Briefing Paper

The Effect of Endocrine Disruptors of Fish

Endocrine Disrupting Chemicals (EDCs) are silent killers, threatening biodiversity on a huge scale. An EDC is a substance which interferes with the bodies' endocrine system and hormonal activities. There are currently over 200 species known or suspected to be affected by EDCs (Miyamoto and Burger, 2003).

Aquatic organisms are at enormous risk from EDCs, which enter watercourses through both diffuse and point source pollution. There are a wide range of known EDCs, these include natural (e.g. estrogen) and synthetic hormones (such as ethynylestradiol; found in contraceptive pills), industrial chemicals (such as alkylphenols, bisphenol A, ethoxylates and TBT) and pesticides, fungicides and herbicides (including atrazine, diazinon, permethrin and DDE).

The Salmon &Trout Association (S&TA) believe the precautionary principle should be implemented now to reduce the quantity of these substances reaching our watercourses, before irreversible damage occurs.

Impacts

EDCs have been shown to cause most damage to fish at larval or development stages, by causing abnormalities in sexual development, behaviour and fertility (Gross-Sorokin *et al*., 2006). The adverse alternations reported in the sexual development of exposed fish include:

- Gonadal intersex (gonads contain eggs and sperm developing simultaneously)
- Feminisation of reproductive ducts
- Reduced gonad (testis and ovary) growth rate and size
- Reduced gamete quality
- Increased levels of vitellogenin (egg-yolk protein), indicative of exposure to feminizing chemicals.

The molecular pathways causing these effects are poorly understood, and the wide range of effects caused by EDC exposure makes them difficult to assess and monitor. As well as causing intersex and feminisation, EDCs have been shown to affect courtship and territorial behaviour in three-spined stickleback (*Gasterosteus aculeatus*: Bell, 2001). Research on Atlantic salmon (*Salmo salar*) has also shown oestrogenic compounds can significantly inhibit the development of smolt physiology (Madsen *et al*., 1997). EDC can also differ in the species they affect, for example steroidal estrogens can have a have potent effect on fish, but little endocrine effect on invertebrates such as copepods (Sumpter and Johnson, 2005).

Research from the U.K clearly shows an association between the incidence of fish feminisation and their exposure to effluent discharges (Centre for Ecology and Hydrology (CEH), 2002; Jobling *et al*., 1998). Data from fish populations also correlates the severity of intersex with the proportion of estrogenic effluent (Jobling *et al*., 2006).

Research on wild roach (*Rutilus rutilus*) in the UK indicates more severely feminized fish are found in the older year classes, suggesting the condition is progressive (EA, 2004). These delayed effects mean exposure during early life stages could result in irreversible changes which remain undetected until the offspring reaches maturity (Lyons, 2006: Jobling *et al*., 2006). Other studies indicate some EDCs have the ability to bioaccumulate and can be passed on to offspring, resulting in transgenerational effects. For example, laboratory experiments on the Pacific oyster (*Crassostrea gigas*), has shown exposure to the industrial chemical, nonylphenol, results in poor survival rates in subsequent generations (Nice *et al*., 2003).

The occurrence of intersex individuals in fish populations is affecting their reproductive success and possibly their population stability. Studies assessing gamete quality of wild intersex roach have found moderately to severely feminised male fish have reduced sperm quality and quantity (on average 50% less), and were less able to release their milt compared with 'normal' males (Jobiling *et al*., 2002). Elevated levels of vitellogenin in male fish have also been shown to disrupt kidney function (Herman and Kincaid, 1988), and result in calcium loss and lipid diversion from the scales, which can make the fish more susceptible to disease (Carragher and Sumpter, 1991).

EDCs are a widespread problem, now known to affect freshwater, estuarine and even marine fish. Research from the Tyne, Mersey and Solway estuaries have shown signs of feminisation in male flounder (*Platichthys flesus*: Allen *et al*., 1999: Kleinkauf *et al*., 2004). A study by CEFAS (2006) found North and Irish Sea cod (*Gadus morhua*) had elevated concentrations of vitellogenin, which correlated to the size their diet changed from mainly nektonic (free-swimming) to benthic organisms. This worryingly suggests cod are accumulating EDCs through their food-chain, as the benthic organisms live in sediments which typically contain far higher concentrations of oestrogenic compounds than seawater (Scott *et al*., 2006).

