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ZOOLOGY

Predation rate of dragonfly (Odonata: Libellulidae) on tilapia (*Oreochromis niloticus* Linnaeus 1758) and the availability of alternative preys (Insecta: Diptera: Chironomidae) to increase fish survival

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ABSTRACT. The objective of this work was to evaluate the predation rates of two genera of Odonata *Miathyria* Kirby, 1889 and *Erythemis* Hagen, 1861 in post-larviculture of tilapia with and without availability of Chironomidae. For that, 3 experiments were carried out, the first to analyze which size scale of these two genera would be more efficient in the predation of tilapia and the other 2 experiments with the selected size scales, to analyze the predation rates on tilapia with different Odonata densities, with and without availability of the aquatic insect Chironomidae. For statistical analysis of the data, an analysis of variance (ANOVA) was applied with the Duncan test searching for the means in all experiments. In experiments 2 and 3 a linear regression model was also applied. In experiment 1, there were significant differences between treatments, and in the phase with *Miathyria* the predation of tilapia post-larvae was higher among odonates that corresponded to the size scale from 7.1 to 9.9 mm and therefore the scale was also selected for the next experiments. For *Erythemis*, the consumption of tilapia was higher in the size scale between 12.1 to 14,2 mm. In the following experiments, there were significant differences between treatments. With the increase in Odonata densities the predation of the fish was greater. With the availability of Chironomidae, the consumption of tilapia post-larvae decreased. The consumption of Chironomidae was higher than the consumption of fish in experiment 3. *Miathyria* proved to be more efficient than *Erythemis* in predation and the use of Chironomidae can be a sustainable alternative for post-larvae predation control on fish farms.

Keywords: fish farms; sustainable; odonates.

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Introduction

Fish production has expanded in the last years in Brazil and worldwide (PeixeBR, 2022; Schulter & Vieira Filho, 2017). In Brazil, in relation to the diversity of animal protein consumed, fish showed the highest growth rate with 4.7%, with fish farming in 2021 producing 841,005 tons (PeixeBR, 2022). The exotic species Nile tilapia *Oreochromis niloticus* Linnaeus, 1758, represented 63.5% (534,005 tons) of the national production, taking the country to the position of 4th largest producer of Nile tilapia in the world, the production of natives decreased in relation to 2020, being the tambaqui *Colossoma macropomum* Cuvier, 1818 the most cultivated among them. The exotic Pangasius *Pangasianodon hypophthalmus* Salvage, 1878, is grown mainly in the Northeast (FAO, UNICEF, PMA, & OMS, 2018; PeixeBR, 2022).

Commercial production of tilapia in Brazil is carried out in semi-intensive, intensive and super-intensive systems, with the most common and tested production methods being cultivation/ in excavated tanks and production in net-tanks (Sebrae. Serviço de Apoio às Micro e Pequenas Empresas [SEBRAE], 2014). The rearing of tilapia in excavated tanks is very much related to the larviculture phase and it is precisely in this culture that there is a greater complexity of management. Larviculture is one of the most important stages in the fish breeding process, as it comprises a very dynamic period of development, when they are more sensitive to physical and chemical variations in the water, nutritional management and exposure to pathogens and predators (Portella, Leitão, Takata, & Lopes, 2012).

Predation in fish farming can be considered, among other factors that affect the initial stage of fish life, one of the most harmful to production, with the larvae of aquatic insects considered as important predators in these environments (Louarn & Cloarec, 1997; Soares et al., 2001). Among predators, dragonfly larvae (Odonata) can consume fish larvae, post-larvae and fingerlings causing from a significant decrease to the complete loss of fish production (Kubitza, 2004).

Insects of the order Odonata are popularly known as dragonflies and damselflies. Odonata belong to the superorder Odonatoptera, one of the oldest insect radiations to fly. They are highly predatory and found throughout the world (Suhling et al., 2015; Edgehouse & Brown, 2014). Among aquatic insects, they are the second largest group in number of species, reaching close to 6,317 in the world (Paulson, Schorr, & Deliry, 2021). Brazil is the fullest in the world with 749 registered species (Olaya, 2019).

Odonata larvae develop to adulthood in the water and play the role of efficient predators in aquatic ecosystems, being able to consume any other individual and even their peers (Lopes & De Marco Jr, 2000). In addition to their importance in aquatic ecosystems as predators, they are also considered bioindicators mainly due to the dependence on local environmental conditions for habitat selection (Pereira, Oliveira Junior, & Juen, 2019; Buczynska & Buczyns, 2019; Martinez & Rocha Lima, 2020).

However, despite their ecological importance in aquatic communities, when referring to fish farming environments, specifically in excavated ponds and in the initial moments of fish life, these insects can cause great productive losses as mentioned above (Tave, Rezk, & Smitherman, 1990). According to studies by Santos, Costa, and Luz (1988), De Marco Junior, Latini, and Reis (1999), Fonseca, Sanches, Fonseca, Quintilhiano, and Silva (2004), and Fortunato et al. (2021), among the main genus of Odonata found in fish farms, *Pantala* Hagen, 1861, *Orthemis* Hagen, 1861, *Miathyria* Kirby, 1889, *Erythrodiplax* Brauer, 1868, *Erythemis* Hagen, 1861, all belong to the Libellulidae family.

As a solution to control these predators in fish ponds, more specifically in post-larviculture, the producer opts most of the time for chemical control, which can indeed minimize Odonata populations, but with consequences for fish and water (Fortunato, Melo, & Mendes, 2020). A choice as an alternative of chemical control is the use of biological control with the presence of easy prey, such as Chironomidae (Diptera), the most abundant family in freshwater aquatic systems. Chironomidae is very common in freshwater aquatic systems and can colonize different environments, which allows different environmental responses ranging from sensitivity to impacts to tolerance, to more severe environmental changes (Cordeiro, Guedes, Kisaka, & Nardoto, 2016).

