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Influence of the use of calcium oxide and calcium hydroxide on water quality and zooplankton structure in *Colossoma macropomum* fingerling rearing

Influencia de la utilización de óxido e hidróxido de calcio en la calidad del agua y la estructura zooplanctónica en la cría de alevines de *Colossoma macropomum*

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Resumen: El objetivo fue evaluar la asociación del período sanidad (vaciar el estanque) y la aplicación de cal enérgica en la calidad del agua y la comunidad zooplanctónica. El experimento se realizó en una Unidad de Producción de Alevines del municipio de Ariquemes (Rondônia – Brasil). Se realizaron dos ensayos con período de sanidad y aplicación de cal enérgica, cada uno de ellos con un estanque control y un estanque tratamiento (Ensayos 1 y 2). Para el período de sanidad, los estanques se vaciaron al final del ciclo anterior durante 30 días. Se aplicó óxido de calcio 200 g/m² en el Ensayo 1, y 150 g/m². Se midió pH, alcalinidad total, dureza total, amoníaco, nitrito, nitrato, oxígeno disuelto, temperatura y transparencia; las muestras de zooplancton se tomaron en la sub-superficie, filtrando entre 20 L de agua para el abastecimiento y la incubadora, y 1500 L para ensayos, utilizando una red de plancton de malla de 68 µm de abertura. Los resultados indican la necesidad de aumentar el período de suelta de animales en los estanques en relación con el utilizado actualmente al aplicar 200 g/m² de cal enérgica. Respecto al zooplancton, también se determinaron diferentes patrones de estructura de la comunidad.

Palabras clave: Acuicultura; Amazonía brasileña; Encalado; Exposición; Vacío sanitario.

Abstract: The objective was to evaluate the association between the sanitation period (emptying the pond) and the application of strong lime on water quality and the zooplankton community. The experiment was conducted in a Fry Production Unit in the municipality of Ariquemes (Rondônia - Brazil). Two trials with sanitation period and application of vigorous lime were conducted, each with a control pond and a treatment pond (Trials 1 and 2). For the sanitation period, the ponds were emptied at the end of the previous cycle for 30 days. Calcium oxide was applied 200 g/m² in Trial 1, and 150 g/m². pH, total alkalinity, total hardness, ammonia, nitrite, nitrate, dissolved oxygen, temperature and transparency were measured; zooplankton samples were taken in the subsurface, filtering between 20 L of water for the supply and hatchery, and 1500 L for the trials, using a 68 µm aperture mesh plankton net. The results indicate the need to increase the period of animal release in the ponds in relation to the one currently used by applying

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200 g/m² of strong lime. With respect to zooplankton, different patterns of community structure were also determined.

Keywords: Brazilian Amazon; Fish farming; Liming; Purging; Sanitation period.

1. Introduction

In Brazilian Amazon, the Rondônia state produced 90 thousand tons of fish in year 2016, followed by an internal commercial collapse, saturation of the internal market and consequent sanitary problems. However, it became the largest producer of native species even with a considerable reduction in crops due to the high production cost (Cavali & Lopes, 2017). Production reduced to 65 thousand tons in year 2019 when the opening of two new refrigerating plants certified by the Federal Inspection Service took place. Currently, Rondônia is the 3rd largest producer of fish and the largest producer of native species in Brazil, corresponding to a production of 57.2 thousand tons of farmed fish in year 2022 (Peixe BR, 2023). Being the world's largest producer of tambaqui (*Colossoma macropomum*).

The lack of adequate management practices, in addition to causing several health problems, can also contribute to the establishment of parasites and pathogens. Which may become a serious problem, compromising development, survival and consequently the economic result, jeopardizing the viability of fish farming (Borges et al., 2013). Currently, it is possible to find information that makes it possible to carry out analyzes and corrections capable of providing an adequate environment, optimizing the development of cultivated fish, directly and positively impacting. The lack of sanitary maintenance in the nurseries, especially with regard to organic matter at the bottom of the fish ponds, promotes the existence of a favorable environment for maintaining the life cycle of unwanted organisms. Parasites such as acanthocephalans can benefit from this condition, being able to guarantee its perpetuation either through eggs deposited in organic matter, other aquatic organisms (ostracods or copepods) carrying the young form of the parasite (Acanthocephala) (Jerônimo et al., 2017). Castro et al. (2020) discusses the zooplankton-eating feeding habit of *C. macropomum* and how the intermediate hosts of *Neoechinorhynchus buttnerae* are part of the plankton, pointing out that the life cycle of this species of Acanthocephala is completed in fish ponds, causing infections in fish. In view of this, carrying out a sanitary void procedure associated with purge liming, aims at the implementation of sanitary barriers, with the main objective of eliminating undesirable organisms in their various forms of development, in addition to optimizing the chemical conditions of organic matter (da Silva et al., 2022).

Zooplankton constitute the heterotrophic part of plankton, both protists and metazoans, which live in the water column. Among the metazoans, rotifers, cladocerans and copedodes stand out. These three planktonic communities contribute approximately 90% of the total zooplankton biomass and play an important role in the food chain, as they are a link for transferring mass and energy from primary producers to higher trophic levels (Macêdo et al., 2017). They are also a source of food for different stages of development of fish larvae, planktivorous fish and aquatic invertebrates (Oliveira et al., 2010; Pereira et al., 2011). The zooplanktonic groups (testaceous, rotiferous and cladoceran protozoans and copepods) are composed of organisms highly sensitive to environmental changes, and have short and medium life cycles (Xiong et al., 2016), which gives them the ability to follow the temporal variation of the system in relatively short periods. Furthermore, zooplankton taxonomy is not very complex, and sampling methods are easily compatible with limnological methods (de Souza et al., 2019). In this sense, they are a relevant component of the aquatic ecosystem and, as they are sensitive to various substances in the water, such as nutrient and pollutant enrichment, they are potential environmental bioindicators (Lomartire et al., 2021; Parmar et al., 2016). Thus, assessing the structure of the zooplankton community (species composition and abundance) can be, on numerous occasions, a very useful tool for the environmental characterization of aquatic systems.

In view of the overview showed, this study aimed to evaluate the effect of a protocol involving the joint implementation of a sanitary void (emptying the fish ponds) with purge liming (application of a significant amount of lime), on the water quality and the structure of the zooplankton community in *C. macropomum* fingerling. More specifically, we intend to propose a new protocol evaluating the water quality and the zooplankton community in ponds, compared to the protocol often used in fish farming.

2. Materials and methods

The study was conducted out in a fingerling production unit located in Ariquemes municipality, Rondônia state, where four rectangular fish ponds with an area of 1,600 ± 300 square meters and an average depth of 1.50 ± 0.3 m were used. The experimental unit is on the banks of the São João River, a tributary of the Branco River, which flows into the Jamari River, a tributary of the Madeira River, which in turn flows into the Amazon River.

