Journal of the Selva Andina Animal Science
ISSN: 2311-3766
ISSN: 2311-2581
directoreditoranimalscience@gmail.com
Selva Andina Research Society
Bolivia

Quesquén-Fernández, Roberto Orlando; Gutiérrez-Romero, Gloria Albina; Haeeun, Jeon; Cabrera-Simon, Alison Estefh; Samaniego-Pipo, Lidia Silvana
Current status of aquaculture in the Peruvian rainforest: case of Ucayali
Journal of the Selva Andina Animal Science, vol. 9, no. 2, 2022, pp. 49-63
Selva Andina Research Society
Bolivia

DOI: https://doi.org/10.36610/j.jsaas.2022.090200049x

JOURNAL OF THE Selva Andina Animal Science
Official Journal of the Selva Andina Research Society.

Research Article

ISSN 2311-3766 (print edition)
JSAAS
ISSN 2311-2581 (online edition)

Current status of aquaculture in the Peruvian rainforest: case of Ucayali

Estado actual de la acuicultura de la Selva Peruana: caso Ucayali

Quesquén-Fernández Roberto Orlando[1], Gutiérrez-Romero Gloria Albina[1], Haeeun Jeon[2], Cabrera-Simon Alison Estefh[1,3], Samaniego-Pipo Lidia Silvana[1,4*]

Article Data

[1]National University of Callao.
Postgraduate School.
Faculty of Fisheries and Food Engineering.
Juan Pablo II 306, Bellavista 07011.
Callao, Peru.

[2]Pusan National University.
Centre for International Development Cooperation.
Korea Maritime Institute.
26, Haeyang-ro 301 beon-gil, Yeongdo-gu, Busan.
South Korea.

[3]Peruvian Ministry of Production.
Directorate of Aquaculture Promotion and Development.
General Directorate of Aquaculture.
Calle uno oeste 060 Urb. Corpac-San Isidro.
Lima, Peru.

[4] KOLAC.
Centro de Cooperación Oceánica y Pesquera de América Latina.
Juan Pablo II 306, Bellavista 07011, 2do piso.
Callao, Perú.

***Contact address:**
National University of Callao.
Faculty of Fisheries and Food Engineering.
School of Fisheries Engineering.
KOLAC, Latin America Ocean and Fisheries Cooperation Center.
Juan Pablo II 306, Bellavista 07011, 2do piso.
Perú.

Lidia Silvana Samaniego-Pipo
E-mail address: lssamaniegop@unac.edu.pe
Roberto Orlando Quesquén-Fernández
roquesquenf@unac.edu.pe

Keywords:

Amazonian aquaculture,
characterisation,
productivity,
aquaculturist.

J. Selva Andina Anim. Sci.
2022; 8(2):49-63.
Article ID: 117/JSAAS/2022

Article history

Recibido julio 2022.
Devuelto agosto 2022.
Aceptado septiembre 2022.
Disponible en línea, octubre 2022.

Edited by: Selva Andina Research Society

Abstract

The objective of this research was to determine the characteristics of the aquaculture activity in the department of Ucayali. A questionnaire was applied to 88 fish farmers in the districts of Callería, Campoverde, Padre Abad and Neshuya. The results show that 73 % of the Aquaculture Centres are AREL, although 78.4 % have a production level of less than 3.5 t. The ponds are earthen, with a predominance of ponds in the area. The ponds are earthen ponds, predominantly CA with 1-2 ponds (54.6 %). Only 22 % have their water tested once a month. The stocking density was 1 fish/m^2, using 423 kg/ha of lime, less than a quarter of what is recommended. In addition, due to the high cost of feed, they also use natural feed, increasing the average culture time by two months. The species they cultivate are gamitana and paco. It is concluded that aquaculture production in the department of Ucayali is atomised and has a low level of technification.

Resumen

El objetivo de esta investigación fue determinar las características de la actividad acuícola del departamento de Ucayali. Se aplicó un cuestionario a 88 acuicultores de los distritos de Callería, Campoverde, Padre Abad y Neshuya. Los resultados muestran que el 73 % de los Centros Acuícolas son AREL, aunque el 78.4 % tienen un nivel de producción menor a 3.5 t. Los estanques son de tierra, predominando CA con 1-2 estanques (54.6 %). Solo el 22 % realizan análisis del agua una vez al mes. La densidad de siembra fue 1 pez/m^2, usa 423 kg/ha de cal, menos de la cuarta parte de lo recomendado. Además, por al alto costo del alimento balanceado usan también alimento natural aumentando el tiempo de cultivo promedio en dos meses. Las especies que cultivan son gamitana y paco. Se concluye que en el departamento de Ucayali la producción acuícola está atomizada y tiene bajo nivel de tecnificación.

Palabras clave:

Acuicultura amazónica, caracterización, productividad, acuicultor.

Introduction

The Amazon is a global public good in constant transformation, mainly due to human action. It has great potential for aquaculture development, because it has abundant freshwater and edible fish[1]. In addition, aquaculture contributes to food security, as it is a source of protein and economic income[2-4], prevents overfishing of rivers and lakes (some wild species are close to extinction) and promotes sustainable development in the region[5,6].

The Peruvian rainforest is made up of five departments: San Martin, Amazonas, Madre de Dios, Loreto and Ucayali, its average GDP (Gross Domestic Product) of Ucayali, Amazonas, Loreto, Madre de Dios from 2007 to 2016 was 4.05 %, San Martin 5.6 %[7]. Aquaculture in Peru has grown by 13 % in the last decade, based on three species (trout, fan shells and prawns) which account for 95 % of total production[8]. In 2019, Peru's aquaculture harvest was 161279.12 t[9] The main actors in aquaculture in the Peruvian rainforest are communities and small farmers who entered into this activity as a result of State promotion with a welfare-based approach[10]. Both the development opportunities and their impact must be evaluated in their real magnitude, especially the limited resource aquaculture types (AREL)[11].

