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ORIGINAL ARTICLE

Overview of Fish Farming in the State of Rio Grande do Sul, Brazil

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Abstract - To contribute to the knowledge about fish farming in the state of Rio Grande do Sul in southern Brazil, an online questionnaire was administered throughout 2021, answered by approximately 1,770 fish farmers. The water surface area is nearly 2,000 ha, with almost 90 % used for raising carp, the main species produced for 70 % of the respondents, and 20 % for tilapia farming, the main species for 20 % of the respondents. The polyculture system was mentioned by approximately 70 % of the interviewees, and carried out extensively, producing up to one tons/ha/year by approximately 50 % of the fish farmers. About 60 % of producers responded that they produce fish for personal consumption and sell the surplus, while around 38 % engage in commercial fish production, and 10 % sell their fish to the industry. Nearly 98 % of the fish farms are small (up to 5 hectares of water surface) and, in general, the productivity reported was 4 tons per cycle per farmer. The results obtained in the study represent an initial step towards understanding the situation of fish farms in the State and may contribute to the development of public policies aimed at addressing the main challenges of the activity.

Keywords: Aquaculture. Assessment. Fish farming statistics. Status of the fish farming activity.

Panorama da Piscicultura no Estado do Rio Grande do Sul, Brasil

Resumo - Com o objetivo de contribuir para o conhecimento sobre a piscicultura no estado do Rio Grande do Sul, foi aplicado um questionário online ao longo de 2021, respondido por cerca de 1.770 produtores. A área alagada é de cerca de 2.000 ha, sendo aproximadamente 90 % destinada à criação de carpas, principal espécie produzida para 70 % dos produtores, e 20 % destinada à criação de tilápia, principal espécie para 20 % dos piscicultores entrevistados. O sistema de policultivo foi mencionado por cerca de 70 % dos entrevistados, realizado no sistema extensivo e produzindo até 1 t/ha/ano por aproximadamente 50 % dos piscicultores. Aproximadamente 60 % dos produtores responderam que produzem peixe para consumo próprio com venda do excedente, enquanto 38 % produzem peixe comercialmente, e 10 % responderam que vendem o pescado produzido para a indústria. Aproximadamente 98 % das pisciculturas podem ser classificadas como pequenas (até 5 ha de lâmina d'água), e, no geral, a produtividade mencionada foi de 4 t/ciclo/produtor. Os resultados obtidos no estudo representam um passo inicial para a compreensão da situação das pisciculturas no Estado, podendo contribuir para o desenvolvimento de políticas públicas voltadas aos principais desafios da atividade.

Palavras-chave: Aquicultura. Levantamento. Estatísticas da piscicultura. Situação da piscicultura.

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Introduction

Aquaculture has been presented as a rapidly developing food production sector. The Food and Agriculture Organization of the United Nations (FAO, 2016) recognizes aquaculture as an activity of global importance, contributing significantly to future food security and fish supply.

In 2020, Brazil ranked 13th in global aquaculture production, with a total output of 630,000 tons (FAO, 2022). That same year, it was estimated that there were around 455,000 aquaculture farmers in the country (PEIXEBR, 2020). However, the total production from fish farming has been increasing, reaching 860,355 tons and a turnover of around R$ 9 billion in 2022 (PEIXEBR, 2023). The states that emerged as the most significant fish farmers in Brazil in the last three years were Paraná, São Paulo, and Rondônia (PEIXEBR, 2023). Located in the South region of the country, the state of Paraná is the most prominent national tilapia producer, contributing 34 % of the total volume. In 2022, its production reached 550 thousand tons, representing around 64 % of the national production of farmed fish. Tilapia accounts for 88 % of fish exports, and Brazil is considered the fourth largest producer of this species in the world (PEIXEBR, 2023).

The South region of Brazil plays a prominent role in fish farming, accounting for 32 % of the national production (PEIXEBR, 2023). Despite having the lowest production within the South Region, Rio Grande do Sul has around 30 thousand fish farmers (PEIXEBR, 2022), showing the socio-economic relevance of fish farming in the state. According to the State's Holy Week Fish Sales Report in 2022 (Emater, 2022 João Alfredo de Oliveira Sampaio, pers. com.), approximately 3,000 tons of fish were sold, among different species at an average price of US$ 4.23 per kg. In 2022, Rio Grande do Sul's aquaculture output reached 27,300 tonnes, marking a 1.4 % decrease from 2021. This production mainly consisted of carp (17,000 tons), tilapia (9,000 tons), and other species, including native fish (1,300 tons). Currently, the state occupies the 12th place in Brazil's ranking of farmed fish production (PEIXEBR, 2023). However, between 2008 and 2010, Rio Grande do Sul held the top position in continental aquaculture production (MPA, 2012), with production estimates nearing 50 thousand tons.

As stated in the “PeixeBR Fish Farming Yearbook” report (PEIXEBR, 2023), obtaining updated and more accurate data on the activity is essential for the development of the sector in the state of Rio Grande do Sul. Moreover, data aimed at identifying various aspects of fish farming activity in the state can contribute to decision-making in several critical areas. This includes promoting the standardization of the supply chain and formulating public policies to enhance the sector.

The FAO report “The State of World Fisheries and Aquaculture 2022” (FAO, 2022) raises concern about countries like Brazil not responding to FAO questionnaires in recent years or report providing incomplete data. This issue was exacerbated in 2020 due to the interruption of regular data collection activities caused by the COVID-19 pandemic.

Therefore, this study was conducted using an online questionnaire specifically designed to gather sample information from fish farms in Rio Grande do Sul. The objective was to identify and characterize the state's aquaculture enterprises in terms of their purpose, production management practices, and safety measures adopted, and to evaluate the perceptions of the sector regarding investments, business operations, research, and public policies aimed at addressing the challenges

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of aquaculture activities.

Material and Methods

The study was based on a sample field survey in the state of Rio Grande do Sul, utilizing a structured online survey via Google Forms following the ethical guidelines of the National Health Council 1996 (BRASIL, 2012). To preserve the confidentiality of participants' information, the study was conducted with strict anonymity of respondents.

The questions were drafted by the authors and the online survey was applied by technicians and extension agents from Emater-RS/Ascar (Company for Technical Assistance to Rural Extension - Rio Grande do Sul) to fish farmers in the municipalities served by the institution. The online survey was also answered by some fish farmers directly through Google Forms, without the assistance of Emater technicians.

Overall, the survey gathered information on various aspects including fish farms, fish farming, fish marketing, fish ponds, and water supply/management.

Information related to the characterization of fish farms was collected, such as the location of properties and processing plants where the fish produced is sent, the water surface used for the activity, the number of ponds, the number of staff involved, safety measures adopted at work, access to agricultural loans, intention to expand the activity, environmental regularization and technical support available to farmers.