Despite being an important topic for fish farming, few studies have been carried out in Brazil with the aim of verifying the predation rates of Odonata larvae on fish, beside Soares, Hayashi, and Faria (2001), Soares, Hayashi, and Reidel (2003), Fonseca et al. (2004), Lacerda, Hayashi, Galdioli, and Fernandes (2011), and Junior, Franco, Casaca, Munarini, and Dal Magro (2011).

Therefore, the objective of this work is to evaluate the predation rates of two genera of Odonata, *Miathyria* and *Erythemis*, aquatic insects of the Chironomidae family, on tilapia post-larvae in environments with and without the presence of prey.

Material and methods

The study was carried out at the *Universidade Professor Edson Antônio Velano* in the city of Alfenas, Minas Gerais State, Brazil, from November 2019 to March 2020 in the campus fish farming sector. Three experiments were carried out with 40 L aquariums in a water recirculation system (Figure 1) with controlled temperature, to analyze the predation rates of dragonfly larvae on Nile tilapia post-larvae with and without availability of aquatic insects of the Chironomidae family. All procedures and the use of fish were approved with the opinion No. 03 A/2019 of the ethics committee of the *Universidade José do Rosário Velano*.

Selection of Odonata genera

The selection of the Odonata genera used in the experiments was based on the results of studies of Fortunato et al., 2021 with a survey of the genera in five excavated fish farming ponds at the *Universidade Professor Edson Antônio Velano* between October 2018 and March 2019. In this survey 692 larvae were collected, being 34.41% of them represented by the *Miathyria* genus and 20.4% by the *Erythemis genus*. Therefore, these two genera were the ones selected for experiments with tilapia post-larvae.

Figure 1. Laboratory and experimental aquariums.

Obtaining and acclimatizing Odonata

Odonata larvae were collected with a 300 μm mesh net for 2 days before each phase of the experiments in all excavated tanks and artificial lakes on the *Universidade Professor Edson Antônio Velano* campus. There was no set number of collections, as they were discontinued when there was enough *Miathyria* and *Erythemis* individuals of the desired sizes. After each collection, the screening and subsequent identification of the genera was carried out.

To identify the *Miathyria* and *Erythemis* species, a magnifying glass and the manual for identification of Libellulidae by Thorp and Covich (2018) (Libelluloidea) (Neiss, Fleck, Pessacq, and Tennessen, 2018) were used. Afterwards, the length of the larvae was measured with a caliper.

After such procedures, the larvae were distributed in aerated aquariums, where they were acclimatized for 24 hours in a 12-hour photoperiod before the beginning of the experimental phases. For the acclimatization of experiment 1, there was a separation of larvae by size scale, using six aquariums, three for *Miathyria* in the first phase and three for *Erythemis* in the second. There were also larvae for replacement separated by size in 10-liter containers with aeration. This separation by size was made to facilitate the beginning of the experiments and also due to the common cannibalism of larvae of different sizes (Lacerda et al., 2011).

For experiments 2 and 3 (for each phase), there were three acclimatization aquaria where the larvae stayed for 24 hours before the experiments, there was 1 container (for each phase) of 10 liters with aeration with larvae for replacement. During this period, the larvae received an inoculum with plankton.

The plankton available throughout the experiment to feed the Odonata larvae was produced by fertilizing two 500-liter fiber boxes with water from a university dam with natural plant fertilizer and 50% of the surface covered with water hyacinth (*Eichhornia crassipes*) to promote the availability of food for the exuviae during acclimatization. After the acclimatization period, the larvae were placed in the experimental aquaria, where they remained for 8 hours without food. After this period, the experiments began.

Collection and acclimatization of Chironomidae

To obtain the prey insects of the Chironomidae family, 4 containers were installed for each phase of experiment 3, with a capacity of 40 liters with 3 kg of fertilizer. The fertilizer was composed of topsoil, humus and bovine manure. In all, there were 8 boxes and 16 kg of fertilizer.

The boxes were assembled 40 days in advance of each phase of experiment 3. After this period of colonization of the insects, the material was sorted out and, with the aid of a sieve, a superficial washing and subsequently the identification of the live animals with magnifying glass was carried out, according to Trivinho-Strixino (2011). Larvae were measured and those between 6.0 and 7.5 mm were used.

This process of separating and identifying the exuviae occurred 12 hours before the experiments and as they were being measured and identified, they were separated into groups of 75 individuals in 500ml containers (number to be used in the experiments). For both experiments, 1,125 Chironomidae exuviae were used. More than 200 Chironomidae were also separated and inserted into 2 plastic trays for filling, if necessary, in the pre-experiment period.

Obtainment and acclimatization of *Oreochromis niloticus* post-larvae

Tilapia post-larvae were acquired at the NewFish fish farm (Alterosa, Brazil) at 6 days of age. Upon arrival, they were acclimatized for 2 days in 40 L aquaria with aeration in a filtered water reuse system with input from a local weir at a temperature of 27 to 30°C. A commercial mash feed with 32% CP (Supra, Rio Claro, Brazil) was provided.

After these two days, the post-larvae were transferred to the aquaria where the odonates had already been inserted for 8 hours before the beginning of the experiments. In each experimental aquarium 75 post-larvae were distributed and the experiment began, leaving 2 aquaria with 500 post-larvae for replacement.

The initial and final weight of the fish was measured (during and post-acclimatization), having in experiment 1: phase 1: the average weight and initial and final standard deviation 16.01 mg ± 0.5 – 17.7 mg ± 1; phase 2 16.9 mg ± 0.5 – 17.8 mg ± 0.5; experiment 2: phase 1: 17 mg ± 0.5 – 18 mg ± 0.5, phase 2: 17.3 mg ± 0.6 – 17.9 mg ± 0.5; experiment 3: phase 1: 16.4 mg ± 1.26 – 17.3 mg ± 1.05, phase 2: 16.2 mg ± 0.24 – 16.7 mg ± 0.5, respectively. During acclimatization there were 14 dead post-larvae and during the experiments there was a need to replace 9 post-larvae.

