Accepting limitations and embracing benefits: why we need both laboratory and field-based studies in aquatic sound research

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Twitter handle: @EdBolger

Twitter abstract: The impacts of underwater noise on aquatic animals could be studied in the lab or the field. Is either approach better? We explore the benefits and limitations of both options and champion a combined lab-field approach. #MASTSasm2020

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

Those who wish to research the impacts of sound on aquatic fauna in a laboratory setting, will often use underwater speakers in tanks to expose animals to playbacks of sound recordings taken from the field. When doing so, one accepts that the nature of sound playback per se, and several factors unique to the laboratory setting, do not allow an exact recreation of 'real world' sound fields. Reflections of sound waves from tank walls, reverberations and limitations in sound playback equipment all influence the physical characteristics of the sound waves received by experimental subjects. This situation is particularly pertinent to invertebrates and most fish, as they perceive the particle motion component of sound, and particle motion levels within laboratory settings can be larger and more sporadic than those in the field.

In this context, why bother with laboratory experiments, if only field experiments provide 'realistic' sound exposures?

In this talk, we evaluate the benefits and limitations of both laboratory and field experiments in aquatic sound research, drawing from recent work from the Aquatic Noise Research Group @ Napier to illustrate these points. We conclude by championing a combined a lab-field approach. Laboratory work allows researchers to use techniques that are difficult to apply in the field, thereby gaining valuable insight into questions such as: 'What are the mechanistic pathways for observed sound exposure effects?', whilst field work allows for larger-scale effects (e.g. behavioural/movement change) to be measured in the context of real sound source exposures in an animal's natural environment. By combining laboratory and fieldwork, one can capitalise on the benefits of one approach, whilst offsetting the limitations of the other. Further, resources can be allocated effectively to screen large numbers of candidate species in laboratories (less than 1% of invertebrate species have been studied with respect to sound so far). Insights gained in finely controlled laboratory settings can then provide important information for the optimal design and choice of study species of complimentary field experiments.

Mapping cold-water coral biomass: an approach to derive ecosystem functions

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Area being submitted to: *1. General Science Session; 5. Marine Science Technologies & Methodologies; 9. Marine Biogeochemistry*

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An exciting novel approach by @LDeClippele to map underwater coral biomass using ROV video footage can be used to assess reef carbon turnover @changing_oceans @GeosciencesEd @eu_atlas #MASTSasm2020.

This study presents a novel approach resulting in the first cold-water coral reef biomass maps, used to assess associated ecosystem functions, such as carbon (C) stock and turnover. We focussed on two dominant ecosystem engineers at the Mingulay Reef Complex, the coral *Lophelia pertusa* (rubble, live and dead framework) and the sponge *Spongosorites coralliophaga*. Firstly, from combining biological (high-definition video, collected specimens), environmental (extracted from multibeam bathymetry) and ecosystem function (oxygen consumption rate values) data we calculated biomass, C stock and turnover which can feed into assessments of C budgets. Secondly, using those values, we created a predictive predictively map of whole-reef live coral and sponge biomass. This study revealed that the epi- and microbial fauna associated with coral rubble was the largest contributor towards C turnover in the area with 163 T C year-1. The live and dead framework of *L. pertusa* were estimated to overturn 32 T C year-1 and 44 T C year-1, respectively. Our calculations showed that the Mingulay Reef overturned four times more C than a soft-sediment area at a similar depth. As proof of concept, the supply of C needed from surface water Primary Productivity to the reef was inferred. Since 65-124 T C year-1 is supplied by natural deposition and our study suggested that 241 T C year-1 was turned over by the reef, 117-176 T C year-1 of the reef would therefore be supplied by tidal downwelling and/or deep-water advection.

References

De Clippele LH, Rovelli L, Ramiro-Sánchez B, Kazanidis G, Vad J, Turner S, Glud RN,, Roberts JM (2020) Mapping cold-water coral biomass: an approach to derive ecosystem functions, Coral reefs, under review

Effects of extra feeding combined with ocean acidification and increased temperature on the isotopic signature (δ13C) of the mussel shell.

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Mussels grow shells using carbon from either the environment or food source. We assessed how extra feeding under acidification can impact mussel shell growth. Metabolic carbon uptake into the shell increased under acidification and extra food altered shell growth to compensate.

@Fitzersusan.

