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Analysis of the period of expansion of fish farms in the state of Rondônia, Brazil

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ABSTRACT

In this study, we evaluated the records of fish farming facilities over 20 years (2000-2020) according to regions in the Rondônia State. The growth of fish farming activities began in 2004 and reached its peak in 2012, with 1,143 enterprises. In 2017, the activity began to stagnate, suggesting the need for constant monitoring. To understand the registration of fish farms per region, time evolution analyses were used. To compare this expansion between municipalities, comparative methods such as Mann-Whitney (for two groups), Kruskal-Wallis and Fisher's test (for more than two groups), also the Bray-Curtis distance grouping index to identify groups and patterns, were applied. The most developed municipalities were highlighted by the annual absolute frequency, using the nonparametric Kolmogorov-Smirnov test (considering $\alpha = 0.05$). The municipalities of Urupá, Alta Floresta d'Oeste, Mirante da Serra, Vale do Paraíso, Ji-Paraná, Ariquemes, Ouro Preto do Oeste, and Porto Velho presented the highest numbers of new fish farming. Thus, we concluded that fish farming expanded throughout the state. However, after a period of intense growth, there was a drastic reduction in the number of new registrations. This decline may be associated with possible saturation of environmental support capacity or the lack of government incentives.

Keywords: Amazonia; Native fish; Tambaqui fish farming.

Análise do período de expansão dos empreendimentos piscícolas no estado de Rondônia, Brasil

RESUMO

Neste estudo avaliamos o registro de instalações de piscicultura ao longo de 20 anos (2000–2020) por regiões no estado de Rondônia. O crescimento da atividade piscícola teve início no ano de 2004, atingindo seu ápice em 2012, com 1.143 empreendimentos. Em 2017, uma atividade começou a estagnar, contribuindo para a necessidade de um monitoramento constante. Para entender o registro de pisciculturas por regiões, foram empregadas as análises de evolução temporal. Para comparar essa expansão entre os municípios, aplicaram-se os métodos de Mann-Whitney (para dois grupos), Kruskal-Wallis e o teste de Fisher (para mais de dois grupos), também o índice de Bray-Curtis para identificar grupos e padrões. Os municípios mais desenvolvidos foram destacados pela frequência absoluta anual, utilizando o teste não paramétrico de Kolmogorov-Smirnov (considerando $\alpha = 0,05$). Os municípios de Urupá, Alta Floresta d'Oeste, Mirante da Serra, Vale do Paraíso, Ji-Paraná, Ariquemes, Ouro Preto do Oeste e Porto Velho obtiveram os maiores números de novas pisciculturas. Assim, concluímos que a piscicultura se expandiu por todo o estado, no entanto, após um período de intenso crescimento, houve uma redução drástica no número de novos registros. Tal declínio pode estar associado à possível saturação da capacidade de suporte ambiental ou à ausência de estímulos governamentais.

Palavras-chave: Amazonia; Peixe nativo; Piscicultura de tambaqui.

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INTRODUCTION

The growing demand for food is one of the main problems associated with population growth (Bjørndal et al., 2024), which is expected to reach approximately nine billion people by the year 2050 (UN, 2022). Currently, one of the main sources of protein in the human diet comes from the cultivation of aquatic species, which accounts for over 15% of the total (Boyd et al., 2022). The production of food from aquaculture reached 223 million tons in 2022, surpassing capture fisheries, but it is facing stagnation in developed countries due to high costs and competition with nations with lower production expenses (FAO, 2024).

Brazil stands out for being a leading nation in the Americas for inland aquaculture due to its favorable characteristics, including abundant water resources, low production costs, extensive irrigated areas, and rich natural assets that support the growth of the sector (Valenti et al., 2021). Among the most promising regions for aquaculture, the state of Rondônia, located in the Brazilian Amazon, has significant water resources including the Madeira, Guaporé, Mamoré, and Machado River basins, which, along with their tributaries, play a crucial role in supplying water to the state's fish farming operations.

The farming of native species of fish in Brazil has shown a strong expansion in recent years, with the state of Rondônia being the largest producer, especially of the species *Colossoma macropomum*, popularly known as tambaqui (Peixe BR, 2024). Although periods of local growth in this activity have imposed substantial challenges to sustainability, such obstacles can be mitigated through the production of species that have lower environmental impact (Liu et al., 2025). In 2016, the state of Rondônia reached the level of the largest national producer of native fish, achieving a production volume of 90,600 tons, with *C. macropomum* and *Arapaima gigas* being the most prominent species (Pereira, 2020). Economic activity in Rondônia is predominantly concentrated in the agricultural sector, which also benefits fish farming (Ceballos-Concha et al., 2025).

