MASTS Annual Science Meeting 2023

"Science, Sustainability and Society – valuing and protecting our marine systems"

Abstracts for MASTS Multiple Aquatic Stressors Session

09.00-11.00 on Wednesday 6th December

Physiological response and skeletal dissolution of the cold-water coral *Desmophyllum pertusum* to multiple environmental stressors

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Area being submitted to (delete as appropriate): *2. Multiple aquatic stressors*

Preferred presentation medium (delete as appropriate): (i) oral

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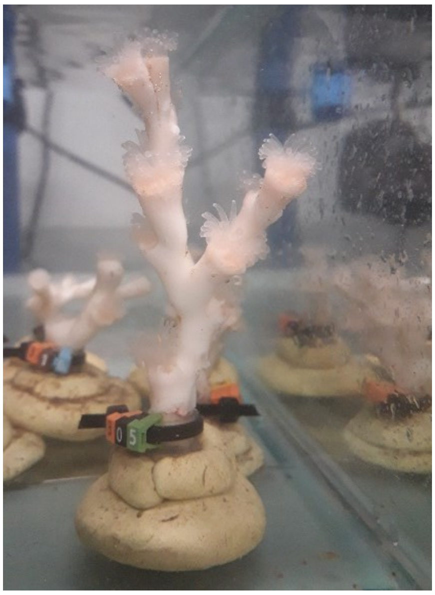
Are you a student? (Delete as appropriate): No

Our long-term experiment provides first insights into the physiological response and skeletal dissolution of the cold-water coral *Desmophyllum pertusum* to future environmental changes of multiple stressors (ocean acidification, warming, deoxygenation and limited food supply).



@KristinaKBeck

The cold-water coral (CWC) *Desmophyllum pertusum* is an important ecosystem engineer, forming complex three-dimensional reefs in the deep sea. These reefs consist of both live corals and dead skeletal parts and are associated with high biodiversity. However, CWCs are threatened by various environmental stressors due to climate change. Previous laboratory studies mainly focused on the effects of individual environmental factors, especially elevated temperature and reduced pH. So far, little is known about the effects of reduced oxygen concentration and food availability on CWCs and the combined effect of all these stressors. Therefore, we are conducting a long-term aquarium experiment with *D. pertusum* under end-of-century conditions. We are investigating the combined effect of increasing pCO_2 (400 and 1000 ppm), elevated temperature (9 and 12 °C), reduced oxygen concentration (80 % and 100 %) and reduced food supply (25 and 50 mg C m^{-2} d^{-1}) on coral mortality, calcification, respiration, and energy reserves over one year. In a parallel experiment, we are also examining dissolution rates of live and dead skeletons at different pCO_2 levels (750, 1000 and 1250 ppm) using buoyant weighing and computed tomography (CT) scans to better predict how ocean acidification will affect the structural integrity of CWC reefs in the future. Here, we will present preliminary data collected after nine months of the experiment. After six months, calcification rates were lowest in the multiple stressor treatment with reduced food availability. The dissolution rate of dead coral skeletons decreased with decreasing seawater pH. We hypothesise that live corals are able to cope with projected environmental changes over short time periods, but not over one year. In the long-term, we predict the combination of all four factors will negatively impact the physiology of *D. pertusum*, mainly driven by warming and reduced food availability.

Investigating cumulative stressor impacts: challenges and approaches in the context of estuarine biofilms

James E V Rimmer[1], Andrew J Blight[1], and David M Paterson[1]

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Area being submitted to (delete as appropriate): *2. Multiple aquatic stressors*

Preferred presentation medium (delete as appropriate): (i) oral

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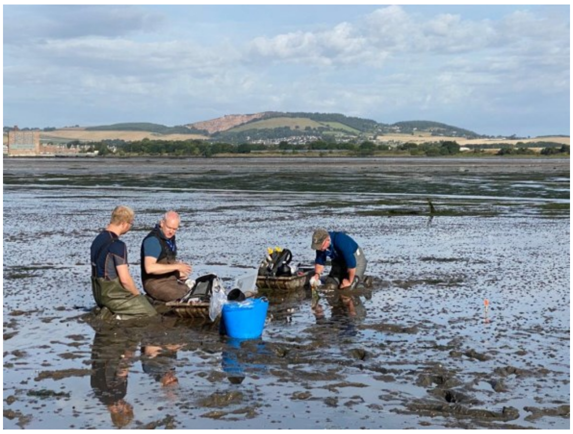
Biological responses to stressor effects are rarely simple; they may cause nonlinear, hormetic, or non-additive effects which can be difficult to quantify/may be missed in analysis. Cumulative stressor effects were considered in the context of estuarine microalgae. #MASTSasm2023