Experiment 1

The larvae of the genera *Miathyria* and *Erythemis* were distributed in a two-phase experiment Table 1 using a completely randomized design (DIC) with 5 replications per treatment, to evaluate the size scale of greater efficiency of predation on the tilapia post-larvae. During the experimental period, the number of surviving/predated fish was counted every 3 hours to see the longest period of predation. It is noteworthy that the number of tilapia post-larvae in all treatments was 75 individuals.

Table 1. Experiment 1 model that evaluated the predation rates of two Odonata genus at different size scales on tilapia post-larvae.

Experiment 1	Treatments	Odonata/aquarium	Odonata size scale (mm) Control
Miathyria (Phase 1)	T1	0	Control
	T2	6	5.0 a 7.0
	T3	6	7.1 a 9.9
	T4	6	10 a 12
Erythemis (Phase 2)	T1	0	Control
	T2	6	5.0 a 7.0
	T3	6	7.1 a 9.9
	T4	6	10 a 12
	T5	6	12.1 a 14.2

Experiment 2

According to the best results of Experiment 1, the size scale was chosen to evaluate predation in relation to the different densities per treatments for experiment 2 Table 2 using a completely randomized design (DIC) in two phases with 4 treatments and 5 repetitions. In phase 1, *Miathyria* larvae with sizes from 7.1 mm to 9.9 mm were used and in phase 2, *Ertyhemis* with sizes from 12.1 to 14.2 mm were used. During the experimental period, the number of surviving/predated fish was counted every 3 hours to verify the longest period of predation. It is noteworthy that the number of tilapia post-larvae in all treatments was 75 individuals.

Table 2. Experiment 2 model that evaluated the predation rates of two Odonata genus at different numbers of individuals with standardized size scale on tilapia post-larvae.

Experiment 2	Treatments	Odonata/aquarium
Miathyria (Phase 1) *	T1	0
	T2	4
	T3	6
	T4	8
Erythemis (Phase 2) *	T1	0
	T2	4
	T3	6
	T4	8

*Phase 1: Use of the 7.1 to 9.9 mm *Miathyria* genus for predation tests on tilapia post-larvae. *Phase 2: Use of the 12.1 to 14.2 mm *Erythemis* genus for predation tests on tilapia post-larvae.

Experiment 3

Experiment 3 used a completely randomized design (DIC) with 4 treatments and 5 replications in two phases and evaluated the predation of Odonata with the selected size scale (Table 3) with the results of experiment 1 on tilapia post-larvae with the availability of aquatic insects of the Chironomidae family. During the experimental period, the number of surviving/predated fish was counted every 3 hours.

It is noteworthy that the number of tilapia post-larvae in all treatments was 75 individuals.

Table 3. Experiment 3 model that evaluated the predation rates of two Odonata genus at different numbers of individuals with standardized size scale on tilapia post-larvae with availability of Chironomidae.

Experiment 3	Treatments	Odonata density/aquarium	Chironomidae/aquarium
Miathyria (Phase 1)	T1	0	0
	T2	4	75
	T3	6	75
	T4	8	75
Erythemis (Phase 2)	T1	0	0
	T2	4	75
	T3	6	75
	T4	8	75

*Phase 1: Use of the *Miathyria* genus from 7.1 to 9.9 mm for predation tests on tilapia post-larvae with availability of Chironomidae. *Phase 2: Use of the *Erythemis* genus from 12.1 to 14.2 mm for the tests of predation on post-larvae tilapia with availability of Chironomidae.

Physical and chemical parameters of the experiments

The physical and chemical parameters pH, dissolved oxygen, temperature, toxic ammonia, total hardness and nitrite were measured with the kits for water quality (LABCON PET®) twice in each experimental phase and twice on each day of the fish acclimatization period.

Statistical analysis

Both for the comparison of the means between the Odonata size scales and for the predation tests with and without availability of Chironomidae, an analysis of variance (ANOVA) was applied at 5% probability by the Duncan test (the subsequent test was selected by the ability to calculate amplitudes). All experiments were submitted to normality and homogeneity tests.

For experiments 2 and 3, the linear regression model $p > 0.05$ was applied in relation to increasing levels (Odonata/aquarium densities). All analyzes were performed in the software R Project for Statistical Computing (R Core Team, 2021).

Results

Physical and chemical variables

The physical and chemical variables during all treatments Tables 4, 5, and 6 were within the limits established for fish farming (Kubitza, 1999; Boyd & Tucker, 1998; Sipaúba-Tavares & Moreno, 1994).

Table 4. Mean values and standard deviation of physical and chemical variables measured in experiment 1.

Physical and Chemical Variables	Treatments* (Phase 1)				
	T1	T2	T3	T4	T5
Temperature (°C)	24.21±0.35	24.16±0.35	24.34±0.14	24.14±0.28	
O_2 (mg L^{-1})	6.6±0	6±0	6±0	6±0	
pH	7.24±0.28	7.36±0.56	7.24±0.28	7.2±0	
Total Ammonia (ppm)	0.2±0	0.2±0	0	0	
Total Toughness (ppm)	50-150	50-150	50-150	50-150	
Nitrite (mg L^{-1})	0	0.1±0.35	0	0.05±0	
*Phase 2					
Temperature (°C)	24.34±0.49	24.13±0.28	24.46±1.06	24.67±0.28	24.13±0.28
O_2 (mg L^{-1})	6.6±0	6±1.41	5.8±0	5.6±1.41	6±1.41
pH	7.36±0.28	7.32±0.28	7.24±0	7.45±0.28	7.2±0
Total Ammonia (ppm)	0.4±0	0	0.6±0	0.4±0	0
Total Toughness (ppm)	50-150	50-150	50-150	50-150	50-150
Nitrite (mg L^{-1})	0	0.05±0	0	0	0

*Phase 1: Use of the 7.1 to 9.9 mm *Miathyria* genus for predation tests on tilapia post-larvae. *Phase 2: Use of the 12.1 to 14.2 mm *Erythemis* genus for predation tests on tilapia post-larvae.