We suggest that the expansion of fish farming production in Rondônia is intrinsically associated with the significant increase in the number of new fish farms over the past two decades. This hypothesis is strongly supported by the observation that periods of significant production growth are typically accompanied by a corresponding increase in the cultivated area (Belton et al., 2017). The state's water characteristics currently allow the occupation of an area of 14,400 hectares of water on approximately 4,000 rural establishments, where production in captivity in the state increased by 198.4% between 2013 and 2014 (Cavali & Dantas Filho, 2024; Oliveira, 2024). This growth was driven by government support, less bureaucratic environmental licensing and affordable credit (EMBRAPA, 2018).

There are, to date, no studies that analyze the expansion of fish farming enterprises over the years in Rondônia. These territories may be influenced by intervening factors related to the geopolitics of the state, which occupies a strategic position as an integration hub between the Northern and Central-Western regions of Brazil, in addition to bordering the states of Acre, Amazonas, and Mato Grosso, and its international neighbor Bolivia. This geopolitical context may directly influence the success or failure of the activity as a result of possible resistance to future investments (Knudsen, 2025).

As such, it is still necessary to implement continuous monitoring of data correlated to state fish farming activities so that possible growth parameters or even stagnation points can be predicted. Therefore, the objective of this study was to analyze the period of expansion in the numbers of fish farming enterprises in the state of Rondônia, considering its geopolitical characteristics and divisions, in order to assist in the management measures of this activity, which is still in the phase of consolidation in the state.

MATERIALS AND METHODS

Study area

The information analyzed in this study came from the State Secretariat for Environmental Development and the Agrosilvopastoral Health Defense Agency of the state of Rondônia and is organized in electronic spreadsheets and reports. These documents contain data collected for all the 52 municipalities in the state of Rondônia, covering the number of fish farms established annually between the years 2000 and 2020. However, the data does not include information on the annual closure of fish farms. The opening of new fish farms depicted in the data refers exclusively to ventures with excavated nurseries, which account for most the state's fish farming operations.

The state of Rondônia is the third most populous in the Northern region of Brazil and the 13th nationally, and it comprises 52 municipalities. Among the highlighted geographical divisions, the state is segmented into eight microregions (composed of groups of municipalities):

- Porto Velho: Buritis, Campo Novo de Rondônia, Candeias do Jamari, Cujubim, Itapuã do Oeste, Nova Mamoré and Porto Velho;
- Guajará Mirim: Costa Marques, Guajará-Mirim and São Francisco do Guaporé;
- Ariquemes: Alto Paraíso, Ariquemes, Cacaulândia, Machadinho d'Oeste, Monte Negro, Rio Crespo and Vale do Anari;

• Ji-Paraná: Governador Jorge Teixeira, Jaru, Ji-Paraná, Mirante da Serra, Nova União, Ouro Preto do Oeste, Presidente Médici, Teixeirópolis, Theobroma, Urupá and Vale do Paraíso;
• Alvorada do Oeste: Alvorada d'Oeste, Nova Brasilândia d'Oeste, São Miguel do Guaporé and Seringueiras;
• Cacoal: Alta Floresta d'Oeste, Alto Alegre dos Parecis, Cacoal, Castanheiras, Espigão d'Oeste, Ministro Andreazza, Novo Horizonte do Oeste, Rolim de Moura and Santa Luzia d'Oeste;
• Vilhena: Chupinguaia, Parecis, Pimenta Bueno, Primavera de Rondônia, São Felipe d'Oeste and Vilhena;
• Colorado do Oeste: Cabixi, Cerejeiras, Colorado do Oeste, Corumbiara and Pimenteiras do Oeste (Fig. 1).

Additionally, Rondônia is subdivided into three geographical sub-regions:
• The intermediate geographical region of Porto Velho and Ji-Paraná, with 18 and 34 municipalities, respectively;
• The immediate geographical region divided into Porto Velho, Ariquemes, Jaru, Ji-Paraná, Cacoal and Vilhena, with five, eight, five, 13, 14 and seven municipalities, respectively;
• The geographical mesoregion of Madeira-Guaporé and Leste de Rondônia, with 10 and 42 municipalities, respectively.

In the present study, all these divisions were addressed.

Data analysis

In the evaluation of the number of new fish farms registered throughout the state of Rondônia, the absolute frequency and the frequency accumulated over the years were used, as well as the accumulated frequency for fish farms in the geographical divisions of the state. Among the geographical divisions, comparisons were also made considering the total number of enterprises in each of their respective municipalities. As the assumptions of normality and homoscedasticity were not met, we used the nonparametric Mann-Whitney tests for the comparison of two groups and the Kruskal-Wallis test with Dunn's multiple comparisons post-test for the comparison of more than two groups.

In the analyses between the municipalities, comparisons were made between the locations to address individual aspects. For the comparisons, a cluster analysis was used considering the Bray-Curtis distance index. In the cluster analysis, the data were transformed (logN+1) to reduce the variability between the numbers of enterprises and for better indications of possible groups. The municipalities that presented the greatest prominence (total number of fish farms) were also evaluated via the distribution of annual absolute frequency, and the distributions were compared by pairs using the nonparametric Kolmogorov-Smirnov test. In the individual cases of each municipality, in which the number of fish farms was verified, we performed a covariance analysis (ANCOVA). The significance level for all tests was set at $\alpha = 0.05$. All the analyses were performed in the program R 4.4.1 (R Core Team, 2024).

