these species to these abiotic stressors, PAM fluorimetry was used to assess the photophysiology, and cells were preserved in order to quantify the cellular stoichiometry and pigmentation during both the exponential and stationary phases of growth. Preliminary results indicate a dynamic photophysiological system that allows these snow algal species to adapt their light adaptation mechanisms to the light to which they are incubated. There also appears to be a correlation between the availability of nitrogen and the capacity at which the algal species can adapt themselves to the increased exposure to light.

Jasmin L. Millar: Polar cryoconite associated microbiota is dominated by hemispheric specialist genera

Cryoconite holes, supraglacial depressions containing water and microbe-mineral aggregates, are known to be hotspots of microbial diversity on glacial surfaces. They contain microalgae, fungi, protists and bacteria. Cryoconite holes form in a variety of locations and conditions, which impacts both their structure and the community that inhabits them. Using high-throughput 16S and 18S rRNA gene sequencing, we have investigated the communities of a wide range of cryoconite holes from 15 locations across the Arctic and Antarctic. 24 bacterial and 11 eukaryotic first-rank phyla were observed in total. The various biotic niches (grazer, predator, photoautotroph, chemotroph), are filled in every location. Significantly, there is a clear divide between the microalgal and bacterial communities of the Arctic and those of the Antarctic. We were able to determine the groups contributing to this difference and the family and genus level. The most striking divide between the Arctic and Antarctic was found within the Archaeplastida. The microalgal communities of Arctic cryoconite holes are dominated by *Chlamydomonas* whereas the Antarctic cryoconite holes are dominated by *Pleurastrum*. Therefore cryoconite holes may be a global feature of glacier landscapes, but they are inhabited by regionally distinct microbial communities. Our results are consistent with the notion that cryoconite microbiomes are adapted to differing conditions within the cryosphere.

Xiaoxu Ma: Coccolithophore response to seawater Mg/Ca ratio

Coccolithophores are calcifying unicellular phytoplankton sensitive to environmental change. Although Mg is essential for photosynthesis, Mg also has the potential to inhibit mineral growth in inorganic calcite and raises the saturation state needed for precipitation of calcite. The primary mineralogy of inorganic carbonates in the high Mg/Ca modern ocean is aragonite. Whether an increasing Mg content of the ocean relative to Ca, as has occurred over the last 60 Myrs, may also interfere with calcite biomineralisers, particularly coccolithophores which calcify intracellularly and have reduced in size over this same timescale, is unknown.

In this study, we cultured 6 strains which represent 4 coccolithophore species including over-calcified *Emiliania huxleyi* (RCC1216), regular-calcified *E. huxleyi* (RCC911 and OA1), *Gephyrocapsa oceanica* (RCC1314), *Coccolithus braarudii* (RCC1198) and *C. pelagicus* (RCC3776) under a range of Mg/Ca ratios (Mg/Ca: 0.5, 1, 5, 10, 15, 20). We evaluated their cell adaption and calcification sensitivities under different magnesium concentrations by measuring the growth rate(μ), chlorophyll concentration, morphology and whole cell magnesium content. We find that for all strains, there is a hint that the lowest Mg/Ca ratio could limit growth, while no signification malformation is observed under such condition. *E. huxleyi* strains appear to exert the strongest control over the chemistry at the site of calcification, as they are still able to calcify under extreme magnesium concentration. However, more malformed and incomplete coccoliths are observed with the increasing of magnesium. *G. oceanica* can maintain calcification abilities across the Mg/Ca range except under extremely high magnesium concentration, *Coccolithus spp*. are more vulnerable compared to other species as they grow slowly at a Mg/Ca ratio of 10 and growth is completely inhibited at higher Mg concentration. We checked the whole cell chemical composition for *E. huxleyi* strain OA1 and find that Mg/Ca ratio in cells increased simultaneously with the rise of the ambient Mg/Ca ratio. Meanwhile, the Sr/Ca ratio decreased despite of the increase of the growth rate under high Mg/Ca ratio, which might indicate the replacement of functional metal element under changing magnesium concentration.

Akanksha Agrawal: One-pot processing of Ulva seaweed biomass with deep eutectic solvent-optimized fermentation

We demonstrate that one-pot consolidated bioprocessing using deep eutectic solvents can improve the extraction of fermentable sugars from the green seaweed, *Ulva linza*. *Ulva* biomass was first pretreated with either sulfuric acid, the deep eutectic solvent choline chloride-oxalic acid, or the ionic liquid 1-ethyl-3-methylimidazolium bromide. After pretreatment, we separated solubilised sugars from residual solids. The residual solids were saccharified using green solvent-stable glycosidases that were isolated from a newly identified strain of the ascomycetous fungus, *Penicillium oxalicum*. The factors affecting this saccharification were quantified from the response surfaces of a Box-Behnken design. Finally, the sugars extracted from *Ulva* biomass were fermented into bioethanol using a dual yeast culture. We obtained higher bioethanol yields from *Ulva* biomass with consolidated processing in deep eutectic solvents, compared to lower yields from *Ulva* biomass with other solvents or two-stage processing.