A synthetic oestrogen, ethinyloestradiol (EE2), commonly used in the conceptive pill, is causing particular concern due to its widespread occurrence, high potency and persistent nature (Santos *et al*., 2007). Concentrations in UK freshwater systems have been shown to reach 3.4 ng l^{1} (Williams *et al*., 2003). This is very concerning as laboratory experiments have shown EE2 exposure in zebrafish (*Danio rerio*) of 1.67ng l^{1} increases vitellogenin synthesis (Fenske *et al*., 2001), and 3 ng l^{1} exposure reduces reproductive development in males (Fenske *et al*., 2005). A recent study by Santos *et al*., (2007) demonstrated that current environmental concentrations of EE2 decreased the quality and quantity of gametes produced by both male and female zebrafish.

Oestrogen contamination of drinking water has also been attributed to reproductive disorders and reduced sperm counts in humans (Sharpe and Skakkebaek, 1993).

Actions being taken

In 2004 the Environment Agency concluded that the effects of endocrine disruption on fish were sufficient to develop a risk management strategy for biologically active effluents that discharge into the aquatic environment. The Endocrine Disruption Demonstration Programme was established to assess the effectiveness and costs associated with removing steroid hormones at sewage treatment works (STW). This programme will run from 2005-2010.

The well-documented endocrine disruptor TBT, which leaches into aquatic systems from boat anti-fouling paint, was shown to cause imposex in dog whelks, oysters and mussels. It now faces a total European ban, coming into force on the 1st January 2008.

The S&TA helped lobby for ban of cypermethrin, a pyrethroid insecticide used in sheep dipping, which was shown to cause endocrine disruption in fish, including salmon (*Salmo salar*) and brown trout (*Salmo trutta*: Jaensson *et al*., 2007), and fatal impacts on aquatic invertebrates. The lobbying resulted in a temporary suspension on the sale of cypermethrin in February 2006. Further action is still awaited from the Government, as to whether the ban will become permanent or if the destructive chemical will be reintroduced.

The EA have funded the development of a model which predicts the concentrations of three steroid oestrogens, oestradiol (E2), oestrone (E1) and EE2, and their associated risk of causing endocrine disruption in fish in 10,313 UK river reaches (William *et al.,* 2008). The model calculated 39% of the river reaches were ‘at risk’ from causing endocrine disruption effects in fish. The regions at greatest risk were Thames, Midlands and Anglian regions, with 67%, 55% and 50% respectively, of river reaches in the area predicted to be ‘at’ risk’ (William *et al.,* 2008).

Call for Further Action

The S&TA feel the severity of this problem requires urgent attention. We feel precautionary action should be implemented now to reduce the exposure to EDCs in the aquatic environment before it’s too late. We feel sufficient evidence exists to demand;

- By 2012, universal threshold levels for total endocrine loads and specific estrogen threshold standards, in STW discharges.
- Immediate action to reduce natural and synthetic steroid estrogens in priority STW discharges in ‘at risk’ areas.
- Reduction in the use of other manufactured chemicals with endocrine activity and replacement with safer alternatives. Priority should be given to the prevention of the release, rather than end of pipe solutions.
- The development of new assays and screening methods for the identification of endocrine disrupters relevant to humans and wildlife.
- Research to be adequately funded, prioritised and co-ordinated. All species in decline to be investigated for potential effects of endocrine disruptors, and all relevant data to be made publicly available wherever possible.
- Reassessment of current toxicity tests and chemical standards, as current assessments are dominated by single-chemical exposure studies; however these chemicals are mixed in effluents, which are likely to result in additive effects. Precautionary limits/standards should therefore be set to take this into account.
- Phasing out of persistent chemicals known to accumulate in the environment.
- Investigations into population level impacts caused by EDC exposure, including population declines and loss of genetic diversity.
- Further research into the other effects of EDC exposure, as besides reproduction disruption these chemicals have the potential to affect other body functions also under hormonal control; such as growth, metabolism, immune response and metamorphosis (in amphibian species).

Conclusion

The full extent of endocrine disruption and its effects on the environment are not fully understood. However, many experts believe that one thing is certain; that they are far more widespread than currently confirmed.

The future of commercial and recreational, marine and freshwater fish populations could be threatened by the effects of EDC exposure. The S&TA strongly believe this issue needs addressing now to help safeguard our native fish populations, and enable us to obtain the Water Framework Directive (WFD) requirement of ‘good ecological status’ in all of our waterbodies by 2015.

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