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Research Article

Effects of Ultraviolet Radiation (UVR) on Some Stages of *Clarias gariespinus* (Catfish) Growth

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Abstract

UVR is a stressor that affect ecological and social systems. It has been noted that UVR presents numerous difficulties for aquatic and human worldwide. It's critical to understand how UVR affects *Clarias gariespinus* in order to promote healthy fish growth. This study determined how UVR affected catfish. 172 catfish samples were divided into four groups: UV-A, UV-B, UV-C, and controls. The control group was not exposed, whereas the other groups were exposed to UV-A, UV-B, and UV-C, respectively. The exposure period was 131 days, from 8:00 am to 5:00 pm daily. The result on color change shows that UV-C causes a change in color from dark to pink at the fingerling stage and UV-A causes a change in color from dark to slightly pink at the jumbo size, while no color change was observed in other samples. The result on growth rate indicates that the UV-B sample grew faster throughout the period of study, with the highest growth rates of 18.4, 16.2, 14.1, and 8.6 cm for the UV-B, UV-C, control, and UV-A samples, respectively. The result on the mortality rate of the samples shows that the control sample recorded the highest death rate (23) at the fingerling stage, followed by the UV-A (22), UV-C (19), and UV-B (12) samples. The result depicts that UV-B is capable of a rapid increase in the weight, growth, and life span of catfish; hence, exposure of catfish to UV-B can be adopted by fish farmers to improve the healthy fish growth of their farm.

Keywords

Ultraviolet Radiation, Catfish, Color Change, Weight, Growth, Mortality Rate

1. Introduction

UVR is a stressor that has a wide range of effects on ecological and human systems [1, 2]. Globally, it has been noted that UVR presents several difficulties for both human and aquatic ecosystems [3, 4]. Effects of UVR exposure in fish includes: a decrease in growth, impaired development, and behavioral changes [5, 6], as well as an increase in the mutation rate in fish eggs and larval stages, the emergence of skin and eye lesions, the suppression of the immune system, a decrease in disease resistance, and DNA damage changes [7, 9]. UV-A, which is moderately energetic and less dangerous (UV-A, 320–400 nm) [10, 11], UV-B, which is very energetic and moderately harmful (UV-B, 280–320 nm), and UV-C, which is highly harmful (UV-C, 200–280 nm), are the three spectral bands that are typically used to classify UV radiation [12, 13]. Compared to other UV bands, ultraviolet C is more energetic [14]. It mostly interacts with ozone in atmosphere and little of its amount reach the earth surface [15], it typically does not increase the risk of developing skin cancer [16, 17]. However,

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some artificial sources of UV-C radiation, such as arc welding torches, mercury lamps, and UV sanitizing bulbs used to destroy germs and bacteria (found in water, air, food, and on surfaces), can also emit UV-C radiation [18-20].

The lifecycle stages of fish where UVR damage is most likely to occur are those during early development [21]; however, the tolerance of juvenile and adult fish to UVR exposure appears to be highly sensitive to all UV bands at later development [22-24]. Recent meta-analyses have further confirmed the detrimental effects of UVR on aquatic organisms [25], despite the fact that fish species can adapt a variety of defense mechanisms against UVR's negative effects (such as UV avoidance, the production of UV-absorbing compounds, and DNA damage repair mechanisms) [26].

The seeming decline in the population of fish in water (rivers and ponds) has posed a serious challenge to researchers as this could be attributed to relatively high exposure of water bodies to UV- radiation and other natural factors [27-29]. Currently, there is a substantial interaction between stratospheric ozone dynamics and climate change, increasing the likelihood that fish may be exposed to UVR underneath [30-32]. Fish are exposed to novel and intricate interactions between UVR and environmental stressors as a result of these environmental changes, which may have an impact on fish growth and survival [33-35].

