COMMENT

ENVIRONMENTAL OESTROGENS AND SEXUAL DEVELOPMENT IN FISH

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When hermaphrodite roach Rutilus rutilus were found in settlement lagoons and in a river in the south-east of England, it was suggested that our watercourses might be harbouring a chemical(s) affecting the sexual development in fish. It was then discovered (Purdom et al. 1994) that male fish downstream of sewage treatment works (STWs) were producing an oestrogen-dependent blood protein, vitellogenin, usually found only in maturing females, suggesting that the causative agent(s) for these sexual disruptions was oestrogen-like in nature.

Vitellogenin normally fuels the growth of developing oocytes in fish (as it does in many egg-laying vertebrates) and is synthesised by the liver in response to oestrogen (reviewed in Tyler 1991). Male fish have the vitellogenin gene(s) but it is not usually expressed (because of the absence of oestrogen) and thus male blood is normally free of vitellogenin. When exposed to oestrogens, however, male fish produce vitellogenin and, furthermore, because
males do not have ovaries, vitellogenin accumulates in the blood, giving an indication of the level of oestrogen exposure (Sumpter & Jobling 1995).

A survey of rivers around the UK found that disruptions in male sexuality in fish was widespread. Male rainbow trout *Oncorhynchus mykiss*, placed in cages below STWs at over 20 sites around the country, all synthesised vitellogenin, indicating oestrogen exposure and, after only 3 weeks, levels in the plasma were up to 100,000-fold higher than in the controls — producing concentrations that are normally found only in fully mature females. Carp *Cyprinus carpio*, a species native to our rivers, showed a similar response (Purdom et al. 1994) when maintained in effluent.

A number of man-made chemicals present in the environment have been found to be oestrogenic; they include: ethinyl oestradiol (largely derived from the contraceptive pill), degradation products of alkylphenolethoxylates (APEOs, primarily used in detergents and other cleaning products, but also in a wide range of other products including paints, herbicides, food packaging and personal care products; Jobling & Sumpter 1993), pesticides (Soto et al. 1994), some polychlorinated biphenyls (used in sealants, plastics and paints), polycyclic aromatic hydrocarbons (contaminants from petroleum-related sources) and some plasticisers (Krishnan et al. 1993). Some of these chemicals are used widely, others have a restricted use, but may still be present in considerable quantities because they persist in the environment due to their resistance to biodegradation. Natural oestrogens found in plants (phyto-oestrogens) and fungi (myco-oestrogens) may also be a source of oestrogenic pollution in the aquatic environment when present in significant concentrations, as they can be in agricultural slurry that may pass untreated into our rivers and streams.

Originally it was thought that the primary candidate for sexual disruptions in male fish in British rivers was ethinyl oestradiol, because millions of women take the contraceptive pill in the UK and ethinyl oestradiol is a very strong oestrogen. Furthermore, it had been claimed that ethinyl oestradiol could be detected in river-water in the UK. However, it is now known that much of the ethinyl oestradiol excreted by women is metabolised to glucorinated and sulphated (conjugated) forms, and these are inactive in fish (there are bacteria in STWs, however, which possess enzymes making them capable of rendering conjugated ethinyl oestradiol physiologically active).

More recent work suggests that degradation products of APEOs, such as nonyl phenol and octylphenol may be, at least in part, responsible for the sexual disruptions seen in fish exposed to sewage effluent (Jobling & Sumpter 1993). APEOs are significant, widespread pollutants of rivers in the UK (Blackburn & Waldock 1995), and exposure of male fish to some of their degradation products has been shown not only to cause elevated blood levels of vitellogenin, but also to result in a significant reduction in testis growth (Jobling et al. 1995).
British rivers contain chemicals other than degradation products of APEOs that are now known to be oestrogenic, however, and since the effects of exposure to a mixture of oestrogenic chemicals appear to be additive, we have to consider the cocktail of chemicals that the fish are exposed to, rather than individual chemicals, if we are to appreciate their potential effects. Furthermore, most of the chemicals found with oestrogenic activity so far have a strong tendency to bioaccumulate, resulting in higher levels in fish than in the environment (pesticides, for example, may be concentrated by as much as 100,000-fold). This in turn means that chemicals that are only weakly oestrogenic may nevertheless be sufficiently concentrated to have biological effects. Resolving the question of what chemicals in our rivers are contributing to the pool of environmental oestrogens is made more difficult by the fact that often, apparently, this cannot be done based on their chemical structure alone. Some man-made chemicals have a structure similar to natural oestrogens and may therefore bind to the oestradiol receptor and subsequently to the DNA, to switch on the genes under the control of oestrogens. Some environmental oestrogens, however, appear to bear no structural relationship to natural oestrogens (how these chemicals are still able to switch on the genes under oestrogenic control is not known).

In summary, studies have shown that our rivers contain environmental oestrogens that are capable of causing disruptions in the sexual development of fish. Whether or not these environmental oestrogens are causing a widespread disruption in reproduction in wild fish, however, has yet to be determined. It may be that the "oestrogens problem" is restricted to specific locations; for example, in waters close to toxic dumps, sewage outfalls, or areas receiving high runoffs of pesticides. However, if the problem is widespread in our rivers, then it is potentially a major issue for wild fisheries in the UK.

References