Table 5. Mean values and standard deviation of physical and chemical variables measured in experiment 2.

Physical and chemical variables	*Treatments (Phase 1)			
	T1	T2	T3	T4
Temperature (°C)	24.14±0.21	24.13±0.77	24.61±0.49	25.42±0.42
O_2 (mg L^{-1})	5.8±0	6±0	5.6±0	6±0
pH	7.24±0.28	7.32±0.28	7.2±0.28	7.36±0
Total Ammonia (ppm)	0.2±0	0	0	0
Total Hardness (ppm)	50-150	50-150	50-150	50-150
Nitrite (mg L^{-1})	0	0	0	0.1±0.35
	*Phase 2			
Temperature (°C)	24.33±0.56	25.08±1.27	25.64±0.21	25.77±0.84
O_2 (mg L^{-1})	5.2±0	5±1.41	5.4±1.41	5.6±1.41
pH	7.2±0.28	7.32±0.28	7.4±0	7.32±0.28
Total Ammonia (ppm)	0.6±1.41	0.2±0	0	0
Total Hardness (ppm)	50-150	50-150	50-150	50-150
Nitrite (mg L^{-1})	0	0.1±0.35	0.05±0	0.05±0

*Phase 1: referring to the use of the *Miathyria* genus in the predation of tilapia post-larvae. *Phase 2: regarding the use of the genus *Erythemis* in the predation of tilapia post-larvae.

Table 6. Mean values and standard deviation of the physical and chemical variables measured in experiment 3.

Physical and chemical	Treatments (Phase 1) variables			
	T1	T2	T3	T4
Temperature (°C)	24.5±0	24.02±0.63	24.57±0.77	25.01±0.35
O_2 (mg L^{-1})	5.6±1.41	6±0	6±0	5.4±1.41
pH	7.4±0	7.36±0.28	7.24±0	7.4±0
Total Ammonia (ppm)	0	0	0.2	0
Total Hardness (ppm)	50-150	50-150	50-150	50-150
Nitrite (mg L^{-1})	0	0	0	0
	Phase 2			
Temperature (°C)	24.3±0.56	24.67±0.56	24.91±0.21	25.01±0.07
O_2 (mg L^{-1})	6±0	6±0	6±0	5.2±1.41
pH	7.52±0.28	7.56±0.28	7.24±0	7.4±0
Total Ammonia (ppm)	0	0	0.2±0	0.6±0
Total Hardness (ppm)	50-150	50-150	50-150	50-150
Nitrite (mg L^{-1})	0	0	0	0

*Phase 1: referring to the use of the *Miathyria* genus in the predation of tilapia post-larvae with the availability of Chironomidae. *Phase 2: regarding the use of the genus *Erythemis* in the predation of tilapia post-larvae with availability of Chironomidae.

Experiment 1 (Size scales x Post-larvae of tilapia)

Regarding the size scale of *Miathyria* most efficient in the predation of fish in the period of 24 hours, treatment 3, which used sizes from 7.1 to 9.9 mm, obtained the highest average among the others with 29 post-larvae consumed in 24 hours, followed by treatments 4 and 2 respectively. In the control aquaria (treatment 1) there was no mortality of tilapia post-larvae. In experiment 2, to evaluate the most efficient size class of *Erythemis* in predation of tilapia post larvae, treatment 5, referring to sizes 12.1 to 14.2 mm, obtained the highest average consumption.

In the analysis of variance of the two phases of the experiments, the treatments differed significantly ($p < 0.05$) (Table 07).

Table 7. Mean values of predation rates of Odonata larvae at different size scales on tilapia post-larvae (T3 Phase 1 with *Miathyria*; T5 Phase 2 with *Erythemis*).

Treatments	Predation rate of tilapia post-larvae
T1	0 ± 0.00^a
T2	9.2 ± 5.78^b
T3	29 ± 6.59^c
T4	2.4 ± 5.02^c
T1	0 ± 0.00^a
T2	2.4 ± 2.88^a
T3	7.6 ± 2.79^b
T4	11.6 ± 1.51^c
T5	14.96 ± 1.94^d

Experiments 2 and 3

In both experiments Table 8 there were significant differences ($p < 0.05$) for predation rates with increasing Odonata/aquarium densities. In phase 1 of experiment 3, treatments 1 and 2 were different from each other, while treatments 3 and 4 were considered equal, with higher consumption of tilapia post-larvae. In phase 2, the same happened, however, the predation of *Erythemis* was lower in relation to *Miathyria*.

In experiment 3, with the availability of Chironomidae, there was a significant difference between treatments ($p < 0.05$). Treatment 4, phase1, presented the highest rate of fish predation. It is possible to notice a reduction in the average consumption of tilapia post-larvae with the availability of Chironomidae, comparing the averages of experiment 2 (phase 1). In phase 2, treatments 3 and 4 showed the highest predation rate on tilapia post-larvae, with a small decrease due to the availability of Chironomidae compared to experiment 2 (phase 2).

Table 8. Means and standard deviation compared by Duncan's test of predation rates of Odonata on tilapia post-larvae with and without availability of Chironomidae with ($p < 0.05$).

Treatments	Experiment 2*		Experiment 3*	
	Phase 1	Phase 2	Phase 1	Phase 2
T4	31.6 ± 4.94^{a}	11.8 ± 3.53^{a}	17.2 ± 0.70^{a}	9 ± 2.12^{a}
T3	26 ± 2.82^{a}	10.2 ± 0^{a}	10.2 ± 1.41^{b}	7.2 ± 2.82^{ab}
T2	14.6 ± 2.12^{b}	6.8 ± 2.12^{b}	4.8 ± 0.00^{c}	4.6 ± 1.41^{b}
T1	0 ± 0.00^{c}	0 ± 0.00^{c}	0 ± 0.00^{d}	0 ± 0.00^{c}

*Experiment 2: Analysis of Odonata predation rates at different densities on tilapia post-larvae. (Phase 1: Use of *Miathyria*; Phase 2: Use of *Erythemis*).
*Experiment 3: Analysis of Odonata predation rates at different densities on tilapia post-larvae with the availability of Chironomidae (Phase 1: use of *Miathyria*; Phase 2: use of *Erythemis*).