Information was also collected regarding the characterization of fish farming, encompassing the culture system used, the purpose and final destination of the farmed fish, the species and grow-out season of the main species, productivity metrics, as well as details on harvesting, slaughter, and processing procedures within the participating fish farms. Additionally, information regarding the commercialization of fish was collected, including details on the main species supplied to the industry, the industries receiving this farmed fish, the pricing of the farmed fish, and other relevant data. Furthermore, data on fish farming management were obtained, covering aspects such as sources of water supply, management and monitoring of water quality, sanitary measures, control of fish escape, disposal of deceased animals, and inputs used in fish farms, provided by the interviewees participating in the research.

The interviews were conducted throughout 2021, resulting in a total of 1,790 responses. Upon analysis, certain questionnaires had to be disregarded due to errors or uncertainties in the responses, leaving approximately 1,770 questionnaires for use in the study. Any variations in sample size were duly noted, and the sample number (n) was reported accordingly.

The collaboration between Emater-RS/Ascar and the Secretariat of Agriculture, Livestock, Rural Development, and Irrigation - RS (SEAPI) to carry out the project was formalized through a formal agreement (Proa No 21151100003007).

Results and Discussion

Survey responses

There were 1,790 completed questionnaires and, after data analysis, approximately 1,770 questionnaires were used. About 62 % of the questionnaires were answered by a technician or extension agent from Emater-RS/Ascar. The remaining ones were answered directly through Google Forms by the fish farmers themselves.

Fish farms

Location of the fish farms and processing plants

The regions with the highest number of

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interviews conducted were the Northwest and Midwest Regions, as well as the Metropolitan Region of Porto Alegre (Fig.1).

Water surface area

Regarding the area of fish farming, the total water surface area was estimated to be 2,000 hectares (ha). Based on the interviews (n = 1,755), it was found that in approximately 47 % of the properties surveyed, the area occupied by fish farming (pond surface area) in the state does not exceed 0.5 hectares. Properties with water surface areas between 0.5 and 1.0 hectares represent 24 % of the responses, while those between 1.0 and 5.0 hectares represent 27 % of the total. A small number of farmers interviewed reported that their properties have an area for fish farming between 5.0 and 10.0 hectares (1 %) and over 10.0 hectares (1 %) (Fig. 2).

According to the area of the property occupied by fish farming, Conama Resolution No. 413 of June 26, 2009 (BRASIL, 2009) classifies excavated ponds as follows: small (area smaller than five hectares), medium (area between five and 10 hectares) and large (area greater than 50 hectares). Thus, as shown in Fig. 2, 98 % of the fish farms mentioned in the study are classified as small, using a smaller volume of water to implement and maintain grow-out systems. Also, 98 % of the properties on the North Coast of Rio Grande do Sul are classified as small (BASSANI and ROCHA, 2020). The number of ponds/tanks on farm properties varied widely, with an average estimated at four ponds/tanks per property, according to the respondents.

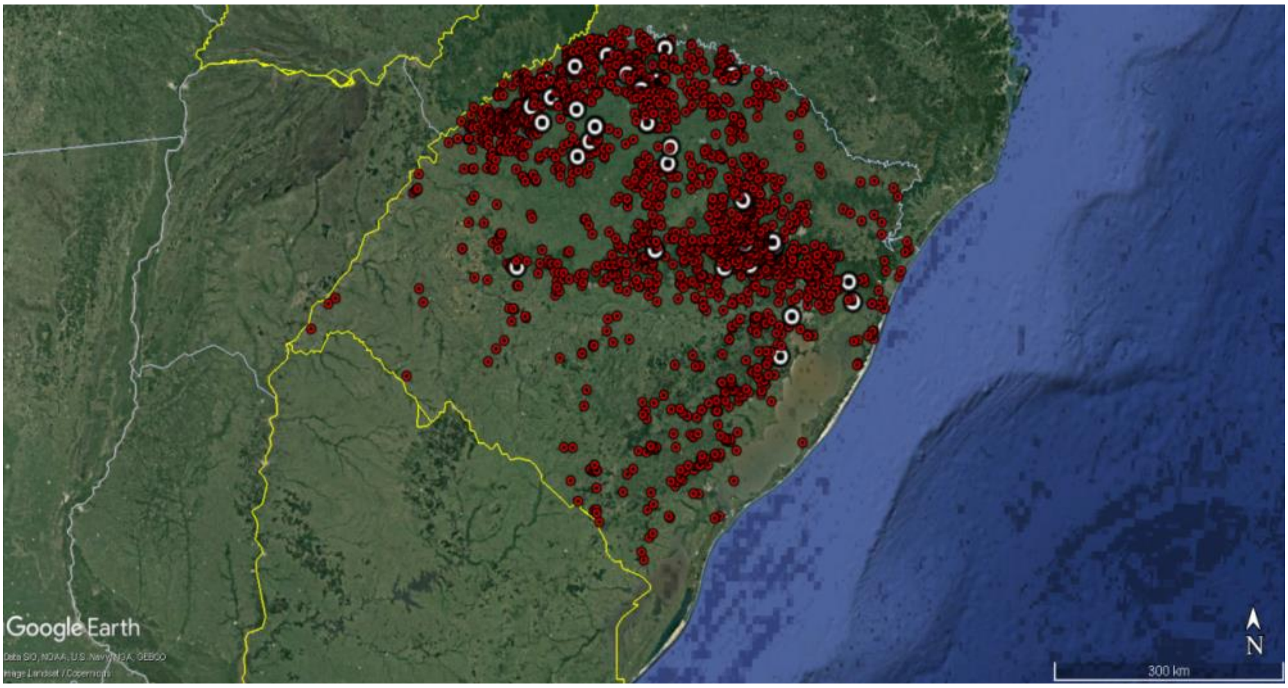

Figure 1. Location of the properties and industries/fish processing plants mentioned in the survey. The image is from Google Earth, adjusted by the authors (2023). The red marker represents the location of the interviewee's property, while the white marker represents the fish processing plant mentioned by the farmers.

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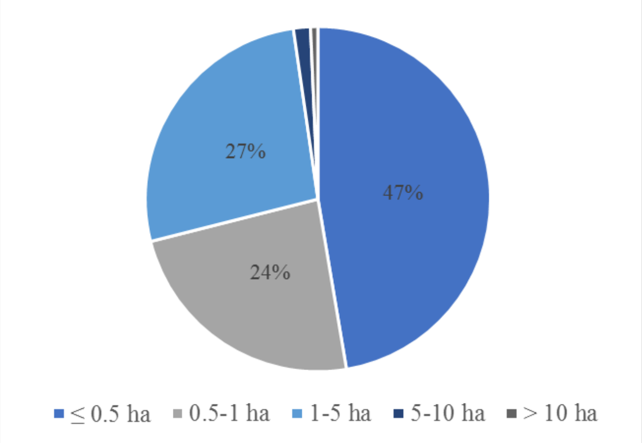

Figure 2. Percentage of properties according to the size of the water surface area used for fish farming in Rio Grande do Sul, Brazil, according to the survey.

