UNIVERSIDAD NACIONAL MICAELA BASTIDAS DE APURÍMAC

FACULTAD DE MEDICINA VETERINARIA Y ZOOTECNIA

ESCUELA ACADÉMICO PROFESIONAL DE MEDICINA VETERINARIA Y ZOOTECNIA

TESIS

Caracterización y análisis de conglomerados del cultivo de trucha arcoíris (*Oncorhynchus mykiss*) en la provincia de Abancay (Apurímac, Perú)

Presentado por:

José Abelardo Ancco Surquislla

Para optar el Título de Médico Veterinario y Zootecnista

Abancay, Perú

2023

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Presentado por **José Abelardo Ancco Surquislla** para optar el Título de:

Médico Veterinario y Zootecnista

Sustentado y aprobado el 22 de junio del 2023 ante el jurado evaluador:

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Agradecimiento

A mis padres, familiares y amigos que me apoyaron en todo el proceso de formación profesional y personal.

A mis asesores Ph.D. Oscar Elisban Gómez Quispey Mg. Rutniss Alecy Vasquez Onzueta.

A los especialistas Mg. Nieves Sandoval Chaupe, Dr. Ivar Zarate M. y al Dr. Carlos E. Smith D. por su apoyo en la ejecución de este proyecto de tesis.

A la Universidad Nacional Micaela Bastidas de Apurímac y a toda la plana de docentes de la Facultadde Medicina Veterinaria y Zootecnia.

Dedicatoria

A mi querida madre Alejandrina Surquislla Arango y a mi padre Justo Ancco Huachaca, por elapoyo incondicional de siempre.

“Caracterización y análisis de conglomerados del cultivo de trucha arcoíris (*Oncorhynchus mykiss*) en la provincia de Abancay (Apurímac, Perú)”

Línea de investigación: Ciencias veterinarias

ÍNDICE

Pág.

ÍNDICE DE TABLAS

Pág.

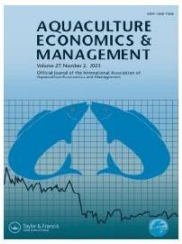
ÍNDICE DE FIGURAS

Pág.

RESUMEN

El estudio tuvo como objetivo analizar las características de los conglomerados y estimar losfactores involucrados en la rentabilidad de la trucha arcoíris (*Oncorhynchus mykiss*) en la provincia de Abancay (Apurímac, Perú). El ámbito se encuentra ubicada en la cordillera de losAndes a 2 378 metros de altitud. La investigación fue de tipo descriptivo y analítico, la recolección de información se realizó mediante un cuestionario. El tamaño de la muestra analizada consistió del 100% de los acuicultores registrados en el Catastro Acuícola Nacional del Ministerio de la Producción del Perú para el ámbito. La aplicación del instrumento se realizóen el último trimestre 2021. El desarrollo de la investigación evidenció información relevante para la mejora de la gestión de la acuicultura. Los piscicultores agrupados según categoría productiva tenían características de AREL (acuicultura de recursos limitados) y AMYPE (acuicultura de micro y pequeña empresa), pero había acuicultores que compartían algunas características productivas. Se identificaron cuatro conglomerados, granjas de monocultivo (exclusivamente producción de trucha) de micro y pequeña empresa, granjas mixtas (producción de trucha más otras actividades) con una experiencia de 1 a 2 años orientado a la trucha, granjas mixtas que producen para el abastecimiento y el emprendimiento familiar empleando mano de obra no remunerada, y granjas mixtas de sistema extensivo que producen para el autoconsumo aprovechando los recursos naturales de la zona. También se encontró, quelos años de experiencia, fuente de recurso hídrico, mercado de venta y actividad principal estuvieron relacionadas con la rentabilidad.

Palabras clave: *Acuicultura, laguna, rentabilidad, ríos, agua*



Aquaculture Economics & Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uaqm20

Characterization and cluster analysis of rainbow trout (*Oncorhynchus mykiss*) farming in the province of Abancay (Apurímac, Peru)

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To cite this article: Jose A. Ancco, Saúl Utani, Keyro Melendez, Rutniss A. Vasquez, Aldo R. Meza & Oscar Gómez-Quispe (2023): Characterization and cluster analysis of rainbow trout (*Oncorhynchus mykiss*) farming in the province of Abancay (Apurímac, Peru), Aquaculture Economics & Management, DOI: 10.1080/13657305.2023.2204833

To link to this article: https://doi.org/10.1080/13657305.2023.2204833

AQUACULTURE ECONOMICS & MANAGEMENT
https://doi.org/10.1080/13657305.2023.2204833

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Characterization and cluster analysis of rainbow trout (*Oncorhynchus mykiss*) farming in the province of Abancay (Apurímac, Peru)

