IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, August 2023

Impact of Environmental Pollution on Fish Personality and Cognitive Processes

Dr. Anju Verma
Assistant Professor, Department of Zoology
Kashi Naresh Government P. G. College Gyanpur, Bhadohi, U.P., , India

Abstract*: Pollution and environmental stressors are significant yet often underappreciated drivers of variability in fish behavior, cognition, and fitness in wild populations. This review examines recent research on the impact of pollution on fish and highlights four key areas of interest in understanding these effects.*
First, the neurotoxic effects of contaminants on the brain and psyche of fish are discussed, revealing how pollution-induced behavioral and cognitive changes may influence exposure levels. These feedback loops can amplify the adverse effects of pollution on fish fitness. Second, the effects of pollutants are explored within a multistress context, recognizing that realistic environmental conditions often involve the interaction of pollution with other stressors, potentially exacerbating behavioral impacts on fitness.
Third,studies demonstrate a strong correlation between physiological, personality, cognitive, and fitness traits, indicating that pollutant-induced disruptions to these syndromes could alter evolutionary trajectories. Investigating the complex interplay of traits is essential to understanding how environmental stressors shape population dynamics. Finally, prolonged exposure to pollutants may lead to local adaptation or maladaptation, creating varying levels of sensitivity to pollution within the same species. Additionally, the evolution of resistance to pollution could constrain or conflict with the development of resistance to other environmental stressors. Future research should aim to unravel these intricate relationships to better predict and mitigate the impacts of pollution on fish populations and ecosystems.

Keywords: Personality, cognitive, fitness traits, population dynamics, and environmental stressors etc

I. INTRODUCTION

Human activities release a wide array of organic and inorganic contaminants into the environment, including plastics, pharmaceuticals, pesticides, and metals, which adversely impact terrestrial and aquatic ecosystems. Despite decades of research, significant knowledge gaps remain regarding the precise impacts of these pollutants on wildlife. Traditional ecotoxicological studies have focused predominantly on the physiological and lethal effects of pollutants on animals, whereas the more complex impacts on behavior, particularly under realistic multistressor conditions in wild species, have been understudied. Furthermore, the long-term consequences of human activities on population persistence and evolutionary trajectories remain difficult to predict because research seldom addresses the links between behavioral changes, cognitive performance, and individual fitness.

In this review, we consolidate findings on the interactions between pollution and fish behavior, cognition, and fitness. Fish have been widely used as model organisms in ecotoxicology, serving as "sentinel" species to monitor environmental health and as subjects in behavioral and cognitive research. We present a synthesis of the scientific literature that examines how chemicals influence the behavior of wild fish (Table 1). While most previous studies have examined the effects of pollutants within a "single stressor" framework under environmentally relevant pollution levels, the real-world scenarios often involve exposure to multiple natural or human-made stressors simultaneously. These combined stressors can exacerbate the effects of pollution, leading to synergistic interactions that compound their impacts on fish. However, research investigating multistressor effects on fish behavior remains scarce (Table 1).

In addition, pollutant effects on behavioral syndromes (i.e., correlations among traits such as personality, cognition, and fitness) remain poorly understood. Despite well-documented links between behavioral traits, the impact of pollutants on syndrome structure has received limited attention (Table 1). Previous research has predominantly focused on

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, August 2023

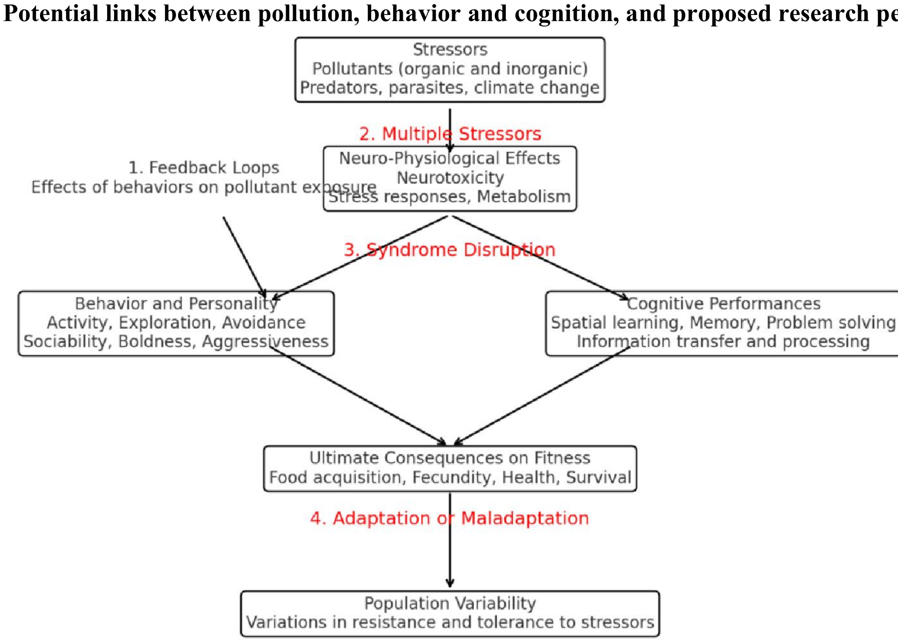
domesticated species or single wild populations, neglecting the variability in behavioral responses across different populations and over evolutionary time.