Workers

Regarding the work carried out in fish farms, around 70 % of those interviewed mentioned that activity is regularly carried out by only one man. Eleven percent of fish farmers responded that two men work regularly in fish farming. However, in times of greater labor demand, such as fish harvesting, for example, this number can increase to three (16 %), four (10 %), five (8 %), or six (4 %). According to those interviewed, at least one woman is regularly present in around 37 % of fish farms, but it can be as many as two (4 %). During peak periods such as harvest, the number of women working on farms rarely changes, with 37 % reporting an increase from one woman to two (16 %). These data confirm that fish farming in Rio Grande do Sul is predominantly operated within a family-based farming system, where family members are involved in the activity. Additional labor may be hired during peak periods such as harvests.

Safety at work

Regarding worker safety, less than 5 % of respondents mentioned that fish farm workers use personal protective equipment (PPE). However, it is worth noting that this number may be higher, as some producers may have had uncertainties regarding personal protection items. According to Lenz *et al.*. (2022), there are several risks associated with work in aquaculture, categorized into physical, chemical, biological, ergonomic, and accidents. These risks include exposure to extreme environmental temperatures, electrical shock, injuries and burns, infections, falls and even drowning in deeper tanks. Identifying the risks and dangers of the activity is essential to prevent accidents and illnesses that may result from harmful exposure without proper training or the use of PPE (CAVALLI *et al.*., 2020). Therefore, the use of appropriate PPE is an essential requirement to reduce the risk of accidents or injuries to aquaculture workers, as highlighted by Lenz *et al.*. (2022).

Agricultural loan access

Regarding access to the DAP (Declaration of Aptitude to Pronaf - agricultural loan), around 80 % of fish farmers declared having DAP, a fairly considerable number, both for carp (82.5 %) and tilapia (84.2 %) farmers.

According to the Ministry of Agriculture and Livestock, the DAP is how family farmers access public policies to encourage production and income generation. The document contains the owners' personal data, territorial and productive information on the rural property, and family income. For example, the DAP is essential for accessing a line of credit that enables farmers to receive financing (MAP, 2023).

Official data from the Central Bank show that the Southern Region of Brazil raised the most resources for fish farming in 2022, totaling USD 67 million. Of this amount, the state of Rio Grande do Sul requested only USD 5.5 million. In contrast, the state of Paraná, also in the Southern Region, requested the most resources, totaling USD 43 million, and was also the state with the highest production (PEIXEBR, 2023).

It also highlights the importance of access to types of financing that support the acquisition and installation of environmentally sustainable systems and innovations (FAO, 2022). However, it has not been established whether the fish farmers in this study used DAP to access credit, whether for aquaculture or other purposes.

Intention to expand the activity

Farmers were asked whether they intended to expand their investments in fish farming and the responses were quite divided. Nearly 50 % of those interviewed indicated that they intended to expand the activity while the other half indicated that they did not. These results may be linked to the period in which the questionnaire was applied. The crisis caused by the COVID-19 pandemic has impacted all sectors of the economy to some extent. According to the NOAA report (2021), in the US, COVID-19 has impacted sales in the seafood sector. At the end of the second quarter of 2020, 78 % of aquaculture, aquaponics, and related companies reported impacts from COVID-19, and 74 % reported loss in sales (NOAA, 2021).

Environmental regularization

Regarding the environmental regularization status of the activity through licensing, more than 70 % of a total of 1,753 valid responses indicated that they do not have such a license. Almost 20 % responded that they had a license for the activity. Among these licensed farmers, were 50 % carp farmers and 44 % tilapia farmers, but also included other farmed species such as jundiá (*Rhamdia quelen*) and traíra (*Hoplias* spp.), among others. Around 5 % of respondents declared themselves exempt from environmental licensing. Among these, 83 % were carp farmers, 11 % tilapia farmers, but also farmers of other species such as trairão (*Hoplias* spp.), jundiá (*R. quelen*), and lambari (*Astyanax* spp.). Furthermore, around 2.5 % of farmers responded that they were in the process of acquiring a license, all of whom were involved in tilapia and carp farming.

The issue of environmental regularization in fish farming has long been highlighted as one of the bottlenecks for the advancement of the activity (BALDISSEROTTO, 2009). Not having environmental licensing or an exemption makes it difficult for farmers to access certain types of financial credits and, consequently, limits the expansion of the activity.

In Brazil, the National Electric Energy Agency (Aneel) allows rural producers engaged in irrigation and aquaculture activities to apply for discounts on their electricity bill, which can range from 67 to 90 %. These discounts apply for up to 40 hours per week, depending on the case and region of the country. According to Aneel Normative Resolution No 1000/2021 (BRASIL, 2021), access to this benefit depends on the consumer complying with legal requirements, such as having a rural producer registration, aquaculture registration or license (except for aquaculture for subsistence purposes), environmental licensing and water concession, when necessary.

According to Conama Resolution No. 413/2009 (BRASIL, 2009), it is the responsibility of the farmer to obtain environmental licensing (or exemption from it) from the competent institution, starting from the initial stages of planning and installation until its effective operation. Likewise, the granting of the right to use water, which is the instrument that controls the quantitative and qualitative use of water, precedes environmental licensing and must be requested from the relevant authorities, both for its use and exemption purposes.

Technical support

Approximately 80 % of farmers responded that they receive some technical support on fish farming issues. Emater-RS/Ascar was mentioned by more than 90 % of them. Other sources of technical support provided to fish farmers include the municipality (15 %); feed suppliers (12 %) and fingerling (11 %) suppliers; technicians or professionals in the field (5 %); and, to a lesser extent, unions (3 %), cooperatives (2 %) and associations (2 %).

In a questionnaire applied by Bassani and Rocha (2020) to fish farmers on the North Coast of the state of Rio Grande do Sul (RS), Brazil, 50 % reported not receiving any technical assistance, while 42 % responded that they received technical assistance from Emater-RS/Ascar. These data are closer to those mentioned in a previous report released by the Ministry of Agriculture, Livestock and Supply (MAPA, 2020), where half of the 60 interviewees mentioned receiving or having already received some technical assistance from Emater-RS/Ascar. Only 13 % of fish farmers reported having a designated technician in charge. Technical support from universities was also mentioned by 26 % of the respondents. The report also concluded that, based on observation of the productive characteristics of the fish farming system, there is a need to professionalize and enhance the technology used by producers and in their production systems.

Fish farming

Culture system used

Around 74 % of fish farmers cited the fish polyculture system, where more than one species is produced, while approximately 26 % of respondents mentioned the monoculture system, which involves producing just one species. Fish farming in consortium with ducks or pigs was also mentioned by some fish farmers. Similar data were reported by Bassani and Rocha (2020) when identifying fish farming activity in the North Coast Region of the state (78 % polyculture, 20 % monoculture, and 2 % fish intercropping).

Regarding the intensification of production, the questionnaire reveals that approximately 50 % of fish farming is conducted in an extensive system, while around 36 % of the producers interviewed practice semi-intensive farming. About 9 % of farmers mentioned using the intensive system, and 1 % mentioned using the super-intensive system.

However, when differentiating the main species produced, carp and tilapia, it is observed that, according to the farmers who participated in this research, carp is carried out mostly in extensive (63 %) and semi-intensive (36 %) systems, while tilapia farming is carried out mainly in semi-intensive (41 %) and intensive (34 %) systems.