Charlotte E. Walker: Investigating inorganic carbon transport in the Chlamydomonas CO2 concentrating mechanism

Algae are responsible for ~30% of global photosynthesis, they provide the O_2 we breathe, fuel the bottom of the global food web and play a key role in the removal of CO_2 from our atmosphere. In order to enhance the efficiency of their photosynthesis, many algae operate a CO_2 concentrating mechanism (CCM). The current understanding of the algal CCM is largely focussed on the model green alga *Chlamydomonas reinhardtii*. Current models of the *Chlamydomonas* CCM postulate that HCO_3^- is taken up from outside the cell through a series of transporters to the thylakoid lumen, where a carbonic anhydrase (CA) dehydrates accumulated HCO_3^- to CO_2. The CO_2 subsequently diffuses into the pyrenoid, a phase separated liquid organelle traversed by thylakoid tubules, which contains the photosynthetic enzyme Rubisco. Previously, HCO_3^- transporters have been identified at both the plasma membrane and the chloroplast envelope, but the mechanism of how HCO_3^- crosses the thylakoid membrane has remained a mystery. We have recently identified and extensively characterised a thylakoid localised HCO_3^- channel that we predict is fuelling the thylakoid luminal CA and playing an essential role in the CCM. As well as providing valuable insight into the process responsible for approximately a third of global carbon fixation; the outcomes of this project feed directly into an effort to engineer the algal CCM into crop plants, potentially enhancing the yield and directly alleviating food security issues arising as a result of population increase and climate change.

Tom Fairchild: Canopy-forming seaweeds drive ecosystem multifunctionality cascades on rocky shores

The physical characteristics of habitats play an important role in determining the structure and diversity of coastal communities. This interaction between substrate structure and diversity is becoming an increasingly important area of research as habitat homogenisation and change accelerates through the proliferation of artificial coastal structures. However, while evidence of substrate effects on biodiversity are becoming apparent, the functional consequences are poorly understood. We created habitat units with varying surface roughness to examine how structuring effects of rugosity can alter ecosystem functions and multifunctionality. We found differences in substrate roughness drove facilitation cascades through the presence of canopy-forming macroalgal species, which strongly structured understory communities. Greater algal canopy cover of substrates enhanced the diversity and abundances of algae and animals, and in turn resulted in higher biomass stocks and rates for individual ecosystem functions and overall multifunctionality. As such we highlight how increasing complexity of artificial coastal structures could be leveraged to support higher diversity and more functional ecosystems.

Robert Hatfield: The application of nanopore sequencing to the study of phytoplankton

Oxford Nanopore Technologies provides a selection of a low-cost and scalable solution for the sequencing of DNA, RNA and proteins. It has been extensively used in all manner of environments and applied to innumerable fields of research. Its application to the study of phytoplankton has, however, had little uptake. This has primarily been due to the low accuracy of raw reads from early iterations of the technology (<90%). Since the release of new chemistry that facilitates raw read accuracy of >99% and the promise of further developments providing orders of magnitude improvements, the technology is coming of age. This talk introduces the technology and outlines an assay developed by Cefas that sequences a ~3.2kb region of the ribosomal DNA genes. Ranging from 18S to 28S, this region includes the notably including the highly divergent ITS regions as well as almost all of the conserved 18S gene and a small section of the 28S. The assay has been applied to both environmental samples and reference cultures and has generated high accuracy (>99.9%) sequences from both types of samples. Practical hurdles and future developments such as the potential for field deployment will also be discussed.

Posters – Blue Carbon and Kelp Ecology

Bronwen Paxton: Assessing the blue carbon potential of seagrass restoration in the UK

Seagrass habitats provide a wealth of ecosystem services such as carbon sequestration and acting as a nursery habitat, however seagrass is being degraded around UK coastlines at an alarming rate. Previous restoration projects in the UK have successfully begun restoring sub-tidal seagrass habitats, but it is unclear whether degraded intertidal seagrass habitats can be effectively restored. This study investigates the success of reseeding as a restoration method and quantifies the carbon storage potential of *Zostera noltei*. The restoration site in Langstone Harbour, Hampshire contains a mixture of healthy and degraded seagrass enabling 9690 seeds to be collected locally from healthy beds in September 2021 for reseeding. Seeds were extracted from seagrass leaves over a two-month rotting process and then deployed in December within a 225 m^2 restoration site at a seed density of 40 seeds m^{-2}. The restoration area, two reference meadows within Langstone Harbour and a pristine meadow on the Isle of Wight will be surveyed before restoration, and seasonably after. Blue carbon storage potential of these seagrass sites will be assessed via; carbon standing stock in sediment cores, plant productivity and associated carbon in algal mat biomass. Ultimately, this research aims to determine if seagrass restoration in the UK will support carbon sequestration and thus reduce greenhouse gas emissions, allowing it to be upscaled and commercialised through the incentives of blue carbon.