The Department of Ucayali is divided into 4 provinces and 17 districts[12]. Aquaculture is practiced in all provinces, mainly in Padre Abad and Coronel Portillo, which together have 95 % of AREL type Aquaculture Centres (CA) and micro and small enterprise aquaculture (AMYPE), which, according to the legal norm, the Regional Production Directorate of the Regional Government of Ucayali promotes their development, but not adequately because it has an insufficient number of extensionists to attend them (Daniel Velarde, 2020, personal communication, director of the Aquaculture Area) and therefore it is not known how they carry out their activities[13]. Padre Abad is known as a coca-producing area, linked to illicit drug trafficking, and represents an area of interest for the Peruvian state[14].

In 2014, the National Programme "A Comer Pescado" reported that in Loreto and Ucayali per capita consumption was 51.6 and 42.1 kg/year respectively, being the two regions with the highest fish consumption in the country[15]. Fishing in the Amazon basin is under pressure due to overfishing, which is showing signs of depletion and possible collapse of fish stocks[16], fish farming represents the greatest opportunity for food security and increase in fishermen's income[17,18]. The Amazon has the world's largest freshwater reserves and easily accessible land. Aquaculture is therefore a strategic choice to promote regional development[5].

The objective of this study was to characterize the infrastructure, farming system, social and economic conditions of fish farmers in the department of Ucayali, comprising the districts of Padre Abad, Neshuya, Campoverde and Calleria.

Materials and methods

In Ucayali there are 637 CA, 93.7 % are in the provinces of Padre Abad and Coronel Portillo. From these, the districts with the highest number of CA were selected, Table 1, representing 54.6 % of the CA in the department. The sample consisted of 88 CA.

The sample was drawn considering access to the CA, the conditions of the state of health emergency due to the COVID-19 pandemic, as well as the protective measures issued by the Ministry of Health. Prior to the application of the survey, 3 aquaculture extensionists in the area were coordinated to contact the aquaculture farmers to be surveyed in order to ensure their acceptance. A questionnaire constructed ad-hoc for the research was applied to obtain data on economic and social conditions (educational level, housing, access to health system, family, technical training, employment, investment and aquaculture production) as well as facilities (infrastructure, water resources) and culture system (species, feeding, culture control, period and harvesting).

Table1 Formal aquaculture centers in Ucayali by type of development: AREL and AMYPE[19]

Province	District	Registered aquaculture centers
Coronel Portillo	Callería	40
	Campoverde	141
Padre Abad	Padre Abad	56
	Neshuya	79
	Total	**316**

The surveys were cleaned by eliminating surveys that had complete or contradictory information, and a database was created in Excel.

The present work was carried out from July to December 2020. The field visit was carried out from 14 to 25 September 2020.

Results

In Ucayali, 73 % of the CA are AREL, 8 % have a production of 3.5 t, 42 % of the AMYPE category produce <3.5 t (Table 2).

Table 2 Distribution of aquaculture centers by category and range of production

Production level (t)	AREL (%)	AMYPE (%)
Up to 3.5	92	42
More than 3.5	8	58
Total	73	27

61.4 % of CA depend on water provided by rain, limiting control of supply, AMYPE 12.5 % with low production. Other water sources (spring, stream, stream, well) with low flow Table 3. Water from rivers and lagoons, due to their high contamination, is not used[20]. 22.7 % of the water is collected by pumping, 77.3 % is collected using the gravity of the rainwater that falls directly into the pond (no transfer system, 38.6 %) or because the water collection point (from well, stream, river and lagoon) is at a higher level than the ponds and is transferred mainly with PVC pipes of small diameter (54.6 %).

Table 3 Characterization of the water catchment used in aquaculture centers

Water source	Water source		Form of capture		Transfer mode		
	AMYPE (%)	AREL (%)	Pumping (%)	Gravity (%)	Canal (%)	Tubería (%)	Sin/T *(%)
Rain	12.5	48.9	6.8	54.6	3.4	21.6	36.4
Well	9.1	6.8	10.3%	6.8	1.2	14.8	
River	5.7	5.7	4.5	5.7	1.1	9.1	1.1
Water hole		4.5		4.5	1.1	2.3	1.1
Creek		5.7		5.7		5.7	
Lagoon		1.1	1.1			1.1	
Total	**27.3**	**72.7**	**22.7**	**77.3**	**6.8**	**54.6**	**38.6**

(*) Sin/T = No transfer

Table 4 Analysis of water quality in the aquaculture centers of Ucayali

Production range (t)	AREL (%)		AMYPE (%)		Total (%)	
	Yes	No	Yes	No	Yes	No
<2	22.8	30.7	2.3	1.1	25.1	31,8
2 – 3.5	4.6	9.1	5.7	2.3	10.3	11.4
3.5 - 10	1.1	4.5	6.8	3.4	7.9	7.9
10 - 20			1.1	4.5	1.1	4.5
Total	28.5	44.3	15.9	11.3	44.4	55.6

Water quality analysis of CA ponds producing <2 t in the AREL category is performed by 22.8 %, in the AMYPE category 2.3 % do analyse the water. Those producing 2-3.5 t among the ARELs and do not test the water are twice as many as those who do. Overall, 55.6 % of the CA do not test water, with the highest proportion (31.8 %) among those producing <2 t (Table 4).

Aquaculture production is atomised in small CA with a low level of production (Table 5). 54.6 % of the CA in Ucayali have between 1 and 2 culture ponds with a production level of less than 2 t per season. There are CA with 1 to 3 ponds producing between 3.5 to 10 t per season. Productions higher than 10 t are recorded in CA with 4 to 6 ponds. There is one case with more than 10 ponds and a production of 10 to 20 t.

Table 5 Used ponds (EU) and unused ponds (ENU) in the aquaculture centers of Ucayali

	Number of ponds in the Aquaculture Centers										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**>10**	**Total**
EU (%)	28.4	26.2	10.2	9.1	8.0	4.5	3.4	2.3	1.1	6.8	100
With 1 ENU (%)	4.5	11.4	2.3	1.1			1,1			2.3	22.7
With 2 ENU (%)			1.1	4.5	2.3						7.9
With 3 ENU (%)				1.1	2.3	1.1	1.1	1.1			6.8
With 4 ENU (%)				1.1	1.1			1.1		1.1	4.5
With 5 ENU (%)					1.1						1.1
With 6 ENU (%)						1.1	1.1			1.1	3.4

Regarding the number of ENUs, 22.7 % of the CA have one inoperative pond, half of them have a total of two ponds. Those with two inoperative ponds account for 7.9 %, half of them have 4 ponds in total (Table 5). 6.8 % of the CA have 3 inoperative ponds, 9.0 % have 4 to 6 inoperative ponds. Table 6 shows the reasons for non-use of the ponds, the main reasons are: lack of fry (47.5 %) and lack of financing (27.5 %).

