Noise in the North Sea: How man-made underwater sound playbacks impact Norway lobster development

Bolger Edward[1], Diele Karen[1,2] and Briers Robert[1]

[1] School of Applied Sciences, Edinburgh Napier University, Room 0.B.02, School of Applied Sciences, Sighthill Campus, Edinburgh Napier University, Edinburgh EH11 4BN, United Kingdom
E-mail: edward.bolger@napier.ac.uk
[2] St Abbs Marine Station, St Abbs, UK, St Abbs Marine Station, The Harbour, St Abbs, Berwickshire TD14 5PW, United Kingdom

Low-frequency sound levels (10 – 500Hz) in the oceans have increased by at least 100-fold globally over the last century, predominantly caused by increased commercial shipping. This has led to concern over potential impacts on marine fauna and international legislation e.g. Marine Strategy Framework Directive; requiring EU member states to ensure that anthropogenic (man-made) noise levels in the oceans do not adversely affect the environment.

Tolerance to stressors such as underwater noise in early life history may be particularly important to an individual's fitness; planktonic larval phases such as the zoeal stages I, II and III (ZI, ZII and ZIII) of the commercially important Norwegian Lobster *Nephrops norvegicus* (L.) have been suggested to be a bottleneck for reproductive success and recruitment to the adult population.

We conducted a controlled laboratory experiment to investigate whether and how ship noise, played back throughout the early life stages of *N. norvegicus* affects larval development. Three sound treatment groups, emulating different levels of shipping activity were compared:
- 'Busy' treatment consisting of frequent ship noise with regular timings.
- 'Occasional' treatment consisting of less frequent ship noise at randomized intervals.
- 'Ambient' treatment consisting of constant ambient noise (Control).

At ZI, neither treatment affected development time to the next stage in comparison to the control. However, the duration of ZII was significantly longer in the 'Busy' treatment than the other two treatments. The duration of ZIII was significantly longer in the 'Occasional' group than the other two treatments. Both 'Busy' and 'Occasional' groups also showed significant (33% and 46% respectively) reductions in escape response stamina compared to the control.

Our results are the first to our knowledge to demonstrate that anthropogenic noise has the potential to prolong the larval phase *and* reduce anti-predator escape response stamina of decapod crustaceans. In the wild this would likely increase the risk of predation, leading to reduced recruitment to the adult population. The fact that ship noise playbacks only affected the duration of the later larval stages of *N. norvegicus* suggests that longer-term cumulative exposure is required before developmental delays occur. Alternatively, the later larval stages could be particularly sensitive to ship noise playbacks. The significantly longer duration of larval ZIII in the 'Occasional' treatment compared to the 'Busy' treatment suggests that the regular timing of the ship noise exposure allowed the larvae to develop tolerance to these conditions, whereas the random timings of the noise exposure in the 'Occasional' group did not allow tolerance buildup to the same degree. This has implications for methods used in future noise experiments and may highlight a potential for studies to underestimate the likely effects of noise if they utilize a regular exposure regime.

Our findings underline the need to investigate the responses of invertebrate larvae, including crustaceans, to noise. It is not clear (and rather unlikely) that results can be reliably extrapolated between species, so a wider range of ecologically/commercially important invertebrate species deserve further study.

Acknowledgements
Work was conducted at St Abbs Marine Station, Scotland. Thanks to Sam Freeman for practical assistance.

Keywords: marine; stressor; noise; sound; anthropogenic; development; nephrops; crustacean; larvae; invertebrate