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ABSTRACT

This study aimed to examine the characteristics of clusters and the factors that influence the profitability of rainbow trout (*Oncorhynchus mykiss*) farming in Abancay province (Apurimac, Peru). The area is located in the Andes mountains at an altitude of 2,378 meters. Information was collected through a questionnaire. The sample consisted of 100% of the aquaculture farmers registered in the National Aquaculture Registry of the Ministry of Production of Peru for the area. Fish farmers were classified as LRA (limited resource aquaculture) or MSAE (micro and small aquaculture enterprise) according to their production category, however there were also fish farmers who fit into both categories. Four conglomerates were identified, monoculture fish farmers (only trout) from micro and small businesses, mixed fish farmers (trout production plus other activities) with 1–2 years of experience in the activity, mixed fish farmers who produce for consumption and familiar enterprises using unpaid labor, and an extensive system with mixed fish farmers who produce for self-consumption. It was also found that years of experience, water source, sales market, and the main activity were related to profitability.

KEYWORDS

Aquaculture; lagoon; pisciculture; profitability; rivers; water

Introduction

Salmonids are the second most valuable species group in aquaculture after shrimp (Garlock et al., 2020). However, most research has been focused on Atlantic salmon, the largest species in the group (Asche et al., 2022), despite the fact trout is a salmonid species produced in a much larger number of countries and production systems (Landazuri-Tveteraas et al., 2021). The culture of rainbow trout (*Oncorhynchus mykiss*) involves the

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management of its complete or partial life cycle in natural or artificially controlled aquatic environments (Glencross et al., 2011). Trout is a salmonid that requires cold, clean and abundant water for cultivation or rearing, and is produced all over the world in various production systems (Barbosa et al., 2020).

Peru provides a good example of a country where trout aquaculture is diverse and important. There are around 2,800 rainbow trout farmers, 45 percent of whom are involved in limited resource aquaculture (LRA), 54 percent in micro and small businesses (MSB), and less than 1% in aquaculture of medium and large enterprises (MLEA) (CAN [Catastro Acuícola Nacional], 2021). The government promotes this trout aquaculture activity through development projects (Avadí et al., 2015). However, to formulate development plans, a baseline is required. This facilitates the definition of goals and intervention strategies differentiated by the various producer groups (Rosenthal et al., 2013).

Challenges faced by rural aquaculture producers are related to factors such as unfavorable environmental parameters, little training of aquaculture farmers, poor sanitary surveillance, insufficient productive infrastructure, high food costs, limited access to communication technologies and transportation modes (Michielsens et al., 2002), and difficulties to obtaining embryonated eggs (Ortega & Valladares, 2017). These limitations change according to educational, environmental, cultural, and economic factors in each area, so it is necessary to identify and characterize the different clusters to facilitate the support and organization of fish farmers.

Achieving sustainability in trout farming involves the development of its main components, such as profitable production, environmental conservation, and community development (Barbosa et al., 2020). However, the aquaculture industry in several regions of Peru has a basic agricultural production structure in the sense that it is fragmented, with low levels of production and productivity (Zárate et al., 2018). Moreover, it does not take into account factors such as multiculturalism, biodiversity (Zinngrebe, 2016), variations in altitude, humidity, and microclimates (Joy et al., 2015). In most of these regions, the production and marketing of trout is a self-sufficient, artisanal, and isolated activity. Fish farmers are not aware of the organization of clusters as a business organization strategy to improve production and marketing (Johnson et al., 2017).

These considerations have motivated an analysis of the formation of clusters and their main attributes, in addition to knowing some factors that influence the profitability of trout rearing centers in the province of Abancay (Peru). The research provides knowledge that may improve the management and capacity building of rural fish farmers.

Materials and methods

The study was carried out in the province of Abancay (Apurímac, Peru), at an altitude of 2,378 meters. The area has records of maximum rainfall of 79.9 and minimum of 7.3 mm, relative humidity between 57 and 67%, and maximum temperatures that can reach peaks of 5.2–28 °C (SENAMHI [Servicio Nacional de Meteorología e Hidrología del Perú], 2012).

A descriptive, analytical, and cross-sectional investigation was carried out. The research was conducted using most of the 104 producers registered in the National Register of Aquaculture of the Ministry of Production of Peru (May 2021). Of all the trout farms, 47 were in operation, 17 had abandoned production, four were in process of implementation, 11 were registered without a production unit, two fish farmers did not have production records, 22 integrated other fish farms in production, and only one farmer refused to participate. The 47 fish farmers in operation belonged to the province of Abancay. Within this province, they were distributed in districts, and these were Abancay (48.9%), Chacoche (6.4%), Circa (8.5%), Curahuasi (2.8%), Huanipaca (4.3%), Lambrama (10.6%) and Pichirhua (8.5%).

This study used a questionnaire about the production characteristic of aquaculture farms, previously reviewed and approved by a panel of experts, which allowed improving the instrument. In addition, a different questionnaire was used to estimate the profitability because fish farmers in this region normally did not have the accounting information of their businesses.