In North Central Nigeria, vegetation around natural ponds and rivers is seriously being destroyed because of construction works and farming activities, leading to high penetration of UVR in the water column. This UVR penetration, if not properly assessed and controlled, could result in a decline in growth, impaired development, changes in behavior, an increase in the mutation rate in eggs and larval stages of fish, the development of skin and eye lesions, suppression of the immune system, a reduction in disease resistance, and DNA damage in fish in North Central Nigeria [36].

Different authors have conducted a number of research on the effects of UV light on aquatic ecosystems, and some of these studies are reviewed below. Ricardo and Susana [8] determine the harmful effects of ultraviolet B (UV-B) and A (UV-A) radiation on fish at various lifecycle stages, and observed the increase in mortality as the most noticeable adverse effect during the early development stages. Using a specialized medium-pressure UV system, Studer [38], Maricela [39] assessed the effects of ultraviolet light treatment on quagga mussel settlement and veliger survival and discovered that mortality rates differed depending on the UV intensity examined. They came to the conclusion that veliger size, ambient water temperature, and UV exposure all affected mortality. In the review of ultraviolet radiation's effects on domestic animals, according to Sherri, [40], UV-B had some beneficial effects on domestic animals, such as preserving the proper internal body temperature for the metabolism of some homoeothermic creatures, maintaining vitamin D metabolism, which is crucial for bone maintenance and growth regulation, hormonal functioning, organ development, and embryogenesis. In his research on how UV radiation increases the toxicity of deep-water horizons, Alloy [3] found that excess UV-B radiation can harm a variety of aquatic animals and aquatic ecosystems. Luke [41] investigated how Ultraviolet-B radiation affected wound fin eggs and larvae and found that these organisms are vulnerable to modest doses of UV-B when exposed for an extended period of time. Lee [42] and Conde [43] investigated how deeply UVR penetrated water. When Llabres and Agusti [44], Holmquist [45] researched UV-B's effects on aquatic life, they noted both beneficial and detrimental outcomes. The absence of information in the literature regarding the effects of UVR on fish in north-central Nigeria necessitated the necessity for this study to ascertain the effects of UVR on *Clarias gariespinus*.

The objective of this study is to determine the effects of UVR on *Clarias gariespinus* in northern Nigeria. A further insight into the determination of the effects of UVR on catfish in North Central Nigeria will boost the production of fish in the region and subsequently provide another regional resource base for the nation. The effects of UVR bands on catfish in North Central Nigeria have not been determined in any reported prior analogous work. Similar studies conducted in other nations either focused on one of the effects of UVR on mammals or other species of fish without due attention to catfish that is widely grown and consumed in North Central Nigeria, suggesting a critical knowledge gap that is likely to be a major contributing factor to the low production of cat fish in North Central Nigeria. By determining the effects of UVR on catfish in north-central Nigeria, this work fills the identified knowledge gap.

2. Materials and Methods

2.1. Study Location / Area

The study location and area are the fish farm of the Department of Fishery and Aquaculture at Joseph Sarwuan Tarka University in Benue State, North Central Nigeria, which is situated geographically in the middle belt region of the country, spanning from the west around the confluence of the River Niger and the River Benue. Benue State is located in the middle belt of Nigeria, and it has a population of 4,256,641 [46]. The state was carved out of the former Benue-Plateau, and the capital city is Makurdi.

2.1.1. Geology of the Study Area

According to the Koppen climate classification, Benue State lies within the tropical Savannah climate and experiences two distinct seasons: the rainy season and the dry season. An air flux from the South Atlantic Ocean characterizes the rainy season, which lasts from April to October with annual rainfall ranging from 100 to 200 mm, while a dusty air flux from the Sahara Desert, known as Harmattan, characterizes the dry season [47], which begins in November and ends in

March. The temperature fluctuates between 22 and 37 ℃. Much of Benue State falls within the Benue Valley, which is believed to be structurally developed. During the tertiary and possible interglacial periods of the Quaternary glaciation, the Benue and Niger valleys, otherwise known as the Niger/Benue trough, were transgressed by the waters of the Atlantic Ocean. As a result, marine sediments form the dominant surface geology of much of Benue State [48].

