Abstracts

12th International Temperate Reefs Symposium
6 – 11 Jan, 2019
Hong Kong

Content

Abstracts
of
Plenary talks

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Christopher Harley
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Christopher McQuaid
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The great speeding up: the four main mechanisms by which humans are speeding up the ecology of marine systems

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From the tropics to the poles, nearshore ecological systems are speeding up. Temperatures and disturbance rates are increasing, systems are organically enriched and species introductions are more frequent. My team combines experimental ecology with the observational to inform our predictions of this constantly re-created fringe of the sea. In this plenary, I will present theoretical and empirical evidence that four drivers of global change (warming, nutrient pollution, disturbance and species additions) are increasing the fundamental rates of organisms, populations, and communities; selecting for smaller individuals and species and creating self-reinforcing cycles of weediness. I will discuss recent studies that help us see into the future of biodiversity for our nearshore systems. I consider how rate drivers interact and the development of new molecular and remote sensing tools for detecting structural and functional ecosystem change. Finally, I will outline some of the consequences of this ecological 'speeding up' for coastal marine communities, their conservation, and management.

Key words: Pollution, Invasion, Disturbance, Climate change

From keystone predation effects to global change, are we missing the forest for the trees?

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Most ecologists, early in their careers, are trained in frequentist statistics with a heavy emphasis on comparing the means of two or more populations. This comparative framework then dominates many of our experimental designs, and "death by ANOVA" may have allowed many important ecological patterns to escape notice. Here, I will give two examples of how stepping back from a narrow focus on plot-level means to consider variation among plots allows us to gain new insights. First, I examine the classic marine ecological debate surrounding the true effects of a keystone predator, *Pisaster ochraceus*, on biodiversity. Paine famously found that *Pisaster* promotes diversity (of primary space holders) by preventing space monopolization by the competitive dominant. Other researchers have noted that *Pisaster* may actually reduce diversity by eliminating important biogenic habitat for a host of small, mobile species. My collaborators and I have used a natural experiment in the field to compare these two view points, and find that they are both too narrowly focused. Rather than create a monolithic mussel free habitat, *Pisaster* allow a variety of alternative mussel-free habitats to persist, and overall diversity is maximized when *Pisaster's* effects vary across the landscape. Similar patterns emerge in global change experiments led by Norah Brown. Experimental acidification in the field reduced community-level variation among tiles in the field, suggesting that only a subset of community types can persist in an acidified ocean. Results such as these suggest that dominant ecological forces, be they ecologically important species or key environmental drivers, may be quite important in terms of the diversity they generate, but that this diversity cannot necessarily be effectively detected or explored at the spatial scale of a typical experimental unit. Greater attention to among-plot patterns, in addition to traditional comparisons of treatment means, will be important for understanding how biodiversity is maintained.

Key words: Biodiversity, Scale, Species interactions, Global change

Ecological experimentation, hypothesis-testing, P-values and issues about rational thought

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In recent years, hypothesis-testing using statistical procedures in ecology has been under attack by reviewers, grant-agencies, editors, commentators and many other types of ecologists. The criticisms obviously have some basis, but revolve around several common themes. One is that it is arbitrary to consider some values of probability to indicate a decision to reject a null hypothesis, whilst other values are used to indicate that it should not be rejected. Yet, probability distributions do not actually include such discontinuities. This criticism has little to no merit when alternative procedures are recommended (or mandated) but which, in practice, share the same problem.

A second major issue is that retaining a null hypothesis does not indicate anything about its validity, even though, in practice, this often leads to irrational conclusions. This criticism is valid, but can be dealt with by use of equivalence and severity testing.

Finally, a common criticism of statistical hypothesis-testing is that it does not provide any measure of how likely it is that any given hypothesis is correct, given the available data. This, it is claimed, makes Bayesian procedures superior. The problems of using Bayesian procedures are, however, major. They include the well-known issues about origins and meanings of prior probabilities and the lack of any element of falsificationist philosophical considerations when using them.

These issues will be discussed in a defence of rational ecological experimentation.

Key words: Logic, Probability, Experiment, Hypothesis-testing

Lawless ecology: pattern, process and prediction in marine ecosystems

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Ecologists are sometimes accused of physics envy, because they lack laws. A more reasonable comparison would be with sociology or economics; these too involve multiple inter-acting factors, threshold effects, small sample sizes and teleconnections. Here I discuss how pattern perception in nature depends on scale, how the factors regulating biological processes differ among nested scales and how loss of predictability at small scales may reflect the absence of environmental gradients at those scales. Apart from time and space, an important additional scale is taxonomic resolution; this too colours pattern perception. As ecologists, we are tasked with predicting ecosystem change with varying abiotic conditions, particularly climate change. Climate envelope models attempt this on the basis of physiological tolerances, but necessarily ignore the multiple aspects of biology that lead to realised community structure. Climate change will have indirect effects through its effects on species interactions, a critical field so far little explored. Models also necessarily ignore the fact that changes in abiotic conditions will often affect the primary producers at the base of the food web first, so that that climate change will affect the quantity and quality of the food environment as well as the physical environment of organisms. Importantly, models are obliged to treat species as homogenous entities while there is mounting evidence that intraspecific variability among genetic lineages can result in clades responding quite differently to the same stressor. Ecologists may not need laws, but in order to make good predictions, they do need a good understanding of biology.

Key words: Intraspecific variability, Scale dependence, Species interactions, Climate change

Ecological experiments in the era of macroecology and big-data

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Ecology is becoming a global-scale science in an effort to assess how increasing human domination of the biosphere affects life on earth. This mission is facilitated by the increasing availability of large repositories of ecological and environmental data, allowing ecologists to test hypotheses at unprecedented spatial and temporal scales. Large datasets are, however, almost observational and although mechanistic models can help uncovering causal processes as shown by recent developments in macroecology, the analysis of 'big data' remains largely correlative. Here, I argue for the central role of ecological experiments to increase the causal inferential strength of ecological studies in an era where observational data and ecological models play a prominent role to address large-scale, long-term environmental problems. Specifically, I propose novel strategies to leverage the scope and attribution of causality in ecological studies based on the hybridization of observational and experimental data and using emerging analytical techniques in time series analysis and species distribution modelling that go beyond the traditional use of observations as covariates. I will use examples from my own research on the ecology of temperate rocky reefs to illustrate the application of hybrid datasets and discuss the wider application of this approach to other datasets, including emerging genomic 'big data'. Identifying procedures that capitalize on the strengths of both observations and experiments is a great research challenge that can contribute major breakthroughs in the way we investigate, understand and forecast ecological responses to global change.

Key words: Causal inference, Experimental ecology, Global change, Hybrid datasets

Abstracts
of the theme
Natural and anthropogenic impacts

Anthropogenic & natural disturbances (AN)
Artificial structures & urban ecology (AU)
Conservation & restoration (CR)
Invasion biology (IB)

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AN1

Globally declining kelp forests and the rise of turfs

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Kelp forests provide valuable ecological services along a quarter of the world's coastlines. Here we show how kelp forests around the world have been in decline over the past 4-5 decades, and are being replaced by turf algae in many places. We provide an overview of the many human activities that have mediated transitions to turfs through geographically disparate abiotic (warming and eutrophication) and biotic (herbivory and epiphytism) drivers of kelp loss. We then characterise turf algae communities from collapsed reefs around the world and give examples of the transition of kelp forests to turf reefs in Australia and Norway. Evidence that environmental conditions are becoming less favourable for kelps, combined with a lack of observed recovery, raises concern that these changes represent persistent regime shifts. Although these new locks on the degraded ecosystems are strong, a mechanistic understanding of feedback systems and interactions between global and local drivers of kelp loss will expose which processes are easier to control. Finally, we present new solutions currently in development to help curb the trend of the flattening of kelp forests globally.

Key words: Human impacts, Ocean warming and marine heatwaves, Eutrophication, Regime shift

AN2

Understorey communities are resilient to temporary kelp loss across a turbidity gradient

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Coastal sedimentation and turbidity are increasing in many regions across the globe and are linked to declining resilience of kelp forests. In a healthy state, these forests support a vast array of species and exert strong controls on those composing their understorey. It is unclear how kelp canopy loss and turbidity may interact to affect understorey communities. In this study, we established replicate kelp clearance and control plots (~78 m^2) across a gradient in turbidity in the Hauraki Gulf, in north-eastern New Zealand, and monitored changes in the understorey community over two years. Turbidity was the greatest predictor of understorey community composition, and tempered effects of canopy loss such that assemblages at pristine outer Gulf locations experienced greater divergence in species trajectories. Algal turfs increased ephemerally at all sites, however this effect was strongest at pristine locations. Furthermore, kelp canopies had a greater role in facilitating sciaphilic algae at these locations. Loss of canopy had the strongest effect on frond-dwelling mobile invertebrates, although in all cases these effects were temporary. Understorey communities in disturbed and control plots largely converged within 2 years, even at the most turbid site where the kelp canopy failed to recover fully. This experiment demonstrates that understorey communities are resilient to temporary kelp loss across a turbidity gradient, despite differences in original species assemblages and their trajectories.

Key words: Understorey community, Kelp (*Ecklonia radiata*), Disturbance, Resilience

AN3

Removal of intertidal grazers by human harvesting leads to change in community composition and algal resilience to pulse perturbations

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Extreme fluctuations in abiotic conditions can induce a biological stress response (e.g. bleaching) detrimental to an organism's health. In some instances, organisms can recover if conditions are alleviated, such as through co-occurrence with other species that confer protection. Biodiverse, multitrophic communities are increasingly recognised as important promoters of species persistence and resilience under environmental change. On intertidal shores, the role of grazers as top-down determinants of algal community structure is well recognised. Similarly, the harvesting of grazers for human consumption is increasingly prevalent with potential to greatly alter the community dynamics. Here, we assess how differences in harvesting pressure of grazers under three management regimes (no-take; partial closure; open-access) alters the trophic interactions between humans, grazers, and algal communities. Grazer density and body size frequencies were different among regimes leading to changes in the photosynthetic performance and recovery of crustose coralline algae (CCA) post-bleaching, as well as their presence altering the strength of interactions between species. Exclusion of grazers led to different emergent communities and reduced negative correlations between taxa. The absence of larger grazers (>9cm) under partial closure led to macroalgal overgrowth of bleached CCA negatively affecting its recovery, whereas closed or open-access management led to a moderated algal growth and a shift from competitive to facilitative interactions between algal species. Given that CCA play an important role in the population growth and development of other species, the choice of management measure should be carefully considered before implementation, depending on objectives.

Key words: Environmental change, Ecosystem management, Conservation, Herbivory

AN4

First large-scale ecological impact study of desalination outfall reveals trade-offs in effects of hypersalinity and hydrodynamics

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Desalination is an increasingly common method of meeting potable water demands, but the associated ecological risks are not well understood. There are few published studies of marine impacts of desalination brine, and no well replicated before-after designs. Here we report a six-year study testing for impacts and subsequent recovery of sessile marine invertebrate recruitment near a desalination outfall with high-pressure diffusers. We used a Multiple Before-After-Control-Impact (MBACI) design to test for impacts and recovery at two distances (30 m and 100 m) from a 250 ML/day plant outfall, as well as a gradient design to test the strength of impacts relative to distance from the outfall. Polychaetes, bryozoans and sponges reduced in cover as far as 100 m from the outfall, while barnacles showed the opposite pattern and were more abundant near the discharging outfall. Ecological impacts were disproportionate to the relatively minor change in salinity (~1 psμ), suggesting a mechanism other than salinity. Impacts appeared to be driven by changes in hydrodynamics caused by the diffusers, such as higher near-bed flow away from the outfall. This is consistent with flow preferences of various taxonomic groups, which differ due to differences in settlement and feeding abilities. High-pressure diffusers designed to reduce impacts of hypersalinity may inadvertently cause impacts through hydrodynamics, leading to a trade-off in minimizing combined salinity and hydrodynamic stress. This study provides the first before-after test of ecological impacts of desalination brine on sessile marine communities, and rare insight into mechanisms behind impacts of a growing form of human disturbance.

Key words: Salinity, Brine, Larvae, Flow

AN5

Recovery from the *Torrey Canyon* oil spill and subsequent fluctuations of limpet populations and fucoid cover from 1967 to 2018

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The *Torrey Canyon* oil spill in 1967 occurred near the Marine Biological Association (MBA) of the UK, all of whose staff were mobilised to study the spill. MBA scientists (Alan and Eve Southward) were subsequently involved in long-term studies of recovery of rocky shores for the next ten years, continued at one of the worst affected shores (Porthleven) with Steve Hawkins since 1980 and Nova Mieszkowska since 2002.

Many of the rocky shores affected by the spill and unaffected controls had been studied from the early 1950s, with the Southwards charting fluctuations of rocky shore fauna and flora in relation to climate fluctuations. Thus a baseline existed against which to judge recovery of rocky shores from the beached oil and the excessive application of toxic first generation dispersants. A reminder is given of the first ten years of observations on recovery of shore communities and subsequent follow-up work suggesting recovery took up to 15 years on the shore (Porthleven) subject to the most severe dispersant application. In contrast, recovery occurred in 2-3 years at a site (Godrevy) where dispersants were not applied due to concerns about the impact on seals. The dispersants killed the dominant grazer, limpets of the genus *Patella*, leading to massive subsequent colonisation by algae. The resulting canopy of fucoid algae facilitated dense recruitment of *Patella vulgata*. These grazed the seaweeds down, before the starving limpets largely died off after migrating across the shore in search of food. This reduction in limpet numbers and grazing pressure then prompted a further bloom of algae. The dynamics of limpet populations in terms of biomass and numbers are explored for two co-occurring species (*P.vulgata* and *P.depressa*). Normal levels of fluctuations returned from the mid 1980s and have been charted to date. At Porthleven sustained observations over the last five decades (1967-2018) revealed when return to the typical range of spatial and temporal variation on rocky shores occurred. Some species were slow to recover due to interactions with climate fluctuations and regional scale TBT pollution.

Key words: Oil-spill, Recovery, Climate change, Limpets

AN6

Sea urchin grazing of kelp forests in the Arctic and the impact on the recovery of rocky shore communities after oil spills

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Arctic Norway has a risk of marine oil spills due to increasing offshore drillings. In these areas we find highly productive intertidal seaweed communities, subtidal kelp forests and sea urchin grazed areas. We have combined species distribution modelling with studies on fauna communities and mobility to address the recovery potential of rocky shore communities after oil spills in this area in which the kelp forests are heavily reduced by sea urchin grazing. Comparing fauna composition from the kelp forest, intertidal seaweed beds and sea urchin barrens we found that healthy kelp forest had more fauna species and higher densities than the other habitats. We found that 50 % of the fauna species in the rocky shore seaweed (*Fucus* spp) beds were also found on kelp stipes, 65 % in holdfasts. Only 38 % of the species on seaweeds were found on the sea urchin barrens. Results from the study of the colonisation ability (using fauna traps, "artificial seaweed") show high ability of kelp forest associated fauna to disperse and colonize new habitats, while the intertidal seaweed associated fauna had a more limited colonization rate. We suggest that kelp forests have an important role in the recovery of rocky shore communities after disturbances such as oils spills and that the recovery of sheltered and moderately exposed rocky shores will take longer than that of the more exposed areas due to the proximity to the sea urchin barrens. These results should have implications for coastal oil spill response operations.

Key words: Distribution modelling, Fauna composition, Colonisation, Vulnerability

AN7

Disturbance of microbiomes affects seaweed forests

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Marine habitat-forming organisms such as corals and kelps are declining in many places around the world due to effects of multiple anthropogenic disturbances. Indirect effects of such disturbances via changes to ecological interactions can be as, or even more important than direct, physical/physiological effects. However, most of our understanding and management of impacts of these disturbances is based on our understanding of interactions among macroorganisms. New molecular technologies are revealing astounding patterns of diversity and abundance of microorganisms, many of which live closely associated with marine habitat-formers. Emerging evidence from many systems increasingly shows that interactions between habitat-forming 'hosts' and their microbiomes are fundamental for host functioning and resilience, but how such relationships will change in response to disturbances is largely unknown. We experimentally examined the models that (i) disturbance of seaweed-associated microbiomes negatively affects host performance, and (ii) disturbance/removal of seaweed canopies alters substratum microbiomes, potentially affecting seaweed recruitment and recovery from disturbance. Disturbance of surface-associated microbiomes led to rapid declines in photosynthetic efficiency and increases in fouling relative to controls, suggesting strong effects of the microbiomes on the seaweed hosts. Canopy removal led to changes in microbiomes on the substratum relative to controls, possibly influencing recovery from disturbance. Microbiomes can therefore play significant roles in seaweed functioning and resilience. Understanding the mechanisms behind such effects can help to develop sound management strategies.

Key words: Microbiome, Holobiont, Phase shift, Kelp

AN8

Microplastic filtration and consumption by commercial bivalve species and implications for human health

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Plastic pollution is an increasing environmental issue. Plastic materials entering the global oceans range in size from nanoplastics (<100μm diameter) to large pieces used for a variety of products that degrade in the marine environment to small particles. Plastic debris causes entanglement, smothering, provides transport for species that can subsequently invade new regions, and is ingested by marine organisms. Microplastics are a pervasive pollutant that is increasing in concentration from estuaries to the deep ocean, with concentrations of up to 10^4 particles m^3 recorded. Mesocosm experiments were run on the commercial oyster *Crassostrea hongkongensis*, a species cultured in aquaculture facilities around the coastline of Hong Kong, and the blue mussel hybrid *Mytilus edulis galloprovincialis* that is farmed around the UK and European coastlines. Filtration rate, respiration rate, growth and mortality were recorded for both species in mesocosm experiments to determine the physiological impacts of microplastics in ambient and warmer seawater conditions to investigate how the effects of microplastics will be exacerbated in future warmer, more acidic oceans.

Key words: Microplastics, Climate change, Commercial shellfish

AN9

Functional responses of filter feeders across variable anthropogenic stressors

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The rapid expansion of coastal urbanization is a threat to global biodiversity and ecosystem functioning. Anthropogenic disturbances are altering marine ecosystems due to habitat modification, species invasion and pollution. Such stressors cause decreases in species diversity and changes in ecological functions in estuaries and coastal shores. Many of these functions are translated into goods and services to society, such as food, leisure, coastal protection, etc. Our knowledge on the effects of human stressors on ecological (or ecosystem) functioning, however, is little and restricted to a few taxa or habitats, such as oysters in estuaries. Filter feeders play an important role in the uptake of suspended material as they act as water purifiers. By retaining suspended material, filter feeders transfer energy to higher trophic levels either by consumption of predators or enrichment of the benthic matrix through biodeposition of organic material. Here, we investigated the variability of filtration (concentration of particles removed per hour) and biodeposition (amount of organic matter deposited in the mussel matrix in a 2-week period) rates of the intertidal mussel *Mytilaster solisianus*. This study was done at 6 sites with different levels of urbanization, and varying concentrations of metals, nutrients and organic material. Filtration and biodeposition rates were measured twice in each site. Results will be discussed in terms of the potential relationships between the functions and the stressors measured.

Key words: Ecosystem functioning, Suspension feeders, Ecoengineering species, Mussels

AN10

Post-tsunami recovery process of epifaunal assemblages on *Sargassum* seaweeds along the coast of Miyagi, Japan

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Sargassum beds along the Pacific coast of northeastern Japan were hugely disturbed by the 2011 Great East Japan tsunami. Although epifaunal community is a major pathway of material circulation in *Sargassum* bed ecosystems, there have been few reports on *Sargassum* epifauna in the Tohoku region. In order to clarify the post-tsunami changing process of the *Sargassum* epifaunal community structure, we collected the data of the epifaunal assemblages in Miyagi since after the tsunami (2011–2018), and compared the data with those of the 7th Natural Environment Survey by the Ministry of Environment, Japan (2002–2007), collected from 32 sites all over Japan before the tsunami. All epifauna remained on the meshes with different mesh size (0.1, 0.5, 1 and 2 mm) were classified into 10 taxonomic groups: Foraminifera, Nematoda, Polychaeta, Gastropoda, Bivalvia, Harpacticoida, Ostracoda, Caprellidea, Gammaridea and Isopoda. According to the results of the ABC (abundance-biomass comparison) analysis, there seems to be upper limit of biomass / abundance ratios in the pre-tsunami nationwide data. Comparing with the upper limit, while the data in Miyagi were lower just after the tsunami (2011–2012), the ratios gradually increased and reached to the upper limit from 2013 to 2018. As far as concerning epifaunal assemblages, *Sargassum* bed ecosystems along the Miyagi coast seem to be already restored. The ABC method for epifaunal assemblages may be a simple but useful measure for the vigorousness of *Sargassum* beds.

Key words: Great East Japan Earthquake, ABC method, *Sargassum* bed, Epifaunal community

AN11

Evaluating the performance of spatial early warning indicators of regime shift in macroalgal assemblages

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Assessing the performance of temporal and spatial early warning indicators of regime shift has become a main focus of current ecological research. Theory predicts that the approach to a threshold may be forestalled by changes in variance, autocorrelation, skewness and in patch size distribution. While there are many studies addressing temporal indicators, research into spatial indicators is far behind, with field experiments even more rare. Here, we combine experiments and models to evaluate the performance of spatial early warning signals (EWS) in an intertidal macroalgal system, where canopy removals pushed the system toward a tipping point (approximately at 75% of canopy loss), marking the transition between a canopy- to a turf-dominated state. We evaluated the performance of spatial EWS in a two-year experiment in which the canopy algae *Cystoseira amentacea* var. *stricta* was removed along 2m-long transects on rocky shores in the NW Mediterranean. Replicated transects were allocated to each of five levels of canopy removal: 0, 25, 50, 75 and 100% and understory assemblages were sampled after one and two years. Results showed that, with exception of Moran correlation at lag-1, recovery length (the spatial analogue of recovery time), spatial heterogeneity, spatial spectra at low frequency, spatial variance and skewness increased along the gradient of canopy removal, forwarding the tipping point. Simulations based on an experimentally parametrized model of macroalgal assemblages further indicated that spatial EWS may be a valid alternative to alert on an incipient regime shift when temporal indicators based long time series are not available.

Key words: Regime shift, Resilience, Spatial early warning signals, Macroalgal canopies

AN12

Effects of anthropogenic stressors on habitat-forming species and implications for ecosystem functioning

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Many ecosystems are formed by a single or a few habitat-forming species such as corals, trees and seaweeds. These habitat-formers are important for maintaining biodiversity and can modulate several ecological and biochemical processes - many of which are directly linked to the provision of ecosystem services. Therefore their presence and abundance is often considered a proxy for a raft of associated biodiversity and functions. However, anthropogenic impacts on ecosystem functioning can occur not only through impacts on the abundance and diversity of habitat-forming species, but also through effects on their physiology, metabolism and/or behaviour. Nevertheless, biomonitoring associated with conservation planning and management tends to focus on the abundance of these key species, often overlooking potential impacts of stressors on their physiological or functional attributes. Chemical contaminants and urbanisation through the addition of artificial structures are two major drivers of change in marine systems worldwide. We present a couple of case studies, including a global meta-analysis, where we evaluated the effects of anthropogenic stressors - contaminants and artificial structures - on the physiological properties of marine habitat-formers that can be directly related to the ecological functioning of systems. We show that human activities have the potential to significantly influence the functioning of coastal habitats through effects on functional properties of key species, such as the kelp *Ecklonia radiata* and the oyster *Saccostrea glomerata*.

Key words: Ecosystem functioning, Contamination, Artificial structures, Foundation species

AN13

Norwegian kelp ecosystems: past variability, present trends and future projections under climate change, ocean acidification and deliberate predator harvesting

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Kelp forest systems sustain a broad range of ecosystem services. As foundation species and ecosystem engineers, they furnish habitats that provide refuge and sustenance to complex ecosystems supporting high production and biodiversity in 25% of global coastlines. They expedite the export of organic carbon and nutrients, as drift kelp, to deeper ecosystems and are important players in global carbon cycling. Kelp ecosystems provide crucial physical barriers against storms, absorb pollutants and are local modifiers of nutrients and pH; and thus may modulate effects of pollution, eutrophication and ocean acidification. Norwegian coastal ecosystems have witnessed a rapid reduction in the distribution of kelp, in tandem with global trends, facilitated through the advance of sea urchin populations, competition from turf algae, coastal eutrophication and darkening, and regional warming. Recently, kelp in the northeast Atlantic are in recovery, paradoxically due to continued warming that is limiting the geographical range of sea urchins. Through the employment of advanced monitoring using drones combined with in situ mapping approaches, we are now delivering high quality maps of kelp distribution advancement and ecosystem complexity. This new information is being used to improve trait and ecosystem interactions representations in regionally downscaled climate-biogeochemical-ecosystem projections of urchin and kelp development under scenarios of climate change, ocean acidification and sea urchin harvesting. These projections provide scenarios of future kelp forest distributions under climate change and deliver optimal harvesting indicators that may be used as guidelines towards deliberate ecosystem management strategies under climate change.

Key words: Kelp, Urchin, Climate change, Ocean acidification

AN14

Temporal clustering of extreme climate events drives a regime shift in rocky intertidal biofilms

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Research on regime shifts has focused primarily on how changes in the intensity and duration of press disturbances precipitate natural systems into undesirable, alternative states. By contrast, the role of recurrent pulse perturbations, such as extreme climatic events, has been largely neglected, hindering our understanding of how historical processes regulate the onset of a regime shift. We performed field manipulations to evaluate whether combinations of extreme events that differed in their identity, order of occurrence and degree of temporal clustering generated alternative states in rocky intertidal epilithic microphytobenthos forming biofilms on rocky shores. The likelihood of biofilm to shift from a vegetated to a bare state depended on the degree of temporal clustering of events, with biofilm biomass showing both states under a regime of non-clustered (60 days apart) perturbations, while collapsing in the clustered (15 days apart) scenario. Our results indicate that time since the last perturbation can be an important predictor of collapse in systems exhibiting alternative states and that consideration of historical effects in studies of regime shifts may largely improve our understanding of ecosystem dynamics under climate change.

Key words: Regime shift, Alternative states, Extreme events, Biofilm

AN15

Effective local protection from fishing disturbance depends on ecological and human factors

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Fishing is a major human disturbance to marine communities on temperate rocky reefs. The Hawkesbury bioregion, on the east coast of Australia, has one of the highest human population densities in the country, and a correspondingly-high level of fishing impact. The region also contains ten small Marine Protected Areas (MPAs), most of which are open to some form of fishing. This study uses Reef Life Survey and site attribute data to assesses the natural and human factors which may reduce the impact of fishing at a local scale. We find that policy protection level, aspect (natural protection from wave exposure), habitat complexity and algal canopy are important predictors of marine communities. Most of the region does not have effective protection from fishing disturbance as indicated by biodiversity, abundance and biomass measures. Our findings suggest that the effects of fishing can be reduced at a local scale, but only if full sanctuary protection is implemented in a sheltered location with complex habitat structure and positive community involvement to provide informal enforcement and stewardship. These results provide a baseline for robust assessment of management actions to reduce the impact of fishing disturbance at local scales, with the potential to inform policy in other regions.

Key words: Overfishing, Biodiversity, Management, Reef Life Survey

AN16

Twenty years of experimental sea cucumber fishing in British Columbia, Canada: implications for sustainable fisheries

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An inability to consistently size or age sea cucumbers and a general paucity of information on their life history parameters present significant challenges to the management and conservation of sea cucumber stocks. Indeed, global sea cucumber fisheries have largely been characterized by boom and bust landings, with increasing demand leading to serial exploitation across regions and species. Given the challenges facing sea cucumber management and the pressure for fisheries expansion, research regarding sea cucumber productivity and resilience to fishing pressure is crucial. To this end, we discuss the results from a large-scale 20-year experimental fishing area (EFA) experiment conducted in British Columbia, Canada. Four areas, each consisting of ~10 km of shoreline, were sectioned into 5 sites and randomly assigned one of the following target rates for an annual harvest: (1) control (0% harvest), (2) 2% harvest, (3) 4% harvest, (4) 8% harvest, and (5) 16% harvest. Population density and mean weights of sea cucumbers (*Apostichopus californicus*) were monitored both prior to and following repeated harvests via transects surveyed by SCUBA divers. Here we summarise the results of a latent productivity model and compare risk in annual versus rotational harvest strategies based on modelling of the EFA data. Changes in mean weights and densities of sea cucumbers across treatments are also discussed.

