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A national, GIS-based risk assessment for intersex in fish arising from steroid oestrogens – England and Wales

A.C. Johnson[1], R.J. Williams[1], V.D.J. Keller[1], A.R.Young[2], M.G.R.Holmes[2], C. Wells[3], M. Gross-Sorokin[3] and R. Benstead[3]

[1]Centre for Ecology and Hydrology, Wallingford, Oxon, UK. OX10 8BB
[2]Wallingford Hydrosolutions, Wallingford, Oxon, UK. OX10 8BB
[3]Environment Agency, Red Kite House, Wallingford, Oxon, UK. OX10 8BD
Email contact: rjw@ceh.ac.uk

1. Introduction

The Environment Agency of England and Wales (EA) has reviewed the evidence for the feminising effects of natural (oestradiol (E2), oestrone (E1)) and synthetic (ethinyloestradiol (EE2)) steroid oestrogens in fish. The UK and European surveys of intersex fish (feminised males) have demonstrated that the widespread occurrence of these fish is associated with domestic sewage treatment plants (STPs) effluent discharges, and that the incidence and severity of intersex fish is also significantly and positively correlated to the proportion of treated effluent from human sources in receiving waters. These datasets also show that the reproductive success of moderately to severely intersex fish is adversely affected [1].

The aim of this work was to undertake a national, catchment-based risk assessment of steroid discharges from STPs to the aquatic environment to assess the potential extent of the problem across England and Wales. This risk assessment will be used to help in identifying and prioritising STPs that may require improvement in terms of steroid oestrogen removal in future water industry investment rounds.

2. Methods

2.1 Predicting Environmental Concentrations using the LF200-WQX Model

The model has been set up for 357 catchments covering the inland waters of England and Wales in unprecedented detail. It incorporates spatial and physical data for over 2,000 STPs serving over 29 million people. The model predicts the mean (plus standard deviation) and 90th percentile concentrations of E2, E1 and EE2 for 10,313 individual river reaches (21,452 km). The results are output as an ArcGis shapefile. The model computes how much of each of the three oestrogens would be discharged into the receiving waters from the flow of the STPs, the type of treatment and the populations they serve. The in-stream concentrations are then calculated from dilutions down through the catchment river network including a natural attenuation rate. It also accounts for the for the initial conversion of oestradiol into its first degradation product, oestrone. The model inputs and some model parameters are described by distributions. Therefore outputs are in terms of predictions of distributions of concentrations for each river reach.

2.2 Estimating Risk Classes

Recent scientific studies measuring the effects of steroid oestrogens were reviewed and predicted no effect concentrations (PNECs) of 0.1 ng/L, 1 ng/L and 3 ng/l were established for EE2, E2 and E1 respectively. E2 equivalent concentrations were estimated by dividing each steroid by its respective PNEC to introduce a measure of relative potency before the values were summed (the effects of steroids have been shown to be additive). Thus the [E2 equivalent] = [EE2]/0.1 + [E2]/1 + [E1]/3 (where the square brackets denote concentrations). The risk class boundaries were also reviewed and it was established that the total steroid oestrogen PNEC (1 ng/L E2 equivalent) distinguished ‘no risk’ from ‘at risk’ sites. It also determined that the ‘at risk’ to ‘high risk’ boundary should be set at 10 ng/L E2 equivalent which was estimated to be equivalent to the lowest measured population effect end-point in published literature for E2.

3. Results and Discussion

3.1. Overview of results

The mean concentrations of the steroids were used in the risk assessment and all percentages are based on river length. Overall, 61% of river reaches were predicted to be not at risk from endocrine disruption (< 1 ng/L E2 eqv), 38% were predicted to be at risk (>1 ng/L E2 eqv) and 1% at high risk (>10 ng/L E2 eqv).

The distribution of concentrations with modelled reach length across England and Wales showed that 90% of the rivers modelled were predicted to have concentrations below 4 ng/L E2 eqv (Figure 1).The median reach concentration was 0.6 ng/L E2 eqv. Previous work has shown male intersex roach were found at almost all of the 47 sites sampled across England in two Environment Agency national surveys (1995 and 2003) suggesting the risk levels predicted here may not be unreasonable, at least for the roach.

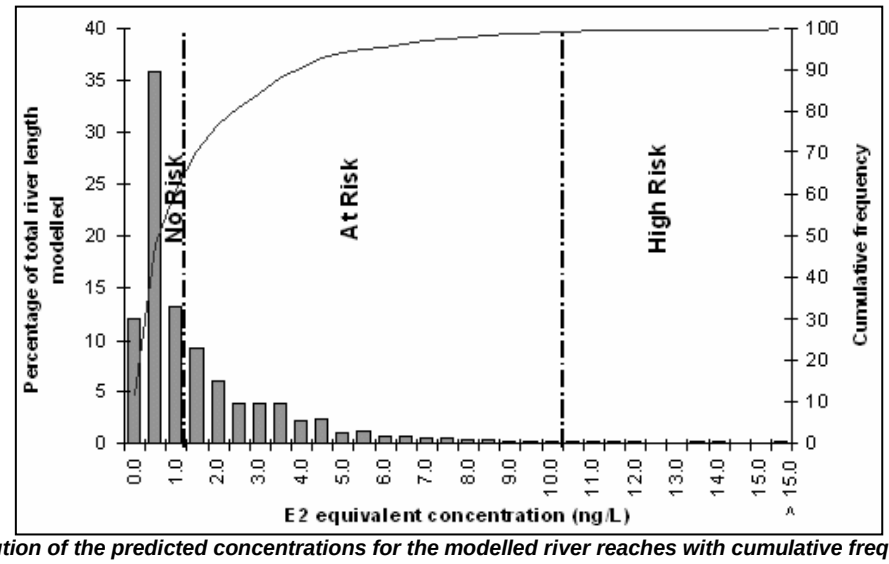

Figure 1: Distribution of the predicted concentrations for the modelled river reaches with cumulative frequency curve (assigned to the right hand Y axis).

3.2. Regional Variations

The 'at risk' proportion is not evenly distributed around the country. The factors influencing the proportion of river reaches being at risk are the population density (location and aggregation) and the available dilution in the river. Thus the lowest proportions predicted as being 'at risk' in are in the sparesly populated areas with high rainfall notably Wales, (5%) where approximately 50 m^3 of water is avaiable to dilute each persons daily effluent. The highest proportion of reaches predicted to be at risk is in the Thames basin (67%); a densly populated and relatively dry area, where only 1.5 m^3 of runoff is available for each person served by an STP. The East of England has the lowest runoff in the area studied and although the population density is the third lowest, it has the third highest percentage of river at risk (50%).

3.3. High Risk Sites

A very small proportion of reaches, around 1% were predicted to be at 'high risk' (>10 ng/L E2 equiv) which equates to approximately 250 km in total. However, many of these 'high risk' reaches were either drains from the STP or natural ditches/headwater streams which were composed almost entirely of sewage effluent.

4. Conclusions

The majority of reaches in England and Wales are not predicted to be at risk of endocrine disruption. Howvever, approximately 39% of rivers modelled were predicted to be at risk of endocrine disruption applying the >1 ng/L E2 eqv threshold. A very small proportion of river reaches are predicted to be in the high risk category (>10 ng/L E2 eqv). These reaches were typically small streams or ditches where the effluent volume from the STP was large compared to the flow in the receiving water.

5. References

[1] Environment Agency, 2004. Causes and consequences of feminisation of male fish in English Rivers. Science Report SC030275/2. Environment Agency, Bristol. UK.

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