The effect of diatom-derived aldehydes on aquatic organisms

Hannah J. Dunstan, Gary S. Caldwell & Matthew G. Bentley
Marine Science & Technology, Newcastle University, Newcastle upon Tyne, NE1 7RU, U.K. Email: h.j.dunstan@ncl.ac.uk

INTRODUCTION: Due to changes in agricultural practice many river catchments in the UK and around the world are experiencing a growing problem with eutrophication. This often results in an increased incidence of algal blooms, including blooms of toxin producing species. Cyanobacteria are the most commonly implicated group but other autotrophs (including diatoms and chrysophytes) also produce toxins. When a diatom is exposed to physical stress such as during grazing, a lipoxygenase/hydroperoxide lyase enzyme cascade is initiated that rapidly oxidises polyunsaturated fatty acids to highly reactive α,β,γ,δ-unsaturated aldehydes (PUAs). Recent studies have demonstrated that PUAs inhibit DNA replication, fertilisation, and embryonic development in aquatic invertebrates resulting in reduced egg viability and larval recruitment leading to suggestions that diatoms may be exhibiting bottom-up regulation of aquatic food webs. The River Bush in Northern Ireland has experienced a decline in its salmon population concomitant with an increase in diatom biomass. We explore two hypotheses; 1) PUAs suppress recruitment by limiting the population growth of key salmon prey and 2) PUAs suppress recruitment by being directly toxic to early salmon life stages.

In this study, the effects of 2,4E-decadienal (a model diatom-derived PUA) were assayed for physiological stress and growth retardation in the water flea (Daphnia magna) and for growth and morphological integrity in larval Atlantic salmon (Salmo salar).

Daphnia magna – physiological stress and growth rate after exposure to decadienal

Individual D. magna were positioned on a bead of silicon grease in a solution of decadienal and allowed to acclimate for 1 h before being filmed using time lapse video microscopy. The number of heartbeats observed in a period of 15 s were recorded and beats per min extrapolated. This technique provides a useful measure of physiological stress at the organismal level. Heartbeat rate declined in a clear dose-dependant manner reducing from in excess of 300 beats per min to 100 beats per min at a concentration of 10 µg/ml (fig. 1).

For growth measurements, 24 h old D. magna were cultured for 23 d in a 1.5 µg/ml decadienal solution or solvent control and body length recorded. Animals cultured with decadienal were significantly smaller than controls with a difference of approximately 0.5 mm by day 23 (fig. 2).

Salmo salar - eyed stage exposure to 2,4-decadienal

1µl of decadienal at set doses was topically applied to the surface of blotted dry, eyed ova at 285 accumulated temperature units. The eggs were left to develop in darkness in reconstituted RO water at 8°C and at hatching were sacrificed by an overdose of anaesthetic (Ethyl 3-aminobenzoate).

Body length was measured and any morphological abnormality recorded. The embryos were then fixed with 10% neutral buffered formalin to solidify the yolk sac which was subsequently removed and the dry weight of embryo and yolk sac determined after 48 h at 60°C.

Abnormal development was characterised by a distinctive kink in the spine as shown in Fig. 3 a and c. Body length was also reduced, declining from approximately 19 mm in control to 17 mm in 20 µg/ml treatments.

Discussion: The diatom-derived aldehyde 2,4-decadienal caused pronounced physiological stress in D. magna as can be seen in figures 1 and 2 with a reduction in heart rate and retardation of somatic growth. The morphological abnormalities observed in larval salmon (Fig. 3) are consistent with observations made in other species and the reduction in growth (Fig. 4) appears consistent in both invertebrate and vertebrate models. Although these chemical cascades have been investigated in marine systems, less is known about their effects in freshwater and in particular their effects on vertebrates. These results suggest a direct toxic effect to both daphnids and salmon but offer no clear evidence towards reproductive inhibition. It is unlikely that PUAs are the direct cause of salmon reproductive failure in situ, but rather they may contribute an additional level of environmental stress on a species already under pressure from declining water quality and habitat degradation.

References