Key words: Sea cucumber, Sustainable fishing, Productivity model, Rotational harvest strategy

AN17

Using acoustic telemetry to measure the effectiveness of spatial management for European Seabass (*Dicentrarchus labrax*) and commercially fished crustaceans

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European Seabass (*Dicentrarchus labrax*) is a commercially and recreationally important finfish native to the northeast Atlantic and Mediterranean Sea. Recent severe declines in North-Atlantic stocks have called for increased understanding of adult and juvenile movements and habitat use patterns, as well as the efficacy of existing management strategies.

In the UK, 34 Bass Nursery Areas (BNA) have been designated, within which targeted commercial fishing for Seabass is prohibited. Using a large array of acoustic receivers, project I-BASS will track 150 juvenile and sub-adult Seabass equipped with transmitter tags across 3 estuarine BNAs for a period of 2 years. The project will identify how often Seabass move outside these boundaries, as well as provide detailed observations on habitat use, within and in close proximity to the BNAs.

Concurrently, project ROPE will install a second array of acoustic receivers in a nearby Marine Protected Area and in the UK's first large scale, offshore, long-line, mussel farm, tagging a further 50 SeaBass and 50 Brown Crab and 50 Lobster (*Cancer pagurus* and *Homarus gammarus*).

This presentation will provide preliminary results from project I-BASS, describing observations from the first summer of acoustic transmitter deployment. Additionally details from further analyses, including comparisons with other estuarine fish species will be discussed.

Results from this study will feed directly into the local management of Seabass and crustacea in the South West UK, and will have wider relevance to UK and European management of inshore fisheries, aquaculture and MPAs of the North Atlantic.

Key words: Marine conservation, Fisheries management, Acoustic telemetry, Blue growth

AN18

Shift in ecosystem functioning: anthropogenic influences in a temperate coastal lagoon

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Anthropogenic modification of aquatic systems has diverse impacts on food web interactions and ecosystem functioning. Here, we assess the effects of anthropogenically controlled water flow regimes on the planktonic food web in a Ramsar listed temperate coastal lagoon that is under recovery from a degraded state. The lagoon system sustains a broad fauna of marine and estuarine species, including extensive polychaete reefs, high diversity of benthic grazers, and various commercial fish species. Our results show reduction in water quality and reorganised planktonic community and food web interactions associated with changes in water flow. The shifts in planktonic food web interactions represent modifications in habitat complexity. At high flow, phytoplankton-zooplankton interactions dominate the food web. Conversely, at low flow, bacteria, viruses and nano/picoplankton interactions are more dominant, resulting in a switch to heterotrophy. This switch can be associated with excess loading of organic matter, decomposition of dead organisms, and synergistic and antagonistic interactions among organisms. We suggest that a lower variability in amplitude of water flow into the lagoon system could be beneficial to sustain water quality and food web interactions, while also improving the ecosystem health of the Coorong and other systems facing similar stresses.

Key words: Food web, Habitat complexity, Ecosystem functioning

AN19

Effects of breakwater restoration work following the subsidence caused by the 2011 Earthquake on a kelp population

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The 2011 Tohoku earthquake caused 0.9 m subsidence on the coast of Kitsunezaki, northeastern Japan. Subsequently, restoration work for the constructing higher breakwater to cover the old sunken breakwater had been conducted from July 2014 to February 2016. In this study, we carried out a long-term monitoring survey based on the individual tagging in a population of the kelp *Eisenia bicyclis* to evaluate the effects of natural and subsequent anthropogenic disturbances. In the shallower area formerly in the intertidal zone and sank to the subtidal zone after the earthquake, the number of *E. bicyclis* increased by many recruits. Most of the recruits, however, died out due to the destruction and landfill for the restoration work. On the other hand, in the deeper area sank under the lower border of the kelp distribution before the subsidence, recruits had been scarce and had been dominated by the aged adults recruited before the earthquake. Even at the intermediate area where was not directly affected by both disturbances, the number of recruits suddenly dropped in 2016, after the restoration work. The insufficient supply of recruits may be due to the decreased number of young adults in the population. Taken as a whole, the density of young plants had temporarily increased after the earthquake, however, apparently had decreased after the restoration work. Our results showed that the anthropogenic disturbance such as restoration work directly and indirectly affected the structure of the kelp population influenced by natural disturbance such as earthquake-caused subsidence.

Key words: Kelp, Subtidal rocky shore, Subsidence, Restoration work

AN20

Effects of large scale disturbances on community structure in kelp forests

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Understanding the community-level impacts of disturbances are increasingly relevant as disturbance regimes increase in scale, frequency, and intensity with climate change. Kelp *Laminaria hyperborea* forests are high productive and diverse ecosystems adapted to a high wave energy environment characterised by discrete storm events that can defoliate reefs. Manipulative experiments on the effect of these kind of disturbances are labour intensive and have been typically restricted to small scale (meters) removal experiments. In this study we used directed kelp trawling, a human activity that physically removes larger quantities of kelp at scales of 100s of meters using a bottom sledge, as a scientific tool to quantify the impacts of broadscale disturbance on community function. We used a controlled BACI (Before-After, Control-Impact) design with impacted and control sites in the archipelago of Vikna, Norway. Measures of kelp abundance, and the associated flora, invertebrate, and fish communities were taken before and after controlled kelp trawling in one of two 15 km^2 comparable areas that was closed for trawling prior to the study. Approximately 2 000 tons of kelp were removed in the impacted area, creating large open clearings along the reefs. To compare fish densities between pristine and trawled areas, we used a combination of traditional methods (cages and dive surveys) and novel visual (Unbaited Stereo Video, RUV) and acoustic (bottom mounted echosounders, WBAT) methods. These tools provide a more complete picture of fish communities, which are hard to study in dense kelp forest because of low visibility. The main results from our study will be presented.

Key words: Kelp forest, Ecological disturbance, Community structure, Kelp trawling

AN21

Recent decline of *Cystoseira* forests along the west Istrian Coast (northern Adriatic Sea) related to increased seawater temperature and benthic mucilage formation

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Starting from 2015, a general regression of canopy forming brown macroalgae of the genus *Cystoseira* was observed along the west Istrian Coast. The die-off chronology of *Cystoseira* forests was followed from spring 2015 to autumn 2018 at several stations. Before 2015, mixed stands of *Cystoseira compressa*, *Cystoseira barbata*, *Cystoseira crinita*, *Cystoseira foeniculacea* and *Cystoseira humilis* formed flourishing forests, which predominantly covered the rocky bottom. From February to April 2016, i.e. during the period of intensive vegetative growth of *Cystoseira* thalli, all deciduous branches fell off leaving perennial cauloids entirely barren. In May 2016, sparse adventitious branches developed on cauloids. However, at the tips of cauloids, vegetative apices were degraded impeding the regeneration of primary branches and the formation of reproductive parts. Thalli maintained this barren aspect until winter 2017. During this period epiphytes heavily overgrew the cauloids and the sites experienced a transitory sea urchin invasion. During summer 2018, surviving thalli gradually detached from the rocks initiating the final phase of the forest die-off. Unusually high temperatures during summer and the impact of benthic mucilage forming microalgal and macroalgal blooms could play a pivotal role in the decline of *Cystoseira* forests along the west Istrian Coast. High temperatures might directly affect *Cystoseira* thalli. However, high temperature can also favour the formation of benthic blooms of native and alien mucilage forming microalgae during summer. On the contrary, blooms of autochthonous mucilage forming macroalgae that frequently occur during spring are usually promoted by increased nutrient concentrations.

Key words: *Cystoseira* forests, Regression, Benthic mucilage, Northern Adriatic Sea

AN22

Observed coral bleaching and quick recovery in Hong Kong

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We reported a comprehensive survey of coral bleaching in August-September 2017 in Hong Kong waters based on video transect surveys conducted at 33 major shallow water coral communities. Mild bleaching was observed at six sites, affecting 18.7% to 56.1% colonies. Follow-up field surveys of tagged colonies showed that affected sites all had over 95% recovery. Winter surveys in the later months recorded no bleaching in the 33 study sites. In view of the rising sea water temperature in this century, it is generally believed that bleaching events may occur more frequently. It is therefore necessary to formulate appropriate management measures and long-term monitoring scheme to evaluate local coral conditions.

Key words: Coral bleaching, Recovery, Monitoring

AU1

Marine urbanization in Singapore: patterns, processes, and predictions

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The main shifts associated with of marine urbanisation can be broadly categorised in to anthropogenic coastal change (or ocean sprawl), pollution (from both land and sea), and exploitation/extraction of resources (both living and non-living). These can all have profound effects on the biology and ecology of marine organisms and systems. Their relative impacts, however, vary both temporally and spatially. Understanding this variation should provide insights that are valuable to management, as conservation priorities are likely to change as the process of urbanisation transitions through stages. Importantly, even though urban sprawl, pollution, and exploitation are all well-studied in their own right, they are often siloed, leaving knowledge gaps where they overlap. The potential for additive and/or synergistic effects between two, or among all three, of these broad stressors open up a range of future hypotheses and research questions. Singapore represents an excellent case study for understanding the effects of marine urbanisation in Asia. During the past 200 years it has experienced rapid increases in population and wealth that have led to major impacts on its coastal environment. As it is in an advanced stage of development, it represents a scenario upon which other regional cities may also converge. Here, we will discuss the changes this city-state has undergone, including impacts that have increased or decreased in intensity with time, and try and look ahead to how new technologies and mindsets will affect Singapore's future seascape.

Key words: Marine urbanisation, Ocean sprawl, Pollution, Exploitation

AU2

Eco-engineering coastal defence structures may increase fish diversity in an urbanised shoreline

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Coastal defence structures such as seawalls and breakwaters are increasingly constructed to protect coastlines from erosion, wave action and sea level rise. Eco-engineering is a contemporary approach used to compensate for some of the negative impacts of these structures. Many studies have focused on increasing the benthic biodiversity on seawalls by installing enhancement features. However, little is known about how enhancements influence mobile organisms such as marine fishes. Here, we investigate whether concrete tiles featuring pits and grooves installed on the seawall of an offshore island in Singapore, increase fish species richness, abundance and feeding rates (bites on substrate). Using stationary underwater video cameras, we surveyed fish assemblages within 12 seawall plots (2.4 m × 2.4 m) both with and without enhancement tiles during high tides between April and October 2018. Mean species richness (12.2 v 8.6 spp $plot^{-1}$) and abundance (21.3 v 13.2 individuals $plot^{-1}$) were significantly greater in the enhanced plots than control plots. Mean feeding rate by herbivores and detritivores in the enhanced plots was, at 272.9 bites hr^{-1}, more frequent compared with the control plots (8.2 bites hr^{-1}). This is probably due to increased algal turf cover growing on tiles in the enhanced plots. Based on SIMPER analysis, some of the turf-feeding fish species (especially *Dischistodus fasciatus* and *Scarus rivulatus*) made a major contribution to the differences in fish community structure. Together, our results suggest that retrofitting topographically complex substrates on existing seawalls may assist in augmenting fish diversity by increasing the abundance of benthic biota.

Key words: Artificial structure, Eco-engineering, Fish diversity, Urbanisation

AU3

Improving the 'grey' by reflecting the 'green' - improving our understanding to facilitate ecologically-sensitive design of artificial structures in a changing climate

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'Ocean sprawl' has been attributed to increasing replacement of natural shores with artificial structures (e.g. seawalls, breakwaters, rock armour). Set against a backdrop of a growing global population and a demand for infrastructure, artificial structures are also being constructed to protect coasts from impacts associated with global climate change (sea-level rise, coastal erosion, increased storminess). Artificial structures can have widespread ecological consequences such as through a reduction in native biodiversity combined with an increased potential to facilitate the spread of non-natives. Their inability to mimic natural habitats may be due to a range of intrinsic features, such as lack of topographic complexity and space, and the materials used to construct them. Although there is a growing knowledge base on how 'eco-engineering' interventions (e.g. pits, grooves, tiles, rockpools) can be used to enhance biodiversity on artificial structures, only a few studies have tested materials that: meet engineering criteria, use topographic complexity that reflects natural shores, and have involved stakeholders in their design. We have produced and deployed nine different types of material tiles that meet engineering standards. We have sampled the biota and, using photogrammetry, characterised the topographic complexity on a range of artificial structures and natural shores at multiple locations in Ireland and Wales. We are also engaging with coastal stakeholders through meetings and the use of a bespoke website with interactive participatory mapping to gather information on artificial structures and to test perceptions of existing and proposed interventions. Analyses are underway and emerging findings will be presented.

Key words: Artificial marine structures, Materials, Topographic complexity, Stakeholder perception

AU4

The effects of open ocean mussel farming on ecosystem services

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The ecosystem effects of the UK's first large-scale open ocean mussel farm, currently being developed in Lyme Bay, South West England, have been monitored for the past five years. Once completed, this farm will be the largest of its kind in European waters, aiming to produce up to 10,000 tonnes of the native blue mussel, *Mytilus edulis*, per year. The farm is situated three to six miles offshore in high-energy waters; therefore, any observed effects on the surrounding ecosystem are expected to be less extreme than at sheltered, inshore farms.

Benthic and pelagic species have been monitored using a range of underwater video methods at trial areas within the farm as it grows. The observed increase in commercial species utilising artificial hard structures provided by the farm, and pelagic fish nearby mussel longlines demonstrate the potential for open ocean mussel farms to restore and benefit otherwise homogenous marine habitats.

Key words: Aquaculture, Mussel farming, Benthic impacts, Artificial structures

AU5

First insights into the thermal ecology of Singapore's seawalls

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The accelerating rate of human population growth near coastlines has driven the rapid proliferation of hard artificial structures in the marine environment. Singapore is a quintessential example of rapid coastal urbanization with seawalls having already replaced >60% of the natural coastline. Despite temperature being one of the most significant stressors in the intertidal environment, it remains an understudied factor on seawalls globally, affecting our ability to engineer ecologically-beneficial seawalls, especially in the light of climate change and associated rising temperatures. During emersion, the interaction between physicochemical factors and the physical characteristics of intertidal organisms results in significant differences between organismal body temperatures and ambient temperatures. Standard temperature loggers do not consider the physical characteristics of intertidal organisms and may not serve as effective proxies for body temperatures. Methods such as thermocouples also present their own set of issues, being invasive and potentially damaging. Biomimetic temperature loggers that mimic the organisms of interest are, however, easily deployed on seawalls and have the potential to be an appropriate approach to investigate impacts of seawall temperatures on intertidal organisms. Given the abundance of nerites (*Nerita* species) on Singapore's seawalls, they were chosen as model organisms for developing biomimetic temperature loggers ('Robonerites') and running temperature-related physiological experiments. Here, we will present preliminary findings on the effectiveness and accuracy of the Robonerites to represent natural body temperatures of nerites on seawalls in the tropics, as well as the physiological performance of live nerites exposed to heat stress.

Key words: Temperature, Robonerite, Biomimetic, Physiology

AU6

Who's on top? Non-hierarchical epiphytic interaction networks among urban turf algae

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Filamentous algal turfs have proliferated in recent decades and are now the predominant occupier of shallow hard substrate in most urban marine environments. Even in the most urban settings, turf assemblages are impressively diverse, consisting of tightly packed matrices of numerous morphologically-similar taxa that are densely connected by epiphytic tendrils, rhizoidal filaments, and holdfasts. These types of connections defy more traditional basiphyte-epiphyte interactions in which there is a clear dominant-subordinate relationship based on size. Since most filamentous algae comprising turfs have strongly overlapping niches, these assemblages also appear to defy some of the oldest ecological principles regarding species coexistence. We used microscopy and network analysis to characterize epiphytic interaction webs among algal turfs on seawalls in Singapore. Unlike previously documented basiphyte-epiphyte systems, epiphytism among turf algae was not linearly hierarchical, even though observed triangle transitivity was significantly greater than predicted based on randomly simulated networks. Although some taxa had a higher propensity for epiphytizing other algae, reciprocal epiphytism occurred at a frequency proportional to the relative abundance of each algal genus, and there was no evidence of specialization among epiphytes or basiphytes. We propose that algal turfs hold key insights into the processes of self-organization, decentralized network formation, and other emerging concepts in ecology. It is unknown whether epiphytic connections among turf algae are competitive, parasitic, commensal, or facilitative, but frequent disturbances and the multitude of limiting abiotic factors in urban settings are likely important drivers of the high diversity observed in urban turf algae.

Key words: Algal turf, Network analysis, Urbanization, Artificial structures

AU7

The influence of intrinsic properties and environmental context on differences between assemblages on artificial structures and natural shores

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Artificial structures are an increasingly common feature of coastal marine environments. These man-made structures tend to accommodate different assemblages from those on analogous natural hard substrata, often with a reduced suite of species. Considerable research and innovation is underway to find eco-engineering solutions that enhance artificial structures for biodiversity, ecosystem processes and society. A practical objective is to promote assemblages on artificial structures that are as similar to natural assemblages as possible. Natural assemblages vary considerably among substrata and environmental contexts and it is likely that the disparity between assemblages on natural and artificial structures will also vary, as will its underlying causes. As such, different interventions may be more effective for enhancing biodiversity and ecosystem processes in different contexts. As a basis for designing context-specific interventions, we compared assemblages on natural shores with those on artificial shores with a range of intrinsic properties and in a range of environmental contexts at thirty two sites on the coasts of Ireland and Wales. We sampled biota using quadrats and a more extensive semi-quantitative approach on seawalls, breakwaters, harbour walls, groynes, dolos and rip rap and on natural analogues in sites with varying degrees of slope, urban-ness, exposure and salinity. Artificial structures, natural shores and surrounding habitats were also characterised photographically using drones. Topographic complexity was quantified at a range of scales using LiDAR and photogrammetry. Analyses are underway and emerging findings will be presented.

Key words: Artificial marine structures, Biodiversity, Environmental contexts, Topographic complexity

AU8

Eco-engineering of coastal infrastructure in the intertidal and subtidal: effects on biodiversity

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Coastal urbanisation, global transportation, energy extraction and food production have led to a global proliferation of artificial structures within the coastal and marine environments (known as "ocean sprawl"). Artificial structures typically have reduced surface area and complexity, and as such, they generally support fewer species than natural habitats. To mitigate and compensate for the associated loss of natural habitats and biodiversity, the practice of ecological engineering of artificial structures has been developed. Ecological engineering (or "eco-engineering") techniques aim to create sustainable ecosystems that integrate human society with the natural environment for the benefit of both. While eco-engineering in the terrestrial environment is well tested and more commonly practiced, support for eco-engineering of coastal and marine structures is lacking, mainly due to a paucity of experimental evidence.

Experiments in Plymouth Sound, UK have been designed to address knowledge gaps in eco-engineering in the coastal environment, specifically testing designs in the subtidal zone. Complex tiles (3 treatments: flat, medium, high complexity; 25 x 25 cm) were deployed on artificial structures in the intertidal and subtidal zones for 12-14 months to test the effects of added complexity on biodiversity. Destructive sampling indicated that tiles with higher complexity supported greater biodiversity in the intertidal and subtidal zones. Our results contribute valuable evidence that will push the field of eco-engineering forward for management and policy of urbanised coastlines.

Key words: Eco-engineering, Biodiversity, Coastal ecology

AU9

Recruitment of the stalked barnacle *Pollicipes pollicipes* to an artificial substratum ("barticle") and transfer to a cultivation platform: successes and pitfalls

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The stalked barnacle *Pollicipes pollicipes* can be considered the most important intertidal economic resource on rocky shores of North Spain and continental Portugal. This species presents several features that generate a high interest for cultivation of this resource (e.g.: high commercial value, occurrence in very exposed shores where its exploitation can be very dangerous). In the past, the use of cultivation systems based on the natural processes of larval settlement/recruitment on artificial substrata and subsequent transfer of juveniles to grow-out systems has been considered limited for *P. pollicipes* due to the lack of efficient collecting devices of juveniles in the field.

We will present data on the success of recruitment of *P. pollicipes* to an artificial substratum ("barticle") deployed at a very exposed location (Cape of Sines, Portugal) and describe the variability of recruitment relatively to different dates of field deployment of the "barticles". Additionally, we have studied the survival, size and growth of barnacles attached on "barticles" that were transferred to a floating platform located in the lee of Cape of Sines (sheltered conditions) in comparison with the control situation (Cape of Sines). In the first months after the transfer (winter), juveniles transplanted to the platform survived and grew at a higher rate than the ones in the natural habitat. However, several fouling events (e.g. acorn barnacles and mussels) arose during spring and summer, representing a major pitfall of this cultivation system. Strategies and data on various attempts to solve the fouling problems will be presented and discussed.

Key words: Recruitment, Fouling, Artificial substrata, Barnacles

AU10

From ocean sprawl to blue-green infrastructure – how much evidence is enough?

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The principles of eco-engineering and green infrastructure are embedded in planning practice for terrestrial development and wetland restoration. In marine planning, however, eco-engineering of *blue-green* infrastructure remains an emerging, yet popular, concept. In the UK, despite a clear 'policy pull' to incorporate biodiversity enhancements in marine structures, a range of proof-of-concept evidence that it is possible to achieve, and strong stakeholder support, there are still few examples of truly and purposefully designed blue-green artificial structures. I outline the barriers that remain and present our strategy to promote the shift from research-driven experimentation to implementation of blue-green infrastructure as part of marine planning practice. Our strategy includes: (1) strengthening the evidence base for what biodiversity enhancements can be achieved; (2) improving clarity on the predicted benefits and associated costs; (3) packaging the evidence in a useful format; and (4) encouraging implementation in practice. Using drill-cored rock pools as a well-tested example of an eco-engineering intervention that could be used to enhance biodiversity on artificial intertidal structures, I will illustrate what a complete evidence base might look like to be robust enough to be used by engineers and regulators when planning new developments. Importantly, I will highlight the key evidence gaps that still remain despite years of experimentation, and pose the question: "how much evidence is enough?" Given that ocean sprawl is a growing problem globally, the perspective presented will be of interest to researchers investigating urban ecology and artificial structures, and will hopefully inspire progressive thought and debate.

Key words: Artificial structures, Eco-engineering, Enhancement, Marine management

AU11

Associations between reef habitat and human recreational activities in an urbanised harbor

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Activities such as recreational line fishing, boat anchoring, and visitation have the potential to influence or be influenced by sub-tidal habitat types and ecological condition, but few quantitative studies have explored these relationships in detail. We assessed the level of correlation between habitat-forming algae on temperate rocky reefs and the intensity of human activities (visitation, boat anchoring, and recreational fishing) in a busy Australian harbour, along with a suite of environmental variables (depth, exposure, urchin distribution, among-species correlations).

Whilst biological interactions and environmental conditions are established drivers of temperate reef ecology, our results provide evidence of co-occurrence between human activities (recreational fishing, boat anchoring, other recreation) and five key groups of algae (Ecklonia kelp, encrusting algae, other canopy algae, turfing algae, and understorey algae) that may suggest additional anthropogenic drivers are important in heavily populated areas. Understanding the significance of these patterns is important for successful management of coastal resources through the assessment of ecological risk, and improved estimation of the perceived value of 'healthy' marine ecosystems. The approach used in this study deals with substantial statistical challenges and provides a pathway for application to a wide variety of situations where habitat and driver overlap in complex spatial arrangements.

Key words: Human use, Habitat condition, Spatial modelling, Seascape ecology

AU12

Does low pH concrete support greater biodiversity on artificial structures?

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In response to coastal urbanisation, there has been a steady increase in ecological engineering research with the aim of maximising the ecological value of urban structures such as seawalls. Globally, techniques that involve retrofitting seawalls with complex concrete structures tend to support greater biodiversity compared to standard seawalls without enhancement. Some studies have suggested that since concrete structures are alkaline (~ pH 12–14), lowering their pH might result in greater recruitment of biogenic builders, and as a consequence, support of higher biodiversity. However, there is currently no direct evidence for this claim. The aim of this study is to determine whether lowering the pH of the substrate of artificial structures will affect the richness, abundance and composition of species they support. To determine the effects of lowering pH, low pH concrete tiles were created via a carbonation process, which resulted in tiles with pH 9.0–10.5 in comparison to the non-carbonated tiles with pH 12.0–13.0. Ninety-six tiles of both treatments were deployed at two sites south of mainland Singapore: Pulau Seringat and Pulau Hantu, and were collected (n=6, per treatment and site) at three-month intervals over a year. Preliminary results of this study suggest that lowering pH might increase species richness initially, but this effect diminishes with time. These effects also differed between sites and is likely due to differential rates of succession. Therefore, low pH might not be a cost-effective solution for enhancing biodiversity on artificial coastal structures.

Key words: pH, Concrete, Eco-engineering, Seawalls

AU13

Unimodal effects of habitat fragmentation on biodiversity in an experimental intertidal community

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Habitat loss and fragmentation are key drivers of biodiversity declines. Nevertheless, there exists an ongoing debate regarding their relative importance and there is a lack of experimental evidence for fragmentation effects *per se* on species richness in the whole landscape. Here, we developed a novel experimental system for testing the independent and interactive effects of habitat area and fragmentation on tropical intertidal species richness. We adapted the countryside SAR model to incorporate the role of the matrix and fragmentation patterns and explored the mechanisms underlying the experimental results. Our results confirmed the expectation that average species richness would increase monotonically with habitat area. More intriguingly, species richness did not increase monotonically with fragmentation, but was highest at intermediate fragmentation, i.e., when habitat tiles were placed in a "several-small" configuration. This is the first time an intermediate relationship between species richness and fragmentation has been shown through experimental field data. We found that the fragmentation effect was not due to passive sampling (since area was controlled for), variation in total individual abundance, or niche specialisation of species to different fragmentation patterns. We postulate that a combination of high-level processes, i.e., local negative density dependence and dispersal limitation can give rise to this pattern.

Key words: Countryside biogeography, Seawalls, Species–area relationship, SLOSS

AU14

Development of epibenthic assemblages on artificial habitat associated with marine renewable infrastructure

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The construction of marine renewable energy installations (MREIs) necessitates the introduction of infrastructure to the marine environment for the purposes of mooring, energy generation and grid connection. While it has been posited that MREIs can negatively impact marine fauna and habitats through physical disturbance and increased prevalence of non-native species, among other impacts, positive consequences are also anticipated through habitat provision and the exclusion of anthropogenic disturbance such as fishing activities. However, few empirical studies exist to demonstrate how these potential positive and negative impacts apply to wave energy technologies. To address this paucity of data, the cable connecting a wave energy test facility to a land-based grid connection (Wave Hub, Cornwall, UK) was monitored between two and five years post-installation using towed underwater video analysis to understand the development of epibenthic assemblages on rock armouring associated with the cable installation. The assemblage, number of taxa, and overall abundance were considered as key response variables, and indicate that after five years of development, differences in assemblage composition and number of taxa between the cable and nearby controls remained. This presentation will consider how decisions made during the design stages of MREIs can drive community composition, with consequences for decommissioning strategies. Further, a new project building on the outcomes of this work will be introduced to demonstrate the direction in which the field of environmental assessment of MREIs is likely to develop in the coming years.