Table 6 Causes for the non-use of ponds in aquaculture centers in Ucayali

Causes of non-use of ponds	Aquaculture centers (%)	
Lack of fry	19	47.5
Financing	11	27.5
Lack of water	4	10.0
Lack of maintenance	3	7.5
Other	3	7.5
Grand total	**40**	

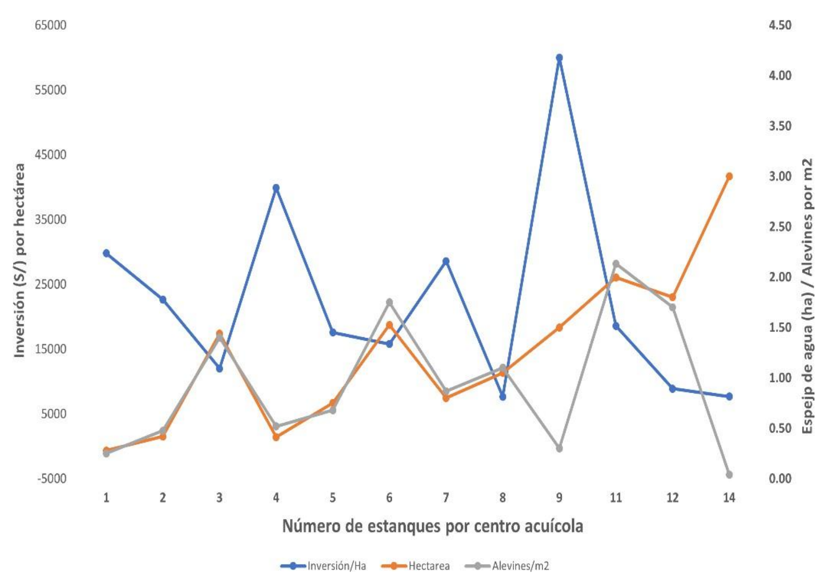
Those that produce <2 t have an average of 0.34 ha of water surface and an average investment of S/ 3382, and those that produce 2 to 3.5 t invest an average of S/ 12184, which are the extreme values (Table 7).

Regarding the investment/ha of the water mirror, <2 t of production invest S/10064.3/ha, in the range 2-3.5 t they invest S/13820.9/ha. In the 3.5-10 t range they only invest S/8602.4/ha, in the 10-20 t range they invest S/10365.5 per hectare, a value similar to those that produce <2 t. At the regional level, it has an average water mirror of 0.67 ha with an average investment of S/7131, while the investment per hectare of water mirror is S/10682.6 and the investment per fingerling planted is S/ 1.12.

Table 7 Average values regarding water mirror, investment and fry planted in the aquaculture centers of Ucayali according to production range and number of ponds

	Water mirror, ha		Investment (S/)		Fry			
Production range	Sum	Average	Sum	Average	Sum	Average	Investment S/ha	Investment/Fray
<2	16.8	0.34	169100	3382	164720	3294	10064.3	1.03
2 - 3,5	16.75	0.88	231500	12184	124500	6553	13820.9	1.86
3,5 - 10	19.39	1.39	166800	11914	163300	11664	8602.4	1.02
10 -20	5.8	1.16	60123	12024	107500	21500	10365.5	0.56
Grand total	58.74	0.67	627520	7131	560020	6364	10682.6	1.12

Figure 1 Average water surface (ha), fry planted and investment (S) of the aquaculture centers, categorized by the number of ponds constructed



The average value of fingerlings per water mirror (ha) grows with the number of ponds, from 3 thousand in CA with 1 pond to more than 20 thousand in those with 10 or more ponds. Figure 1 shows the correspondence of the water mirror with the number of ponds, it increases in the CA with 5 or more ponds. The data from the water mirror and fingerlings have a normal distribution (the Shapiro-Wilk test was applied). In the Pearson test, a high correlation (0.853) was recorded between the number of ponds with the investment and the hectares of the water mirror, including its linear regression with an R^2 of 0.728.

The use of lime varies from one species to another, in the crops with paco and paiche they use 2667 kg/ha. In the case of boquichico cultivation, they use only 71 kg of lime/ha (Table 8). 93 % of CA use lime. According to Table 9, the CA use an average of 422.7 kg of lime/ha. In the range of 10 to 20 t, they use 185.3 kg/ha of lime. The CA with the production range of 3.5 to 10 t use 545.2 kg cal/ha.

Table 8 Lime use (kg) per hectare of water mirror of aquaculture centers by species

Cultivated species	Cal/kg	Water mirror	kg cal/ha water mirror
Paco	8958	34.98	256
Gamitana	1420	8.42	169
Boquichico	20	0.28	71
Paiche	1507	4.5	335
Tilapia	5	0.05	111
Paco - Gamitana	4800	6.92	694
Paco - Paiche	8000	3	2667
Paco - Boquichico	120	0.6	200
Grand total	**24829.5**	**58.74**	**423**

Table 9 Use of lime (kg) and fertilizer/ha of water mirror of the aquaculture centers of Ucayali according to production range and species

Production range	Average values		kg cal/ha water Mirror	Fertilizer		kg Fert/ha water mirror
	Cal	Water Mirror		Organic	Inorganic	
< 2	102.65	0.34	305.5	105.2	27.2	242.6
2 – 3.5	423.68	0.88	480.6	103.1	28.3	133.7
3.5 - 10	755.14	1.39	545.2	150.0	185.8	150.6
10 a 20	215	1.16	185.3	24.8	200.0	40.9
Grand Total	**282.15**	**0.67**	**422.7**	**99.8**	**107.4**	

Table 10 Purchase of fingerlings by production ranges and by institution that sells them

Institutions that sell fingerlings	Production Range (%)				aquaculture centers %	Number of fingerlings
	< 2	2 – 3.5	3.5 - 10	10 a 20		
Private laboratory	14.8	14.8	5.7	3.4%	38.7	325000
IIAP	26.1	3.5	3.4		33.0	109300
Regional government	4.5				4.5	6000
IVITA		1.1		2.3	34	16000
Natural environment	2.3	1.1			3.4	4020
Private laboratory, IIAP	8.0	1.1	6.8		15.9	99500
Natural environment, IIAP	1.1				1.1	200
Total	**56.8**	**21.6**	**15.9**	**5.7**		**560020**

The average fertilizer used per hectare of water mirror in CA is 8588 kg, predominantly organic (43 %), especially those that produce <2 t. Those that produce 10 to 20 t use 257.8 kg/ha. Those that produce <2 t use an average of 7698.5 kg/ha. 36 % of CA do not use fertilizer.

