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Editorial

Fish Ecotoxicology in a Changing World: do we Need New Biomarker Endpoints in Light of Climate Change?

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Editorial

Owing to their relative longevity, sensitivity and the possession of some human analogous metabolic detoxification processes, fish have long been used as sentinel species for environmental pollution (Hartl, M.G.J., 2002). Biomarkers, loosely defined as measurable effects providing evidence of exposure, will ideally lead to the establishment of causality and provide the necessary data to inform management decisions. Despite the increasing importance of fish cell lines and the development of *in vitro* co-culture models in routine toxicity testing, the use of whole organism exposure models still deliver ecotoxicological information, such as condition, growth, fecundity and population dynamics, that the former cannot, especially where novel contaminants are concerned. Whole animal ecotocxicology studies should therefore be part of an integrated, appropriately regulated and licenced 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 vairables, 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 CO_2 has depressed pH by -0.0014 to -0.0024 per year (IPCC, 2013). Climate change and associated changes to environmental physicochemical parameters, such as temperature rise, 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 fish 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, e.g. many non-migratory freshwater species. 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 (Krümmel, E.M., et al., (2003). Secondly, the fate of contaminants, particularly persistence, bioavailability and toxicokinetics, is strongly driven by abiotic environmental factors that affect the characteristics of contaminants, such as speciation, partitioning behaviour, and solubility (Noyes, P.D., et al., 2009). Temperature-induced volatilization of POPs and other contaminants (e.g. mercury) will increase the mobility of these contaminants even to locations unaffected by fish migration and monitoring programmes will need to be amended accordingly. Ocean acidification, the drop of pH in seawater through uptake of anthropogenic CO_2, 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, etc. (Craig, J.M., et al., 2003). 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 the cytochrome P450 monooxygenase system, which is popular for monitoring exposure to PAHs and planar PCBs using fish as biomarker organism. It 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. Fish spend a lot of energy balancing their internal acid-base conditions, a physiological adaptation for 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 fish 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 fish exposed 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 (Zanette J., et al., 2011; Tu, H.T., et al., 2012) whilst others appear unaffected (Singh, R. and M.G.J. Hartl, 2012)

The evidence for anthropogenically-driven climate change is overwhelming and it is clear that it is affecting oceans and freshwater habitats for fish, albeit in different ways. Nevertheless, the growing realization 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.

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