*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 24, No. 3 (2023)
http://www.veterinaria.org
Article Received: 19 September 2023; Revised: 20 October 2023; Accepted: 29 November 2023

# Exploring the Impact of Biochemical Factors on Fish and Their Cognitive Behavior: A Comprehensive Review

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**Abstract**

Numerous pollutants are being introduced into aquatic ecosystems both directly and indirectly as a result of industrialization and urbanization. The evaluation of toxicity has made extensive use of behavioral bioassay. Evaluating growth and reproduction requires a lengthier bioassay; behavior-based bioassay is quicker, more sensitive and more ecologically relevant. Behavioral bioassay presents a more promising option for risk evaluation of toxicants than lethality assessing bioassay. When it comes to the health of the exposed population, behavioral changes offer early warning signs that other routine testing overlooks. Behavior is an effect at the organism level and refers to the response, action, or operation of a system under specific conditions. We explain this by saying that our knowledge of how behavior reacts to chemical stress might grow. As a result, in the current environment, it is necessary to design fresher, more efficient techniques for researching behavioral responses. Fish behavior changes provide an effective way to gauge changes in the surrounding environment.

**Keywords**: Stressors, Toxicants, Behavior, Bioassay

## INTRODUCTION

Mercury (Hg) and other industrial pollutants like persistent organic pollutants (POPs) have not been used or produced in large quantities in the circumpolar Arctic. However, long-range atmospheric transport, in addition to ocean currents and rivers, carries POPs into the Arctic from more southerly latitudes. They are brought there by their precursors, degradation products and metabolites (1). Hydrogen is a chemical element that is present in many different things, most notably hydrocarbons, while being difficult to obtain (2). Despite recent improvements, hunger and malnutrition continue to be serious global issues. The United Nations Food and Agriculture Organization estimate that 11% of people globally live in poverty and lack access to enough nutrient-rich food, which is necessary for human health (3). Concern has been raised since the early 2000s regarding the existence of micro plastics in the marine environment. The problem of micro plastics infiltrating soil has received increased attention lately (4). Polycyclic aromatic hydrocarbons (PAHs), which have a high lipophilicity and stay in the environment for a substantial amount of time, are known to be the dangerous constituents of crude oil. Three-ringed (tricyclic) PAHs are the most harmful and cardiotoxic to fish in their delicate early-life stages (ELS), according to several studies analyzing the effects of crude oil exposure (5). The physiological functions of omega-3 unsaturated fatty acids are numerous and significant. They have the ability to lower blood cholesterol, regulate physiological and biochemical processes, promote the growth of the brain, enhance memory, aid in the formation of the developing brain in a baby and bolster anti-inflammatory properties (6). Animals have a high prevalence of ontogenetic dietary shifts (ODSs) or alterations in diet consumption that take place throughout an individual consumer's lifetime. Fish has been recognized as a readily available and significant source of protein for nutraceuticals, providing benefits to people

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worldwide. Furthermore, fish and other marine animals make up around half of the biodiversity. These species are a great source of novel bioactive chemicals that are linked to ongoing improvements in human health (7). The most studied organisms for ODSs are fish, amphibians and insects. The well-researched instances in insects and amphibians are connected to transformation and occasionally drastic changes in habitat utilization, including moving from freshwater to terrestrial settings (8).