@JEV_Rimmer

The range of stressors to which ecological systems are exposed is vast and growing, due to effects of global drivers such as climate change, local effects associated with industrial and commercial activities, and the increasing range of manufactured, xenobiotic compounds – such as PPCP's – which may be discharged into the environment. Predicting how these potential sources of stress may affect the ecological functioning of aquatic systems is challenging (Crain et al., 2008)

Firstly, because it is impractical to investigate the full suite of potential stressors and cumulative combinations thereof, which may interact non-additively with one-another. Secondly, even individual nonlinear effects, which may not be effectively captured by factorial experimental designs, leading to misleading conclusions regarding stressor-response relationships (Kreyling et al., 2018). Thirdly, contextual factors may influence the individual and cumulative response(s) of biological systems to stress – for example, a chemical stressor which induces a negative response when applied during one season may have no effect, or even a hormetic effect, in another. In the case of intertidal biofilms, the vertical migratory behaviour of epipelic diatoms may attenuate or exacerbate the impact of a stressor at even finer temporal scales. Finally, the relative realism of an experimental system – and the scale of a disturbance event – may affect the biological response. Mesocosms can be used to effectively replicate stressor scenarios, but often lack the properties of natural systems such as migration, habitat heterogeneity, and many trophic interactions. Field studies, particularly where an entire ecosystem is manipulated, may be more realistic, but these are much harder to control, usually more costly to run, and simulating a disturbance even of an appropriate scale may not be possible.

The challenges and some solutions to these problems are considered in the context of estuarine, intertidal biofilms, which have received relatively little attention compared with equivalent freshwater or planktonic assemblages. These biofilms are key primary producers in unvegetated intertidal flats and are involved in the biostablisation of soft sediments (Hope et al., 2020). Conducting appropriate managerial to conserve or restore soft-sediment communities in these environments depends therefore on the best possible understanding of the most relevant factors which may shape responses to the individual and cumulative effects of multiple stressors.

Acknowledgements

We should like to thank Melanie Chocholek and Irvine Davidson for significant practical and technical support of some of the experiments which are discussed.

References

Crain, et al. (2008). Interactive and cumulative effects of multiple human stressors in marine systems. Ecology letters 11(12), 1304-1315.

Kreyling, et al. (2018). To replicate, or not to replicate–that is the question: how to tackle nonlinear responses in ecological experiments. Ecology Letters 21(11), 1629-1638.

Hope, et al. (2020). The role of microphytobenthos in soft-sediment ecological networks and their contribution to the delivery of multiple ecosystem services. Journal of Ecology 108(3), 815-830.

Combined Effects of Polycyclic Aromatic Hydrocarbons and Microplastics on a Model Marine Amphipod, *Parhyale hawaiensis*

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Area being submitted to (delete as appropriate): *Multiple aquatic stressors*

Preferred presentation medium (delete as appropriate): (i) oral

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Are you a student? (Delete as appropriate): Yes

IMarEST Student Membership Name and Number: Ibrahim Lawan, 8102496

Tweetable abstract (Tweeter handle: @ibnlawan2010)

Investigating the hidden risks in our marine ecosystems: How do microplastics change the game for marine life when combined with harmful chemicals like PAHs? Dive into our study (sponsored by @PTDF_Nigeria) on Parhyale hawaiensis to uncover the surprising findings. #MASTSasm2023 #MarineLife #Pollution #Research