Ocean acidification and global warming present future challenges for shell producing organisms such as mussels. These valuable aquaculture species control their shell growth through biomineralisation, but under acidification shell growth is limited due to reductions in environmental carbonate[1]. It is unclear how carbon is taken into the shell from the environment compared to the food source. Shell production is energetically costly to mussels and metabolic processes and energetic partitioning may affect the ability to perform underlying mechanisms of biomineralisation under ocean acidification. It is possible that additional food consumption might alleviate any impacts caused by acidification[2]. We assessed the ability of extra feeding to alter the impacts of acidification and increased temperatures on adult *Mytilus sp*. Carbon isotopes ($\delta^{13}C$) were used to examine the change in biomineralisation pathway in mussels[3]. Ocean acidification did not alter the $\delta^{13}C$ directly in separate analyses of the shell calcite and aragonite layers, mussel tissue and extrapallial fluid. Ambient treatments with increased temperatures altered the mussel biomineralisation pathway in the shell calcite using carbonate instead of hydrogen carbonate as the main source of carbon for shell growth. The proportion of metabolic carbon uptake into the mussel shell calcite layer increased under ocean acidification, with additive effects when exposed to increased temperatures and extra feeding. The proportion of metabolic carbon uptake is 7-11% higher in the shell aragonite layer compared to calcite layer under ambient treatments. Ocean acidification initially reduced the metabolic carbon uptake into the shell aragonite layer, but under prolonged experimental acclimation at 4-months with extra feeding, the mussels were able to adjust their metabolic carbon uptake to similar levels experienced under ambient treatments. This indicates that an abundance of food resources may enable changes in mussel biomineralisation to compensate for any decrease in environmental carbonate associated with ocean acidification. The impact of acidification on phytoplankton varies from species to species, changing the structure of the community which could provide sufficient food resources to maintain metabolic carbon uptake for mussel shell growth. This study of shell carbon isotopic signatures has identified changes in biomineralisation pathways relating to the mussel metabolic carbon uptake from their food source. Results varied for the shell aragonite and calcite layers. The implications of these findings suggest that bivalve species with different shell composites may cope better with biomineralisation under ocean acidification than others[3], demanding further study into species-specific pathways.

Acknowledgements

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Startle response and habituation of the blue mussel, *Mytilus edulis,* to shipping continuous noise playbacks

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Tweetable abstract
With increasing ship traffic in our oceans, understanding how #shipnoise affects reef building species, such as #bluemussels, is integral to understanding its ecosystemic effects. Mussels react to sound, but can they habituate to continuous noise? Find out at the MASTS ASM.

Twitter handles - @CaitlinOrr14, @BucketofCrabs

Abstract
Shipping is a major source of low-frequency sound in the world's oceans (Hildebrand, 2009), yet there is little understanding of whether and how this anthropogenic noise source affects key reef building filter-feeders and commercially important marine species. In a previous study by Wale et al. (2019) the effects of continuous one hour ship-noise playback on blue mussels *Mytilus edulis* was studied A decreased respiration rate, and increased valve gape was observed, and interpreted as akin to a shock response. Whether *M. edulis* (or any other mollusc) can habituate to noise when exposed to this stressor for longer time periods is unknown. Here, this critical gap of knowledge is addressed. In a laboratory experiment mussels were exposed to continuous ship noise playbacks for a duration of 5 hours (n=10) and their oxygen consumption compared to a control group (n=10). The mussels elicited a four-phased response when exposed to shipping noise, comprised of a (i) suddenly suppressed oxygen consumption during the first hour of exposure (i.e. startle response), (ii) a two-hour lag phase where oxygen consumption occurred at a similar rate in both the noise exposed and control mussels, but no compensation for the startle response was seen, (iii) a period of hyperventilation to counteract the initial startle response and (iv) a return to the standard rate of oxygen consumption in the fifth hour (i.e. habituation). This study is the first to evidence, for a sessile invertebrate, habituation to noise during continuous noise exposure, which may explain their continued presence, and thriving, in, e.g., busy ports. In more natural habitats however, immediate shipping noise is often sporadic, highlighting the need for further work to identify whether *M. edulis* can elicit multiple startle responses, the metabolic and fitness costs thereof, and potential ecosystemic effects.

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Global biogenic reef restoration and project design: Lessons for emerging oyster restoration in Europe?