The regression in relation to survival with the different densities/treatment. Figure 2 had significance $p < 0.05$. Note that with increasing density of immature Odonata per aquarium, survival of tilapia post-larvae decreases, but densities of 6 and 8 are close.

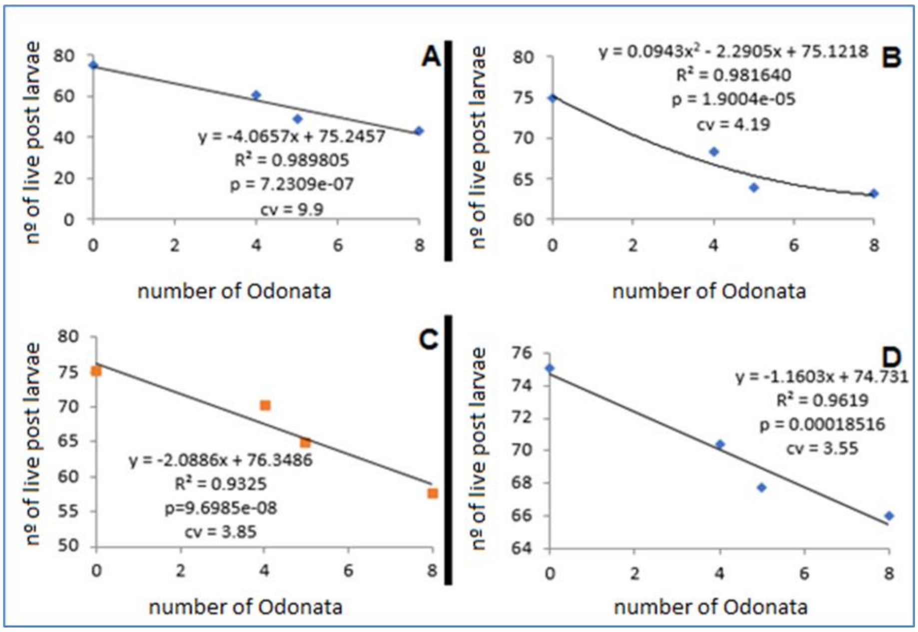

Figure 2. Regression of tilapia post-larvae survival rates in relation to the increase in Odonata density per treatment. Experiment 1. Odonata predation on tilapia post-larvae at different densities/treatment. (A) Phase 1: Use of *Miathyria*. (B) Phase 2: Use of *Erythemis*. Experiment 2. Odonata predation on tilapia post-larvae at different densities/treatment with availability of Chironomidae. (C) Phase 1: Use of *Miathyria*. (D) Phase 2: Use of *Erythemis*.

Consumption of Chironomidae

As for the predation rates of Chironomidae Table 9 there was a significant difference ($p < 0.05$) between treatments and the consumption averages were higher in relation to the consumption of tilapia post-larvae in the experiment, as already mentioned. In experiment 3 T1 and T2 were different from each other and from the other treatments. T3 and T4 were close. In experiment 6, however, except for T1 (control), all treatments were considered equal.

Table 9. Standard deviation and means compared by Duncan's test of consumption of Chironomidae during experiment 3.

Treatments	Phase 1*	Phase 2*
T4	2.82 ± 51.4 [a]	10.60 ± 27.6 [a]
T3	14.4 ± 47.6 [a]	12.72 ± 21.2 [a]
T2	4.94 ± 30.2[b]	16.9 ± 23.2 [a]
T1	0 ± 0.00[c]	0 ± 0.00[b]

*Phase 1 corresponding to the use of *Miathyria* in predation tests on fish. *Phase 2 corresponding to the use of *Erythemis* in predation tests on fish.

In the regression analysis for the survival of Chironomidae larvae Figure 3, which was also significant between treatments in experiment 3 ($p < 0.05$), it is possible to observe that with increasing Odonata density per treatment, there is a greater reduction in the survival rate of Chironomidae, but the densities of 6 and 8 do not differ much from each other.

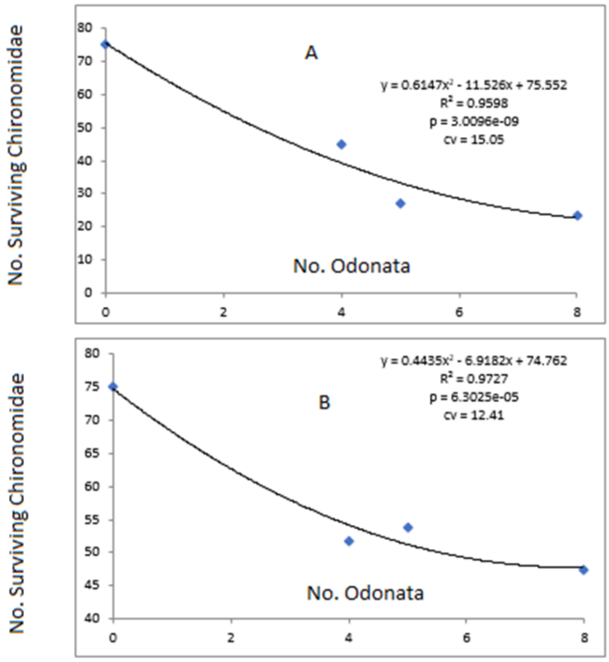

Figure 3. Regression analysis of Chironomidae consumption during experiment 3. (A) Phase 1; (B) Phase 2. Experiment 3. Odonata predation on tilapia post-larvae at different densities with availability of Chironomidae. Phase 1: Use of *Miathyria*. Phase 2: Use of *Erythemis*.

