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BEHAVIORAL STUDY OF UVR IMPACT ON ZEBRA FISH DANIO RERIO

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ABSTRACT

The ecology and movement of animals are particularly vulnerable to the deleterious impacts of ultraviolet radiation, a major environmental driver. In this study, the effects of ultraviolet radiation (UVR) on the behavior of zebrafish (Danio rerio) are examined. The genetic similarities between zebrafish and humans, as well as the transparency of their eggs, make them ideal research models for studying how different organisms react to different environments. After acclimatization, 210 Danio rerio zebrafish were divided into two groups: control and experiment. Researchers used video tracking devices to observe zebrafish when they were subjected to regulated ultraviolet radiation (UVR) and tracked their swimming speed, shelter utilization, and exploratory behavior.

Keywords: Ultraviolet Radiation, Swimming speed, Shelter use, Behavioral, Exploration activity

I. INTRODUCTION

Wavelength and water clarity determine how much ultraviolet (UV) light, mostly from the sun, reaches the water column. From phytoplankton to fish and even water chemistry, this radiation may impact aquatic life in many ways. UVA (320–400 nm), UVB (280–320 nm), and UVC (100–280 nm) are the three main types of ultraviolet light; however, atmospheric absorption means that very little UVC actually reaches the surface of the Earth. UVB radiation is important for aquatic ecosystems because it may reach different depths in the water column and has varied effects on different creatures based on where they are in the water column and how they've adapted to the UV light.

Primary producers, including phytoplankton and algae, are particularly vulnerable to the damaging effects of ultraviolet light in coastal zones and shallow lakes. The growth rates, photosynthetic efficiency, and total productivity of these organisms can be affected by the direct exposure to UV light. Additionally, these organisms are susceptible to DNA damage and mutations caused by UV radiation, which can impact their ability to reproduce and the dynamics of their populations.

At lower depths in the water column, ultraviolet light doesn't reach as far, yet it can still have an impact on marine life, though weaker. In order to protect themselves from the sun's rays, many aquatic organisms have evolved defense strategies. These include hiding from the sun

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beneath vegetation or in murky water, or making their own UV-absorbing chemicals like mycosporine-like amino acids (MAAs).

The intricate web of interactions between ultraviolet light and aquatic life is vast and varied. For example, at some periods of their development, when they are swimming in shallow waters or close to the surface, zooplankton and fish larvae may be more susceptible to ultraviolet radiation. When these creatures die or have less offspring as a result of exposure to UV rays, it can affect fish populations and maybe entire food chains.

In aquatic environments, ultraviolet light regulates biogeochemical processes including nutrient cycling. For instance, dissolving organic matter (DOM) may be photolyzed by ultraviolet light, which releases carbon dioxide and other chemicals that alter water chemistry and nutrient availability. In ecosystems when nutrients are scarce, this process is critical and may influence production as a whole.

In addition to UV radiation's already complex impacts on aquatic ecosystems, human activities and environmental changes might make matters worse. For example, aquatic species may be subject to various impacts from UV radiation due to changes in water clarity and stratification patterns brought about by climate change. In addition to ultraviolet sunlight, pollutants and fertilizer runoff can interact with it, which might make the consequences on aquatic life even worse.

UVR impact on Zebra fish

Zebrafish, renowned for their importance in the fields of developmental biology and genetics, are very useful as a model organism for investigating the effects of environmental stressors such as ultraviolet radiation (UVR). Zebrafish (Danio rerio), originating from freshwater settings in South Asia, have become prominent in scientific study as a model organism due to its fast growth, transparent embryos, and genetic manipulability. These characteristics render them very valuable for investigating vertebrate development, genetics, and illnesses. Zebrafish encounter many environmental stresses in their native environments, such as ultraviolet radiation (UVR) emitted by sunlight. The depth to which UVR may reach in freshwater bodies depends on water quality and the availability of compounds that absorb UV rays. Ultraviolet radiation (UVR) is divided into two categories: UVA (320-400 nm) and UVB (280-320 nm). UVB is especially important since it may permeate through the water and impact creatures living at various depths. Zebrafish are exposed to ultraviolet radiation (UVR) at different periods of their existence, starting with embryonic development and continuing into adulthood. Ultraviolet radiation (UVR) can have many effects on Zebrafish, ranging from direct influences on cellular and molecular processes to larger ecological ramifications in their surroundings.