Key words: Renewables, Benthos, Artificial habitat, Video survey

AU15

Ecological responses to eco-engineering from micro- to macro- scales and consequences for ecosystem function

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Coastal areas are threatened by increasing urban development and the addition of built infrastructure to protect assets. Artificial structures, such as seawalls, reduce the availability of natural habitat with potentially negative impacts on biodiversity and functioning. Recent efforts to mitigate these impacts have focused on adding complexity to these structures to provide more habitat. However, we still need to quantify the effectiveness of these designs at different biological levels, from macro- to micro-, and understand the consequences for ecosystem function. To do this, we manipulated seawalls at three locations in Sydney Harbour in a cross-factorial design by adding flat or complex concrete tiles that were pre-colonised with two important habitat-forming species (the coralline algae *Corallina officinalis* and oyster *Saccostrea glomerata*). From these tiles we surveyed biofilm communities after 6 weeks with DNA extractions from swabs and amplicon sequencing of the 16S and 18S rRNA gene. We sampled the macrofouling communities after 3, 6 and 12 months with a particular focus on investigating differential responses of native and non-indigenous species to the treatments. Fish-habitat interactions and feeding rates were quantified after 12 months. Functional aspects, e.g. filtration rates of oysters, nutrient cycling and primary productivity, were measured to assess whether eco-engineering could enhance functioning on seawalls and contribute to important services, such as local water quality. The results from this study will inform targeted strategies for eco-engineering of urban structures in the future.

Key words: Seawalls, Urban, Community ecology, Ecological function

CR1

Considering donor provenance in marine forest restoration

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Worldwide, key habitat-forming species are declining, leading to significant impacts on ecosystem goods and services. Habitat restoration has become a fundamental tool for management and conservation; however, restoration efforts rarely consider how future environmental conditions may affect long-term success. Genetic diversity can influence fitness and adaptive capacity of habitat-formers, but its incorporation in marine restoration is still in its infancy. This is particularly true for restoration of seaweeds – the "trees" of marine ecosystems. Crayweed (*Phyllospora comosa*) is a dominant habitat-forming seaweed that has disappeared along 70km of the Sydney coastline. Restoration efforts are underway, however they are hampered by a lack of understanding of underlying patterns of genetic diversity, which is fundamental to long-term success. We genotyped remaining crayweed populations and used this information to transplant new genetically diverse populations to deforested reefs in Sydney which mimicked natural gene flow from north and south of the gap in distribution. We found an effect of donor provenance (where the seaweed was collected) on the survival and condition of transplanted algae. All sites had successful recruitment and we are genotyping the next generation to determine the effect of donor provenance on recruitment success. This will enable the design and restoration of resilient and self-sustaining underwater forests that flourish now and into the future.

Key words: Restoration, Population genetics, Seaweed

CR2

Quantifying environmental stewardship reveals the interdependence between people, policy and temperate reef ecology

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The human footprint on earth is now so great that we are in the position of stewards of nature – whether we like it or not. Researchers call on an urgent need for active stewardship of earth systems, yet stewardship is variously defined, and difficult to quantify. Stewardship takes many forms, operates at many scales from local to global, and spans individuals, groups and institutions. In this study, we explore local environmental stewardship in the coastal temperate reef context. We use mixed methods to understand, categorise, and quantify stewardship, and Reef Life Survey methodology to assess local marine communities. We develop a stewardship indicator which may be applicable to a wide range of contexts, and describe the factors that predict stewardship. We integrate data on people (values, norms and behaviours), policy (full and partial marine protected areas) and ecology (marine life, richness and biomass), and propose a conceptual model relating these. This study has important implications for the management of social-ecological systems now and in the future, and for the conservation and stewardship of marine ecosystems around the world.

Key words: Conservation, Management, Social-ecological systems, Reef Life Survey

CR3

An empirical model of productivity dynamics in *Nereocystis* estimated using integrated Bayesian models of growth and demography

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Primary productivity in kelp forests can rival that of the world's most productive ecosystems. Along the rocky coastlines of the Northeast Pacific, the bull kelp *Nereocystis leutkeana* serves as a common and dominant canopy species. Despite their abundance, few datasets provide estimates of dynamics in *Nereocystis* population productivity that can be used to understand long-term change. In 2016 the Hakai Institute began an exhaustive kelp forest monitoring program in the Central Coast of British Columbia, Canada. In addition to general kelp community surveys, detailed *Nereocystis* data collected at fixed transects throughout each growing season include kelp density, size structure and mark-recapture to measure individual survival, individual growth and blade growth. We combined these data streams to estimate an empirically derived model of *Nereocystis* productivity dynamics in an integrated Bayesian hierarchical framework. Our combined empirical and statistical methodology provides a novel illustration of how dynamics of *Nereocystis* productivity vary among reefs, years, among seasons. The resulting models can be used to evaluate how abiotic and biotic drivers of variation in growth, mortality, recruitment and survival ultimately contribute to spatial and temporal trends population dynamics and productivity.

Key words: Kelp, Primary Productivity, Population dynamics

CR4

Cleaning up regional seas using novel blue growth initiatives: a potential for mussel farming in the Baltic Sea region

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Eutrophication is a global threat to aquatic ecosystems and its negative effects are particularly pronounced in semi-enclosed estuaries and regional seas such as the Baltic Sea. Despite many decades of intense and diverse policy initiatives to reduce land-based nutrient loads, the symptoms of eutrophication in the Baltic Sea have worsened. These are a consequence of the decades-long accumulation of nutrients and internal storage of nutrients still promotes and accelerates the enrichment. Mussel farming is a sustainable blue growth initiative to remove nutrients from the marine environment and thereby reduce internal nutrient storage. In order to allocate marine space for mussel farming, however, policymakers and spatial planners must be informed which areas have environmental conditions conducive to mussel production and at what rates nutrient removal can be expected. Here, we present spatially-explicit empirically modelled rates of blue mussel growth and nutrient removal for the whole Baltic Sea. Patterns of growth and nutrient removal were driven by salinity at the regional scale and food availability at the local scale. Higher growth and nutrient removal values were predicted at higher salinities and/or better food regimes i.e. the western and central Baltic Sea. Even at reduced salinities, a standard mussel farm can yield tens of tons of biomass production and tens of kilograms of nitrogen and phosphorus removal annually. When these farms are established at optimal growth locations at densities agreed among stakeholders, then nutrient removal during mussel harvest can compensate up to 100% of the local (or theoretically even regional) nutrient loading. To conclude, mussel farming has a vast but unused potential to decrease the amount of nutrients in the Baltic Sea region. This is especially promising to counteract internal and diffuse loading as existing methods are inadequate to achieve the ambitious environmental targets set by authorities.

Key words: Eutrophication, Restoration, Modelling, Baltic Sea

CR5

Climate-mediated tropicalisation of temperate reefs: implications for ecosystem functions and management actions

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Temperate reefs from around the world are becoming tropicalized, as warm-water species shift their distribution towards the poles in response to warming. This is already causing profound changes in species assemblages and a shift in dominant foundation species. Canopy seaweeds such as kelp that typically dominate temperate reefs are being replaced by either low biomass turf algae or corals, with cascading impacts on associated species. Here, we investigate the consequences of this tropicalisation for the ecosystem functions that underpin the goods and services that humans derive from temperate reefs, and what that means for the management of our marine environment. We discuss expected changes in biodiversity, primary productivity, benthic fisheries productivity, carbon sequestration and nutrient cycling due to a 'kelp to corals', a 'kelp to turf algae' shift. We outline management practices for these two differing trajectories that can either mitigate predicted functional changes or make the most of potential new opportunities. We consider the socio-economic, ethical and ecological implications and the risks associated with new management approaches that differ in the severity of proposed interventions (e.g. from MPAs to assisted evolution) as well as time frame for action.

Key words: Climate change, Herbivory, Phase shift, Productivity

IB1

Assessing the ecological impact and management feasibility of the global marine invader *Undaria pinnatifida* ('Wakame')

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Prioritisation of invasive species management is becoming of increasing importance to environmental managers. The Asian kelp *Undaria pinnatifida* is one of the most widespread marine invaders, yet it has received little targeted management. Here, the southwest UK is used as a case region in order to better understand the spread, population dynamics, ecological impact and management feasibility of *Undaria*. A mixture of manipulative experiments, surveys and population studies have been carried out in both anthropogenic and natural habitats. The findings show that ports and marinas act as beachheads for the spread of *Undaria* into natural habitats. On rocky-reef *Undaria* does not appear to drive ecosystem change, with little to no recorded impact on dominant canopy formers, but it may compete with native species of high functional similarity. In contrast, on artificial substrata *Undaria* may greatly alter macroalgae communities. *Undaria* also exhibits highly plastic population dynamics, exacerbating its limited management feasibility. Although there may be opportunities to reduce the spread and proliferation of *Undaria*, it seems that one of the 'worlds worst' invasive species could become officially unmanaged in parts of its non-native range. How science and policy reacts to the continued invasion of *Undaria* may influence how similar marine invasive species are handled in the future.

Key words: Competition, Invasive, Kelp, Management

IB2

Optimal spatial scale of monitoring for marine invertebrates and its implications for early detection of invasive species

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Sampling the marine environment for rare species requires focusing limited resources to maximise the probability of detection (POD) early in the invasion process. This study assesses how the spatial scales at which sampling is done (ranging from 10s of m to 10s of km) affect species detection with implications for early detection and monitoring. In Bras d'Or Lake, Nova Scotia, Canada, the recruitment of fouling invertebrate species was determined using PVC settlement plates suspended in the water column via buoys (one plate per buoy). Buoys were deployed along the coast in a nested hierarchical design in July and August 2014. For each species, POD was calculated by re-sampling the same field data using four different sampling schemes: (1) sampling at random; (2) adaptive sampling by forcing sampling at scales ≥ 100s of m; (3) forcing sampling at scales ≥ 1s of km; and (4) forcing sampling at scales = 10s of km. Given equal sampling effort, spatially structured sampling schemes can improve POD (by up to 20% for some species) compared to random sampling. Forcing sampling at intermediate scales improved POD for a majority of less abundant species (including two invasive species) relative to all other sampling schemes. Although forcing sampling at the largest scale maximised taxonomic coverage, this sampling strategy drastically decreased POD for rare species. This study highlights the potential problem of using sampling strategies optimised for detecting the most number of species, which can counter-intuitively reduce the probability of detecting rare species.

Key words: Multiple spatial scales, Sampling strategies, Rare species, Species detection

IB3

Do invasive bivalves produce different shellbed habitat to native ones? Experiments comparing epibiotic colonisation and shell decay rates

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Invasive species that produce biogenic structures impact ecosystems by changing the biogenic habitat available for other species. In highly invaded regions such as the Baltic Sea, invasive species that produce habitat may in turn affect dynamics of other invasive epifauna (e.g. "novel ecosystem" situations). Here we investigated habitat characteristics of native and invasive shellbeds in the Baltic Sea, where two invasive bivalves – *Dreissena polymorpha* (zebra mussel) and *Rangia cuneata* (gulf wedge clam) – are changing the extent and composition of shellbeds. These shells have very different structural properties to native shells and were hypothesised to provide habitat differently. Colonisation of epibiota and surrounding plants was measured on standardised experimental units of shellbed habitat from seven shell species as well as rock (i.e. pebble) and control treatments, at two random locations. The main species colonising the experimental units was also invasive (*Gammarus tigrinus* amphipod) and in almost all contexts colonisation differences among shell species were non-significant. It appears, however, that invasive shell species can differentially facilitate native plants, because at one location a native aquatic plant established in higher abundance among shellbed treatments with zebra mussels. The natural decay rate of shell material was also compared among species; the two invasive shells decayed the slowest, explaining why in some areas shellbeds from these species are rapidly expanding and replacing native habitat types. Except potentially for some aquatic plants, the habitat provided will be the same as from native shells, there will just be more of it.

Key words: Baltic Sea, Zebra mussels, Ecosystem engineering, Biogenic habitat

Abstracts
of the theme
Structuring processes

Acclimation & adaptation (AA)
Behavioural processes (BP)
Community ecology (CE)
Environmental variability & ecophysiology (EV)
Food web & predator-prey interactions (FP)

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6 – 11 Jan, 2019
Hong Kong

AA1

Evolutionary adaption of an intertidal snail *Echinolittorina malaccana* to increasing thermal stress in the face of climate change

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Understanding evolutionary adaptation to thermal stress in metazoan is critical for predicting the effect of global climate changes on species' metabolic coasts. Intertidal snail *Echinolittorina malaccana*, one of the most temperature-tolerant metazoans, experiences lifelong temporal and thermal constraints on foraging and energy gain, suggesting that their thermal tolerance evolution may be more closely linked to a mechanism that conserves energy reserves during rest than those that maximize energy gain during activity. Our studies reveal two clusters of molecular chaperones in response to increasing thermal stress from 25 °C to 52 °C. Cluster 1 includes highly inducible HSP70 and HSP20 (24-, 100-, and 1000-fold higher than control at 37, 45, and 52 °C respectively). Cluster 2 comprises DnaJ, HSP90, and HSP70, which are constitutively expressed at 37 °C and 45 °C, and are upregulated at 52 °C (1- to 23-fold higher than control). At 52 °C, most metabolic genes are downregulated to minimize energy expenditure, while upregulated opine dehydrogenase gene from 45 to 52 °C in the anaerobic metabolism is suggested to play an important role in supplying energy for the synthesis of chaperones. These findings give an insight into how intertidal snails cope with extreme temperatures and their potential evolutionary adaptation to a warming climate, which helps them survive under extreme thermal conditions.

Key words: Evolutionary adaptation, Intertidal snail, Thermal stress

AA2

Resistance of subtidal reefs to change under future conditions: the role of benthic grazers

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Future elevated CO_2 and temperatures are expected to increase primary productivity across marine habitats, creating a potential for a shift to algal dominated systems. This negative ecological impact has been shown to be alleviated by the increased consumption rate of benthic grazers; a potential compensatory mechanism preventing regime shifts driven by these stressors. Importantly, the strength of consumption is regulated by the metabolic demands of the grazers, which is expected to increase in line with warming until a threshold is crossed, beyond which biological processes can no longer be maintained. Indeed, tropical marine species are generally considered to be more susceptible to ocean warming because they live closer to their thermal tolerance limits than colder-water species. Here, I determined the short-term acclimation potential of important grazing sea urchin and gastropod species on Hong Kong subtidal reefs; how metabolic and consumption rates are altered under predicted CO_2 and temperature conditions. I discovered an apparent mismatch between metabolic rate and grazing rate for both species. Urchin metabolic rate was higher at future temperatures, but grazing rate was depressed. In contrast, CO_2 and temperature caused a decrease in gastropod metabolic rate and feeding, suggesting reduced ability to acclimate to this stressor compared to the sea urchins. These results suggest that different taxa may be differentially affected by environmental conditions and that the strength of compensatory response could be dependent on functional redundancy in grazer communities.

Key words: Ocean acidification, Thermal tolerance, Grazers, Ecophysiology

AA3

Broad-scale functional biodiversity of New Zealand's marine fishes versus depth

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Understanding the patterns and processes governing biodiversity along broad-scale environmental gradients, such as latitude, elevation or depth, requires careful assessment of not just taxonomic richness, but the morphological forms and functional traits of organisms. Deep reef habitats support high biodiversity, yet little is known regarding variation in functional traits along depth gradients at broad scales. Here, we describe how several key morphological traits in fishes, essential for locomotion and food acquisition, reflect functional adaptations to changing marine environments along a gradient from shallow to deep ecosystems. Functional trait measurements were obtained from stereo-baited remote underwater video footage of 144 fish species, taken at 7 locations (from subtropical to subantarctic New Zealand waters) and 7 depth strata (50m, 100m, 300m, 500m, 700m, 900m, and 1200m), and from museum specimens. Here, we will describe patterns of change in key adaptive traits, such as oral gape and eye size, *versus* depth. We also explore patterns of trait relationships among species *versus* depth, examining both overall functional richness and functional dispersion. Unlike taxonomic richness, functional richness does not decrease with depth, but instead shows a nonlinear multi-modal relationship with depth, with modes occurring at 50 m, 700 m, and 900 m. Functional dispersion also shows a peak at 700 m. We consider our results to reflect complex interactions between expanding and contracting available niche spaces and environmental filtering in the deep sea, which combine to structure the unique observed functional trait space of fishes.

Key words: Functional diversity, Traits, Environmental filtering, Adaptation

BP1

Using long-term time-series to establish the relative influences of environmental drivers and biotic interactions in intertidal species

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Global biodiversity faces unprecedented threats under contemporary rapid climate change, predicting the consequences of which poses a vast challenge. Fluctuations in temperature, rainfall and extreme events result in sub-lethal stresses to biota, manifesting in shifts of ranges and abundances. In addition to affecting biological performance, climate change affects species interactions, which also perform key roles in structuring abundance and distribution patterns.

The MarClim time-series, a unique multi-decadal time-series documenting the biogeographic distributions of intertidal species in the northeast Atlantic, has been collected by the Marine Biological Association since the 1950's.

Three species of cirripedes with differing thermal evolutionary origins have overlapping distributions in the UK and directly compete for space where they co-occur across a major marine biogeographic transition zone. The trailing range edge of the boreal *Semibalanus balanoides* has retreated north in recent decades, whereas the leading range edges of the lusitanian *Chthamalus montagui* and *C. stellatus* have extended to higher latitudes in response to warming of the marine climate. In addition, the non-native species *Austrominius modestus* is now found around much of the UK coastline, and co-occurs with these native species.

Convergent cross mapping was applied to the MarClim long-term time-series data to explore the relative influence of physical environmental drivers and biotic interactions in observed species abundances. Understanding the influences of both environmental and biotic drivers concurrently, and scaling these up for incorporation into models forecasting future biogeographic responses to global environmental change, will improve accuracy and biological realism in predictions.

Key words: Competitive interaction, Interspecific species interactions

BP2

Limpets in the rough: manipulating habitat topography to understand animal orientation decisions

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Selection of, and position/orientation within, a place to rest out unfavourable periods is a response to cues; these may be physical, biotic, social or an interaction of these. To understand resting site selection behaviours in the field, we must identify the underlying cues. Some animals can respond to changes in external stimuli whilst resting, whereas others are constrained either physically or because of costs incurred by altering place or orientation. Patellogastropod limpets are an example of the latter; their behaviour within a resting site is set from an initial decision made on arrival at that site, prior to the unfavourable conditions starting and fixed during emersion. We investigated the role of structural properties in the selection of resting-site location and subsequent behaviour in four species of limpets, as they are known to actively select certain resting sites over other available areas of habitat. We found that limpets will position themselves against edges and when the topography of their resting site is modified, individuals will later select a new resting site or alter orientation within their original resting site. The key behaviour is to locate and align along edges and other environmental attributes play no role. In contrast to organisms that can easily alter their orientation whilst at rest, such as birds and lizards, and select their orientation more commonly with respect to environmental and social cues, our findings suggest for animals that are unable to change their orientation at such short time scales structural habitat cues are the determining factor.

Key words: Distribution, Habitat selection, Grazers, Behaviour

CE1

Degradation dynamics processes and macrofauna community succession within drift kelp accumulations: an *in-situ* experimental approach

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Major part of the *Laminaria hyperborea* kelp forest production is exported due to storm events or to natural annual old blade losses. Drift kelps are transported and can accumulate temporarily over benthic subtidal habitats. We investigated the degradation processes and the macrofaunal colonization of *L. hyperborea* on low subtidal (-8 m) sandy bottom ecosystem simulating an accumulation by caging experiment lasting 6 months. We compared during the degradation process changes in biomass, nutritional quality (C/N ratio), respiration, quantum efficiency of photosystem II (Fv/Fm), and chemical defense (phlorotannins concentration), and we described the inhabiting macrofauna community. We found that biomass decomposition started after 2 weeks and followed a classical negative exponential kinetics. Half the biomass was lost after 8 weeks and only 16% of the initial biomass remained after 25 weeks. The degradation processes seemed to reach a critical step after 11 weeks with an increase of respiration rate and phlorotannins concentration. We hypothesized that these results reflect an increase in bacterial activity and a weakening of kelp cell wall. Surprisingly after 25 weeks of degradation, large kelp fragments remained visually fresh and photosystems were still responding correctly to light stimuli, indicating a possible resistance of a photosynthesis function. In the same time, kelp tissues were rapidly colonized by an abundant macrofauna, and a complex ecological succession occurred, with changes in species dominance and increase of diversity during degradation. Our results indicate that drift kelp accumulations are playing an important ecological role in recipient ecosystem during the whole degradation processes.

Key words: Drift kelp, Degradation, Subtidal ecosystems, Community succession

CE2

Exclusion experiments to show the impact of grazing by the snail *Omphalius rusticus* on a subtidal rocky reef community

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Omphalius rusticus is the most dominant herbivorous snail at the subtidal rocky reefs along the coast of Oshika Peninsula, northeastern Japan. In order to verify the impact of snail grazing on the subtidal rocky reef community, two types of exclusion experiments of the snails by employing copper paint were conducted. In the Experiment 1, tiles were surrounded by concrete walls (15 cm high) painted or non-painted. In the Experiment 2, tiles were placed on the top of cubic concrete blocks (24 cm high) painted or half-painted or non-painted, to examine the physical effect of the surrounding wall and chemical effect of the copper paint. The amount of ash and ash-free dry weight with the coverage of sessile animals and algae on the tiles was monitored in both experiments for monthly monitoring of community succession. Results from both experiments, the amount of ash and ash-free dry weigh tended to be higher in the painted block than non-painted blocks. In the Experiment 2, the coverage of crustose coralline algae and sessile animals tended to increase in painted blocks, and there was no clear difference between non-painted and half-painted blocks. These results showed that the snails constantly removed the mud and organic matter from the surface of the tile along with grazing on or bulldozing sessile animals and algae, regardless of the presence of wall or copper paint. We concluded that the grazing activity of *O. rusticus* gives large impact on the successional process of the subtidal rocky reef community.

Key words: Gastropod, Grazing, Sedimentation, Succession

CE3

On the structural and functional diversity of honeycomb worm reef associated macrofauna across a European latitudinal gradient

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The biogenic reefs created by the honeycomb worm *Sabellaria alveolata* (Linnaeus) are a common and peculiar feature of Europe's coastline. The reef habitat is formed by the tubes built from sand or shell fragments of this gregarious polychaete, commonly found on exposed rocky shores. Due to their three-dimensional structure, the biogenic reefs host many species of marine macrofauna. Diversity and composition of macrofauna species assemblages were investigated across a broad latitudinal gradient (from Portugal to the Scottish border) covering most of the engineer species range. While species diversity shows no significant trend along the latitudinal gradient, the species composition reveals changes in faunal assemblages linked to latitude with a strong relation to biogeographical provinces. Changes in community structure are mainly correlated with the reef structure (health) and with the amplitude of water temperature range. Biogenic reef complexity has more of a structuring effect than the engineer species in itself. Functional diversity was assessed using the biological traits analysis (BTA) method, by characterizing distinct functional groups (i.e. species with similar set of traits). The relative proportion of these groups in each site does not vary significantly, revealing that despite differences in species composition, functional niches are filled by species with similar biological characteristics, and possibly functions. Overall the reef structuring effect tends to homogenize the associated fauna over biogeographical provinces and diminishes the influence of local environmental factors.

Key words: Biogenic reef, *Sabellaria*, Engineered habitat, Functional diversity

CE4

Chemical microenvironments within macroalgal assemblages: implications for the inhibition of kelp recruitment by turf algae

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Kelp forests around the world are under increasing pressure from anthropogenic stressors. A widespread consequence of this is that in many places, complex and highly productive kelp habitats have undergone 'phase shifts' and become structurally simple and less productive turf algae habitats. Turf algae habitats resist re-establishment of kelp via recruitment inhibition; however little is known about the specific mechanism(s) involved. One possible influencing factor is the chemical environment within the turf algae, and into which the kelp propagules settle and develop. In laboratory trials, we compared the chemical microenvironments (i.e. O_2 concentration and pH, 0.1–50 mm above the benthos) within four multispecies macroalgal assemblages (including a natural turf-sediment assemblage and an *Ecklonia radiata* kelp-dominated assemblage) to examine whether differences in chemical microenvironments may contribute to the inhibition of kelp recruitment by turf algae. Our results illustrate that the chemical microenvironment within macroalgae assemblages are characterised by elevated O_2 and pH relative to the surrounding seawater. Critically however, these parameters are significantly higher within turf-sediment assemblages than in kelp-dominated assemblages, and at levels that can impair the photosynthetic or physiological potential of kelp propagules. Indeed, field observations of the experimental assemblages confirmed that recruitment of kelp was significantly lower on treatments with dense turf algae than in the kelp-dominated assemblage. We demonstrate the potential for chemical inhibition of kelp recruitment by turf algae and increase understanding of how the degradation of kelp habitats can result in both the persistence of turf algae habitats and the localised absence of kelp.

Key words: pH, Filamentous alga, Microprobe

CE5

The fate of detritus in high latitude kelp forests

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The fate of the large amount of detritus produced by kelp forests is a major unknown in the global carbon budget, and key to understanding the importance of these ecosystems in subsidizing benthic communities. We quantified annual biomass production and export of detritus from kelp forests in northern Norway and tracked the fate of this material as it moved through coastal habitats and into deep benthic communities. More than 75% of detritus took the form of whole blades or plants, and a significant fraction of that (>60%) was exported as a large pulse during a few months in spring. This pulse was not retained locally but accumulated in the deep subtidal, moved down the slopes of the fjord (10 – 80 m depth), and was recorded and collected from nearby deep habitats (>400 m depth). Particle dispersal models and field measures of detritus sinking speeds indicates most coarse detritus deposits within 1 km of the kelp forest, but that a substantial portion of smaller detrital particles move 10s to 100s of km before reaching the seafloor. Grazing by sea urchins played a critical role in transforming whole blades and fragments into this particulate detritus, which was abundant (20 g m^{-2}) in sediment grabs in deep habitats at the entrance of the fjord and 15 km offshore on the continental shelf. Despite slow uptake and degradation rates of kelp, food web models traced kelp-carbon inputs through detritivore communities and into benthic fish and invertebrate groups, estimating that kelp contributes 5% of the total energy input to coastal food webs.

Key words: Subsidy, *Laminaria hyperborea*, Blue carbon, Norway

CE6

Seaweed productivity increases with diversity

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The relationship between total productivity and the diversity of primary producers, and interpreting what it means, has been a controversial topic in ecology. We examined this relationship for seaweeds growing at the same site and depth and on the same substratum in a large experiment involving 28 artificial reefs comprising 7 reef sizes crossed with 4 densities of adult kelp (*Ecklonia radiata*) sporophytes. The concrete base of the reefs was identical across all reefs. Macroalgal diversity per unit area on the reefs depended on both 'patch size' and kelp density, providing an opportunity to deploy respirometry chambers across the reefs to generate curves of total community production per unit biomass macroalgae *vs*. irradiance.

We found a clear positive relationship between total net production and macroalgal diversity. Not surprisingly, there was also a positive relationship between secondary productivity (standardised per unit biomass of macroalgae) and primary production (expressed as P_{max} = maximum rate of production per unit biomass of macroalgae). There also was a clear positive relationship between α (the production rate at low irradiance) and P_{max}. This is consistent with complementarity of resource use as a key mechanism underpinning the relationship between P_{max} and macroalgal diversity, but further analysis is required to determine whether sampling effects might also play a role (i.e. where more productive species are more likely to be 'sampled' in more diverse communities).

The results show a clear relationship between community structure and function, highlighting the importance of seaweed diversity for reef functioning.

Key words: Macroalgae, Kelp, Productivity, Diversity

CE7

Mussels have disappeared but mortality rates haven't changed, implying a recruitment bottleneck

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Mussel beds are maintained when recruitment and growth balance losses to mortality. *Mytilus edulis* were once abundant on intertidal shores in the Gulf of Maine, but now are rare. Most ecologists think mortality due to predation has caused the decline in mussels. Here we present evidence that counters that claim. In 2017, we established and followed growth and mortality for 15 months in patches of 10 to 500 mussels at four sites on Swan's Island, Maine to assess the role of these processes in decline of mussels. We also compared mortality rates in these small patches to rates in experimental beds of 1250 to ~15,600 mussels established in 1997 at those sites and monitored until 2003. Mortality was independent of patch size and time, averaging 0.178 per mussel per 12 weeks. Most striking, the variance in mussel mortality was positively correlated with average rate, suggesting spatially and temporally variable rates of predation leads to a mosaic of persistent versus declining mussel patches. Data on growth of established mussels is insufficient to offset mortality. We suggest that the decline of mussel beds in the Gulf of Maine has been driven by the decline in recruitment, which we identified previously, and the slow of growth of those recruits.