Fingerlings buy it from IIAP because it sells it cheaper than private laboratories (LP), which are important producers of fingerlings (Table 10) that together supply 87.6 % of CA or 95.3 % of stocked fingerlings.

Table 11 Quantity of fry purchased by species and number of aquaculture centers by type of hatchery

Institutions selling fingerlings	Species cultivated in the aquaculture centers of Ucayali																Fingerling Subtotal
	Paco		Gamitana		Boquichico		Paiche		Tilapia		Paco-Gamitana		Paco-Paiche		Paco-Boquichico		
Laboratorio particular	22	170000	3	44000			2	23500			7	87500					325000
*IIAP	23	83000	1	5000					1	500	4	6500	1	12300	1	2000	109300
Gobierno Regional	4	6000															6000
**IVITA											1	16000					16000
Medio natural	1	2000	1	1020	1	1000											4020
Laboratorio particular, IIAP	13	94500											1	5000			99500
Medio natural, IIAP	1	200															200
Total	**64**	**355700**	**5**	**50020**	**1**	**1000**	**2**	**23500**	**1**	**500**	**12**	**110000**	**2**	**17300**	**1**	**2000**	**576020**

* IIAP: Peruvian Amazon Research Institute. ** IVITA: Veterinary Institute for Tropical and High Altitude Research.

Table 12 Type of feed by species, time in months to grow to commercial size, the value is in parentheses, and amount of feed supplied

Cultivated species	Type of feed and growing time			Amount of feed (t) used per cultivated species					
	Commercial	Natural	Commercial-natural	<1	1 - 2	3 - 4	4 - 5	5 - 6	> 7
Paco	52 (5.7)	1 (12.0)	11 (5.6)	24	10	13		5	12
Gamitana	4 (4.5)		1 (4.0)	3					2
Boquichico	1 (7.0)			1					
Paiche	2 (18.0)						1		1
Tilapia	1 (4.0)								
Paco - Gamitana	12 (7.3)			1	5	3			3
Paco – Paiche	2 (5.0)								2
Paco - Boquichico	1 (6.0)				1				
Grand total	**75**	**1**	**12**	**29**	**16**	**16**	**1**	**5**	**20**

Table 13 Water mirror by species cultivated in the aquaculture centers of Ucayali

Cultivated species	Water mirror (ha))			Total fingerlings	Thousands fingerlings/ha
	Total	%	Promedio		
Paco	35.0	59.5	.5	355700	10.20
Gamitana	8.4	14.3	1.7	50020	5.95
Boquichico	.3	.5	.3	1000	3.33
Paiche	4.5	7.7	2.3	23500	5.22
Tilapia	.0	.1	.0	500	
Paco Gamitana	6.9	11.8	.6	110000	15.94
Paco - Paiche	3.0	5.1	1.5	17300	5.77
Paco Boquichico	.6	1.0	.6	2000	3.33
Grand total	58.74		.67	**560020**	9.53

68.3 % of CA AREL buy fingerlings from LP and/or IIAP, the same as 100 % of those that produce 3.5-10 t. 100 % of those who produce 10-20 t buy from IVITA or LP. Fingerlings from the natural environ ment are of lower quality and contain other species, representing 0.7 % of the total sown. The Regional Government supplies those that produce <2 t. In Ucayali, 63.5 % cultivated paco, 9 % gamitana, and in combined sowings (paco - gamitana) 19.6 %, these two species represent 92 % of aquaculture production (Table 11).

In addition, in Ucayali, the prevention of fish diseases is not common. Only 20 % of the CA use some prevention method, being the most common method the treatment with salt, and more practiced among those who grow paco. The species they take care of the most is the paiche.

Table 12 shows the months of cultivation up to its commercial size, which depends on the type of food (the value in parentheses). The paco cultivated with commercial feed (balanced pellet feed) alone or combined with natural feed is 5.7 and 5.6 months old, respectively. When only natural food is given, the time is 12 months.

Table 13 shows the amount of water mirrors used in each cultivated species. Between paco and gamitana, 85.6 % of the total water mirror is dedicated to it, as well as 92 % of the fingerlings planted in this region, that is, they are planted with greater density compared to other species. It should be noted that when two species are cultivated in the same pond, the density increases by 50 % (15.9 thousand/ha), which makes it reasonable for their densities to be added.

Discussion

In Ucayali, 73 % of CA are of the AREL type, 27 % AMYPE, information similar to the cadastre PRODUCE[21]. It should be noted that 8 % of the ARELs have a production greater than that which corresponds to them (3.5 t), showing improvements in their production (Table 2).

The CA are dependent on the rains (61.4 %), this being their main water source, limiting the control of their supply and making them vulnerable to climate change[22]. They pointed out that over the years the rain cycle in the Amazon has presented alterations due to climate change causing droughts making them vulnerable for their development.

Likewise, the CA, AMYPE, with low production (representing 12.5 %) also depends on the rain. This form of aquaculture is far from the typical forms that exist[23,24]. These conditions limit its expansion to increase aquaculture production in Ucayali. The other supply options (water hole, stream, well) are characterized by the low flow. The water of rivers and lagoons, due to its high contamination, are not suitable according to the aquaculturists. Similarly, in 2014 in the Ucayali river samples were recorded with the presence of coliforms, suspended solids, and lead, being a non-optimal water source for the development of aquaculture activity as indicated in the Basic Manual of Fish Health[20,25].