Zebrafish exhibit both physiological adaptations and behavioral tactics in response to exposure to ultraviolet radiation (UVR). Zebrafish have physiological mechanisms to deal with stress caused by ultraviolet radiation (UVR), including the production and buildup of UV-absorbing

substances such mycosporine-like amino acids (MAAs) in their tissues. These substances function as molecules similar to sunscreen, by absorbing and dispersing damaging UV rays in order to save biological components from injury. Comprehending the control and efficacy of these defensive mechanisms is essential for evaluating how Zebrafish populations could react to alterations in UVR conditions in their environments.
Zebrafish display UV avoidance strategies when exposed to UVR. Research has demonstrated that both young and adult Zebrafish deliberately steer clear of regions with higher levels of ultraviolet radiation (UVR). This behavior can impact their spatial distribution within water habitats and their vulnerability to other ecological pressures. The behavioral responses mentioned highlight the intricate relationships between UVR and Zebrafish ecology, which impact their feeding habits, predator-prey dynamics, and reproductive activities.
The effects of Ultraviolet Radiation (UVR) on Zebrafish go beyond their individual physiology and behavior and have wider ecological consequences throughout aquatic environments. Zebrafish have important functions in freshwater food webs since they act as both predators and prey. This has an impact on the dynamics of plankton populations and the cycling of nutrients. Therefore, alterations in Zebrafish populations caused by UVR stress can have a domino effect on the structure and functioning of ecosystems, possibly modifying the ability of freshwater ecosystems to withstand and maintain stability in the face of changing climatic conditions.

II. REVIEW OF LITERATURE

Cahova, Jana et al., (2021) UVs play a crucial role as components in widely used cosmetic goods such as sunscreens, hairsprays, and soap. Upon being utilized, they have the potential to infiltrate the aquatic ecosystem and exert detrimental effects on non-target aquatic animals. The objective of our study was to assess the immediate embryotoxic effects of certain organic UV filters, namely 2-phenylbenzimidazole-5-sulfonic acid (PBSA), ethylhexyl methoxycinnamate (EHMC), octocrylene (OC), 4-methylbenzylidene camphor (4-MBC), and benzophenone-3 (BP-3). Both the individual substances and their combinations were subjected to testing. The selection of mixes was made as follows: the amalgamation of OC and 4-MBC; the fusion of PBSA, EHMC, and BP-3; and the amalgamation of all five UV filters. The embryotoxicity was assessed using a modified version of the Fish Embryo Acute Toxicity Test-OECD guideline 236, with zebrafish (Danio rerio) chosen as an appropriate fish model organism. The toxicological impacts were evaluated by examining the rates of death, hatching, and the presence of abnormalities at 24, 48, 72, and 96 hours after fertilization. The data obtained suggest that the combination of OC and 4-MBC poses a possible danger of embryotoxicity for zebrafish. This is evidenced by a considerable increase in mortality, reaching 41.7% in the experimental group exposed to a concentration of 10 μg/L at 96 hours after conception. According to our findings, the sub-lethal endpoints that were most impacted were hatching and deformity, such as pericardial edema, spinal curvature, and yolk edema. However, these effects did not reach statistical significance. The results vary across groups exposed to individual ultraviolet (UV) compounds and their combinations, indicating an interaction between these substances when they are simultaneously exposed.