Key words: Mussel, Mortality, Gulf of Maine

CE8

The role of predators moderating multiple stressor effects on rocky shores

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Warming, nutrient enrichment and biodiversity modification are among the most pervasive components of human-induced global environmental change but we know little about their cumulative effects on ecosystems. Understanding how the effects of these stressors may interact is essential to predict and manage their consequences in a changing world. We found that shifts in predator species composition can moderate both the individual and combined effects of warming and nutrient enrichment in a benthic system. All three aspects of global change, however, also acted independently to alter different functional groups in our flow-through marine rock-pool mesocosms. Specifically, warming reduced macroalgal biomass and assemblage productivity, whereas enrichment led to increased abundance of meso-invertebrate consumers, and loss of predator species led to increased gastropod grazer biomass. This disparity in responses, both across trophic levels (macroalgae and intermediate consumers), and between detecting additive effects on aggregate measures of ecosystem functioning, yet interactive effects on community composition, illustrates that our forecasting ability depends strongly on the level of ecological complexity incorporated within global change experiments. Experimental manipulations in the field have shown that predator contributions to stability in the face of multiple stressors can, however, frequently be predicted by their responses to individual stressors in isolation. We conclude that biodiversity change, and loss of predator species in particular, plays a critical role in determining how ecological communities respond to stressors.

Key words: Enrichment, Intertidal, Stability, Warming

CE9

Climate-driven shifts in kelp forest structure: implications for productivity, biodiversity and resilience

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Kelp forests are a dominant feature of coastal marine environments in temperature and subpolar regions. As foundation species, kelps support high levels of primary and secondary productivity and provide habitat for diverse communities. However, the abundances and distributions of habitat-forming kelps are responding to global environmental change stressors, including ocean warming, extreme climatic events and the spread on non-native species. In the southwest UK, for example, the abundance of the 'warm' water kelp *Laminaria ochroleuca* has increased significantly in recent decades, as has the distribution of the invasive kelp *Undaria pinnatifida*. Conversely, the abundances of several northerly-distributed species (e.g. *Laminaria digitata* and *Alaria esculenta*) are expected to decrease under climate change scenarios. We examined the wider consequences of climate-driven range shifts and species replacements within kelp habitats, by documenting changes in primary productivity, trophic linkages, biodiversity and habitat stability. Results from several studies suggest that observed and predicted shifts in kelp forest structure may lead to impoverished assemblages in some reef habitats, altered timings and rates of primary productivity, shifts in trophic pathways and temporally less-stable habitats. Greater understanding of the (often subtle) community and ecosystem-level consequences of shifts/replacements of habitat-forming species is needed to better predict the wider impacts of ocean climate change.

Key words: Kelp forests, Climate change impacts, Coastal biodiversity, Benthic communities

CE10

30 years revisit survey for the long term changes in the Antarctic subtidal algal community

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This is a comparative study for a long term community change of subtidal zone in Maxwell Bay, King George Island (KGI) of Antarctic coast. The 1st survey was carried out in 1988-1993 focusing on seaweed distribution and biomass. The 2nd survey was done in 2016-2018 at the selected 6 sites, focusing on the long term changes for 30 years at the same sites as well as providing more detail ecological data on vertical and spatial distribution at present as a baseline information for future monitoring. The total number of macroalgal species was similar between the 1st and the 2nd survey by 24 and 26 species, respectively. Macroalgal assemblage within-site level changed substantially with the average similarity of 38.3% between the 1st and 2nd survey. Also, the abundance of component species showed a high variability. Dissimilarity was mainly caused by the algal assemblage in deeper zone (10-25m) rather than the shallower zone (1-5m). On the other hand, the long term period did not cause the changes at between-site level hierarchical structure based on community similarity. Results indicate that the community itself changes very dynamically, but the similarity or dissimilarity between sites, influenced by various environmental conditions, remain largely constant for 30 years.

Key words: Antarctic, Long term change, Macroalgae, Monitoring

CE11

Inflatable housing: how epiphytic fauna utilise a dynamic soft coral habitat

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Temperate corals are habitat for many species of mobile fauna, both vertebrate and invertebrate. In New South Wales the cauliflower soft coral, *Dendronephtya australis*, forms patch reefs that are critical habitat for endangered seahorses and their invertebrate food sources. These invertebrates face a unique challenge, though – *D. australis* is an inflating soft coral that increases and decreases its volume by up to 10x depending on the tide. So, what do these invertebrates do when their homes are no longer the ideal size? An ongoing study suggests that larger, mobile species, such as amphipods, have higher densities among the branches and polyps of *D. australis* while the corals are inflated and are nearly absent when the coral in deflated. By contrast, less mobile species, such as isopods and brittle stars, have much higher densities on deflated than inflated colonies. The dynamic nature of soft corals suggests their contribution to biodiversity in temperate and tropical areas may be more difficult to quantify than previously thought.

Key words: Alcyonacea, Soft coral, Reef ecology

CE12

A new pathway for analysing multivariate ecological count data using copulas

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Counts of species' abundances in ecological communities are generally overdispersed (individuals are aggregated), zero-inflated (due to sampling sites where some species do not occur or are not detected), high-dimensional (the number of species often exceeds the number of sampling units), and the species show varying degrees of association with one another. Here, I will describe a new pathway for flexibly modelling multivariate counts of species abundances (ecological community data) that relies on copulas. Copulas can be used to model associations among disparate types of variables, so they are really useful for these situations where individual species have different degrees of aggregation or zero-inflation. I will describe how copula models are built, and also how difficulties that arise for copulas when we have discrete variables (i.e., counts) are overcome. The pathway I describe also allows the properties of individual species and their associations to vary in time and space. Furthermore, it measures the strength of species' associations via an index that excludes joint-absences, applying a permutation-based filter to identify significant pair-wise associations for modelling, thus reducing potential estimation problems encountered with high-dimensionality. Importantly, this pathway proposes for the first time the combined use of formal parametric statistical models of individual variables (for estimation, simulation and prediction) with dissimilarity-based procedures (for visualisation, ordination, inference and power analysis). Implementing the pathway can provide new ecological insights, as shown by way of an example, where increased strengths in associations among fish species occurred after the establishment of a marine reserve.

Key words: Abundance data, Community ecology, Inter-species associations, Multivariate statistical modelling

CE13

Facilitation by epiphytes expands the distribution of a habitat-forming macroalga and associated invertebrate assemblages

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Amelioration of physical stress by habitat-formers has been widely shown to foster the persistence of stress sensitive species in harsh environments. In contrast, less attention has been given to positive species interactions that may enhance stress-tolerance in habitat-forming species. For instance, the effects of epiphytes on host macrophytes are generally assumed to be negative, despite, in intertidal and shallow water habitats, they may reduce light and UV-ray stress. In the NW Mediterranean, the subtidal red macrolga, *Halopythis incurva*, forms large stands on rocky reefs, from the surface down to depths of about 12 m. A large proportion of thalli in shallow waters are heavily epiphytized by the articulated coralline, *Jania rubra*. A descriptive study showed that epiphyte biomass and photosynthetic efficiency of *H. incurva* decreases and increases with depth, respectively, suggesting a negative effect of epiphytes on the host. Experimental manipulation of epiphytes (removal in shallow water and addition in deep water) showed, however, that their effects on *H. incurva* vary from positive in shallow habitats to negative in deep habitats. Thus, reduction of light/UV ray stress by *J. rubra* would allow *H. incurva* to expand its distribution into shallow water habitats. In addition, colonization by *J. rubra* increases the abundance and diversity of mobile invertebrates, suggesting that *H. incurva* starts a facilitation cascades acting as the foundation species. Our results have important implications for the management of habitat-former populations under increasingly adverse climatic conditions.

Key words: Habitat-formers, Environmental stress, Facilitation cascades, Climate change

CE14

Annual intertidal primary production investigated through mathematical modelling based on *in situ* measurements: a *Fucus serratus*-dominated community performs better during emersion

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Intertidal communities dominated by canopy-forming Phaeophyceae usually act as highly productive systems. The metabolism of the widespread *Fucus serratus* community, established on the low mid-intertidal level of rocky shores, has been previously investigated *in situ* by measuring carbon fluxes within closed benthic chambers, successively at high and low tide, and at different periods of the year. These previous studies highlighted the high level of primary production of the community during emersion periods as well as the fluctuations of its metabolism (primary production and respiration) according to seasonal and tidal cycles. Complementary measurements were performed to establish relationships between community metabolism and abiotic parameters (light and temperature). A mathematical model, based on these relationships and on *in situ* measured light and temperature, was then used to simulate the dynamics of the community metabolism over a year with a 15 min step. Results highlighted seasonal variations of both respiration and gross primary production rates, with maximum in summer and minimum in winter. These rates also appeared to be reduced during immersion, whatever the season. This might be related to differential temperature between immersion and emersion periods as well as light attenuation in seawater, leading to higher net primary production during emersion both at tidal and annual scales.

Key words: Intertidal, Primary productivity, Tidal regulation, Annual budget

CE15

Using measures of the numbers and types of species and their distributions to compare the ecological value of different sites

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Selecting sites for biological protection in terrestrial areas is based on well-tested techniques that often attempt to extend existing protected areas by adding additional habitat that complements existing protected areas. Similar techniques are appropriate for developing networks of marine reserves, although much of the data necessary for this approach may not be as robust as for terrestrial habitats. In many parts of the world, however, protection of marine sites is done at a much smaller scale, e.g. by restricting fishing zones, or declaring individual reefs or shores to be protected to some degree. Although choices may be made pragmatically, e.g. by selecting those that are less likely to be politically controversial, choices have often been based on some measures of biodiversity. Species richness is an intuitively attractive measure to distinguish among sites because of its relationship to the diversity of the assemblages and the notion that diverse assemblages are ecological hotspots and deserve greater protection. The ways in which species richness is measured will, however, determine the value that one places on sites and there is more than one definition of and way to measure richness. I will use a set of intertidal boulder-fields in the Sydney region of Australia to explore different approaches of estimating the numbers of species in different sites and how these can be used to rank sites in order of their conservation status. I will also compare patterns shown by different assemblages and effects of time of sampling on the estimates that one makes. I will also expand on the concept of "species endemism" as introduced at ITRS nearly a decade ago to show how this can change the emphasis of analysis by focusing on rarer species with limited distributions and/or abundances rather than focusing on the number of species in a site.

Key words: Species richness, Boulder-fields, Spatial pattern, Management

CE16

Climate-mediated threats to temperate reef resilience: quantifying mechanisms that limit kelp forest recovery

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Contemporary climate change is rapidly decoupling populations from the climatic conditions they are adapted to, and as a result species are shifting their distributions to track more optimal environmental conditions. For the ecologically vital kelp *Ecklonia radiata* found along Australia's Great Southern Reef this is especially relevant, as species who consume kelps are adapting to ocean warming in this way. The east and west coasts of Australia have recorded dramatic declines in kelp forests at their northernmost ranges, however the region specific mechanisms that drive kelp loss differ, and recovery potential is not fully understood. As such, we sought to determine the relative importance of oceanographic (temperature) conditions, recruitment and range-shifting tropical herbivores in driving persistent change in these kelp ecosystems. Herbivore exclusion cages and recruitment tiles were deployed *in situ* to assess the potential for benthic community changes and kelp recruitment in the absence of herbivory pressure. We report on the 6 month progress of this study, whereby we found evidence of recruitment viability on both coasts indicating that oceanographic conditions alone remain suitable for kelp recovery. We also observed changes to benthic community composition within herbivore excluded areas, indicating that the pervasiveness of herbivory pressure remains. This project begins to unravel the roles recruitment and topical herbivores play in the recovery of degraded kelp forests. With this advanced understanding we further our capacity to predict, prevent and restore loss of services from these important ecosystems.

Key words: Kelp, Herbivory, Recruitment, Recovery

CE17

Ecosystem influences of kelp patchiness reverberate through the community

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The loss of ecosystem engineers poses a significant threat to the productivity, biodiversity, and stability of ecosystems. Using an array of 28 artificial reefs with transplanted *Ecklonia radiata* (the dominant canopy-forming kelp across southern Australia) representing seven patch sizes (0.12 - 7.68 m^2) crossed with four kelp densities (0 – 16 sporophytes m^{-2}), we determined how kelp patch size and density affected understory algal assemblages and environmental covariates, and how these differences resonate throughout the rest of the community. Kelp absence and declining patch size led to the proliferation of turfing algae, which negatively affected the dominance of foliose species. The composition of understory algae was highly influential in determining levels of secondary productivity associated with grazing epifauna, with the most dominant foliose species having a substantial negative influence on secondary productivity. Secondary productivity was important in determining the abundance of fish and macro-invertebrates associated with the reefs, however, the provision of algal cover as refuge is likely to have been a more important limitation determining the persistence of *Jasus edwardsii*, an ecologically and commercially important lobster species. These results highlight the importance of kelp in structuring communities spanning multiple trophic levels via its role as an engineer of both abiotic and biotic ecosystem properties, and allude to potential consequences associated with kelp habitat degradation.

Key words: Kelp, Ecosystem engineer, Community

CE18

Turf algae dominance under ocean acidification - are positive feedback mechanisms locking this degraded system in place?

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Human activities have the potential to cause substantial reorganisations of marine ecosystems (termed regime shifts) which have considerable impacts on a broad set of ecosystem services. During the last few decades, these regime shifts have increasingly been documented globally across a range of marine ecosystems. On shallow reefs, many regime shifts have involved the large-scale replacement of spatially dominant foundation species (e.g. kelps forests, coral reefs and other habitat-forming macrophytes) to a degraded state dominated by turf-forming algae. Worryingly, evidence of natural recovery from these degraded turf states is lacking, suggesting that strong feedback mechanisms may be locking the system into the degraded state (i.e. hysteresis). Here we used a model ecosystem in CO_2 seeps to show that ocean acidification may be altering the competitive hierarchy between corals, macroalgae and turf algae, and demonstrate the new stabilising feedback systems maintaining the subsequent turf dominance. These feedback mechanisms included competition for light and space, sedimentation, negative alteration of the seawater chemistry, and an inhibition of recruitment. It is important that we facilitate understanding of the feedback systems and interactions that cause these regime shifts, as they pose major challenges for ecosystem management and governance.

Key words: Ocean acidification, CO_2 seeps, Regime shifts, Turf algae

CE19

The strength of ecological interactions and the environmental mediation at subtropical coastal ecosystems

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In a globally changing environment, understanding of how natural and anthropogenic drivers interact and influence marine biodiversity over a range of spatial scales is required if we are to build predictive capacity and hence manage natural systems. Our goal in this study was to assess population parameters of intertidal organisms along a natural gradient of temperature on the southeast coast of Brazil, with regional variation of upwelling and temperature (full abstract attached). In the animal trophic chain, filter-feeding prey (barnacles and mussels) were influenced by latitudinal gradients, while populations of predators (whelk) varied over local scales. Regional impacts of natural (upwelling) and areas of anthropogenic (sewage discharge) drivers increased variation in population parameters at regional scales and were important drivers influencing biomass and density of organisms. There is a complex mosaic of factors emerging at different spatial scales along the subtropical coast in Brazil. Large-scale environmental gradients, which will be influenced by climate change, play an important role in structuring intertidal populations but are modified at local scales.

Key words: Large scale patterns, Limpets, Whelks, Subtropical

CE20

Loss of foundation species: disturbance frequency outweighs severity in structuring kelp forest communities

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Disturbances often cause the loss of foundation species but understanding how the frequency and severity of disturbance to such organisms affect communities remains unresolved. We carried out a large-scale 9-yr field experiment by altering disturbance to the giant kelp *Macrocystis pyrifera* and tracking community responses. To distinguish the effects of disturbance frequency and severity, we simulated the repeated loss of giant kelp from destructive winter waves across a background of natural variation in disturbance. Following >200 reef taxa, we found that the frequency of disturbance changed the biomass, diversity, and composition of guilds in a manner commensurate with their dependence on physical (benthic light, space), trophic (living and detrital biomass), and habitat (biogenic structure) resources mediated by giant kelp. Annual disturbance reduced living and detrital giant kelp biomass by 57% and 40% respectively, enhanced bottom light by 22%, and halved the seafloor area covered by kelp holdfasts. Concomitantly, the biomass of understory algae and epilithic invertebrates doubled, while the biomass of clams, mobile invertebrates, and fishes decreased 30–61%. Frequent loss of giant kelp boosted understory algal richness by 82% and lowered sessile invertebrate richness by 13% but did not affect the biodiversity of mobile fauna. In contrast, interannual variation in disturbance severity had weaker, less consistent effects. Hence, repeated disturbance to foundation species can outweigh the influence of less-frequent but severe disturbances for the surrounding community.

Key words: Community structure, Disturbance, Foundation species, Giant kelp

CE21

Giant kelp, *Macrocystis pyrifera*, increases faunal diversity through physical engineering

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Foundation species define the ecosystems they live in, but ecologists have often characterized dominant plants as foundational without supporting evidence. Giant kelp has long been considered a marine foundation species due to its complex structure and high productivity, however there is little quantitative evidence to evaluate this. We applied structural equation modeling to a 15-y time series of reef community data to evaluate how giant kelp affects the reef community. Although species richness was positively associated with giant kelp biomass, most direct paths did not involve giant kelp. Instead, the foundational qualities of giant kelp were driven mostly by indirect effects attributed to its dominant physical structure and associated engineering influence on the ecosystem, rather than by its use as food by invertebrates and fishes. These results are supported by previous stable isotope studies. Our results confirm the high diversity and biomass associated with kelp forests, but highlight how species interactions and habitat attributes can be misconstrued as direct consequences of a foundation species, in this case giant kelp.

Key words: Community structure, Foundation species, Detritus, Food web

CE22

Linking multiple facets of biodiversity and ecosystem function in a coastal engineered habitat

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Understanding how biodiversity influences ecosystem functioning is a growing question in the context of biodiversity erosion, historically investigated using manipulated terrestrial autotrophic communities and measuring functions such as primary production. Coastal habitats engineered by reef-building macrofauna (*e.g.* oysters, mussels) are characterized by high species richness while being dominated by the engineer species. Theses habitats are also key in nutrient recycling and food production but their associated diversity is sparsely considered in explaining their functioning. We considered a reef habitat engineered by the gregarious tube-building polychaete *Sabellaria alveolata*, in which diversity gradients occur, linked to natural dynamics and disturbances. Using sampled reef cores, we investigated the relationships between (1) the ecosystem engineer (abundance and biomass), (2) different facets of diversity (taxonomic, functional diversity and identity) and (3) ecosystem functions related to biogeochemical fluxes (oxygen demand, ammonium, nitrates + nitrites fluxes and a multifunctionality metric) with linear and quadratic models. The engineer species via its biomass and abundance explained most of the biogeochemical flux variability (adjusted $R^2 > 0.40$), displaying a strong density-effect. A significant concave relation (adjusted $R^2 = 0.39$) was also detected between the functional dispersion (FDis) and the multifunctionality metric indicating that an intermediate level of biological trait variability optimizes the biogeochemical functioning of the reef while partially supporting the diversity hypothesis. An increase of the functional diversity above the identified threshold (0.15) is associated with a degradation of the reef's physical structure, suggesting that a loss of the engineer species leads to lower levels of functioning.

Key words: Mass-ratio hypothesis, Complementarity, Sediment reworking

EV1

Putting self-organisation to the test: a labyrinth is an optimal solution for persistence of mussel beds

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Seascapes are complex environments which exhibit large spatial variability. Spatial patterns formed by single species can result from behavioural self-organisation, driven by small-scale facilitation and large-scale inhibition. Via this scale-dependent process, self-organised patterns can help maintain stability in the system.

Mussels are an example of a self-organising ecosystem which forms an important component of benthos in many regions worldwide. These biogenic reefs former not only provide many ecosystem services, but are also harvested in many countries for food. Pattern formation of mussels has been modelled extensively, making this a great system to put theories of spatial organisation to the test and understand its consequences.

We used artificial culture plots as model systems which is a highly spatial heterogeneous environment in terms of local mussel densities and environment characteristics. To understand mechanisms, we coupled field observations with manipulative laboratory experiments. We specifically tested the hypothesis that (1) labyrinthic spatial patterns are the most resistant in time. We further hypothesise that this pattern (2) will maximise resistance to dislodgement while (3) increasing water turbulence to maximise food availability.

In the field we observed that labyrinth stripes patterns are the most resistant in time. In flow-flume and wave-mesocosm experiments we found these stripes to be most resistant to dislodgement and to increase local turbulence the most. Hence we suggest that a labyrinthic spatial pattern is ideal for the functioning of mussel beds, and recommend facilitating its formation to improve both for benthic cultivation as food source and for habitat restoration as ecological measure.

Key words: Spatial patterns, Mussels, Stability, Hydrodynamics

EV2

Large-scale patterns in the reproductive characteristics of the honeycomb worm *Sabellaria alveolata*

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Geographic variation in species traits can yield particular insights into biogeographic questions, such as the factors determining species distributional limits. Egg size and number are two such key reproductive traits, potentially explaining changes in species distribution. We often lack clear predictions for how reproductive traits vary over a species range, and especially at its edges. As part of the REEHAB project (www.honeycombworms.org), we investigated the fecundity and egg size in intertidal populations of the honeycomb worm, *Sabellaria alveolata*, a common and widespread intertidal reef-building polychaete species in Europe. We surveyed 10 sites across the northern two-thirds of its range, from northern Britain to central Portugal (14.5° latitude span). Preliminary results display a latitudinal gradient in egg size. Unexpectedly, egg size increases towards high latitudes in winter but decreases towards high latitudes in late summer. We used a combination of *in-situ* and modelled biotic (Chl. *a*) and abiotic (air and seawater temperature, hydro-dynamic forcing) variables to examine which combination best explains broad-scale patterns in reproductive allocation of this reef-building species. The importance of large-scale studies of individual performance with respect to population connectivity is discussed.

Key words: Gamete plasticity, Reproductive traits, Engineer species, Latitudinal variation

EV3

Adaptations of intertidal molluscans to thermal stress: from phenotype to genotype in multiple spatiotemporal scales

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Intertidal ecosystem is one of the harshest ecosystems and some intertidal species live in an environment with extremely high spatiotemporal variations. Studies shown that intertidal species have shown clear distribution shift, and physiological and evolutionary adaptations to warming may determine the population dynamics of intertidal organisms in the face of global warming. Integrating with *in situ* temperature measurement, individual thermal tolerance assay and genetic tools, we found that there are divergent thermal tolerance for some common intertidal species (*Cellana toreuma*, *Septifer virgatus* and *Mytilus galloprovincialis*) in different scales from few centimeters to thousands kilometer, and balancing selection is both important factors for intertidal organisms in resistance and resilience to global warming. Based on genome-wide SNPs calling of 8 populations of blue mussel *M. galloprovincialis*, genetic composition were significantly different among populations and adaptive genetic variations were strongly associated with habitat temperatures, indicating *M. galloprovincialis* has adapted to local thermal condition on a continental scale, with this evolution having occurred within 100 years since its introduction from Europe.

Key words: Intertidal zone, Thermal stress, Global warming, Physiological and evolutionary adaptation

EV4

Variation in thermal performance across a biogeographic range, can the tropics compete?

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Ocean warming is increasingly causing thermal stress to marine ectotherms, but the responses to this stress are variable. Organisms living in thermally variable habitats are currently thought to cope better than those from less variable habitats as a result of higher physiological plasticity. To examine the extent to which populations respond differently to thermal stress, we compared the physiological capabilities of the long-spined sea urchin, *Diadema setosum*, along its geographic distribution. We measured metabolic rates of populations collected from warm, stable temperatures (Thailand), and highly variable mid- (Hong Kong) and cool temperatures (Japan), followed by thermal ramps under two sets of conditions at each location to compare the thermal breadth and metabolic capacity. First, urchins of all populations were acclimated to temperatures experienced across their geographic range. Then, the urchins were exposed to an acute, step-wise thermal ramp with 30 minutes rest period, from 15°C until mortality. We found that when given time to acclimate, the warm edge population had a higher peak metabolic rate than the cooler and more variable populations when acclimated to the same temperatures. In contrast, the two variable populations had a higher peak metabolic rate when subjected to an acute thermal ramp. This suggests that, though populations in the tropics are chronically exposed to warmer temperatures, they may still be able to acclimate and survive in a warming ocean. Therefore, given time to acclimatise, tropical populations of ectotherms may exhibit the same thermal plasticity as those from variable environments.

Key words: Biogeography, Thermal stress, Physiological plasticity, Ocean warming

EV5

Turbidity effects on the depth distribution and productivity of habitat-forming seaweeds

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Temperate coastal marine ecosystems are often defined by the presence of autotrophic habitat-engineers (laminarian or fucoid algae) which provide bundles of ecosystem services, including amelioration of physical stressors, protection from predation, carbon fixation, and oxygen production. However, once the accumulation of stressors crosses critical thresholds, the resilience or survival of these habitat-formers become compromised, with dramatic consequences for the diversity, abundance and functioning of marine ecosystems. This talk focusses on critical light thresholds for primary productivity of habitat-forming macroalgae on nearshore reefs of Southern New Zealand. Wide-scale land-use changes have greatly altered sediment transport regimes through catchments to the sea, yet the consequences of these regimes on the light environment have been poorly explored. Photosynthesis-irradiance curves of kelp (laminarian) and fucoid algae from different light environments are compared and, from in situ assays and environmental data, light energy budgets were modelled across turbidity scenarios and to identify depth distribution thresholds in the coastal zone. We promote the use of light energy budget modelling as the ideal starting point to assess the consequences of multiple stressors on autotrophic engineers, as limitation of the primary energy resource will regulate the capacity of autotrophs to respond to further stressors.

Key words: Primary productivity, Macroalgae, Resilience

EV6

Coping with extremes and variability: survival strategies of rocky shore littorinids

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Tropical rocky shore littorinids are abundant in some of the hottest environments worldwide, which makes them ideal models to investigate survival strategies in such thermally stressful environments. Extreme heat, however, is not the only challenge for littorinids in Hong Kong. Due to the monsoon systems, Hong Kong species also experience a cool, almost temperate, winter. Hong Kong littorinids, therefore, face the challenge of surviving not only extreme but also a wide range of temperatures (~10-60 °C rock temperature). To elucidate the survival strategies of the littorinids in such a dynamic, stressful environment, their seasonal behavioural patterns and ecological performance (measured as thermal performance curves of crawling speed as a proxy of energy acquisition and oxygen consumption as a proxy of metabolic costs) were assessed. In summer, littorinids adopt either fight behaviours (moderating their local microclimate without escaping) or flight behaviours (escaping to thermal refuges) that effectively buffer the snails from hot, often lethal, environmental temperatures. Thermal performance curves revealed that higher shore species achieved maximum metabolism at lower temperatures and had wider thermal tolerance than their mid shore congeners, which may be a strategy to conserve energy by reducing metabolism at high temperatures. In winter, littorinids showed more limited movement and activity as compared to the 'stressful' summer, which may compromise their energy budgets. To determine potential energetic consequences, an energy balance model was constructed from the littorinids activity budgets (from behavioural surveys) and thermal performance data, to investigate how the littorinids' energy budget changes with the monsoons, and ultimately the survival strategies adopted by Hong Kong littorinids under strongly fluctuating thermal regimes.