Abstract

Polycyclic aromatic hydrocarbons (PAHs) and microplastics (MPs) are pervasive environmental pollutants that are known for their harmful effects on marine ecosystems. Despite their well-documented ecotoxicity and widespread distribution in aquatic environments, the long-term synergistic effects of PAHs and MPs on tropical aquatic organisms remain largely under-studied. Our study aimed to investigate the combined acute and chronic effects of phenanthrene (Phe), a priority PAH, and three environmentally common MPs, polyamide (PA), polyethylene (PE), and polyethylene terephthalate (PET), on *Parhyale hawaiensis*, a tropical marine amphipod. Adult male and female *P. hawaiensis* were exposed to Phe (50µg/L) and each MP individually (fixed at 500µg/L), as well as Phe (50µg/L) combined with each MP. Short-term exposure (96-h) revealed that individual MPs altered the median lethal concentration (LC50) of Phe: Phe alone (131.93 µg/L), Phe+PET (375.16 µg/L), Phe+PE (486.35 µg/L), and Phe+PA (515.22 µg/L). This reduction in Phe toxicity suggests that MPs can modulate Phe acute effects by altering its bioavailability. However, long-term exposure (21 days) posed concerns regarding the ecological fitness of Parhyale. Phe alone and in combination with MPs resulted in reduced survival and growth, decreased feeding rate, impaired chemosensation to feed, and increased pre-mature moulting ($p \leq 0.05$). These findings underscore the long-term ecotoxicological consequences of PAH–MP interactions, highlighting the potential impact of MPs as vehicles for hydrophobic pollutants. This study emphasises the complex and synergistic interplay between PAHs and MPs in tropical marine environments, shedding light on the intricate nature of hydrophobic pollutant interactions and their implications for tropical marine ecosystems.

Acknowledgements

We want to thank Petroleum Technology Development Fund (PTDF) Nigeria for providing the funding to conduct this study. We also thank Robert Rennie for improvising the cylindrical moulds plate for preparing the experimental feeds, John Fox, Sean McMenamy, Dominique Anderson and other Institute of Life and Earth Sciences members for their help and advice.

Developing a Health Indices for Cetaceans as a Tool for Measuring the Impacts of Multiple Stressors

Rachel Lennon[1], Andrew C. Brownlow[2]

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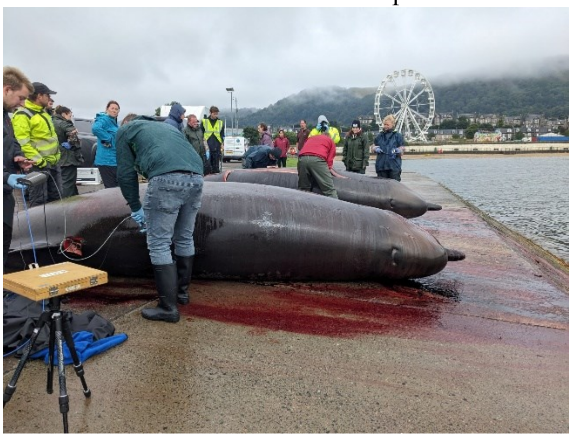
Tweetable Abstract:

@Rach_lenn talk at #MASTSasm2023 outlines her research which aims to develop a pathology driven health indices using @strandings data to provide a multidimensional approach to capturing changes in cetacean physiology and understanding the cumulative effects of multiple stressors



Understanding stressors and their impacts to health is an important component of establishing effective conservation measures against declining marine animal populations. Environmental stressors often act in tandem with synergistic or antagonistic relationships resulting in cumulative effects. Therefore, it is important to monitor these stressors concurrently to ensure accurate reflections of the environment that species contend with. These effects are notoriously difficult to quantify but modelling changes in health is presented as a valuable tool for understanding how species are being impacted by multiple stressors. As top predators, cetaceans are considered sentinels for environmental change whilst also being particularly vulnerable to these stressors. Current assessments of health in cetaceans use morphometrically assessed body condition which is known to naturally fluctuate throughout an individual's life history and vary depending on species. Development of a pathology driven health indices can provide an alternative, multidimensional approach that can accurately capture changes to the physiology of an individual. However, due to a lack of homogenisation of post mortem data, developing a health indices that is robust and universally applicably present a challenge. Using pathology data from cetacean post-mortem reports, this research aims to develop a multidimensional health index. Principal component analysis will identify key variables of significance and generate eigen values to be used as a measure of health. This will provide valuable insight into target regions for data collection during resource limited cetacean post-mortems. Such a health index will then be used as a response against which the impacts of multiple stressors can be measured, improving monitoring efforts for these sentinel species.