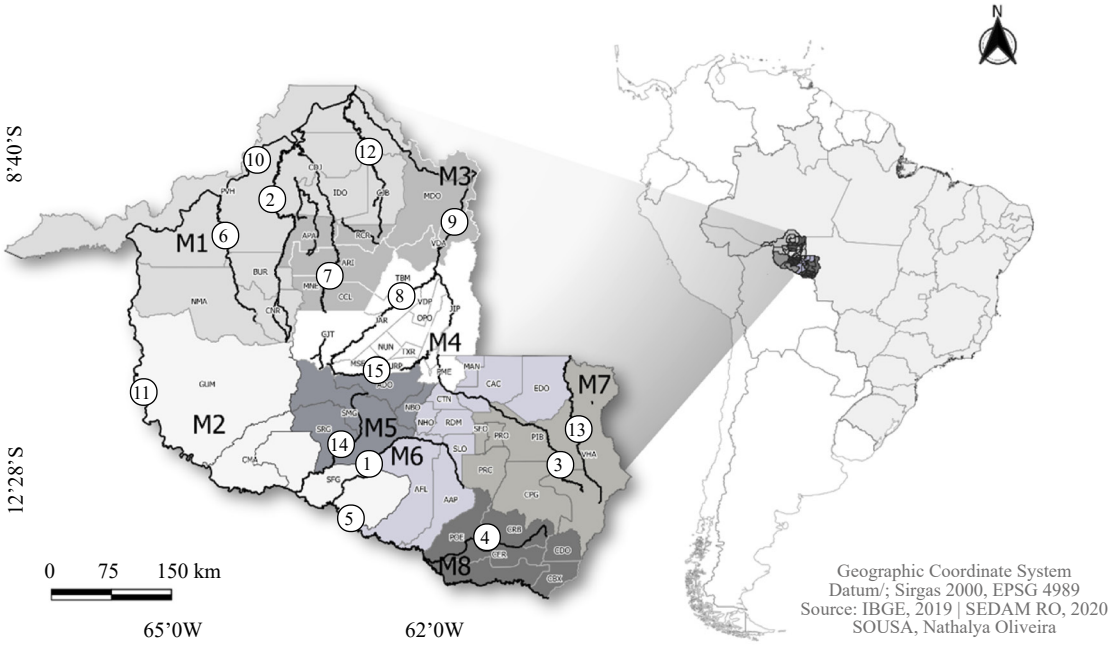


Figure 1. Delimitations of the microregions of the state of Rondônia: M1) Porto Velho; M2) Guajará Mirim; M3) Ariquemes; M4) Ji-Paraná; M5) Alvorada do Oeste; M6) Cacoal; M7) Vilhena; M8) Colorado do Oeste.

RESULTS

In the evaluated time series, a total of 4,038 fish farms were registered, which were distributed throughout the municipalities of the state. The highest frequency of records of fish farms peaked in 2012, with a percentage of almost 30% of the analyzed time series, though a decrease in records was observed from 2013 onwards, which continued until 2020 (Fig. 2). In 2017, the records of fish farms that are presented in the cumulative frequency show a stagnation in the growth of this activity in Rondônia.

When analyzing the records of fish farms by region, it was found that the intermediate and immediate regions of Ji-Paraná were the ones with the highest numbers of fish farms (Figs. 3a and 3b). The mesoregion of East Rondônia stood out in the summations (Fig. 3c). The microregion of Ji-Paraná (M4) showed the highest growth in new fish farms, followed by Cacoal (M6) and Ariquemes (M3), with totals of 1,569, 706 and 581, respectively (Fig. 3d).

In the annual sum of the number of fish farms per municipality (Fig. 4), separated by intermediate region, there were no

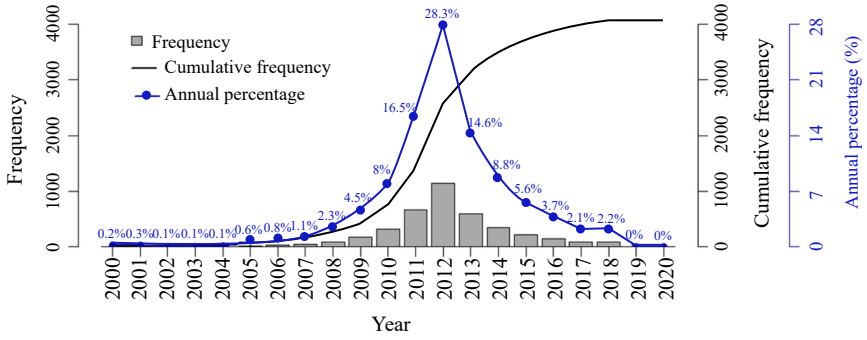


Figure 2. Frequency of the number of fish farms (bars), cumulative frequency of the number of fish farms (black line), and annual percentage of the number of fish farms (blue line) registered between the years 2000 and 2020 in the state of Rondônia.