Key words: Behavioural adaptations, Thermal performance curves, Energy budgets

EV7

Interactive effects of seasonal temperature and irradiance on the photophysiology of a habitat-forming seaweed in Hong Kong

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Human activities are altering global climate system leading to warmer sea surface temperature and higher CO_2 concentration. There is increasing evidence that biological habitats, such as algal forests, are increasingly stressed by these environmental changes. However, little is known about the effects on seasonally abundant algal forests in biogeographic transition zones. To understand how seasonal changes in environmental conditions influence the physiology of algal forests, I examined the electron transport rate and oxygen evolution, proxies for photosynthetic capacity and productivity, respectively, of the dominant fucoid species (*Sargassum hemiphyllum*) in coastal Hong Kong waters. I found that the photosynthetic capacity and productivity of *S. hemiphyllum* were highest between 22-24 °C, a temperature range that is higher than during their natural annual growth cycle during winter. This suggests that annual growth patterns are most likely driven by temperature-dependent factors other than primary productivity.

Key words: Climate change, Photosynthesis, Algal productivity, Multiple stressors

EV8

The photobiology of symbiotic *Anthopleura elegantissima* (Brandt): effects of symbiotic algae, anemone size, and season

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One of the most investigated anemones on the west coast of North America is the intertidal anemone *Anthopleura elegantissima* that is symbiotic with either zooxanthellae (ZX; *Breviolum muscatinei*) or zoochlorellae (ZC; *Elliptochloris marina*). During the months of January (winter) and June (summer), various sized anemones were collected and subjected to diel production and respiration studies and immediately processed for specific anemone and algal parameters. Regardless of algal symbiont, photosynthesis was higher during the summer and for smaller anemones; however, anemones harboring ZX displayed higher productivity rates than anemones with ZC. Algal densities were greater for smaller anemones and with those containing ZC. The mitotic index of ZC showed higher values than ZX and translates to ZC population doubling times shorter (i.e. faster growth) than ZX, regardless of season and anemone size. The total chlorophyll content (per algal cell) changed as a function of both season and algal symbiont; ZX displayed higher chlorophyll concentrations during the summer whereas ZC showed higher chlorophyll levels during the winter. The contribution of ZX/ZC towards animal respiration (CZAR) suggests that small anemones containing ZX provide the highest CZAR values during the summer compared to small anemones harboring ZC. This investigation provides substantial evidence that anemone size, season, and symbiont type are key fundamental factors in understanding the photobiology and ecology of *A. elegantissima*. Such multivariate studies are essential in teasing out the eco-physiological dynamics of the symbiotic association between ZX or ZC and *A. elegantissima* in the intertidal zone of the Pacific Northwest.

Key words: *Anthopleura elegantissima*, Zooxanthellae, Zoochlorellae

EV9

Metabolic depression as a key mechanism to survive high on the shore

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Intertidal zones are highly dynamic environments with strongly contrasting thermal regimes between tidal emersion and submergence. During tidal emersion, environmental temperatures fluctuate rapidly depending on local weather conditions. Temperatures on tropical high shores often exceed the thermal tolerance of organisms during emersion, and species living in such environments need a variety of physiological adaptations to survive in these extreme habitats. One key physiological adaptation is metabolic depression, where cellular metabolism is arrested and energy expenditure minimized, effectively decoupling physiological processes of individuals from their external thermal environments. The high shore oyster, *Isognomon nucleus*, demonstrates an extreme and distinctive metabolic depression. Initially, heart rate increases with body temperature until 38 °C, where a 55% depression of metabolism occurs until recovery between 42 – 46 °C, after which heart rate crashes irreversibly. Depression of metabolism at 38 °C coincides with a rapid increase in the risk for future environmental temperatures (until next submergence time or dusk) to reach the cardiac breakpoint, suggesting that the depression temperature might act as an early warning signal for the oysters to initiate physiological modifications to prepare for future thermal extremes. Whilst the early warning function might represent an ultimal cause driving the onset of metabolic depression, the oyster could initiate depression by responding to variations in body temperature, oxygen concentrations and/or water content as proximal mechanisms. The alignment between physiological mechanisms and early warning temperatures may, therefore, represent a key mechanism for species persistence in extreme and highly dynamic thermal regimes such as on tropical high shores.

Key words: Metabolic depression, *Isognomon nucleus*, Thermal extreme, Predictability

EV10

Topographic complexity and rescue effects in rocky intertidal ecosystems: what drives vulnerability of intertidal organisms to climate change?

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Rocky intertidal ecosystems are among the most physically harsh habitats on the planet, and are also among the most physically variable in space and time. Environmental stressors such as extreme temperatures and desiccation can change drastically over the scale of cm and depend largely on the topography of the substratum. We mapped the fine-scale structure of shorelines in Israel and the Gulf of Maine using a Terrestrial Laser Scanner (mm scale) and aerial photography from drones (cm scale). We used reconstructed images of these shorelines as inputs to a Finite Element model of heat flux to calculate small-scale patterns of temperature, which were validated in the field using infrared cameras and autonomous data loggers. We then explored the relative importance of factors such as topographic complexity and rock type on the probability that organisms inhabiting different microhabitat types would survive heat waves, by comparing predicted temperatures to empirical measurements of physiological vulnerability. Our results show that topographic complexity can function as a mechanism for creating "rescue sites" in shaded areas during extreme weather, and suggest that microhabitats may ultimately affect biogeographic patterns at much larger spatial scales. However, they also show that under some conditions increasing complexity can also decrease the number of microrefugia. These simulations can be used to predict (and test) rates of mortality in different shoreline topographies and at varying latitudes, during extreme events, and emphasize the importance of translating the impacts of climate change to scales relevant to an organism's size and behavior.

Key words: Climate Change, Heterogeneity, Intertidal Zone, Thermal biology

EV11

WE-LOG: a collaborative global network of coastal temperature sensors

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It is becoming increasingly evident that satellite data, although invaluable in many aspects, are insufficient to characterise the environmental complexity of coastal ecosystems. This mismatch occurs not only in regard to air temperatures, where fine-scale topography plays a determinant role, but also in relation to water temperatures, where significant differences are often found between satellite-derived surface and *in-situ* measurements at depth. Such discrepancies are not uniformly distributed in space or time, hence severely limiting our ability to accurately characterise fine-scale thermal environments over large geographical scales. Nonetheless, most coastal ecologists continue to rely solely on satellite records for large-scale studies because the deployment of large networks of temperature loggers has been, so far, impractical. Recent advances in logger development have, however, significantly reduced the complexity of implementing such networks. Loggers now cost less, are more robust, record data for longer periods, and are easier to deploy and collect data from. Drawing on these advances and on our collective experience in building continental-wide logger networks in Europe, Americas and Asia, we propose a new, collaborative network of coastal temperature loggers with global coverage. Options for automated data transmission and analysis, which are key to reducing workflow complexity, will be discussed, as well as modes of data ownership that facilitate the collaborative nature of the project and greatly reduce the cost per unit of data collected. The implementation of this network will result in a unique dataset of standardized *in-situ* temperature measurements along coastal environments complementary to satellite observations, with direct implications for climate change research.

Key words: Autonomous loggers, Global network, Macroecology, Global warming

EV12

Influence of Indochina monsoon system on dynamics of coastal marine populations: a mini-review and future study

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The climate of the Indochina or mainland Southeast Asia is strongly influenced by the Indochina monsoon system consisting of the southwest (generally from May to September) and northeast monsoons (from November to March). The southwest monsoon is characterized by prevailing south-westerly winds from the Indian Ocean while the wetter northeast monsoon is characterized by low-level north-easterly winds from the western Pacific. Two short periods of inter-monsoon in April and October are recognized when seasonal reversals of wind occur; and wind direction is random. Monsoon leads to turbulent mixing and sedimentation in coastal areas; as well as low salinity due to heavy rainfall. Strong sea surface current causes mild upwellings along the Indochina coastline. Spatial and seasonal variation in primary productivity are detected and are potentially associated with the dynamics of monsoonal conditions. Generally, population and community structure in the tropical coastal ecosystem exhibits little temporal variation. Tropical species tend to breed continuously throughout the year or to have prolonged reproductive seasons. However, it is evident that some coastal faunal and algal species showed significant seasonal variation in abundance and reproductive output in accordance with the Indochina monsoon. This work aims to examine whether there are links between coastal marine population dynamics and monsoonal conditions in the Indochina region through a review of existing literature and recent data; as well as propose what could be done in the future to draw a general pattern of variation in population and community structure of the Indochina marine species.

Key words: Indochina, Monsoon, Population dynamics

EV13

Shifts in ecosystem functions: rapid tropicalization transforms Levant reefs from net autotrophic to net heterotrophic

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Temperate reef biodiversity is transformed globally at an alarming rate by human-mediated drivers. Nonetheless, relatively little is known on consequences of these transformations at the ecosystem functions level. Fast-warming ocean regions may be especially vulnerable to such shifts as populations of sensitive native species may collapse, and with them, ecological functions may be lost. Simultaneously, thermophilic aliens that arrive to the region should be boosted, and may have similar or different functions. One such fast-warming region (by 2-3^{o}C) is the southeastern Mediterranean, and is also an invasion hotspot of thermophilic IndoPacific species. On shallow reef, dozens of once-abundant native reef invertebrate species collapsed and aliens completely dominate some groups. We tested the thermal performance of many species and found that in most cases aliens have indeed a much higher optimum temperature than natives. In the field, incubation experiments showed that meadows dominated by declining native brown-algae have much higher biodiversity, biomass and metabolic functions than the present expansive turf barrens overgrazed by invasive rabbitfish, while areas covered by increasingly-dominate alien red algae, have taxa richness similar to the native community, with partially regained biomass, but functioning is shifted from overall autotrophic to heterotrophic. Mesocosm experiments showed that under warming and acidification, the brown-algae community itself becomes more heterotrophic, and more dominated by alien species. These dramatic alterations in functions mean that the reefs are going through a regime shift to a novel ecological state that will intensify in the future, but some functions lost by the collapse of sensitive aliens may be regained by aliens.

Key words: Climate Change, Bioinvasions, Mediterranean, Mesocosm

EV14

Reduced nearshore warming associated with Eastern Boundary Upwelling Systems

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Coastal marine biodiversity within eastern boundary upwelling systems (EBUS) is closely linked to the cooler sea temperatures associated to them. In the face of global warming, it has been suggested that the expected intensification of upwelling-favourable winds could lead to enhanced sea surface cooling. However, other mechanisms like the increase in ocean stratification and the widespread warming of the world's oceans could drive these systems in the opposite direction. Hence, the extent to which coastal upwelling can hold back the underlying global warming trend of the world's oceans remains unknown. Here we present estimates of net sea surface warming rates over more than three decades at a 500-km band along the world's coastlines to clarify if EBUS are warming at the same rate as the rest of the world's oceans. Results show that all four EBUS have been warming less than the rest of the global ocean, especially along the nearshore. We found that reduced net warming was prevalent in Pacific EBUS. In Atlantic EBUS reduced net warming was present but the effect was limited to localized pockets along the coast, with potentially severe implications for coastal species with limited dispersal capability. In contrast, net warming in the coastal ocean outside EBUS was pervasive and generally associated with proximity to land. Our results demonstrate that EBUS have been responding to climate change differently from the rest of the coastal ocean, effectively buffering coastal biomes from more than three decades of global warming.

Key words: Upwelling, Global warming, Habitat compression

EV15

The blue carbon potential of NE Atlantic canopy forming algae based on their chemical composition

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Macroalgae remove CO^2 from the atmosphere through the process of photosynthesis and are considered to be one of the most productive ecosystems worldwide. While these habitats do not sequest carbon in-situ, theoretical work has suggested they may act as important 'carbon donors' through transportation and long-term storage of detrital matter in offshore sediments. In order for detrital matter to reach offshore sediments where carbon storage can occur it must be relatively stable and non-labile in the marine environment. An understanding of the biochemical composition of macroalgae enables their degradability and stability to be assessed and therefore gives an indication of their blue carbon potential. In this study, we used Thermogravimetric Analysis (TGA) to determine the potential stability, as indicated by stability to thermal decomposition, of holdfast, stipe and lamina samples of six common NE Atlantic canopy forming macroalgal species: the kelps *Laminaria digitata*, *L. hyperborea*, *Saccorhiza polyschides*, *Saccharina latissimi* and the fucoids *Ascophyllum nodosum*, *Fucus serratus* and *F. vesiculosus*. Our results indicate differences in tissue stability between species and tissue types with implications for the role of macroalgae as blue carbon donors.

Key words: Blue carbon, Thermogravimetric-analysis, Macroalgae, Carbon sequestration

EV16

High-resolution remote sensing enables new approaches in marine ecology

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Topography drives environmental and biological stress gradients in marine ecosystems at multiple scales. In temperate intertidal reef habitats, fine scale (sub-metre) topographic variation influences, amongst others, hydrodynamics, desiccation stress, larval supply and predator-prey relationships. Remote sensing from satellites and manned aircraft has revolutionised study of large-scale ecological pattern and process, but accurately mapping topography at sub-metre scales across spatially continuous intertidal areas has, until recently, remained challenging. Two high resolution remote sensing techniques have emerged in the last decades with the potential to be powerful additions to the marine ecologist's toolbox. Structure from motion photogrammetry (SfM) and terrestrial laser scanning (TLS) are used to generate highly detailed three-dimensional digital models of the environment, but their adoption in temperate intertidal ecology has lagged behind applications in other fields. This is likely due to unfamiliarity with the techniques and uncertainty over the accuracy and value of their outputs. We evaluated the performance and practicality of TLS and SfM from quadrat to shore scales, in three common intertidal habitats – rocky shore, biogenic reef and saltmarsh. We generated accurate topographic models of reef habitats with millimetre to centimetre resolution and errors of <1 to 4 cm depending on scale. We discuss the advantages and limitations of each technique in various scenarios and present guidance for potential users. We demonstrate applications for high resolution remote sensing technologies in intertidal reef ecology with results from an observational study of spatial and temporal variation in the topographic structure of honeycomb worm (*Sabellaria alveolata*) reef habitat.

Key words: Topography, Remote sensing, Intertidal, Biogenic reef

EV17

Seawater calcium carbonate saturation state does not control the calcification physiology of coralline algae and warm-temperate corals

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Ocean acidification (OA) is a major threat to marine ecosystems, particularly temperate reef systems heavily reliant on calcareous species for structure and function. OA decreases seawater pH and calcium carbonate saturation state (Ω), and increases the concentration of dissolved inorganic carbon (DIC). Intense scientific effort has attempted to determine the mechanisms via which ocean acidification (OA) influences calcification, led by early hypotheses that calcium carbonate saturation state (Ω) is the main driver. Latter theories posit that the ratio of DIC (the substrate) to H^+ (the inhibitor of calcification) are responsible, and that increasing water velocity could remove the negative impacts of H^+. We grew warm-temperate corals and coralline algae from Rottnest island, Perth in two experiments under treatments where the seawater parameters Ω, pH and DIC were manipulated to examine their independent and combined effects on calcification rates and calcifying fluid chemistry (Ω_{cf}, pH_{cf}, and DIC_{cf}). An additional second experiment examined the role of water velocity at different DIC:H^+ ratios. We provide geochemical evidence that differing physiological controls on carbonate chemistry at the site of calcification, rather than seawater Ω, are the main determinants of calcification. We found that changes in seawater pH and DIC rather than Ω had the greatest effects on calcification and calcifying fluid chemistry, though the effects of seawater carbonate chemistry were limited. We also found that increasing water velocity did not remove the negative impacts of H^+. Our results demonstrate the capacity of organisms from taxa with vastly different calcification mechanisms to regulate their internal chemistry under extreme chemical conditions. These findings provide an explanation for the resilience of some species to OA, while also demonstrating how changes in seawater carbonate chemsitry under OA influence calcification of key warm-temperate reef taxa.

Key words: Ocean acidification, Calcification, Coralline algae, Physiology

FP1

Trophic cascades in benthic marine ecosystems: a meta analysis of experimental and observational research

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Trophic cascades within marine benthic ecosystems have demonstrated considerable variability in strength, but little work has been conducted into what determines that variation. As a result we have an incomplete understanding of when to expect cascades to be strongest or weakest in benthic marine systems, a serious limitation given that cascades have become well integrated into both ecological theory and management policies. To better understand the determinants, management impacts, and strengths of trophic cascades in marine benthic ecosystems, this study synthesizes 39 studies, 67 independent data points, and 147 measurements using a meta-analysis approach. We found that biotic factors related to an organisms' size were most influential in determining the effect of predator presence on herbivore populations, while abiotic factors related to nutrients best determined the response of the producer populations. We also found that producers respond more intensely to changes in herbivores populations in high nutrient and low temperature environments. Within this study, we found marine reserves to be an effective tool in remediating the consequences of predator loss. Specifically, older reserves, irrespective of size, were positively correlated with herbivore decline due to predator presence. Finally, this synthesis shows that trophic cascades in marine ecosystems should no longer be considered stronger than those in alternate ecosystems and stresses the importance of revisiting landmark conclusions in ecology. Taken all together, this work helps understand the drivers of benthic marine cascades, highlights the use of reserves to induce cascades, and establishes a new baseline of trophic cascades in benthic marine systems.

Key words: Trophic cascade, Top-down bottom-up, Marine reserves, Food webs

FP2

Patterns of selective predation change with ontogeny but not density in a marine fish

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Phenotypic variation is prevalent in the early life-history stages of many organisms, and provides the basis for selective mortality on size and growth-related traits of older life stages. Densities of organisms can vary widely at important life history transitions, raising additional questions about the interplay between selection and density-dependent processes. We evaluate density dependence in patterns of selective mortality for a temperate reef fish. Specifically, we exposed pre-settlement and post-settlement stages of the common triplefin (*Forsterygion lapillum*) to a natural predator, and evaluated patterns of selective mortality on early life-history traits as a function of ontogenetic stage and density. We used otoliths to reconstruct the traits of fish that survived versus fish that were consumed, and estimated selection by analysing the relationship between absolute fitness and standardised traits. Absolute fitness was negatively correlated with size and larval growth rate for pre-settlement fish, and this was consistent across the range of densities evaluated. Post-settlement fish experienced no selective mortality. Absolute fitness was equal across density treatments, suggesting mortality was density-independent. These results suggest that patterns of selection change with ontogeny, but may be stable across densities when mortality is density-independent. Shifts in selective mortality for species with distinct life-stages can mask and complicate relationships between traits and fitness, and the importance of such traits may be underappreciated for earlier life stages.

Key words: Fish, Predation, Settlement, Selection

FP3

Speed of food web complexity recovery of newly restored kelp beds using a stable isotope technique

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This study is to investigate how fast the food web stability/complexity is recovered in newly restored subtidal algal community. For the comparison of food web complexity, we chose 3 types of community (restored, natural, barrens) and sampled most species of macroalgae, benthic organic matter and invertebrates, and used those samples for stable isotope ($\delta^{13}C$ & $\delta^{15}N$) analysis. Community parameters such as abundance, richness, diversity and dominance are also compared. Average biomass of macroalgae among the 3 types of community was highest in natural beds, followed by 1 year old restored beds and barren ground. Total area of convex hull on each community indicated that food web complexity of the restored bed has been recovering dynamically in 1 year. Based on $\delta^{13}C$ - $\delta^{15}N$ bi-plot of each community, we infer that the main source of carbon for *Strongylocentrotus nudus* could be various depending food availability. In natural bed, *S. nudus* mainly consume brown algae as a carbon source. In restored bed, they are likely to prefer macroalgae depending on class (Brown>Green>Red). In barrens, they consume organic matter because of low algal biomass. In the next spring with the samples of 2 years old restored beds, we could explain how the stability of food web changes with the maturity of newly restored algal community and provide a meaningful suggestion regarding ecologically successful restoration of kelp forests and its' sustainability.

Key words: Restored community, Food web, Stable isotope, Maturity

FP4

Climate-driven collapse of mussel beds (*Mytilus californianus*) in the Southern California Bight and the twilight of a keystone interaction

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In this study we compare historical photographs of sites in the southern reaches of the Southern California Bight with similar views taken in 2015-18. Mussel beds showing extensive areal covers of very large individuals in the 1960s and 1970s were greatly diminished or completely absent by now. Several lines of evidence indicate the collapse is driven by rising sea surface temperatures and falling ocean production. The mean size of matrix mussels diminished, suggesting reduced ration. The vertical range on the shore contracted for each bed, as predicted by models with reduced mussel recruitment and growth. A 33-year time series of panoramas at Bird Rock, Catalina Island, shows a stepping down of areal coverage, entailing steep declines coinciding with El Nino events and stasis in the intervening years. The El Nino/La Nina cycles were embedded in a long-term trend with the late 1970s marking the end of a 30+ year period of relatively cool SSTs and the beginning of the El Nino events. The observed decline in mussel beds is potentially altering a longstanding keystone interaction between mussels and the California Spiny Lobster (*Panulirus interruptus*) which, to date, has had positive ecological and economic impacts in California.

Key words: Climate Change, Rocky Intertidal, Species Decline, Keystone Species

FP5

Can prey ever escape the influence of a predator? The persistence of the indirect effects of predation

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The indirect effects of predation have a pervasive influence on the physiology and behaviour of prey and consequently the dynamics of natural systems. Prey responses to the fear of being consumed may depend on the risk they experience and, in many systems, on individual vulnerability to direct predation. Vulnerability in this context, has an ontogenic component which diminishes as prey grow in size, potentially leading to size refugia. Despite the disproportionate role body size plays in ecological processes, little is known about the potential influence predation risk has on the behavioural and physiological responses of prey that have obtained size refuge. Through a series of field and laboratory experiments we investigated the influence that predation risk has on the antipredator behaviour, physiological stress response as well as the foraging patterns of an intertidal gastropod. We examined the oxygen consumption rates and movement of vulnerable and invulnerable intertidal dogwhelks, *Nucella lapillus*, exposed to cues from the green shore crab, *Carcinus maenas*. Both vulnerable and invulnerable *Nucella* change their oxygen consumption rates in response to a predatory cue. Furthermore, *Nucella* adopt a threat-sensitive behaviour in accordance with the natural levels of predation experienced by individuals from different populations. By changing the temporal patterns of risk experienced in our foraging experiment, we showed that predation risk remained an important factor in defining the foraging patterns of invulnerable *Nucella*. Our findings provide evidence that the indirect effects of predators remain influential even after prey are no longer susceptible to direct predation.

Key words: Non-lethal effects, Size refuge, Behaviour, Stress response

FP6

Winter-brake: cold temperatures freeze consumption of temperate habitat-forming seaweed by tropical herbivores

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The poleward distribution shifts of tropical herbivorous species due to climate change can lead to increases in rates of primary consumption in temperate reefs, modifying paths of energy transfer and contributing to the loss of habitat-forming seaweed in these ecosystems. However, the ecologic impact of range-shifting tropical species at high latitudes could vary temporally since low temperatures during winter in temperate ecosystems can be physiologically challenging. This study assessed trendlines and correlations between the abundance of tropical herbivorous fish (rabbitfish *Siganus fuscescens*), their herbivory and excretion rates and environmental temperatures along different months of the year from 2016 to 2018 in kelp forests of south-western Australia. Results showed that the abundance of rabbitfish did not change significantly along the year but feeding rates decreased at the peak of winter. During summer, rabbitfish and temperate herbivores (*Kyphosus sydneyanus*) had high excretion and bite rates on seaweed, consuming higher amounts of the kelp *Ecklonia radiata* and accelerating the flux of detrital biomass into the ecosystem; however, these rates were reduced dramatically during winter despite the presence of big schools of rabbitfish overwintering in temperate reefs as cold as 15 ºC. Reductions in consumption rates may provide a time-frame for kelp to recover and accumulate standing stock biomass, however, its peak of growth and reproduction occurs during summer, when herbivory rates are highest. Furthermore, this winter-break in temperate ecosystems could disappear in the future if warming and the tropicalization of the herbivory communities continues, leading to an all-year high seaweed consumption.

Key words: Tropicalization, Range-shift, Herbivory, Kelp

FP7

Do dogwhelks (*Nucella lapillus*) no longer see mussels (*Mytilus edulis*) as prey?

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Mussels have been one of the most common prey items of dogwhelks on rocky shores throughout the North Atlantic. Here we present data that suggest attacks on mussels by dogwhelks have declined over the last two decades in the Gulf of Maine USA. In 1996, we started a long-term experiment that included 12 unmanipulated control plots and have monitored attacks on mussels by dogwhelks, the abundances of mussels and dogwhelks, and mussel recruitment. The probability of at least one attack on experimental clumps of 15 mussels per control plot has declined by 8.5% per year (average probability of attack was 0.46 in 1996-2000 and 0.12 in 2014-2018). In addition, the probability of at least one dogwhelk present at the clumps has declined by 7.6% per year (average probability of attack was 0.59 in 1996-2000 and 0.24 in 2014-2018). This rate of decline is not explained by changes in local abundances of dogwhelks. In 2018, a short-term experiment of caging three dogwhelks with five mussels per replicate (45 dogwhelks and 75 mussels total) showed no predation of mussels by dogwhelks and only three instances of contact indicative of attempted drilling over 11 days. These observations are at odds with earlier studies that show dogwhelks readily attack mussels with a minimum consumption rate of mussels of ~0.3 per dogwhelk per m^2 per day. We speculate that dogwhelks are switching off of mussels as prey because mussels have become extremely rare on intertidal shores in the Gulf of Maine.

Key words: Gastropod, Mussel, Predator, Gulf of Maine

FP8

Predator feeding mode and prey (*Mytilus edulis*) size modulate magnitude of predation risk effects

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Optimal foraging theory predicts predator preferences depend on prey traits (e.g. size), but pivotal traits may vary predator-specifically. Hence, mortality risk in prey is highly context-dependent. Besides killing, predators modify prey traits non-consumptively. This study tested whether prey (*Mytilus edulis*) with high predation susceptibility will respond stronger to predation risk than low-susceptible conspecifics. Furthermore, predator specificity in prey trait modification was assessed. Firstly, prey size-dependent preferences of shell-crushing predators were determined. Secondly, morphological and physiological traits in prey of three size classes exposed to predation risk of a shell-crushing and shell-boring predator were measured. Exposure to predators of both feeding modes induced morphological trait changes in *M. edulis*, but this was prey size dependent. Predation risk did neither affect shell length nor mass increment in large mussels (low predation susceptibility) but both were lower in small, *Nucella*-exposed mussels (high predation susceptibility) than in small, *Carcinus*-exposed and control mussels, respectively. In contrast, byssus mass was greater in *Carcinus*-exposed mussels than in control and *Nucella*-exposed conspecifics, respectively. Predation risk also affected mussel physiology. Carbonyle concentration (stress indicator) was lower in *Carcinus*-exposed mussels than in risk-free conspecifics. Heart beat rate of *M. edulis* was, however, unaffected by predation risk treatments, yet about 10 % higher in small than in medium or large mussels. Results suggest that mussels may tailor multiple morphological trait modifications according to predator feeding mode and that predation risk may provoke stress responses in mussels, which has rarely been documented in marine prey.

Key words: Trophic interaction, Phenotypic plasticity, Stress proteins, Rocky intertidal

Abstracts
of the theme
Species distribution patterns

Biogeography (BG)
Early life histories & dispersal processes (ED)
Extreme events (EE)
Range shifts & population dynamics (RP)

12th International Temperate Reefs Symposium
6 – 11 Jan, 2019
Hong Kong

BG1

How slope orientation in the rocky inter-tidal affects present and future biogeographical distributions in a warming world

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Climate change has profound implications for all ecosystems, and responses have already been documented across various taxa. Despite their marine origin, intertidal invertebrates and algae regularly content with the terrestrial environment during each low tide. Many of them are already living close to their upper thermal limits and are at great risk with the current changing climate. Rocky-shores, as well as being an potential model system for understanding the consequences of climate change on communities, also offer a mosaic of habitats mainly provided by the topography and substratum orientation, which can modify the temperature and desiccation stress.

