



Hormonal Disruption in Fish Caused by Aquatic Pollutants

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Aquatic ecosystems today are increasingly contaminated with chemicals that do more than cause direct toxicity—they can interfere with the hormonal systems of aquatic organisms. Among the most concerning effects is endocrine disruption, a process in which environmental pollutants alter normal hormone function in fish. Because hormones regulate growth, reproduction, development, metabolism, and behaviour, disruption of the endocrine system can produce profound biological consequences even when pollutants are present at extremely low concentrations. Unlike acute toxicants that kill fish rapidly, endocrine-disrupting chemicals often act silently over long periods, causing reproductive failure, developmental abnormalities, skewed sex ratios, and population decline. This has made endocrine disruption one of the most important emerging concerns in aquatic organisms

Endocrine-Disrupting Chemicals (EDCs)

Endocrine-disrupting chemicals (EDCs) are exogenous substances or mixtures that interfere with the normal functioning of the endocrine system by altering the synthesis, secretion, transport, binding, metabolism, or biological action of endogenous hormones. These compounds disrupt hormonal homeostasis through several mechanisms, including:

- Mimicking endogenous hormones such as estrogens, androgens, or thyroid hormones and activating their receptors inappropriately
- Antagonising hormone receptors and thereby blocking the action of natural hormones
- Modifying the synthesis, metabolism, or clearance of hormones leads to altered circulating hormone concentrations
- Disrupting endocrine feedback mechanisms that regulate hormone production and glandular activity

Because fish depend heavily on tightly regulated endocrine signalling for growth, sexual differentiation, reproduction, osmoregulation, and development, they are particularly susceptible to endocrine disruption by aquatic pollutants.

Major Sources of Endocrine-Disrupting Chemicals

Endocrine-disrupting chemicals (EDCs) enter aquatic environments from a wide range of human activities and have become pervasive contaminants in freshwater and marine ecosystems worldwide. One of the most significant sources is agricultural runoff, where pesticides and herbicides such as atrazine and certain organochlorine compounds are washed from agricultural fields into nearby ponds, rivers, and lakes during rainfall or irrigation. In livestock farming, manure and waste products may contain natural steroid hormones excreted by animals, which can also leach into surrounding water bodies.

Another major route of contamination is domestic and municipal wastewater discharge. Wastewater treatment plants often fail to completely remove pharmaceutical residues, including synthetic estrogens from oral contraceptive pills, allowing these hormonally active compounds to persist in treated effluents. Household detergents and

cleaning agents also contribute endocrine-active substances such as nonylphenol, a breakdown product of industrial surfactants. In addition, residues from personal care products, cosmetics, and soaps further increase the endocrine-disrupting load entering aquatic systems.

Industrial activities represent another important source of EDC contamination. Effluents from manufacturing facilities may contain persistent organic pollutants such as polychlorinated biphenyls (PCBs), dioxins, and various chemical intermediates generated during plastic and chemical production. These compounds are often highly stable and can remain in sediments and aquatic food webs for extended periods.

Plastic pollution has also emerged as a major contributor to endocrine disruption in aquatic habitats. Common plastic-associated chemicals, such as bisphenol A (BPA), used in polycarbonate plastics and epoxy resins, and phthalates, used as plasticisers, can leach into water over time. Once released, these compounds may be absorbed by aquatic organisms and interfere with normal hormonal regulation.