The location of the trout farms was made using the aquaculture map available on the website of the aquaculture registry of the province of Abancay. Subsequently, a pilot test was applied to trout producers, which allowed the questionnaire to be improved. The instrument was applied through a visit to fish farmers or their representatives, with prior informed consent.

The information obtained was systematized in a database with the help of OpenOffice. Various statistical techniques were used for the analysis. Data mining techniques were used to clean and correct data collection. The technique of multiple correspondence analysis to characterize trout farms by production category. For this purpose, seven qualitative variables were used, such as the purchase of fingerlings, years of experience, technical assistance, type of feed, training, and product category. Similarly, a cluster analysis was conducted using the Ward method and Hamming distances to identify clusters and their characterization. In addition, a multiple binary logistic regression was performed, where the dependent variable was the level of profitability, and the independent variables were technical assistance, main activities, training, biological seeds, water sources, sales market, prevention method, production records, and invested capital. Data processing was carried out using R v3.5 statistics software.

Results

Characterization of the trout farms by productive category

Association between variables

Figure 1 (panel A) illustrates that the output category and the main activity variables behave as variables closely linked to dimension 1. This indicates that there are aquaculture farmers dedicated only to trout production, and

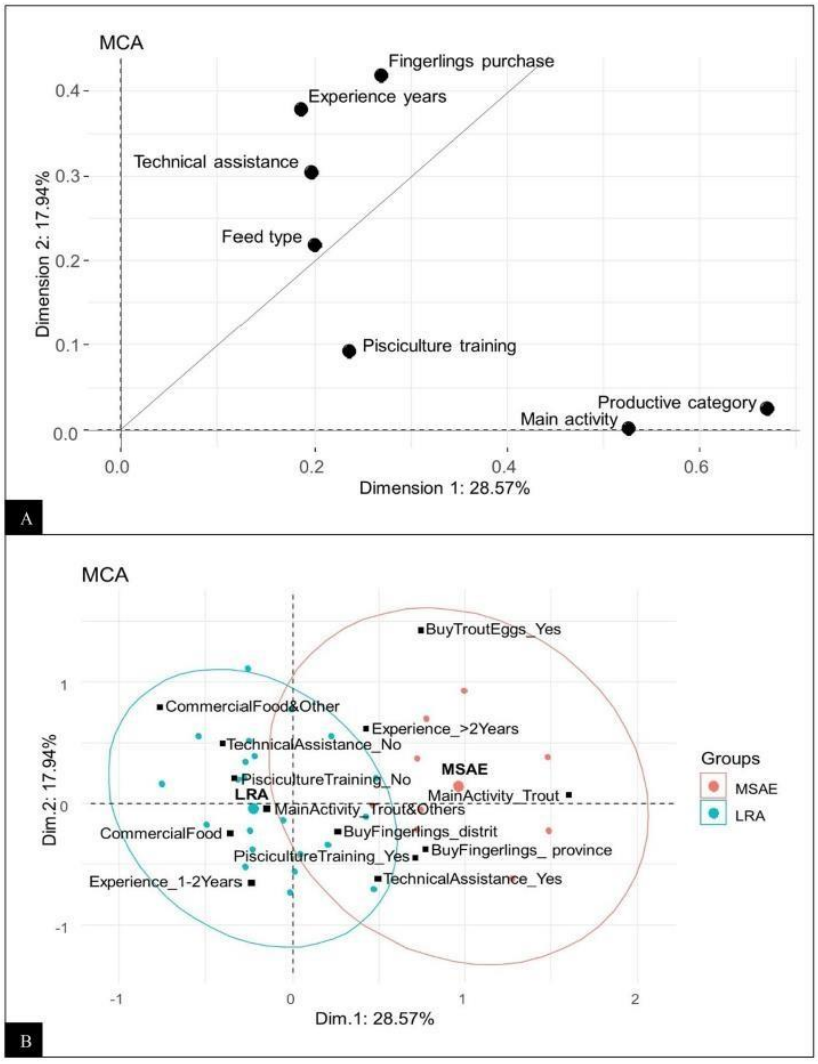

Figure 1. Panel A shows the relationships of the variables across two dimensions. Panel B illustrates the characterization of trout farms by productive category (LRA and MSAE).

other fish farmers for whom trout farming is a secondary activity. In the same way, an association is visualized between the type of food, technical assistance, years of experience, and the purchase of fry, which are related to dimension 2. These variables are important for strengthening production capacities. Training is a variable linked to both dimensions, but only slightly to dimension 1.

Relations between production categories

The trout farmers grouped in the MSAE productive category (Figure 1, panel B), were characterized by buying trout fingerlings at the provincial level, receiving training, having more than two years of experience, buying embryonated eggs, and devoting themselves solely to trout production. On the other hand, LRA fish farmers are characterized by not receiving training or technical assistance, dedicating themselves to aquaculture and other activities, having two years of experience, and using commercial feed and homemade feed. Both production categories are characterized by receiving technical assistance and the use of commercial feed.