Let there be Light: Marine Oil Snow formation and its associated Bacterial Communities

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Area being submitted to (delete as appropriate): *1. General Science Session or 2. Multiple aquatic stressors.*

Preferred presentation medium (delete as appropriate): (i) oral

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Tweetable abstract

Marine Oil Snow (MOS) may transport toxic constituents to the sea floor, however, become oil degradation hotspots. Photosynthetically active radiation (Light) impacts heterotrophic bacterial communities of MOS, influencing MOS formation, size, and oil degradation. #MASTSasm2023

Marine Snow (MS) is an important natural process for transferring Particulate Organic Carbon to the sea floor, during oil spills, oil can integrate with MS forming Marine Oil Snow (MOS)[1], potentially transporting toxic oil constituents to deep-sea benthic environments. MOS can become a hotspot for hydrocarbon-degrading communities, with substantial biodegradation taking place[2]. Light intensity, spectrum and photoperiod all impact phototrophic communities, leading to changes in associated heterotrophic communities[3]. Thus, we

proposed the hypothesis that light intensity significantly impacts the bacterial community composition of MOS, which may also contribute to MOS formation, size and structure. North Sea MOS forming microcosms contaminated with crude oil and chemical dispersants were set up comparing the effect of a simulated day/night cycle and dark conditions. Community abundance and composition were analysed from MOS flocculants collected after 6 days of formation via qPCR and Illumina DNA amplicon sequencing of bacterial 16S rRNA. The formation of MOS was analysed through novel imaging techniques over 14 days, qunatifiying MOS abundance and size per microcosm. High resolution imaging of collected samples will also be performed to observe changes in MOS structure with and without the use of chemical dispersants. Using nMDS and PERMANOVA, community structures under simulated light and dark conditions were significantly different. Notable genera associated with hydrocarbon degradation such as *Marinomonas* and *Thalassospira,* tripled and doubled in relative abundance under simulated light conditions within oiled flocculants, indicating the importance of light intensity during MOS formation and observations.

Acknowledgments

I would like to briefly acknowledge me assistance my supervisory team has provided me, alongside the multiple research assistance and students who provided support in sample collection and processing.

References

[1] Gregson, B. H., McKew, B. A., Holland, R. D., Nedwed, T. J., Prince, R. C. and McGenity, T. J. (2021). Marine oil snow, a microbial perspective. Frontiers in Marine Science, 8, 11.

[2] Quigg, A., Passow, U., Daly, K.L., Burd, A., Hollander, D.J., Schwing, P.T. and Lee, K. (2020). Marine oil snow sedimentation and flocculent accumulation (MOSSFA) events: learning from the past to predict the future. Deep Oil Spills: Facts, Fate, and Effects, pp.196-220.

[3] Ruiz-González, C., Simó, R., Sommaruga, R. and Gasol, J.M. (2013). Away from darkness: a review on the effects of solar radiation on heterotrophic bacterioplankton activity. Frontiers in Microbiology, 4, p.131.

Stressor Identity *versus* Stressor Burden as Drivers of Observed Effects on Life History Traits in *Lymnaea stagnalis* (Gastropoda)

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Area being submitted to (delete as appropriate): *2. Multiple aquatic stressors;*
Preferred presentation medium (delete as appropriate): (i) oral
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Are you a student? (Delete as appropriate): No.

