The ups and downs of stressor interactions: how response directionality can impact reported results

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Area being submitted to (delete as appropriate):; *Multiple Marine Stressors;*

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ABSTRACT

Interpreting and defining stressor interactions is not as straightforward as it may initially seem. Whilst the terms addition, antagonism, synergism, and potentiation are accepted lexicon in literature, there remains disparity in the use of these terms between studies and authors as a result of different interpretations of the terms, contextual subjectivity, and directional aspects of specific stressors (Piggott et al., 2015).

Strictly speaking, antagonism and synergism mean a combination of stressors having respectfully a lesser and greater effect than the sum of each of the component stressors – thus the terms are a mathematical description of how the stressors combine. Unfortunately, such mathematical descriptions do not always intuitively lend themselves to interpreting the biological or ecological implications of these interactions. Resultantly – whether through misunderstanding, or to provide desirable context – the terms are instead commonly (mis)used to signify an *outcome* which is lesser or greater when compared to control groups, with the terms used to imply directionality.

During the talk, these contrasting interpretations of stressor interactions will be briefly exemplified and discussed. The audience will likewise be made aware of how to identify these differing reporting methods in scientific literature, and the consequences of each on appropriately reporting and interpreting claims of stressor interactions.

References

Piggott, J.J., Townsend, C.R., Matthaei, C.D. (2015). Reconceptualizing synergism and antagonism among multiple stressors. Ecol. Evol. 5, 1538–1547.

TWITTER ABSTRACT

Despite accepted terms defining multi-stressor interactions, differences in their interpretations & use can lead to different conclusions when assessing results. **@Stressful_times** will explain why this is, and how to identify pitfalls in the literature. **#MASTSasm2020 @MASTSStress**

Twitter Handle: @Stressful_times

Evaluating cumulative stressor impacts on depositional estuarine habitats

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Estuarine systems are exposed marine, freshwater, terrestrial, and atmospheric sources of stress, yet we have a limited understanding of how these stressors interact with each other and the environment to cause cumulative impacts. Experiments are carried out to better understand these interactions. #MASTSasm2020.

@JEV_Rimmer

Estuaries, situated at the boundary between marine, terrestrial and freshwater environments, are subject to sources of stress arising in any or each of these realms, as well as the atmosphere. Moreover, stressors which may occur are concentrated within a relatively confined environmental space (Wolanski and Elliot, 2015), potentially exacerbating their impacts.

Despite the ecological significance of estuarine systems and their associated ecosystem services (Barbier *et al.*, 2011), a good understanding of how these systems will respond to cumulative stressor impacts is currently lacking. In particular, few experiments have investigated the response of the microphytobenthos – biofilm-forming photosynthetic microorganisms – to multiple stressor exposure in depositional intertidal habitats. As well as being the key primary producers of unvegetated intertidal flats, dominate organisms within biofilm assemblages, notably benthic diatoms, produce extracellular polymeric substances (EPS) which bind sediment grains together, reducing rates of erosion (Tolhurst *et al.*, 2003). It is important to understand how multiple stressors may interact to negatively impact these assemblages, as well as the extent to which associated ecosystem functions such as primary productivity and sediment stabilisation are also affected.

Experiments carried out and upcoming seek to understand and characterise the impacts of multiple stressors have on organisms and ecological processes of depositional estuarine habitats. Mesocosm experiments are used to quantify impacts under controlled, isolated conditions, supplemented by fieldwork to test to what extent predictions made under controlled conditions can be replicated in the field, and to identify physical and biological factors which may affect the stress response.

Acknowledgements

The authors would like to thank Irvine Davidson and Melanie Chocholek for technical assistance with laboratory and fieldwork, as well as valuable conceptual discussions.

References

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Wolanski, E. and Elliot, M. (2015). Estuarine ecohydrology: an introduction. 2nd edn. Amsterdam: Elsevier.

Tools to investigate the effect of multiple stressors on marine top predators

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Most marine environments have experienced growing industrialisation over the past several decades with increases in marine transportation, energy generation, oil and gas exploration and extraction, and fisheries. These activities may expose marine top predators (MTP), such as marine mammals, to a range of stressors that can have acute and chronic effects on foraging and breeding success, resulting in a decrease in individual fitness and potential population level consequences. Noise associated with the construction of offshore renewables developments (ORDs) is known to affect the behaviour of MTPs. They may also be displaced or attracted through the creation of the artificial reefs associated with these developments and decommissioned oil and gas rigs. A range of other marine activities, such as seismic surveys, naval exercises and shipping may also generate noise that affects the behaviour of MTPs. In addition, other ecological drivers, such as increasing numbers of competing, and potentially predatory, species (e.g. grey seals and harbour seals), and changes in prey distribution and abundance due to climate change may affect MTP populations.

