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Ecological experiments: between a rock and a hard place

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Editorial

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When I ask my first-year marine science students what they think science is, apart from some blank looks, I get a range of answers. One of the most common themes that emerges is that science is not a thing, but a way of doing things and that way of doing centres on experiments. Brought up in a western culture, for them science has become synonymous with a 'Popparian philosophy' (Popper, 1962), focused on the experimental falsification of hypotheses. This is difficult to do in the marine environment. In the dynamic offshore environment, the concept of replication becomes challenging, conditions are never matched exactly in space or time; while constraining organisms such as plankton or fish that live in intimate contact with the medium and travel large distances likely brings with it the potential for experimental artefacts. It is, perhaps, therefore surprising that marine rocky shores have been a major site for ecological experiments that have been fundamental to our understanding of the ecological workings of the world and underpin a significant amount of ecological theory. Hawkins *et al.* (2020) describes the evolution of our knowledge of rocky shore ecology and in particular how experimental studies on rocky shores have been used to develop theoretical frameworks and to test ecological hypotheses.

Their ready accessibility and the diversity of life forms attracted early natural historians, including Darwin (1854), to work on rocky shores, while the strong natural gradients (emersion time, wave exposure) provided clear patterns, such as zonation, that could be described in a manner that provided a link between organisms and environmental drivers for early ecological studies (Stephenson & Stephenson, 1949). These clear gradients also provided opportunities for the application of so called 'natural experiments' where observations along gradients substituted for manipulation in the experiment (see Kitching, 1987 for some classic examples). However, perhaps the greatest contributions have come from the application of well-designed manipulative experimental approaches. Studies on rocky shores have, amongst others, contributed to ecology such fundamental concepts as keystone species, physiological harshness–species diversity relationships, intermediate disturbance theory, succession, supply side control as well as shedding light on top down vs bottom up control of system dynamics (see Hawkins *et al*., 2020). The scale of these contributions prompted Berlow (1997) to compare the contribution of the marine intertidal to ecology, to the importance of the 'fruit-fly' to genetics.

While historically important, experimental studies of rocky shores continue to contribute to ecological understanding. Recent advances in technologies ranging from satellite-based remote sensing to molecular biological techniques are finding applications in rocky shore experimental studies while new techniques, including better experimental designs, advanced materials and statistical approaches are increasing the range and nature of the questions that can be addressed. However, as Hawkins *et al.* (2020) and others have noted, while these technical advances are exciting and enabling, making ecological advances remains rooted in, and bounded by, our knowledge of the identity and natural history of the organisms. So, contemporary experimental rocky shore ecology continues to be dependent on the natural history of these attractive and accessible environments, while employing a diverse and technologically advanced range of approaches to deliver new fundamental understandings. These contribute both to the wider field of ecology but also provide key lessons for society, environmental regulators, planners and politicians to assist in delivering sustainable marine systems.

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