The study (9) suggests that fluctuations in temperature can trigger metabolic alterations that could impact the well-being and conduct of fish. Fish plasticity and thermal acclimation are supported by processes that are revealed by this combination approach. In nature, markets are created when parties engage in the exchange of goods and services. To analyze the viability and possible uses of various Environmental Enrichment (EE) tactics to enhance fish welfare on a commercial scale, they evaluate the body of research on EE and impact on the well-being of a variety of farmed fish species (10). A practical approach is presented here to handle the technological issues of delivering enrichment for farmed fish, as well as the design, validation and implementation of EE by the aquaculture industry (11). DHA's physiological (functional) and biochemical (mechanistic) activities in neuronal cell membranes about G-protein coupled receptors (GPCRs) the paper concentrates on the distinct neuro-ecological technique. They connect the metabolic reliance on dietary omega-3 PUFA to the coevolution of these brain processes (12). The study (13) demonstrates the constant effects of non-lethal Triclocarban (TCC) concentrations on teleost fish behavior, cognitive function and brain function. The non-assimilation of excess carbon dioxide by ocean water, a condition shared by fish species, algae and coral reefs in marine settings, upsets the ocean's food chain (14). The study (15) examines recognition memory and mechanisms of action in response to prolonged exposure to ecologically relevant BPS concentrations, with particular attention on the brain's glutamatergic/ERK/CREB system. The study (16) explains the effects of strong water currents on fish physiology, behavior and ultimately fish welfare. Fish grow weary and become trapped on the cage wall if ambient current speeds are higher than their swimming capabilities, which results in unsatisfactory welfare. The ability to swim will be influenced by the current speeds' duration and amplitude. The study (17) highlights the key areas that require more investigation and to provide an overview of what is known about the effects of diarrhoeic shellfish poisoning (DSP) toxins. Fish exposed to DSP poisons show a variety of adverse consequences, ranging from mortality to changes in morphology and behavior. The study (18) compiles and evaluates the detrimental effects that different formulations of glyphosate have on fish behavior at different developmental stages. Furthermore, behavioral abnormalities were linked to additional detrimental consequences of glyphosate, including energy imbalance, stress reactions, inhibition of AChE and disruptions of the body's endocrine system and physiological processes. Major Depressive Disorder (MDD) is a crippling illness that is estimated to afflict 280 million individuals globally. The interaction of biological, psychological and societal elements results in the complex phenomenon. Strong evidence indicates that MDD is an illness that arises from an evolutionary mismatch and bad lifestyle choices (19). The study (20) provides examples of how animals' nervous systems have adapted to rapidly changing environmental conditions by changing their behavior. The need for further investigation into the neurobiology of dynamic ecosystems is highlighted by our limited comprehension of the cellular, molecular and circuit-level component mechanisms underpinning these behaviors.

## MATERIALS AND METHODS

Fish and their cognitive behavior are affected by biological parameters and this research uncovers an intriguing interaction between these aquatic creatures' physiology and behavior. Fish cognitive capacities are shaped in large part by biological elements, such as hormones, neurotransmitters and other molecular processes. Reactive distance, or the maximum distance at which a fish can locate its food, determines how accessible prey is to a predator fish that feeds visually. Taste buds can be affected by contaminants, making it difficult for them to identify food. This becomes clear when we dive more into the complex realm of fish cognition. This section investigates how

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biochemical factors affect fish and their cognitive behavior. The behavioral stress assessment in fish is displayed in Figure (1).

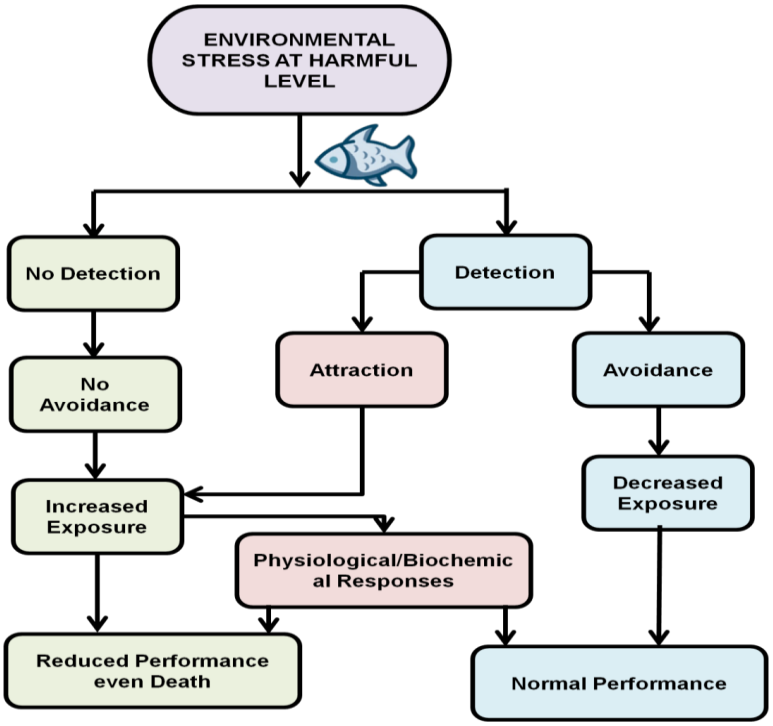


**Figure (1).** Behavioral stress assessment in fish

(Source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTp5ItUJe8oru1e-yPSYaNuFrvQMos9G8_7yw-wqeglRf3lt5xT**)**