Regarding the cultivation structures, these are tanks excavated, which have individualized supply and drainage. The supplies are carried out using a centrifugal pump component of the system, the fish farmed used had dimensions of approximately 110 m x 50 m x 1.50 m (LxWxD), as areas according to Table 1.

Table 1. Fish ponds areas used to farmed C. macropomum fingerlings, treatments 1 and 2 and control 1 and 2.

Viveiro	A2	B3	C3	C4
Area (m^2)	1.300	1.800	1.900	1.900
Tests	Control 1	Treatment 1	Treatment 2	Control 2

To carry out the experiment in a completely randomized design, two tests were carried out, each one with a "Control" pond, using the standard protocol carried out in the enterprise, and a "Treatment" pond. The tests were carried out in the first quarter of year 2021, in January and February, the first test lasted 25 days and the second lasted 42 days in March and April, using the protocols described below. The "Control" protocol used the emptying of the fish pond and the application of 100 g/m^2 of calcium oxide (quicklime) on the bottom of the fish ponds the following day. In order to safely disinfect the fish ponds, procedures were carried out that present as residual substances capable of generating optimized conditions, both for the environment and for the cultivated organisms. For this reason, we opted for the combined sequential performance of management procedures, "sanitary evacuation" and "purge liming".

For the sanitary void, the fish ponds used were drained at the end of the previous cycle, remaining in this condition for about 30 days, with the bottom of the fish ponds exposed to sunlight and atmospheric air. To carry out the liming, calcium oxide substances, better known as quicklime, were used in a concentration of 200 g/m^2, in the first test, while in the second test the substance was calcium hydroxide, better known as hydrated lime in a concentration of 150 g/m^2, values above the minimum recommended doses to prevent diseases and their vectors (Massago & Corrêa da Silva, 2020).

Three samplings were carried out to evaluate the zooplankton in the fish ponds. The first sampling carried out when the larvae were received/released in the fish ponds, the last on the day of the 1st capture management, in addition to an intermediate sampling. In addition to these, two samplings were carried out at the supply, one with and the other without the filter screen, to evaluate the zooplankton present in the supply water used to fill the ponds; Sampling was also carried out in the incubators, where the tambaqui larvae used in cultivation are produced. In water analysis, the variables pH, total alkalinity, total hardness, ammonia, nitrite and nitrate, dissolved oxygen, temperature and transparency were measured. The collections for the water analysis were carried out in five stages, three of which were concomitant with the zooplankton sampling, one carried out previously during the supply of the fish ponds, with the collection of a sample of the water directly from the supply, so that there was no influence of the protocol in this sampling, allowing the evaluation of the water to be used to fill the ponds, in addition to sampling the water from the incubators, where the larvae used in the cultivation observed in this research are produced, the collection scheme can be seen in Table 2.

Table 2. Collection scheme conducted out in *C. macropomum* fingerling, Tests 1 and 2.

TEST 1				
Day	**Date**	**TQ**	**Treat.**	**ID zoo**
6th	01/26/21	Abast. (supply)		-
	04:00 pm	C-4	Control	01-C
		B-3	Treatment	02-T
8th	01/28/21	C-4	Control	-
	10:00 am	B-3	Treatment	03-T
17th	02/04/21	C-4	Control	04-C
	10:00 am	B-3	Treatment	05-T
24th	02/11/21	C-4	Control	06-C
	10:00 am	B-3	Treatment	07-T
	02/11/21	C-4	Control	08-C
	03:00 pm	B-3	Treatment	09-T

TEST 2				
Days	**Date**	**TQ**	**Treat.**	**ID zoo**
1st	03/20/21	Abast. T. (supply with screen)		10-A
		Abast. L. (free supply)		11-A
	10:00 am	A-2	Control	-
		C-3	Treatment	-
6th	03/26/21	Fish pond fingerling		12-I
	10:00 am	A-2	Control	13-C
		C-3	Treatment	14-T
35th	04/24/21	A-2	Control	-
	10:00 am	C-3	Treatment	-
41th	04/30/21	A-2	Control	16-C
	10:00 am	C-3	Treatment	17-T

The physical and chemical parameters of the water were obtained using equipment such as an oxygen meter (Model: AT-155 Alfakit), dissolved oxygen (mg/L) and temperature (ºC); pH meter (Model: AK95 Akso), for pH values; photocolorimeter (Model: AT100P Alfakit), for reading the values of the ammonia (mg/L), nitrite (mg/L) and nitrate (mg/L) analysis, which were performed using a specrokit (Brand: Alfakit); in addition to the Secchi disk, which was used to measure the values of water transparency (cm). And finally, the titrations for alkalinity (mg/L $CaCO_3$) and hardness (mg/L $CaCO_3$) analyses, performed using a freshwater technical kit (Brand: Alfakit). Analyzes of dissolved oxygen, temperature, pH and water transparency were carried out *in loco*, with the aid of the aforementioned equipment. For the other water analyses, samples were collected at a depth of 25 cm, in sterilized polyethylene bottles with a capacity of 0.5 L, and then the analyzes were carried out on the bench.

Zooplankton samples were taken from the sub-surface, filtering a volume between 20 L of water (collections from the supply and incubator) and 1500 L (collections from the scallop), using a plankton net with a 68 µm mesh opening. The collected material was placed in polyethylene bottles, fixed in a final solution of 70 % alcohol. Zooplanktonic density was determined by counting the samples in Sedwigck-Rafter chambers, under an optical microscope. The samples were concentrated in a volume of 1.0 L, and the counts performed from sub-samples taken with a Hensen Stempel-type pipette, with the final density expressed in individuals per 100 L.

To identify the zooplankton, specialized literature was consulted based on the data collected by Souza et al. (2021) and Santos et al. (2022). The frequency of occurrence (Fo%) and species abundance were calculated considering the ratio of the number of samples in which the organism was identified and the total number of samples collected.

The data obtained were stored and organized in the Epi info™ software, version 3.5.3 - 2011 (OS: MS-Windows, C Sharp programming language). These data were submitted to descriptive statistical analysis, averages and standard deviation. All statistical analysis were performed using RStudio Development Core Team, version 3.5.3.

3. Results and discussion

The use of the proposed management techniques aims to condition the bottom of the fish ponds in order to prevent the survival of unwanted organisms in their various forms of development. As well as favoring suitable chemical conditions for the processes of decomposition of organic matter and the availability of nutrients associated with it, as well as for the aquatic environment. It is worth noting that the use of liming has the residual effect of raising the alkalinity and hardness of the water, thus ensuring the availability of calcium and magnesium, carbonates and bicarbonates, neutralizing acids. These factors strengthen the buffer system and consequently favor the pH balance.