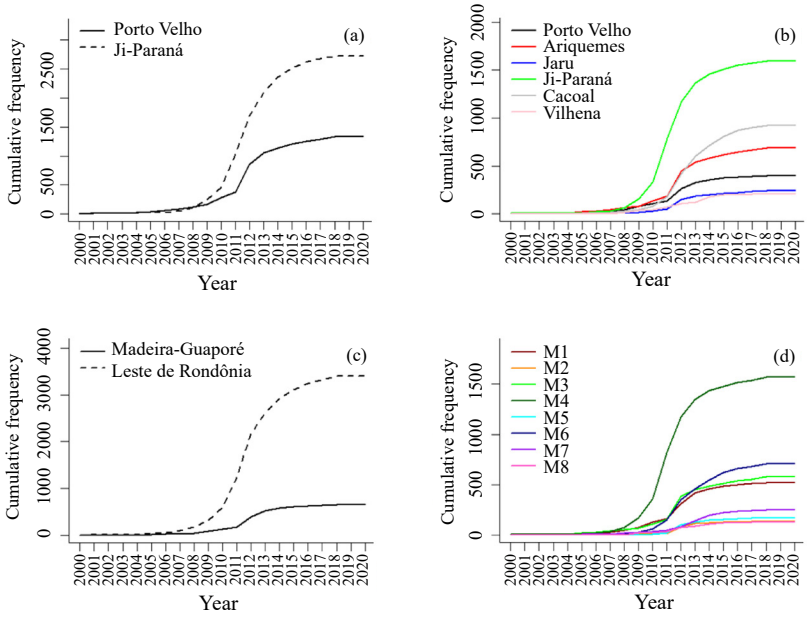
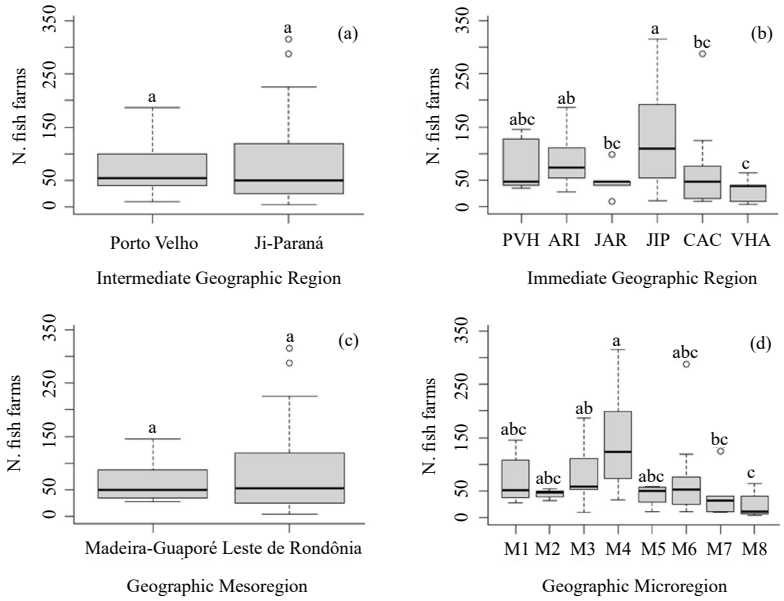


Figure 3. Cumulative frequencies of the numbers of registered fish farms (lines) between the years 2000 and 2020 in the (a) intermediate, (b) immediate, (c) mesoregions, and (d) microregions of the state of Rondônia, Brazil. The microregions are indicated in the graph as: Porto Velho (M1, red), Guajará Mirim (M2, orange), Ariquemes (M3, light green), Ji-Paraná (M4, dark green), Alvorada do Oeste (M5, cyan blue), Cacoal (M6, navy blue), Vilhena (M7, purple), and Colorado do Oeste (M8, pink).



PVH: Porto Velho; ARI: Ariquemes; JAR: Jaru; JIP: Ji-Paraná; CAC: Cacoal; VHA: Vilhena.