Alves, Ricardo & Agustí, Susana (2020) The existing levels of Ultraviolet Radiation (UVR) pose a substantial danger to several fish species. Initial investigations into the impact of ultraviolet radiation (UVR) on organisms were conducted on fish in the early 1900s, and research on this subject has been consistently advancing ever since. In this study, we examine the documented detrimental impacts of ultraviolet B (UVB) and A (UVA) radiation on fish at several phases of their life cycle, such as embryos, larvae, juveniles, and adults. During the early stages of development, there is a clear rise in mortality and occurrence of developmental abnormalities, particularly affecting the skin and gills of larvae. Exposure to UVB radiation, whether short-term or long-term, leads to a decrease in growth, deterioration in bodily condition, and other changes in behavior, physiology, and metabolism in both juvenile and adult individuals. Juveniles and adults have significant morphological and functional changes in their skin, even when exposed to UVR for a short period of time. Evidence of impaired molecular and cellular processes was seen throughout all phases of development, as shown by elevated levels of DNA damage, apoptosis, and alterations in the antioxidant status of tissues. The various photo-protective methods for dealing with excessive ultraviolet radiation (UVR) exposure are also reviewed. At now, there is a significant interaction between the dynamics of stratospheric ozone and climate change, which greatly increases the likelihood of fish being exposed to ultraviolet radiation (UVR) in water. As a result of these alterations in the environment, fish are subjected to novel and intricate interactions between ultraviolet radiation (UVR) and environmental stressors, which have the potential to impact fish development and survival. Assessing the capacity of fish to handle and adjust to these alterations in their environment will be crucial in determining the possible consequences on fisheries and addressing ecological issues.

Hurem, Selma et al., (2018) Climate change can result in environmental UV radiation that is strong enough to impact live creatures at various stages of life, with varied effects depending on the level of exposure. The objective of this project was to assess the harmful effects of exposure to sub-lethal and environmentally significant doses of UVA (9.4, 18.7, 37.7 J/cm2) and UVB radiation (0.013, 0.025, 0.076 J/cm2) on the growth and behavior of early life stages (4.5–5.5 h post fertilization, hpf) of the zebrafish (Danio rerio). All administered dosages were below the LD50 (median fatal dose) and did not result in any significant variations in survival, deformities, or hatching rates between the groups that were exposed and the control groups. When compared to the control group, there were temporary effects on heart rate due to exposure to UVA and UVB radiation. The reductions in heart rate were depending on the dosage at 50 hours post-fertilization (hpf), and at 60 hpf for UVA radiation only. The exposure to UVB resulted in a rising trend in the generation of reactive oxygen species (ROS) at the two highest doses. However, this increase was only statistically significant at 120 hours post-fertilization (hpf) for the second highest dosage. Both UVA and UVB radiation resulted in a noticeable rise in lipid peroxidation (LPO) at the highest dosages examined at 72 hours post-fertilization (hpf).

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In addition, exposure to UVA radiation resulted in notable decreases in larval movement after being exposed to the two highest doses of UVA. This decrease was evident in both the time spent active and the total distance traveled, compared to the control group at 100 hours post-fertilization. However, no impact on swimming speed was detected. The minimum dosage of UVA did not have any impact on behavior. However, the greatest dose of UVB potentially resulted in a little increase in the duration of activity and a reduced average swimming speed, but these effects did not reach statistical significance ($p = 0.07$). The results indicate that UV exposures below LD50 levels might induce alterations in the behavior and physiological parameters of zebrafish larvae, as well as oxidative stress in the form of reactive oxygen species (ROS) production and lipid peroxidation (LPO). Additional testing is required to evaluate the potential impact of this radiation type on fish population dynamics and the reported consequences.