2.1.2. Relief and Drainage of the Study Area

The land is generally low-lying (averaging 100–250 m) and gently undulating, with occasional inselbergs, knolls, laterite, etc. Some of the boundaries (Cameron, Kwande, and Oju) are hilly terrain with appreciable local relief. The River Benue is the major geographical feature in the state. It is one of the largest rivers in Nigeria. River Katsina- Ala is the largest tributary, while the smaller rivers include Mu, Apa Ogede, Amile, Guma, and Dura. The flood plains are characterized by extensive swamps and ponds. Though Benue State has a high drainage density, many of the streams are seasonal [48].

2.2. Sample Collection

Experimental catfish were purchased from Mondays' fish farm in Makurdi. The samples were all dark in color and were measured before buying, with the average weight and length of sample being 0.9 grams and 4.2 cm, respectively. A total of 172 samples were bought, kept in a safe environment, and transported to the hatchery unit of the Department of Fishery and Aquaculture Joseph Sarwuan Tarka University, where they were kept indoors in acrylic containers (aquaria) and examined.

2.3. Determination of the Effects of UVR on Cat Fish

The samples were kept in four plastic ponds labeled UV-A, UV-B, UV-C, and Control samples. In each group, forty-three (43) samples of cat fish were kept. The groups labeled UV-A, UV-B, and UV-C were respectively exposed to artificial UV-A, UV-B, and UV-C sources from UV lamps and shielded using dark blinds (thick polythene sheets) so as to prevent the interference of external UV irradiance. The plastic ponds were made such that flow through system was ensured throughout the experiment. The ponds were filled up to 75 cm deep, and the artificial UV lamp sources were kept at heights of 40 cm from water surface. The UV sources were switched on from 8 a.m. to 5 p.m. daily for 131 days.

The samples were given equal treatment and the same feeds (coppens) at regular intervals, morning afternoon and evening daily. The ponds were emptied and cleaned every five days to ensure sanity for the fish. The samples were transferred to four different plastic containers before cleaning of the plastic ponds. The effects of UVR on the samples were recorded every five days. Color change of the samples was done by physical observation; growth rate was measured using a meter rule; the weight of the samples was measured using an electronic weighing balance; and mortality rate was determined by physical counting of the samples. The experimental setup was as shown in Figures 1 and 2.

Figure 1. *Experimental Set-up Before Shielding.*

Figure 2. *Experimental Set-up After Shieldin.*

3. Results and Discussion

3.1. Effects of UVR on Some Stages of Cat Fish Sampled

The effects of UVR on the color change, length, weight, and mortality rate of samples were determined, and the results are presented in figures and graphs.

3.1.1. Effects of UVR on the Color of Cat Fish

The effects of UVR on the color change of samples were determined by physical observation, and the result is presented in Figures 3–7.

Figure 3. *Fingerlings Samples obtained from a fish farm (dark in color).*

Figure 4. *Juvenile Size of the Control Sample (Dark in Color).*

Figure 5. *Jumbo Size of sample exposed to Artificial UV-A (Slightly Pink in Color).*

Figure 6. *Jumbo Size of sample Exposed to Artificial UV-B (Dark in Color).*

Figure 7. *Jumbo Size of sample Exposed to Artificial UV-C (Pink in Color).*

3.1.2. Effects of UVR on the Growth Rate (cm) of the Samples

The effects of UVR bands on the growth (cm) of the samples were measured, and the results are presented in Figures 8–10.