Harrison Catherall: The structure and morphology of *Laminaria hyperborean* kelp forests in the North Sea

Subtidal kelp forests form some of the most productive and critically important marine habitats on Earth. Despite having their importance recognised as well as having a potentially active role in climate change mitigation, kelp forests around the UK, and in particular the North Sea, have been relatively understudies compared to other regions around the world. We surveyed **Laminaria hyperborea** dominated kelp forests across various depths at six sites within two regions representing the northeast of England and the southeast of Scotland. We used both quadrat scale density and individual canopy former morphology, biomass and age to quantify ecological structure.

In general, *L. hyperborea* canopies had lower age, biomass, density and morphology at greater depth, and each response variable varied between site (nested in region). At the regional scale kelp forests were denser in northeast England, principally due to a denser sub-canopy. They were also older and had greater length and biomass. All density and morphological response variables were highly variable between sites (nested in region), suggesting patterns are driven by a variety of environmental factors (e.g. turbidity, temperature, wave exposure) that interact across small spatial scales.

Emma A Ward: Carbon provenance and coastal connectivity - implications for temperate seagrass carbon sequestration capacity

Seagrass has long been established as a coastal blue carbon habitat with near global presence. Their capacity to accumulate sedimentary organic carbon, poses them as a manageable resource to sequester carbon and reduce greenhouse gas emissions. Seagrasses accumulate carbon two-fold through in situ photosynthetic fixation of autochthonous carbon and sedimentation of allochthonous carbon from outside the ecosystem. This study collates an updated global synthesis of δ13C analyses from seagrass sediments and leaves, enabling its categorisation into seagrass bioregions alongside grouping by seagrass species size. For paired δ13C seagrass sediment and leaf values there was a consistent difference in δ13C of seagrass leaf tissue and seagrass sediment (Δδ13Cseagrass-sediment median = 7.36‰), indicating regular presence of allochthonous carbon. The temperate North Atlantic and North Pacific bioregions have significantly higher Δδ13C seagrass-sediment compared to all other seagrass bioregions (Temperate Southern Oceans, Mediterranean, Tropical Atlantic and Indo-Pacific). The composition of seagrass species inhabiting global seagrass meadows was a significant factor in the Δδ13C seagrass-sediment, with the lowest Δδ13C seagrass-sediment found in either monospecific meadows dominated by large seagrass (Median = 5.24‰) or mixed meadows (Median = 5.63‰), which generally included large seagrass species. The meadows with the highest Δδ13C seagrass-sediment are monospecific meadows dominated by mid-range sized seagrass (e.g., *Zostera spp.*, *Cymodocea spp.* and *Syringodium spp*.). Seagrass meadows within the North Atlantic and North Pacific are dominated by mid-range sized seagrass and contain no large seagrass species. These temperate seagrass meadow's affinity for allochthonous carbon from adjacent habitats, means their placement within the coastal landscape influences their carbon sequestration potential. This global review of seagrass meadows demonstrates that a meadow's seagrass species composition and placement within the seascape influences its carbon sequestration capacity; making them necessary forecasters of a meadow's carbon offset potential, particularly in the context of temperate seagrass meadows.

Emma Stuart: The influence of *Laminaria hyperborea* canopies on the local physical environment and implications for kelp forest associated flora and fauna

Understanding the role of species interactions, such as competition and facilitation, in structuring communities is a fundamental goal of ecology. It is well established that large canopy-forming seaweeds (e.g. kelps and fucoids) exert a strong influence on community structure, by offering biogenic habitat, altering environmental conditions and interacting with co-existing species. However, empirical information derived from manipulative studies exploring how canopy-forming seaweeds alter the local environment and mediate species interactions is lacking from many regions and habitat types. We conducted a manipulative experiment in subtidal *Laminaria hyperborea* forests at two sites in Plymouth Sound, UK. Three treatments were established in multiple replicate plots using SCUBA: 100% kelp removal, 50% kelp plant removal (i.e. thinning), and 0% removal (i.e. unmanipulated control). Within each plot, temperature, light levels and sedimentation rates were monitored over 3 months, and after 5 months the density of juvenile kelp recruits and biomass of understory macroalgae was quantified. We found that kelp canopies had no impact on seafloor temperature or sedimentation rates, but exerted a strong influence on light levels. Removal of kelp canopies led to marked increases in light availability, juvenile kelp recruitment and understorey macroalgal biomass. Overall our study shows that physical disturbance to *Laminaria hyperborea* canopies alters resource availability (i.e. light and space), with subsequent shifts in associated community structure.