Izel-Silva et al. (2020) discuss the importance of understanding the dynamics of physical and chemical phenomena that occur in the aquatic environment. As well as the adoption of management practices that guarantee acceptable conditions for the farmed species. The authors point out the strong impact of two phenomena on water quality, photosynthesis in the photic period, highlighting carbon dioxide (CO_2) sequestration, increasing pH values, and respiration in the aphotic period, decreasing pH values by releasing of carbon dioxide in the water.

J. S. Castro et al. (2020), relate the quality of water in cultivation systems, factors such as source water, management (liming, fertilization and cleaning), cultivated species in addition to the quantity and composition of the food supplied, and detail the first of these factors in primary productivity, concentration of organic material, chemical elements and presence of microorganisms, especially coliforms, in addition to a relationship with the constitution of the soil of origin and/or the path taken by the water.

Gasparotto et al. (2020) explain that the total alkalinity reflects the concentration of the titratable bases in the water, expressed in equivalence of mg of $CaCO_3$/L, pointing bicarbonate ions (HCO^{3-}) and carbonates (CO^{3-}) as the main titratable bases (CO^{3-}), while the total hardness refers to the concentration of free divalent cations in water, also expressed in equivalent milligrams of $CaCO_3$/L, being represented almost entirely by calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions; also state that values of alkalinity and total hardness above 20 mg of $CaCO_3$/L indicate adequate buffering power, with less intense daily pH variations and also detail that in ponds with waters of low alkalinity and total hardness (<20 mg $CaCO_3$/L) may vary in a daily cycle from approximately 6.0 - 6.5 in the early hours to values of 9.5 - 10.0 at dusk while in waters with adequate buffering power (total alkalinity > 20 mg $CaCO_3$/L) these values hover around 7.5 - 8.5.

J. S. Castro et al. (2020) indicate alkalinity as the ability of water to neutralize acids, detailing that it refers to the total concentration of salts in water, expressed in milligrams per liter, in equivalent of calcium carbonate ($CaCO_3$), bicarbonate (HCO_3) , carbonate (CO_3), ammonia (NH_3), hydroxyl (OH), phosphate (PO_4), silica (SiO_4) and some organic acids, can react to neutralize hydrogen ions (H^+)", indicate alkalinity values above 20 mg/L for fish farms, with values between 200 - 300 mg/L being the most indicated, it also clarifies that the term indicates the content of calcium and magnesium ions that are combined with carbonates or bicarbonates, or even sulphides and chlorides; also point out that total hardness is generally related to alkalinity anions and hardness cations are derived from mineral solutions. 24 hours, and detail that despite the positive correlation between hardness and alkalinity, it cannot be said that highly alkaline waters have high hardness.

Corrêa (2018), explains that alkalinity expresses the concentration of bases in water (compounds with alkaline characteristics: hydroxides, ammonia, phosphate, silicate, with bicarbonates and carbonates being more abundant), states that carbonates and bicarbonates are the main compounds that determine the total alkalinity of water, details that carbonate is a truly basic compound and bicarbonate, due to its amphoteric character, can react as a base or as an acid and as bases have the capacity to neutralize acids, forming salt and water, d 'water with high total alkalinity is able to keep its pH relatively unchanged when acidic compounds are introduced into it (buffering power); or when there is removal of H^+ ions from the medium, as during photosynthesis. It points out that the appropriate level for fish farming in fresh water ranges 60 mg to 150 mg per liter of carbonate (mg/L $CaCO_3$), and reinforces that maintaining high alkalinity brings benefits, such as buffering the pH of the water, which favors better conditions for the growth of organisms (plankton, fish, bacteria, among others), increased primary productivity (phytoplankton growth), detailing that the presence of bicarbonate in the water keeps the photosynthetic rates unchanged, if the alkalinity of the water is low, there will be limitation of primary production due to lack of CO_2.

However, when there is bicarbonate, microalgae continue to develop by using bicarbonate as a source of inorganic carbon for glucose production. Corrêa (2018) also points out that the high alkalinity of the water indicates that the soil pH should be close to neutrality, reinforces that fish ponds dug in acid soils normally have low alkalinity water, requiring correction (liming). He points out that the tendency is that, over time, water and soil come into pH balance, stating that liming the water in a fish pond, over time, also promotes soil pH correction. In addition, the pH of the soil close to neutrality favors the activity of decomposing bacteria in the fish pond sediment, preventing the accumulation of organic matter in the soil when its pH is close to 7, optimizing the supply of mineral salts for the development of primary producers when the alkalinity is high (> 60 mg/L $CaCO_3$) and the pH of the soil is close to 7. It also points to a decrease in the risks of mineral toxicity, detailing that the sediment at the bottom of the fish pond works as a reservoir of chemical elements, where nutrients are concentrated (phosphates and nitrates, among others) and also, sometimes, heavy metals (cadmium and nickel). These heavy metals are harmful to organisms when absorbed by plants (algae) and animals, which occurs when the metals are free in the water column, because, retained in the sediment, they do not harm farmed fish, describing the two situations in which this can occur: i) when the environment is anaerobic, and ii) when the soil pH is acidic, and this release is maximized under these conditions, reinforcing the importance of alkalinity.

As shown in Figure 1, during the experiment, the results of the analysis of alkalinity and total hardness of the supply water showed values below the recommended level, indicating the need for liming. The values obtained for the samplings carried out in the fish ponds, throughout the entire experiment, were above 20 mg for both variables, acceptable values for fresh water, as cited by Corrêa (2018). In the first test, a more intense response was observed in the Test (200g/m² CaO) in relation to the control (100g/m² CaO) in the first collections, but the values were practically equal in the final collections, both for alkalinity and for hardness. However, in the second test, the values obtained were higher in the control (100g/m² CaO) in the first two collections, but in the last two, the results were 10 to 20 % higher for the Test (150g/m² $Ca(OH)_2$).

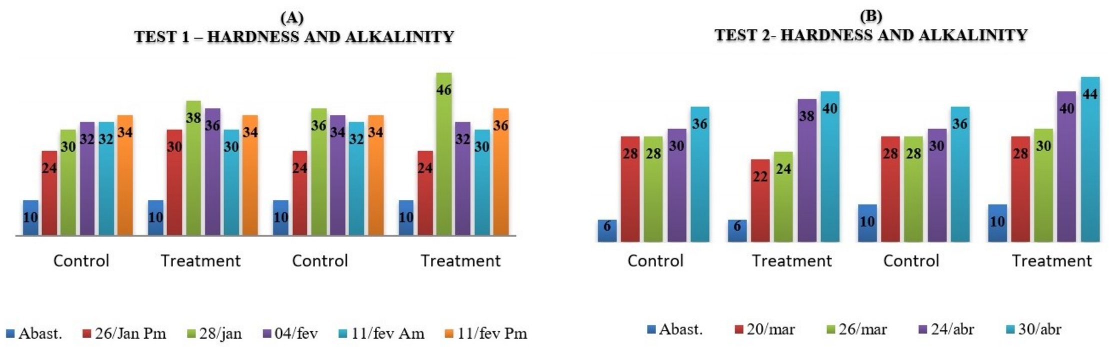

Figure 1. Alkalinity and hardness variations, treatment and control. (A) Test 1 and (B) Test 2.