Table 1: Non-extensive summary of the existing literature on the link between pollution and behaviour in fish.

Contaminant	Ecological Relevance	Fish Species	Behavioral Traits	Multi-stress	Syndrome	Variability
Microplastics	Yes	Bathygobiuskrefftii	Boldness, exploration	No	No	Yes
Nanoplastics	Yes	Carassius carassius	Activity, feeding, exploration	No	No	Yes
Oxazepam	Yes	Perca fluviatilis	Boldness, sociability, feeding rate	No	Yes	Yes
Vinclozolin, flutamide	Yes	Betta splendens	Activity, shoaling, exploration	No	Yes	Yes
Ethinylestradil	Yes	Poecilia reticulata	Sexual behaviors	No	No	No
Fluoxetine	Yes	Several species	Aggression, associative learning	Yes	Yes	Yes
Metals (e.g., Mercury, Ag)	Yes	Danio rerio, Fundulusheteroclitus	Spatial learning, avoidance	Yes	No	Yes
Trenbolone	Yes	Poecilia reticulata	Reproductive behaviors	No	No	No
PAHs	Yes	Oncorhynchus kisutch	Territoriality	No	No	Yes
Benzo[a]pyree	NA	Neogobius	Competition	No	No	Yes

Exploring how pollutants influence fish fitness through behavioral and cognitive changes in wild populations, as well as the implications of these changes for evolution, represents a critical scientific challenge for the coming decades. To address these gaps, we propose four key areas of research (Figure 1) to enhance our understanding of how pollution affects fish behavior, cognition, fitness, and survival.

Figure 1: Potential links between pollution, behavior and cognition, and proposed research perspective



Long-Term Behavioral and Cognitive Impacts of Pollution

Pollution can have enduring effects on fish health by altering various aspects of behavior, including learning and memory. These changes may create positive feedback loops where pollution-induced behavioral shifts increase exposure to contaminants, further exacerbating the negative effects on fitness.

Multistressor Contexts in Pollution Studies

As wild fish often experience multiple concurrent stressors, it is critical to study pollutants within a multistressor framework. Interactions between pollutants and other environmental stressors can modify the effects of pollution on fish behavior and fitness, underscoring the need for realistic experimental conditions.

Syndromic Disruptions and Evolutionary Impacts

Environmental stressors like pollution can alter the links between physiology and behavior, disrupting or reinforcing behavioral syndromes. These changes may have significant implications for evolutionary trajectories by influencing trait correlations and selection pressures.

Local Adaptation and Maladaptation to Pollution

Prolonged exposure to pollution may lead to local adaptation or maladaptation, resulting in variability in sensitivity to contaminants within species. Adaptive processes rely heavily on behavioral and cognitive responses, which are shaped by evolutionary history and may facilitate or hinder adaptation to environmental stressors like pollution.

This review emphasizes the need for integrative approaches that bridge behavioral, cognitive, and evolutionary ecology to address the complex challenges posed by pollution. By advancing our understanding of how contemporary and future stressors impact wild fish populations, we can better predict and mitigate the ecological consequences of pollution on aquatic ecosystems.

Effects of Pollutants on Fish Behavior and Feedback Loops

Pollution is a significant driver of behavioral changes in fish. A range of organic and inorganic pollutants, including pesticides, pharmaceuticals, metals, and herbicides, can alter essential behaviors such as movement, exploration, social interactions, aggression, reproduction, and feeding patterns (Table 1). Additionally, pollutants may influence behavioral types or personalities, which are fixed differences in behavior between individuals. These changes often stem from neurological impacts, such as altered cholinesterase activity, neurotransmitter levels, or hormonal imbalances. For instance, the herbicide carbofuran impaired nerve function and reduced activity levels in the sea bass (*Dicentrarchuslabrax*). Similarly, studies on the antidepressant fluoxetine (Prozac) revealed altered aggression, confidence, and learning in Siamese fighting fish (*Betta splendens*), with these effects linked to disruptions in the serotonin pathway. Detoxification and stress responses caused by pollutants can also disrupt energy balance, indirectly affecting behavior. For example, low doses of pesticides reduced the activity levels of goldfish (*Carassius auratus*), likely due to the high metabolic cost of detoxification.