**Feeding habits**

Fish behavior changes can provide insights into behavioral changes that are linked to physiological indicators in aquatic animals. Behavior connects ecological processes and physiological function and it is highly responsive to chemical exposure and environmental cues. Ecotoxicology is increasingly examining the use of an organism's response to a contaminant to modify behavior and determine the ecologically appropriate risk endpoint. Feeding-related behavioral changes are significant from an ecological perspective (21). This has an impact on finding and getting to the food, which could have an impact on population dynamics and eventually the structure of the community. Since both swimming and avoidance behavior are essential to a fish's ability to survive namely, obtaining food and avoiding dangerous situations they have a direct impact on the appetite of fish.

**Various investigations on the behavioral reactions of metal and pesticide exposure**

Fish that were exposed to fenvalerate poisoning exhibited symptoms such as decreased schooling behavior, erratic swimming, convulsions, surfacing, hyperactivity, mucus secretion in the gills, high cough, head shaking, loss of buoyancy, flaring of the gill arches and agitation prior to death. Fish with affected fish displayed altered behavior toward toxicants, especially pesticides or heavy metals. Fish with their tails facing downward were seen to be hung vertically. At last, the fish settled to the bottom and stopped moving. The investigation showed that the fish

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exhibited delayed opercular movement, inconsistent swimming and surfing behavior because it was unable to maintain posture and stability over time. Fish behavior changes in response to several toxicants are displayed in Table (1).

**Table (1).** Fish behavior changes in reaction to various toxicants

(Source: Author)

| Reference | Fish | Toxicant/ chemical | Changes in behavior |
|---|---|---|---|
| (22) | Common Carp fry | Biopesticide | Impact on Motion Fish that are exposed for 72 hours grow lethargic and as concentration levels rise, so does their activity. |
| (23) | Rainbow trout | Ammonia | Reduced or eliminated the establishment of dominance hierarchies in juvenile |
| (24) | Aquatic snail | Cd | Feeding behavior decreased |
| (25) | Channa punctatus | Endosulphan | Reduced swimming, greater surfacing, elevated opeculum activity and greater secretion of mucus |
| (26) | Anabas testudineus | Triclosan | Bulging and hemorrhagic eyes, surfacing, air golfing, decreased operculum movement and mucus deposition |
| (27) | European Seabass | Microplastic and murcury | Fish swimming speed and resistance time reduction |
| (28) | Clarius garipinus | Bitter leaf Varonia amygdalina | Swimming erratically caused lethargy, respiratory disruption and loss of equilibrium |

**Reproductive Behavior**

Behavioral bioassay has ignored fish reproductive activity, even though fish reproductive behavior has been the subject of several studies and it is ecologically significant and relevant. Reproductive behavior includes behaviors related to courtship, spawning and caring for offspring. The effects of environmental stresses on reproductive output, including the number of normal eggs laid, the hatching rate and the survival rate of swim-up fry, have been documented in several articles; however, the impacts of chemicals on fish courtship behavior have not been well studied. Reproductive behavior is discussed in passing, non-quantitatively, in informal remarks (29). Male spawning individuals displayed "distressed" and hyperactive behaviors. The fathead minnow's ability to reproduce was almost completely abolished after 21 weeks of exposure to chloramine values of 0.085 mg/L while spawning was decreased at concentrations of 0.043 mg/L.

**Swimming behavior**

Swimming behavior is taken into account while evaluating the aquatic environment's physiological state for the presence of pollutants. During toxicological research, swimming is one of the most prevalent and easily evaluated behavioral reactions. Since swimming is essential to many facets of fish biology, a decline in ability might have significant effects on intraspecific and interspecific relationships, which could lower the fitness of the impacted individuals (30). Any organism's response to a chemical will vary depending on its method of action in terms of behavior. Research has been done on how some chemicals, such as tributyltin, chromium polychlorinated biphenyls and chlorpyriphos, alter behavior.

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**Periodic Reactions to Oxygen and Temperature**

Abiotic substances can serve as guiding factors to affect fish dispersal, especially when they exist as gradients. The two most evident and extensively researched guiding factors for fish are oxygen and temperature.

