The use of sunscreens in a changing world: combined impacts of nano-enabled sunscreens and thermal stress on coral reef systems.

Alice Tagliati[1,2], Sebastian J. Hennige[2] and Teresa F. Fernandes[1]

[1] *Heriot-Watt University, Institute of Life and Earth Sciences, Edinburgh, UK – at56@hw.ac.uk*
[2] *University of Edinburgh, School of Geosciences, Edinburgh, UK*

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Are you a student? Yes.

Over 16000 tons of sunscreens are used in tropical countries annually and their ingredients are released into the water either through swimming or via wastewater treatment plants[1]. Suncare products are complex mixtures of UV filters, emollients and emulsifiers and, given the lipophilic characteristics and the resistance against degradation of these compounds, they can potentially have important consequences on environmental contamination. At present, coral reefs are facing multiple stresses as a consequence of human activities, and elevated seawater temperatures are recognized as the major cause of coral reefs decline worldwide[2].

This project aims to assess the impacts of inorganic sunscreens, containing titanium dioxide nanoparticles ($nTiO_2$) as UV filter, on tropical corals in a changing ocean by evaluating the effects of inorganic sunscreen formulations on both cultured endosymbiotic algae (*Symbiodinium* spp.) and coral hosts under present and projected future ocean warming conditions.

Coral tolerance and recovery to environmental stress depends on their endosymbiotic algae[3], therefore first of all the toxicity of three $nTiO_2$, commonly used in cosmetic products was tested on *Symbiodinium* spp. $nTiO_2$ were dispersed in a mixture of emollients and emulsifier, to mimic the oil phase composition of commercially-available sunscreens. Two *Symbiodinium* phylotypes, known for their different tolerance to environmental change and stress, were exposed to oil:$nTiO_2$ dispersions at both ambient temperature (26°C) and thermal stress conditions (32°C) to evaluate growth rate, maximum photosynthetic activity and reactive oxygen species (ROS) production.

Two coral species (*Seriatopora hystrix* and *Porites* sp.) were then exposed to a custom-made sunscreen lotion, formulated with one of the $nTiO_2$ previously tested as UV-filter, to characterize the corals' response at both ambient and warming conditions, as predicted by global climate change scenarios.

Sunscreen ingredients induced stress in both endosymbiotic algae and coral species. *Symbiodinium* spp. exposed to oil:$nTiO_2$ dispersions showed growth reduction, impaired photosynthetic activity and increased ROS production, while sunscreen exposure severely affected net photosynthesis and respiration in both coral species at both tested temperatures. This stress is enhanced with warming, indicating that sunscreen exposure may exacerbate bleaching response in corals ultimately affecting corals' survival in a changing ocean.

Interestingly, all $nTiO_2$ types produced similar effects, and *Symbiodinium* exposed to high oil treatments exhibited the same trends both with and without $nTiO_2$ dispersed in the oil phase. Our findings indicate that toxicity of inorganic sunscreens is likely driven by the oil carrier, a major ingredient in all sunscreen products, underlying the importance of taking into account oil phase ingredients, along with UV filters selection, in developing environmentally friendly sunscreens.

Acknowledgements

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References

[1] Sánchez-Quiles, D. & Tovar-Sánchez, A. (2015) Are sunscreens a new environmental risk associated with coastal tourism? *Environ. Int.* **83,** 158–170 (2015).

[2] Hoegh-Guldberg et al. (2017) Coral Reef Ecosystems under Climate Change and Ocean Acidification. *Front. Mar. Sci.* **4**.

[3] Suggett et al. (2017) Symbiotic Dinoflagellate Functional Diversity Mediates Coral Survival under Ecological Crisis. *Trends Ecol. Evol.* **32,** 735–745 (2017).

Impacts of natural and anthropogenic stressors on fat tissue function in marine mammals: effects of feeding, fasting and contaminant exposure

Kimberley A Bennett[1], Kelly J Robinson[2], Gauthier Eppe[3] , Cathy Debier[4] and Ailsa J Hall[2]

[1] *Department of Science Engineering and Technology, Abertay University, Dundee,…. – k.bennett@abertay.ac.uk*
[2] *NERC Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews*
[3] *Center for Analytical Research and Technology, Department of Chemistry, Université de Liège, Belgium*
[4] *Institut des Sciences de la Vie, Université Catholique de Louvain*

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It is important to understand how anthropogenic stressors interact with natural stressors to impact wild populations. Persistent organic pollutants (POPs) are toxic, ubiquitous, fat-soluble chemicals that resist breakdown. They accumulate in living tissue and biomagnify up food webs, generating high concentrations in top predators, such as marine mammals (Jones & Voogt 1999). POPs were identified as environmental toxins in the 1970s and are endocrine disrupters. They are toxic to the immune system, cause skeletal abnormalities and reduce fertility. Environmental levels fell initially after restrictions on their production, transportation and use. However, emissions continue from poorly regulated and unidentified sources. POPs remain a major risk to marine mammal and ecosystem health.