Cluster analysis of trout farming centers

Figure 2 shows the characterization of each of the four clusters. Cluster 1 is characterized by having the largest number of trained producers, a greater number of aquaculture farmers who use trout eggs as seed, more than 2 years of experience, and the highest level of education (higher). In this group, fish farmers use floating cages and concrete pools, as well as lagoons and river waters. Production is sold on a provincial scale and production records are used more often. Cluster 2 fish farmers are characterized by a lack of training, higher frequency of technical assistance, and trout farming with other businesses as their main activities. They mainly use commercial feed, fry as seeds for production, and have two years of experience. Most of them have elementary and high school education, their infrastructure is made of concrete, and their main source of water are rivers and springs. Their main sales market is local, they have no prevention methods, nor do they use production records. The fish farmers of cluster 3 are characterized by having two years of experience, infrastructure made of concrete, and the use of the river as the main water source. They do not use production registration and their primary sales market is at the district level. Aquaculture farmers in cluster 4 are defined by a lack of training and technical assistance. Furthermore, trout fry is used as seed for cultivation, the river is their main source of water, they have no preventative procedures, and do not keep track of production.

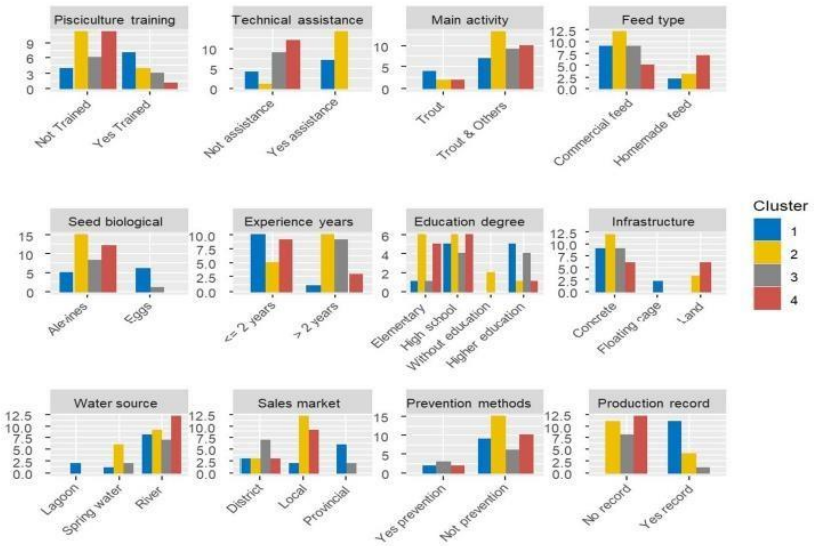

Figure 2. Characterization of each of the four trout farming cluster in the province of Abancay (Peru).

Table 1. Factors that affect the profitability of trout farming using the logistic regression model.

Variables	Estimate	Std. error	*Z* value	*p*-Valor	OR	Sig.
(Intercept)	3.445	2.064	1.669	0.0951	31.34	*
Pisciculture training 1	0.164	0.921	0.178	0.8589	1.178	
Technical assistance 1	−0.700	0.962	−0.728	0.4669	0.496	
Main activity 2	−3.350	1.569	−2.135	0.0328	0.035	**
Seed biological 2	−2.561	1.485	−1.724	0.0846	0.077	*
Experience years 2	2.792	1.167	2.393	0.0167	16.31	**
Water source 2	2.931	1.391	2.108	0.0351	18.74	**
Water source 3	−19.610	2031.0	−0.01	0.9923	0.00	
Sales market 2	1.653	1.011	1.635	0.102	5.223	
Sales market 3	3.255	1.628	2	0.0455	25.91	**
Prevention methods 1	−2.694	1.714	−1.571	0.1161	0.067	
Production record 1	−2.123	1.192	−1.782	0.0748	0.119	*
Invested capital	0.210	0.000	−1.325	0.1852	1.23	

OR: odds ratio.
Significance codes: 0.01**, 0.05*.
Variable codes: Pisciculture training 0 = no, 1 = yes; technical assistance 0 = no, 1 = yes; main activity 1 = trout, 2 = trout and others; seed biological 1 = alevines, 2 = eggs; experience years 1 = ≤2 years, 2 = >2 years; water source 2 = river 3 = lagoon; sales market 1 = local, 2 = district, 3 = provincial; prevention methods 0 = no, 1 = yes; production record 0 = uses, 1 = not use; invested capital (quantitative value); profitability 1 = <28%, 2 = ≥28%.

