Review

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Discussing Behavioural Ecotoxicology in the Light of Some Environmentally Available Anthropogenic Contaminants and their Influence on Behavioural Alterations in Animals

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Discussing Behavioural Ecotoxicology in the Light of Some Environmentally Available Anthropogenic Contaminants and their Influence on Behavioural Alterations in Animals

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Abstract

Behavioural ecotoxicology is a field of applied ecotoxicology, where researchers consider the alterations in the behavioural markers due to the impact of environmental toxicants or contaminants. In fact, understanding the changes in behavioural manifestations helps to understand the respective underlying neurological mechanisms in the organisms and therefore, it effectively helps to describe or predict the neuro-behavioural context of behavioural modifications due to exposure to anthropogenic pollutants. Through this review we are addressing how environmentally available chemicals (such as pesticides, heavy metals (or metalloids), plastics and also pharmaceuticals can have significant acute and/or long-term impact on the behavioural profile of organisms (bioindicator species).

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Introduction

Emerging Contaminants (ECs) including metals, metalloids, wastewater, effluents, sediments, nutrients, pharmaceuticals, polycyclic aromatic hydrocarbons, Persistent Organic Pollutants (POP), pharmaceuticals as well as illegal drugs, pesticides, herbicides, and endocrine disruptors are known toxicological agents to have impact on the ecosystem health **(Amoatey and Baawain, 2019)**. For decades, we have known that chemicals influence the behavioural patterns of animals as well as humans. However, behavioural linkages to reproduction and development may appear obvious within the scope of behavioural ecology, they must be aligned with normal toxicity procedures in order to allow for side-by-side comparisons **(Ford et al., 2021)**. The impact of anthropogenic induction on the stress physiology and behaviour are well-established in a variety of taxonomic groups. Anthropogenic activities on organisms can have indirect impacts on large populations, leading to cascading effects throughout interactive networks, as all organisms interact with conspecifics as well as other species within their groups. Therefore, human-induced modifications to one species stress physiology and the ensuing behavioural effects may interact with other creature's physiological and behavioural reactions to modify emergent ecological phenomena. These illustrations highlight how individual-level stresses may affect ecological interactions and have cascading effects on ecological and behavioural dynamics. Ultimately, because of their cascading effects on behaviour, alterations in the stress physiological manifestations on one or both sides of organismal interactions can influence the higher-level of population and community changes **(Hammond et al., 2020)**.

Behaviour-based biomarker assessments are quicker, sensitive, and ecologically appropriate for measuring growth and development. Behavioural bioassays or behavioural bioindications are more promising than assays to quantify lethality, which are presently employed to evaluate toxicological

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risks to organisms. Behavioural changes can give early warning signs regarding a population's health that routine testing do not evaluate. Chemicals can generate prompt behavioural reactions in organisms at low doses, making these endpoints potentially 10-100 times more sensitive than acute or chronic testing **(Sharma et al., 2018)**. However, traditional techniques to study the impact of chemical pollutants on animal behavioural patterns occasionally takes into account the complexities of the natural ecosystems in which contamination occurs **(Bertram et al., 2022)**.

This article broadly deals with the significant impact of several ECs on the behavioural patterns of organisms. The behavioural response to chemical stress is a contemporary issue in the area of behavioural ecology. The fundamentals of the behavioural modifications are important to understand the underlying ecological conditions in terms of toxicity. Ethological analysis of behavioural markers of respective bioindicator species can generate substantial information on the climatic or ecological changes.

Impact of Pharmaceutical Pollution on Animal Behaviour

The degree of exposure to several pollutants may be influenced by these behavioural (and cognitive) impacts, which might create feedback loops that increase the negative effects of pollutants on fish health. Since some stressors may intensify the behavioural impacts of pollutants on fitness, the effects of pollutants should be investigated in a multi-stress context, that is, under realistic environmental conditions in conjunction with several other environmental stressors. Current research indicates that traits related to physiology, personality, cognition, and fitness are frequently associated with syndromes. Long-term exposure to pollution may cause local adaptation or maladaptation, which may contribute to substantial intraspecific sensitivity and variability in wild populations **(Jacquin et al., 2020)**. Pharmaceutical pollutants, which are resistant to biodegradation and can have therapeutic effects at low doses, have become environmental stresses for animals. Concern over the potential for neuroactive substances, discharged into the environment to alter animal behaviour is developing. Among these substances, medications like anxiolytics and antidepressants have drawn more attention lately as they are administered definitely to alter behavioural reactions **(Sumpter and Margiotta-Casaluci., 2022)**.