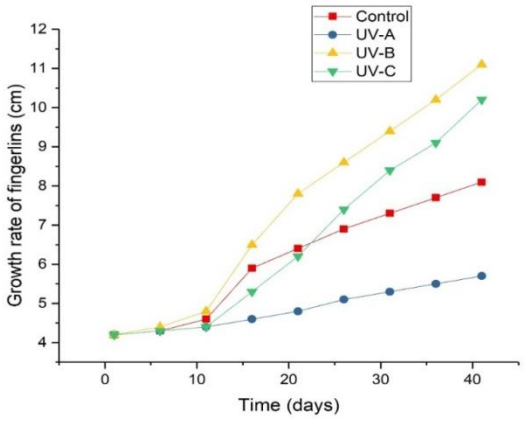

Figure 8. *Effects of UVR on the Growth Rate (cm) of Fingerlings sample.*

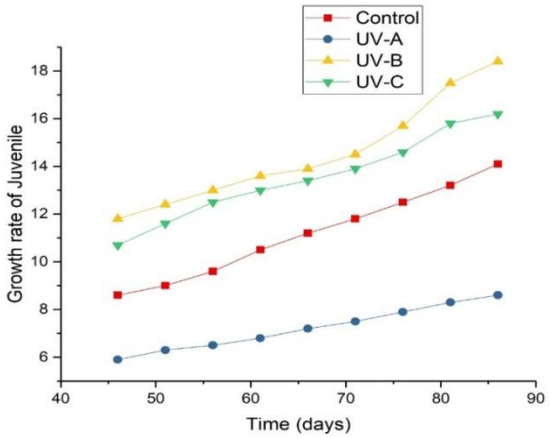

Figure 9. *Effects of UVR on Growth Rate (cm) of Juveniles sample.*

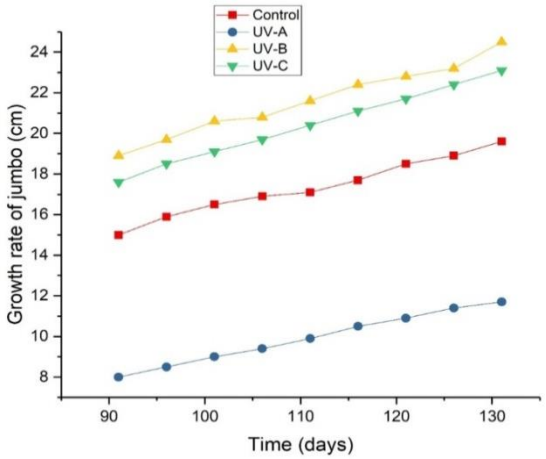

Figure 10. *Effects of UVR on Growth Rate (cm) of Jumbo Size of sample.*

3.1.3. Effects of UVR on the Weight (g) of Samples (Catfish)

The weight of the samples was measured using an electronic weighing balance, and the results are presented in Figures 11–13.

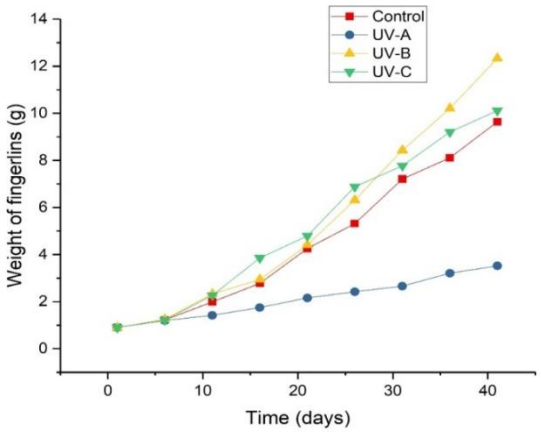

Figure 11. *Effects of UVR on the Weight (g) of Fingerlings sample.*

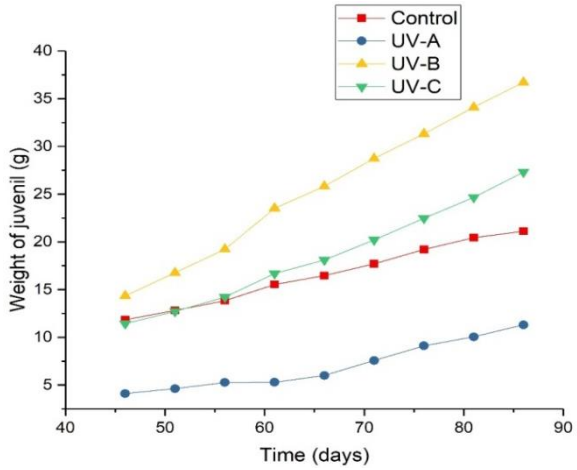

Figure 12. Effects of UVR on the Weight (g) of Juveniles sample.