Posters - Sustainable Food Systems

Hanan Al-Adilah: Assessment of Arabian Gulf Seaweeds from Kuwait as Sources of Nutritionally Important Polyunsaturated Fatty Acids (PUFAs)

The fatty acid (FA) compositions of ten seaweeds representative of Chlorophyta, Rhodophyta, and Ochrophyta from Kuwait in the Arabian Gulf region were determined and are discussed in the context of their potential nutritional perspectives for seaweed valorization. All the seaweeds had higher saturated fatty acid (SFA) and lower monounsaturated (MUFA) and polyunsaturated

fatty acid (PUFA) contents than those typical of tropical environments. Palmitic, myristic, stearic, oleic, linoleic, α-linolenic, and stearidonic acids were the major FAs detected. Arachidonic, eicosapentaenoic, and docosahexaenoic acids were detected in minor amounts. Conserved fatty acid patterns revealed phylogenetic relationships among phyla, classes, and orders matching the molecular phylogenies at higher taxonomic ranks. Hierarchical clustering analyses clearly segregated different seaweeds (except *Codium papillatum* and *Lyengaria stellata*) into distinct groups based on their FA signatures. All but one species (*Chondria sp.*) had health-beneficial n6/n3 PUFAs (0.33:1–2.94:1) and atherogenic (0.80–2.52) and thrombogenic indices (0.61–5.17). However, low PUFA/SFA contents in most of the species (except *Ulva spp.*) may limit their utilization in the formulation of PUFA-rich functional foods. *Ulva spp.* had substantially high PUFAs with PUFA/SFA > 0.4, n6/n3 (0.33–0.66) and atherogenic (0.80–1.15) and thrombogenic indices (0.49–0.72), providing substantial potential for their utilization in food and feed applications.

Eleanor Wood: Investigating biorefinery methods on the Rhodophyte Porphyridium aerugineum

Production of algal biomass for specific products is a costly procedure that can often lead to waste. Microalgal biorefineries aim to valorize the whole biomass to obtain multiple extracts for different commercial products in an environmentally and economically sustainable manner. *Porphyridium aerugineum* is a freshwater Rhodophyte that uniquely does not produce phycoerythrin and therefore phycocyanin is the primary phycobiliprotein. There is potential for biorefinery of this species due to the high value of natural phycocyanin and the presence of other products including EPS, starch, proteins, and lipids. Therefore, there is scope for *P. aerugineum* to compete with *Spirulina sp.* in the commercial market. Biomass optimisation, cell disruption and product separation are being investigated to achieve the most efficient and economic separation of products. For cell disruption, bead beating, ultrasonication, and freeze-thawing are being explored, and results are collated based on the percentage of cells disrupted and the rate of release of intracellular compounds. Membranes and centrifugation are used for product separation. Once each stage has been established, they will be combined to create a sequential biorefinery process. This project will offer a roadmap for future development of industrial biorefinery processes.

Karen MacKechnie: CCAP – Introducing the Algal Research, Innovation and Environmental Science (ARIES) centre

Algal biotechnology is an exciting and growing discipline of applied phycology and CCAP is extending its services to accommodate this growth with the new Algae Research, Innovation, and Environmental Science centre (CCAP-ARIES). The purpose of the CCAP-ARIES facility is to complement the culture collection and centralise research and service provision by enabling CCAP to cultivate and harvest larger volumes of algal material (up to 280 liters), as well as providing biochemical, metabolomic, and molecular biology services to industry and academia.

To ensure best science practice in scale-up we are utilising four 70L Phyco-lift photo-bioreactors that will facilitate comparative studies and increase flexibility of scale. CCAP-ARIES is also equipped with cutting-edge analytical equipment which enables us to provide users with biochemical analyses and metabolomic screening of biomass. Furthermore, the enhanced genomic service will support CCAP's core molecular work and enhance technological advances to include collaboration with whole genome sequencing projects (e.g., Darwin Tree of Life). CCAP-ARIES also aims to support algal research in the user community and deliver advanced training to UK and International collaborators.

These latest developments will enable CCAP to continue to build upon its world-class research facility, with which to investigate the unique and underexplored diversity of protistan organisms for the understanding of the natural world and the development of new biotechnological applications.