One notable pharmaceutical contaminant is the anxiolytic oxazepam, a psychotropic medication that is commonly found in surface waters across the world. The multi-stressor strategy involved exposing perch to oxazepam at two temperatures to northern pike (*Esox lucius*). Oxazepam significantly increased boldness, with treated fish visiting the exposed region (high risk). Fish under low temperature treatments (oxazepam, predation) froze longer than fish at high temperatures (**Sasristo et al., 2018**). The developmental and behavioural effects of medicines in quaternary combinations were assessed using zebrafish (*Danio rerio*) embryos. The combination index-isobologram model proved to be appropriate in describing the nature of potential interactions between the combined medicines. The combined action of the quaternary medicines on *D. rerio* embryos does not appear to generate developmental or behavioural acute unfavourable effects at the concentrations typically encountered in surface fresh waters **(Godoy et al., 2019)**. It is crucial to comprehend the combined effects of blended neuroactive compounds are a class of pollutants that are predominately occurring in the environment. Spontaneous tail coiling is the first detectable motor activity in the developing brain network **(Ogungbemi et al., 2021)**.

Fluoxetine is one such pharmaceutical (antidepressant) contaminant that has been found in surface waters all over the world at concentrations that may change the physiology and behaviour of aquatic life. Predation risk, a particularly significant natural stressor that can have both direct (such as death) and indirect (such as altered prey behaviour) fitness impacts, is one of the many stressors that animals exposed to pharmaceutical pollutants. In the presence of either a non-predatory rainbowfish (*Melanotaenia splendida*) or a predatory spangled perch (*Leiopotherapon unicolor*), fluoxetine exposure changed the mating behaviour of both male and female guppies (*Poecilia reticulata*). Male guppies reproductive behaviour was changed, but not that of females, when exposed to an ecologically relevant concentration. More precisely, independent of perceived predation danger

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(i.e., in the presence of both a predator and a non-predator), males in the high-fluoxetine treatment displayed a modified mating strategy, engaging in more forceful stealth copulations than unexposed males **(Fursdon et al., 2019)**. Fluoxetine decreased the behavioural flexibility of guppies at the individual level. Additionally, fluoxetine changed between-individual correlations in pace-of-life syndrome traits: interactions between behavioural and life-history traits (e.g., activity and body condition) and between life-history and sperm traits (e.g., gonopodium size and sperm vitality) were triggered, while other between-individual correlations (e.g., activity and gonopodium size) were collapsed **(Aich et al., 2025)**. Using a mesocosm system, fish were subjected to solvent control or ecologically realistic fluoxetine concentrations. Temperature stress and fluoxetine exposure did not appear to have any combined impact on guppy behaviour. Fish activity levels were unaltered by fluoxetine exposure, however male forceful copulatory behaviour increased. Both sexes were less active; however, males engaged in reproductive behaviour less frequently under cold-temperature stress. Acute temperature stress and prolonged exposure to a common pharmaceutical contaminant change basic fitness-related behaviours in fish, which may change population dynamics in polluted environments **(Wiles et al., 2020)**. The effects of fluoxetine in a reproductive environment, namely mating behaviour and sperm quality were examined. Fluoxetine exposure caused males to spend more time pursuing females **(Martin et al., 2019)**. Individual activities were homogenised by fluoxetine; in communities exposed to even modest doses, individual alteration decreased to less than half of that of populations not exposed. The hidden effects of a common pollutant on fish phenotypic variation likely to hinder adaptive potential to environmental change are revealed by the way that fluoxetine reduces activity variation across but not within individuals **(Polverino et al., 2021)**.