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Area being submitted to (delete as appropriate): *1. General Science Session; Coastal ecosystem-based solutions: Climate-change adaptation and mitigation.*

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Tweetable abstract:
Key components of project design may not play a vital role in the survival of restored biogenic species but greater transparency, consistency and extended monitoring may be needed to ensure progress of future oyster restoration in the EU.
#MASTSasm2020 @HeriotWattUni #DEEP

Biogenic reefs such as those formed by coral and oysters provide essential ecosystem services but are now some of the most degraded marine ecosystems globally. Active coral restoration and, increasingly, American oyster restoration has been developed since the late 1900s and studies have reported both 'successes' and 'failures'. However, as oyster restoration in Europe begins to gather momentum in the last five years, there is an opportunity to learn from the successes of previous studies.
This study aimed to review and analyse active coral and non-European oyster reef restoration projects to determine progress in terms of their survival, identifying if key components of project design such as temporal scale, spatial scale, restoration method or monitoring length influence survival and if there are any common principles or expectations that may be applied to European oyster restoration. Survival was found to differ significantly between coral and oyster reefs with an average of 60% survival of restored reefs however, design components were found to have no effect on the survival of coral or oysters, both independently and combined. This may imply that other aspects of project design may be more essential to measure progress such as funding or stakeholder engagement. Only 10% of oyster projects were monitored for >5 years and the average survival was found to decrease over time, suggesting that while a reef may have greater survival after one of two years of monitoring, it is unlikely this will persist at a similar level. Although oyster restoration to date has taken onboard some of the issues surrounding restoration, there is still need for further transparency, consistency in measuring and extended monitoring to allow for greater understanding of natural fluctuations and for comparisons between projects. Future oyster restoration in the EU will need to address these issues and ensure that the overarching aim to restore a functioning ecosystem is not lost in the race to meet targets.

European oyster (*Ostrea edulis*) reef restoration and recovery: oyster shell density predicts biodiversity

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Area being submitted to (delete as appropriate): *1. General Science Session*

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Tweetable abstract:

Can the biodiversity of oyster restoration be predicted? Here we uncover the relationship between native oyster reefs, their shell and their associated megafauna. #MASTSasm2020 #DEEP @mastscot @HeriotWattUni @TheGlenmorangie @mcsuk @StranraerOyster

The reintroduction and restoration of oyster reefs is now increasing rapidly across Europe for nature conservation and fisheries management purposes. It is therefore important to establish the relationship between oyster reefs and their associated biodiversity if the consequences of these activities are to be understood and justified. If better understood this could also prove a useful monitoring tool for the restoration manager. This study set out to determine the relationship between disturbance, oyster shell and the megafaunal biodiversity of an oyster reef community. It also examined the effect of time since disturbance on oyster reef recovery.

Field survey was undertaken in Loch Ryan, Scotland, where the Loch Ryan Oyster Fishery Company, harvests oysters in a 6-year plot rotation system. Three treatments plots were surveyed for megafaunal biodiversity, oyster shell density and oyster shell percentage cover and other variables. Plots were harvested: the year before, two years before, and six years before. The plots were surveyed with SCUBA using a combination of video transects and photo quadrats.

The plot that had not been harvested for 6 years had the significantly highest megafaunal biodiversity, oyster shell density and oyster shell percentage cover indicating that time since disturbance influences the recovery of an oyster reef and its associated megafaunal community. Oyster shell density had a positive influence on megafaunal biodiversity. Linear regression showed that oyster shell density could be used to predict megafaunal biodiversity and this has the potential to be a vital tool for restoration management and to inform future restoration management.

Acknowledgements

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Re-finding the missing jigsaw piece: Selecting sites for the restoration of the native European oyster (*Ostrea edulis*)

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Area being submitted to (delete as appropriate): *1. General Science Session*

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Tweetable abstract:
Re-finding the missing jigsaw piece: Where and when is 'best' for the restoration of European oysters? #MASTSasm2020 @marinestation @HeriotWattUni #DEEP @TheGlenmorangie
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As we approach the UN decade of Environmental Restoration, site selection for marine environmental restoration is an emerging but challenging consideration. In the present study a spatial and seasonal review was undertaken of existing and novel ecological data in a Marine Protected Area. Data were processed to minimise conflict between other nature conservation priority features as well as stakeholder interests. The study was divided into two main parts: the benthic environment and the influence of disturbance on protected marine mammal and avian species.

Hydroacoustic survey, scientific diving, drop-down video and intertidal survey data were all used to eliminate physically unsuitable areas, other biodiversity hotspots and important commercial resources, leaving a polygon representing the area believed to be the most suitable for oyster restoration, whilst having the least impact on conservation and economic interests.

Subsequently a review was conducted on the protected marine mammal and wading bird species within the site in order to determine the potential impacts of the construction and operational phases of the project. Best available information was obtained on the distances at which species might be disrupted, the times of day that they would be most vulnerable and the seasonality of their distribution and behavior. Recommendations were then developed to limit the disruption of environmental restoration activities, including seasonal limitations, spatial-distancing and synchronizing to particular states of the tidal cycle.

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