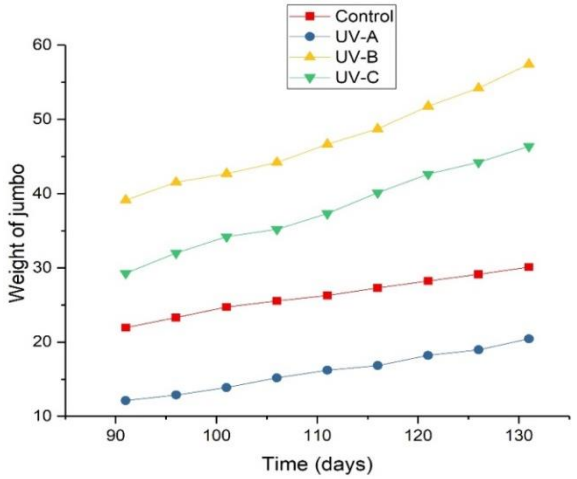

Figure 13. Effects of UVR on the Weight (g) of Jumbo sample.

3.1.4. Effects of UVR on the Mortality Rate of the Samples (Catfish)

The mortality rate of the samples was determined by physical counting, as presented in Figures 14–16.

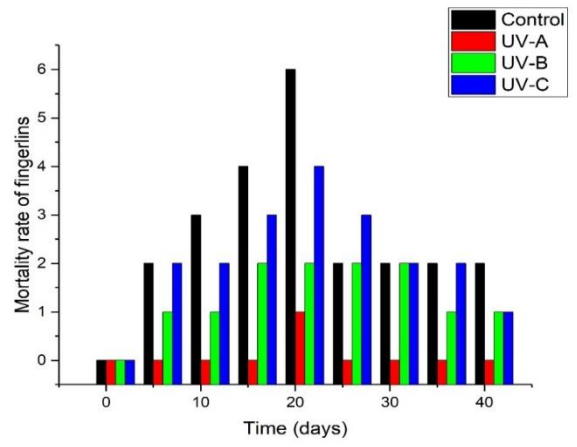

Figure 14. Effects of UVR on Mortality Rate of Fingerlings sample.

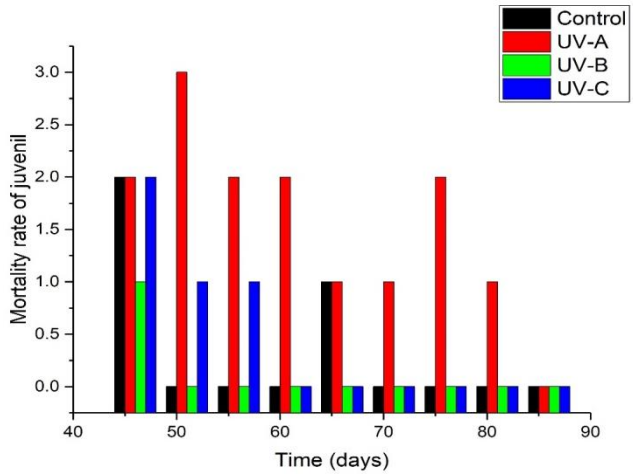

Figure 15. Effects of UVR on the Mortality Rate of Juvenile sample.