Onyedika Chukwuma: Investigating the potential of seaweed as novel bioherbicides against common weed species

Foresters and farmers alike are continually facing environmental challenges with the search for alternatives to the use of chemical herbicides being one such challenge. These herbicides are known to be hazardous to the environment. Additionally, their overuse, with the lack of sustainable alternatives, have resulted in weeds developing resistance. This study aims to explore the option of using seaweeds as a sustainable novel bioherbicide source.

Crude extracts from two Phaeophyta (*Fucus serratus* and *Fucus vesiculosus*), two Rhodophyta (*Mastocarpus stellatus* and *Porphyra dioica*) and one Chlorophyta (*Ulva spp*.) were generated using hexane, ethyl acetate, methanol and water. At 1.5 mg/ml extract concentration, phytotoxicity was established against *Lactuca sativa* (lettuce) seeds. The result demonstrated the allelopathic properties of seaweed extracts on plants. Extracts very rich in polar compounds mostly stimulated lettuce germination and growth, whereas the ethyl acetate extract of the two Rhodophyta, *M. stellatus* (MEE) and *P. dioica* (PEE) exhibited inhibitory properties, (with MEE producing the strongest inhibitory effect). The phytotoxicities of MEE and PEE were further investigated by conducting germination and growth assays (pre-plant emergence) using seeds of a broad-leaf weed, *Trifolium repens* (wild white clover) and a grass, *Lolium multiflorum* (Italian ryegrass), in addition to lettuce seeds. It was noted that the phytotoxicities exhibited by MEE and PEE was concentration dependent. At

5 mg/ml, MEE produced a stronger phytotoxic effect than PEE, significantly inhibiting germination and growth of lettuce seeds (18.3 ± 10.41%, 0.10 ± 0.09 cm) and white clover seeds (13.3 ± 16.17%, 0.07 ± 0.10 cm) by at least 75%, compared to the respective solvent control (Lettuce: 90.0 ± 5.00%, 3.76 ± 0.55 cm; White clover: 65.0 ± 10.07%, 2.70 ± 0.26 cm). Both MEE and PEE produced a weaker effect on ryegrass seeds, especially on its germination. However, MEE significantly inhibited growth of ryegrass seedlings (1.79 ± 0.91 cm) up to 65%, compared to the solvent control (4.91 ± 0.33 cm).

These findings are indicative of the presence of phytotoxins in MEE and PEE. This could lead to the development of novel greener, sustainable alternatives for replacing or augmenting the current use of chemical herbicide.

Valerie Rodrigues: Genomes of Three Marine Vibrio sp. Demonstrates Their Potential to Valorise Macroalgal Polysaccharides

Macroalgae are an essential part of the marine ecosystem and have traditionally been used as food, animal feed and fertiliser supplements. However, with the increasing need to shift from fossil fuels to a bio-based economy, they are being explored as raw material for the manufacture of biofuels, fine chemicals, cosmetics, and biomedical products. High rates of carbon fixation, quick proliferation and ability to grow in industrial, agricultural and domestic wastewater make them an attractive source of sustainable feedstock. Macroalgal biomass is predominantly made up of carbohydrates in the form of storage and cell wall polysaccharides. These polysaccharides have unique chemical compositions with huge existing and potential commercial value. Conversion of polysaccharides to value-added products often necessitates their breakdown to monomers, which can then be bio-transformed to various products by organisms capable of metabolising them. Saccharification using enzymes is preferred over chemical saccharification owing to their non-toxic and environment-friendly nature. Genome analysis of three marine *Vibrios* isolated from the surface of the green macroalgae *Ulva* reveal a plethora of enzymes that are capable of saccharifying diverse seaweed polysaccharides. These enzymes can potentially be used in the development of enzymatic technologies aimed at valorising macroalgal biomass.

Sarah Read: Remediation of potentially toxic elements using living nuisance algae, *Cladophora sp.*

The presence of heavy metals and other potentially toxic elements (PTEs) can lead to oxidative stress, cell death, and even extirpation in populations of exposed flora and fauna. Though PTE's occur naturally in trace concentrations through weathering of bedrock and sediments, recent heightened fluctuations are mainly attributed to the point sources of wastewater discharge from industrial sources.

To reduce the concentration of PTEs in discharged wastewaters, chemical and physical treatments such as chemical precipitation, ion exchange, adsorption, coagulation and reverse osmosis have been demonstrably employed during wastewater treatment (WWT). These systems, however, can be expensive, energy-intensive, lead to secondary waste streams, and inefficient at PTE concentrations in the ppb range. To expand the financial accessibility, sensitivity, and sustainability of WWT technologies, innovative solutions, including algal biosorption, must be sought after and researched. Algae are particularly suitable for WWT as they can be fast-growing, resilient, and capable of bioaccumulating PTEs.