Figure 4. Diagrams of the total numbers of fish farms registered in the period from 2000 to 2020 in the municipalities of the state of Rondônia, Brazil, separated into (a) intermediate, (b) immediate, (c) mesoregions, and (d) microregions. The microregions are indicated in the graphs as Porto Velho (M1), Guajará Mirim (M2), Ariquemes (M3), Ji-Paraná (M4), Alvorada do Oeste (M5), Cacoal (M6), Vilhena (M7), and Colorado do Oeste (M8).

significant differences in the Mann-Whitney test (W = 343,500, $p = 0.476$) (Fig. 4a). On the other hand, in the annual sum of the number of fish farms by municipality, separated by immediate region, there were significant differences in the Kruskal-Wallis test ($\chi^2 = 11.477$, degree of freedom–df = 5, $p = 0.043$), with the values of the immediate region of Ji-Paraná (median = 109) being significantly higher than those of Cacoal (median = 47), Jaru (median = 48), and Vilhena (median = 39), as indicated by Dunn's post-test (Fig. 4b). Also, no significant difference was observed in the Mann-Whitney test when separated by mesoregion (W = 204,500, $p = 0.908$) (Fig. 4c). In the separation by microregion ($\chi^2 = 15.193$, df = 7, $p = 0.034$), M4 microregion presented significantly higher values (median = 123) compared to M7 (median = 32) and M8 (median = 12), according to Dunn's post-test (Fig. 4d).

The municipalities that recorded the greatest numbers of fish farms in the microregions M1 to M8 were Porto Velho (146), São Francisco do Guaporé (54), Ariquemes (187), Urupá (315), São Miguel do Guaporé (59), Alta Floresta d'Oeste (288), Pimenta Bueno (124), and Puente do Oeste (64), respectively, while the lowest totals were observed in the municipalities of Campo Novo de Rondônia (28), Costa Marques (32), Vale do Anari (10), Texeirópolis (33), Seringueiras (12), Ministro Andreazza (11), Primavera de Rondônia (10), and Cabixi (4), respectively. The totals of fish farms in the municipalities of Alta Floresta d'Oeste (M6) and Pimenta Bueno (M7) were discrepant in relation to their microregions.

The variations in the number of fish farms registered in the municipalities of Rondônia throughout the analyzed time series are presented in the form of a dendrogram, evidencing the division into two groups. The smaller group includes eight municipalities–Ji-Paraná (JIP), Porto Velho (PVH), Mirante da Serra (MSE), Urupá (URP), Ariquemes (ARI), Alta Floresta d'Oeste (AFL), Ouro Preto do Oeste (OPO), and Vale do Paraíso (VDP)–, while the larger group covers the other 44 municipalities (Fig. 5). The municipalities belonging to the smaller group were the ones that presented the highest numbers of fish farming records, being, therefore, subsequently analyzed.

The municipalities with the most fish farming enterprises in the state of Rondônia in descending order were Urupá (URP), Alta Floresta d'Oeste (AFL), Mirante da Serra (MSE), Vale do Paraíso (VDP), Ji-Paraná (JIP), Ariquemes (ARI), Ouro Preto do Oeste (OPO), and Porto Velho (PVH) (Fig. 6). The municipalities of URP, MSE, JIP, and OPO presented the

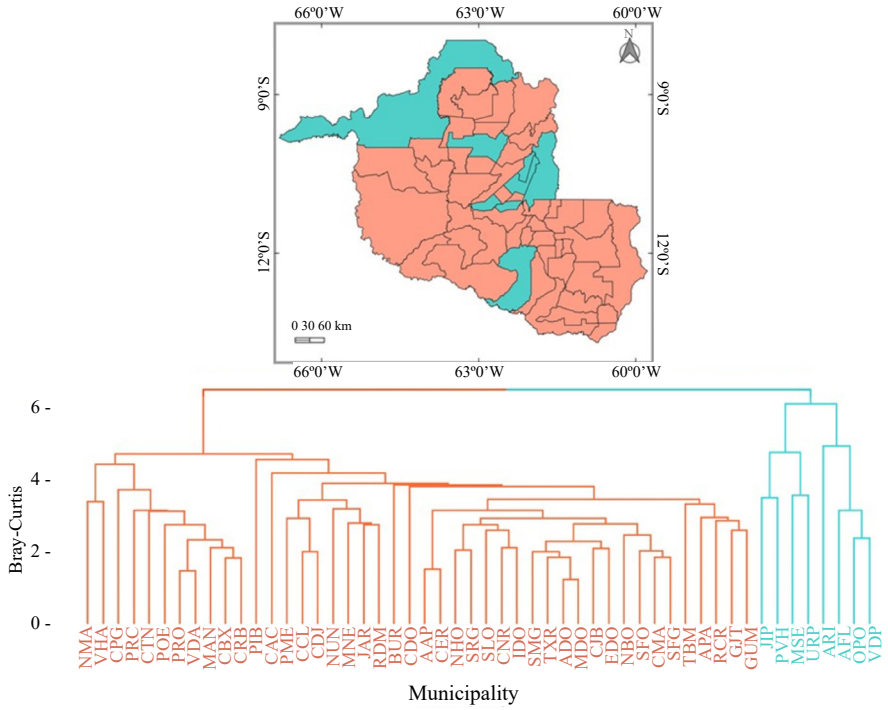
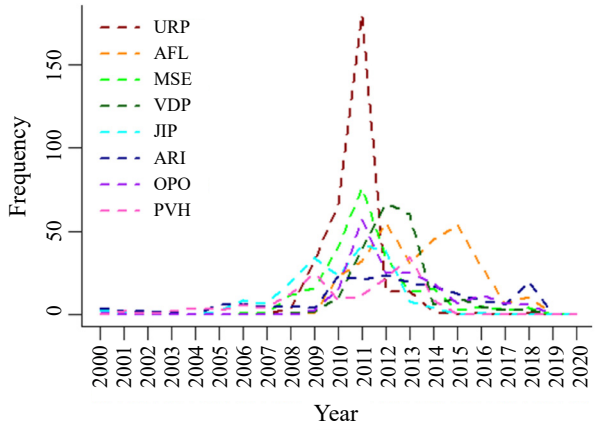