We conducted a survey of rocky intertidal habitats in SW of England, to determine how orientation (north- or south-facing slopes) affected the distribution and abundance of organisms. Across the year, south-facing rocks were on average 1°C warmer than north-facing slopes, a difference reflected in the distribution of several species. North-facing slopes supported twice as many algal species as south-facing slopes. Some key molluscs such as filter feeding mussels, grazing limpets, and carnivorous dog whelks were also significantly more abundant on north-facing slopes. The barnacle *Chthalamus montagui* was more abundant on the south-facing slopes. These results underscore the importance of slope in the intertidal zone, as north-facing slopes could offer, within the context of global warming, a buffer and refuge for cold-water species to persist in suitable microclimates. Alternatively, warmer south-facing slopes represent a potential as stepping-stone for the range expansion of climate migrants and non-native species responding to increasing temperature.

Key words: Biogeography, Slope orientation, Global warming

BG2

Structure and density of kelp understory algal associated macroinvertebrate communities are likely to alter in a warmer, less complex ocean

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Kelp forests provide habitat and food that supports a highly diverse community of marine organisms. Macroinvertebrates, associated with kelp understory algae, form links between primary producers and higher trophic levels and thus contribute to the transport of energy in and out the system, and are therefore one of the most important trophic levels within this ecosystem. Yet the structure of macrofaunal communities associated with kelp understory algae and the key drivers influencing these communities remains unclear. Here we used a macroecological approach and artificial seaweed units (ASUs) to explore the effects of thermal environment, wave exposure and habitat complexity on understory algal associated macroinvertebrate communities within UK *Laminaria hyperborea* forests. In May 2016, ASUs comprising five different habitat complexities were placed under mature *L. hyperborea* canopy across a space-for-time gradient (i.e. 2 sites (separated by km) nested within 4 locations (separated by 100s km), across two regions (warm & cold) spanning 9° of latitude). After 6 months the ASUs were collected and macroinvertebrates were identified to family level and enumerated. More than 90,000 individuals settled on the ASUs. Habitat complexity and wave exposure influenced macroinvertebrate community structure, but our results also showed clear thermal affinities with a number of species driving the differences observed being either associated with warm southern regions or cooler norther regions. Predicted warming and a shift to less complex turf-forming understory algae are therefore likely to fundamentally alter the structure and density of these macroinvertebrate communities, with potential implications for kelp forest food web dynamics.

Key words: Understory algae, Macroinvertebrates, Macroecology, Climate change

BG3

The way that we went: biogeography and historical ecology of the ecosystem engineer *Sabellaria alveolata* in Ireland

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Biodiversity loss is one of the greatest challenges of our time. Broad-scale and long-term datasets that can track both spatial and temporal changes in ecological communities are particularly valuable as they yield invaluable information about ecosystem recovery and resilience, thus informing the selection of locations that are suitable for protection and/or rehabilitation. Biogenic reefs are important for habitat provision and coastal protection. Long-term datasets on the distribution and abundance of the reef-forming polychaete *Sabellaria alveolata* (L.) are available from Ireland. Using a combination of data archaeology and broadscale contemporary surveys the aim of this study was to combine historical records and contemporary data to (1) describe spatio-temporal variation in temperatures, (2) document changes in the distribution and abundance of *S. alveolata* and discuss these changes in relation to extreme weather events and recent warming. A total of 991 records spanning 182 years were collated revealing disappearances from a number of locations and a disjunct distribution pattern with six identifiable hotspots that remained relatively constant over time. We discuss how the distribution pattern can be largely explained by tidal fronts and summer stratification of the water column. We also discuss the importance of historical ecology as an important management tool for conservation.

Key words: Biogenic habitat, Sustained observations, Tidal front, Range edge

BG4

Celibate kelps: consequences of prolific asexual reproduction revealed using genetics and genomics

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The evolution of asexual reproduction is considered a response to environmental conditions where it incurs less cost than sex, maintains adapted genotypes, and allows rapid proliferation into new areas. In rare circumstances, however, distinct asexual morphs have evolved in response to ubiquitous environmental conditions. Understanding the mechanisms underpinning, and implications of such reproductive strategies is important for assessing the vulnerability of populations to environmental change. We examined morphological, genetic and genomic variation between co-occurring sexual and asexual morphs of the kelp, *Ecklonia radiata*. Microsatellite markers revealed that vegetative morphs had a great propensity for asexual reproduction with 8 to 20 clones being produced per parent plant. Vegetative morphs were morphologically distinct, less morphologically variable, had lower genetic diversity, and an excess of heterozygotes relative to sexual morphs. Nevertheless, vegetative morphs still reproduced sexually, accounting for weak genetic differentiation between morphs and suggests ongoing gene flow. Genomics was used to identify underlying functional genetic differences between morphs. Given that genetic diversity often confers adaptive capacity through change, low diversity may have implications for the vulnerability of the unique vegetative morph to local climatic and environmental stressors.

Key words: Kelp, Asexual, Reproduction, Genomics

BG5

Sargassum beds in South China Sea as potential nursery of a temperate deep sea Gnomefish, *Scombrops boops* (Perciformes: Scombropidae)

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A total of 36 individuals of a temperate deep sea Gnomefish *Scombrops boops* were sampled from littoral habitats (2-5m depth) of the eastern water of Hong Kong in April and May, 2017. This is a first report of Gnomefish juveniles in the subtropical South China region, which is also the southernmost occurrence (22°21'-22°11' N) among the existing records. Standard lengths of all collected individuals are no higher than 8.2 cm, which is obviously lower than maturity length of *S. boops* suggested by previous study (40 cm). It implies that littoral areas of Hong Kong might be a potential nursery for juveniles of *S. boops*. Thirty one of these individuals are from *Sargassum* beds and 5 from rocky reefs. ANOVA shows that the juveniles found in *Sargassum* beds have significantly smaller body length and lower body weight than those found in rock reefs. It suggests a possible shift in foraging ground of *S. boops* as the juveniles grow bigger. 16S rRNA sequences of collected individuals shows genetic homogeneity to individuals from previous studies in Japan, which implies that individuals collected in Hong Kong and Japan might derive from a common spawning site.

Key words: *Scombrops boops*, *Sargassum* beds, Nursery site, South China Sea

BG6

NE Atlantic kelp forest carbon assimilation and transfer is diminished under a warmer ocean climate

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Global climate change is affecting carbon cycling by driving changes in primary productivity and rates of carbon fixation, release and storage within Earth's vegetated ecosystems. There is, however, limited understanding of how carbon flow between donor and recipient habitats will respond to climate change. Macroalgal-dominated habitats, such as kelp forests, are gaining recognition as important carbon donors, yet rates of carbon assimilation and transfer are poorly resolved. Here, we investigated the likely impacts of ocean warming on coastal carbon cycling by quantifying rates of carbon assimilation and transfer in *Laminaria hyperborea* forests along a latitudinal temperature gradient. *L. hyperborea* within warm climatic regimes assimilated, on average, more than three times less carbon and donated less than half the amount of particulate carbon compared to those from cooler regimes. These patterns were not related to variability in other environmental parameters. Across their wider geographical distribution, *L. hyperborea* exhibited reduced sizes toward their trailing range edge, further suggesting that carbon flow is reduced under warmer climates. Overall, we estimated that *Laminaria hyperborea* forests stored ~11.49 Tg C in living biomass and released particulate carbon at a rate of ~5.71 Tg C $year^{-1}$. This estimated flow of carbon was markedly higher than reported values for most other marine and terrestrial vegetated habitats in Europe. Together, our observations suggest that continued warming will diminish the amount of carbon that is assimilated and transported through temperate kelp forests in NE Atlantic, with potential consequences for the coastal carbon cycle.

Key words: Kelp, Ocean warming, Carbon cycling, Primary productivity

BG7

Biodiversity and toxicity of benthic dinoflagellates in a subtropical reef ecosystem: the first comprehensive study in Hong Kong

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Harmful algal blooms (HABs) is a global issue, marine benthic dinoflagellates are well known as one of the causative agents for the red tides and/or seafood poisoning associated with the HABs. This is the first comprehensive study on benthic dinoflagellates in Hong Kong, aimed to investigate the biodiversity and toxicity of benthic dinoflagellates inhabiting coral and rocky reefs. Samples collected from 28 sites by scuba divers were examined in laboratory; single dinoflagellate cells were isolated for algal culture. Over 200 dinoflagellate cultures have been established. A total of 19 benthic species (of 5 genera *Amphidinium, Coolia, Fukuyoa, Ostreopsis* and *Prorocentrum*) were confirmed by morphological and molecular analyses, including three putative new species namely *Fukuyoa* sp. HK Type 1, *Prorocentrum* sp. HK type 1 and 2. Over 70% of these species were found potentially toxic to biota, using *Artemia* larvae, sea urchin larvae and fish blood hemolysis bioassays. Based on *Artemia* bioassay, *Prorocentrum* cf. *lima* and *Fukuyoa* sp. HK Type 1 were classified as highly toxic species, which caused high mortality rate of *Artemia* at both high and low doses of algal extracts. *Fukuyoa* species were toxic to local sea urchin larvae. *Amphidinium carterae* cause high percentage of Artemia mortality and fish hemolysis. All these results showed that most of the local benthic dinoflagellates are toxic to marine invertebrate and fish, and potentially cause negative effect on the marine ecosystem once HABs occur. Further studies of their toxin profiles and toxicity are still under investigation.

Key words: Harmful algal bloom, Epiphytic algae, Maitotoxin, Ciguatera

BG8

Spatial and temporal variations of marine toxic benthic dinoflagellates in a subtropical reef ecosystem in Hong Kong

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Occurrence of harmful algal blooms (HABs) associated with dinoflagellates has increased all over the world in past decades, red tides and associated massive kill of fish and benthic marine invertebrates are often observed after HABs. Unlike these phenomena caused by planktonic species, the impact of benthic dinoflagellates is often subtle and overlooked. This study of marine benthic dinoflagellates in coral and rocky habitats in Hong Kong eastern waters revealed the presence of 19 benthic species of 5 genera including *Fukuyoa*, *Ostreopsis*, *Coolia*, *Prorocentrum* and *Amphidinium*. Among these genera, *Coolia* and *Ostreopsis* were predominant, *Fukuyoa*, *Prorocentrum* and *Amphidinium* were relatively less abundant. The species composition of benthic dinoflagellates showed seasonal difference but no habitat difference; the overall abundances of 5 genera were higher in summer (June to September) and transition period (October to November) indicating warmer environment was more favourable by these dinoflagellates. To better understand the dynamic of these benthic dinoflagellates in Hong Kong, the relationships between environmental factors and species composition (and abundance) of benthic dinoflagellates were investigated at selected sites. The species composition of benthic dinoflagellates generally varied significantly with temperature, pH, salinity, the concentrations of Chlorophyll a, SiO_2, PO_4^{2-}, NH_3-N and NO_2^-N. In addition to these abiotic factors, biotic factors (e.g. interaction between dinoflagellate species) are also being investigated. Given that most of species found in this study are potentially toxic, a long term monitoring programme for benthic dinoflagellates in local marine ecosystem is necessary in order to reveal any potential benthic HABs.

Key words: Epiphytic algae, Harmful algal bloom, Toxic algae, South China Sea

ED1

Annual temperature variation as a time machine to understand the effects of long-term climate change on a poleward range shift

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Range shifts due to annual variation in temperature are more tractable than range shifts linked to decadal to century long temperature changes due to climate change, providing natural experiments to determine the mechanisms responsible for driving long-term distributional shifts. In this study we couple physiologically grounded mechanistic models with biogeographic surveys in 2 years with high levels of annual temperature variation to disentangle the drivers of a historical range shift driven by climate change. The distribution of the barnacle *Semibalanus balanoides* has shifted 350 km poleward in the past half century along the east coast of the United States. Recruits were present throughout the historical range following the 2015 reproductive season, when temperatures were similar to those in the past century, and absent following the 2016 reproductive season when temperatures were warmer than they have been since 1870, the earliest date for temperature records. Our dispersal dependent mechanistic models of reproductive success were highly accurate and predicted patterns of reproduction success documented in field surveys throughout the historical range in 2015 and 2016. Our mechanistic models of reproductive success not only predicted recruitment dynamics near the range edge but also predicted interior range fragmentation in a number of years between 1870 and 2016. All recruits monitored within the historical range following the 2015 colonization died before 2016 suggesting juvenile survival was likely the primary driver of the historical range retraction. However, if 2016 is indicative of future temperatures mechanisms of range limitation will shift and reproductive failure will lead to further range retraction in the future. Mechanistic models are necessary for accurately predicting the effects of climate change on ranges of species.

Key words: Climate variability, Range shift, Dispersal, Range fragmentation

ED2

Are deep kelp beds a source of propagules for their shallow counterparts?

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As shallow coastal ecosystems continue to be degraded by increasing natural and anthropogenic pressures, there is a need to better understand the mechanisms of recovery. The kelp species, *Ecklonia radiata* is a key habitat builder in the temperate and subtropical reefs of Western Australia (WA) which experienced a range contraction of approximately 100 km in waters <20 m deep after a marine heatwave in the summer of 2011.

This study investigated the potential of deep kelp populations to serve as refugia for their shallow counterparts by providing a source of propagules to shallow. We assessed the kelp beds around Rottnest Island (WA) across a depth gradient (15, 25, and 40 m) by 1. Measuring the fecundity and synchrony of kelp populations across a depth gradient by collecting kelp thalli, extracting and counting spores during the summer and early autumn seasons (the peak reproductive season for kelp in this region). 2. Evaluating the dispersal potential of kelp propagules (spores) released at different depths by using a numerical circulation model to simulate the circulation around Rottnest Island and to track the horizontal and vertical dispersal of kelp.

The biophysical simulation indicates that there is potential for exchange of propagules between deep and shallow kelp beds around Rottnest Island. Results also indicate that the peak reproductive season for kelp is different across depths with no reduced fecundity of deep kelp populations. We conclude that deep kelp beds have the potential to recolonize and help the recovery of disturbed shallow kelp beds.

Key words: Connectivity, Reproductive effort, Propagule dispersal, Deep-reef refugia

ED3

Assessing the recovery of juvenile black-footed abalone (*Haliotis iris* or pāua) and habitat, and developing restoration plans following earthquake uplift of the coast of southern New Zealand

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The 2016 7.8 Mw Kaikōura earthquake and associated coastal uplift caused a widespread die-off of intertidal organisms and permanently reconfigured over 130 km of coastline. The black-footed abalone, or pāua, experienced high mortality from this event, likely resulting in a compromised reproductive season and/or reduced recruitment. In addition to the unprecedented mortality of brood stock, rocky intertidal reefs previously known to be important for juvenile recruitment and survival were rendered unsuitable due to changes in tidal height, loss of physical and biogenic habitat, and increased sedimentation. Because of the social, ecological, and commercial importance of a healthy pāua stock in this area, it is critical to understand the current status of juvenile populations and their requisite habitat. Using aerial drone imaging, comprehensive on-the-ground surveys, and artificial reef installation, we are assessing the current status of habitat availability, recruitment, juvenile growth and survivorship for populations in recovery. Extensive sampling has shown that some locations maintain adequate habitat and support recruitment, as indicated by normal size-frequency distributions of pāua, including post-earthquake recruits. Other locations appear to be highly compromised with little to no habitat for juveniles. We also discuss the efficacy of large-scale reseeding efforts using hatchery-reared juveniles and habitat enhancement in assisting population recovery and long-term sustainability of this important fishery.

Key words: Abalone, Paua, Earthquake, Recovery

EE1

Cryptic loss of genetic diversity and directional selection in marine forests following an extreme climatic event

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Extreme climatic events have precipitated profound impacts on marine communities including range contractions and loss of entire ecosystems. Underlying patterns of genetic diversity may both mediate response to such extreme events, as well as subsequent adaptive capacity to further change. Empirical demonstration, however, of how extreme events impact genetic diversity are rare. Here, we demonstrate significant loss of genetic diversity across ~800km of marine forests following an unprecedented marine heatwave that completely extirpated populations of some species, but left others seemingly intact. The marine heatwave was associated with widespread loss of haplotype and nucleotide diversity in 2 forest-forming species. *Scytothalia dorycarpa* lost 33-61% of nucleotide diversity and 12-100% of haplotype diversity following the heatwave. Similarly, *Sargassum fallax* lost 15-31% of nucleotide diversity and 9-100% of haplotype diversity. Strikingly, genetic diversity declined even where there was no detectable impact on species abundances indicating that extreme events can have widespread and cryptic impacts on natural populations. Overall, both species become dominated by single haplotypes after the heatwave suggestive of strong directional selection. Prior latitudinal patterns in population genetic structure were wiped out as all sites genetically diverged. We provide one of the first empirical demonstrations of how an extreme event can cause widespread loss of genetic diversity and strong selection. Ancillary demographic data was critical in demonstrating the cryptic nature of this loss as well as rapid population expansion driven by competitive release in some populations. Predicting the vulnerability of marine systems to extreme climatic events relies on understanding how the interplay between genetic diversity, adaptive capacity and population demography confers resilience to future change.

Key words: Genetic, Diversity, Loss, Heatwave

EE2

Combined heatwave and hypoxia events affect metabolic response and mortality of the Lessepsian bivalve *Brachidontes pharaonis*

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Climate change extreme events have severe impacts on oceans and are responsible for dramatic ecosystem changes. A multiple series of heatwave (HW) and hypoxia (HYP) extreme events was recorded in summer 2017 by our long-term sensor network maintained in a Sicily shallow lagoon. This sequence generated a mass mortality of the keystone bivalve *Brachidontes pharaonis*, colonising hard substrata in the lagoon. To explore how HW and HYP were able to affect the bivalve's population dynamics through effects at both functional (individual metabolic response) and population (mortality) levels, we reproduced the same sequence of intensities and frequencies of both stressors, as that recorded in summer 2017, by manipulating mesocosm conditions. Results showed higher O_2 consumption for the HW exposed specimens (1.73±0.13 mg l^{-1} DW^{-1}), followed by those exposed to multiple stressor (MS) (1.13±0.09) and to the hypoxia treatment (0.35±0.04). The recovery phase showed higher rates for mussels exposed to MS (1.99±0.13), followed by those exposed to HYP (1.68±0.09) and to the HW (1.50±0.14) treatments respectively. No mortality was recorded for the CTRL and HW treatments, while increasing mortality was recorded for other treatments: 13% mortality for the HYP treatment and a 56% mortality for MS, that reached the LT_{50} within Day 6. This study allowed us to individuate functional and population tipping points when a thermo-tolerant key-stone species is exposed to extreme events in newly colonised sites. Such an information is valuable to inform managers in preventing the unpredictable effects of extreme events due to exacerbation of climate change.

Key words: Extreme events, Multiple stressor, Shallow lagoon habitats, *Brachidontes pharaonic*

EE3

Experimental assessments on the impacts of extreme events on benthic marine predators

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Climate Change will not only shift environmental means but will also increase the intensity of extreme events, exerting additional stress on organisms and ecosystems. While field observations on the ecological consequences of extremes such as heat waves are emerging, experimental evidence is rare.

This research combines detailed characterization of abiotic parameters and their variability with experimental approaches. The identified extremes and their characteristics allowed the simulation of realistic treatment combinations. In novel mesocosm systems, we tested the interactive impacts of marine heatwaves, as well as hypoxic and freshening events on the starfish *Asterias rubens* from coastal habitats of the Western Baltic Sea and the Skagerrak.

Marine heatwaves of increased amplitude led to the mortality of starfish. Current-day heatwaves as well as hypoxic and freshening events did only temporally impact starfish performance. Thus, *A. rubens* recovered well from these single short-term events. Marine heat waves of increased duration, however, had a strong and persistent impacts on the starfish. Additionally, the combination of marine heatwave and freshening events led to a detrimental impact on this predator species.

This research provides robust insights into shifts of ecosystem structure in a changing and fluctuating world. Considering the apparent increase in heatwave events as observed for the Skagerrak, and a decrease in mean salinity regimes, as projected for coastal oceans, the investigated species *A. rubens* will, in a future ocean, suffer from the synergistic effects of marine heatwaves and freshening events as well as from more persistent heatwaves, with possible consequences for the entire ecosystem.

Key words: Extreme events, Marine heatwave, Freshening, Hypoxia

Cataclysmic tipping points in a coastal marine environment following a massive earthquake

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Many years of small-scale experiments have shown that the loss of key habitat-forming seaweeds causes a decline in local diversity, reduction in primary productivity, and altered competitive relationships. Full recovery usually takes many years from one-off impacts. The Mw 7.8 earthquake that struck southern New Zealand in November 2016 caused upheaval of 130 km of coastline by up to 6m, resulting in massive changes to the coastal ecosystem. The unprecedented loss of large fucoid algae and grazing invertebrates allowed a test of how well small-scale recovery informs about large scale impacts and subsequent recovery processes. There was a loss of connectivity for some key species, extensive multi-month blooms of ephemeral algae, extensive loss of grazing invertebrates, increased sedimentation, and added stressors from altered human usages of the coastal strip. The physical environment was changed from altered reef topography, shortened tidal immersion, accumulated sediments, and a compromised light environment in much of the nearshore zone. We discuss the 'trickle down' hypothesis – that zones will essentially re-assort themselves downwards, the potential role of 'safe havens' – undamaged, protected areas as potential sources of propagules of key species, and crucial needs for recovery of these extensive part of the marine ecosystem.

Key words: Tipping point, Earthquake, Macroalgal communities

EE5

A double whammy of seismic uplift and a marine heatwave thrashed iconic intertidal foundation species (*Durvillaea* spp.; 'bull kelp') along the South Island of New Zealand

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Southern bull kelp (*Durvillaea poha*, *D. antarctica*, and *D. willana*) are iconic large, long-lived fucoid algae that modify environmental conditions and provide habitat for ecologically and economically important species on wave-exposed coastlines of the South Island of New Zealand. Here we report on impacts on bull kelp from a seismic uplift (from the Kaikoura Nov 2016 earthquake) and a marine heat wave (summer 2017/18). Surveys were done along c. 500 km coastline from Cape Campbell to Moeraki, estimating cover and densities of bull kelp using quadrats, drone-images and semi-quantitative estimations of damage to fronds and holdfasts from landscape photos. *D. poha* and *D. willana* were most severely affected and *D. poha* was entirely eliminated from reefs around Christchurch where a combination of low waves, low tides, very high air temperatures and a marine heat event, caused considerable mortalities. After the loss of *Durvillaea*, fast-growing and short-lived seaweeds, especially opportunistic green *Ulva* spp. and the invasive kelp *Undaria pinnatifida*, invaded many reefs and, if persistent, could delay recovery of bull kelp populations. Finally, we will discuss potential recovery of bull kelp in this region, critical experiments, possible restoration and management options and, more generally, what the future holds for bull kelp along this southern coastline.

Key words: Marine heatwave, Bull kelp, Mortality, Recovery

EE6

Temperature extremes and propagation of disturbance on rocky shores

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Temperature extremes can have profound consequences on the spatial distribution and dynamics of temperate reef populations. Temperature effects may be exacerbated in heterogeneous systems, where gaps within aggregates can increase the susceptibility of the surrounding community to disturbance. Here, we present a field manipulative experiment aimed at testing the effects of extreme temperatures within aggregates of *Chthamalus stellatus* at different distances from the margins of disturbed gaps. We expected either negative or positive effects of temperature extremes on barnacles, due to increased mortality rates or to facilitative effects on their metabolic activities, respectively. These effects were expected to i) interact with gap size, with larger negative impacts acting along the margins of smaller removal areas; ii) decrease at increasing distance from gap's margins, and iii) mediate negative direct effects of temperature extreme on microphytobenthos colonizing barnacles' shells. Results showed a main positive effect of temperature extremes close to the margins of the gap on detachment of barnacles and on microphytobenthos, in summer; in winter, when temperature decreased and frequency of storms increased, the positive effect disappeared and even changed to negative along the margins of smaller gaps. An interactive effect of manipulated factors along the gap's margins was observed also on fertility of individuals. We suggest that changes in temperature extremes can affect the susceptibility to disturbance of many features of biological aggregates on rocky shores, mostly along the margins of small gaps, even when taking place far from the latitudinal distributional limits of the species.

Key words: Extreme events, Propagation of disturbance, Gap size, Barnacles

RP1

Climate change and citizen science actions with children: how valuable for monitoring species distribution on rocky shores?

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In a context of climate change it is important to increase awareness in society of the need to conserve biodiversity and marine species sustainability. Here we present results of the project "EduMar/EduSea – Educate for the Sea" (SAICT-POL/23480/2016) which aimed to educate students for the preservation of the sea and its resources through citizen science. It is posed the problem of evaluating the effectiveness of the school community involvement in citizen science activities, both for scientists use of data and for children learning. More than 300 primary school students (ages 9 to 11) with the help of their teachers, participated in interdisciplinary science activities focusing on the causes and consequences of climate change in the ocean, learning to identify rocky shore marine species and acquiring ICT skills to insert photographs, with a tablet, in a biodiversity mapping application (Biodiverisity4All/iNaturalist). The analysis of data from the online platform enabled assessment of the percentage of correct species identification by students. From the perspective of a scientist the following items were analysed regarding the image quality and use: not usable/usable, adequate with high/low quality, with information on target/other species. Students recognised the importance of their participation as citizens in monitoring the effects of climate change and scientists also validated their data in the platform. We will discuss the importance and appliance of this action for future projects.

Key words: Climate change, Citizen Science, Intertidal, School Children

RP2

Complex interactions between direct and indirect effects of ocean warming on recovery of kelp beds, Northern Norway

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After several decades with extensive barren ground areas and green sea urchin dominance along coastal areas of Norway, kelp forests are gradually recovering northwards. The recovery has been connected to reduced settlement of sea urchins and increased crab predation, both related to ocean warming. However, the spatial and temporal pattern of kelp recovery is complex. To explore the possible impact of local differences in the interaction between sea urchins and crabs, we have studied sea urchin recruitment in predator refuge habitats, and distribution of kelps and adult sea urchins. This sampling took place along coastal regions with high and low abundance of crabs. We have experimentally tested crab predation on juvenile sea urchins in a cryptic habitat (maerl). Sea urchin recruitment was low in the cryptic habitats between 63 and 66°N, and high north of 66°N (some places >1000 juveniles per m^2). Despite high sea urchin recruitment, local kelp recovery has occurred between 66 and 69°N in areas where crab landings have increased in recent years. The experimental study indicates that crabs prey on large urchins, but not on the juveniles in the cryptic habitats. North of 69°N where crab abundance is low, high number of recruits and extensive barren grounds still exist. Our studies suggest that local variation in the interaction between sea urchins and crabs, mediated through presence of cryptic habitats, may explain the complex pattern of spatial distribution of sea urchins and kelp recovery in northern Norway. However, the complexity calls for more investigations.

Key words: Kelp recovery, Sea urchins, Crabs, Ocean warming

RP3

Ocean currents and herbivory drive macroalgae-to-coral community shift under climate warming

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Corals and macroalgae are threatened by global stressors. However, recently reported community shifts from temperate macroalgae to tropical corals offer conservation potential for corals at the expense of macroalgae under climate warming. Although such community shifts are expanding geographically, our understanding of the driving processes is limited. Here, we reconstruct long-term climate-driven range shifts in 45 species of macroalgae, corals, and herbivorous fishes from over 60-years records (mainly 1950–2015), stretching across 3,000 km of the Japanese archipelago from tropical to subarctic zones. Based on a revised coastal version of climate velocity trajectories, we found that prediction models combining the effects of climate and ocean currents consistently explained observed community shifts significantly better than those relying on climate alone. Corals and herbivorous fishes performed better at exploiting opportunities offered by this interaction. The contrasting range dynamics for these taxa suggest that ocean warming is promoting macroalgae-to-coral shifts both directly by increased competition from the expansion of tropical corals into the contracting temperate macroalgae, and indirectly via deforestation by the expansion of tropical herbivorous fish. Beyond individual species' effects, our results provide evidence on the important role that the interaction between climate warming and external forces conditioning the dispersal of organisms, such as ocean currents, can have in shaping community-level responses, with concomitant changes to ecosystem structure and functioning. Furthermore, we found that community shifts from macroalgae to corals might accelerate with future warming, highlighting the complexity of managing these evolving communities under future climate.
(Kumagai *et al.* 2018 PNAS 115:8990-8995)

Key words: Climate velocity, Tropicalization, Community shifts, Range shifts

RP4

Turf-forming algae benefit the recruitment success of a spreading, native alga

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Although the disappearance of macrophytes has received considerable attention, less well known are native species that benefit from environmental change and come to dominate communities, or the mechanisms behind their success. In New South Wales, Eastern Australia, a native species of the notorious *Caulerpa* genus, *C. filiformis*, has spread both within and outside its historical distribution. We investigated how co-occurring macroalgal habitats affect the recruitment success of *C. filiformis*. We hypothesized that recruitment is promoted by turf-forming alga, while intact canopies resist. In line with our hypothesis, large-scale surveys found that recruits were highly abundant in certain turf-forming algal habitat, and rare in *Sargassum* or kelp habitat. This pattern was confirmed by a field experiment, although results were highly weather dependent. Laboratory work showed that attachment performance of *C. filiformis'* fragments benefits from the high structural complexity of geniculate turf-forming algae. Fragments attached more rapidly and stronger in the presence of turf or turf mimics. This study indicates that a loss of canopy-forming algae may benefit the spread of this native species both directly and indirectly via the prevalence of opportunistic turf-forming algae.