Human activity is driving biodiversity loss at an alarming rate and multiple stressors are recognised as driving many of these declines. However, much is still unknown regarding how environmental stressors interact to negatively impact biota and how to effectively predict such effects. Here we assessed the importance of stressor identity and overall stressor burden of co-exposure to three ubiquitous stressors (pollutant mixture, invasive predator cue, sub-optimal high temperature) at different combinations of EC30 and EC10 levels (EC10 + EC10 + EC10, EC10 + EC10 + EC30 [x 3: 1. pollution: EC30 + predator EC10 + temperature EC10; 2. pollution EC10 + predator EC30 + temperature EC10; 3 pollution EC10 + predator EC10 + temperature EC30], EC30 + EC30 + EC30); along with the relevant controls (control, solvent control, each single stressor at EC10 and at EC30). The pollutant mixture consisted of 13 components at environmentally relevant concentrations (EC10: 0.015 µg/L, EC30: 0.041 µg/L), a temperature-controlled approach was implemented for the global warming exposure (EC10: 20.2 °C, EC30: 22.0 °C) and the predator cue dilutions were prepared by feeding *Lymnaea stagnalis* to the invasive signal crayfish, *Pacifastacus leniusculus*, and exposing the test organisms to the crayfish water (EC10: 10%, EC30: 57.5%). Exposure levels were derived from single stressor dose-response data generated in our laboratory under the same exposure conditions[1]. Exposure occurred starting from embryos < 24 hours old (n = 10 per replicate, 5 replicates) until adults (~ 5 months). Snails were maintained in artificial freshwater with a 16:8 photoperiod. Water changes (50%) were carried out three times per week. Endpoints measured were survival (hatching, post-hatch mortality), growth (total biomass, shell length), reproduction (fecundity, onset of egg laying, embryo viability) and avoidance behaviour (above water line). Upon single stressor exposure at the EC30 exposure level, negative effects on reproduction (embryo viability) were observed in response to pollution, avoidance behaviour was observed in response to predator cue and a stimulatory effect on reproduction (egg production) was observed in response to higher temperature. These findings were in agreement with those previously recorded for the single stressor exposures at the same levels in our laboratory[1]. Testing the stressor burden hypothesis, as expected, fewer effects were observed when comparing the EC10 + EC10 + EC10 with any of the EC30 + EC10 + EC10 combinations. However, negating this hypothesis, fewer effects were observed in response to the EC30 + EC30 + EC30 combination compared to any other multiple stressor combinations, and this treatment also did not differ from the control. Testing the stressor identity hypothesis, we found that when comparing the different EC30 + EC10 + EC10 combinations, very few differences between treatments were observed, therefore, stressor identity appeared to have little importance on the studied endpoints. In conclusion, we firstly report consistent results in our test system across experiments. Secondly, we show that stressor identity has little importance in our test system, which is contrary to the accepted testing paradigm in ecotoxicology, where the main focus is to identify the stressors that are driving observed negative effects. The relatively few effects observed in response to our highest treatment level (EC30 + EC30 + EC30) may potentially be explained by the 'system stress/ environmental stress' hypothesis[2]. Findings from this study provides crucial insight on how combinations of stressors interact to affect aquatic organisms, reflecting how human activities are contributing to biodiversity loss within natural systems.

Acknowledgements: We thank Sarah Dalesman (Aberystwyth University) for providing snails to start a breeding colony the Galloway Fisheries Trust for obtaining signal crayfish. This research was funded internally by the University of the West of Scotland.

Citations: **1.** Moore, E., *et al. Environ Sci Technol*, 2021. 55(13): p. 8806. **2.** Liess, M. *et al.*, *Scientific Reports*, 2019. 9(1): p. 15248.

What makes polar diatoms polar?

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Area being submitted to (delete as appropriate): *2. Multiple aquatic stressors*

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Polar ecosystems are experiencing especially rapid rates of climate change, as well as increased immigration from temperate systems (Atlantification, in the Arctic context). Projections of how polar primary production will change and how they may compete against invaders require a better understanding of the basic biology of polar phytoplankton, including some knowledge of polar-specific adaptations. While a handful of studies now address the physiology of dark survival and dark-light transitions in polar diatoms, programmes that will allow evolution experiments in polar diatoms are lacking. This limits our ability to evaluate how stable short-term phenotypic changes are, or to evaluate the fitness effects of specific trait values. Our goal is that eventually evolutionary studies will complement current field and laboratory approaches by incorporating an understanding of which adaptations are particular to polar diatoms, as well as how climate change and Atlantification might put evolutionary pressure on polar phytoplankton.

Here, we discuss the practicalities of studying changes in light availability in laboratory experiments with polar diatoms suitable for eventually uncovering eco-evolutionary dynamics. We share data from our initial studies where isolates from Arctic, Antarctic and temperate diatoms were grown under different light regimes that changed every two weeks, including periods of total darkness. This study specifically investigates the role of light history on performance, including the impact of darkness on subsequent growth, photochemistry, cell composition, and respiration rates. Since it is intended to be the basis of future research, we will discuss possible interpretations of these data, as well as how they inform the direction of future studies that include broader phenotypes and multiple drivers.

Acknowledgements

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