Factors related to the profitability of trout farming

Table 1 illustrates the coefficients and significant advantage ratios for several parameters affecting trout farming profitability. It was found that if a person has more than 2 years of experience, there is a 16.31 times greater chance that their profitability will be high. In terms of water resources, the

use of river water as a source of water resources provides an advantage of 18.74 times the likelihood of high profitability. As for the sales market, producers selling their final product to provincial markets are 25.91 times more likely than those who sell locally to make a profit. The main activity, the culture of biological seeds, and the use of production records had a lower negative impact on profitability. Thus, if a productive unit is dedicated to the raising of trout and other activities at the same time, it has a 0.035 times lower chance of creating more profit than those dedicated solely to trout raising. Compared to those raising trout fingerlings, trout farmers using trout eggs have a 0.077 times lower chance of being profitable. Otherwise, if production records are not used, this leads to the possibility of achieving 0.119 times less profitability than those keeping records.

Discussion

Characterization of trout crops by productive category

Trout farmers of the productive category MSAE (Figure 1, panel B) were characterized by the fact that they purchased trout fingerlings in the province, received training, had more than two years of experience, use trout eggs as seed, and dedicated themselves completely to trout production. These features were also seen at various latitudes. For instance, medium-sized fish farmers (36.6 t/year) in Turkey had bought eggs and juvenile trout for commercial rearing (Yildiz et al., 2010). Thanks to partnerships with private enterprises and the government, fish farmers of this productive category can produce up to 150 t of trout per year (Alarcón et al., 2021).

On the other hand, LRA fish farmers shared similarities with small aquaculture farmers in Kenya, who grew trout while simultaneously engaging in other activities, used commercial and homemade feed, and sold fresh and whole fish to local markets (Oyieng et al., 2013). Fish farmers in Nigeria showed similar features. These were characterized by the absence of professional help and training, shortage of fingerlings as seed producers, capital restrictions, and high food expenses (Ozigbo et al., 2014). That is, fish farmers of this group produce to meet basic family needs, do not receive adequate government support, and can produce up to 3.5 t of trout per year (Alarcón et al., 2021). Bangladesh and Zambia provide another example where the productivity level differs between different groups of farmers (Mitra et al., 2022; Naylor et al., 2023; Rahman et al., 2022).

Similarly, both productive groups (LRA and MSAE) were shown to have similar features in terms of receiving technical assistance and using balanced feed at different levels. The results are consistent with those reported for rural fish farmers in India (Dubey et al., 2016). It is known that in many parts of the world, the level of government intervention in training

and technical assistance is variable for this activity. Only 33% of aquaculture farmers in Mymensingh (Bangladesh) obtained these services from public and private institutions; the remaining aquaculture farmers learned through friends and neighbors (Sheheli et al., 2014). If the government or a private development institution wants to intervene in these trout farmers groups, they should not overlook the existence of a group of entrepreneurs who share some features of both (LRA and MSAE), and are in the process of transition from LRA to MSAE.

Trout farming cluster analysis

Four clusters were formed according to the individual characteristics of the fish farmers (Figure 2, panels A and B).

Cluster 1 had similarities with conglomerates of fish farmers studied in previous research. In Mexico (Alarcón et al., 2021), a cluster of producers was identified, characterized by the management of production records, the use of river water, the exclusive production of trout, and the use of qualified and remunerated persons. Although in the cultivation of Asian carp, there were fish farmers who had similar features in various experiences in several Asian countries (Michielsens et al., 2002). These had trained and paid staff, floating cages favored by government financial support, as well as high capital investments, and they sold their product mainly to wholesalers. This group of fish farmers is generally engaged in commercial production and interacts with government and private sector partners.

Fish producers in various West African countries shared several of the characteristics of cluster 2, who used commercial feed and produced agro-industrial by-products, produced trout but also agricultural products, had concrete ponds, experience between 5 and 10 years, and had the absence of prevention methods (Yao et al., 2017). Similarly, in other latitudes (Mexico), the characteristics of cluster 3 were linked to the sale of whole fresh trout on the farm or in restaurants, unpaid family work, lack of organizational framework, and government funding (Alarcón et al., 2021).

Cluster 4 resembled certain fish farms in Kenya, where farmers had limited water management skills, weak extension and training facilities, and insufficient production infrastructure (Opiyo et al., 2018). In this regard, limited market supply and demand, as well as the risks associated with production, could influence the production of this type of conglomerate (Stevenson et al., 2007). This group of trout farmers clearly produces for self-consumption and family business, and they do not receive adequate government support.

Despite the vast distances and border barriers that exist around the world, there is the possibility that certain groups of fish farmers with comparable problems may be found. The identification of aquaculture clusters

is important because it allows us to understand how they are clustered based on some common characteristics (Philis et al., 2019). This information allows companies and public and private institutions to intervene effectively at different levels of production, distribution, and marketing in order to improve their sustained growth (Barbosa et al., 2020).