For categorization purposes, when asked about the production system chosen for the main species of greatest economic importance on the property, the following were established: (1) extensive: productivity of up to 1 t ha^{-1} per year; little or no feed; it is not the main activity; (2) semi-intensive: productivity of up to 5 t ha^{-1} per year; feed supply; economic relevance; (3) intensive: productivity of up to 20 t ha^{-1} per year; suitable feed; monoculture; economic importance; use of equipment such as aerators; (4) super-intensive: productivity over 20 t ha^{-1} per year; more significant investment and management; greater technology; monoculture; economic significance.

Purpose and final destination of farmed fish

As for production - whether for grow-out, hatchery, or recreation - approximately 91 % of farmers who responded to the survey indicated that fish farming is primarily intended for grow-out. For 4 % of the respondents, the purpose of fish farming is recreation. Fish farmers, who are dedicated only to fingerling production, represent 1 % of respondents, while 1.5 % of fish farmers responded that they are dedicated to fry production and grow-out of fish in their fish farms. Around 60 % of farmers responded that they produce fish for subsistence, that is, for their own consumption and sell the surplus. In contrast, approximately 38 % of farmers responded that they produce fish commercially. According to a report released by the Ministry of Agriculture, Livestock and Supply (MAPA, 2020), the production of juvenile fish in Rio Grande do Sul takes place on 15 properties distributed across 12 municipalities.

Fish species raised

Of the producers who responded to the questionnaire, around 90 % mentioned that they raise carp. The carp species were not differentiated, but grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*) are common in polyculture. Approximately 50 % stated that they raise tilapia and around 40 % reported raising jundiá (*R. quelen*). Other species mentioned were lambari (*Astyanax* spp.), pacu (*Piaractus mesopotamicus*), traíra (*Hoplias malabaricus*), surubim (*Pseudoplatystoma corruscans*), tambacu (hybrid from the crossing between *P. mesopotamicus* and *Colossoma macropomum*), tambaqui (*C. macropomum*), rainbow trout (*Oncorhynchus mykiss*), catfish (*Ictalurus punctatus*), black bass (*M. salmoides*), and other native fish species.

Concerning the target species of fish raised on the farm, 70 % of fish farmers responded that carp represent the main species farmed, while tilapia represent the main species farmed for around 20 % of fish farmers who participated in the study. The target species is the one that constitutes the main fish farming species, with greater representativeness, investment, and profit, and other less important species can also be raised, as mentioned above. According to the survey, target species represent, on average, around 85 % of the total fish farming income.

Grow-out

As for the farming cycle of the main species (in months), the responses varied according to the species, with tilapia having a shorter cycle, around six to eight months, while carp, in general, can take from 24 to 36 months to grow out. Overall, the minimum reported rearing cycle length was four months (for tilapia), while the maximum reported was 60 months (for carp).

Fish, as ectothermic/poikilothermic animals, have reduced metabolism at low temperatures (as well as their energy expenditure). This leads to a decrease in the animal's activity and food consumption, consequently reducing its growth and, depending on the lethal temperature limits of the species, mortalities may occur (BALDISSEROTTO, 2002). In regions affected by cold seasons, the choice of the species to be produced is important.

For tilapia, thermal comfort is between 27 and 30 °C, and they can stop feeding at temperatures below 17 °C, while for carp this occurs below 12 °C

(BARRETO, 2001). At temperatures below 15 °C, tilapias become highly susceptible to illness and death (KUBITZA, 2000). However, it is possible to keep tilapia feeding even when kept at lower temperatures (16-18 °C), due to factors such as natural selection, adaptation, and acclimatization (BITTENCOURT, 2021), but the grow-out cycle can take longer than at higher temperatures.

In colder zones with more critical conditions of low temperatures in winter, such as the state of Rio Grande do Sul, Southern Brazil, the production of cold-resistant subtropical species is encouraged. Carp, for example, are known to continue feeding and growing at temperatures between 10 and 18 °C, albeit at a slower rate (CASACA, 1997). Also, in these regions, tilapia farming presents better results when carried out in the warmer seasons of the year (between 6 and 8 months), avoiding exposing the animals to risk in the colder seasons.

Therefore, especially in areas where fish farming may be subject to critical environmental conditions, Rotta *et al.*. (2023) emphasize the importance of prior planning before any production operation, regardless of the species. This planning should consider the producer's investment capacity, the necessity of using aerators, managing stored biomass, and controlling water quality to mitigate potential negative effects, as climatic conditions cannot be controlled.

Productivity

According to the main farmed fish species mentioned in the survey, an average productivity of around 4 tons per cycle per fish farmer and 3.2 tons per hectare was reported, based on 1,657 viable responses. Considering the entire water area used by fish farming mentioned in the research, of around 2,000 hectares, a total production of 6 thousand tons of fish was achieved. The minimum and maximum volumes considered in the research were 100 kg and 105 t per cycle, respectively.

Fish harvesting, slaughter, and processing

Regarding the frequency with which the main species of farmed fish are harvested for commercialization, the total harvest from farms is carried out, on average, once a year. Partial harvests are performed three times a year, on average. The annual harvest is commonly held during “Lent” and “Holy Week”, close to Easter. Extra fish harvests are made on demand for sale at markets, farm gates, or industries/processing plants.

As for the slaughter and processing of farmed fish, focusing on the main species, approximately 54 % of 1,755 farmers reported that they conduct slaughter solely on the property in an artisanal manner, carried out by themselves. Around 40 % of fish farmers indicated that they do not perform slaughter on the farm. About 5 % stated that they conduct slaughter and processing on the farm but without inspection. Less than 2 % of fish farmers mentioned that they slaughter and process under inspection, totaling approximately 70 tons of tilapia and carp (around 57 and 13 tons, respectively). It's noteworthy that this fish is not intended for industry, according to the respondents.

According to a report published by the Ministry of Agriculture, Livestock and Supply (MAPA, 2020) on support for fish farming in Rio Grande do Sul, processed fish comes mainly from small regional farmers, but 25 % comes from their own production, according to the 60 interviews obtained. The same report found that most of the state’s fish processing plants/factories are located in the Northwest Region of the state, in municipalities along the Uruguay River basin. The report also highlights that these processing

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plants operate at 45 % of their capacity, producing approximately 4,000 tons of farmed fish per year, with 93 % of this production attributed to tilapia processing. This indicates the potential for expansion to utilize over 90 % of the current production capacity (MAPA, 2020).

Fish marketing

Regarding the commercial destination of farmed fish, 61.8 % of interviewees responded that they sell at the farm gate. This is followed by sales at fairs (21 %), industry/processing plants/warehouses (around 10 %), and markets (3 %). Approximately 2 % of farmers sell to other fish farmers for grow-out purposes (sale of fingerlings). Some also mentioned selling their farmed fish to aquariums (0.2 %), restaurants (0.4 %), fish-and-pay (0.1 %), middlemen (0.3 %), and direct-to-consumer (0.7 %), and some farmers even have their own processing facilities (0.3 %).