At subtoxic doses POPs alter energy balance in humans and other speces by inducing fat tissue dysfunction (Grün & Blumberg, 2009). Marine mammals have high POP concentrations in blubber, and rely heavily on fat as a metabolic fuel. Their survival and reproductive success is dependent on healthy fat tissue. They are therefore on the front line of energy balance dysregulation by POPs. Some studies show POP-induced alterations to expression of metabolic genes in marine mammal fat and liver (Castelli *et al*. 2014). However, consequences for tissue metabolism and fat tissue function during natural periods of physiological stress, such as fasting, are unknown. This type of information is difficult to obtain for marine mammals because whole animal experiments are logistically and ethically challenging to perform.

We used explants (small pieces of tissue *ex vivo*) of blubber (Bennett *et al*. 2017) from wild, grey seal (*Halichoerus grypus*) pups to investigate impacts of simultaneous natural (fasting) and anthropogenic (POPs) stressors on blubber metabolism. Glucose use by the explants was inversely related to blubber dioxin-like poly-chlorinated biphenyls (DL-PCB) and increased with organochloride pesticides (OCP) or acute PCB exposure, irrespective of whether the tissue came from feeding or fasting animals. PCB and OCPs transferred to pups during suckling are therefore high enough to alter blubber function early in life, when fat deposition and mobilisation are vital. Such POP-induced alterations may alter energy balance regulation in marine top predators and impact on their fitness and survival.

Future work will explore consequences of POP-induced altered fat function for whole animal energy balance. We will also investigate effects on fat metabolism, blubber health (including oxidative stress) and energy balance of simultaneous exposure to pollutants and other stressors, such as heat, dehydration, disturbance and disease.

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References

Jones, K. C.,De Voogt, P. (1999). Persistent organic pollutants (POPs): state of the science. Env. Poll., 100 (1), 209-221.

Grün, F., & Blumberg, B. (2009). Endocrine disrupters as obesogens. Mol. Cell. Endocrinol. 304 (1), 19-29.

Castelli, M. G., *et al.* (2014). mRNA expression of genes regulating lipid metabolism in ringed seals (*Pusa hispida*) from differently polluted areas. Aquatic toxicology, 146, 239-246.

Bennett, K.A. *et al.* (2017) Using blubber explants to investigate adipose function in grey seals: glycolytic, lipolytic and gene expression responses to glucose and hydrocortisone. Sci Rep. 7. Article number: 7731

Modelling Cetacean Populations to Assess Cumulative Impacts from Offshore Wind Farms

Hazel Smith[1,2], Caroline Carter[2] and Fiona Manson[2]

[1] *Department of Mathematics and Statistics, University of Strathclyde – hazel.smith@strath.ac.uk*
[2] *Scottish Natural Heritage, Battleby, Perth*

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Offshore renewable energy developments can impact marine mammals primarily as a result of the underwater noise generated by the installation of foundations. Mitigation is available to prevent injury, but the wider consequences of disturbance for marine mammals also include behavioural and physiological changes. These changes can affect the health and vital rates of individual animals which, in turn, can translate into population effects.

The iPCoD (Interim Population Consequences of Disturbance) model has been developed as a means of assessing the predicted impact of marine developments on the long term population dynamics of marine mammals (King et al 2015). The iPCoD framework was developed specifically to deal with the current situation, where there is limited data on the way in which changes in behavior and hearing sensitivity affect the ability of individual marine mammals to survive and reproduce. However, the model still requires the user to input a number of parameters, many of which cannot be easily estimated. This includes the proportion of the population vulnerable to disruption, the number of days of disturbance experienced by the population and the proposed piling schedule.