Analysis of factors related to profitability

The aquaculture farmers involved in trout production and other activities (Table 1) had a low likelihood of generating revenue (OR = 0.035), which could be due to the small size of fish farms, which were largely made up of LRA. In other studies, trout farmers and other businesses were more likely to be profitable than those engaged in aquaculture alone (Love et al., 2015). In the case of Iran, they had only 1.03 times more possibilities to earn economic gain when they engaged in both occupations, fish farming and agriculture, rather than just aquaculture (Noorhosseini-Niyaki & Allahyari, 2012). Small rural aquaculture farmers who engage in other activities in the field may create higher economic revenue, but they will be less than those who focus solely on trout production.

Aquaculture farmers with more than two years of experience were more likely to achieve higher profitability (OR = 16.31). It is well recognized that profitability, operator experience, operator educational level, and getting extension services have good correlations (Cinemre et al., 2006). In other words, the more years a fish farmer dedicates to this activity, his knowledge, and income will be better.

Profitability was higher for fish farmers who used river water (OR = 18.74). In other cases (Puno, Peru), better economic revenue was obtained when it was raised trout in Lake Titicaca using floating cages (Avadí et al., 2015). The recirculation production method also showed improved yields (D'Orbcastel et al., 2009). The size of the enterprise, the number of trout fingerlings, the feeding method, and the water quality are important factors in this economic activity, as they have a beneficial impact on the results of aquaculture (Ghorbani & Mirakabad, 2010). Trout producers, according to the information available, take advantage of the rivers and natural lagoons of the area, but the quality of the water is crucial to achieving productive efficiency in this activity.

When fish farmers sold their products in provincial markets rather than local ones, they were more likely to have high profitability (OR = 25.91). In the experience of rural Indian fish farmers, if they sold beyond the local market (export), they achieved better economic returns (Singh et al., 2016). Similarly, although in a smaller proportion of sales, when it was destined for export than for domestic consumption, fish farmers in Mexico obtained better income (Ortega & Valladares, 2017). As can be seen, rural

aquaculture is still being developed as a supplement to agriculture or livestock, but there are favorable conditions to increase production and commercial systems and begin the export process.

Fish farmers who utilized embryonated trout eggs were less likely to make more profit than those who used trout fingerlings (OR = 0.077). In contrast, better economic income was obtained in other experiences (Turkey) (Aydın et al., 2018). In fact, access to good-quality eggs and fingerlings leads to increased fish production (Sheheli et al., 2014). One of the main factors identified that contribute to reducing production costs is the adequate purchase of these biological seeds (Engle et al., 2020). It is clear that the insufficient availability of embryonated trout eggs could be a limiting factor for trout production in the diverse environmental and geographical conditions in Peru.

Aquaculturists who did not use production records compared to those they used had less profitability (OR = 0.119). In a region close to the present study, 70% of fish farmers did not use any type of production records (Zárate et al., 2018), although no information on fish farm economic profits was provided. These findings are related to rural aquaculturists in Mexico who used production records to increase their economic revenue (Alarcón et al., 2021). Production records help to improve economic profits (Zárate et al., 2018). It is also used to estimate production characteristics and make timely decisions in fish farming management.

Conclusions

The trout aquaculture sector in Peru is highly diverse. In this study, four groups of trout farmers were identified. These include micro and small business farms dedicated only to trout production, micro business farms dedicated to trout production and other activities (mixed), mixed family enterprise and self-consumption farms, and extensive mixed farms that produce for self-consumption.

Fish farmers in LRA were characterized by a lack of training and technical help, focused on aquaculture and other activities, with 1–2 years of experience and the use of commercial and homemade feed. MSAE fish farmers were differentiated for purchasing trout fingerlings from the province, receiving training, having more than two years of experience, and focusing solely on trout production. In both production categories, there were fish farmers who shared the traits of receiving technical assistance and using balanced feed.

Years of experience, water resources, production records, biological seeds, sales market, and main activity were determined as variables associated with profitability.

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References

Alarcón, G. I., Mondragón, G. D., Pulido, G. D., Fonseca, R. C., & Zepeda, C. I. (2021). Characterization of rural small-scale rainbow trout (*Oncorhynchus mykiss*) farms in Mexico. *Latin American Journal of Aquatic Research*, *49*(5), 828–835. https://doi.org/10.3856/vol49-issue5-fulltext-2454

Asche, F., Eggert, H., Oglend, A., Roheim, C. A., & Smith, M. D. (2022). Aquaculture: Externalities and policy options. *Review of Environmental Economics and Policy*, *16*(2), 282–305. https://doi.org/10.1086/721055

Avadí, A., Pelletier, N., Aubin, J., Ralite, S., Núñez, J., & Fréon, P. (2015). Comparative environmental performance of artisanal and commercial feed use in Peruvian freshwater aquaculture. *Aquaculture*, *435*, 52–66. https://doi.org/10.1016/j.aquaculture.2014.08.001

Aydın, A., Bashimov, G., & Yaykaşlı, M. (2018). The structural and economic analysis of the rainbow trout farming: Case of Erzurum province. *Marine Science and Technology Bulletin*, *7*(1), 4–11. https://doi.org/10.33714/masteb.379336

Barbosa, A. S., Pereira, R. G., Rodrigues, L. A. d M., Casaca, J., Valenti, W. C., & Fabregat, T. E. H. P. (2020). Economic analysis of family trout farming in Southern Brazil. *Aquaculture International*, *28*(5), 2111–2120. https://doi.org/10.1007/s10499-020-00580-7

CAN [Catastro Acuícola Nacional]. (2021). *Information map on aquaculture activity in Peru*. http://catastroacuicola.produce.gob.pe/web/.