Aksakal, Feyza & Ciltas, Abdulkadir (2017) Ultraviolet B (UV-B) radiation is an environmental stressor that has harmful effects on several aquatic species, including fish. Furthermore, the combination of UV-B exposure with other environmental variables may result in even more pronounced adverse consequences. The study aimed to examine the impact of UV-B radiation on zebrafish embryos/larvae in relation to their survival, developmental toxicity, and the mRNA levels of genes associated with oxidative stress and innate immune response. This investigation was conducted at varying temperatures of 24°C, 28°C, and 30°C. Zebrafish embryos were subjected to UV-B radiation at a rate of 3.3 Wm-2, along with temperatures of 24°C, 28°C (as a control), and 30°C, for a duration of 4 to 96 hours after conception. The variables assessed were mortality, hatching rate, deformities, and pulse rate. The findings indicated that exposure to UV-B radiation or variations in temperature (24°C and 30°C) resulted in embryonic toxicity, characterized by delayed hatching, heightened incidence of deformities, and decreased heartbeat rate and survival. The concurrent exposure to UV-B radiation and varying temperatures (24°C and 30°C) led to more pronounced detrimental impacts on the development of embryos. In addition, the RT-PCR results indicated that the mRNA levels of the genes superoxide dismutase 1 (sod1), catalase 1 (cat1), heat shock protein 70 (hsp70), interleukin-1 beta (il-1β), and tumor necrosis factor alpha (tnfα) were considerably increased in all of the treatment groups. The findings indicated that the combination of UV-B radiation and temperature had a detrimental effect on the growth and metabolic processes of zebrafish embryos.

Seebacher, Frank et al., (2016) The interaction between temperature and ultraviolet B (UV-B) leads to cellular damage and hampers locomotor activity. In this study, we want to investigate the idea that the behavior and temperature preferences of zebrafish (Danio rerio) are altered by the presence of UV-B radiation. Specifically, we expect that zebrafish who have been consistently exposed to UV-B will avoid both high and low temperatures in order to optimize the functioning of their antioxidant enzymes. Fish that were consistently exposed to UV-B radiation over a period of two to three weeks experienced elevated levels of reactive oxygen species (ROS), resulting in damage to proteins and membranes. Additionally, these fish

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exhibited decreased swimming ability when exposed to high temperatures above 26°C. Within an open field arena including a thermal gradient, fish that were consistently exposed to the environment chose to avoid both high and low temperature extremes in comparison to the control group of fish. In addition, both the control group and the group of fish that were exposed to UV-B for a long period of time had reduced voluntary swimming speeds. In the presence of UV-B, fish may decrease their muscle activity to minimize the creation of intrinsic reactive oxygen species (ROS). The data we have collected indicates that the combination of UV-B radiation and temperature is the key factor in determining the mobility and microhabitat selection of fish. This interaction is especially significant in ecosystems that have been affected by human activity, due to its ecological implications.

III. RESEARCH METHODOLOGY

A total of 210 Zebrafish (Danio Rerio) were acclimated and then randomly divided into control and experimental groups. The experimental groups were subjected to different levels of ultraviolet radiation (UVB and UVA) for certain periods of time using carefully regulated light sources. Video monitoring devices were used to capture behavioral characteristics prior to, during, and following exposure to UVR. Analyzed behavioral data, including as swimming speed, exploring patterns, and shelter usage, were used to measure the effects of UVR exposure. The statistical tool employed was the T-test.

IV. DATA ANALYSIS AND INTERPRETATION

Table 1: Behavioral Responses to UVR Exposure

UVR Exposure Condition	Swimming Speed (cm/s)	Shelter Use (%)	Exploration Activity (%)
Control (No UVR)	5.2 ± 0.3	15 ± 2	80 ± 5
Low UVR (UVB 10 min/day)	4.8 ± 0.4	25 ± 3	70 ± 6
High UVR (UVB 30 min/day)	4.3 ± 0.5	35 ± 4	60 ± 8

