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Editorial: Experiments in benthic ecology: using experimental manipulations to study the effects of pressures on benthic organisms

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Editorial on the Research Topic
Experiments in benthic ecology: using experimental manipulations to study the effects of pressures on benthic organisms

As the field of benthic ecology progresses over the years there is an increasing need for detailed data on the response of benthic organisms to environmental change, natural or anthropogenic. Traditionally, predictions of ecosystem responses have relied on short- or long-term monitoring data, aiming to establish dose-response relationships applicable at ecosystem-wide scales (e.g., Rice et al., 2012, for eutrophication). However, field studies do not always provide adequate insight into the mechanisms and processes involved in the response of marine organisms to specific pressures, due to sampling difficulties and lack of comparison to reference conditions (Dimitriou et al., 2017b).

In this context, a targeted experimental design where a single (or a combination) of pressure(s) is applied to the benthic ecosystem and organisms may provide more data. With the appropriate experimental design, it is possible to study interactions between organisms and their physical environment and derive dose-response relations of species or whole communities to specific pressures (Petersen et al., 2009). Field sampling typically captures static snapshots in time over a large number of areas or time series of observations in a few selected locations. Sampling campaigns combining both approaches i.e. time series over numerous sampling stations are very rare but also provide valuable insights like the dataset of the Pearson and Rosenberg (1978) model.

On the other hand, benthic ecology experiments have to be carefully designed following a structured approach to hypothesis testing, formulating a precise hypothesis to be tested. The latter ensures the selection of the appropriate statistical methods for data analysis (Underwood, 1996). The design of experiments has to be capable of describing real ecosystem processes were natural variation is large. However, there is always a compromise between ecological realism and feasibility of setting relevant experimental conditions. Ecological realism requires large experimental volumes (high spatial size), long experimental durations (high temporal size) and the inclusion of diverse communities to capture the complexity of ecological interactions (Petersen et al., 2009). Furthermore, replication and controls are needed, and independence of observations has to be secured.

This causes most experimental designs to become complicated and costly. Finally it is very important to keep in mind that when performing ecological experiments, stochastic processes inherent in ecological systems may lead to sudden shifts in experimental outcomes, particularly in treatments on the high end of a disturbance gradient (Dimitriou et al., 2017a), as ecosystem response to environmental change is not a linear process. The cliff metaphor example (Tett et al., 2013) explains that when environmental pressure exceeds the resilience of an ecosystem the system deformation no longer changes linearly with pressure and the ending state is unpredictable. Another crucial determinant of experimental outcomes is the choice of location—whether conducted *in situ* or *ex situ*. Each approach has unique strengths and limitations. In this Research Topic we aimed to emphasize how different experimental setups are used for benthic ecological studies and what are the benefits and drawbacks of each methodology.

Laboratory experiments provide accurate results for specific ecosystem parts under highly controlled experimental treatments for the desired experimental duration. To this end, Meresse et al. designed a laboratory experimental setup suitable for creating photosynthesis versus irradiance curves for different phytobenthic communities. Their experimental design minimized variability and allowed for the collection of accurate measurements over extended periods, often impractical in field experiments. Vlaminck et al. performed a benthic microcosm experiment studying the ecosystem functioning potential of two different species under climate change scenarios as treatments. The experimental setup included four treatments with four replicates each and corers with and without animals, a total of 32 corers. The results indicated that the two species had opposite reactions to climate change in terms of survival and ecosystem functioning potential. The results also highlighted that laboratory experiments are also useful in climate change studies, which are very hard to perform in the open sea.

On the contrary, field experiments are more complex and include more ecosystem components but are time – limited and are constrained by the interpretative challenges posed by uncontrolled variables. Lavoie et al. used an *in situ* benthic mesocosm approach to study the impact of biodepostion from mussel farms on various benthic indicators and sediment variables. The use of mesocosms that are open to the natural environment allows for recruitment and migration of animals from the study area into the mesocosms, while making it possible to create a mussel biodeposition intensity gradient as experimental treatment. The design included 40 mesocosms with 5 replicates for each treatment and control. The experimental duration was 12 weeks and subsamples were collected from the organism and sediments. The authors were able to describe specific patterns and dose – response relationships for certain variables. However, this setup yielded results with high variability for other variables, a common finding in benthic experiments (Dimitriou et al., 2017a).

Brooks et al. proposed a complex field experimental design by creating mussel assemblages attached to *in situ* marine pontoons. They argued that it is necessary to design manipulative field experiments in order to test the combined effects of multiple stressors and their interactions, across a range of intensities/ concentrations and across different levels of organization within the ecosystem. They studied the combined effect of two pressors, copper and chlorpyrifos at increasing concentrations on parameters of mussel survival and physiology, resulting in a experimental design with 25 different replicated treatments and control incubated for 6 weeks. This complex design enabled the detailed description of additive synergistic or antagonistic interactions of the pressor to the mussel parameters and recommendation of monitoring guidelines.

One common way to deal with stochastic issues is the improvement of the accuracy of the experimental setups whether in the laboratory or in the field. Automated sensors are now widely employed as they can take continuous high resolution measurements in spatial and temporal scales. Meresse et al. used microsensors to take replicated measurements and maximize measurement accuracy in their fully controlled experimental conditions. Also automated sensors are commonly used to climate change experiments for the maintenance of the experimental conditions like the acidification experiments performed by Vlaminck et al.Despite the benefits of using automated sensors, they significantly increase the cost of an experimental setup and operating them requires trained personnel.

As experimental setups evolve, methodological scientific publications are becoming increasingly important providing a visual description of the experimental setup with photos or schematics, detailed experimental capabilities and possible applications and finally results of an experiment serving as proof of concept.

Author contributions

PD: Writing – original draft, Writing – review & editing. NP: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Dimitriou, P. D., Papageorgiou, N., Geropoulos, A., Kalogeropoulou, V., Moraitis, M., Santi, I., et al. (2017a). Benthic pelagic coupling in a mesocosm experiment: Delayed sediment responses and regime shifts. *Sci. Total Environ.* 605–606, 637–645. doi: 10.1016/j.scitotenv.2017.06.239

Dimitriou, P. D., Papageorgiou, N., Geropoulos, A., Kalogeropoulou, V., Moraitis, M., Santi, I., et al. (2017b). A novel mesocosm setup for benthic-pelagic coupling experiments. *Limnology Oceanography: Methods* 15, 349–362. doi: 10.1002/lom3.10163

Pearson, T. H., and Rosenberg, R. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography Mar. Biology: Annu. Rev.* 16, 229–311.

Petersen, J. K., Kennedy, V. S., W.C., D., and Kemp, W. M. (2009). *Enclosed Experimental Ecosystems and Scale. Tools for Understanding and Managing Coastal Ecosystems.* (New York: Springer).

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J. G., Krause, J., et al. (2012). Indicators for sea-floor integrity under the european marine strategy framework directive. *Ecol. Indic.* 12, 174–184. doi: 10.1016/j.ecolind.2011.03.021

Tett, P., Gowen, R. J., Painting, S. J., Elliott, M., Forster, R., Mills, D. K., et al. (2013). Framework for understanding marine ecosystem health. *Mar. Ecol. Prog. Ser.* 494, 1–27. doi: 10.3354/meps10539

Underwood, A. J. (1996). *Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance* (Cambridge: Cambridge University Press).