Three model psychopharmaceuticals with antagonistic and agonistic serotonin signalling properties, 4-Chloro-DL-phenylalanine (PCPA), deprenyl, and fluoxetine were exposed to single and opposite pharmacodynamics co-exposure in order to modify the serotonergic system in zebrafish larvae's. Deprenyl and fluoxetine showed similar behavioural effects, including cognitive impairment, a reduction in larval protective reactions, and hypo-locomotion. On the other hand, PCPA increased the larvae's escape reaction and caused them to move more quickly. Behaviours were regained when drugs with opposing mechanisms of action were exposed together **(Faria et al., 2021)**. Two model psychiatric medications with antagonistic and agonistic serotonin signalling properties of PCPA and deprenyl, respectively were administered to modify the *D. magna* monoamine system. Deprenyl and PCPA showed different behavioural effects, with the former chemical showing improved habituation and lower baseline locomotor activities, whereas the latter compound showed delayed habituations. Individuals administered with deprenyl exhibited decreased basal locomotor activity and consistently slower habituations to recurrent light stimulation. The behavioural results of deprenyl were in contrast to those of the PCPA medication or genetically altered people who had lower serotonin levels **(Bellot et al., 2021)**.

Small quantities of physiologically active substances called trace amines are produced endogenously in the brain and share structural similarities with biogenic amines. They have strong behavioural and physiological impacts on both people and animals through their action on certain trace amine-associated receptors (TAARs). However, little is known about the central effects and evolutionary conservation of action of TAAR ligands, despite their recent suggestion as novel potential anxiolytics. At low concentrations, beta-phenylethylamine had overt anxiolytic-like effects and decreased brain acetylcholine levels; at high concentrations, it enhanced whole-body cortisol levels and anxiety-like behaviour in zebrafish **(Quintanilha et al., 2025)**. Clinically utilised as a cognitive enhancer to treat neurodegenerative illnesses, donepezil is a strong acetylcholinesterase inhibitor. Its broader pharmacological perspectives, except cognition is not clearly unknown. The light-dark and shoaling tests, which measure brain acetylcholinesterase activity and whole-body cortisol levels, mimic the anxiety-like behaviours in zebrafish. Overall, donepezil reduced zebrafish locomotor activity and decreased duration in light and in the light-dark test in a dose-dependent manner. These effects are likely to reflect anxiety-like behaviours and hypo-locomotion **(Giacomini et al., 2020)**. Many neuropsychiatric disorders are frequently triggered by neuroinflammation. In a

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variety of *in vivo* animal models, lipopolysaccharide (LPS) injection is frequently utilised to cause systemic and brain inflammation **(Ilyin et al., 2025)**.

Table 1. Discussing the behavioural impacts of some pharmaceutical contaminants.

Contaminants (Pharmaceuticals)	**Animal Group**	**Exposure Route**	**Behaviour Affected (Direct)**	**Reference**
Fluoxetine (Antidepressant)	Fish (*Danio rerio*)	Waterborne (via gills)	Chronic waterborne fluoxetine exposure reduces locomotor and exploratory activity, alters anxiety-like responses, and disrupts shoaling behaviour via serotonergic modulation	Correia et al., 2022
Clarithromycin (CLA), chlortetracycline (CTC) and roxithromycin (ROX) (Antibiotic)	Fish (*Danio rerio*)	Waterborne	Decrease in the travel distance and velocity, as well as an increase in turn angle	Zhang et al., 2023
Ciprofloxacin, Ceftazidime and Chlortetracycline	Fish (*Danio rerio*)	Waterborne	Aggravate aggressive behaviours	Petersen et al., 2021
Diclofenac (NSAID)	Fish	Waterborne	Erratic swimming behaviour, movement, increased aggression and lethargy	Padma, 2018
Fluoxetine (Antidepressant)	Amphibians (Tadpoles)	Waterborne	Alters locomotor activity and antipredator-related behaviour while inducing abnormal morphological development, indicating disrupted neurodevelopment and stress responses	Cordero et al., 2025
Fluoxetine (Antidepressant)	Mammals (Mice)	Oral ingestion	Although chronic fluoxetine treatment proves positive effects in animal models of depression, it may simultaneously increase	Kryst et al., 2022

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			anxiety in adolescent animals in a dose-related manner	

Impact of Pesticides, Insecticides, Heavy Metals (or Metalloids), Plastic and Other Organic Pollutants on Animal Behaviour