Figure 5. Grouping analysis with Bray-Curtis dissimilarity for the number of fish farms registered between the years 2000 and 2020 in the municipalities of the state of Rondônia, Brazil.



URP: Urupá; AFL: Alta Floresta d'Oeste; MSE: Mirante da Serra; VDP: Vale do Paraíso; JIP: Ji-Paraná; ARI: Ariquemes; OPO: Ouro Preto do Oeste; PVH: Porto Velho.

Figure 6. Frequency of the number of fish farms registered between the years 2000 and 2020, considering the eight main municipalities (URP, AFL, MSE, VDP, JIP, ARI, OPO, and PVH), with total fish farms in the state of Rondônia, Brazil.

highest number of records in 2011, while AFL and VDP in 2012, and ARI and PVH presented the highest number of records in 2010 and 2013, respectively.

Among the municipalities highlighted, only AFL, ARI, and PVH are not from the M4 microregion; they are from the M6, M3 and M1 microregions, respectively. The annual frequencies of new fish farms starting in these municipalities did not present significant differences in most cases in peer comparisons, with only ARI being significantly different from URP and presenting marginal differences (close to 0.05) from VDP (Table 1).

The frequency of the number of fish farms registered between the years 2000 and 2020, considering the eight main municipalities (URP, AFL, MSE, VDP, JIP, ARI, OPO, and PVH), with totals of fish farms in the state of Rondônia, are presented in Fig. 6, whereby the maximum number of records of new developments in these municipalities occurred in 2011 followed by a drop in 2012, with the exception of the municipality of URP, which had a brief growth in these records in 2015, followed by a drop in subsequent years (Fig. 6).

The municipality of Ariquemes presented a different pattern in relation to the other municipalities of Rondônia. The results revealed different moments in the number of fish farms recorded over the years, highlighting three perceptible phases of development, which were modeled with linear regressions: the first phase between 2000 and 2004 ($r = 0.92$), the second one between 2005 and 2009 ($r = 0.89$), and the third between 2010 and 2017 ($r = 0.90$).

The ANCOVA indicated significant differences between the phases ($p < 0.01$), with the third phase being significantly

different from the other two. During the third phase, the business opening cycle was more prolonged, starting with more than 20 businesses, compared with four and six in phases 1 and 2, respectively, although it presented a steeper slope (Fig. 7).

Table 1. Kolmogorov-Smirnov tests for the frequency of the number of fish farms registered between the years 2000 and 2020, considering the eight main municipalities–Ji-Paraná (JIP), Porto Velho (PVH), Mirante da Serra (MSE), Urupá (URP), Ariquemes (ARI), Alta Floresta d'Oeste (AFL), Ouro Preto do Oeste (OPO), and Vale do Paraíso (VDP)–, with total fish farms in the state of Rondônia, Brazil.

Municipality × Municipality	*p*-value	Municipality × Municipality	*p*-value	Municipality × Municipality	*p*-value	Municipality × Municipality	*p*-value
URP × AFL	0.841	AFL × MSE	0.841	MSE × JIP	1.000	VDP × PVH	0.980
URP × MSE	0.591	AFL × VDP	0.591	MSE × ARI	0.358	JIP × ARI	0.360
URP × VDP	0.983	AFL × JIP	0.983	MSE × OPO	1.000	JIP × OPO	1.000
URP × JIP	0.841	AFL × ARI	0.095	MSE × PVH	0.983	JIP × PVH	1.000
URP × ARI	0.017	AFL × OPO	0.591	VDP × JIP	0.983	ARI × OPO	0.190
URP × OPO	0.841	AFL × PVH	0.591	VDP × ARI	0.095	ARI × PVH	0.590
URP × PVH	0.358	MSE × VDP	0.841	VDP × OPO	0.983	OPO × PVH	0.980

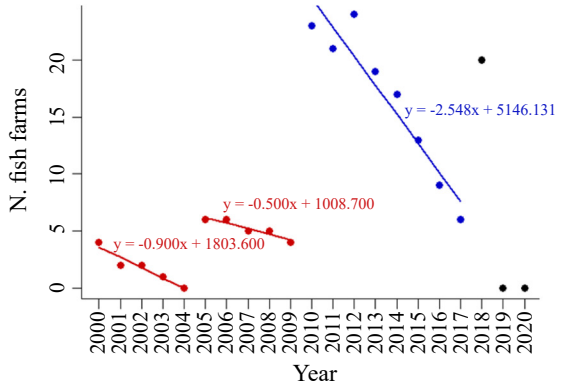


Figure 7. Simple linear regressions for three moments of openings of fish farms in the municipality of Ariquemes, Rondônia, Brazil. Annual intervals with similar colors (in red) represent absence of significant differences, while the period in blue differed significantly from the other phases.