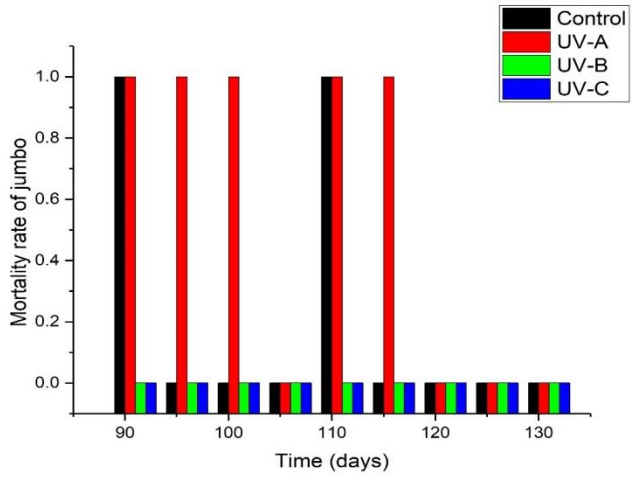

Figure 16. Effects of UVR on Mortality Rate of Jumbo size sample.

3.2. Discussion

3.2.1. Effects of UVR on the Color Change of Samples

All samples bought were fingerlings and dark in color, as seen in Figure 3. Observation of jumbo size of the control samples in Figure 4 indicates that the control samples maintained their dark color throughout the period of the experiment. Figure 5 shows the samples exposed to artificial UV-A. A good observation of Figure 5 compared to Figure 3 indicates that the samples exposed to artificial UV-A had a slight change in color from dark to slightly pink. Again, a careful observation of Figure 6 of sample exposed to artificial UV-B compared to Figure 3 reveals that no color change was observed in the UV-B sample. This observation shows that artificial UV-B has no effect on the color change of the catfish. Another observation of the samples exposed to artificial UV-C in Figure 7 compared with the samples in Figure 3 shows that UV-C samples changed completely from dark to pink color. This observation indicates that UV-C has a greater

effect on the color change of the sample. This could be a result of an alteration of the dermal connective tissue caused by UV-C.

3.2.2. Effects of UVR on the Growth Rate (cm) of Samples

The effects of UVR on the growth rate (cm) of the samples were measured, and the results are presented in Figures 8–10. Figure 8 shows the effects of UVR on the growth rate of fingerlings of catfish for the control sample, UV-A, UV-B, and UV-C samples. The result on day one shows that all samples were of the same size (4.2 cm), while on day six, the UV-B sample grew slightly longer than those exposed to UV-A, UV-C, and the control samples. A careful observation of Figure 8 on days 11 to 21 indicates that UV-B grew faster (8.1 cm), followed by the control (6.4 cm), UV-C (6.2 cm), and UV-A (4.4 cm) samples. The observation from days 25 to 41 shows that the UV-B sample again grew faster (11.1 cm), followed by UV-C (10.2 cm), control (8.1 cm), and UV-A (5.7 cm) sample. This result shows that UV-B sample grow faster compared to other samples. The faster growth rate of the UV-B sample could be attributed to the beneficial effect of UV-B, which is capable of increasing their circulating serum 25-hydroxyvitamin D_3 (25-OHD_3) level, which could in turn enhance their growth rate. The delay in the growth rate of the UV-A sample could be a result of the damaging effect of UV-A on DNA structure. This result is in line with the findings of Megan [49], who carried out an evaluation on the clinical and physiological effects of long-term ultraviolet B radiation on guinea pigs (Cavia procellus) and suggested that, providing guinea pigs with exposure to UV-B will be an important husbandry consideration.

Figure 9 shows the effects of UVR on the growth rate of juvenile sample. A good observation of Figure 9 shows growth rate of 18.4, 16.2, 14.1, and 8.6 cm for UV-B, Control, UV-C and UV-A samples respectively. The speedy growth observed in UV-B sample could be attributed to vitamin D metabolism from UV-B, which is very vital for growth regulation, hormonal functioning, and organ development in animals [39]. Again, the accelerated growth observed in UV-C samples could be attributed to the ability of UV-C to inactivate microorganisms while preserving the visibility of cells [50]. While the tainted growth observed in UV-A sample could be attributed to the formation of many drug photosensitivity reactions caused by UV-A, which play a significant role in diseases such as polymorphic light eruption and chronic actinic dermatitis, which are capable of growth retardation. The result agreed with the findings of Maricela [39], who reviewed the effects of ultraviolet radiation in domestic animals and found some beneficial effects of UV-B in animals, including: maintaining a proper internal body temperature for metabolism in some homoeothermic animals; vitamin D metabolism, and some harmful effects of UV-A, to include: immediate or delayed pigmentation, alternation of the dermal connective tissue, release of vasoactive mediators, and photo-to-oxidative stress.