Several amphibian populations are vulnerable due to environmental pollution. Many pollutants change behaviour at levels found in the environment, with detrimental effects for individual fitness, populations, and communities. Insecticides have been shown impact on amphibian behaviour, perhaps lowering fitness. Behavioural endpoints are important sub-lethal indications of how toxins affect frogs, and when combined with typical ecotoxicological endpoints **(Sievers et al., 2019)**. Large volumes of non-linear data are produced by tracking both individual and group behaviours, necessitating the use of specialized computational techniques for information management and interpretation. Two categories of these non-linear analysis techniques that function as markers of the behaviours complexity and predictability which are fractal dimension and entropy. Changes in its entropy values have a clear potential to be integrated into a biological early warning system (BEWS), which may be especially helpful in precision fish farming settings and to monitor wild populations, since contaminants may modulate behavioural complexity and predictability. These contaminants include toxic compounds, cleaning and disinfecting agents, stimulants (caffeine), anaesthetics and antibiotics, heavy metals (lead, copper, and mercury), selenium, pesticides, and persistent environmental pollutants **(Eguiraun et al., 2023)**.

Plastic nanoparticles formed by weathering plastic debris are new pollutants in aquatic habitats, with unknown mechanisms of action on aquatic creatures. According to recent research, internalised nanoplastics have the potential to alter metabolic processes **(Brun et al., 2019)**. Because microplastics may penetrate biological membranes, they may be more dangerous than macroplastics. There is ample evidence of the harmful effects of microplastic exposure on aquatic life and people, but less is known about the toxicity and behavioural alterations of nanoplastics (NP) in animals. Despite their small size, nanoplastics have a large surface area, which means they have the capacity to bind even more harmful substances than microplastics. Crucially, an examination of many behavioural endpoints and various physiological indicators demonstrated that exposure to polystyrene-nanoplastics (PS-NP) caused oxidative stress, tissue accumulation, and disruption of lipid and energy metabolism. In addition of the dysregulated circadian rhythm locomotion activity following chronic exposure, the high concentration of PS-NP group demonstrated noticeable behavioural changes in their locomotor activity, aggression, shoal formation, and predator avoidance behaviour. Furthermore, following a week of exposure to PS-NP, several critical neurotransmitter biomarkers for neurotoxicity research saw substantial alterations, which may suggest possible toxicity from PS-NP exposure. Furthermore, during about one month of incubation, the fluorescence spectroscopical data showed that PS-NP were distributed and accumulated throughout the zebrafish tissues, particularly in the gonads, which may have an additional impact on fish reproductive function **(Sarasamma et al., 2020)**.

Macrobrachium lamarrei, a native freshwater prawn species that is quite common in India, exhibits the strong habit of auto-grooming, non-lethal concentration of arsenic trioxide caused a significant change in this species auto-grooming pattern. It is determined that in aquatic invertebrates, grooming behaviours are accurate indicators of stress or vulnerability to heavy metals **(Munshi and Bhattacharya, 2020)**. In the broad subject of ecotoxicology, behavioural toxicity is a very relevant area where assessing behavioural changes is a useful method of assessing an organism's brain activity. Exposure to arsenic trioxide can cause a freshwater prawn, *Macrobrachium lamarrei*, to engage in repetitive grooming activities; yet the organism can eventually adjust the grooming performances to less. It is anticipated that recurrent grooming behaviours will result in arsenic neurotoxicity and the development of autism spectrum disorder (ASD) within a brief exposure period **(Munshi et al., 2021)**. Arsenic affects the neurotransmission mechanism, resulting in the repetitive behavioural activities. Arsenic-induced neurotoxicity was confirmed by analysing repetitive grooming and corresponding

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differential gene expression data (acetyl cholinesterase, neurexin-neuroligins) **(Munshi et al., 2024)**. Fish movement is thought to be essential for foraging and prey-predation interaction. Deep insights into the underlying neuroethological and biomechanical principles can be gained by studying fish swimming patterns. Fish use regulated fin strokes, which involve correlation between the pectoral, dorsal, anal, pelvic, and caudal fin stroking patterns, to primarily govern their movement mechanism. Hydrodynamics and geometric morphology, however, are also quite important. To determine how arsenic affected fish movement, the stroking frequencies of each fin were examined. The findings show that fish in water tainted with arsenic have a higher frequency of all fin strokes. Because of the arsenic trioxide contamination, all of the fins move noticeably more in a given amount of time. It is easy to understand how fishes fin stroke patterns change in a contaminated environment. Arsenic poisoning as an abiotic stressor that causes changes in neural activity, which in turn changes the muscle activity that drives fin motions **(Paul and Munshi, 2024)**.

Table 2. Discussing the behavioural impacts of some organic contaminants.

