Grant Report - CZSG20: The effect of underwater noise on marine invertebrates

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My PhD project at Edinburgh Napier University, supervised by Dr Karen Diele and Dr Rob Briers, aims to address the current lack of knowledge concerning how anthropogenic noise affects marine invertebrates, which, despite their pivotal role in marine ecosystems, have received limited consideration in man-made noise research. The MASTS Coastal Zone Forum student grant that I was awarded has assisted me in investigating this is two ways. Firstly, in collaboration with Dr Mark Hartl at Heriot Watt University, we have been conducting a series of laboratory experiments to investigate how playback of ship noise affects the blue mussel, *Mytilus edulis*. This study was conducted using a holistic approach, studying the effects of noise on multiple levels of biological organization. Secondly, in collaboration with Dr Mark Johnson and Rene Swift at the University of St Andrews, we have developed a compact and low cost sensor to allow the particle motion component of underwater sound fields to be accurately measured during laboratory and field studies.

The funding provided by MASTS was used to cover transport from Edinburgh Napier University to both the University of St Andrews for work on the particle motion sensor, and to St Abbs Marine Station for running the noise exposures in the *Mytlius edulis* study. In addition to transport costs, this grant also covered the acquisition of equipment and consumables for the running of these experiments. I was lucky enough to gain industry support from PCB Piezotronics for the development of the particle motion sensor, which allowed the MASTS funding to be spent on a larger suit of experiments than previously planned to determine the effects of noise on *M.edulis*.

The results of both these studies are being written up for publication, and once accepted these papers will be forwarded to the MASTS Directorate. The work will be presented as a talk (*M.edulis* experiments) and poster (sensor production) at the MASTS ASM in October. The abstracts for these are attached below.

The Effects of Anthropogenic Noise Playbacks on the Blue Mussel *Mytilus edulis*

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Marine invertebrates have received scant attention with regard to their responses to anthropogenic noise, despite their pivotal role in marine ecosystems. They are important components of most food webs and perform essential ecosystem services. Preliminary evidence that marine invertebrates can be very sensitive to noise calls for further studies in this context (e.g. reports by the Convention of Biological Diversity and OSPAR).

We conducted a series of carefully controlled laboratory experiments to investigate how short term (up to 6 hours) playback of ship noise affects the blue mussel, Mytilus edulis. To help understand whether it is affected by underwater noise, and also how and why, we employed a mechanistic, integrative approach, as set forth by Kight and Swaddle (2011), considering behavioural (valve movement, algal clearance), physiological (oxygen consumption) and biochemical (structural DNA damage, oxidative stress) responses.

Comet assay analysis of haemocytes and gill cells demonstrated significantly higher single strand breaks in the DNA of cells of mussels exposed to ship-noise playback, compared to those kept under ambient conditions. SOD analysis did not identify an excess of superoxide ions, and GSH, and GPx assays showed no increase in either glutathione or glutathione peroxidase. TBAR assays however revealed increased thiobarbituric acid reactive substances, indicating lipid peroxidation in the gill epithelia of noise exposed specimens.

Algal clearance rates of noise-exposed mussels were significantly lower, and oxygen-consumption rates higher than those of control animals, reflecting stress.

Our integrative approach has evidenced that multiple aspects of the biology of the blue mussel can be negatively affected by noise, from DNA integrity, to cell structure/signaling, physiology and behaviour.

This study is the first to show DNA damage in the gills and haemolymph of any marine species in response to anthropogenic noise and highlights that the Comet assay is an adequate tool in noise research. It is also, to the best of our knowledge, the first to use oxidative stress endpoints as a biomarker of the effects of underwater noise in marine organisms. In addition to the negative effects on the level of the organism, which could lead to reduced growth, reproduction, and immune response, the observed reduction in algal clearance rates suggests a reduced ecological performance of the mussels in terms of water filtration. Further work investigating the effects of chronic noise exposure, as well as field trials are currently planned.

Our results highlight the need to investigate the response of animals from all trophic levels, and demonstrate that sessile organisms must be considered before the ecosystemic effects of noise can be understood.

Our integrative approach to noise research can be used as a model for other invertebrate species, and the results generated can be pooled with those obtained for marine vertebrates to inform governments and industry of the effects anthropogenic noise is having in the marine environment.

Acknowledgements

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References

Kight, C.R. & Swaddle, J.P., (2011) How and why environmental noise impacts animals: an integrative, mechanistic review. Ecology letters, 14(10), pp.1052–61.

New Accessible Devices for Aquatic Particle Motion Measurements in Bioacoustic Studies

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Anthropogenic noise has profoundly changed the acoustic environment of aquatic habitats, with growing evidence that even a short exposure to man-made noise sources can negatively affect organisms. To generate a more complete understanding of the ecosystemic effects of this noise, animals from all trophic levels must be investigated, and the sound field they are exposed to characterized.

To accurately describe the noise experienced by marine organisms, two components need to be measured, the sound pressure and the particle motion. The latter is detected by many fishes and all marine invertebrates. Although devices for measuring the particle motion in water exist they have a number of constraints, e.g. their size, cost, availability, that have prevented their use in most aquatic bioacoustical studies to date. The lack of particle motion data (i.e. accessible devices) has recently been highlighted as a major shortcoming in aquatic sound research (see reviews by Hawkins et al. 2014, Nedelec et al. 2016)

The aim of this work was therefore to create a new compact and low cost particle motion sensor to allow both water borne and sediment borne particle motion measurements during laboratory and field studies. Three commercially available accelerometer models were chosen (PCB Piezotronics YTLB356A12, Meas Spec 832M1, and STMicroelectronics LIS344ALH), representing a range of price points. Each accelerometer was mounted into a custom-made waterproof housing. These sensors were calibrated, and their performance (accuracy, precision, noise floor, frequency response), relative to that of a reference accelerometer, assessed on a shaker table. Finally the sensors were compared in terms of cost-benefit.

The most accurate accelerometer for measuring the particle motion was the YTLB356A12 (£1200, 5.4g, and 100mV/g) which was also the highest cost accelerometer tested. Aside from the price however, this sensor had an ease of use constraint, since it requires coupling to a computer through costly and less readily available systems, such as the Brüel & Kjær Pulse, or National Instruments capture cards.

The LIS344ALH (£3.50, 0.04g, 3.3V/g) was the second best sensor tested, and comes in at the lowest cost. It was also able to accurately measure the particle motion, although not as precisely as the YTLB356A12. This low cost sensor can easily be attached to an M-Audio interface and the signals analysed in Matlab.

The 832M1 (£125, 3.0g, 50mV/g) failed to measure the particle motion of underwater noise. It was unfit for purpose since this accelerometer was originally designed to work with large forces rather than the smaller particle motion movements. It should however be noted that other models of this accelerometer with different sensitivities may perform better.

Following our construction details, both the high- and low-cost sensors can be replicated by anyone working in the field of aquatic noise, allowing the inclusion of this important noise metric in forthcoming research. More accurate presentations of sound fields, and the ability to compare noise exposures across studies can then be made, enabling advancement in this field of research.

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References

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