Here we explore the sensitivity of the model to changes in these often difficult-to-estimate parameters. This work provides a basis for future cumulative assessments carried out using the iPCoD framework and will also help to identify which elements of the interaction between noise and marine mammal species have the most important effect on population dynamics. Furthermore, we also investigate how the iPCoD framework could be used to carry out a cumulative assessment of the impact of proposed wind farm developments across the east coast of Scotland on several key priority species of marine mammals.

References

King, S.L., Schlick, R.S., Donovan, C, Booth, C.G., Burgman, M., Thomas, L. and Harwood, J. (2015). An interim framework for assessing the population consequences of disturbance. Methods in Ecology and Evolution, 6, 1150-1158.

Sum use of dying; What can pathological investigations into marine strandings tell us about cumulative impacts?

Andrew Brownlow[1], Mariel ten Doeschate[1] Nick Davison[1], Robert Deaville[2], Mark Dagleish[6], James Barnett[3], Jon Barber[4], Rod Penrose[5], Matthew Perkins[2], and Paul D. Jepson[2]

(1) *Scottish Marine Animal Stranding Scheme, SAC Consulting Veterinary Services, Drummondhill, Inverness, IV2 4JZ, UK*
(2) *Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK*
(3) *University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9FE, UK*
(4) *Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, NR33 0HT, UK*
(5) *Marine Environmental Monitoring, Penwalk, Llechryd, Cardigan, Ceredigion, SA43 2PS, UK*
(6) *Moredun Research Institute, Pentlands Science Park, Edinburgh, EH26 0PZ, Scotland, UK*

Email andrew.brownlow@sruc.ac.uk

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Marine mammals can act as sensors for the health of the ecological communities they depend on and sentinels of population and ecosystem health. Monitoring health in marine mammal populations is critical to identify and quantify the role of disease, trauma and environmental factors affecting these populations. It is also often required to meet statutory obligations and inform strategies for effective population management.

Assessing the impact of a single stressor on an individual is non-trivial, and quantifying how the individual and interactive effects of multiple stressors effect a marine ecosystem is, currently impossible. Nonetheless assessing the cumulative effects of multiple stressors (eg climate change, bycatch, underwater noise and pollution) is a key issue in marine ecology and management. Insights into cumulative effects guide decisions about which stressors, or combinations of stressors, should be mitigated in order to maintain a population or ecosystem in a favorable state.

A number of stressors can be assessed through detailed examination of strandings. Systematic and coordinated surveillance of marine animal strandings around the UK coast has been in operation since 1992. In the 27-year period between 1991 and 2017, 19,186 marine strandings were reported; Systematic gross necropsy and, where applicable, ancillary histopathological, microbiological, diet, life history and contaminant burden analysis were undertaken on 4285 cases during this period. Here we present a summary of these long term data and highlight what we have, and have not, been able to conclude based on these data. In specific, we use the example of a mass stranding event, where multiple stressors were identified as potential factors, and discuss the difficulties of attributing causation in these cases. Finally, by demonstrating what can potentially be established by pathological examination of beach-cast carcasses, we hope to generate discussion into the value and applicability of such long-term datasets, and their potential contribution to the issue of understanding the effect of multiple stressors on the marine environment.

Acknowledgements

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References

National Academies of Sciences, Engineering, and Medicine. 2017. Approaches to Understanding the Cumulative Effects of Stressors on Marine Mammals. Washington, DC: The National Academies Press. https://doi.org/10.17226/23479.

Assessing the sensitivity of deep-sea communities to multiple marine pressures

Ellen Last[1] and Laura Robson[2]

[1] *Joint Nature Conservation Committee* – ellen.last@jncc.gov.uk
[2] *Joint Nature Conservation Committee*

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The abstract should be submitted to masts@st-andrews.ac.uk, in an editable format, by 16:00 Friday 27th July 2018.

Deep-sea habitats are increasingly at threat from anthropogenic activities and the multiple pressures they cause. To assess the sensitivity of habitats to these pressures, the Marine Evidence-based Sensitivity Assessment (MarESA) method (Tyler-Walters et al., 2018) was developed by the Marine Biological Association. Until now, this has only been used for shallower water biotopes, and there is a large evidence gap on deep-sea biodiversity sensitivity. As such, JNCC are applying this method to undertake sensitivity assessments on the deep-sea biotopes listed in the Marine Habitat Classification for Britain and Ireland. Information on the effects of a range of physical, biological and chemical pressures relevant to the deep-sea is being reviewed from existing literature, to assess the resistance and resilience of the key species associated with each biotope, and therefore their sensitivity to those pressures. The resulting assessments will provide sensitivity scores for each biotope, for the range of pressures, alongside a three-part confidence score. These assessments can be used by industry, researchers and conservation bodies to inform Environmental Impact Assessments and conservation advice.