Contaminants	**Animal Group**	**Exposure route**	**Behaviour Affected**	**References**
PFAS	Fish (*Danio rerio*)		PFSAs (PFHxS, PFOS): Increased swimming distance during darkness Increased burst (large-movement) activity Increased startle responses at light transitions PFOA: Increased swimming distance and burst activity during darkness (hyperactivity) PFNA: Reduced activity during light, increased burst activity and peak responses, Indicates altered arousal and motor control, not uniform hyperactivity FTSA: Increased swimming distance during darkness and suggests stimulatory locomotor effects	Menger et al., 2020
	Birds (Water bird)	Predominantly dietary	Higher PFAS exposures in wild waterbirds were associated with more frequent egg turning and lower egg temperatures during incubation, indicating altered parental care behaviour likely linked to hormonal disruption.	Shahrbabaki et al., 2025

	Mammals (Mice)	Ingestion via water intake	Produce anxiety-like behaviour and impair memory/cognition in adult mice, likely via neurotoxic effects in the brain	He et al., 2025b

Table 3. Discussing the behavioural impacts of some pesticides/insecticides.

Contaminants	Animal Group	Exposure Route	Behaviour Affected (Direct)	Reference
Imidacloprid (Neonicotinoid)	Fish	Waterborne uptake via contaminated water.	Reduced zebrafish swimming speed, distance, and defensive alertness, and impaired social behaviours such as heterosexual attraction and mutual vigilance after waterborne exposure to sublethal pesticide concentrations	Chung et al., 2023
Chlorpyrifos	Fish	Waterborne uptake via agricultural runoff	Induced marked behavioural abnormalities in *Labeo rohita*, including erratic swimming, hyperactivity followed by lethargy, loss of equilibrium, and reduced escape responses, indicating neurotoxic disruption.	Ikram et al., 2023
Imidacloprid	Amphibians	Waterborne uptake via agricultural runoff	Decreased swimming activity and induced lethargy, spasms, and behavioural unresponsiveness in tadpoles during acute sublethal exposure	Samojeden et al., 2022
Imidacloprid	Birds	Oral exposure via ingestion of imidacloprid-treated seeds and contaminated food items	Reduced antipredator behaviour in farmland birds, causing diminished vigilance and weaker escape responses under simulated predation risk	Addy-Orduna et al., 2024
Neonicotinoid	Birds	Oral exposure via ingestion of contaminated nectar,	Neonicotinoid exposure in North American hummingbirds is associated with impaired foraging efficiency, altered activity patterns, and reduced	English., 2020

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		insects, and plant materials treated with neonicotinoid pesticides.	migratory and reproductive performance, consistent with sublethal neurobehavioral disruption	
Chlorpyrifos, carbaryl, imidacloprid	Mammals	Oral exposure via contaminated food and water, with secondary inhalation or dermal exposure in agricultural settings.	Sublethal exposure causes altered locomotion, anxiety-like behaviour, learning and memory deficits, and changes in social or exploratory behaviour driven by central nervous system toxicity	Mora-Gutiérrez et al., 2021

Table 4. Discussing the behavioural impacts of some heavy metals.

Contaminants	**Animal Group**	**Exposure Route**	**Behaviour Affected (Direct)**	**Reference**
Arsenic	Fish (*Danio rerio*)	Waterborne	Impaired photomotor reflexes, reduced locomotion, heightened anxiety-like responses, and compromised cognitive function (e.g., object recognition) at various life stages	Putnala et al., 2025
Cadmium	Fish	Waterborne	Abnormal swimming patterns, reduced activity, and morphological deformities, reflecting impaired locomotor behaviour and physiological stress	Singh and Saxena, 2020
Lead	Birds	Dietary exposure	Reduces locomotor performance, alters exploratory behaviour, and impairs flight initiation, following dietary ingestion of lead-contaminated food	Di Liberto et al., 2024
Lead	Birds	Dietary exposure	Impaired song learning and sexual signalling, leading to reduced female attention and altered reproductive behaviour	Goodchild et al., 2021
Arsenic	Mammals (Mice)	Oral ingestion	Impaired hippocampus-dependent learning and memory and induces transgenerational cognitive deficits via altered gene expression	Hua et al., 2024

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Lead	Mammals (Mice)	Oral ingestion	Increased anxiety-like behaviour via serotonergic system disruption in rodents.	Tamegart et al., 2021
Cadmium	Mammals (Mice)	Oral ingestion	Selective impairment hippocampus-dependent memory in mice	Wang et al., 2021

Table 5. Discussing the behavioural impacts of microplastics.