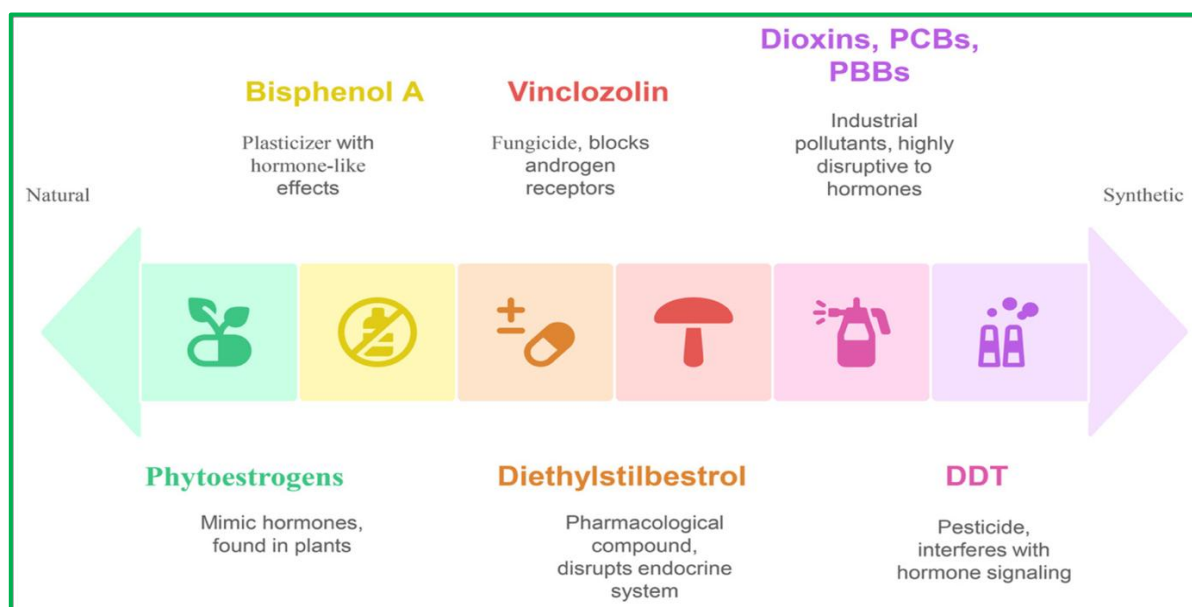


Fig.1 Common Natural and Synthetic Endocrine-Disrupting Chemicals Affecting Fish and Aquatic Ecosystems

Major Effects of Endocrine Disruption in Fish

1. Feminisation of Male Fish - One of the most well-documented effects of endocrine-disrupting chemicals is the feminisation of male fish caused by exposure to estrogenic pollutants. Male fish may begin producing vitellogenin, an egg yolk precursor protein normally found only in females. In severe cases, immature egg cells may develop within the testes, resulting in an intersex condition. Exposure may also reduce sperm quality and sperm production. Vitellogenin induction in male fish is widely used as a biomarker of estrogenic contamination in aquatic environments.

2. Altered Sex Ratios - Exposure to endocrine disruptors during early developmental stages can interfere with normal sex differentiation. This may skew fish populations toward females, induce sex reversal in genetically male individuals, and disrupt hormonal pathways involved in gonadal development. Such changes can reduce breeding potential and threaten long-term population sustainability.

3. Reproductive Failure - Endocrine-disrupting chemicals can severely impair reproductive performance in fish by affecting gonadal maturation, spawning behaviour, gamete quality, fertility, and hatchability. In many cases, fish may appear externally healthy while experiencing significant internal reproductive dysfunction.

4. Developmental Abnormalities - Larval and juvenile fish are especially sensitive to endocrine disruption. Exposure during these critical stages may cause delayed growth and

development, skeletal deformities, abnormal gonadal formation, and impaired metamorphosis. These abnormalities can reduce survival and fitness later in life.

5. Behavioural Alterations - Because hormones regulate many reproductive and social behaviours, endocrine disruption can lead to significant behavioural changes in fish. Affected individuals may exhibit reduced courtship behaviour, altered territorial aggression, poor nest-building activity, and decreased mating success, ultimately impairing reproductive output.

Population-Level Consequences of Endocrine Disruption in Fish

Although endocrine disruption may not cause immediate mortality in fish, chronic exposure to endocrine-disrupting chemicals (EDCs) can have severe consequences at the population level. Long-term reproductive impairment may gradually reduce recruitment and threaten the sustainability of fish populations. A landmark whole-lake experiment demonstrated that exposure to environmentally relevant concentrations of the synthetic estrogen 17 α -ethinylestradiol caused feminisation of male fish, reproductive collapse, and near-extirpation of the exposed fathead minnow population. This study provided some of the strongest direct evidence that endocrine disruption can threaten wild fish populations.

Conclusion

Hormonal disruption in fish caused by aquatic pollutants represents a major emerging concern in aquatic toxicology. Through contamination from agricultural runoff, wastewater discharge, industrial effluents, and plastic-associated chemicals, endocrine-disrupting compounds have become widespread in aquatic ecosystems. Their ability to interfere with hormonal regulation can cause reproductive abnormalities, developmental defects, behavioural changes, and population-level consequences in fish. Protecting aquatic environments from endocrine-disrupting pollutants is therefore essential for preserving fish health, maintaining biodiversity, and supporting sustainable fisheries and aquaculture.

References

1. Kidd, K.A. et al. (2007). Collapse of a fish population after exposure to a synthetic estrogen. *Proceedings of the National Academy of Sciences*, 104(21): 8897–8901.
2. Schultz, I.R. et al. (2011). An Overview of Estrogen-Associated Endocrine Disruption in Fishes. *U.S. Geological Survey*.
3. *Survey*.
4. Söffker, M. & Tyler, C.R. (2012). Endocrine disrupting chemicals and sexual behaviors in fish: A critical review. *Critical Reviews in Toxicology*, 42(8): 653–668.
5. Genes (2025). Sex-Specific Molecular and Genomic Responses to Endocrine Disruptors in Aquatic Species. *Genes*, 16(11): 1317.