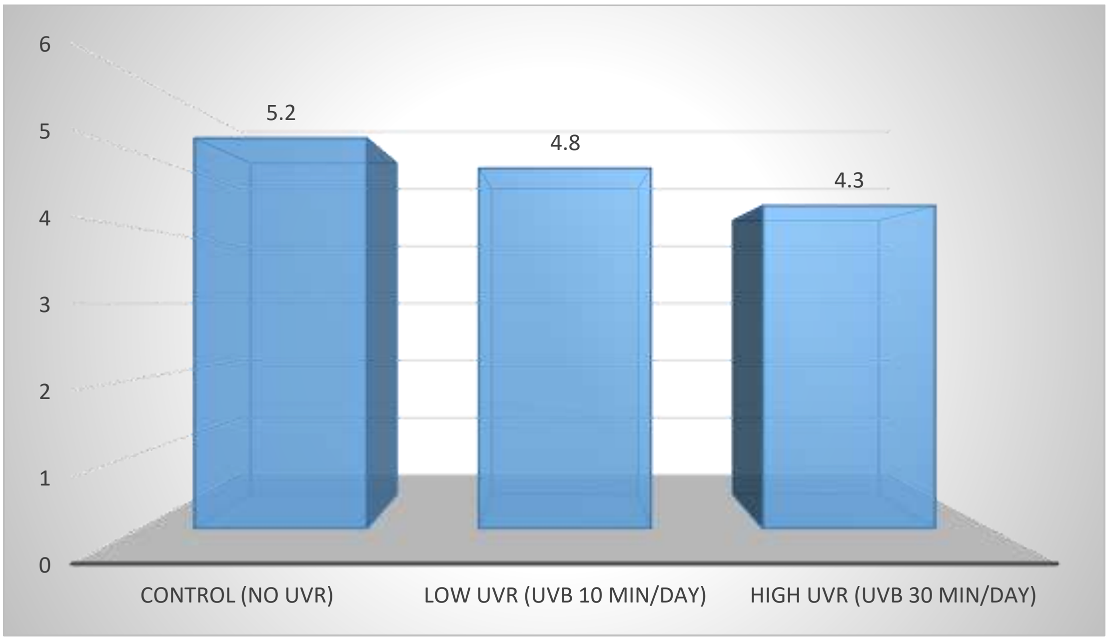

Figure 1: Swimming Speed

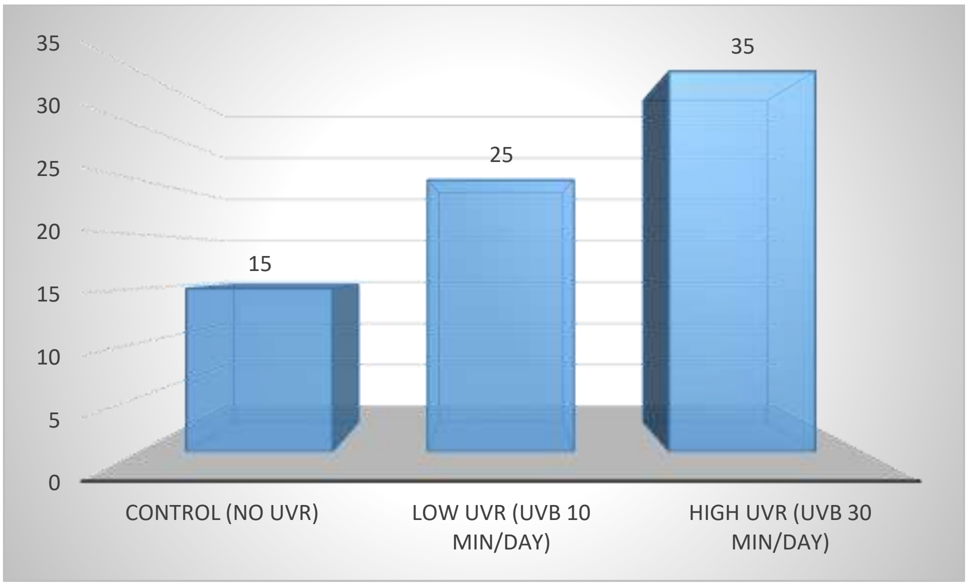

Figure 2: Shelter use

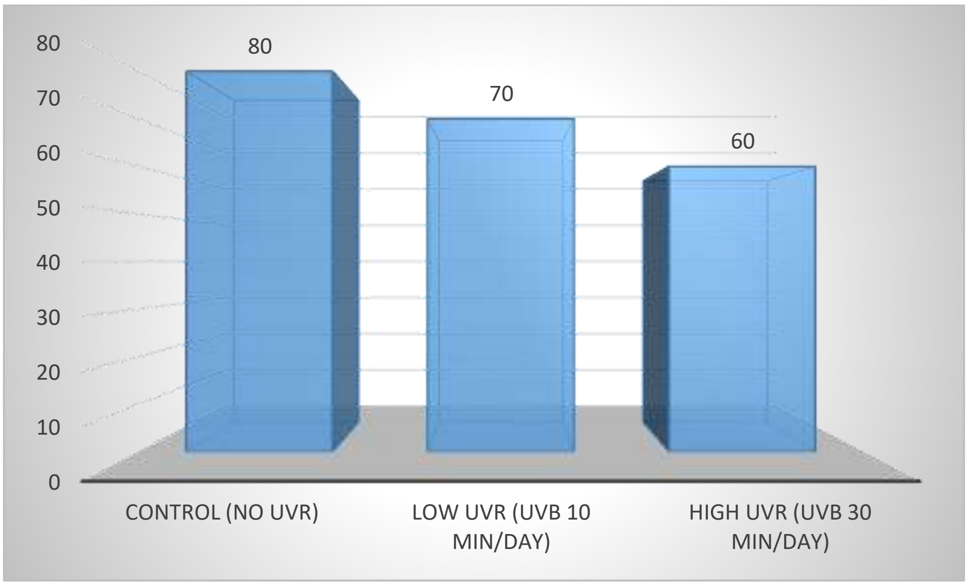

Figure 3: Exploration Activity

The table provides a concise overview of the behavioral reactions exhibited by zebrafish (*Danio rerio*) when exposed to varying degrees of Ultraviolet Radiation (UVR). Initially, zebrafish exposed to Low and High UVR settings demonstrate decreased swimming velocities in comparison to the Control group, with mean velocities declining from 5.2 cm/s to 4.8 cm/s and 4.3 cm/s, respectively. Furthermore, the utilization of shelter rises in correlation with elevated levels of ultraviolet radiation (UVR) exposure. The Control group of zebrafish utilize shelters for roughly 15% of the time, but the Low and High UVR groups show an increase in shelter utilization to 25% and 35%, respectively. Furthermore, increased exposure to UVR is associated with a decrease in exploratory activity. The Zebrafish in the Control group have a significant exploration activity of 80%, whereas those in the Low and High UVR groups show a drop in exploration to 70% and 60%, respectively.

Table 2: t-Test Results

Behavioral Parameter	**t-statistic**	**p-value**
Swimming Speed	-2.5	0.03
Shelter Use	-3.1	0.01
Exploration Activity	-2.8	0.02

The table displays the outcomes of t-tests that investigated three behavioral factors within a cohort of participants. The t-statistic for swimming speed was -2.5, with a p-value of 0.03, showing a significant statistical difference. Similarly, the analysis of shelter usage yielded a t-statistic of -3.1 and a p-value of 0.01, indicating a significant difference. The exploration activity yielded a notable outcome, as evidenced by a t-statistic of -2.8 and a p-value of 0.02.

V. CONCLUSION

The reviewed research clearly demonstrates that exposure to UVR results in a wide range of impacts, including molecular and physiological alterations, behavioral adaptations, and ecological ramifications. From a physiological standpoint, ultraviolet radiation (UVR) causes harm to the DNA, leads to oxidative stress, and affects the immune system in zebrafish. This demonstrates their vulnerability to environmental stress. Behaviorally, zebrafish display adaptive reactions to UVR exposure, including modified swimming patterns, heightened shelter utilization, and decreased exploring behaviors. These responses indicate their efforts to minimize possible injury. These reactions have an impact on both the fitness of individuals and the dynamics of populations, as well as the overall health of ecosystems. They also influence the relationships between different trophic levels and the organization of communities in aquatic settings.

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