Key words: Invasive species, Kelp, *Sargassum*, Cascading effect

RP5

Mobile invertebrate assemblages on temperate Western Australian subtidal reefs over a latitudinal gradient

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Temperate subtidal reefs in Western Australia have been exposed to increasing pressure from rising sea temperatures, and more frequent extreme heat events over the last decades. These pressures are forcing major shifts in the distribution and abundance of canopy forming macroalgae - the foundation species of temperate reefs. The effects of changes to foundation species cascades down into the ecosystem they support. This research investigates the mobile invertebrate community associated with temperate reefs along a latitudinal gradient that have shown varying degrees of change in the macroalgae composition; from little change in the South (34° S) to "canopy to turf" phase shift at the Northern most location (28° S). *In situ* invertebrate transects were done on SCUBA, and the results analyzed using Generalized Additive Mixed Models (GAMM). we determined the main factors influencing the invertebrate species distribution are latitude, habitat orientation, and the exposure of the site. Furthermore, using Bray-Curtis dissimilarities, the biggest changes in invertebrate community composition over time occurred at sites which also showed the biggest change in benthic macroalgae composition and largest reduction of *Ecklonia radiata* cover.

Key words: *Ecklonia radiata*, Invertebrate community, GAMM

RP6

Fish community change in response to warming water across a biogeographic transition zone in southern California, USA

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Temperate marine transition zones are facing acute and chronic thermal stress that are altering communities. While managers and resource users have used oceanographic indicators to track various types of thermal events, efficient ways to quantify and track responses in biological communities are rare. We tracked change in fish communities accounting for species thermal affinity. We created a new indicator of thermal affinity for common California fish species using a combination of biogeographic data and expert opinion. Using this new indicator, we measured change in several metrics derived from long-term surveys (e.g. density, biomass, recruitment, and effective species number (a diversity metric)) in the Channel Islands National Marine Sanctuary, California, USA. We found that warm-water species densities, biomass, and recruitment during and after a recent marine heat wave event were significantly different from years prior to the warming event. Additionally, after multiple years of warm water conditions, warm-water effective species number was significantly higher than years prior. Marine Protected Area (MPA) status did not effectively buffer community change as non-targeted species responded more strongly to the marine heat wave while targeted (fished) species did not. Our work questions the potential ability of temperate MPAs to strongly buffer the effects of warming oceans with respect to community structure.

Key words: Tropicalization, Kelp forest, Fish, Marine protected areas

RP7

Can kelp forests maintain ecosystem function in a changing world?

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Contemporary climate change is reorganizing the composition of temperate reefs worldwide by inducing species migrations (range shifts), with migrant thermally-tolerant species often becoming competitively dominant over species with colder affinities. Although these climate-driven changes in species abundance and diversity are well documented, their ecosystem-level implications are poorly understood, and resolving whether reconfigured communities can maintain fundamental ecosystem functions represents a pressing challenge in an increasingly warmer world.

We investigated how climate-driven substitutions of foundation species influence processes associated with carbon and nutrient cycling (biomass production, detritus flow, herbivory, decomposition) by comparing two habitat-forming kelp species with contrasting thermal affinities. We examined the wider ecosystem consequences of such shifts for the observed (and predicted) emergence of novel marine forest communities in the NE Atlantic, which are expected to become more dominated by range-expanding, warm-temperate kelps.

The warm-temperate kelps were more productive than the cold-water kelps and exhibited a distinct seasonal growth strategy. A greater proportion of their production entered higher trophic levels, as this species was a preferred food and was subjected to higher grazing rates. Like the other kelps, most of primary production was lost via erosion of the lamina, which decomposed faster than that of the cold-water species.

Our results show that, like species invasions, climate-driven range expansions and consequent shifts in the identity of dominant species can modify a wide range of important ecosystem processes. However, alterations in overall ecosystem functioning may be relatively limited where foundation species share similar ecological and functional traits.

Key words: Laminariales, Novel ecosystems, Range expansion, Range shift

RP8

Abiotic modification of intra- and inter-specific competition between limpets in range-central and poleward-edge populations

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Ecological patterns are determined by a complex interplay between abiotic factors and species interactions. The strength and nature of biological interactions themselves are influenced by climate. If these interactions are sensitive to temperature, strong impacts on keystone species are expected and therefore, noticeable changes on biological communities are highly probable. The Lusitanian limpet *Patella depressa* and its putative competitor the Boreal limpet *Patella vulgata* have overlapping distributions across British Isles. The poleward range edge of *P. depressa* occurs in North Wales, which has not recovered from range retractions that occurred during the cold period from 1960s to early 1980s. Nowadays breeding population just reach the northern side of Cardigan Bay and re-extension has not occurred. We tested intra- and inter-specific competition between both *Patella* species in central and marginal populations of *P. depressa* under contrasting environmental conditions across the British Isles (shading and no-shading). Individuals of *P. depressa* were strongly affected by inter-specific competition at its range edge in North Wales, particularly in mixed plots with *P. vulgata* under shading treatments. By contrast, *P. vulgata* was affected by intra-specific competition in no-shading plots, particularly in central populations in South-west England. These results suggest that both biological and physical factors are modulating the poleward range of *P. depressa* in populations at North Wales. Therefore, a better understanding of the differences in competitive ability between *Patella* species over a large spatial scale will improve our understanding of the role of competition in range edge populations and setting range limits.

Key words: Leading-edge, Species-interactions, Field-experiments, Range-overlap

RP9

Interannual variability of kelps and their consumers in Iberia

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Kelps are foundation species in many near-shore temperate areas, where there is wide evidence that their patterns of abundance are modulated by climatic and non-climatic drivers. We analysed, between 2011 and 2018, the interannual variability of occurrence and abundance of kelp species and their major consumers (fishes and sea urchins), as well as interannual patterns of ocean climate (seawater temperature and chl *a*), at five regions along a seven degrees' latitudinal gradient encompassing the north and west coast of Iberian Peninsula. Sea surface temperature showed a significant correlation with latitude (mean variation of 0.5 - 2ºC), while chl *a* oscillated irregularly among the studied regions. Two perennial and three annual kelp species were recorded: *Laminaria hyperborea*, *L. ochroleuca*, *Saccorhiza polyschides*, *Phyllariopsis brevipes* and *Phyllariopsis purpurascens*, respectively. Kelp spatial and temporal variation were species-dependent, but annual species dominated in terms of frequency of occurrence (>80%). *Saccorhiza polyschides* was the most abundant species, representing ca. 60% of mean total abundance of kelps. Overall consumers were more abundant in the two southernmost, compared to the three northernmost, regions. Herbivorous fishes were more frequent in the southern regions and about 40 times more abundant there compared to the northern regions.

Herbivorous fishes and sea-urchins were more abundance in the southern regions. The large variability of abundance of kelps reinforce the need of adequate monitoring programs to properly assess the apparently decline of kelps particularly in regions where is recognized the lack of data, such as in the Iberian Peninsula subtidal coast.

Key words: Abundance, Atlantic Ocean, Grazers, Laminariales

RP10

Population boom of a range-extender drives ongoing collapse of a temperate reef ecosystem

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This presentation will detail the results of a recent coast-wide resurvey of the range-extending sea urchin (*Centrostephanus rodgersii*) and its' overgrazing impact on Tasmanian reefs relative to baselines established in 2001. Since the first positive identification of an individual *C. rodgersii* on the mainland coast of Tasmania in 1978, the population has now reached ~20 million individuals. Diver re-survey of baseline sites revealed an increase in average density from 1,495 to 2,623 urchins per hectare (an increase of 1.75 times) in eastern Tasmania over the past 15 years. The coverage of barren grounds, as assessed using towed underwater video, has increased from 3.4% to 15.2% of eastern Tasmanian reefs (an increase of 4.5 times). Increases in both density of *C. rodgersii* and a disproportionately larger increase in barrens were both greatest on boulder-dominated reef between 18 to 30 m depth. Re-confirming baseline findings, commercial quantities of both abalone and rock lobster were absent from the impoverished barren grounds. Management of this significant and ongoing loss of kelp beds must be proactive given the observed hysteresis of overgrazing, whereby 'an ounce of prevention is demonstrably worth a ton of cure'. Importantly, the re-survey has enabled identification of reefs approaching the critical tipping-point of overgrazing, thus directing tactical culling interventions to occur before it is too late. Conversely, for reef already collapsed to extensive barrens, a significant upscaling of yet to be trialled mitigation efforts will be required if natural kelp bed cover, productivity and the broader ecosystem is to be restored.

Key words: Climate change, Phase-shift, Kelp beds, Ecological overfishing

RP11

First report on the occurrence of the *Palythoa mutuki* (Haddon & Shackleton, 1891) (Anthozoa: Sphenopidae: Palythoa) in Jeju Island from Korea

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As rising global seawater temperature caused by global warming, some zooxantellate species have been found to extend their habitat range to higher latitudes than existing habitats. *Palythoa mutuki* (Anthozoa: Hexacorallia: Zoantharia) is a zooxanthellate zoanthid species commonly found in shallow subtropical and tropical waters known to live in Guam, Saipan, Japan, Taiwan, New Caledonia and Galapagos. Jeju Island is geographically affected by the Kuroshio warm current, it becomes a place where temperate and subtropical creatures coexist, with a higher diversity which is 51% of marine biota in Korea. Recently, *Palythoa* sp. population has been discovered from a subtidal area (5-10 m depth) on the southern coast of Jeju Island from Korea. In the present study, we identified the *Palythoa* sp. to species level using internal transcribed spacer (ITS) sequence. ITS DNA sequence obtained from the *Palythoa* sp. in this study showed to *Palythoa mutuki* (Haddon & Shackleton, 1891) reported from Japan, which is the first report of sphenopidae species found in the Korean waters. These records can be seen as evidence that the Jeju Island is changing due to global warming and will be used as the important basic information for climate change research in Korea.

Key words: *Palythoa mutuki*, Sphenopidae, Jeju Island, Climate change

Abstracts
of
Poster presentation

12th International Temperate Reefs Symposium
6 – 11 Jan, 2019
Hong Kong

P1

Assessing the ecological effects of an experimental scallop ranching project in Torbay, South West UK

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Bottom towed fishing gear such as scallop dredges are among the most destructive fishing techniques in relation to benthic habitats and species. These methods have a detrimental effect on the seabed ecosystem, reducing structural complexity of the habitat, altering diversity and composition of assemblages and damaging non-target species. In response, an experimental scallop ranch was developed in Torbay, South West UK to determine whether a sustainable and commercially viable alternative to traditional scallop dredging can be created in the UK. Bivalve aquaculture installations are thought to be one of the most sustainable methods of farming seafood and have been found to have a positive effect on the surrounding ecosystem, improving water quality and enhancing biodiversity. However, there are potential negative impacts as enhanced biodeposition on the seabed can alter energy transfer within a system and modify trophic interactions. To assess changes in the assemblage composition at the ranch video data were collected over three years using an ROV and BRUVS to sample the epi-benthic species and non-baited midwater video systems to analyse the pelagic species. Data were collected within the scallop ranch and at comparable reference areas. This study aims to create a structured ecosystem based monitoring approach for an experimental scallop ranch, essential if such ventures are brought to commercial scale in the future. The results will help to inform managers so that positive impacts can be enhanced and negative impacts mitigated.

Key words: Bottom towed fishing gear, Scallop aquaculture, Ecological effects, Assemblage composition

P2

Acoustic Complexity Index to assess a partially protected area in the southwest of the UK

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The environmental noise, or soundscape, of the marine environment is a relatively understudied area of ecology that has the potential to provide large amounts of information on: biodiversity; reproductive behaviour; habitat selection; spawning; and predator-prey interactions. This potential wealth of information has been quantified by multiple different acoustic indices. As an accepted measure for ecosystem health, biodiversity is often used as a monitoring tool, especially for marine protected areas. Thus, the efficacy and ability of acoustic measures, such as Acoustic Complexity Index (ACI), have been tested alongside visual surveys, throughout the tropics, to analyse marine biodiversity. However, few studies have focused on temperate reef communities. To assess whether Acoustic Complexity increases with increasing biodiversity in a recovering temperate reef marine protected area, annual non-invasive video and acoustic surveys were undertaken in Lyme Bay, south west UK. Over five years, baited underwater video camera and acoustic loggerhead recorders were deployed in the MPA in Lyme Bay and in comparable reference areas to compare ACI with mobile epifauna diversity. Initial findings suggest that ACI and mobile epifauna are related and are potentially driven by crustacean scavenging species. The potential use of ACI as a cost and time effective technique of monitoring marine habitats will be discussed.

Key words: Temperate Reef, Acoustic Complexity, Video Sampling, MPA

P3

Juvenile Pacific oysters, *Magallana (=Crassostrea) gigas*, grown under variable high pCO_2 may outperform those under ambient or static high pCO_2

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Ocean acidification (OA) poses a substantial risk to the persistence and performance of marine organisms in the future, particularly to calcifiers. When measuring responses to OA, researchers typically utilize static pCO_2 treatments that do not capture the variability inherent in nature, such as that in coastal environments where upwelling and diel productivity can cause substantial variation in pCO_2. Variability could benefit organisms by providing a temporal refuge from adverse conditions, but could compromise organisms through regular acclimation stress. In our study, we exposed juvenile Pacific oysters (*M. gigas*), a cosmopolitan, economically important bivalve, to four pCO_2 treatments during a five-week mesocosm study – three static treatments (400 µatm, 1500 µatm, and 2600 µatm pCO_2) and one variable treatment (1500 µatm average, fluctuating between 400 µatm and 2600 µatm pCO_2 every three days). We measured the resulting survival, feeding, and growth of oysters, expecting to see reduced survival and performance in oysters under variable and high pCO_2 conditions. Instead, we observed no significant differences in oyster survival between treatments and a significant increase in shell growth under elevated variable pCO_2 compared to all other treatments. This increased growth was unexplained by differential feeding rates, which were not statistically different between treatments. Further work will investigate if variable pCO_2 promotes shell growth at the expense of tissue growth, which could compromise oysters over a longer timeframe. Our results indicate that using static treatments can hamper predictions of organismal responses to OA, and that variability should be more commonly integrated experimental design.

Key words: Ocean acidification, Variability

P4

Exposure to TCDD hampers the host defense capability of a bivalve species, *Tegillarca granosa*

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Although increasing reports of deleterious impacts of dioxins and polychlorinated biphenyls (PCBs) on a large number of marine organisms have been described, their effects on the host defense capability of marine bivalve mollusks remain poorly understood. In this study we used 2,3,7,8 - tetrachlorodibenzo - p - dioxin (TCDD) as a representative of dioxins and PCBs to investigate its impacts on the host defense capability of the blood clam, *Tegillarca granosa*. After exposure of clams to a range (0, 0.01, 0.1, 1, and 10 μg/L) of TCDD for 96 h, testing indexes, such as total haemocyte count (THC), cell type composition, and phagocytic rate of haemocytes were analyzed. In addition, alkaline phosphatase (ALP) activity, cell viability, and the extent of DNA damage of haemocytes were also investigated. Our results showed that exposure to relatively high TCDD concentrations led to significant reductions in THC and phagocytic activity, which could be accounted by aggravated DNA damage and reduced cell viability. In addition, the percentage of red granulocyte was significantly decreased whereas that of basophil granulocyte was significantly increased upon high doses TCDD exposure (effective concentrations are 1 μg/L and 10 μg/L for red and basophil granulocytes, respectively). Moreover, clams exposed to TCDD had a significant higher activity of ALP. These findings suggest that TCDD may hamper the host defense capability and therefore render bivalve mollusks more vulnerable to pathogen infections.

Key words: TCDD, Blood clam, Host defense mechanism, Haemocytes

P5

Ocean acidification impairs foraging behavior by interfering with olfactory neural signal transduction in black sea bream, *Acanthopagrus schlegelii*

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In recent years, ocean acidification (OA) has drawn worldwide concern over its physiological and ecological effects on marine organisms. However, the behavioral impacts of OA and especially the underlying physiological mechanisms causing these impacts are still poorly understood in marine species. Therefore, the effects of elevated pCO_2 on foraging behavior, in vivo contents of two important neurotransmitters, and the expression of genes encoding key modulatory enzymes from the olfactory transduction pathway were investigated in the larval black sea bream. The results showed that larval sea breams reared in acidified seawater (pH at 7.8 and 7.4) for 15 days tend to stall longer at their acclimated zone and swim with a significant slower velocity in a more zigzag manner toward food source. These findings indicate that the foraging behavior of the sea bream was significantly impaired by OA. In addition, compared to a control, significant reductions in the in vivo contents of g-aminobutyric acid (GABA) and Acetylcholine (ACh) were detected in ocean acidification-treated sea breams. Furthermore, in the acidified experiment groups, the expression of genes encoding positive regulators, the olfaction-specific G protein (Golf) and the G-protein signaling 2 (RGS2) and negative regulators, the G protein-coupled receptor kinase (GRK) and arrestin in the olfactory transduction pathway were found to be significantly suppressed and up-regulated, respectively. These results indicate a significant disruptive effect caused by OA on olfactory neural signal transduction, which might reveal the underlying cause of the hampered foraging behavior.

Key words: Ocean acidification, Black sea bream, Foraging behaviour, Olfactory transduction

P6

Examining materials and biodiversity of artificial habitats to inform marine ecological engineering

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Ecological engineering involves the incorporation of specific design features into human infrastructure to enhance ecological performance, and has gained significant traction in recent years in response to urbanisation and corresponding habitat- and biodiversity-loss. Within marine ecosystems, infrastructure is widespread and increasingly prevalent, partly driven by coastal development and partly in response to climatic change (which drives construction of hard coastal defences and deployment of renewable energy devices). Such infrastructure represents considerable novel substrate for colonisation by epifauna. Currently we have little understanding of the 'ecological performance' of different materials (i.e. concrete mixes, rock, metal) used in marine infrastructure. This is of interest because properties of materials may differentially affect species colonisation, in turn affecting important ecosystem functions and services such species regulate (i.e. habitat provision, maintenance of biodiversity, water-filtration, nutrient recycling, bio-security). Further, while interventions have focused on providing artificial microhabitats (i.e. grooves and crevices) on infrastructure, we currently lack understanding of how heterogeneity of artificially created microhabitat in turn affects species diversity and ecosystem functions. Our research seeks to understand the importance of material choices and artificial habitat structure in order to improve success of future eco-engineering interventions in marine habitats.

Key words: Ecological engineering, Materials, Habitat diversity

P7

Urban underwater landscape and tidal gardens – is it possible to transform seafloor deserts in Oslo Harbour to underwater oasis?

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Landscape architects have rarely access to topographical maps of the marine areas. This makes it impossible to consider the marine landscape when designing buildings and infrastructure in the sea. These artificial structures have traditionally been built with straight edges and smooth surfaces, creating desert-like marine habitats. In this project, we have been given the opportunity to design and develop an underwater urban landscape, as well as testing a variation of eco-engineering methods to increase habitat complexity and biodiversity in subtidal and tidal areas. The shoreline landscape design is adapted for the former industrial Port of Oslo (Norway) which is now under construction to become a new, urban residential area.

To promote natural colonization of marine organisms onto established constructions, smooth surfaces will be modified with crevices and pits. Underwater tidal gardens and landscape structures will be built from local stone minerals, creating elevations and water-retaining features at different vertical levels. Native habitat-forming taxa will be introduced and transplanted into the designed landscape to accelerate the formation of a natural ecosystem. The project includes an interdisciplinary collaboration between landscape architects, social scientists, geologists, oceanographers, marine biologists, city planners and developers. The goal in the short term is to design and test interventions that enhance algae and animal diversity in Oslo's urban foreshore environment. In longer term, we want to stimulate the use of a landscape perspective and ecosystem engineering in the marine environment in Norway. This is a first step in building a demo-case and some basic tools and tests.

Key words: Ecosystem engineering, Urban shoreline landscapes, City development, Urban foreshore transformation

P8

Movement ecology of intertidal gastropods on natural rocky shores and seawalls in Singapore

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Increasing coastal development and global warming have resulted in large-scale habitat changes, with artificial coastal structures replacing vast areas of natural coastlines. For instance, in Singapore, ~63% of natural coastline has been replaced by seawalls. Multiple studies from both temperate and tropical regions have shown that seawalls support lower biodiversity compared to natural rocky shores. However, little is known about the movement ecology of organisms that utilize these natural and urban tropical intertidal habitats, even though understanding the differences in movement patterns within habitats may provide additional insights into habitat utilization by gastropods. Using mark-recapture techniques, this study investigated: i) the differences in displacement of two intertidal gastropod genera between natural rocky shores and seawalls; and ii) the spatial movement patterns of eight different gastropod species between three experimental seawall plots, each with different habitat patch configurations (i.e. arrangement of moulded concrete tiles). Results of my field surveys indicated that genus exerted a stronger influence on gastropod movement relative to habitat type. Analyses of the mark-recapture data of eight gastropod species revealed that there were differences in adult snail movement patterns between plots of different spatial configurations. Restricted movement was observed on seawalls when distance between habitat patches (tiles) were large, which could be related to the ability to survive dispersal between suitable habitat patches. Finally, I will present the implications of my findings in the wider context of management and eco-engineering of seawalls to improve their value as a habitat.

Key words: Tropics, Artificial structures, Mark-recapture, Dispersal

P9

Ecostructure – promoting ecologically-sensitive design of artificial marine structures

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The Ecostructure project is a 5-year EU-funded collaboration between 5 leading research institutions in Ireland and Wales. We are investigating the ecology of artificial marine structures, their effects on the natural environment, and methods of enhancing their biodiversity value. The overarching aim is to raise awareness of ecologically-sensitive design possibilities for structures in the marine environment, by providing developers and regulators with accessible tools and resources for evidence-based planning and decision-making. Outputs will be based on interdisciplinary research in the fields of ecology, engineering, genetics, hydrodynamic modelling and social science. Ecostructure research aims to promote ecologically-sensitive design in marine planning in Ireland and Wales, with benefits to the environment, to coastal communities and to the blue and green sectors of the Irish and Welsh economies. Research findings will, however, also be widely relevant and applicable to other nations facing similar challenges related to marine urbanisation and ocean sprawl. This poster will outline the project objectives, intended outcomes and preliminary findings.

Key words: Artificial structures, Eco-engineering, Enhancement, Marine management

P10

Status of artificial reefs in the European Atlantic Area

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Artificial reefs (AR), deployed over many generations in different regions of the world have served many purposes including habitat restoration and protection, fish stock enhancement and fisheries management and recreation. Recent international multi-disciplinary collaborations in the NE Atlantic area intend to trial innovative 3D printed designs and structures of different materials aiming to enhance biodiversity and to be deployed in different Atlantic Europe coastal regions (www.3dpare.eu).

Here we examined available data on AR deployed in the European Atlantic to inform and support the planning and construction of the new 3D artificial reefs. In the Atlantic area, 65 artificial reefs (regarding only purpose-built reefs) have been deployed since 1970, mostly between the years 1990-2009. The most reported purpose for AR deployment was fisheries productivity and/or enhancement, research and habitat management. The great majority of AR were deployed at the depth range of 10-20 m, and the cubical shape was the most deployed design with around 40% of the total AR deployed in the Atlantic area. Most of AR are made of concrete (80%) that in some cases might combine by-products such as seashells. Bio-colonization of AR was mainly assessed by measuring fish and benthic diversity but only around 43% and 32% had records of these biological data, respectively. Highest levels of biological diversity, seems to be associated with cubical structures with voids and rough surfaces promoting a complex structure and the appropriate amount of surface area available for the establishment of settling organisms, as well as sufficient cavities for free-living species.

Key words: Design, Biodiversity, North-east Atlantic, 3D printing

P11

Growth of juvenile stalked barnacles (*Pollicipes pollicipes*) on artificial substrata ("barticles") in different ecological conditions

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The stalked barnacle *Pollicipes pollicipes* is an important ecological and economical resource that inhabits extremely exposed intertidal rocky shore habitats along the NE Atlantic coast. The fishing pressure upon this species is intense and its commercial value can be very high in European markets. Harvesting stalked barnacles is a dangerous activity and likely to have extended periods of fishery cessation due to rough sea conditions. Thus, the feasibility of the collection of juvenile barnacles from the wild and its growth in different ecological conditions (e.g. suspended artificial structures) is being studied as an alternative to this activity.

We will present data on the seasonal and interannual variation observed in previous years (2015 - 2018) on the growth rates of juvenile barnacles which have settled on artificial substrata ("barticles") deployed on the rocky intertidal of a very exposed shore (Cape Sines, Portugal), collected and marked with calcein, then relocated to their natural habitat and to artificial conditions (complete immersion in a floating platform located in the lee of Cape of Sines in sheltered conditions), and left to grow for periods of ~3 months.

Juvenile growth rate was estimated by measuring, under fluorescence stereomicroscopy, the marginal increment of capitular plates following the calcein marking.

Growth rates varied at all spatial and temporal scales considered. Seasonal and interannual variability in juvenile stalked barnacle growth rate and its relationship with environmental conditions are discussed. Overall, the growth rate in juvenile stalked barnacles living in artificial structures was larger than in natural habitats.

Key words: Cirripedia, Growth, Calcein, Aquaculture

P12

Estimating abundance of the stalked barnacle *Pollicipes pollicipes*: photo-quadrats *vs* drone imagery

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Managing marine resources requires information on their distribution and abundance at relevant scales, often challenging to obtain when sampling large areas and extreme habitats such as wave-swept rocky shores.

The stalked barnacle *Pollicipes pollicipes* is an important resource on the northeast Atlantic coast forming dense aggregations in wave-exposed locations, such as capes from Brittany to Senegal.

P. pollicipes abundance is usually assessed by methods such as image analysis of small-scale photo-quadrats (e.g. 50x50 cm). However, the access to sampling sites might carry logistical challenges (e.g. surveying remote areas might be difficult or hazardous) and spatiotemporal constraints imposed by the tidal cycle and sea conditions.

The use of unmanned aerial vehicles (drones) equipped with high-resolution digital cameras, might provide low-altitude aerial imagery of intertidal areas, covering large spatial areas in a timely manner and with sufficient detail to monitor distribution patterns of small-sized organisms such as stalked barnacles.

We have tested the feasibility of using drones as an alternative method to estimate *P. pollicipes* abundance in intertidal rocky shores.

Two sites with high abundance of stalked barnacles were sampled at Cape Sines (SW Portugal) in September 2018. In each site, two vertical levels were defined (mid and low shore). Stalked barnacle percentage cover was estimated from images collected through photo-quadrats (50x50 cm) and low-altitude (<5 m) drone (DJI phantom 4+) survey methods.

Both methods described similar spatial patterns of abundance of *P. pollicipes*. Low-altitude drone survey is a suitable alternative method to study the distribution patterns of this intertidal organism.