DISCUSSION

When it comes to the rearing of native fish, fish farming in the state of Rondônia has been highlighted in Brazil and around the world, especially regarding the rearing and commercialization of tambaqui (*C. macropomum*) (Pacheco et al., 2025). Several studies have been carried out on the rearing of tambaqui in Rondônia, with themes related to zootechnical growth rate (Carli et al., 2024), quantification of fatty acids (Oliveira et al., 2020), nutritional differences of the species (Oliveira et al., 2021), impacts of fish farming (Freitas et al., 2022), and geographic identification (Acripar, 2023), but no study was found for the state that addressed the numbers and expansion of fish farms that rear this native Amazonian species.

In the present study, the frequencies of fish farms being registered in the state of Rondônia in a period of 20 years (from 2000 to 2020) were verified, and it was observed that the expansion of fish farms in the state began in 2004. Therefore, when this expansion per municipality was analyzed, it was observed that Urupá presented the highest number of registered enterprises between the years 2019 and 2020. However, even with this growth of fish farming in Urupá, of more than 16,000 ponds existing in the state, most are still in the municipality of Ariquemes, which also has the largest area of water (Pereira, 2022).

The municipality of Ariquemes possibly provided the greatest significant difference with the other municipalities due to the actions promoted by the government of Rondônia, which encouraged the large-scale production of tambaqui, motivating the development of fish farming in 2011 for this region (Costa et al., 2015). This municipality was the only one to exhibit three phases of the opening of new fish farm establishments, reflecting a higher level of organization in the local aquaculture sector.

Thus Ariquemes has a slightly more structured development, which was further reinforced by the establishment of the

Association of Fish Farmers of the State of Rondônia at the end of the second phase in 2009, which likely played a pivotal role in driving the third phase of aquaculture expansion in 2010, during the studied period, Ariquemes recorded the highest number of newly implemented fish farms in the historical series. Despite this achievement, concerns remain, as significant challenges persist in accessing relevant information for more comprehensive research, which could contribute to recommendations and improvements for the sector (Rosa et al., 2025).

On the other hand, other municipalities can be also highlighted, with a high number of fish farms being registered in 2011, a period that coincides with the government incentive carried out through the Productive Water Program, which was launched in July 2011. This program aimed to serve the 52 municipalities of the state, and five municipalities in the central region–Urupá, Mirante da Serra, Vale do Paraíso, Ouro Preto do Oeste and Ji-Paraná–, which received investments for the development of the fish farming sector.

As a result, these municipalities distinguished themselves in different aspects of fish farming activities, as occurred in Urupá and Ji-Paraná, with the highest number of fish farmers engaged in small-scale, family-based aquaculture, whereas Mirante da Serra ranked fifth in total water surface area and third in fish feed consumption, followed by Ouro Preto do Oeste (fourth), Vale do Paraíso (seventh), and Ji-Paraná (ninth) (Cavali & Dantas Filho, 2024).

Among the municipalities highlighted in this study, some rank in the thirty largest economies in the Northern region. The capital, Porto Velho, has the fifth-largest gross domestic product in the Northern region, while Ji-Paraná ranks 18th and Ariquemes 24th, and Ouro Preto do Oeste and Alta Floresta d'Oeste are among the 100 largest municipalities (IBGE, 2021).

In the context of location of fish farms by geographical separations with more than two strata, the differences were evident, indicating that fish farms in Rondônia are concentrated in the central portion of the state. This finding aligns with the results of previous studies on aquaculture in the region (Albuquerque et al., 2023; Cavali & Dantas Filho, 2024). The fish farms in this central region are predominantly small-scale operations that rely on family labor (Sousa et al., 2019). These concentration characteristics are apparently not related to the geopolitical complexity of the state. An approach that considers production is also necessary, since a greater concentration of enterprises does not necessarily denote greater production. However, it is a fact that the agribusiness sector of Rondônia, in general, is characterized by the central concentration of rural activities and establishments, which can promote a continuous development with several economic frontiers composed of family fish farming by small producers (IBGE, 2017).

In most geographical regions and, consequently, in the municipalities of Rondônia, the opening and registration of new fish farms seem to have been driven or even fostered by public policies initiated in 2009. This growth can be attributed to the great potential of the state for the sustainable development of fish farming, which is based mainly on native species, the large number of small producers and the ease of acquisition of environmental licenses from government agencies (Meante & Dória, 2017).