Gasparotto et al. (2020) state that the pH is influenced by the concentration of carbon dioxide (CO_2), which causes an acidic reaction in the water, they explain that during the day photosynthesis removes CO_2 from the water raising the pH, and that during the night, the accumulation of CO_2 from respiratory processes promotes a reduction in the pH of the water.

Izel-Silva et al. (2020), state that the acidity of the water is determined by the concentration of H^+ ions present and that the higher the concentration of H^+ in the water, the more acidic it is; the lower, the more alkaline, explains that it is measured by pH, and has a scale that varies from 0 to 14, pointing to a range compatible with aquatic life from 4 to 11, with 6.5 to 9 being the ideal level for well-being animal (Table 3). They also advise that the pH should be measured in the late afternoon and early morning of the following day, suggesting that differences greater than 2 units between these values indicate a failure in the buffer system, which can be confirmed through the alkalinity of the water. If the alkalinity value is adequate, the cause of the pH variation may be related to excess phytoplankton, which can be evaluated using the Secchi disc.

Table 3. Table pH ranges and effects on fish

Effect of pH on fish				
0 – 4	4 – 6,5	6,5 – 9	9 – 11	11 – 14
Death due to acidosis	Stress due to acidosis	Ideal pH	Stress due to alkalosis	Death due to alkalosis

Adapted from: Corrêa (2018).

The supply water was slightly acidic, proving to be suitable for filling the cultivation fish ponds. The pH values observed during the first test remained within the recommended range, varying between 7.0 and 8.5, except in the first sampling carried out in the treatment fish ponds, shown itself in conditions of acid stress, being above the recommended value. 9.5 (Figure 2). These results suggest extending the period between supply (1st day) and planting (6th day), for the use of quicklime at a concentration of $200g/m^2$. Also, on the last day of collection, samples were taken by period, with values within the recommended range being observed, both in the morning (7.0 and 7.5) and in the afternoon (8.0 and 8.5), with adequate diurnal variation, not greater than 1.0.

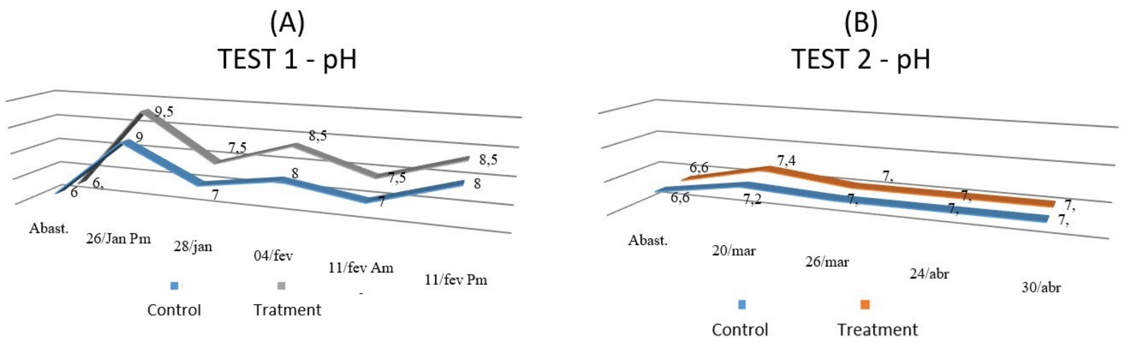

Figure 2. Variations in pH, treatment and control. (A) Test 1 and (B) Test 2.

J. S. Castro et al. (2020), point to ammonia as the main nitrogenous residue excreted by fish, a protein metabolite, contributing to the microbial decomposition of organic waste (food remains, feces and organic fertilizers), state that ammonia comes from the biological conversion of organic nitrogen, most forms are proteinaceous and are converted to ammonia molecules or ammonium ions, depending on the pH, explain that "in aerobic habitats, nitrification converts ammonia to nitrate, which is reduced by denitrification, where nitrogen is volatilized, in the which the nitrate is converted to gas and released into the environment", since with low dissolved oxygen, nitrite accumulates in the water. The observed values for the nitrogenous compounds were within the recommended ranges throughout the experiment period. The observed peaks are due to the fertilizations performed during cultivation (Figure 3).