Discussion

In this study, the physical and chemical variables were within the accepted limits for the cultivation of tilapia and therefore did not influence post-larvae mortality (Chipepe, Vento-Tielves, & Atkinson, 2021; Kubitza, 1999; Boyd & Tucker, 1998; Sipaúba-Tavares & Moreno, 1994).

Regarding experiment 1, it was not possible to state whether the last size scales of the two genera are the last larval stages of these insects, due to the result of this work not having kept the rearing of the specimens until the adult phase, in the last stages of development. larvae, odonates tend to show greater lethargy in metabolism and ecological activities, including predation. It is known that some *Erythemis* species that occur in southeastern Brazil, such as *Erythemis credula*, can reach 15 mm, and *E. plebeja* 15.5 mm in the last larval instar (Rodrílguez, Sarmiento, & González-Soriano, 2015; Vilela, Ferreira, & Del-Claro, 2016).

Among the two existing species of *Miathyria*, we have *M. marcella* and M. *simplex.* As for *M. marcella*, studies on the instars of these larvae are scarce in Brazil. However, according to Westfall (1953), analyzing samples of this species in Florida, he witnessed exuviae of up to 17 mm, differing from the total length of specimens found in Cuba and Puerto Rico. Regarding to *M. simplex*, the last instar varies from 12 to 14 mm (Costa & Assis, 1992).

Lacerda et al. (2011), studying different size scales of *Pantala flavescens* in the consumption of pacu (*Piaractus mesopotamicus*) and tilapia (*Oreochromis niloticus*), observed a decrease in fish consumption by the larger Odonata, *P. flavescens* species. The same occurred in Soares et al. (2003), that analyzing the different size scales of *Pantala* sp in the predation of *Simocephalus serrulatus* (Cladocera, Crustacea), they noticed that the intermediate sizes had greater efficiency in the consumption of these crustaceans, validating the results obtained in this study with *Miathyria*.

Regarding *Erythemis*, for reasons already mentioned, it is not possible to say if the class of size used for this genus corresponds to its largest larval size.

In experiment 2, which used *Miathyria* larvae with and without availability of Chironomidae, the treatments with density of 8 larvae/aquarium had the highest average consumption with 31.4 post-larvae in a 24-hour period. In the *Miathyria* phase of experiment 3 with the availability of Chironomidae there was a reduction in consumption, with an average of 11.8 post-larvae being consumed, being a density of 8 larvae/aquarium the highest average in this experiment, which can attest the influence of Chironomidae in increasing the survival rate of fish.

The results suggest that the predation of tilapia post-larvae decreases with the availability of prey (Chironomidae) due to the fact that these aquatic insects move and settle in aquaria with greater proximity of the odonates, it is possible that this reduction might occur due to food preference and obviously also to satiety, because in all experiments, when consumption was accounted by observation periods, fish predation decreased as the experiment progressed. Soares et al. (2001) mentions that, as a result of the increased availability of prey, the prey-predator frequency factor weakens due to the biological characteristics of Odonata, such as satiation.

Concerning preference, some studies that analyzed the stomach contents of Odonata observed a higher percentage of Chironomidae comparing to other aquatic invertebrates such as Baetidae, Leptophlebiidae, among others (Dudgeon & Wat, 1986; Alencar, Hamada, & Magni-Darwich, 1999). This may be due to the anatomical characteristics of Chironomidae facilitating predation and total consumption by the odonates.

Miathyria specie was more active than *Erythemis*, but when observing the act of predation, both genera wait for prey to attack, validating findings of Soares et al. (2001), Soares et al. (2003), Junior et al. (2011), and Lacerda et al. (2011). Soares et al. (2001) that carrying out an experiment with Odonata in predation of cladocerans, observed that they wait for the prey, showing that they are visual predators, stimulated to attack with the movement of the prey.

Thus, the exuviae of *Miathyria* can be considered important in fish farming, agreeing with Santos et al. (1988) who placed *Pantala*, *Miathyria* and *Tramea* in this group of importance for these environments. It is also possible to mention that the availability of Chironomidae significantly reduces the predation affected by this genus.

In experiments 2 and 3, which used *Erythemis* larvae in predation of tilapia post-larvae, there were minimal differences in relation to fish consumption. In both experiments, the densities of 8 larvae/aquarium were the treatments with the highest consumption, with the respective averages of 17.2 and 9 exuviae, both consumed in 24 hours.

Erythemis showed greater lethargy in predation, but the consumption of Chironomidae in relation to post-larvae doubled when compared to the average consumption of experiments 2 and 3. Fulan and Anjos (2015), in a study analyzing the predation of *Erythemis* on Chironomidae and Elmidae with and without the presence of macrophytes, observed total predation of both families of aquatic insects in the treatments without the aquatic plants.

In summary, the results indicate a high potential for *Miathyria* predation on *Oreochromis niloticus* and a low predation potential for *Erythemis*. The availability of Chironomidae significantly influenced the survival rates of tilapia post-larvae, emerging as an alternative for the use organophosphates, but it is necessary to carry out tests in excavated fish farming ponds with the mass production of Chironomidae, as well as similar studies with *Pantala flavescens*, since it is considered the major predator of fish farming.

The use of Chironomidae can be an alternative to the chemicals used to control Odonata since their production requires little investment and simple fertilization, which can minimize the predation of Odonata on fish in the early stages, not resulting in the total loss of production and great damage to producers, even more so when one thinks of small producers.

Conclusion

With this work, it was possible to conclude that the Chironomidae can benefit fish farming by being alternatives for Odonata predation on tilapia post-larvae and with that the producer can save on organophosphates and still have a more sustainable production environment.