Although only 10 % of fish farmers responded that their farmed fish is for industry/warehouses/ processing plants, the volume of this fish represents around 40 % of the total that was reported in the questionnaire as farmed fish. Of this amount, 86 % is tilapia production, as indicated by the survey data.

According to a previous survey carried out by the Ministry of Agriculture, Livestock, and Supply (MAPA, 2020), which included information from 60 fish farmers, 90 % of the fish for the industry is tilapia, in line with the data obtained in this questionnaire applied during the year 2021. The same report (MAPA, 2020) states that approximately 49 % of the production of the state's fish processing industries is directly sold, which benefits both the industry and the consumer. This direct sale model eliminates intermediaries in the distribution chain, leading to potentially lower prices for consumers and higher profits for the industry.

Regarding the commercialization of farmed fish, approximately 40 % of fish farmers mentioned that they sell their products within the municipality, around 10 % sell within the state of Rio Grande do Sul, and less than one percent sell their farmed fish to other states within the country (Fig. 3).

A total of 166 fish farmers, around 10 % of those interviewed, indicated the industries to which they send their farmed fish. The most cited industry was Petilé Pescados (16 %) in the municipality of Horizontina (RS), followed by Pescados São Francisco (around 9 %) in the city of Chapada (RS) and Natupeixe (around 5 %), in the municipality of Guaporé (RS).

According to the questionnaire, the fish farmers mentioned at least 40 industries/processing plants/agroindustry located in 29 municipalities in the state of Rio Grande do Sul, most of them located in the Northwest region of the state, as shown in Fig. 1.

These data are similar to those from the report previously published (MAPA, 2020), in which 40 fish processing plants in 35 municipalities in the state of Rio Grande do Sul were interviewed, most of them were located in the Northwest of the state, in municipalities along the Uruguay River basin.

Farmed fish price

The average selling price of farmed fish obtained from the questionnaire, including sales at fairs, at the gate, and to industry, was estimated at around US$ 2.4 per kilo for tilapia and US$ 2.2 per kilo for carp. The mean values of the main fish farmed in the state of Rio Grande do Sul are shown in Table 1.

Although the values per kilogram of the different species of farmed fish obtained in this 2021 questionnaire are different from the values obtained in 2020 by the Ministry of Agriculture, Livestock and

Supply - MAPA, both carried out in the state of Rio Grande do Sul, the data can be considered congruent, taking into account the number of interviews and the area where the research was carried out.

Based on information provided by 160 fish farmers who sold their production to processing plants/factories, the price paid for tilapia was around US$ 1.5 per kg, while the price paid for carp was around US$ 1.8 per kg, according to the questionnaire applied in 2021. These values are close to those published in the report released in 2023 by PEIXEBR, in which the selling price of tilapia for the industry in 2022 was between R$ 7.44 and R$ 8.02 per kg (US$ 1.44 - 1.54 per kg) (PEIXEBR, 2023). These values align with the trend of an increase in the average international price of fish in 2021 compared to 2020 as reported by the FAO (2022).

Water supply and management

Water supply

Questions about the water supply were asked to the fish farmers. Concerning the estimation of water availability for fish farming, approximately 18 % of respondents indicated having a volume of water sufficient to maintain good water quality. On the other hand, 76 % responded that the available water is sufficient to maintain water quality, but requires attention. To a lesser extent, around 6 % of fish farmers who participated in the survey stated that the volume of water for fish farming is insufficient, with frequent water shortages, poor water quality, and fish mortality.

According to Avnimelech *et al.* (2008), although feed costs are lower in less intensive aquaculture systems, water consumption per kg of fish produced decreases with increasing production intensity. The authors state that in an average extensive system pond, with annual loss through evaporation and infiltration of 35,000 m^3 ha^{-1} and annual production of 2,000 kg ha^{-1}, 17.5 m^3 of water is used to produce one kg of fish, while only 50 % of this value is needed when yield reaches 4,000 kg ha^{-1} per year. Therefore, it is crucial to consider water availability before fish farmers decide on the production system to adopt. This precaution helps mitigate the risk of production collapse due to water scarcity, particularly in periods or areas with low rainfall.

Water source

Regarding the source of water supply to the fish ponds, 50 % of the interviewees answered that this is due to a “drowned”/”flooded” water source inside the pond/dam (water well), and another around 40 % responded that the water supplied to the ponds comes from a water source outside the ponds. Other sources of water supply cited by the interviewees are water containment basins (28 %), streams (7 %), rivers (1.5 %), lakes (1 %) and water wells (1 %).

The origin of the water used in fish farming is of significant importance. The success of production will depend on the quality of the water placed in the ponds where fish will be stored. It is quite common to utilize reservoirs formed from groundwater sources for fish production, as some can be substantial in size and flow rate. However, it is necessary to analyze the water quality to know if it is suitable for fish farming, as well as pay attention to environmental issues. Furthermore, it is necessary to consider the difficulty of managing this kind of tank, as it does not dry completely and there is no way to change the water flow. Additionally, licensing issues for water use may be necessary in certain circumstances.

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Table 1. Average price (R$) per kg of the main farmed fish in Rio Grande do Sul, Brazil.

Fish	Average price 2020 (R$ kg $^{-1}$)*	Average price 2021 (R$ kg $^{-1}$)ᵞ
tilapia (*Oreochromis niloticus*)	5.3	13.0 ± 7.9 (n = 393)
carp (several species)	4.3 to 4.9	12.0 ± 3.9 (n = 1,218)
jundiá (silver catfish) (*Rhamdia quelen*)	7.0	15.0 ± 4.8 (n = 39)
pacu (*Piaractus mesopotamicus*)	4.0	11.0 ± 3.8 (n = 4)
traíra (*Hoplias malabaricus*)	10.0	19.0 ± 7.2 (n = 16)
lambari (*Astyanax* sp.)	8.0	12.5 ± 8.8 (n = 6)
trairão (*Hoplias lacerdae*)	6.0	16.5 ± 6.5 (n = 4)

*Values in Brazilian currency (R$), according to a report published in 2020 by the Ministry of Agriculture, Livestock and Supply (MAPA, 2020) with 60 interviewees from Rio Grande do Sul, Brazil. ᵞValues are presented as mean ± standard deviation in Brazilian currency (R$). Values in parentheses are the number of information obtained from the online survey applied during 2021 to fish farmers in the state of Rio Grande do Sul, Brazil. ϕ The carp species were not differentiated, but grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*) are common in polyculture.