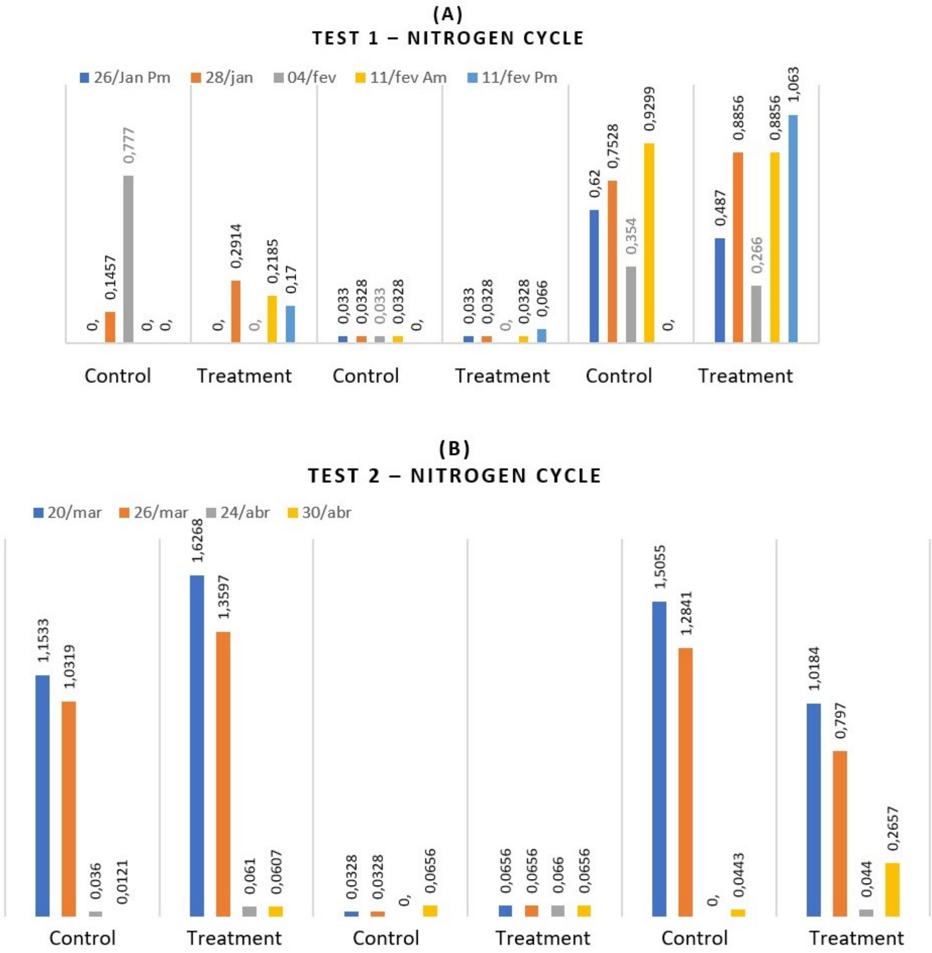

Figure 3. Variations of ammonia, nitrite, nitrate, treatment and control. (A) Test 1 and (B) Test 2.

According to Jia & Yuan (2017), nitrogen is scarce in water and can be sequestered from the air by some cyanophytic microalgae. This nutrient can be present in the water in molecular, ammonia, nitrite, nitrate forms, being indispensable to microalgae. Although in excess, it can cause eutrophication. According to these authors, ammonia would be the second impediment to nitrogen sequestration, right after oxygen, and that non-ionized ammonia values in water do not exceed 0.05 mg/L in tropical fish culture tanks, so that values higher than this determine low feed efficiency, thus reducing the growth of individuals. These authors also emphasize the relationship between ammonia and pH, warning that the concentration of non-ionized ammonia increases with an increase in pH. Finally, it should be noted that about 40 % of the crude protein (CP), present in a complete feed, is used as energy, resulting in the production of ammonia.

In relation to Nitrite, this is the intermediate product of the transformation of ammonia into nitrate, by the action of bacteria of the genus Nitrosomonas and its concentrations are related to the decomposition of protein components of organic matter, they warn about the critical range of nitrite values (0.3 to 0.5 mg/L) can compromise the growth and resistance of fish to diseases. Nitrates are relevant for the development of phytoplankton, not being toxic to fish, even in high concentrations, being of low risk to fish farming.

Corrêa (2018) points out dissolved oxygen as the most critical variable in a fish farm, emphasizing the importance of monitoring it due to its great influence on activity, especially regarding food consumption, growth and feed conversion of the animals. According to this author, the solubility of oxygen in water varies with temperature, salinity and altitude, indicating that the ideal condition is for water sources to have oxygen concentrations close to saturation, emphasizing the need to know the dynamics of dissolved oxygen production in fish ponds. The main source of oxygen in the in fish pond is photosynthesis, with an increase from the beginning of the morning (5 am to 6 am) until the afternoon (3 pm to 4 pm) and later the concentration tends to decrease until the morning of the next day, when the cycle restarts. Thus, the most critical period for the fish (lower concentrations of dissolved oxygen in the pond) is at dawn (before sunrise).

The observed values for dissolved oxygen were excellent throughout the experiment, with values above 7mg/L (Figure 4). As for temperature, two moments with values above 34 °C were obtained, in January and February 2021, which leads us to recommend an adequate minimum depth, in order to guarantee shelter for animals grown on days with extreme temperatures (Figure 4).

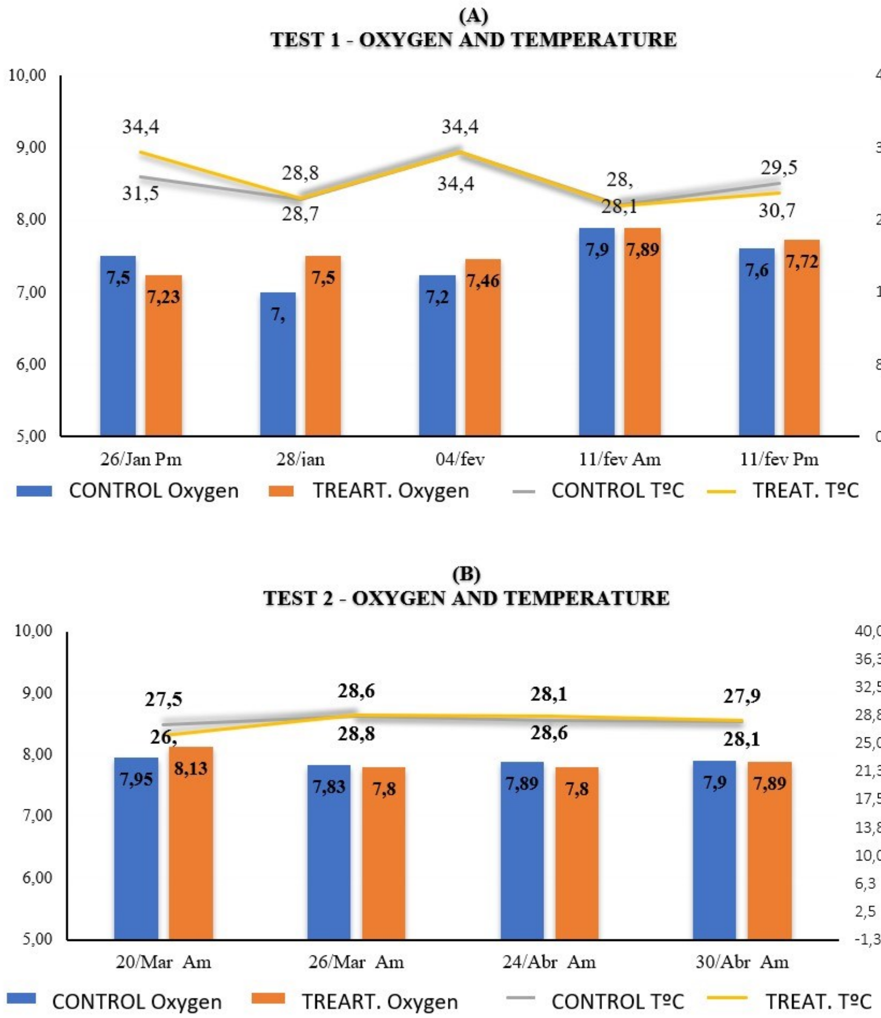

Figure 4. Dissolved oxygen and temperature variations, treatment and control. (A) Test 1 and (B) Test 2.

Jia & Yuan (2017) point out that oxygen is the most important gas for fish and we owe it the greatest attention; explain that the concentration of oxygen in water varies with its temperature, and the increase in temperature decreases the solubility the solubility of oxygen in water decreases as the temperature increases; warn that temperatures outside the ideal range affect growth, while extreme temperatures can lead to higher mortality rates. In the samples taken in the fish farms, throughout the experiment, 41 species of zooplankton were recorded, with emphasis on Rotiferos, with 25 species (Table 4).