This Ph.D. project explores the constraints and opportunities associated with living algal cultures with the WWT context, using a robust and opportunistic genus of macroalgae, *Cladophora* sp. This poster summarises essential information on PTE toxicity and removal achieved in long-term exposure experiments. Four PTEs have been investigated, i.e., Se, Cu, Mn, and V, and were selected based on their prevalence in the environment, industrial wastewaters, or their economic value if recovered.

Toxicity was determined using several metrics as proxies for productivity, including: nutrient removal, pH change, pigmentation, and biomass yield. The concentration of relevant anions including nitrate, chloride, and sulfate were measured using ion chromatography. In this evaluation, fresh weight (FW) and pigmentation are also used to establish culture health and productivity. Whilst PTE removal was quantified by analysing day 0 and day 14 PTE concentration using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Posters – General Phycology

James Barrett: Dissecting the dynamic carbon-fixing organelle in *Ulva*

The pyrenoids of eukaryotic algae concentrate the primary carbon fixation enzyme, Rubisco, into a non-membrane-bound organelle that resides in the chloroplast stroma. Pyrenoids enhance photosynthesis in aquatic environments as the epicentre of a biophysical carbon dioxide concentrating mechanism. In *Chlamydomonas*, the pyrenoid is a dynamic liquid-liquid phase separated condensate that is underpinned by the multivalent interaction of Rubisco with a disordered linker protein, EPYC1. Assembly and function of the pyrenoid with ultrastructural features is coordinated by a Rubisco-binding motif (RBM) that is shared between EPYC1 and several pyrenoid proteins. To date, our molecular knowledge of pyrenoids is limited to *Chlamydomonas*, though it is hypothesised that assembly of pyrenoids across the tree of life is guided by the same principles, despite lack of sequence conservation outside of the Chlamydomonadales. Here we demonstrate the sequence-independent identification of an analogous linker protein in the multicellular green algae *Ulva mutabilis*, along with a suite of RBM-containing analogues of

pyrenoid assembly proteins. Using a range of in vitro and in vivo techniques we demonstrate that the linker protein demixes *Ulva* Rubisco, is localised in the pyrenoid matrix and that the matrix demonstrates dynamic properties. A preliminary cryo-EM structure for linker-bound Rubisco is also presented, along with the in vivo localisation of putative pyrenoid assembly proteins. Our findings suggest the blueprints for pyrenoid assembly have evolved convergently in the core chlorophytes, and that differences between the systems have evolved accordingly. Being the first molecular characterisation of a pyrenoid from a multicellular algae, our findings align well with ongoing efforts to engineer pyrenoid-based CCMs into higher plants.

Jordi Sola: Environmental stress and negative species interactions limit the effect of heterogeneity on rocky shore communities

Rocky shores and other benthic marine and intertidal habitats have varying degrees of surface roughness – a fundamental habitat property that creates heterogeneity in environmental conditions. While previous studies demonstrate that heterogeneous or complex substrates tend to host more species (including macroalgal taxa), how the role of heterogeneity varies across common environmental stress gradients, and the ecological mechanisms responsible for heterogeneity -diversity relationships remain unclear. Here, to test how substrate heterogeneity influences community composition and diversity, we distributed replicated (n = 70) heterogeneous (pitted) and homogeneous (smooth) experimental substrates (limestone tiles) from the low to high intertidal (low to high environmental stress) at a moderately exposed rocky shore in south Wales, UK. Over 18 months, establishing communities on each substrate were surveyed seasonally through image analysis. Preliminary analyses show that heterogeneity effects on diversity tended to be maximized in the lower shore, with further analyses showing these increases were caused by a steeper species-accumulation curve rather than more individuals, and by an increase in species persistence rather than recruitment. Notwithstanding the overall strengthening of heterogeneity effects lower on the shore, heterogeneity actually promoted negative interactions –particularly competition – which tended to reduce species richness and therefore temper the heterogeneity-diversity relationship. Therefore, heterogeneity effects were limited by environmental stress -as less species were available to benefit from heterogeneity- and by negative species interactions – as the new microenvironments provided by heterogeneity were limited and thus trigger competition for space. Managing for biodiversity on natural and artificial rocky shorelines will entail explicit consideration of environmental stress (shore height) and species interactions.

Adam Lewis: ScillyHAB: An initial harmful phytoplankton survey facilitated by citizen science

Between 2018 and 2021 Cefas was involved in a multi-year research programme, funded by Interreg, this was ALERTOXNET. As a component of this project, Cefas undertook an initial Harmful Algal Blooms (HAB) survey of the Isles of Scilly. The Isles of Scilly (IOS) is an archipelago of 145 islets, 45 km southwest of England. Whilst no commercial shellfish fisheries exist, bivalves are harvested and consumed recreationally. To date this region has not been investigated for the presence of harmful algal species and with the expansion of certain HAB species globally along with escalating impacts of others it was deemed to be a valuable exercise to assess the current state of HAB in the IOS.