Predicting the cumulative effects of exposure to these different stressors is of fundamental ecological and legislative importance, but our understanding of these effects on MTPs is very limited. However, a suite of tools that have been developed to predict the potential effects on MTPs of stressors associated with ORDs are being extended to allow their cumulative impacts to be investigated. These tools are based on the same fundamental ecological principles, but structural differences between them mean that each is best suited to answer a different set of questions.

We will describe the strengths and weaknesses of these tools and explain how they can be integrated to provide a robust framework for investigating the potential cumulative effects of multiple stressors on the energy budgets, individual vital rates and population dynamics of MTP. The interim population consequences of disturbance approach (iPCoD) provides rapid predictions of the potential population effects of disturbance associated with ORD construction for five marine mammal species, but it relies on independent estimates from environmental impact assessments of the number of MTP individuals that are likely to be affected by each development. DEPONS and AgentSeal are agent-based models (ABMs) that have been developed for harbour porpoises and harbour seals, respectively. These ABMs use fundamental ecological principles to predict the movement of individual animals in a realistic landscape with a high degree of spatio-temporal resolution. As a result, they can provide detailed estimates of the cumulative exposure of different individuals to a range of stressors, and the effect of this exposure on their behaviour and energy budgets. This information can then be used as an input to iPCoD to establish long-term, population-level consequences.

Please provide an additional tweetable abstract first (max. 280 characters) to assist online promotion. #MASTSasm2020.

We describe a suite of modelling tools that can be used in a complementary way to investigate the potential effect of cumulative exposure to multiple stressors on the behaviour and population dynamics of marine top predators.

If you are on twitter please provide your twitter handle @someone.
@_SMRU_

The full abstract should be submitted to masts@st-andrews.ac.uk, in an editable format, by 16:00 Friday 14th August 2020.

Food for thought: The importance of prey in assessments of stressors impacts on harbour porpoise

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Abstract

Exposure to human activities and changes in the environment can cause changes in the behaviour and physiology of individual animals. These responses need to be understood in the context of their long-term effects on individual vital rates (such as survival or reproduction) and, ultimately, population dynamics in order to effectively inform management actions. The most common pathway considered is that of energy balance which for any species is governed by the effort they expend to acquire food, the energetic value of that resource and how the energy acquired is utilized. This forms a cost-benefit equation, where the costs are represented by the energy expenditure involved in prey capture and that expended to maintain body processes, such as thermoregulation, growth and reproduction.

Research has shown that noise disturbance can disrupt the behaviour of a top generalist predator, the harbour porpoise. The significance of such disturbance is unclear but, these animals are considered to be vulnerable to starvation when disturbed due to their high energy requirements.

Recent work by Booth (2020) has highlighted the important parameters determining harbour porpoise energy balance are the size and energy content of their prey, their foraging behaviour and their energetic requirements for homeostasis, growth, and reproduction. Energy intake and expenditure can be estimated using published data from animal borne tagged. Such analysis indicates a broad range of plausible levels of energy intake, in line with those from captive studies.

Metabolizable energy intake estimates were most strongly affected by variations in target prey size and to a lesser extent, by the foraging intensity of porpoises. In all but the worst-case scenarios, harbour porpoises are well equipped for their ecological niche due to their generalist diet, consisting of a range of moderate to high energy-density prey combined with ultra-high foraging rates and high capture success. If animals can find suitable prey, porpoises may be capable of recovering from some lost foraging opportunities.

Porpoises have been described to exist on an ‘energetic knife-edge’ due to their life history strategy. The estimates presented in this study indicate how inclusion of prey quality (specifically prey size distribution and energetic density) can meaningfully advance this research area. Critical, here, is the consideration of prey species, target size and energy content when assessing how a species exists in its ecological niche.

Minimizing disturbances is, however, important for their health. And other critical pathways must be also be considered in future research (e.g. stress response).

Further research into prey and the environment are required to better understand this top predators’ ecology and balance in the ecosystem. This study also highlights the requirement for greater cross-disciplinary collaborations (ie across marine mammals, lower trophic levels, oceanographers and energetics/physiology) to address these knowledge gaps.

These findings have applications in the fields of multiple stressors, population level assessments, fisheries and climate change.

