

RISING SEA TEMPERATURES AND ECOTOXICOLOGY: ARE WE PREPARED?

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Biomarkers, loosely defined as measurable effects in organisms providing evidence of exposure to pollutants, will ideally lead to the establishment of causality and provide the necessary data to inform management and regulatory decisions. Despite the increasing importance of *in vitro* cell cultures in routine toxicity testing, the use of whole organism exposure models still deliver toxicological information with environmental relevance. Parameters such as condition, growth, fecundity and population dynamics cannot be assessed using cell cultures. Whole animal ecotoxicology studies should therefore be part of an integrated, appropriately regulated and licensed biomarker study.

Alas, single biomarkers in isolation are rarely sufficient to establish causality. Instead, a suite of biomarkers on various levels of biological organisation is applied, giving rise to a biomarker profile that can be correlated with specific substances or substance classes. However, this requires intimate knowledge of the species in question and the relevant environmental variables, including how these may influence the respective biomarkers.

The latest IPCC reports on climate change show that the upper 75m of the world's oceans have been warming at a rate of 0.11°C per decade since at least 1971 and the uptake of anthropogenic CO₂ has depressed pH by -0.0014 to -0.0024 per year[1]. Climate change and associated changes to environmental physicochemical parameters, such as rising sea temperature, quality and quantity of particulate matter owing to increased erosion and runoff, ocean acidification etc., will affect ecotoxicology on several levels: first of all it will affect the distribution of many species. This could mean that well characterized marine taxa will no longer be available as sentinel species in given locations, because they will either start to migrate North, especially where they are already at their maximum thermal tolerance, or will disappear completely where this avoidance behaviour is not possible. Therefore, the disappearance of naturally occurring populations of established biomarker species will need to be taken into account when interpreting relevant data obtained by applying these species in caging surveys under the changed conditions. Furthermore, changing migratory patterns are likely to increase the biotic transfer of contaminants in significant quantities to other



locations, in some cases even becoming more important than abiotic transport[2]. Secondly, the fate of contaminants, particularly persistence and bioavailability is strongly driven by abiotic environmental factors that affect the characteristics of contaminants, such as speciation, partitioning behaviour, and solubility[3]. Temperature-induced evaporation of volatile organic compounds and other contaminants (e.g. mercury) will increase the mobility of these contaminants even to locations unaffected by organism migration, and monitoring programmes will need to be amended accordingly.

Ocean acidification, the drop of pH in seawater through uptake of anthropogenic CO₂, will affect the behaviour and fate of contaminants because of the relationship between pH and charge. This will have a major effect on bioavailability of contaminants and also on how different contaminants interact with each other, altering their respective toxicities. Climate change-related shifts in salinity, either from increased evaporation in tropical oceans, or increased precipitation in mid to high latitudes, are also known to influence chemical contaminants and modulate their fate and bioavailability. Thirdly, endpoint (biomarker) results (toxicity) can be altered by environmental variables, such as temperature, salinity, pH[4], etc. Increased temperatures are likely to speed up processes involved with metabolizing organic contaminants, often leading to increased bioactivation and subsequent toxicity. This is likely to be particularly relevant for enzyme-based detoxification systems and may also be relevant for other membrane-bound processes that rely on certain cell and organelle membrane characteristics and integrity, such as fluidity and permeability.

Aquatic organisms spend a lot of energy maintaining internal homeostasis that allows them to inhabit practically every aquatic environment. Shifts in the external pH, through for instance ocean acidification, may place additional stress on species already at the limit of their physiological range. Compensating for this will divert energy from growth and reproduction and lead to an increased occurrence and intensity of oxidative stress. A similar effect on growth and reproductive success is likely to occur in organisms subject to osmotic stress brought about by climate change-related fluctuations in salinity. Furthermore, assays measuring the activity of key antioxidant and other detoxification systems can be influenced by salinity[5, 6], whilst others appear unaffected[7].

The evidence for anthropogenically-driven climate change is overwhelming and it is clear that it is affecting oceans and freshwater habitats, albeit in different ways. Nevertheless, the realization is growing that some established biomarker species and endpoints may need to be re-evaluated if they are to be used in future and adapted accordingly in order to ensure meaningful results in a changing environment.

Research currently underway at the Centre for Marine Biodiversity & Biotechnology is trying to answer many of these questions. One PhD project funded by a Heriot-Watt

University James Watt Scholarship is providing pioneering insight into the response of established biomarkers to rising sea temperatures. Another project, facilitated by the MASTS Marine Stressors Forum and funded by a MASTS Prize PhD studentship in collaboration with Dr. Karen Diele (Edinburgh Napier University and St. Abbs Marine Station) is looking at temperature as one of several multiple stressors that, in isolation, may not be a problem but, in combination could pose a risk to commercially valuable shell fish species in Scottish waters.

Links to relevant pages:

Stressors Forum: <http://www.masts.ac.uk/research/research-forums/marine-stressors-forum/>

Centre for Marine Biodiversity & Biotechnology <http://www.cmbb.hw.ac.uk>

Dr Mark Hartl: <http://markhartl.hw.ac.uk>

Dr Karen Diele: <http://www.napier.ac.uk/people/karen-diele>

St Abbs Marine Station: <http://marinestation.co.uk/>

References:

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2. Krümmel, E.M., et al., *Delivery of pollutants by spawning salmon*. *Nature*, 2003. **425**(18 Sept 2003): p. 255.
3. Noyes, P.D., et al., *The toxicology of climate change: Environmental contaminants in a warming world*. *Environment International*, 2009. **35**(6): p. 971-986.
4. Craig, J.M., et al., *Effects of salinity, pH and temperature on the re-establishment of bioluminescence and copper or SDS toxicity in the marine dinoflagellate *Pyrocystis lunula* using bioluminescence as an endpoint*. *Environmental Pollution*, 2003. **125**(2): p. 267-275.
5. Zanette, J., et al., *Salinity influences glutathione S-transferase activity and lipid peroxidation responses in the *Crassostrea gigas* oyster exposed to diesel oil*. *Science of the Total Environment*, 2011. **409**(10): p. 1976-1983.



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7. Singh, R. and M.G.J. Hartl, *Fluctuating estuarine conditions are not confounding factors for the Comet assay assessment of DNA damage in the mussel Mytilus edulis*. Ecotoxicology, 2012. **21**: p. 1998-2003.