Pollutants also have profound effects on fish cognition and survival. Spatial learning and memory, essential for avoiding predators, finding food, and navigating the environment, are particularly vulnerable.Thealuminum contamination impaired maze-learning abilities in Atlantic salmon (*Salmo salar*), suggesting a disruption in cognitive processing and adaptability. Similarly, organic toxins such as pesticides impaired movement and spatial memory in zebrafish (*Danio rerio*) and the rare minnow (*Gobiocyprisrarus*), potentially compromising their ability to assess environmental quality.

Behavioral changes caused by pollution can create feedback loops that exacerbate exposure and amplify negative impacts on fitness. For example, contaminants often reduce exploratory behavior, which is critical for assessing environmental quality. Trinidadian guppies (*Poecilia reticulata*) exposed to crude oil exhibited reduced maze exploration. Similarly, lead and cadmium exposure decreased exploratory behavior in great tits (*Parus major*). A decline in exploration reduces the ability of fish to identify and avoid contaminated areas, potentially increasing their exposure to pollutants.

Social behaviors are also disrupted by contaminants, which can hinder learning and communication among individuals. For instance, pollution can impair social interactions and reduce opportunities for social learning, as demonstrated in studies on other animals. Such disruptions can have cascading effects on survival and reproduction, as fish fail to acquire critical information from conspecifics.

Pollution also affects migratory and homing behaviors, which are vital for maintaining life cycles and avoiding contaminated areas. Pesticides and pharmaceuticals have been shown to impair the homing and downstream migration of salmonids. Fish unable to return to their natal rivers may face increased exposure to pollutants in suboptimal habitats.

In conclusion, pollutants not only impair a wide range of fish behaviors but also create positive feedback loops that increase exposure and exacerbate their adverse effects. These disruptions, combined with impaired cognition and social behavior, compromise the ability of fish to adapt to and navigate their environments, ultimately threatening their fitness and survival. Further research is needed to unravel the neurological and physiological mechanisms underlying these changes and to explore their broader ecological and evolutionary implications.

Further research is essential to confirm the potential links between pollution and increased vulnerability to environmental contaminants through altered fish behavior. Pollution impacts key behavioral traits such as confidence, appetite, and foraging habits, which may increase the likelihood of fish consuming contaminated food. For example, perch (*Perca fluviatilis*) exposed to psychiatric medications demonstrated increased boldness and activity, initiating feeding earlier compared to control fish. While this suggests that pollution-induced behavioral changes could enhance susceptibility to contamination in natural environments, these hypotheses require empirical validation.

In summary, pollution-driven alterations in curiosity, sociability, memory, learning, appetite, boldness, and foraging habits can significantly impact fish fitness by creating positive feedback loops. These feedback loops may increase exposure to environmental or dietary contaminants, thereby amplifying the effects of pollution on individual and population health. However, current evidence remains largely circumstantial, and additional experimental research is needed to test these concepts further. Pollution also influences energy allocation, as detoxification and repair processes are metabolically costly. Organisms exposed to pollutants may exhibit heightened activity and increased foraging frequency, which could inadvertently elevate their exposure to dietary contaminants. For instance, crucian carp (*Carassius* spp.) fed polystyrene nanoparticles through the food chain displayed altered feeding behaviors and changes in activity levels, likely driven by increased energy demands and/or changes in brain structure. These findings underscore the need for further research to explore the interactions between pollution, behavior, and energy dynamics in aquatic ecosystems.

Multiple Stressor Effects on Behavior and Fitness

Pollution-induced behavioral alterations in fish are often exacerbated when combined with other environmental stressors, such as predation, diseases, or climate change. For example, pollution has been shown to impair predator escape responses by altering activity levels, aggression, and cognitive abilities. Copper exposure damages olfactory nerve cells in fathead minnows (*Pimephalespromelas*), reducing sensitivity to danger cues and thereby increasing vulnerability to predation. Similarly, exposure to organophosphate pesticides compromises the predator avoidance ability of banded tetra (*Astyanax aeneus*).

Biological stressors like parasites also interact with pollutants to influence behavior and physiology. Resistance to environmental and parasitic stressors often involves shared neurophysiological pathways, creating significant interactions between these stressors. Additionally, climate change and rising water temperatures may intensify or alter the effects of pollutants by modifying their chemical properties or influencing neurophysiological pathways.

Pollution as a Revealing or Masking Factor of Behavioral Syndromes

Behavioral syndromes, which represent consistent groupings of traits such as boldness, activity, and sociability, play a critical role in determining fitness and evolutionary trajectories. Pollution can alter the structure of these syndromes, either enhancing or weakening trait correlations. For example, aggressive and bold *Gasterosteus aculeatus* individuals tend to exhibit higher fitness by reducing predation risk. However, pollution-induced stress can disrupt these beneficial trait linkages, leading to maladaptive behaviors.