Table 3. Inventory of zooplankton species and their respective abundances in the different treatments and sampling periods, under the conditions of use of 200g/m² of quicklime (treatment I – 2t/3t/5t/7t/9t/), 150g/m² hydrated lime (treatment II - 14t/17t) and 100g/m² of quicklime (Control – 1c/4c/6c/8c/13c/16c), Supply (with AT screen and without AL screen) and incubator (12i), in fish farms, Rondônia state, Brazil.

Group	Family	Species/points	1c	2t	3t	4c	5t	6c	7t	8c	9t	13c	14t	16c	17t	10AT	11AL	12i
Testaceos	Arcellidae	*Arcella discoides*	0	0	0	0	0	16	0	80	0	0	0	0	0	150	200	0
		Arcella megastoma	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0
	Difflugiidae	*Difflugia corona*	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
		Difflugia gramen	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
		TOTAL TESTACEOS	0	0	0	0	0	32	0	160	0	0	0	0	0	150	200	0
Rotíferos	Asplanchinidae	*Asplanchna sp.*	0	0	2667	1167	12320	0	0	360	0	533	0	0	0	0	0	500
	Brachionidae	*Brachionus sp.*	13600	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Brachionus angulares	0	0	0	0	40	0	0	0	0	133	0	0	0	0	0	0
		Brachionus bidentata	0	200	0	233	80	0	0	160	0	0	0	0	0	0	0	0
		Brachionus calyciflorus	0	0	20333	0	0	0	0	0	0	5333	533	0	0	150	0	100
		Brachionus dolabratus	200	33	1333	0	280	0	0	0	267	0	0	267	0	0	0	0
		Brachionus falcatus	267	0	333	1000	0	0	0	0	0	0	133	267	0	0	0	0
		Brachionus mirus	0	0	0	0	0	0	0	0	0	267	133	0	0	0	0	0
		Brachionus quadridentata	0	233	22333	0	0	0	133	0	0	2667	933	5600	0	450	0	100
		Keratella americana	0	0	0	67	0	0	0	40	800	0	0	0	0	0	0	0
		Keratella tropica	0	100	0	133	240	16	1067	120	4267	0	0	533	400	0	0	0
		Plationus patulus macrachantus	267	0	333	0	0	0	0	0	267	0	0	0	0	0	0	0
		Plationus patulus patulus	0	0	0	67	0	0	0	0	0	0	0	267	0	0	0	0

Group	Family	Species/points	1c	2t	3t	4c	5t	6c	7t	8c	9t	13c	14t	16c	17t	10AT	11AL	12i
		Platyias quadricornis	0	33	0	0	0	0	133	0	0	0	0	0	0	0	0	0
	Conochilidae	*Conochilus sp.*	0	0	333	0	0	0	0	40	0	0	0	267	0	0	0	0
	Dicranophoridae	*Dicranophorus sp.*	0	0	0	0	0	0	0	0	0	267	0	0	0	0	0	0
	Filinidae	*Filinia opoliensis*						0	0	0	0	0	0	0	267	0	0	0
	Floscularidae	*Floscularia sp.*	0	167	0	33	160	0	13067	80	376000	0	0	15733	0	0	0	0
	Hexarthridae	*Hexarthra mira*	133	0	0	0	0	0	0	0	0	0	0	267	0	0	0	0
	Lecanidae	*Lecane bulla*	0	33	0	67	0	80	0	80	0	133	0	267	1200	0	0	300
		Lecane lunaris	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0
		Lecane papuana	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
		Lecane sp.	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0
	Philodinidae	*Bdelloidea*	0	0	0	0	0	0	133	80	0	133	0	0	0	0	0	0
	Trichotridae	*Trichotria tetractis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0
		TOTAL ROTÍFEROS	14467	833	47667	2767	13160	112	14533	1000	381600	9467	1733	23467	1867	600	200	1000
Cladóceros	Chydoridae	*Nicsmirnovilus fitzpaltriki*	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0
	Daphniidae	*Ceriodaphnia cornuta*	0	0	0	0	0	0	133	40	0	0	0	0	0	0	0	0
	Moinidae	*Moina minuta*	40800	2967	19333	300	3080	0	1467	1000	3200	1600	3467	1600	3467	6150	2600	0
		Moina reticulata	0	433	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sididae	*Diaphanosoma birgei*	0	0	0	0	0	0	0	0	0	0	0	1067	0	0	0	0
		Diaphanosoma spinulosum	0	33	1000	233	80	0	1200	360	2133	400	0	0	4800	0	0	0
		TOTAL CLADÓCEROS	40800	3433	20333	533	3160	0	2800	1400	5333	2000	3467	2667	8267	6300	2600	0
Copépodes	Cyclopidae	Náuplio de Cyclopoida	533	67	1667	633	1000	16	2400	920	9867	400	0	12533	14667	0	0	0

Group	Family	Species/points	1c	2t	3t	4c	5t	6c	7t	8c	9t	13c	14t	16c	17t	10AT	11AL	12i
		Copepodito de Cyclopoida	0	33	667	333	640	16	2533	600	10400	133	0	4267	3867	0	0	0
		Mesocyclops sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0
		Metacyclops mendocinus	0	0	0	0	0	0	0	0	267	0	0	0	533	0	0	0
		Thermocyclops decipiens	0	100	333	133	680	0	5600	240	5867	0	0	1600	0	0	0	0
		Thermocyclops minutus	0	133	0	233	920	16	15067	160	0	0	0	6933	0	0	0	0
	Diaptomidae	*Argirodiaptomus cf. azevedoi*	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0
		Náuplio de Calanoida	0	0	0	133	0	0	0	240	533	0	0	1067	10000	0	0	0
		Copepodito de Calanoida	0	0	0	0	0	0	0	480	0	0	0	0	9467	0	0	0
		Notodiaptomus sp.	0	0	0	33	0	0	133	240	267	0	267	533	1867	0	0	0
		TOTAL COPEPODOS	533	333	2667	1500	3240	48	25733	2960	27200	533	267	26933	40400	150	0	0
Ostracodes		TOTAL OSTRACODES	0	33	0	267	40	224	533	80	1600	0	0	533	0	0	0	0
Chaoboridae		TOTAL CHAOBORIDAE	0	0	667	0	0	0	0	0	0	0	4667	0	0	0	0	0

In addition to these, Cladoceros and Copepodos were represented by six species each, in addition to young forms of Copepodos (nauplii and copepodites), and testaceous protozoa by four species. The high diversity of Rotiferos is a frequently observed pattern for the most diverse Brazilian freshwater ponds (Neumann-Leitão et al., 2018), especially those predominantly lentic. This predominance is related to the high diversity and colonization capacity of rotifers, r-strategist organisms, adapted to the colonization of unstable environments such as reservoirs (Sampaio et al., 2002).