The survey started in March 2020, however, one week later the UK entered lockdown due to the Covid pandemic. Consequently, Cefas turned to citizen science to allow the field survey to continue. A team of local volunteers was recruited to carry out water sampling and shellfish collection and supplied with a portable inverted light microscope. The use of portable microscopy allowed for images to be captured and shared, with Cefas taxonomists able to review these remotely to provide additional taxonomic support. Fixed water samples and shellfish were sent to Cefas for further analysis and confirmation of field results.

Microscopy confirmed the presence of HAB genera well known in mainland waters: *Pseudo-nitzschia*, *Karenia*, *Dinophysis acuminata* and *D. acuta*, *Alexandrium*, *Prorocentrum cordatum* and *P. lima*. Nanopore sequencing (MinION) was used to generate consensus sequences confirming the presence of *Azadinium*, *Dinophysis*, *Pseudo-nitzschia* and *Alexandrium* genera. Shellfish analysis confirmed domoic acid, saxitoxins, dinophysis toxins, azaspiracids and tetrodotoxin, albeit at concentrations well below regulatory/guidance limits and those determined in shellfish harvested in SW England.

Although there were many challenges with data and sample collection due to the restrictions in place as a result of Covid-19, the project provided valuable baseline data on HAB species and impacts in IOS. The multi-faceted approach confirmed the presence of low concentrations of regulated and non-regulated marine toxins as well as HAB genera/species in an island region of the UK previously unassessed for these hazards.

David Hartnell: Discriminating toxic *Alexandrium* cells by FITC-conjugated saxitoxin monoclonal antibody and flow cytometry

Marine phytoplankton account for half of global primary production, feeding fisheries, molluscan aquaculture, and provide many ecosystem services i.e., climate regulation, carbon drawdown, nutrient & biogeochemical cycling. However, numerous species produce potent toxins which have negative human health impacts when bioaccumulated in bi-valve shellfish and subsequently harvest-

ed for human consumption. These can take many forms including paralytic, amnesic and diarrhetic shellfish poisons; produced by numerous phytoplankton taxa, such as *Alexandrium* (saxitoxin, spirolides), *Pseudo-nitzschia* (domoic acid), *Gonyaulax* (yessotoxins), *Dinophysis* & *Prorocentrum* (okadaic acid) amongst others. Consequently, marine phytoplankton are monitored under food safety legislation, these data are used as an early warning mechanism to inform and target toxin testing of shellfish flesh.

In the United Kingdom, routine phytoplankton monitoring is undertaken by light microscopy to identify and enumerate potentially harmful algal cells, using traditional methodologies. This requires skilled taxonomists, is resource intensive and, importantly, cannot differentiate between morphologically similar species or identify toxicity; potentially distorting relationships between cell counts and sample toxicity. Such is the case in the dinoflagellate *Alexandrium*, which is the primary causative organism of paralytic shellfish poisoning in many parts of the world, due to morphologically similar species, with some producing saxitoxin and others not.

This study aims to develop expertise in flow cytometry as a tool for the rapid, robust enumeration and speciation of phytoplankton. Initial work analysed and characterised *Alexandrium* cultures, by size and autofluorescence using a bench top flow cytometer. Results were similar between toxic and non-toxic cells, demonstrating the need for additional flow cytometer techniques. Therefore, a rapid immunohistochemical protocol using a FITC-conjugated saxitoxin monoclonal antibodies to allow the differentiation of saxitoxin positive *Alexandrium* cells, was developed. Preliminary results indicate that immunohistochemistry with flow cytometry is capable of distinguishing between toxic and non-toxic *Alexandrium* cells.

This study has been funded by Cefas Seedcorn (Project DP439)

Damiano Duci: Talking algae: an early warning system for Harmful Algal Blooms

Harmful Algal Blooms (HAB) are responsible for the degradation of freshwater resources worldwide. With ongoing climate change and increases in nutrient pollution, the intensity and frequency of HAB events has been increased over the past two decades. Freshwater management is currently challenged by HAB events since remediation techniques have little effectiveness and are only reactive. Thus, better remediation techniques of a proactive nature are required to address HAB events. For this purpose, fundamental knowledge of phytoplankton physiology should be investigated. Electrophysiology detection of phytoplankton cell signalling has shown great potential in explaining phytoplankton physiology. For example, the diatom *Pseudonitzschia fraudulenta* was shown to emit an electrical signal under prolonged darkness exposure as a response to stress. This signal was a synchronized collective electrical oscillation that the community of *P. fraudulenta* employed to detect an adverse environmental variation (darkness). Talking Algae is developing novel electrophysiology detection methods to investigate cues of phytoplankton cohort communication events under exposure to adverse environmental stressors. Our overriding aim is to whether cohort communication between algal cells can provide an early warning system for HAB events. If proven, this technique would hold the potential to aid development of proactive freshwater management remediation techniques pushing a paradigm shift in the sector.