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References

Alencar, Y. B., Hamada, N., & Magni-Darwich, S. (1999). Stomach content analysis of potential predators of Simuliidae (Diptera: Nematocera) in two lowland forest streams, Central Amazonia, Brazil. *Anais da Sociedade Entomológica do Brasil*, *28*(2), 327-332. DOI: https://doi.org/10.1590/S0301-80591999000200017

Boyd, C. E., & Tucker, C. S. (1998). Ecology of aquaculture ponds. In C. E. Boyd, & C. S. Tucker (Eds.), *Pond aquaculture water quality management* (p. 8-86). Boston, MA: Springer. DOI: https://doi.org/10.1007/978-1-4615-5407-3_2

Buczyńska, E., & Buczyński, P. (2019). Aquatic insects of man-made habitats: Environmental factors determining the distribution of Caddisflies (Trichoptera), Dragonflies (Odonata), and Beetles (Coleoptera) in Acidic Peat Pools. *Journal of Insect Science*, *19*(1), 1-15. DOI: https://doi.org/10.1093/jisesa/iez005

Chipepe, F. A. L., Vento-Tielves, C. R., & Atkinson, J. (2021). Evaluation of the main physical and chemical water quality parameters for tilapia production. *Revista Ciências Técnicas Agropecuárias*, *30*(4), 12-20.

Cordeiro, G. G., Guedes, N. D. M., Kisaka, T. B., & Nardoto, G. B. (2016). Avaliação rápida da integridade ecológica em riachos urbanos na bacia do rio Corumbá no Centro-Oeste do Brasil. *Revista Ambiente & Água*, *11*(3), 702-710. DOI: https://doi.org/10.4136/ambi-agua.1857

Costa, J. M., & Assis, C. V. (1992). Estudo morfológico da larva de último ínstar de *Miathyria simplex* (Rambur) (Odonata, Libellulidae). *Revista Brasileira de Zoologia*, *9*(3-4), 329-336. DOI: https://doi.org/10.1590/S0101-81751992000200020

De Marco Jr, P., Latini, A. O., & Reis, A. P. (1999). Environmental determination of dragonfly assemblage in aquaculture ponds. *Aquaculture Research*, *30*(5), 357-364. DOI: https://doi.org/10.1046/j.1365-2109.1999.00338.x

Dudgeon, D., & Wat, C. Y. (1986). Life cycle and diet of *Zygonyx iris insignis* (Insecta: Odonata: Anisoptera) in Hong Kong running waters. *Journal of Tropical Ecology*, *2*(1), 73-85. DOI: https://doi.org/10.1017/S0266467400000614

Edgehouse, M., & Brown, C. P. (2014). Predatory luring behavior of odonates. *Journal of Insect Science*, *14*(1), 1-3. DOI: https://doi.org/10.1093/jisesa/ieu008

FAO, FIDA, UNICEF, PMA, & OMS. (2018). *El estado de la seguridad alimentaria y la nutrición en el mundo: fomentando la resiliencia climática en areas de la seguridad alimentaria y la nutrición*. Retrieved on Aug. 10, 2022 from https://hdl.handle.net/11537/27978

Fonseca, A. R., Sanches, N. M., Fonseca, M. C., Quintilhiano, D. M., & Silva, E. S. (2004). Levantamento de espécies de Odonata associadas à tanques de piscicultura e efeito de *Bacillus thuringiensis* var. *israelensis* sobre ninfas de *Pantala flavescens* (Fabricius, 1798). *Acta Scientiarum. Biological Sciences*, *26*(1), 25-29. DOI: https://doi.org/10.4025/actascibiolsci.v26i1.1655

Fortunato, M. H. T., Melo, C. L. D., & Mendes, H. F. (2020). Piscicultura brasileira e a influência da ordem Odonata, uma revisão. *Arquivos de Ciências Veterinárias e Zoologia da UNIPAR*, *23*(1), 1-7. DOI: https://doi.org/10.25110/arqvet.v23i1cont.2020.7818

Fortunato, M. H. T., Mendes, H. F., Hayashi, C., Faria, L. R., Melo, C. L., & Ananias, I. M. C. (2021). Levantamento de imaturos de libélulas (Insecta: Odonata) em tanques escavados de piscicultura na mesorregião de Alfenas-MG. *Research, Society and Development*, *10*(11), 1-13. DOI: https://doi.org/10.33448/rsd-v10i11.19846

Fulan, J. Â., & Anjos, M. R. D. (2015). Predation by *Erythemis* nymphs (Odonata) on Chironomidae (Diptera) and Elmidae (Coleoptera) in different conditions of habitat complexity. *Acta Limnologica Brasiliensia*, *27*(4), 454-458. DOI: https://doi.org/10.1590/S2179-975X2415

Júnior, O. T., Franco, G. M. S., Casaca, J. M., Munarini, A. C., & Dal Magro, J. (2011). Efeito do extrato de *Melia azedarach* sobre a predação de alevinos de carpa comum (*Cyprinus carpio*) por larvas de *Neuraeschna* (Odonata: Aeshnidae). *Brazilian Journal of Aquatic Science and Technology*, *15*(1), 19-25. DOI: https://doi.org/10.14210/bjast.v15n1.p19-25

Kubitza, F. (2004). Coletânea de informações aplicadas ao cultivo do tambaqui, do pacu e de outros peixes redondos. *Panorama da Aquicultura*, *14*(82), 27-39.

Kubitza, F. (1999). Nutrição e alimentação de tilápias-parte I. *Panorama da Aquicultura*, *9*(52), 42-50.