Cinemre, H. A., Ceyhan, V., Bozoğlu, M., Demiryürek, K., & Kılıç, O. (2006). The cost efficiency of trout farms in the Black Sea Region, Turkey. *Aquaculture*, *251*(2–4), 324–332. https://doi.org/10.1016/j.aquaculture.2005.06.016

D'Orbcastel, E. R., Blancheton, J. P., & Aubin, J. (2009). Towards environmentally sustainable aquaculture: Comparison between two trout farming systems using Life Cycle Assessment. *Aquacultural Engineering*, *40*(3), 113–119. https://doi.org/10.1016/j.aquaeng.2008.12.002

Dubey, S. K., Chand, B., Trivedi, R. K., Mandal, B., & Rout, S. K. (2016). Evaluation on the prevailing aquaculture practices in the Indian Sundarban delta: An insight analysis. *Journal of Food, Agriculture & Environment*, *14*(2), 133–141.

Engle, C. R., Kumar, G., & Senten, J. (2020). Cost drivers and profitability of U. S. pond. Raceway, and RAS aquaculture. *Journal of the World Aquaculture Society*, *51*(4), 847–873. https://doi.org/10.1111/jwas.12706

Garlock, T., Asche, F., Anderson, J. L., Bjørndal, T., Kumar, G., Lorenzen, K., Ropicki, A., Smith, M. D., & Tveterås, R. (2020). A Global Blue Revolution: Aquaculture growth across regions, species, and countries. *Reviews in Fisheries Science & Aquaculture*, *28*(1), 107–116. https://doi.org/10.1080/23308249.2019.1678111.

Ghorbani, M., & Mirakabad, H. Z. (2010). Factors influencing on trout production in Khorasan Razavi Province. *Trends in Agricultural Economics*, *3*(1), 19–27. https://doi.org/10.3923/tae.2010.19.27

Glencross, B., Hawkins, W., Evans, D., Rutherford, N., Mccafferty, P., Dods, K., & Hauler, R. (2011). A comparison of the effect of diet extrusion or screw-press pelleting on the digestibility of grain protein products when fed to rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, *312*(1–4), 154–161. https://doi.org/10.1016/j.aquaculture.2010.12.025

Johnson, H. j., Dirado, A. J., Mackey, G., & Abbett, R. (2017). Comparative diets and foraging strategies of subyearling Atlantic salmon, brown trout, and rainbow trout during winter. *Journal of Applied Ichthyology*, *33*(6), 1158–1165. https://doi.org/10.1111/jai.13488

Joy, E., Van Baak, K., Katherine, L., Semakula, B., Cardin, A. D., Lemery, J., Wortley, G. C., Yaron, M., & Madden, C. (2015). Wilderness preparticipation evaluation and considerations for special populations. *Wilderness & Environmental Medicine*, *26*(4 Suppl), S76–S91. https://doi.org/10.1016/j.wem.2015.09.010

Landazuri-Tveteraas, U., Oglend, A., Steen, M., & Straume, H. (2021). Salmon trout: The forgotten cousin? *Aquaculture Economics & Management*, *25*(2), 159–176. https://doi.org/10.1080/13657305.2020.1857469

Love, D. C., Fry, J. P., Li, X., Hill, E. S., Genello, L., Semmens, K., & Thompson, R. E. (2015). Commercial aquaponics production and profitability: Findings from an international survey. *Aquaculture*, *435*, 67–74. https://doi.org/10.1016/j.aquaculture.2014.09.023

Michielsens, C. G. J., Lorenzen, K., Phillips, M. J., & Gauthier, R. (2002). Asian carp farming systems: Towards a typology and increased resource use efficiency. *Aquaculture Research*, *33*(6), 403–413. https://doi.org/10.1046/j.1365-2109.2002.00686.x

Mitra, S., Khan, M. A., Nielsen, R., & Rahman, M. T. (2022). Improving aquaculture productivity, efficiency and profitability in Bangladesh: Does land ownership matter? *Aquaculture Economics & Management*, *26*(2), 215–231. https://doi.org/10.1080/13657305.2021.1983069

Naylor, R., Fang, S., & Fanzo, J. (2023). A global view of aquaculture policy. *Food Policy*. *116*, 102422. https://doi.org/10.1016/j.foodpol.2023.102422