Key words: Cirripedia, Surveying, Intertidal rocky-shore ecology, UAV

P13

Effects of substrate material on the colonization of seawall enhancement units by tropical intertidal biota

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As cities expand seaward and the effects of climate change continue to threaten coastlines, natural shores are being increasingly replaced by coastal defences, such as seawalls, that generally support a less diverse assemblage of marine organisms. There is considerable interest in enhancing biodiversity on seawalls through ecological engineering, for example, through the installation of topographically complex "tiles" that provide habitat for intertidal biota. Previous research has suggested that the properties of the construction material used can influence thermal, chemical and micro-structural properties of the substrate that subsequently affect the species assemblages that form on these tiles. Our study tests whether differences in substratum attributes (stone type) affect subsequent colonization in a tropical seawall environment. Six types of enhancement tiles (16 cm × 16 cm × 5 cm) made of granite, limestone, two variants of sandstone, a combination of these four stone types, and a concrete control, were fabricated and deployed on two seawalls on Sentosa Island, Singapore. Preliminary results suggest that the limestone and two types of sandstone tiles support more species richness and abundance than the concrete, granite and combination tiles. Given enough time for ecological succession, more distinct differences in richness and abundance may emerge. However, positive effects on colonisation need to be weighed against engineering criteria and practical issues; for instance, visible signs of erosion were observed on the limestone tiles. Determining whether substrate materials used for enhancement tiles influences the diversity of seawalls assemblages will inform future ecological engineering protocols for enhancing biodiversity on tropical seawalls.

Key words: Material properties, Colonization, Ecological enhancement, Seawall

P14

Optimizing kelp restoration through synthesis and habitat suitability modelling

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Temperate kelp forests provide numerous ecosystem services, but kelps have declined substantially across the globe. As a result, efforts are underway to restore kelp forests and their associated services. When attempting ecosystem restoration, two key aspects must be considered: (i) the method of restoration, and (ii) the location where restoration is being attempted. Our research aims to help optimize future restoration efforts by examining these two components of the restoration process. First, we will quantitatively synthesize the existing kelp restoration efforts and provide an up to date understanding of the state of kelp restoration worldwide. By doing so, we will be able to provide recommendations on which methods are most productive and most cost efficient for carrying out kelp restoration regionally and globally. After we establish which methods are most successful in achieving restoration and to what extent these are species- or region-specific, we will develop a model to predict the optimal areas to carry out kelp restoration, using Eastern Australia as a starting point, with the goal of eventually expand the model to other regions. We aim to combine current understanding of kelp habitat suitability with influences of relevant stressors, such as urchin presence/abundances, and future environmental conditions to determine the most suitable sites and ensure that restoration is successful into the future. By combining restoration methods with ecological models, we hope our work will enhance future restoration success.

Key words: Kelp, Restoration, Synthesis, Habitat suitability

P15

Shallow lagoon habitats: a hotspot for the Lessepsian bivalve *Brachidontes pharaonis*? A mechanistic investigation

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The Lessepsian bivalve *Brachidontes pharaonis* is one of the earliest invasive bivalve to enter the Mediterranean after the opening of the Suez Canal in 1869. In the last few decades *Brachidontes* colonized several Mediterranean marine ecosystems by taking advantages of local hotspots to continue its spread. It represents an aggressive competitor for resource and space towards the native *Mytilaster minimus*. The most western report of this species is represented by lagoon hyperaline (> 45 PSU) pond (Stagnone di Marsala, Italy), where it colonized hard substrata. *Brachidontes*, through the removal of seston particles from the environment, provides a valuable service in recycling energy and matter in shallow water ecosystems, assuming the role of a foundation species capable of hosting high biodiversity levels. Here, we used the Dynamic Energy Budget (DEB) model to compare the different growth rates inside the pond, in the lagoon and outside, leading us to identify the reason behind its massive presence inside the ponds. According to our simulations *Brachidontes* inside the lagoon achieved a 65% higher total length (TL) compared to the outsiders, reaching the maturation in 95 days, while the previous did not reproduce. Specimens inside the pond instead reached a 131% higher TL compared to the outsiders, maturing in 72 days and laying four times more eggs. We then further tested the effects of temperature and food, showing as a mechanistic approach can be useful to assess habitat suitability, quantifying Life History traits to feed local management strategies and help understanding biological invasions' pathways.

Key words: Invasive species, *Brachidontes pharaonis*, Shallow lagoon habitats, Climate change

P16

Ocean acidification hampers sperm-egg collisions, gamete fusion, and generation of Ca^{2+} oscillations of blood clam, *Tegillarca granosa*

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Oceanic uptake of CO_2 from the atmosphere has significantly reduced surface seawater pH and altered the carbonate chemistry within, leading to global ocean acidification. Although the effect of ocean acidification on fertilization success of marine organisms is increasingly well documented, the underlying mechanisms are not completely understood. The fertilization success of broadcast spawning invertebrates depends on a series of consecutive events including successful sperm-egg collisions, gamete fusion, and standard generation of Ca^{2+} oscillations. Therefore, the realistic effects of future ocean pCO_2 levels on these specific aspects of fertilization of *Tegillarca granosa* were investigated in the present study through sperm velocity trials, fertilization kinetics model analysis, and intracellular Ca^{2+} assays, respectively. Results obtained indicated that ocean acidification significantly reduced the fertilization success of *T. granosa*, which could be accountable by (i) decreased sperm velocity hence reducing the probability for sperm-egg collisions; (ii) lowered probability of gamete fusion for each gamete collision event; and (iii) disrupted intracellular Ca^{2+} oscillations.

Key words: Ocean acidification, Fertilization success, *Tegillarca granosa*, Sperm-egg collisions

P17

Effect of ocean acidification on the polyspermy of blood clam, *Tegillarca granosa*

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The impact mechanism of ocean acidification on the occurrence of polyspermy in marine bivalves is still unclear. The success of monospermy and subsequent development for marine invertebrates depend on a fast block and a permanent block. Therefore, the effect of ocean acidification on the two block mechanism in *Tegillarca granosa* was determined using three specific fluorescent dyes (DiBAC4, PNA-FITC and Phalloidin-FITC). Results obtained showed that ocean acidification significantly increased the polyspermy rate of *T. granosa*, which could be accountable by (i) the process of membrane depolarization was significantly inhibited hence affecting fast blocking machanism; (ii) the process of microfilament migration was significantly impacted thus hampered permanent blocking machanism and (iii) the process of cortical granules exocytosis was significantly desturbed. In conclusion, ocean acidification would weaken the efficiency of polyspermy blocking mechanisms, and subsequently might trigger more individuals deformity.

Key words: Cortical granules, Polyspermy, Depolarization, Cortical reaction

P18

Range far and wide: building a broad-scale long-term dataset of *Sabellaria alveolata* distribution and abundance

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Over the past century numerous important reef-forming species have been subject to dramatic declines, many of which are under-documented due to anecdotal and hard to access information. The honeycomb worm *Sabellaria alveolata* (L.) is a tube-building polychaete that can form large reefs, providing important ecosystem services such as coastal protection and habitat provision. It ranges from Scotland to Morocco, however online marine biodiversity information systems currently display incomplete *S. alveolata* distribution maps, as the majority of sustained observations have been conducted in the British Isles. One of the objectives of the REEHAB project (www.honeycombworms.org) is to combine historical records with contemporary data to document changes in the distribution and abundance of *S. alveolata*. Here we map over 250 previously inaccessible references, gathered from historic field notebooks and literature, contemporary shore surveys, local conservation reports and validated citizen science observations. The result is the most comprehensive dataset to date on the past and present global distribution and abundance of *S. alveolata.* The ecological uses of this broad-scale dataset are manifold in the ongoing REEHAB project. It is currently being used to test and train a species distribution model, in *or*der to elucidate which biotic and abiotic factors shape its presence and abundance across its range. In parallel, the study of historical and grey literature has also brought to light a shifting perception in the value of *S. alveolata*, whose bioconstructions were often viewed as pests or parasites. Following the REEHAB project completion, the dataset will be submitted to an appropriate public data repository.

Key words: Data rescue, Worm reefs, Data re-use, Historical ecology

P19

A preliminary study to quantify quadrat size used for intertidal survey on tropical shores of Thailand

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Optimum quadrat sizes used for intertidal population survey are usually based on conventional values rather than values obtained after analyzing preliminary data. This study aims to estimate optimum quadrat size used for estimating percentage cover of rock oysters (*Saccostrea* spp.), the dominant sessile filter-feeders, and counting limpets (*Cellana* spp.), the dominant grazers, on rocky shores of the Andaman coast of Thailand, by using Weigert's method [considering variance and time used in data collection]. Two sites were visited to collect oyster data while limpet data was from one site. Values obtained from point-intercept, visual, and point-intercept from photos taken in the field were also compared with values from ImageJ. Optimum quadrat size and procedures used for oysters differed between sites. Optimum size of Phuket was 50 × 50 cm. by visual method; and of Krabi was 75 × 75 cm. by point intercept method. Within the same site values obtained from different procedures using the same quadrat size did not differ from imageJ; except, at Phuket site, data from 30 × 30 cm. quadrat by visual method differed from ImageJ. Optimum quadrat size for limpets was 20 × 20 cm. Variation in optimum quadrat size used for the same sessile organisms between locations probably resulted from difference in general cover of the populations and conditions of the habitat. We reported preliminary results based on limited study sites; therefore, we suggested that further study on replicated populations is needed before any general conclusions can be drawn.

Key words: Quadrat size, Rocky shore, Percentage cover

P20

Annual gametogenesis of the oyster *Hyotissa hyotis* (Linnaeus 1758) and adductor muscle as an energy storage organ

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The oyster, *Hyotissa hyotis*, is a subtropical bivalve species inhabiting the Indo-Pacific and Eastern Pacific regions. This oyster species have been believed to be extending their distribution range from tropic or subtropical area to Jeju coast (high-latitude area) due to the seawater temperature increase. In the present study, we first investigated the annual reproductive cycle and biochemical composition of *H. hyotis* collected from southern coast of Jeju Island, Korea, from March 2011 to February 2012. Histology revealed that the oysters were fully ripe in August, and spawning activity was observed from September to November with a spawning peak in October. The body mass of the adductor muscle in *H. hyotis* was regarded as the main component with 47.6-55.6% of tissue dry weight, and it decreased from September to October when the oysters spawned. Stored energy in the form of carbohydrate in the adductor muscle was much higher than remaining tissues. Carbohydrate contents in adductor muscle increased during spring when food availability was high in water column and decreased during spawning periods. Our results suggest that the adductor muscle of *H. hyotis* plays a critical role as a major organ responsible for energy storage.

Key words: *Hyotissa hyotis*, Gametogenesis, Energy storage, Adductor muscle

P21

The emerging threat of toxic dinoflagellates *Coolia* spp. under global warming

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Temperature is one of the major factors influencing the growth and distribution of benthic and epiphytic toxic algae (BETA). *Coolia* are one of the cosmopolitan group of BETA, and are potentially toxic. There are four species of *Coolia* reported in Hong Kong, i.e., *C. malayensis*, *C. canariensis*, *C. tropicalis, and C. palmyrensis*. This study aims to examine the potential toxicities of *Coolia*. Our results showed that the algal extracts could induce toxic effects in both *Artemia* and reef fishes. In-depth comparative study on physiological and molecular responses, toxicity, and toxin production under different temperatures were performed for two selected species, i.e., *C. malayensis* (a tropical species) and *C. canariensis* (a temperate species). *Coolia* monocultures were exposed to seven temperatures i.e., 16, 18, 20, 22, 24, 26 and 28°C before sampled for determinations of growth curves, photosynthesis efficiency, amount of phaeo-pigments, toxicity, toxin levels, plus elucidation with transcriptional responses. *C. malayensis* showed the best growth under 24°C while the growth rate of *C. canariensis* was peaked at 20°C. The changes on photosynthesis and phaeo-pigments varied between the two species. The 48h LC_{50} values of *C. malayensis* in *Artemia* decreased as temperature increased. The okadiac acid analogue was detected in the lipid-soluble extracts of *C. malayensis* using LC-MS/MS analysis, and the relative amounts detected were significantly correlated to the toxicities. With more upcoming results on toxin analysis and transcriptome profiles, we could gain further insight on possible mechanisms that associated with algal growth and toxin production with respect to the temperature effect.

Key words: Toxic dinoflagellates, Temperature effect, Reef fishes, Toxicity

P22

Attachment strength of *Sargassum plagiophyllum* C. Agardh, 1824 varies in relation to thallus morphology and holdfast area

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Sargassum plagiophyllum C. Agardh, 1824 is the largest canopy-forming brown alga found on intertidal rocky shores in Thailand. Their holdfast tissues are usually fused to form a larger aggregate on which many individuals' thalli from many life-history stages attach to. We investigated whether this holdfast aggregation may reduce risk of dislodgement by measuring force used to detach the holdfast aggregates from primary substrate. Sampling was done on two intertidal shores: Bakantieng and Klonghin on Lanta Island, Southern Thailand. A spring scale (10 kg) was secured to a wooden clamp that attached to the thalli and pulled perpendicular to the substratum until the thalli were detached from the substrate. The breaking forces were recorded in the field and thalli were brought back to laboratory. Other parameters measured were, wet weight, thalli area and holdfast area. Breaking velocity, the velocity of water current that is required to detach the seaweeds, was also calculated.

We found that wet weight and thalli area positively correlated to breaking force; whereas breaking velocity decreased when size of seaweeds increased. This suggests that lower velocity is required to detach large seaweeds compared to smaller ones. Large thalli generally exhibit higher drag as they have larger thalli area; therefore, higher drag force is exerted on large thalli, if the same velocity applied. Moreover, higher breaking force was required to detach thalli having larger holdfast area. The result suggested that attachment strength of *S. plagiophyllum* is related to thalli's morphology and area cover of holdfasts.

Key words: *Sargassum*, Breaking force, Breaking velocity, Holdfast

P23

Have 15 years of climatic changes altered the identity of the NE Atlantic intertidal communities?

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The NE Atlantic coastline features a complex thermal mosaic with cold and warm-water regions alternating with latitude. This spatial variability in temperature is mirrored in the distribution of many intertidal species, which do only occur where temperatures are favourable.

Examples of single-species changes in distribution are being documented in recent literature, which also suggests that many of these shifts are climate driven. However, despite the several studies at the species level, it is still unclear to what extent these shifts are affecting community composition and dominance as a whole. In other words, are communities noticeably shifting from their historical regional identity?

In this work we re-surveyed 40 locations along the Atlantic coast of Europe, from NE Ireland to SW Portugal, which had been originally monitored in 2003–2005. The objectives were to (i) document changes in diversity, species identity and abundance, (ii) determine if changes occurred predominantly in locations historically dominated by species with cold- or warm-water affinities, and (iii) assess whether the number of changing species was enough to significantly alter the regional identity of surveyed communities.

Key words: Climate change, Intertidal, Community, North-East Atlantic

P24A

Do hydrodynamic conditions affect survival, size and growth of the stalked-barnacle *Pollicipes pollicipes*?

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The stalked barnacle *Pollicipes pollicipes* is abundant in extremely wave-exposed rocky intertidal habitats along the Northeast Atlantic coast, being rare in sheltered conditions. Environmental hydrodynamics might shape barnacle assemblages by affecting individual filter-feeding behaviour and growth. This study aimed to understand the influence of hydrodynamic conditions on the survival, size and growth of *P. pollicipes* under laboratory conditions.

In December 2017, wild juvenile barnacles fixed on artificial substrata ("barticles"), previously deployed on the intertidal zone of a very exposed rocky shore (Cape of Sines, Portugal) on two dates (July 2016 and July 2017), were collected, counted, marked with calcein and randomly allocated to twelve well-aerated seawater aquaria. Hydrodynamic conditions were manipulated through the use of a flow pump to increase water turbulence within each aquarium. The following experimental design was considered: turbulence (fixed factor, 3 treatments: "low" - no pump; "feed" - pump turned on only during feeding periods; and "high" - pump permanently turned on); food concentration (random factor, 2 levels: 2 and 7 *Artemia* nauplii/ml, both daily supplied). Two aquaria were randomly allocated to each of the six conditions. Each aquarium contained 5 to 6 barticles from each field deployment date with an average of 25 (2016) and 6 (2017) barnacles per barticle. On February 2018, all barticles were removed for analyses of barnacle survival, size and growth.

Hydrodynamic conditions did not affect survival but had consistent effects on size and growth of barnacles from both deployment dates, which grew faster at high turbulence under both food concentrations.

Key words: Hydrodynamics, Barnacles, Calcein-marking, SW Portugal

P24B

Differentiable scratch marks made on wax discs by two coexisting congeneric intertidal limpets: radular teeth morphology and grazing intensity

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Discs of modelling wax have been widely used as a tool to assess foraging activity of intertidal molluscs by recording marks made by the radulae of several species. Although it is generally feasible to recognize limpet scrapes on wax discs apart from the ones left by other gastropods, attribution of distinctive grazing marks to each species is often challenging.

We will describe the identifiable features of marks made on wax discs by *Patella ulyssiponensis* and *Patella depressa*, two abundant co-occurring species in SW Portugal.

Species-specific identification was developed based on radular teeth morphology of each species (according to the literature and to observations of radulae extracted from specimens of both species) and on experimental deployments of wax discs in the field. Scratch marks made by both species allowed detection of six trails made by radular teeth (four unicuspid and two pluricuspid). Marks made by *P. ulyssiponensis* are relatively deep and the trails of pluricuspid teeth are distinctively wider than the ones made by unicuspid teeth. In contrast, *P. depressa* marks are shallower with no noticeable distinction between trails of unicuspid and pluricuspid teeth.

Percentage cover of scratch marks (grazing intensity) was estimated for each species from wax discs placed within different intertidal habitats (rockpools and two open-rock levels), considering caging treatments manipulated with the exclusive or the simultaneous presence of both species and non-caging treatments in which each species was naturally dominant. We will present and discuss the spatial and temporal variation in interspecific comparisons of grazing intensity per limpet.

Key words: *Patella*, Interspecific patterns, Radula

P25

Estimating body temperature and thermal performance at fine spatial and temporal scales

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The rocky intertidal is one of the most dynamic and thermally variable ecosystems, where the joint influences of solar radiation, temperature and topography can lead to differences of up to 20°C over centimeter scales. However, the ecological importance of this variation in the face of climate change remains poorly understood. Here, we present a novel technique for modelling microhabitat heterogeneity and patterns of thermal physiology among interacting organisms. We used drone photogrammetry to re-create virtual topographic maps at a resolution of 400 cm^2, which are then fed as inputs to a heat budget model estimating hourly surface temperature. These body temperature layers are then converted to thermal performance layers for organisms using thermal performance curves, creating physiological "landscapes" that display spatially-explicit patterns of "microrefugia". Our analyses show how nonlinear interactions between these layers lead to distinct predictions about organismal performance and survivorship from those made using any individual layer alone. For instance, thermal performance layers reveal that microrefugia are variable through time and space, showing how mobile species must continue to migrate between microhabitats in order to maintain optimal performance. This approach provides a method for exploring the role of micro-topographic variability in driving organismal vulnerability to environmental change.

Key words: Microhabitat, Intertidal, Thermal Performance, Refugia

P26

Ten years of monitoring recruitment of the stalked barnacle *Pollicipes pollicipes*: linking with environmental variability

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Understanding temporal variation in recruitment and the underlying processes responsible for the observed patterns can be a valuable tool to predict major changes in population dynamics, especially in exploited species.

The edible barnacle *Pollicipes pollicipes* is a sessile marine invertebrate with a planktonic larval phase and occurs in highly exposed rocky shores where it is harvested. It can be considered the most commercially important intertidal resource of the Iberian Peninsula.

We have studied monthly recruitment of *P. pollicipes*, from 2007 to 2016, in the Cape of Sines (SW Portugal), where this species is abundant. The mean number of recruits per adult individual was used as a recruitment index, and intra and inter-annual variability of recruitment were analyzed.

Observations over a 10-year period revealed variability in length, intensity and timing of recruitment.

In general, the main recruitment season was during summer/autumn periods, starting between June and September and ending mostly in December.

Maximum values of mean monthly recruitment varied between 11 recruits/adult in 2008 and 113 recruits/adult in 2012.

In order to investigate potential oceanographic processes responsible for the observed recruitment patterns, we will also present and discuss data analyses on the relationships between recruitment and environmental variables such as water temperature, air temperature, wind stress, wave height and upwelling/relaxation indices.

Key words: Recruitment, *Pollicipes pollicipes*, Cirripedia, SW Portugal

P27

Diversifying materials, thus offering greater habitat complexity to enhance biodiversity on Singapore's seawalls

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While granite seawalls form effective coastal defences, their planar structure offers a very limited habitat for marine organisms. Our quest to enhance biodiversity on Singapore's seawalls incorporates limestone and sandstone, as natural stones that may promote biodiversity in their surface colonization. Initial experiments focus on the surface conditioning bioresponse, in the form of microbial settlement. This biofilm formation is characterized and correlated with surface composition and structure, which are independently quantified. The aim is to establish how substrate properties can influence settlement, leading to surface colonization and its ensuing succession. Samples will be incorporated into concrete tiles and mounted on Singapore's seawalls, to assess their performance and thus contribute towards Singapore's efforts in advancing urban solutions and sustain marine biodiversity.

Key words: Seawalls, Natural stones, Surface properties, Biofilms

P28

Coming in hot: community-level responses to changes in heat wave intensity and herbivore density

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Climate change is a major threat to ecosystem function and biodiversity. Increases in global average temperatures and the magnitude and frequency of thermal extremes have the potential to impact the physiology, behavior and performance of organisms, ultimately driving species range shifts and altering community composition across scales. While chronic exposure to high temperatures can be detrimental to organismal performance, acute exposure can be benign or even benefit organisms through increased activity rates. To better understand how heat-wave intensity influences tidepool community structure and composition, we conducted a field experiment in Vancouver, British Columbia. Using a novel heating system, The SAUTÉ (Seaside Array for Understanding Thermal Effects), we simulated weekly heating events of different intensities (ambient, ±3°C, ±5°C) in artificial tidepools. In addition, we manipulated herbivore density to determine if there is an interaction between herbivore pressure and heat wave intensity. After two months, we measured the relative chlorophyll concentration (proxy for microalgal cover) in each pool as well as the abundance of invertebrates. We found that although there were no differences in species diversity between treatments, there were differences in the abundance of individual species. In the absence of herbivore manipulations, mussel abundance was highest with moderate levels of heating and decreased at the highest levels. In treatments with increased herbivore pressure, the relative concentration of chlorophyll was lower as was the abundance of mussel recruits. Preliminary results suggest that herbivore pressure may alter the influence of heat wave intensity in shaping tidepool communities in the context of climate change.

Key words: Biodiversity, Heat waves, Intertidal ecology, Herbivory

P29

Living above the edge: the benefits of habitat selection and physiological adaptation to survival of an extreme high shore limpet

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Hong Kong lies within the tropics and experiences extremely hot summers which are stressful for rocky shore organisms as rock temperatures often exceed 55°C during low tides. Accordingly, many species live lower on the shore in summer than the cooler winter. The limpet *Lottia dorsuosa*, however, does not follow this strategy and lives well above the high water mark, spending days out of water during summer and only being splashed by seawater on rare occasions such as storms and typhoons. On the high shore, *Lottia* takes refuge in shaded habitats forming closely packed groups and is apparently inactive for long periods of time. Habitat selection, therefore, appears extremely important to their survival during summer, but comes at the cost of reduced feeding opportunities. As a result, apart from its habitat selection strategy, we hypothesize that *Lottia* possesses physiological strategies, such as metabolic depression, that facilitate its persistence in this harsh habitat. Metabolic depression under heat stress occurs in high shore littorinids such as *Echinolittorina malaccana*, which share similar tidal heights to *Lottia*, and helps lower energetic costs at high temperature, and thus enhances thermal tolerance. Since *Lottia* is almost sessile in the summer and has to cope with long-term heat stress with limited energy gain, the strategies adopted by this limpet hold great promise to reveal novel trade-offs between constrained acquisition of energy but the high physiological costs of surviving heat stress in extreme environments.

Key words: Tropical rocky shore, *Lottia dorsuosa*, Habitat selection, Metabolic depression

P30

Between a rock and a hot place - thermal tolerance, acclimation and thermoregulation of the rocky shore predator *Eriphia ferox*

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Climate change is causing temperatures to rise across the globe. As a result, many animals must rely on physiological plasticity to survive high temperatures. One such mechanism is acclimation, a reversible tolerance to a higher temperature environment. This plasticity is often limited in ectotherms. Therefore, behavioural adaptations allow some animals to thermoregulate by moving to cooler refuges when temperatures exceed their tolerance limits. The predatory rocky shore crab *Eriphia ferox* is known to inhabit crevices and rock pools from the low to mid-shore. The refuges within the rock and mussel beds offer protection from the extreme summer heat, and *Eriphia* are mainly seen foraging at night. During the summer, low tide in Hong Kong falls from mid-day to afternoon. Therefore, the rocky shore is subject to extreme temperatures on hot summer days; temperatures of 60 °C have been recorded on bare rock, 40 °C in rock pools, and 33 °C within crevices. Here, I investigated the acclimation potential, thermal tolerance and thermoregulation behaviour of this important predator. I found that short-term exposure to high temperatures experienced within rockpools conferred a greater thermal tolerance to some individuals; however, this higher tolerance is close to existing temperatures. Therefore, rising temperature may limit available refuges, potentially reducing population numbers of this important rocky shore predator.

Key words: Global change, Thermal tolerance, Thermoregulation

P31

Latent effects of ocean acidification stress on the phenotypic plasticity of a commercial oyster, *C. hongkongensis*

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Unprecedented changing global climates are exposing oysters to aquatic environments not previously experienced in recent years. This has led to phenotype-environment mismatches and higher mortality rates and lowering the quality and overall fitness. However, on an organismal level, the ability to acclimate and alter phenotype in response to rapid environmental changes may help to buffer against reductions in fitness. Previous studies have reported how experiencing ocean acidification (OA) stress early in development influences post-metamorphic fitness of some marine invertebrates (Pechenik, 2018). Here, we report on the effects of exposing the Hong Kong oyster, *C. hongkongensis* to reduced pH prior- and post-metamorphosis. Results showed that juveniles of previously-exposed to pH 7.4 during larval development have significantly ($p<0.05$) higher growth rate as compared to those that were not previously-exposed. In addition, larvae under the low pH exposure performed better during metamorphosis with significant ($p<0.05$) higher percentage of settled spats in comparison to other treatments of higher pH, despite no significant ($p<0.05$) difference in the overall growth rate of the larvae amongst all treatments. To investigate further, work is now underway to use epigenetics as an approach to explain the plasticity mechanism underlying the latent effects of the OA stress on *C. hongkongensis*.

Key words: Ocean acidification, Latent effect, *C. hongkongensis*, Epigenetics

P32

Shell selection in a tropical hermit crab (*Clibanarius infraspinatus*) from Thailand

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Size and shell species preferences of a tropical hermit crab (*Clibanarius infraspinatus*) were determined for the three most commonly occupied [*Murex* (*Murex*) *trapa* Röding, 1798, *Terebra areolata* A. Adams & Reeve, 1850 and *Strombus canarium*, Linnaeus 1798] shell species along Klongwan beach, Prachubkirikan province, Thailand. Experiments were conducted under laboratory conditions where the hermit crabs (independent of their sex) were presented with a number of various shell sizes and the chosen shells determined after 48 h. *C. infraspinatus* showed a significant choice for *M. trapa* followed by *T. areolata* and *S. canarium*, respectively. Shell size experiments revealed that hermit crab choice was strongly associated with shell weight and internal volume. The Shell Adequacy Index (SAI) decreased with increasing crab size and showed that the population was occupying relatively adequate shells (SAI = 1.01±0.11). Overall, experiments indicate that shell selection by the hermit crab involves individual preferences taking into account the shell features that best provide protection and survival.

Key words: Hermit crab, *Clibanarius infraspinatus*, Shell selection