Contaminants	Animal Group	Exposure route	Behaviour Affected	References
Microplastics	Fish	Oral ingestion	Hyperactive swimming behaviour	Chen et al., 2020; McCormick et al., 2020
	Amphibians (Axolotl)	Bio-accumulation via zooplanktons	Altered effects on feeding behaviour	Manríquez-Guzmán et al., 2023
	Amphibians (*Physalaemus cuvieri*)	not specified	Anxiety-like behaviours and anti-predatory defensive response deficit	da Costa Araújo and Malafaia, 2020.
	Birds	Direct or indirect ingestion	Affected foraging and nesting behaviour	Tariq et al., 2022 ;Nguyen et al., 2025
	Mammals (Mice)	Oral ingestion	Elevated locomotion/exploration, increased exploratory behaviour, Altered anxiety or risk behaviour	Gaspar et al., 2023

Table 6. Discussing the behavioural impacts of nanoplastics.

Contaminants	Animal Group	Exposure route	Behaviour Affected	References
Nanoplastics	Reptiles (oviparous skink, *Scincella modesta)*	embryonic exposure	Reduced locomotor performance	He et al., 2025a
	Mammals (Swiss mice)	in vivo exposure	Anxiolytic-like behaviour (in the open field test) and alterations in the	Guimarães et al., 2023

			antipredatory defensive response	

Discussion and Conclusions

Awareness of how human-made pollution might change the behavioural characteristics of many aquatic creatures has grown over the past ten years. Changes in neuro-behavioural indices have become sensitive and physiologically integrative endpoints in chemical risk assessment, in addition to their substantial ecological consequences **(Wlodkowic et al., 2022)**. The eco-neurotoxic effects of most industrially important chemicals are still poorly understood, despite growing evidence of pleiotropic ecological dangers. Changes in neuro-behavioural traits have been proposed as highly sensitive and physiologically integrative endpoints to evaluate the eco-neurotoxicological risks associated with industrial pollution. It is necessary to change the paradigms from expensive, low-throughput ecotoxicity test models to next-generation systems that can handle higher throughput because of the significant backlog of risk assessments of both new and old commercial chemicals. The creation of the behavioural fingerprints, such as motion index (MI)-based fingerprints, behavioural phenoclustering, bioinformatic techniques are useful for elucidating common patterns of behavioural responses, and data-intensive computational approaches are used to cultivate rich biometric data from all areas that require state-of-the-art technological innovations **(Bownik and Wlodkowic, 2021)**. The mechanistic analysis of the behavioural changes due to contamination exposure also includes genomic and molecular protocols **(Pyle and Ford, 2017)**.

Environmental contamination can impair behavioural adaptation to other stressors, reducing behavioural plasticity. Contamination can impair behavioural flexibility in response to permissive settings, causing more and less infected individuals to act similarly under increasingly stressful conditions. Such shape changes in reaction standards may be explained by a variety of reasons, including the combined impact of pollutants and other stresses on endocrinology, energy balance, sensory systems, and physiological and cognitive constraints **(Grunst et al., 2023)**.

The effects of anthropogenic pollutants vary according on the matrix, exposure duration and route, and the kind and quantity of pollutants present in the ambience **(El-Gendy et al., 2021)**. The use of the animal personality paradigm, for instance, has made it possible to break down the effects of copper, temperature, and microplastics on behavioural variance into mean level effects, among individual variation, and changes in behavioural reaction norms **(Briffa et al., 2024)**. By reflecting various physiological changes and connecting individuals to population-levels, altered behavioural patterns serves as a sensitive instrument for evaluating the overall effects of ecologically relevant contaminants **(Saaristo et al., 2018)**.

To conclude, still we have many issues to understand the long-term and acute effects of industrial/anthropogenic pollutants on the nervous system and, their respective impact on behavioural manifestations. This can effectively be related with the assessment of ecological and evolutionary fitness. To describe and measure the exposure and detrimental effects of different contaminants, several biomarkers have been used to understand the significant effects of anthropogenic contaminants on the ethological perspectives in animals.

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