Regarding species richness, the values varied between 3 and 19 species throughout the experiment and in samples taken in the environment (São João River) and incubator, with an average of 10 species. Higher values of richness for zooplankton and its different groups were observed, in general, in the control, with emphasis on Rotiferos and Testaceos, better represented under these conditions, and the lowest in samples from the environment (10AT; 11AL) and incubator (12I) (Figures 5 and 6).

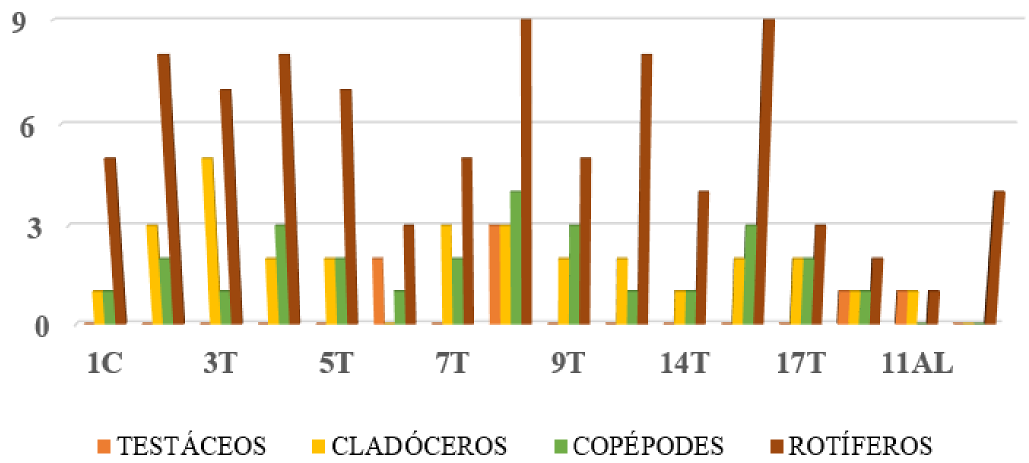

Figure 5. Species richness of the zooplankton groups in the collections carried out throughout the experiment, in the different treatments and sampling periods, in the conditions of use of 200g/m² of quicklime (Test 1 - 2t/3t/5t/7t/9t /), 150g/m² hydrated lime (Test 2 - 14t/17t) and 100g/m² of quicklime (Control – 1c/4c/6c/8c/13c/16c), Supply (with AT screen and without AL screen) and incubator (12i), in fish ponds, Rondônia state, Brazil.

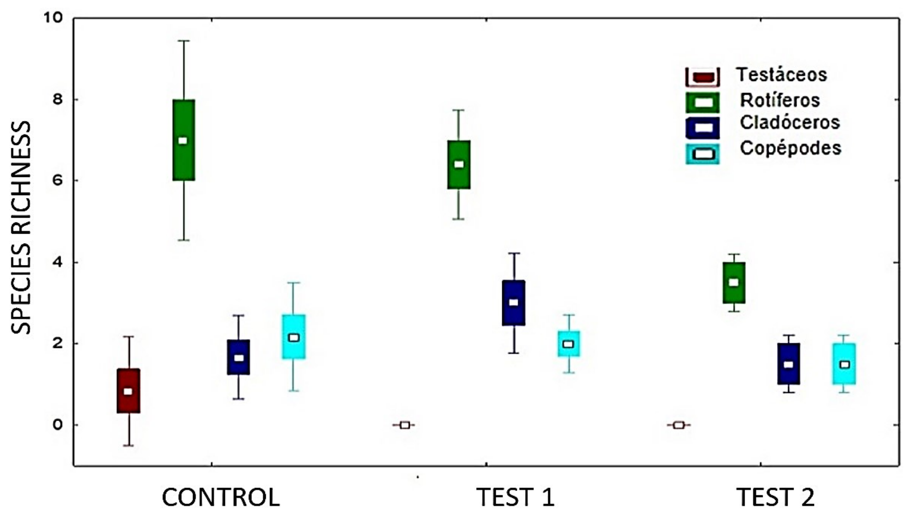

Figure 6. Species richness of zooplankton groups under conditions of use of 200g/m² of quicklime (Test 1), 150g/m² hydrated lime (Test 2) and 100g/m² of quicklime (Control), in fish ponds, Rondônia state, Brazil.

Therefore, for this attribute of the zooplankton community, it seems that Tests 1 and 2 (liming of 200 g/L of quicklime and liming of 150 g/L of hydrated lime) have an effect on the zooplankton richness, especially of Rotiferos and Testaceos, while for cladocerans and Copepodos this effect does not seem to be significant (Figure 6).

When analyzing the abundance of zooplankton, the observed pattern is quite different, so that, for this attribute, lower values are generally observed for the control, while in Test 1 (200 g/L of quicklime) it stands out. if the high contribution of Rotiferos, and in Test 2 (150 g/L of hydrated lime), the expressive contribution of Copepodos, especially their young forms (nauplii and Copepodos), as well as an important relative contribution of Ostracodes (Figure 7 & Table 4).

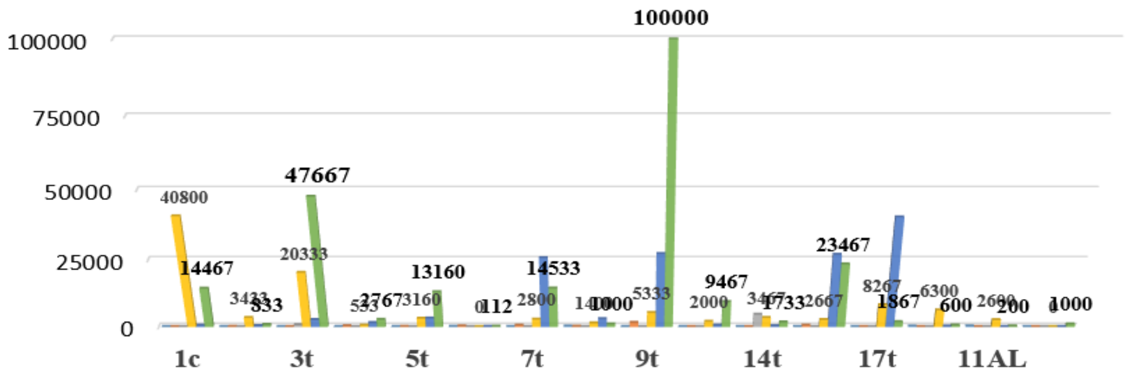

Figure 7. Abundance of zooplankton groups in the collections carried out throughout the experiment, in the different treatments and sampling periods, in the conditions of use of 200g/m² of quicklime (Test 1 - 2t/3t/5t/7t/9t/), 150g/m² hydrated lime (Test 2 - 14t/17t) and 100g/m² of quicklime (Control – 1c/4c/6c/8c/13c/16c), Supply (with AT screen and without AL screen) and incubator (12i), in fish ponds, Rondônia state, Brazil.