77.3 % of CA collect water using gravity since the water falls directly into the pond due to rain or because the point of water intake from the well, stream, river, and lagoon is at a level above the ponds. There are cases in which they are supplied by rain, but these have a pond to store water and need to pump it and transfer it through pipes to the culture ponds, for this reason, they are transferred through plastic pipes, which makes filling or water replacement slow. of the pond. Another characteristic is that all the ponds are earthen, they lack the typical structures for this type of activity[26]. In times of intense rain, the water rises, allowing it to be replaced.

Pond water quality testing is a rare practice[27]. The CA that produce <2 t in the AREL category (30.7 %) do not perform any water analysis, in the AMYPE 66 % do analyze the water. Those that produce 2-3.5 t among the AREL do not analyze the water is twice as many as do. Overall, 55.6 % of CA do not test their water. Little practice is common in those that produce <2 t (31.8 %). The importance of water quality guarantees us an optimal production of fish in earthen ponds, for this reason, one of the important parameters is the obtaining of dissolved oxygen, which is recommended for the growth and survival of this species[28], however, they are not suitable for the conditions mentioned for the native species of the Peruvian Amazon, which can develop optimal growth with 5.8±0.7 mg L^{-1} of dissolved oxygen[29]. Similarly, there is a study mentioned by the IIAP indicating that paco can resist low concentrations of dissolved oxygen 1-3 mg L^{-1} without fish mortality[30].

Aquaculture production is atomized in small CA with low production levels (Table 5), likewise, the Piscicultura technical guide, it mentions that one of the factors to obtain good results in production depends on the size of the pond[31], however, the 10 % of the CA surveyed have an average water mirror of 600 m^2 for each pond. 54.6 % of the CA of Ucayali that have between 1 and 2 culture ponds have a production level of less than 2 t/campaign, and these have 1000 m^2 to 1750 m^2 respectively, a stocking density of 1.5 fingerlings/m^2 and 0.7 fingerlings/m^2, this would be one of the factors for the correct management of production since the recommended area in its ponds for this activity is 1000 to 5000 m^2 and the depth of 1.20 m in the supply and 1.50 m in the drainage point because at greater depth it makes it difficult harvesting and depth less than 70 cm allows overheating of the water with the risk of fish death[32].

In addition, aquaculture production will also depend on the number of inoperative ponds found in 22.7 % of the CA surveyed due to lack of fingerlings (45 %) and lack of financing (22.5 %) as main causes. These factors limit the growth of aquaculture activity in Ucayali in the short term.

According to PRODUCE[33], the water mirror varies between 0.0072 to 0.4396 ha with a total of 76.45 ha. Likewise, in the survey carried out, different values were found, having a total sum of 58.74 ha. The CA with the largest water mirror have 3.6 ha, a correlation was observed that the greater the production, the larger the water mirror, except at the level of 10 to 20 t since it has an average of 1.16 ha, which could be explained because the ponds They are smaller than the general average. According to DIREPRO[33], the average water mirror was 0.12 ha, while in CA they have an average of 0.67 ha.

There is a decreasing amount of purchase of fingerlings no greater than 3.5 thousand for 9 ponds presenting a low investment and this would give low productivity according to some authors. Thus, for species such as paco and gamitana[34] they use a density of 1 fish/m^2/[35] they sow 1.5 to 2.5 fingerlings/m^2 of water mirror[36] they cultured at 2.6 fish/m^2, and Deza et al.[37] cultivated paco at 0.5 to 1.5 fingerlings/m^2 indicating that the higher the density, the more profitable the crop. According to these reports, the average density value can be taken at 2 fish/m[2] or 20 thousand fingerlings/ha. But we report that the CA of Ucayali sows 9.5 thousand/ha, evidencing the low productivity in Ucayali. If 100 % of all existing ponds were used, aquaculture production would increase by 30 %. With proper techniques[38] production could easily be doubled. If all the ponds were used and with adequate techniques, the production would be multiplied by 3.5 times the current production.

The data from the water mirror and fingerlings have a normal distribution (the Shapiro-Wilk test was applied). In the Pearson test, a high correlation (0.853) was observed between the number of ponds with the investment and the hectares of the water mirror (Figure 1), its linear regression is included with an R^2 of 0.7281. These results show that not all the ponds have the same dimension and that the greater number of ponds increases the water mirror in greater propor tion because they are larger ponds. There is a moderate correlation (0.666) between the hectares of water mirror and the number of fingerlings stocked, which shows that there is no single criterion to establish stocking density in culture ponds, which is not based on technical criteria.

The "water mirror - investment" correlation was 0.504, showing little criteria to invest, especially when there is no technical management to establish the density of cultivation. The correlation (Spearman's Rho) "investment - stocked fingerlings" was 0.442, a low value that justifies the diversity in the productivity of the CA. The correlation "number of ponds - fingerlings stocked" was 0.624, this low value is due to the fact that CA with more than 8 pounds have low crop loads, demonstrating limited technical knowledge. The correlation "investment - number of ponds" was 0.782 (with Spearman's Rho), a relatively high value, showing that investments in relation to available ponds are managed with better criteria in CA. The use of lime for ponds is a common practice in Amazonian aquaculture because the soil has a low pH and eliminates contaminating microorganisms[39]. The use of lime by cultivated species is different. The CA that grow paco and paiche use the quantity recommended by the authors (2667 kg/ha). In the case of the boquichico crop, since it is a species of lower value, almost no lime is used, only 71 kg/ha) (Table 8). 93 % of the AC surveyed in Ucayali use lime, however, the amount used is not recommended, so in the production range of 3.5 to 10 t, they are the ones that use the most lime per hectare (545.2 kg) when expected, according to Boyd[40] it was 3000 at 5000 kg/ha of hydrated lime, although Deza et al.[37] recommend 1500 kg/ha. That is to say, the practice of using lime is not very effective since they only use it in Ucayali from 185.3 to 545.2 kg/ha.

Primary production is a complementary food for farmed fish and contributes to the supply of dissolved oxygen, so it is common to add fertilizer to promote photosynthetic flowering[41]. 58 % of the CA use fertilizer, 43 % use the organic type (43 %), especially those that produce <2 t, use an average of 8588 kg/ha of water mirror. Those that produce <2 t use an average of 7698.5 kg/ha, this is 5 times what is recommended by Deza et al.[37], 1500 kg/ha. The CA that produce 3.5-10 t use a quantity of 1398.2 kg/ha of water mirror, a value close to what is recommended.