Jaz Millar: Novel instrumentation for the *in situ* measurement of glacier algae physiology within ice

Microalgae on glacier surfaces are an important contributor to the biogeochemistry, albedo and net carbon production on the glaciers they inhabit. They may also hold the key to how early plants colonised land in the Ediacaran. In the aftermath of the Cryogenian Snowball Earth, cold-adapted algae were deposited across the Earth's land masses, having proliferated and diversified during the Cryogenian interglacial period. Established communities of green algae on this recently exposed land gave rise to the first land plants. By examining the physiology and adaptations of modern glacier Streptophyte algae, we can uncover key processes and strategies that allowed these algae to survive Snowball Earth and subsequently colonise the land, staging the conditions for evolutionary development. Here we present our outline for a new 'Photosynthetron' device under development through collaboration with Photon Systems Instruments (Czech Republic) as part of the iDAPT (ice Dependent Adaptations for Plant Terrestrialisation) Leverhulme Trust funded project. The aim of this novel instrumentation is to allow the first *in situ* quantification of algal physiology within surface ice on glaciers, allowing direct measurement of glacier algal responses to their environment. We will then be able to link the known physiological potential of algae collected from genomic and *ex situ* experimental data to the actual activity of these organisms in their native ecosystems, providing a new view of algal processes on ice today, and a functional analogue to glacial algae of the past.

Larisa Lewis: Spatial and seasonal variability in the structure of *Himanthalia elongata* populations on rocky shores in Plymouth Sound, UK

Himanthalia elongata (Sea Spaghetti), is a large brown fucoid that is commonly found across rocky shores from Portugal to Norway. Despite its widespread distribution, few studies have documented spatiotemporal patterns of growth, recruitment, and density within natural populations. This is increasingly important as natural populations become potentially impacted by harvesting pressure from rising popularity of *H. elongate* as a nutritional food product and "seed stocks" for cultivation practices. Moreover, this species may play an important role in habitat

provision and inshore carbon dynamics, yet it remains understudied. We conducted monthly surveys over a year to characterise population structure (i.e. density, standing stock, growth, fecundity, and recruitment rates) at four sites in Plymouth Sound, situated along a gradient of wave exposure. At all sites, *H. elongata* exhibited rapid elongation of receptacles during the Spring, however, specific rates and timings of growth varied across the wave exposure gradient. Populations at sheltered sites reached maximum biomass in June/July and began degrading after August. Conversely, populations at exposed sites attained peak biomass later, in August, and receptacles remained in good condition until November. Population density reflected these trends, with the next cohort of receptacle producing *H. elongata* occurring earlier at sheltered sites. Generally, the receptacles at sheltered sites were consistently longer, wider, and darker in coloration and there were obvious differences in the reproductive morphology between levels of wave exposure. Gamete release was first detected at all sites in July and subsequent lab-based trials revealed that levels of oogonia release and rates of recruitment remained high across all sites from August until November. Interestingly, the number of oogonia and successful recruits noticeably decreased in November for populations at sheltered sites only. These results suggest important site-level differences in growth, density, reproductive output and recruitment of *H. elongata* which may have implications for management, harvesting and cultivation practises of this species. This study is on-going and will continue to validate these trends across a two-year period.

Amal Hasan: *Kuwaitiella rubra* (Bangiales, Rhodophyta), a new filamentous marine alga from the Arabian Gulf

A new filamentous bangiophycean marine red alga, treated here under the provisional name *Kuwaitiella rubra*, was found in Kuwait in the North-western Arabian Gulf. The intensively red upright thallus of up to 1 cm in length, fixed to the substratum by a colourless rhizoid, is initially uniseriate but becomes biseriate in its distal part upon transformation into globular archaeospores. Cells contain a single stellate plastid. In culture, bipolar asymmetric germination of the spores led to a new generation of identical erect thalli. Phylogenetic analyses of partial small subunit nuclear ribosomal DNA (18S) and of the plastid-encoded ribulose-1,5-bisphosphate carboxylase/oxygenase large subunit (rbcL) gene placed the new taxon in the Bangiales, however genetic similarity with other species was limited (maximum 91% in SSU and 90% in rbcL). It was no clear member of any known clade but weakly associated with Minerva and Dione from New Zealand. In the SSU phylogeny, it formed a basal branch of the Bangiales and clustered with Minerva aenigmata. In the rbcL phylogeny, it appeared in the middle of the tree, its closest relative being Dione arcuata.