Figure 10 shows the effects of UVR on the growth rate of jumbo-sized samples. The result shows that UV-A, UV-B, UV-C, and control samples had growth rates of 11.7, 24.5, 23.1, and 19.6 cm, respectively, on day 131. This shows that the UV-B sample grew faster, this could be attributed to the beneficial effects of UV-B, which are capable of increasing their circulating serum 25-hydroxyvitamin D_3 (25-OHD_3) level, which could in turn enhance their growth rate. The delay in the growth of the UV-A sample could be a result of its high penetrating power, which causes damage to tissue. This result is in line with the findings of Megan [49], who carried out an evaluation on the clinical and physiological effects of long-term ultraviolet B radiation on guinea pigs and observed no apparent negative clinical or pathological effects between the long- and short-term exposure groups.

3.2.3. Effects of UVR on the Weight (g) of Samples (Cat Fish)

The weight of the samples was measured using an electronic weighing balance, and the results are presented in Figures 11–13. Figure 11 shows the effects of UVR on the weight (g) of the fingerlings sample. A good observation of Figure 11 shows that the samples were of the same weight (0.9 g) on day one but differed in weight within the next six days, control and UV-B samples gained more weight compared to other samples. A careful observation of Figure 12 from day 11 to day 41 also indicates that UV-B sample gain more weight, followed by UV-C, control and UV-A samples. The weight of the samples on day 41 was observed to be 3.52, 12.34, 10.11, and 9.64 g for UV-A, UV-B, and UV-C and the control samples respectively. The result of this study agrees with the findings of Megan [50], who carried out an evaluation of the clinical and physiological effects of long-term ultraviolet B radiation on Guinea pigs (Cavia procellus) by exposing them to long- and short-term ultraviolet B radiation and found that there were no apparent negative clinical or pathological effects between the groups. However, the result of this work disagreed with the findings of Williamson [50], who examined the beneficial and detrimental effects of UV on aquatic organisms and observed that UV-B radiation is generally damaging, while UV-A radiation may cause damage or stimulate beneficial photo repair of UV-B damage. Figure 12 shows the effects of UVR on the weight of juvenile samples. An observation of Figure 13 shows that UV-B sample gained more weight, followed by UV-C, control, and UV-A samples. The weight of the control, UV-A, UV-B, and UV-C on day 86 was observed to be 21.11, 11.31, 36.71, and 27.32 g, respectively. The result of this study shows that UV-B and UV-C samples gain more weight. The accelerated weight of UV-B and UV-C samples could be a result of the presence of vitamin D produced by UV-B, which is vital for bone maintenance and growth regulation, hormonal functioning, organ development, and embryogenesis, and the potential of UV-C irradiation as an alternative antimicrobial approach used to treat

localized infections [39, 51]. The result of this work is in line with the findings of Maricela [39], who reviewed the effects of ultraviolet in domestic animals and found that UV-B is capable of maintaining proper internal body temperature for metabolism in some homoeothermic animals and that vitamin D is very vital for bone maintenance and growth regulation in animals.

Figure 13 shows the effects of UVR on the weight of jumbo-sized catfish exposed to UVR for 40 days. Observation of Figure 14 depicts that UV-B samples gain more weight followed by UV-C sample. A careful observation of Figure 14 shows little increase in weight of UV-A and the control samples. The result indicates that UV-B and UV-C are more capable of improving the weight of the jumbo size of the catfish. This result agrees partially with the findings of [51], who reviewed the potential of UV-C irradiation as an alternative antimicrobial approach used to treat localized infections and reported that UV-C is capable of promoting wound healing and is less damaging to tissue than UV-B.

