Fish on Drugs
Behaviour Modifying Contaminants in Aquatic Ecosystems

ANNELIE LAGESSON

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Lilla Hörsalen, KB.E3.01, KBC-huset, fredagen den 21 September, kl. 12:00.
Avhandlingen kommer att försvaras på engelska.

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Contamination of surface waters is a worldwide problem. One group of emerging contaminants that reach aquatic ecosystems via sewage treatment plant effluents and agricultural run-offs is pharmaceuticals. Impacts of pharmaceuticals on the behaviour of aquatic organisms can have important ecological and evolutionary consequences because behaviour is directly linked to fitness. The aim of my doctoral thesis was to increase our understanding of the fate and effects of behaviour modifying drugs in aquatic ecosystems.

While studying an aquatic ecosystem spiked with pharmaceuticals, I found that the benthic species at the bottom of the food chain were the main receivers (highest bioaccumulation factor; BAF) while fish at the top of the food web had the lowest uptake of the studied drugs. Interestingly, the BAF of the anxiolytic pharmaceutical oxazepam, increased in fish (perch; *Perca fluviatilis*) over the study period, suggesting that this drug can be transferred between trophic levels in food webs. To assess whether oxazepam could affect growth and survival in perch, I exposed perch populations to oxazepam for 2-months in a replicated pond experiment. In this study, I tested the hypothesis that oxazepam exposed perch would grow faster but also suffer from increased predation. Oxazepam has been shown previously to induce ‘anti-anxiety’ behaviours that improve foraging but may also make individuals more exposed to predators. In contrast, I found no statistically significant increase in growth and mortality in the exposed perch. However, the study revealed that the natural predator of perch (pike; *Esox lucius*) became less effective at catching prey when exposed to oxazepam. This exposure effect on predation efficiency likely contributed to the absence of predation effects in the exposed ponds. In two following laboratory studies I investigated effects of behaviour modifying drugs (oxazepam and a growth hormone, 17β-trenbolone) in combination with additional stressors (temperature and predator cues). Drug and temperature interactions were found for 17β-trenbolone, where water temperature interacted with treatment to induce changes in predator escape behaviour, boldness, and exploration in mosquitofish (*Gambusia holbrooki*). However, in the other study, we found that oxazepam, temperature, and predator cue all affected perch ‘anti-anxiety’ behaviours, but independently.

I conclude that pharmaceuticals can alter ecologically important behaviours in fish, and that at least some, can accumulate in aquatic food webs. It seems that *in situ* effects of behaviour modifying drugs in aquatic ecosystems depend on both species-specific responses and abiotic interactions. As such, it is far from straightforward to predict net ecosystem effects based on experiments conducted using single species and static conditions. Future studies should assess the effects of pharmaceuticals in aquatic ecosystems under more complex conditions for us to gain a better understanding of what consequences behaviour modifying drugs have in the environment.

**Keywords**
Aquatic ecosystems, Behavioural effects, Ecotoxicology, Endocrine disruptors, Pharmaceuticals, Interaction effects