**Concentration of Toxicants**

The water medium was changed every 24 hours and the test substance was added at the appropriate concentration. The test drug concentrations during the short-term definitive testing ranged from the highest concentration at which death was 0% to the lowest concentration at which mortality was 100%. Table (2) and Figure (2) present the fingerling C. carpio death rate.

**Table (2).** Death rate of C. carpio fingerlings

(Source: Author)

| Number of live fish out of eleven | Chlorpyrifos concentration (mg/L) | Log concentration | % Death rate | Probit Kil |
|---|---|---|---|---|
| 11 | 0.110 | -0.820 | 0 | - |
| 10 | 0.120 | -0.800 | 10 | 2.72 |
| 9 | 0.130 | -0.860 | 20 | 4.26 |
| 8 | 0.145 | -0.850 | 30 | 4.50 |
| 7 | 0.160 | -0.805 | 40 | 4.70 |
| 6 | 0.162 | -0.780 | 50 | 5.02 |
| 5 | 0.170 | -0.765 | 60 | 5.30 |
| 4 | 0.175 | -0.748 | 70 | 5.42 |
| 3 | 0.185 | -0.700 | 80 | 5.92 |
| 2 | 0.190 | -0.620 | 100 | - |

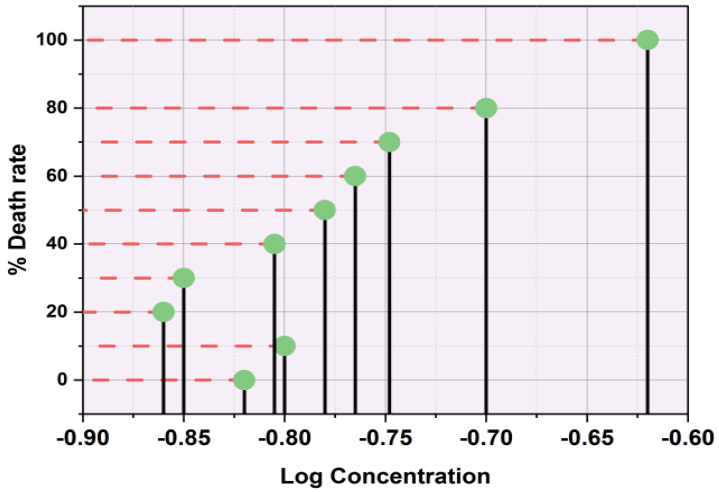


**Figure (2).** Fingerling C. carpio Death rate

(Source: Author)

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The acute toxicity of chlorpyrifos was found to be 0.260 mg/L (95-hour LC50) in the freshwater fish C. carpio. Table (3) shows the upper and lower 96% confidence bounds.

**Table (3).** Acute toxicity (LC50 after 95 hours), slope and 96% confidence intervals

(Source: Author)

| **Pesticide** | **Mound** | **95 h LC50 (mg/L)** | **96% Confidence limits** | |
|---|---|---|---|---|
| | | | Upper bound | Lower bound |
| Chlorpyrifos | 1.007 | 0.260 ± 0.005 | 0.158 | 0.251 |

## DISCUSSION

Fish can benefit from the heterothermal nature of aquatic settings because they are highly mobile creatures with acute temperature discrimination skills. They do this by actively seeking out and occupying some temperatures while avoiding others. A list of various fish species' selection and/or avoidance temperatures has been supplied. Because fish could respond to temperature through behavior, worries about thermal contamination of aquatic ecosystems from the electricity-generating industry have been mooted. Fish's behavioral reactions to oxygen gradients can be obscured by factors like as temperature, light, carbon dioxide, accessibility to the surface layer, availability of alternate respiratory locations and the presence of aquatic or aerial predators (31). Despite the significance of fish behavior in reaction to oxygen, it was unable to locate any research that used fish behavior in response to oxygen avoidance or attraction as a bioassay for other stressors, namely chemical ones.

## CONCLUSION

This study highlights the complex interaction between the physiological processes of aquatic species and their capacity for perception, learning and environmental adaptation by investigating the effects of biochemical parameters on fish and their cognitive behavior. The results show that fish cognitive development is influenced by biochemical elements, including hormones, neurotransmitters and other molecular signaling pathways. The knowledge gathered from this investigation might be useful for managing fisheries, aquaculture and environmental conservation. Research on the relationship between biochemical variables and fish cognitive behavior provides new directions and insightful information that can be used to manage aquatic environments and protect these amazing creatures.

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