Pollutants often trigger stress responses, such as elevated cortisol levels, which can affect energy balance, food intake, and metabolism. Stress may enhance the expression of syndromes by strengthening trait correlations, as seen in perch (*Perca fluviatilis*) exposed to the anti-anxiety drug oxazepam, which reinforced links between boldness and activity. Conversely, stressors may mask trait correlations by suppressing behavioral variation. For instance, fluoxetine exposure reduced behavioral consistency in Siamese fighting fish (*Betta splendens*;), while zinc exposure in damselflies (*Ischnura* spp.) had no measurable effects on stress reactivity or performance. Pollution can also act as a form of natural selection, favoring specific trait combinations in polluted environments. For example, pleiotropic genes may constrain the evolution of behavioraldefenses against pollution, resulting in stable trait syndromes However, physiological trade-offs caused by resource limitations may drive divergent trait combinations across populations exposed to different stressors

Evolutionary Divergence in Behavior Under Pollution

Long-term exposure to pollution can lead to local adaptation in fish populations. For instance, killifish (*Fundulusheteroclitus*) in highly polluted environments have evolved genetic adaptations to tolerate organic pollutants. However, the contributions of genetic and plastic responses to pollution-induced behavioral divergence remain unclear.

In brown bullhead (*Ameiurus nebulosus*) from polluted and non-polluted rivers, behavioral differences in aggression were observed only in the F0 wild-caught generation, making it difficult to separate genetic and plastic influences. Similarly, guppies (*Poecilia reticulata*) from polycyclic aromatic hydrocarbon (PAH)-polluted rivers exhibited behavioral divergence that persisted across multiple generations in common garden conditions, suggesting a genetic basis for these differences. However, limited evidence exists for adaptive plasticity that mitigates the negative fitness impacts of pollution, particularly in unpolluted environments.

Adapting to pollution may impose fitness costs in non-polluted environments. For example, reduced exploration due to pollution may limit toxicant uptake in contaminated areas but become maladaptive when food resources are scarce. Additionally, the costs of adapting to one stressor, such as pollution, may reduce the ability to cope with others, such as diseases.

II. CONCLUSION

Understanding the interactions between pollution and other stressors is crucial for predicting how wild fish populations respond to environmental change. Pollutants not only alter behavior and cognition but also disrupt behavioral syndromes, leading to trait variability and potential evolutionary divergence. Future research should investigate how these behavioral and physiological disruptions influence evolutionary trajectories, particularly in ecosystems experiencing rising pollution levels. Bridging ecotoxicology, behavioral ecology, and evolutionary biology will enhance our ability to predict the long-term impacts of pollutants on fish populations and ecosystem resilience.

REFERENCES

[1] Anttila, K., Dhillon, R. S., Boulding, E. G., Farrell, A. P., Glebe, B. D., Elliott, J. A. K., et al. (2013). Variation in temperature tolerance among families of Atlantic salmon (Salmo salar) is associated with hypoxia tolerance, ventricle size and myoglobin level. J. Exp. Biol. 216, 1183–1190. doi: 10.1242/jeb.080556

[2] Arkoosh, M. R., Clemons, E., Huffman, P., Kagley, A. N., Casillas, E., Adams, N., et al. (2001). Increased susceptibility of juvenile chinook salmon to Vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries. J. Aquat. Anim. Health 13, 257–268. doi: 10.1577/1548-8667(2001)013<0257:isojcs>2.0.co;2

[3] Ashauer, R., Thorbek, P., Warinton, J. S., Wheeler, J. R., and Maund, S. (2013).A method to predict and understand fish survival under dynamic chemical stress using standard ecotoxicity data. Environ. Toxicol. Chem. 32, 954–965.a doi: 10.1002/etc.2144

[4] Bell, A. M., and Sih, A. (2007). Exposure to predation generates personality in threespined sticklebacks (Gasterosteus aculeatus). Ecol. Lett. 10, 828–834. doi: 10.1111/j.1461-0248.2007.01081.x

[5] Brady, S. P., Richardson, J. L., and Kunz, B. K. (2017). Incorporating evolutionary insights to improve ecotoxicology for freshwater species. Evol. Appl. 10, 829– 838. doi: 10.1111/eva.12507

[6] Braunbeck, A., Streit, A., and Hinton, A. (eds) (2013). Fish Ecotoxicology. Basel Birkhäuser: Birkhäuser Verlag.

[7] Critchell, K., and Hoogenboom, M. O. (2018). Effects of microplastic exposure on the body condition and behaviour of planktivorous reef fish (Acanthochromispolyacanthus). PLoS One 13:e0193308. doi: 10.1371/journal.pone.0193308

[8] Schiedek, D., Sundelin, B., Readman, J. W., and Macdonald, R. W. (2007). Interactions between climate change and contaminants. Mar. Pollut. Bull. 54, 1845–1856. doi: 10.1016/j.marpolbul.2007.09.020