Regarding the purchase of fingerlings, the CA buy mainly from the IIAP because it is cheaper than the LPs, which are important producers of fingerlings (Table 10), as a whole they supply 87.6 % of the CA or 95.3 % of stocked fingerlings, however, this does not satisfy the demand of the aquaculturists, because it is one of the causes of inoperability of the ponds (45 %). Fingerlings from the natural environment are of lower quality and contain other species, which is why they represent 0.7 % of the total sown. The Regional Government supplies those that produce <2 t.

In Ucayali, paco and gamitana farming represents 92 % of aquaculture production (Table 11). It should be noted that in 2019, 55.8 % paco-gamitana and 44.1 % paiche were produced. In 2020, due to the pandemic, the production of paiche fell, highlighting paco and gamitana. In Ucayali, paco[38] is traditionally grown.

In Ucayali it is not common to take measures to prevent diseases in fish, since they are considered resistant[38]. Only 20 % of the CA use some prevention method, the most common is salt treatment and it is more practiced among those who grow paco. The species that cares the most about its health is the paiche because of its higher commercial value.

The most used type of food is balanced food. There are cases in which natural food consisting of vegetables and fruits from the area is used for several months of fattening, which are well accepted[38]. Therefore, in Table 12 are the months of cultivation up to its commercial size, which depends on the type of food (the value in parentheses). The paco cultivated with commercial feed (balanced pellet feed) alone or combined with natural feed is 5.7 and 5.6 months old, respectively. When they only give natural food, the time is 12 months. Small producers are the ones that use more natural food, but their cultivation periods are longer. In the case of paiche, they use more balanced feed because they have a higher commercial value.

Table 13 the amount of water mirror used in each cultivated species. Between paco and gamitana, 85.6 % of the total water mirror is dedicated to it, as well as 92 % of the fingerlings planted in this region, that is, they are planted with greater density compared to other species. It should be noted that when two species are cultivated in the same pond, the density increases by 50 % (15.9 thousand/ha), which makes it reasonable for their densities to be added.

In conclusion, the main source of water is rain for 67 % of the ARELs and 46 % of the AMYPEs, aquaculture production is fragmented due to the low capacity of the CA, 1 out of 4 do not using at least one pond due to the lack of fingerlings (45 %) and financing (22.5 %), 93 % apply lime in their ponds, although in very low quantities (185.3 to 545.2 kg/ha), questioning its effectiveness. In the paiche and paco crops, they use adequate amounts of lime, the most cultivated species are paco and gamitana (92.04 %) due to COVID-19 that limited the cultivation of paiche, the main producers of fingerlings are the IIAP and the LP (71.6 %), combine balanced feed with natural feed to lower production costs.

Source of financing

This study was funded by the Korea Maritime Institute through an agreement between the National University of Callao (UNAC) and the Korea Maritime Institute (KMI).

Conflicts of interest

The manuscript was prepared and reviewed with the participation of the authors, who declare that there is no conflict of interest that could jeopardize the validity of the results presented.

Acknowledgments

We are very grateful for the financial support provided by the Korea Maritime Institute (KMI) for the realization of this project. For this we express our gratitude to the President of KMI, Dr. Youngtae Chan, the Director General of KMI, Dr. Jung Hee Cho. We also thank the Korea Maritime Institute for the trust placed in the team of researchers from the Faculty of Fisheries and Food Engineering of the Universidad Nacional del Callao to carry out this research. Furthermore, we thank Dr. Daniel Abelardo Velarde Ríos, Director of the Aquaculture Area in the Ucayali region. Thank you very much to all of them.

Ethical considerations

A validated instrument built ad hoc for the research was applied to obtain data on the installation of production centers, volumes per harvest, investment, feed, weight, among others.

Authors' contribution to the article

Roberto O. Quesquén Fernández, conceptualization, writing: revision and editing, formal analysis, writing-preparation of the original draft, supervision, project management. *Gloria A. Gutiérrez Romero*, research, writing. *Jeon Haeeun*, review and editing, fund acquisition, supervision. *Alison E. Cabrera Simon*, writing: review, preparation of original draft and formal analysis. *Lidia S. Samaniego Pipo*, methodology, formal analysis, research, writing -preparation of the original draft, writing: review and editing.

Research limitations

There were no limitations in the research.

Literature cited

1. Loreto. Sumario regional. Abril de Elaborado por la Dirección de Estudios Económicos de Mype e Industria (DEMI) [Internet]. Library. 2016 [citado 5 de marzo de 2021]. Recuperado a partir de: https://1library.co/document/y94rlwjq-loreto-sumario-regional-elaborado-direcci%C3%B3n-estudios-econ%C3%B3micos-industria.html
2. Organización de las Naciones Unidas para la Alimentación y la Agricultura, editor. Estado mundial de la pesca y la acuicultura. Contribución a la seguridad alimentaria y la nutrición para todos [Internet]. Roma: Organización de las Naciones Unidas para la Alimentación y la Agricultura; 2016 [citado 22 de octubre de 2020]. 226 p. Recuperado a partir de: https://www.fao.org/3/i5555s/i5555s.pdf
3. Pradeepkiran JA. Aquaculture role in global food security with nutritional value: a review. Transl Anim Sci 2019;3(2):903-10. DOI: https://doi.org/10.1093/tas/txz012
4. Ahmed N, Thompson S, Glaser M. Global aquaculture productivity, environmental sustainability, and climate change adaptability. Environ Manage 2019;63(2):159-72. DOI: https://doi.org/10.1007/s00267-018-1117-3
5. Berger C. La acuicultura y sus oportunidades para lograr el desarrollo sostenible en el Perú. South Sustain 2020;1(1):e003. DOI: https://doi.org/10.21142/SS-0101-2020-003
6. Heilpern SA, Fiorella K, Cañas C, Flecker AS, Moya L, Naeem S, et al. Substitution of inland fisheries with aquaculture and chicken undermines human nutrition in the Peruvian Amazon. Nat Food 2021;2:192-7. DOI: https://doi.org/10.1038/s43016-021-00242-8
7. Banco Central de Reserva. Informe Económico. [Internet]. Lima: Banco Central de Reserva; 2018 [citado 10 de octubre de 2020]. 273 p. Recuperado a partir de: https://www.bcrp.gob.pe/docs/Publicaciones/Memoria/2018/memoria-bcrp-2018.pdf
8. Saldarriaga M, Regalado F. Potencial Acuícola en el Perú. [Internet]. Lima: Banco Central de Reserva; 2017 [citado 2 de octubre de 2020]. 6 p. Recuperado a partir de: https://www.bcrp.gob.pe/docs/Publicaciones/Revista-Moneda/moneda-172/moneda-172-07.pdf
9. Anuario Estadístico Pesquero y Acuícola 2019 [Internet]. Ministerio de la Producción. 2019 [citado 5 de marzo de 2021]. Recuperado a partir de: https://ogeiee.produce.gob.pe/index.php/en/shortcode/oee-documentos-publicaciones/publicaciones-anuales/item/949-anuario-estadistico-pesquero-y-acuicola-2019
10. Organización de las Naciones Unidas para el Desarrollo Industrial. La Cadena de Valor Acuícola Amazónica en Perú. Un diagnóstico de cadena de valor. [Internet]. Lima: Organización de las Naciones Unidas para el Desarrollo Industrial; 2017 [citado 10 de octubre de 2020]. Recuperado