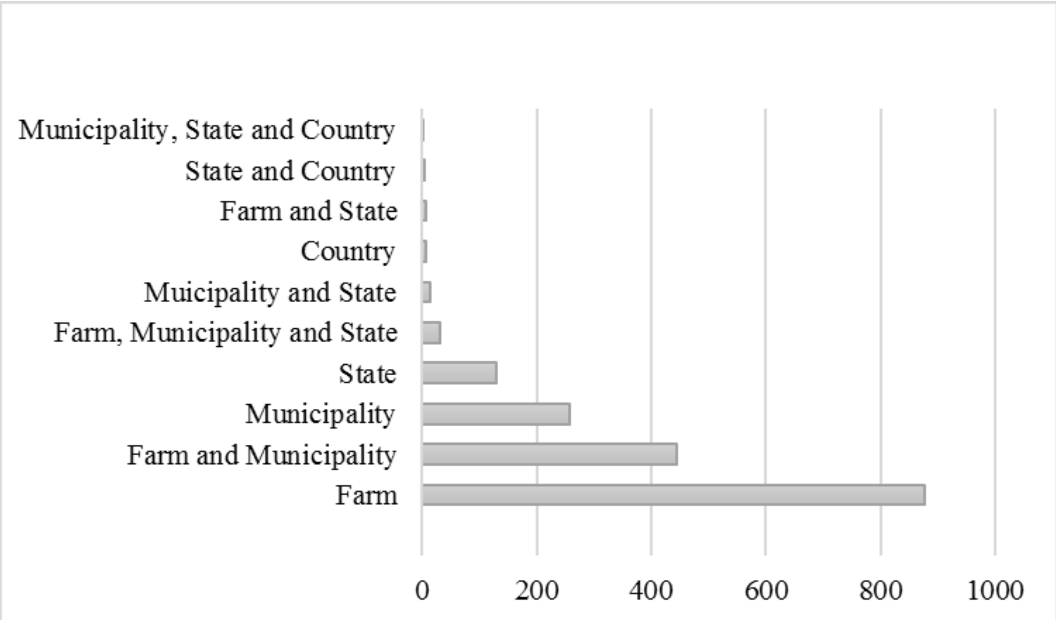

Figure 3. Fish marketing according to the survey. The y-axis shows the main destination of the fish sold by fish farmers and the x-axis shows the number of respondents.

Table 2. Inputs used in fish farming and percentage of occurrence according to the fish farmers who responded the survey.

Input	(%)
Quicklime	51.6
Dolomitic limestone	46.1
Calcitic limestone	25.2
Organic fertilizers	44.1
Chemical fertilizers	32.5
Parasiticides	5.3
Additives (prebiotics, probiotics, synbiotics)	3.2
Antibiotics	2.9
Herbicides	0.7
Insecticides	1.3
Chemicals (formaldehyde, anesthetic, hormones, growth promoters)	0.4
Vaccine	0.3
Homeopathy	0.1

Drying of fish ponds

As for the management of drying fish ponds, 50 % of fish farmers responded that they dry them completely, while approximately 35 % dry them partially (water remains at the bottom), and around 13 % of fish farmers never dry the ponds.

Worryingly, only half of fish farmers reported being able to completely dry out their fish farming ponds. A tank that does not dry completely is not conducive to adequate management.

According to Ostrensky and Boeger (1998), the bottom of the pond eventually needs to be completely dry and exposed to the sun, so that it can, mainly, carry out the oxidation and mineralization processes of organic matter deposited in the soil, taking advantage of soil nutrients and reducing the need for the fertilization of ponds. Furthermore, by drying the tanks it is possible to eliminate parasites and eggs from other fish and/or predators of farmed fish due to the incidence of ultraviolet rays, as well as oxygenate the soil, contributing to better aquatic health and optimization of the farming system.

Water outflow

Regarding the water outlet from ponds, according to fish farmers who responded to the survey, around 5 % of fish ponds do not have a water outlet; around 30 % of ponds have surface water outlets and around 65 % of fish farmers responded that it is through the bottom of the pond. Of this 65 %, about 40 % of respondents reported that it occurs from the bottom of the pond through a simple pipe, as opposed to almost 30 % who have a monk drainage structure in the ponds to drain water from the bottom.

Regarding the water output from a fish farming tank, it is very important which water is "exchanged", whether the water is from the bottom or the surface. It is at the bottom of the tank that most of the organic matter is deposited (feed, feces, leaves, and dead animals, among others). As mentioned by Tavares and

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Santeiro (2013), the decomposition processes of the organic matter accumulated at the bottom consume oxygen, leading to low rates of dissolved oxygen if there is low water flow. In addition, anoxic and even toxic zones can form at the bottom, which can cause serious health problems for the fish. For this reason, it is recommended that the water at the bottom be changed to promote water and soil quality.

Water exchange

To maintain the good quality of the water used in fish farming, it may occasionally be necessary to exchange the water.

The need for water changes is related to the use and management of the tank, such as the density of the fish (the more intensive the farming, the greater the need for water renewal or water treatment), the size of the fish, feeding management, water temperature, as well as soil permeability, water evaporation rate, water flow rate, and available water source. Ponds that are "drowned"/"flooded" usually already have some water exchange, even if the flow rate is low. Ponds that are filled only with rainwater, for example, are likely to have serious water quality problems in rainless seasons, which can lead to fish diseases and deaths, as can ponds that are heavily disturbed at the edges by large fish or tanks that receive waste from other animals, for example, pigs and ducks.

Thus, the water exchange rate will depend on several individual characteristics of each fish farm. In any case, to assess the need for water exchanges, monitoring water quality is essential.

Questions related to water management in fish farms participating in the survey showed that around 65 % of fish farmers who responded to the survey do not change the water, they just maintain the level of the tanks, and 25 % carry out up to 5 % water changes per day. Water exchange rates of 5 % to 20 % are performed by about 8 % of fish farmers, while water exchange rates above 20 % are performed by less than 2 % of respondents.

According to Ostrensky and Boeger (1998), although there is a recommendation to exchange 5 to 7 % of the water per day, there is no single criterion for performing these water exchanges, therefore this rate can vary according to the individual needs of each fish pond. It must be taken into account that a one-hectare pond in a conventional fish farming system, for example, will use 35,000 m^3 of water per year just to replace losses through evaporation and infiltration (AVNIMELECH *et al.*., 2008).

Water quality monitoring

When asked about monitoring the main water quality parameters, only 15 % of fish farmers responded that they frequently monitor two or more parameters. Less than 20 % responded that they frequently monitor at least one parameter, while approximately 65 % responded that they do not frequently monitor water quality. However, around 60 % of respondents mentioned that they observe at least one water quality parameter, even occasionally.

When these data are analyzed separately for tilapia producers and carp producers, it is observed that, among tilapia producers, 31 % of them frequently monitor two or more water quality parameters, 25 % frequently monitor at least one parameter, while 44 % do not monitor any water quality parameters regularly. In contrast, only 11 % of carp producers responded that they frequently monitor two or more water quality parameters, 17 % regularly monitor at least one water quality parameter, while 72 % reported that they do not regularly monitor any water quality parameters.