This presentation will describe the sensitivity assessment process and the deep-sea pressures which assessments are being undertaken for. The preliminary results of selected sensitivity assessments to a range of pressures will be presented, alongside the key gaps and challenges faced, for which discussion will be invited.

References

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F., Stamp, T. (2018). Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth, pp.91

Effects of acute anthropogenic noise exposure and elevated temperature on the sea urchin *Echinus esculentus*

Diele, K.[1,2], Mackay-Roberts, N.[1], Briers, R.[2], Wale, M.[2], Chapman, E. [1], Bolger, E. [2] and Hartl, M.[3]

[1] *St Abbs Marine Station, UK*
[2] *School of Applied Sciences, Edinburgh Napier University, UK: k.diele@napier.ac.uk*
[3] *Centre for Marine Biodiversity & Biotechnology, Heriot-Watt University, UK*

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In today's oceans, organisms are confronted with multiple anthropogenic stressors. Since these can combine in an additive, synergistic, potentiational or antagonistic manner (and can result in nonlinear responses), it is important to study multi-stressor effects on biota to understand and predict their responses[6]. Here we investigate the single and combined effects of anthropogenic noise and elevated water temperatures. While a considerable number of studies have focused on the responses of marine invertebrates to increased temperature, few have tested responses to noise, and the combination of these two stressors has never been studied for any marine species.

Levels of anthropogenic underwater noise have increased drastically over the last century, and man-made noise is now recognized as a marine pollutant[1]. Marine invertebrates were initially overlooked in the field of noise research. Given their omnipresence and diverse ecological roles, they are key to understanding both large- and small-scale ecosystemic effects of noise. There is increasing evidence that some invertebrate species are negatively affected by exposure to man-made noise, but the responses of most species are currently unknown. It is necessary to gain relevant information for a broad range of species to inform regulatory bodies and government of the wider effects of noise in the environment, and to advise on the development of mitigation strategies[1]. While many mobile animals are deterred away from noise sources (e.g. seals[2]), there are also examples where sound acts as an attractant (e.g. biofouling[3], larval settlement[4]). Hence, there is potential for applying man-made noise as a deterrent or attractant, depending on the desired species-specific responses[5] and the specific purpose.

We chose the urchin *Echinus esculentus* as our model species for our co-exposure experiment. It is a potential keystone species controlling the structure of subtidal rocky reef communities, with a tendency for episodic mass aggregations, and can be a significant contributor to the natural soundscape[7]. If *E. esculentus* responds to noise, this could potentially be used for mitigating negative ecological impacts of acute urchin aggregations. We exposed replicate urchins to randomized 30min playbacks of anthropogenic noise playbacks or silent controls in large tanks over 48 hours. The experiment was repeated in three temperature contexts (ambient (AT), intermediate (IT), high (HT)) and conducted with urchins (10 per treatment) acclimated for four days to the experimental temperatures (0.5, 0.2 and 0 °C increase per day for HT, IT and AT, respectively). Multidisciplinary response parameters are: spine loss, feeding/egestion rate, levels of oxidative stress indicators (SOD, TBARS, GPx, GSH) and structural DNA damage (Comet assay) extracted from coelomic fluid and/or gill tissues. The following hypotheses are tested: (i) noise alone reduces the urchins' feeding/egestion rates, increases spine loss and oxidative stress/DNA damage; (ii) temperature alone influences feeding/egestion rates (highest at IT, lowest at HT) and oxidative stress/DNA damage (increasing with temperature); and (iii) feeding/egestion rates are lower in HT/noise compared to HT/control, with the reverse being true for oxidative stress/DNA damage, due to additive or positive synergistic effects of both stressors. Data analysis is ongoing.

Acknowledgments

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References

1.Van der Graaf *et al.* (2012) European Marine Strategy Framework Directive-Good Environm. Status (MSFD GES). **2.**Harris *et al.* (2014) ICES J Mar Sci. **3.**Wilkens *et al.* (2012) Biofouling 28. **4.**Hinojosa *et al.* (2016) PLoS ONE. **5.**Stocks *et al.* (2012) Open Mar Biol J. **6.**Griffen *et al.* (2016) Mar Ecol Prog Ser 54. **7.**Coquereau *et al.* (2016) Mar Biol 163.