Noorhosseini-Niyaki, S. A., & Allahyari, M. S. (2012). Logistic regression analysis on factors affecting adoption of rice-fish farming in North Iran. *Rice Science*, *19*(2), 153–160. https://doi.org/10.1016/S1672-6308(12)60034-1

Opiyo, M. A., Marijani, E., Muendo, P., Odede, R., Leschen, W., & Charo-Karisa, H. (2018). A review of aquaculture production and health management practices of farmed fish in Kenya. *International Journal of Veterinary Science and Medicine*, *6*(2), 141–148. https://doi.org/10.1016/j.ijvsm.2018.07.001

Ortega, C., & Valladares, B. (2017). Analysis on the development and current situation of rainbow trout (*Oncorhynchus mykiss*) farming in Mexico. *Reviews in Aquaculture*, *9*(2), 194–202. https://doi.org/10.1111/raq.12133

Oyieng, E., Charo, H., Kahi, A., & Ojango, J. (2013). Characterization of fish production and marketing practices under small-holder fish farming systems of Eastern Kenya. *Livestock Research for Rural Development*, *25*(2), 32. http://www.lrrd.org/lrrd25/2/oyie25032.htm

Ozigbo, E., Anyadike, C., Adegbite, O. S., & Kolawole, P. (2014). Review of aquaculture production and management in Nigeria. *American Journal of Experimental Agriculture*, *4*(10), 1137–1151. https://doi.org/10.9734/ajea/2014/8082

Philis, G., Ziegler, F., Gansel, L. C., Jansen, M. D., Gracey, E. O., & Stene, A. (2019). Comparing life cycle assessment (LCA) of salmonid aquaculture production systems: Status and perspectives. *Sustainability*, *11*(9), 2517. https://doi.org/10.3390/su11092517

Rahman, M. T., Nielsen, R., & Khan, M. A. (2022). Pond aquaculture performance over time: A perspective of small-scale extensive pond farming in Bangladesh. *Aquaculture*

Economics & Management, *26*(2), 192–214. https://doi.org/10.1080/13657305.2021.1979122

Rosenthal, N. S., Sandoval, C. N., Gavidia, C. C., & Tabacchi, N. L. (2013). Frecuencia de lipidosis hepática en trucha arcoíris (*Oncorhynchus mykiss*) de fase juvenil en una piscigranja de la sierra central del Perú. *Revista de Investigaciones Veterinarias Del Perú*, *24*(1), 118–124. https://doi.org/10.15381/rivep.v24i1.1675

SENAMHI [Servicio Nacional de Meteorología e Hidrología del Perú]. (2012). Climate change scenarios for the Apurimac and Cusco regions: Precipitation and temperature 2030 and 2050. First edition. Publisher PACC. 155 pp (in Spanish). https://hdl.handle.net/20.500.12542/265.

Sheheli, S., Fatema, K., & Haque, S. (2014). Existing status and practices of fish farming in Trishal Upazila of Mymensingh District. *Progressive Agriculture*, *24*(1–2), 191–201. https://doi.org/10.3329/pa.v24i1-2.19172

Singh, A. K., Kamalam, B. S., & Kumar, P. (2016). Charting ways to invigorate rainbow trout production in India. *Journal of Fisheries Sciences*, *10*(2), 25–32. https://www.itmedicalteam.pl/articles/charting-ways-to-invigorate-rainbow-trout-production-in-india-105227.html.

Stevenson, R. J., Irz, T. X., Alcalde, R. G., Morrisens, P., & Petit, J. (2007). An empirical typology of brackish-water pond aquaculture systems in the Philippines: A tool to aid comparative study in the sector. *Aquaculture Economics & Management*, *11*(2), 171–193. https://doi.org/10.1080/13657300701370358

Yao, H. A., Koumi, R. A., Atsé, C. B., Kouamelan, P. E., & Kouamé, P. L. (2017). Côte d' Ivoire aquaculture systems perception: Characteristics and influence on national fish production. *International Journal of Fisheries and Aquaculture*, *9*(11), 108–118. https://doi.org/10.5897/IJFA2017.0640

Yildiz, M., Doğan, K., Şener, E., & Bayir, A. (2010). Structural, technological and productivity analyses of rainbow trout (*Oncorhynchus mykiss*) farms in the Marmara region, Turkey. *Journal of Applied Ichthyology*, *26*(1), 21–25. https://doi.org/10.1111/j.1439-0426.2009.01322.x

Zárate, M. I., Sánchez, P. C., Palomino, C. H., & Smith, D. C. (2018). Caracterización de la crianza de trucha arcoíris (*Oncorhynchus mykiss*) en la provincia de Chincheros, Apurímac, Perú. *Revista de Investigaciones Veterinarias del Perú*, *29*(4), 1310–1314. https://doi.org/10.15381/rivep.v29i4.15196

Zinngrebe, Y. M. (2016). Conservation narratives in Peru: envisioning biodiversity in sustainable development. *Ecology and Society*, *21*(2), 35. https://doi.org/10.5751/ES-08512-210235