The color of the water was mentioned as being monitored by approximately 50 % of those interviewed. Water transparency was mentioned by 40 % of fish farmers. Even so, this number could be higher, as 15 % responded that they monitor water turbidity, but they may be referring to water transparency rather than turbidity. pH was mentioned by around 22 % of fish farmers, while dissolved oxygen was mentioned by around 10 % of them. Water temperature is checked by about 10 % of fish farmers, while alkalinity and hardness of the water were reported by about 6 % and 3 % of fish farmers, respectively. Salinity is checked by around 1 % of fish farmers. Nitrogen compounds in water were cited as being monitored by about 8 % of farmers for toxic ammonia and 3 % for nitrite and nitrate. Orthophosphate is checked by only 1 % of fish farmers. Furthermore, 0.5 % of fish farmers mentioned monitoring biological oxygen demand (BOD), while 0.2 % of fish farmers mentioned monitoring chemical oxygen demand (COD).

Thus, although it is still a minority that constantly monitors the water quality of fish farms, it can be inferred that tilapia farmers maintain greater control over the management of their farms, recognizing the importance of water quality for the professionalization and success of the activity.

Sanitary measures and fish escape control

As stated in the National Program for the Health of Farmed Aquatic Animals, fish farmers must develop and maintain their own Biosafety Program, appropriate to their reality, which must include the control of various aspects such as animal handling, disinfection of facilities and equipment, access control, vector and pest control, prevention of animal escape (BARCELLOS, 2022).

When asked about the sanitary measures used by fish farmers, almost 50 % of respondents reported not having any sanitary measures on their farms. Around 20 % responded that they control access for people and vehicles to the farm. Additionally, about 25 % indicated they implement a period of sanitary quarantine after harvest, which includes cleaning and disinfection of fish ponds. Only 5 % of farmers quarantine newly arrived fry. Disinfection of vehicles and equipment used in fish farming, along with sanitary footbaths, were cited by fewer than 5 % of farmers.

According to Barcellos (2022), fingerlings must undergo at least 15 days of isolation/quarantine before being introduced into raising tanks, to prevent the spread of diseases. The water source is also an important risk factor for the introduction of diseases in fish farming. It is important to use filters or other mechanisms that promote the sterilization of possible pathogens, to reduce the risk of disease transmission. Furthermore, maintaining a clean environment with regular disinfection of equipment used in the farm's routine, as well as disinfecting the wheels of vehicles that enter the property, helps prevent the spread of diseases.

Regarding the treatment of effluents produced in a fish farm, less than 2 % of the farmers responded that they treat effluents from fish farms. Coldebella *et al.* (2018) mention that regardless of the size of the tanks and fish farming operations, management measures associated with sediments are necessary to mitigate the negative impacts of the effluent generated. The authors also add that the main impacts of effluents on the environment are the increase in nitrogen and phosphorus concentrations in the water receiving the effluent; the accumulation of organic matter in sediments and the increase in suspended solids in the water. It is important to highlight that the main cause of effluents with a higher nutrient load is the use of feed, which generates effluents with large amounts of nitrogen and phosphorus, which is the main cause of water eutrophication. Thus, each and every fish farming tank must have its effluents monitored and treated/disposed of appropriately.

Controlling fish escape, a relevant aspect related to animal management and biosecurity is essential in the raising of exotic species. Around 43 % of respondents reported having control over fish escaping from tanks. On the other hand, only 7 % reported having a filter at the water inlet.

According to Barcellos (2022), any fish escaping from a farm, in addition to financial losses, can cause changes in the environment, including the transmission of pathogens and parasites. For these reasons, farms utilizing excavated tanks, must build safety structures to prevent fish from escaping. Similarly, controlling the entry of other animals into fish farming tanks can avoid several problems, such as the introduction of competing species, predators, parasites, and other pathogens that may accompany these animals.

Disposal of dead animals

For sanitary reasons and even to control the pond population, it is very important to monitor fish mortality and remove dead or sick animals from the tanks. Proper disposal of these animals is also essential.

Concerning fish that die on the farm, almost half of the farmers responded that they bury them on the property. Around 40 % mentioned disposing of them elsewhere, and around 9 % reported composting them. Less than 1 % of fish farmers incinerate the dead fish. Some fish farmers have reported that dead fish in ponds are not removed or disposed of (about 1.5 %). Additionally, some fish farmers reported not observing mortalities in fish ponds.

According to the Manual of Good Practices in Fish Farming (BARCELLOS, 2022), the disposal of sick or dead animals must comply with current environmental legislation. Options include composting, silage, burying on the property in a low-risk location to prevent groundwater contamination and avoid contact with other animals, incineration on the farm, or collection by a company specializing in hospital waste collection.

Inputs

Regarding the use of inputs for fish farming, quicklime, and dolomitic limestone are used by nearly half of the fish farmers who responded to the survey, in addition to organic fertilizers. Chemical fertilizers were mentioned by about 30 % of fish farmers, while 25 % mentioned the use of calcitic limestone. A small percentage of respondents cited the use of other inputs, such as parasiticides, insecticides, and additives. It is noteworthy that less than 3 % of farmers reported using antibiotics in their fish farming (Table 2).

Liming, an important management procedure in fish ponds, whether through the addition of lime or different types of limestone, is performed by a significant portion of fish farms, as indicated by responses obtained in the questionnaire. According to Scheleder and Skrobot (2016), liming is essential for enhancing tank health by increasing alkalinity, and hardness, as well as reducing pH variation. This practice improves the physical, biological, and chemical quality of the soil and water, crucial for pond preparation and maintenance, thereby, enhancing water quality and nutrient cycling. It is important to highlight that pH significantly influences nearly all reactions within the fish farming system

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(SCHELEDER and SKROBOT, 2016).

The use of fertilizers, both organic and chemical, plays a crucial role in promoting the fertilization of fish farming ponds, especially in extensive farming systems. Fertilization releases nutrients into the water stimulating the natural production of plankton, which serves as a natural food source for several fish species, such as tilapia. It is recommended to apply fertilizers before storing fish, while monitoring water transparency and, ideally, oxygen concentration in the water. The use of waste as a source of organic fertilizers can lead to low oxygen levels in the water, especially in tanks lacking supplemental aeration (OSTRENSKY NETO and BOEGER, 1998).

Organic fertilizers were mentioned more than chemical fertilizers. However, this number is still low, considering the importance of fertilizing water for fish farming, especially in less intensified systems.

It is interesting to note that, in this questionnaire, the number of farmers who declared using additives exceeded those who reported using antibiotics in their fish farms. The low number of fish farmers using fish vaccines underscores a reality in the sector in the state, where this practice is not yet widely adopted professionally and technically. This reality, however, may not reflect the national context, especially in tilapia farming, where vaccination practices have been increasing and contributing to the rational use of antimicrobials (BARCELLOS, 2022).

Furthermore, it is necessary to discuss information and accessibility to vaccines and aquaculture additives, which are not yet widely available to fish farmers in the state.

It was reported that herbicides, pesticides used to control weeds and algae, which can be quite toxic and harmful to fish, are used in 0.7 % of fish farms participating in the survey. Although there is no information about their application directly in tanks, it is important to highlight that this product can remain in the sediment and be carried by rainwater into the tanks.