In the years following 2009, fish farming in the state showed an exponential growth until reaching its peak in 2012, when 1,143 new establishments were registered with government agencies. After this phase, the subsequent years recorded a decline, with growth remaining stagnant until 2017 and 2018, when only about 2% of new fish farms were established annually, considering the total quantity assessed in the time series.

The initial expansion of fish farming generally follows similar patterns, driven by factors such as increasing domestic demand and changes in the structure and dynamics of the production chain (Belton et al., 2017). In the context of the state of Rondônia, this demand was predominantly linked to the city of Manaus, the capital of Amazonas state, which represents the primary consumer market for *C. macropomum*, the most farmed fish species in the region (Hilsdorf et al., 2022).

Regarding the sector's structure, investments during the period of highest growth were substantial. However, over the years, this intensity has declined, reinforcing the perception that the expansion of fish farming in Rondônia is intrinsically dependent on public policies and government support (Peixe BR, 2024).

Observing this scenario in the geographic divisions analyzed, stagnation in fish farming records had already begun predominantly in 2017, with no new records observed in 2019 and 2020. This lack of fish farm openings in Rondônia reflected the lack of public policies to promote it. However, the maintenance of this pattern in 2020 may have been exacerbated by the impacts resulting from the COVID-19 pandemic.

During the pandemic, the fish farming sector faced challenges both nationally and internationally due to the frequent interruptions caused by the emergency lockdowns and the need to limit human interactions. Both influenced all sectors of production and may have economically disrupted fish farming in the state of Rondônia.

Although stagnation in fish farming had been already observed in previous years, new registrations continued to occur. Nevertheless, the complete absence of new registrations in 2019, which persisted in 2020, is alarming. The negative impacts of the COVID-19 pandemic, which include job losses, reduced income, rising fish prices, loss of market access, disruptions in the supply of fingerlings and aquafeed, and interruptions in aquaculture monitoring activities (Avento et al., 2024), may have contribute to a scenario of stagnation, not only in terms of new registrations, but also in production volumes and overall productivity.

Tambaqui production in Rondônia reached its peak in 2015, three years after the year of the greatest number of new fish farms being opened, but the pattern of decline was common in subsequent years (IBGE, 2023; Oliveira, 2024), evidencing a scenario of stagnation.

The sustainable development of fish farming faces environmental challenges that could compromise the long-term growth of the industry, requiring innovative policy measures (Garlock et al., 2024). In Rondônia, the use of underutilized areas, such as reservoirs and floodplain lakes, emerges as an effective strategy to expand cultivation and production areas, given that Brazil's potential for fish production in reservoirs is estimated at approximately 2.5 million tons per year (Matias, 2017).

Currently, several governmental agencies prioritize the use of reservoirs, as this system shows significant expansion compared to traditional production systems based on excavated ponds (Valenti et al., 2021). Additionally, floodplain lakes, especially those connected to rivers, can also contribute to expanding cultivation areas and production in the state (Bezerra Neto et al., 2023). However, these practices also face challenges regarding environmental management and the need for appropriate technologies to ensure their sustainability (Leite et al., 2024), but they yet remain viable alternatives.

Further investigations should be conducted, as there is also the possibility that the number of fish farms has stabilized or even declined due to the high operational costs of the activity, which, in the long run, tends to become economically unviable in Rondônia (Belchior & Dalchiavon, 2017). Future studies should focus on the continuous monitoring of fish production to assess the environmental carrying capacity for aquaculture in the state, considering the expansion of other economic activities, such as grain production, which has begun to occupy a significant portion of areas with potential for aquaculture development. Moreover, it is crucial to determine the actual number of fully operational fish farms, as this activity has faced challenges in the Northern region of Brazil, with numerous facilities being abandoned (Hungria et al., 2024).

CONCLUSION

The number of fish farms in the state of Rondônia experienced a cycle of expansion and stagnation over two decades, with initial growth likely driven by government incentives and increased demand. The industry is essential to the region's economy and food security, but the future of fish farming in Rondônia will depend on the implementation of sustainable management strategies, technological advancements and public policies that promote a balance between economic growth and environmental conservation.

The study showed that the current number of fish farms registered in the state of Rondônia is distributed along state and federal highways and that they may have reached their economic and environmental support capacity in their respective geographic regions. In this sense, measures for the maintenance and continuity of the expansion of fish farming can be explored, especially with the use of underutilized spaces such as reservoirs of hydroelectric plants (for the implementation of aquaculture tanks) and floodplain lakes, as well as the use of new technologies in tarpaulin ponds, built on dry land, thereby differentiating from the current model of fish farming that is based on excavated ponds.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the paper.

AUTHORS' CONTRIBUTION

Conceptualization: Oliveira, N.S., Lima, S.A.O.; **Methodology:** Oliveira, N.S., Lima, S.A.O.; **Writing – revision and editing:** Oliveira, N.S., Lima, S.A.O.; **Validation:** Sousa, R.G.C., Lima, S.A.O.; **Final approval:** Sousa, R.G.C.

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