3.2.4. Effects of UVR on the Mortality Rate of the Samples (Catfish)

The mortality rate of the samples was determined by physical counting, and the result is presented in Figures 14–16. Figure 14 shows the effects of UVR on the mortality rate of fingerling sample. Observation of Figure 14 shows that all the samples survived on day 1. On further dates, it can be observed that the death rate in all the samples increases and decreases periodically, with the highest death rate for all the samples occurring on day 21, with death rates of 6, 7, 2, and 4 for the control, UV-A, UV-B, and UV-C samples, respectively. And the total deaths of the fingerlings recorded per sample were 23, 22, 12, and 19, respectively, for the control, UV-A, UV-B, and UV-C samples. The result shows that the control sample recorded the highest death rate (23) followed by UV-A (22), UV-C (19), and UV-B (12) samples. This could be attributed to environmental factors and the temperature of the samples, since the temperature of the control sample was observed to be very low and that of the UV-A sample was observed to be very high, as almost all UV-A energies are converted into heat energy.

This result agrees partially with that of Luke [41] who studied the effects of Ultraviolet-B radiation on wound fin embryos and larvae. They exposed embryos and larvae for 14.5 hours, followed by 9.5 hours of darkness, to artificial Ultraviolet-B radiation to directly examine the effects on mortality. They administered UV-B radiation in treatments of 0.060, 0.030, and 0.015 mW/cm^2 to simulate 100, 50, and 25% of the ambient irradiance levels and found out that no embryos survived UV-B treatments; mortality among control (UV-B-free) treatments varied (5–100%) among females, an indication that there may be important parental effects that influence embryo mortality.

Figure 15 shows the effects of UVR on the mortality rate of juvenile sample. The figure shows that the total death rate for the contro, UV-A, UV-B, and UV-C samples were 3, 12, 1, and 4 respectively, with UV-A samples having the highest death rate (12). The death rate of the juveniles may be attributed to some environmental factors and the stressors from UVR. This result contradicted the findings of Ricardo and Susana [8], who determined the harmful effects of ultraviolet B and A radiation in fish at different lifecycle stages using radiation meters and observed growth reduction, a loss in body condition, and behavioral, physiological, and metabolic changes in juveniles and adults occur under short- or long-term UV-B exposure. They concluded that the destruction of stratospheric ozone, climate change, and interaction with other environmental and anthropogenic stressors can lead to more damaging effects on fish species in inland and ocean waters, which may have an impact on the fisheries and aquaculture sectors.

Figure 16 shows the effects of UVR on the mortality rate of jumbo-sized catfish. A careful observation of Figure 16 indicates death rate of the samples to be 2 and 5, for control and UV-A samples respectively, UV-B and UV-C samples recorded 0 deaths at jumbo size. This could be attributed to the environmental factors. The result of this work is contrary to the findings of Williamson [51], who examined the beneficial and detrimental effects of UV on aquatic organisms using both natural solar and artificial UVR sources to examine the beneficial as well as detrimental effects of different wavelengths of UVR and found that the contribution of UV-B to the total mortality response of Daphnia exposed to full-spectrum solar radiation for 7 h on a sunny summer day was higher (64%), while that of UV-A was lower (36%). And concluded that exposure to damaging UV-B causes daphnia to exhibit a dramatic increase in survival in the presence of longer-wavelength UV-A and visible radiation due to the stimulation of photoenzymatic repair.

4. Conclusion

The study determined the effects of UVR on cat fish in North Central Nigeria. The results obtained shows that UV-B beneficial to catfish for all stages under study; therefore, fish farmers are encouraged to employ the use of artificial UV-B on their fish farms in order to improve production and healthy fish growth of their fish.

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Conflict of Interest

The authors declare no conflicts of interest.

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