a partir de: https://www.unido.org/sites/default/files/files/2018-07/PCP%20Per%C3%BA_Diagnostico_Cadena%20de%20Valor%20Acu%C3%ADcola_Informe%20Final.pdf

11. Ley general de la acuicultura y su reglamento. Decreto Supremo Nº 003-2016-Produce [internet]. Lima: Presidente de la Republica; 2016. [citado 12 de octubre de 2020]. Recuperado a partir de: http://portal.apci.gob.pe/noticias/Atach/Normas-Legales/Marzo2016/NL20160325.pdf
12. Banco Central de Reserva. Caracterización del Departamento de Ucayali [Internet]. Ucayali: Banco Central de Reserva; 2022 [citado 12 de marzo del 2022]. 9 p. Recuperado a partir de: https://www.bcrp.gob.pe/docs/Sucursales/Iquitos/ucayali-caracterizacion.pdf
13. Anuario Estadístico Pesquero y Acuícola 2018 [Internet]. Ministerio de la Producción. 2018 [citado 5 de marzo de 2021]. Recuperado a partir de: https://ogeiee.produce.gob.pe/index.php/en/shortcode/oee-documentos-publicaciones/publicaciones-anuales/item/901-anuario-estadistico-pesquero-y-acuicola-2018
14. Oficina de las Naciones Unidas contra la Droga y el Delito. Monitoreo de Cultivos de Coca 2017 [Internet]. Lima: Oficina de las Naciones Unidas Contra la Droga y el Delito; 2018. [citado 20 de octubre del 2020]. 114 p. Recuperado a partir de: https://www.unodc.org/documents/crop-monitoring/Peru/Peru_Monitoreo_de_Cultivos_de_Coca_2017_web.pdf
15. Encuesta Nacional de Demografía y Salud. Reporte informativo Ucayali [Internet]. Ucayali: Ministerio de la Producción; 2014 [citado 22 de octubre de 2021]. 4 p. Recuperado a partir de: https://www.acomerpescado.gob.pe/wp-content/uploads/2015/08/PNACP_Report-Inform-UCAYALI.pdf
16. Heilpern SA, Sethi SA, Barthem RB, da Silva Batista V, Doria CRC, Duponchelle F, et al. Biodiversity underpins fisheries resilience to exploitation in the Amazon river basin. Proc R Soc B 2022;289:20220726. DOI: https://doi.org/10.1098/rspb.2022.0726
17. Organización de las Naciones Unidas para la Alimentación y la Agricultura. El estado mundial de la agricultura y la alimentación 2020. Superar los desafíos relacionados con el agua en la agricultura [Internet]. Roma: FAO; 2020. 236 p. DOI: https://doi.org/10.1787/9789264258211-en
18. Garcia A, Tello S, Vargas G, Duponchelle F. Patterns of commercial fish landings in the Loreto region (Peruvian Amazon) between 1984 and 2006. Fish Physiol Biochem 2009;35(1):53-67. DOI: https://doi.org/10.1007/s10695-008-9212-7
19. Catastro Acuícola de Produce [Internet]. Catastro Acuícola Nacional; 1984 [citado 10 de octubre de 2020]. Recuperado a partir de: http://catastroacuicola.produce.gob.pe/web/
20. Ministerio de la Producción. Diagnóstico del sector pesquero y acuícola, frente al cambio climático y lineamientos de adaptación [Internet]. Lima: Ministerio de la Producción; 2016 [citado 2 de octubre de 2020]. 34 p. Recuperado a partir de: https://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf
21. Delgado Narváez M. El Catastro Acuícola como Herramienta de Gestión [Internet]. Lima: Ministerio de la Producción; 2011 [citado 20 de octubre del 2020]. 23 p. Recuperado a partir https://rnia.produce.gob.pe/wp-content/uploads/ 2019/11/204_catastro_acuicola_herrramienta_de _gestion.pdf
22. Rodríguez Quirós R, Morris Grainger H, Morales Hidalgo D. Estudio de variabilidad técnica y económica para el desarrollo de opciones de cosecha de lluvia y manejo adecuado en sistemas de riego

en la producción agropecuaria [Internet]. Choroteca: Ministerio de Agricultura y Ganadería; 2010 [citado 12 de octubre de 2020]. Reporte No: SP-16-2009. DOI: https://doi.org/10.13140/RG.2.1.1978.8004