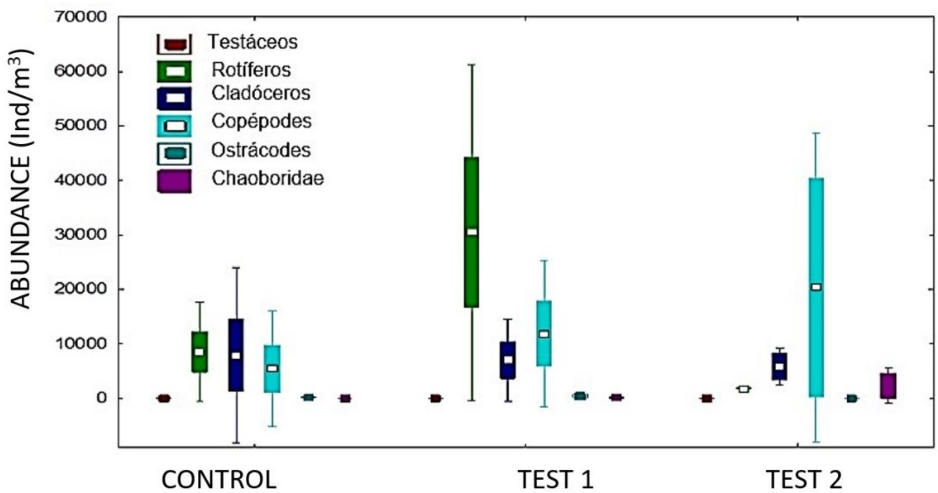

Figure 8. Density of zooplankton groups under conditions of use of 200g/m² of quicklime (Test 1), 150g/m² of hydrated lime (Test 2) and 100g/m² of quicklime (Control), in fish ponds, Rondônia state, Brazil.

The effects on the abundance of Cladoceros and Testaceos were, on the other hand, not very expressive. Thus, the treatment seems to have a positive effect on the abundance of zooplankton in fish ponds, although the greatest effects are on Rotiferos, which have a less relevant participation in the feeding of fingerlings, while Cladoceros, which are generally more important (Zanatta et al., 2010), had no effect.

Still regarding zooplankton abundance, its values were quite high throughout the experiment, however, they varied considerably (Figures 8 and 9). Thus, the recorded density values ranged from 416 to 415,733 ind/100L. Such values are characteristic of environments from oligotrophic (<10000 Ind/m^3) to supereutrophic environments (<1000000 Ind/m^3) (Neumann-Leitão et al., 2018).

Regarding the contribution of zooplankton species to the different treatments of the experiment, it was observed, for the control, a significant predominance of the Cladocero *Moina minuta*, which represented about 30% of all zooplankton abundance. In addition to this, *Floscularia sp.*, *Brachionus sp*. and *Brachionus quadridentatus*, among Rotiferos, and *Thermocyclops minutus* and *Cyclopoida nauplii*, among Copepodos (Figure 9).

Tests 1 and 2, on the contrary, an inversion in the contribution of the groups was observed, with emphasis on the Rotifero *Floscularia sp.*, for which it represented about 65% of all zooplankton abundance (Figure 10), while the *Moina minuta*, had a less expressive participation in the Tests (5%). In addition to these, *Brachionus quadridentatus*, among Rotiferos, and *Cyclopoida nauplii*, among Copepodos, stood out for the treatment (Figure 9).

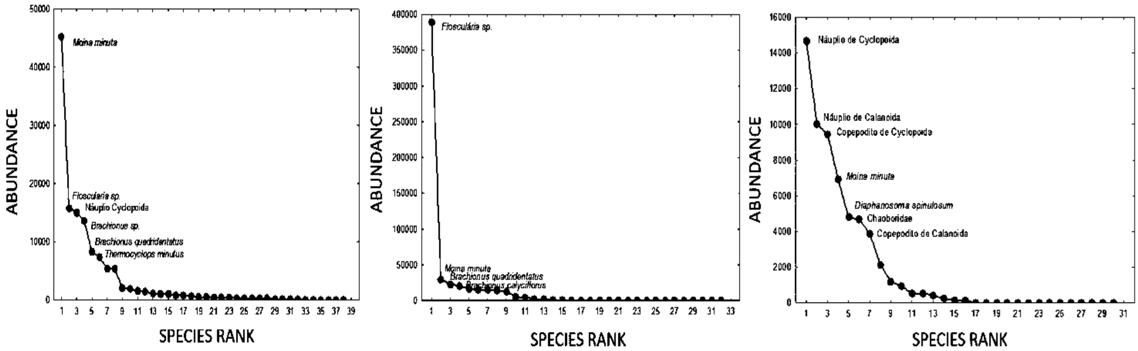

Figure 9. Zooplankton abundance species relationship curves under the conditions of (A) 100g/m^2 of quicklime (Control), (B) 200g/m^2 of quicklime (Test 1), (C) 150g/m^2 of hydrated lime (Test 2), in fish ponds, Rondônia state, Brazil.

4. Conclusions

The data obtained in this research suggest that different forms of management promote different results regarding water quality. We can highlight the intense increase in pH observed in Test 1 (virgin lime at 200g/m^2). The results suggest an increase in the period for releasing the animals in the fish ponds, in relation to the one used (5 days), when using liming at the referred concentration. It can also be observed that the alkalinity and hardness values were more satisfactory in the treatments, when compared to the controls, a result even more noticeable in the second test (41 days) when compared to Test 1 (24 days).

With regard to zooplankton, the different managements also determined different patterns of community structure, not only in terms of abundance and species richness, although these were considerably variable within each trial. However, especially with regard to species composition and dominance. Although the results obtained here bring advances in understanding the effects of sanitary measures on the environmental quality of fish farms, experiments with a more detailed experimental design, with different treatments implemented simultaneously and with a greater number of repetitions, are necessary to corroborate the results. obtained here.

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Declaration of interest's statement

The authors declare no conflict of interests.

Author contribution statement

Vinicius P. Pedroti and Jerônimo V. Dantas Filho.: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper. Bruna Lucieny T. Santos; Jorge Luis V. Cama; Maria Mirtes de L. Pinheiro.: Performed the experiments. Sandro de V. Schons and Luiz Felipe Machado Velho.: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data and Wrote the paper.

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