Citations

Booth, C. G. (2020). Food for thought: Harbor porpoise foraging behavior and diet inform vulnerability to disturbance. Marine Mammal Science, 36(1), 195-208.

Acknowledgements

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Social Media Abstract: Food for thought: counting calories helps to improve assessments of the effects of stressors on harbor porpoises. This study demonstrates how proper consideration of the prey environment and energetics are critical parts of assessment of cumulative effects #MASTSasm2020

Twitter handles: @cormacbooth @smru_consulting

Probing The Future: Use Of Biomarkers In A Marine Environment Subject To Multiple Climatic Stressors.

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Area being submitted to: *4. Multiple Marine Stressors*

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Climate change is affecting the marine environment in several ways. Our research focuses on the following factors: the temperature of the upper 75 m of the global ocean has increased by 0.11°C per decade since 1971; analysis of ocean chemistry from time series stations and merged shipboard studies show consistent rates of decrease of 0.013-0.03 pH units/decade over records of up to 25 years in the ocean surface (both of these trends are predicted to continue) (1, 2); in addition, the near surface salinity of the ocean is predicted to reflect the increased hydrology cycle of the earth (changes in precipitation and increase in evaporation) with coastal and estuarine environments more likely to experience extreme salinity fluctuations as a result of extreme weather events and increased river runoff (2, 3).

In ecotoxicology, a biomarker can be considered an objectively and quantitively measurable response (be it biochemical, physiological, behavioral, or histological etc.) to exposure. An ideal role of biomarkers is to be used as early warning indicators, measurable at an early stage of exposure to and before clear wider adverse consequences manifest themselves – especially in relation to chronic exposure to low-level stressors where organisms might look and behave normally as these stressors take their toll over time.

The previously mentioned parameters of climate change might cause biomarker responses to drift from their current baselines due to increased stress which means they might become less sensitive and thus no longer good indicators of exposure. Therefore, results will need to be contextualized appropriately in order to be able to distinguish responses caused by non-chemical confounding stressors from responses to pollutants or other anthropogenic activities. It might also mean that some biological endpoints normally studied will no longer be suitable for the biomarker task.

Preliminary results of the present study, exposing mussels (*Mytilus sp.)* to increased water temperatures and salinity fluctuations indicate that genotoxicity could be affected by climatic factors.

The present study aims to probe further how biomarkers may be impacted by climate change and to help provide key insights into how marine organisms will be affected by climate change.

Acknowledgements

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Tweetable abstracts 280 characters.

#ClimateChange manifests in the marine environment in several ways: #IncreasingTemperatures #OceanAcidification & #SalinityFluctuations.What's the effect on early warning indicators in #ecotoxicology? Learn more at the tenth MASTS annual science meeting #MASTSasm2020.@MASTSStress

Mussel activity response to Artificial Light at Night (ALAN)

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Tweetable abstract:

Artificial Light at Night (ALAN) could be a threat to nocturnal organisms, altering their feeding activity. Here, we experimentally investigate the effect of different ALAN wavelengths on the gaping activity of coastal mussels.

Twitter handle: @EleniChri_

Abstract:

It is no secret that the rising human population and the urbanization of coastal areas can pose multiple stressors to the marine environment. In 2014, it was estimated that 54.3% of Europe's and 22% of the world's coastlines were exposed to artificial light at night (ALAN) and those percentages could have only increased in the past 6 years. Therefore, ALAN has been identified as a potential anthropogenic threat to marine life like zooplankton, corals and fish; however, the effect of ALAN on other marine invertebrates has yet to be investigated.

Marine bivalves like mussels, clams and oysters are widely distributed around the world, and not only provide invaluable ecosystem services to the coastal environments but they also have a significant economic importance to the aquaculture industry. These organisms display circadian rhythms with usually increased nocturnal activity, including increased feeding, thus ALAN could potentially disrupt their feeding patterns which would consequently impact the health of the coastal habitats and the aquaculture industry.

In this study, we investigate the effect of different ALAN wavelengths on the gaping activity of mussels. Specifically, mussels are equipped with a custom-made system connected to a data-logger where their open/close activity is tracked when exposed to green, red and white LED ALAN.

Findings from the experiment will help us understand the severity of the threat ALAN poses to marine bivalves and facilitate in the identification of the least harmful ALAN wavelength. Therefore, results from this analysis could feed into policy regarding coastal artificial lighting and inform the bivalve aquaculture sector for more optimised lighting practices.