23. Kohler CC, Kohler ST, Camargo Navarro W, Southern Illinois University Carbondale, Campos Basa L, Alcántara Bocanegra F, et al. Cartilla de Acuacultura en la Amazonía [Internet]. Iquitos: Pond Dynamics/Aquaculture Collaborative Research Support Program; 2007 [citado 22 de octubre de 2021]. 30 p. Recuperado a partir de: http://crsps.net/wp-content/downloads/AquaFish/Inventoried%204.16/8-2007-7-600.pdf
24. Organización de las Naciones Unidas para la Alimentación y la Agricultura, editor. Captación y almacenamiento de agua de lluvia. Opciones técnicas para la agricultura familiar en América Latina y el Caribe. [Internet]. Roma: Organización de las Naciones Unidas para la Alimentación y la Agricultura; 2013 [citado 22 de octubre de 2020]. 272 p. Recuperado a partir de: https://www.fao.org/3/i3247s/i3247s.pdf
25. Balbuena Rivarola ED. Manual Básico de Sanidad Piscícola [Internet]. Asunción: Organización de las Naciones Unidas para la Alimentación y la Agricultura; 2011 [citado 22-de octubre de 2016]. 52 p. Recuperado a partir de: https://www.fao.org/3/as830s/as830s.pdf
26. Akifumi Ono E, Campos J, Kubitza F. Construcción de estanques y de estructuras hidráulicas para el cultivo de peces - Parte 3. Panorama da Aqüicultura 2002;12(74):1-19.
27. Balbuena Rivarola ED, Rios Morinigo VM, Flores Nava A, Meza J, Galeano A. Manual Básico de Sanidad Piscicola [Internet]. Asuncion: Ministerio de Agricultura y Ganadería; 2011 [citado 12 de octubre de 2021]. 52 p. Recuperado a partir de: https://www.fao.org/3/as830s/as830s.pdf
28. Organización de las Naciones Unidas para la Agricultura y la Alimentación. El estado mundial de la agricultura y de la alimentación [Internet]. Roma: Organización de las Naciones Unidas para la Agricultura y la Alimentación; 1982 [citado 20 de octubre de 2020]. 204 p. Recuperado a partir de: https://www.fao.org/3/ap661s/ap661s.pdf
29. Tafur Gonzales J, Alcántara Bocanegra F, Del Águila Pizarro M, Cubas Guerra R, Mori-Pinedo L, Chu-Koo F. Paco *Piaractus Brachypomus* y Gamitana *Colossoma macropomum* criados en policultivo con el Bujurqui-Tucunaré, *Chaetobranchus Semifasciatus* (Cichlidae). Folia Amazon 2009;18(1-2):97-104.
30. Miyakawa Solís V, Álvarez Alonso J, Encarnación Cajañahupa F, Gasché J, Montreuil Frías V, Otarola Acevedo E. Análisis sobre la realidad amazónica de temas importantes para la diversidad biológica amazónica [Internet]. Iquitos: Instituto de Investigaciones de la Amazonía Peruana; 2002 [citado 16 de octubre de 2020]. Documento Técnico No: 07. Recuperado a partir de: http://www.iiap.org.pe/upload/publicacion/dt007.pdf
31. Instituto de Investigaciones de la Amazonía Peruana. Memoria Institucional – 2012 [Internet]. Iquitos: Instituto de Investigaciones de la Amazonía Peruana; 2012 [citado 16 de octubre de 2020]. 161 p. Recuperado a partir de: http://www.iiap.gob.pe/Archivos/Publicaciones/Publicacion_1475.pdf
32. Piscicultura Amazonica con Especies Nativas [Internet]. Loreto: Instituto de Investigaciones de la Amazonía Peruana; 1999 [citado 10 de octubre de 2022]. Recuperado a https://www4.congreso.gob.pe/comisiones/1999/ciencia/cd/iiap/iiap1/texto.htm
33. Eufracio Villon PS, Palomino Ramos AR. Manual de Cultivo de Gamitana [Internet]. Lima: Fondo Nacional de Desarrollo Pesquero; 2008 [citado 20

de octubre del 2020].106 p. Recuperado a partir de: http://www2.produce.gob.pe/RepositorioAPS/3/jer/ACUISUBMENU4/manual_gamitana.pdf

34. Rebaza C, Valdivieso M, Rebaza M, Chu-Koo F. (2008). Análisis económico del cultivo de gamitana *Colossoma macropomum* y Paco *Piaractus brachypomus* usando una dieta extrusada comercial en Ucayali. Folia Amazón 2008;17(1-2):7-13. DOI: https://10.24841/fa.v17i1-2.261
35. Guerra RP, Alcántara BF. Alimentación de peces tropicales con productos, subproductos y residuos de las actividades agropecuarias y agroindustriales en Loja [tesis licenciatura]. [Huancayo]: Universidad Nacional del Centro del Perú; 1992. 342 p.
36. Lovishing L, Da Silva A, Fernández J, Sobrino A. Cultivo de *Piaractus brachypomus* y *Colossoma macropomum*. Brasil; 1974. p. 24.
37. Deza S, Quiroz S, Rebaza M, Rebaza C. Efecto de la densidad de siembra en el crecimiento de *Piaractus brachypomus* (Curvier 1818) "paco" en estanques seminaturales de Pucallpa. Folia Amazón 2002;13(1-2):49-64. DOI: https://doi.org/10.24841/fa.v13i1-2.137
38. Organización de las Naciones Unidas para el Desarrollo Industrial, editor. La cadena de valor acuícola amazónica en Perú. Un diagnóstico de cadena de valor [Internet]. Lima: Organización de las Naciones Unidas para el Desarrollo Industrial; 2017 [citado 2 de octubre de 2020]. 82 p. Recuperado a partir de: https://www.unido.org/sites/default/files/files/2018-07/PCP%20Per%C3%BA_Diagnostico_Cadena%20de%20Valor%20Acu%C3%ADcola_Informe%20Final.pdf
39. Organización de las Naciones Unidas para la Alimentación y la Agricultura, editor. Tratamiento de los estanques por encalado [Internet]. Asunción: Organización de las Naciones Unidas para la Alimentación y la Agricultura; 1996 [citado 10 de octubre de 2020]. Recuperado a partir de: http://www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6709s/x6709s05.htm#top
40. Boyd CE. La cal desempeña un papel crucial en el manejo de estanques acuícolas [Internet]. Global Seafood Alliance. 2017 [citado 20 de diciembre de 2020]. Recuperado a partir de: https://www.globalseafood.org/advocate/la-cal-desempena-un-papel-crucial-en-el-manejo-de-estanques-acuicolas/
41. Meyer ED. Introducción a la Acuicultura [Internet]. Zamorano: Escuela Agrícola Panamericana; 2004 [citado 2 de octubre de 2022]. 144 p. Recuperado a partir de: https://bdigital.zamorano.edu/server/api/core/bitstreams/7fce00bc-0466-4957-98bb-f2fdcfd01ddd/content