The use of insecticides was mentioned by 1.3 % of fish farmers, mostly organophosphates, which are not recommended by environmental legislation for use in aquatic environments. They are applied to eliminate ectoparasites and larvae of aquatic insects, mainly dragonflies. It is necessary to highlight that although almost 50 % of respondents reported carrying out fish farming activities in systems that regularly use feed, of which around 38 % produce fish commercially, this input was mentioned in the questionnaire by only one percent of them. This data means that at least these 38 % should have cited feed as a frequent input on their property. Similar findings were reported by Bassani and Rocha (2020), where 39 % of fish farmers on the North Coast of RS, Brazil, who participated in the survey, mentioned that they used feed plus agricultural residues, and 27 % used feed exclusively. The most likely explanation is that producers were not properly guided to answer this question, or were confused about it.

Still, concerning the inputs used in fish farming, around 40 % of farmers responded that they usually consult a professional to indicate which inputs to use, and around 33 % occasionally request professional recommendations.

Remarks about the method

It is important to discuss the challenges in obtaining data. The timing of the research is a crucial factor to consider. During the COVID-19 pandemic, the availability of technicians and extension workers to conduct field activities was reduced, which posed challenges in increasing the sample size. As a result, regions with higher productivity and a greater number of fish farms may not have been proportionally represented in this research.

Regarding the main challenges identified in obtaining information, several issues were noted. This included non-standardization in completing the forms despite instructions provided on the form itself. Many errors occurred during the completion of requested data, and some responses were unclear. Additionally, it was observed that some questions could be difficult to answer, particularly if they relied solely on the farmer's input. Furthermore, certain questions were deemed unnecessary for inclusion in the survey.

Therefore, one way to minimize these errors would be to formulate questions that do not allow for free-text (open-ended) responses. Developing a smaller and simpler questionnaire could potentially expedite and streamline data collection. Moreover, designing the online survey to be farmer-friendly for self-response might enhance efficiency, as reliance on a technician for administration could pose challenges.

Another notable issue is the inconsistency of some reported information, which rendered it unusable for the study. For instance, discrepancies were observed between reported productivity and the stated purpose of production or the system used. In some cases, fish farmers reported very low productivity values that were not aligned with their reported production systems or purposes. Such inconsistencies highlight the importance of verifying and validating data to ensure its reliability for analysis and study purposes. This conflicting information indicates that some farmers may not know the productivity of their property or may not have adequate records of their production. Both situations are more common when the activity is carried out non-commercially, often as a hobby or for subsistence. However, some inconsistencies in the reported data in this form raise doubts regarding the classification of the producer eligible for accessing the DAP (Declaration of Aptitude for Pronaf - agricultural loan), also known as CAF (National Family Farming Registry), and other public policies. Accessing agricultural loans for family farming and other public policies through DAP/CAF requires farmers to meet certain criteria, such as property area, labor, and income from aquaculture, among others (BRASIL, 2017). If such inconsistencies prevail, it poses a significant challenge in obtaining accurate information on the productivity of farmed fish in the state of Rio Grande do Sul. This particularly affects farmers who do not qualify for commercial fish farming, and there is no immediate solution in sight for this challenge.

Final remarks

According to the PeixeBR Fish Farming Yearbook (2023), the development of the fish farming sector in Rio Grande do Sul necessitates organization, professionalization, and environmental regularization of the activity. Additionally, formalizing the production chain is crucial for obtaining more accurate data and advancing the sector.

Based on the responses obtained in this online survey, the fish farming activity developed in Rio Grande do Sul can be characterized as primarily family-based agriculture, aligning with the definition under Law No. 11,326, of July 24, 2006 (BRASIL, 2006). The majority of fish farms operate on a non-professional basis, characterized by minimal management and investment. These farms typically employ small-scale, extensive, and polyculture systems, primarily for personal consumption (subsistence) and the sale of surplus fish to generate additional income.

The peak period for sales generally coincides with Lent and Holy Week, when fish are sold at local fairs or directly from the farm gate. However, there are also fish farmers who approach the activity with commercial objectives, operating more professionally. These farmers utilize advanced resources and technology, allocate significant time to monitoring and managing production, and aim for higher levels of productivity and profitability in their operations.

Although tilapia is present in 50 % of the fish farms participating in the study, it is the main species reared by only 20 % of them. According to respondents who sell their farmed fish to the industry, tilapia constitutes the most significant species, comprising 70 % of sales.

As the tilapia market expands, professionalizing the activity and ensuring environmental compliance of properties become equally crucial. Among survey participants, only 20 % have environmental regulations in place, less than half implement leak control measures, and an insignificant proportion treat effluents or dispose of dead fish properly. Sanitary and biosecurity controls, as well as the monitoring and management of nurseries and water quality, are still inadequate, highlighting the unprofessional manner in which the activity is conducted on most of the properties surveyed. However, the majority of interviewees stated that they had received some technical assistance in carrying out the activity.

The FAO report (2022) underscores several priority areas for Asian aquaculture that hold relevance for Brazil's aquaculture sector. These include genetic improvement and diversification of farmed species, alongside the implementation of public policies such as zoning and regulation aimed at reducing conflicts, improving efficiency, and optimizing the use of environmental resources. Additionally, there is a call to promote fish consumption within the population's diet, foster socio-economic debates on aquaculture resilience through mechanisms like social protection and sustainable financing, and enhance biosecurity and disease control measures. Emphasis is placed on adopting sustainable production systems like heterotrophic and closed recirculation systems to minimize environmental impacts from effluents and advancing research into feed technologies to reduce dependence on fishmeal and improve nutritional profiles for farmed aquatic animals. The integration of digital technologies and smart systems for monitoring water quality, along with the adoption of circular economy principles to maximize resource efficiency, are also highlighted. Lastly, there is a critical need to develop species resilient to climate change effects and adapt management strategies to mitigate the impacts of reduced water availability. These strategies collectively aim to bolster sustainability, productivity, and resilience within Brazil's aquaculture industry amidst evolving global challenges. Therefore, these highlighted themes can serve as guidelines for discussion and evaluation among stakeholders and representatives of the fish farming chain regarding their feasibility for implementation by fish farmers in the state. While studies related to these issues have been developed in Brazil, thefiffir application remains largely nascent and sporadic, particularly in the context of the South Region. Hence, there is an urgent need to implement public policies aimed at enhancing knowledge, regulation, and professionalization of the activity. This should be coupled with the promotion of ongoing research and extension efforts, which have the potential to catalyze growth within the aquaculture sector in Rio Grande do Sul.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical Statements

The project was evaluated and approved by the Research Ethics Committee of the Pontifical Catholic University (CEP-PUCRS), CAAE: 38889320.2.0000.5336, Number: 4,392,302.

The project coordinator and the director of the Institution sign a commitment to comply with the terms of Resolution 466/2012 of the National Health Council (BRASIL, 2012).

The authors confirm that the ethical guidelines adopted by the journal were followed in this work, and all authors agree with the submission, content, and transfer of the publication rights of the article to the journal. The authors also declare that the work has not been previously published, nor is it being considered for publication in another journal, assume full responsibility for the originality of the article, and may incur any charges arising from third-party claims concerning the article's authorship.

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