Lacerda, C. H. F., Hayashi, C., Galdioli, E. M., & Fernandes, C. E. B. (2011). Predation of *Piaractus mesopotamicus* and *Oreochromis niloticus* larvae by *Pantala flavescens* with different length classes. *Acta Scientiarum. Biological Sciences*, *33*(4), 377-382. DOI: https://doi.org/10.4025/actascibiolsci. v33i4.547

Lopes, F. S., & De Marco Jr, P. (2000). Comportamento territorial em insetos: aspectos conceituais e estudo de casos. *Oecologia Brasiliensis*, *8*(1), 193-222. DOI: https://doi.org/10.4257/oeco.2000.0801.07

Louarn, H., & Cloarec, A. (1997). Insect predation on pike fry. *Journal of Fish Biology*, *50*(2), 366-370. DOI: https://doi.org/10.1111/j.1095-8649.1997.tb01364.x

Martinez, N. M., & Rocha-Lima, A. B. C. (2020). A importância dos insetos e as suas principais ordens. *Unisanta BioScience*, *9*(1), 1-14.

Neiss, U.G., Fleck, G., Pessacq, P., & Tennessen, K. J. (2018). Odonata: Superfamily Libelluloidea. In N. Hamada, J. Thorp, D. Christopher Rogers (Eds.), *Thorp and covich's freshwater invertebrates* (4th ed.). *Volume 3: Keys to Neotropical Hexapoda* (p. 399–447). London, UK: Academic Press.

Olaya, M. (2019). Odonatos en Latinoamérica: la riqueza de nuestra región. *Hetaerina*, *1*(2), 4-5. Retrieved from https://bitlybr.com/8AyqHO

Paulson, D., Schorr, M., & Deliry, C. (2021). *World Odonata List*. *Last Revision*, *17*. Retrieved from https://www.biodiversity4all.org/taxon_schemes/33

PeixeBr. (2022). *Anuário brasileiro da piscicultura*. São Paulo, SP: Associação Brasileira da Piscicultura.

Pereira, D. F. G., Oliveira Junior, J. M. B., & Juen, L. (2019). Environmental changes promote larger species of Odonata (Insecta) in Amazonian streams. *Ecological Indicators*, *98*, 179-192. DOI: https://doi.org/10.1016/j.ecolind.2018.09.020

Portella, M. C., Leitão, N. D. J., Takata, R., & Lopes, T. (2012). Alimentação e nutrição de larvas. In D. M. Fracalossi, & J. E. P. Cyrino (Eds.), *Nutriaqua: nutrição e alimentação de espécies de interesse para a aquicultura brasileira* (p. 185-216). Florianópolis, SC: Sociedade Brasileira de Aquicultura e Biologia Aquática.

R Core Team (2021). *R: A language and environment for statistical computing*. Vienna, AT: R Foundation for Statistical Computing. Retrieved on Aug. 10, 2022 from https://www.R-project.org/

Rodrílguez, F. P., Sarmiento, C. E., & González-Soriano, E. (2015). Morphological variability and evaluation of taxonomic characters in the genus *Erythemis* Hagen, 1861 (Odonata: Libellulidae: Sympetrinae). *Insecta Mundi, 428,* 1-68.

Santos, N. D., Costa, J. M., & Luz, J. R. P. (1988). Nota sobre a ocorrência de odonatos em tanques de piscicultura e o problema da predação de alevinos pelas larvas. *Acta Limnologica Brasiliensia*, *2*, 771-780.

Schulter, E. P., & Vieira Filho, J. E. R. (2017). Evolução da piscicultura no Brasil: diagnóstico e desenvolvimento da cadeia produtiva de tilapia. *Instituto de Pesquisa Econômica Aplicada*, *2328*, 1-36.

Serviço de Apoio às Micro e Pequenas Empresas [SEBRAE]. (2014). *Criação de tilápias em tanques escavados*. Natal, RN: Sebrae.

Sipaúba-Tavares, L. H., & Moreno, S. Q. (1994). Variação dos parâmetros limnológicos em um viveiro de piscicultura nos períodos de seca e chuva. *Revista Unimar*, *16*(4), 229-242.

Soares, C. M., Hayashi, C., & Faria, A. C. E. A. (2001). Influência da disponibilidade de presas, do contraste visual e do tamanho das larvas de *Pantala* sp. (Odonata, Insecta) sobre a predação de *Simocephalus serrulatus* (Cladocera, Crustacea). *Acta Scientiarum. Biological Sciences*, *23*(2), 357-362. DOI: https://doi.org/10.4025/actascibiolsci.v23i0.2689

Soares, C. M., Hayashi, C., & Reidel, A. (2003). Predação de pós-larvas de curimba (*Prochilodus lineatus*, Valenciennes, 1836) por larvas de Odonata (*Pantala*, Fabricius, 1798) em diferentes tamanhos. *Acta Scientiarum. Biological Sciences*, *25*(1), 95-100. DOI: https://doi.org/10.4025/actascibiolsci.v25i1.2105

Suhling, F., Sahlén, G., Gorb, S., Kalkman, V. J., Dijkstra, K. D. B., & van Tol, J. (2015). Order Odonata. In *Thorp and Covich's freshwater invertebrates* (p. 893-932). London, UK: Academic Press. DOI: https://doi.org/10.1016/B978-0-12-385026-3.00035-8

Tave, D., Rezk, M., & Smitherman, R. O. (1990). Effect of body colour of *Oreochromis mossambicus* (Peters) on predation by dragonfly nymphs. *Aquaculture Research*, *21*(2), 157-162. DOI: https://doi.org/10.1111/j.1365-2109.1990.tb00452.x

Trivinho-Strixino, S. (2011). *Larvas de Chironomidae: guia de identificação*. São Carlos, SP: Aurora. DOI: https://doi.org/10.4322/978-65-00-62449-6

Vilela, D. S., Ferreira, R. G., & Del-Claro, K. (2016). The Odonata community of a Brazilian vereda: seasonal patterns, species diversity and rarity in a palm swamp environment. *Bioscience Journal*, *32*(2), 486-495. DOI: https://doi.org/10.14393/BJ-v32n2a2016-30491

Westfall, M. J. (1953). The nymph of *Miathyria marcella* Selys (Odonata). *The Florida Entomologist*, *36*(1), 21-25. DOI: https://doi.org/10.2307/3492178