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ECONOMIC-FISHING ANALYSIS OF THE PRAWN *Cryphiops caementarius* (MOLINA, 1782) IN THE MAJES-CAMANÁ RIVER AREQUIPA-PERÚ (2019)*

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ABSTRACT

The prawn (*Cryphiops caementarius*) is the only resource in the Peruvian coastal rivers that supports a commercial fishery. Bioeconomic-fishing aspects are reported based on data (fishing, costs and income derived from fishing) acquired in situ monthly in four altitudinal strata (every 200 meters above sea level - masl) of the Majes-Camaná river during 2019. The catch per unit of effort (CPUE) was expressed in kg h^{-1}, monthly income was estimated based on the average catch values, number of tasks and price of the resource. To evaluate the profitability of the activity of an average fisherman (by stratum), a cash flow based on income and expenses was executed under situations with a constant future, using economic profitability indicators such as the Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost ratio (B/C) and Discounted Payback Period (DPB). There was a predominance of the diving method, the catches (kg) and the fishing yield increased throughout the fishing period (April-December) with a maximum value of 4.8 kg h^{-1} (December - high strata). Investment costs per fisherman were low, roughly 1,000 soles. The sale price increases with altitude, decreasing over the course of the year depending on the availability of the resource; the monthly income per fisherman varied from 964 soles (April - low stratum) to 6,760 soles (December - high stratum). The economic simulation model showed that the income exceeded the costs of the fishing activity from the first year of activity in all the altitudinal strata, the economic profitability indicators showed high profitability for the activity.

Keywords: artisanal fishery; freshwater fishery; spatio-temporal; Palaemonidae.

ANÁLISE ECONÔMICO-PESQUEIRA DO CAMARÃO *Cryphiops caementarius* (MOLINA, 1782) NO RIO MAJES-CAMANÁ AREQUIPA-PERÚ (2019).

RESUMO

O camarão (*Cryphiops caementarius*) é o único recurso hidrobiológico dos rios da costa sul do Peru que sustenta uma importante pesca comercial. Os aspectos econômico-pesqueiros foram reportados a partir de dados (pesca, custos e receitas provenientes da pesca) adquiridos mensalmente *in situ* em quatro estratos altitudinais (a cada 200 m acima do nível do mar - mamsl) do rio Majes-Camaná - Arequipa durante 2019. A captura por unidade de esforço (CPUE) foi expressa em kg h^{-1}; a renda mensal foi estimada a partir dos valores médios de captura, número de operações e preço do recurso. Para avaliar a rentabilidade da atividade de um pescador médio (por estrato), foi executado um fluxo de caixa com base nas receitas e despesas em cenários futuros constantes, utilizando indicadores de rentabilidade econômica, como o valor presente líquido (VPL), taxa interna de retorno (TIR), relação custo-benefício (B/C) e período de reembolso descontado (PCR). Foi registado o predomínio do método de mergulho; as capturas (kg) e o rendimento pesqueiro aumentaram ao longo do período de pesca (abril-dezembro) com um valor máximo de 4,8 kg h^{-1} (dezembro - estratos altos). Os custos de investimento por pescador foram baixos, aproximadamente 1.000 Novos sóis. O preço de venda aumentou com a altitude, reduzindo ao longo do ano dependendo da disponibilidade do recurso; a renda mensal por pescador variou de 964 Novos sóis (abril - estrato baixo) a 6.760 Novos sóis (dezembro - estrato alto). O modelo de simulação econômica mostrou que a receita superou os custos da atividade pesqueira desde o primeiro ano de atividade em todos os estratos altitudinais; os indicadores de rentabilidade econômica mostraram alta rentabilidade para a atividade.

Palavras-chave: pesca artesanal; pesca de água doce; espaço-temporal, Palaemonidae.

INTRODUCTION

The "river prawn" *Cryphiops caementarius* (Molina, 1782) (Decapoda, Palaemonidae), is an endemic crustacean of the fluvial water bodies of the western slope of Peru and Chile, with a latitudinal distribution from 06° to 33°S (Bahamonde and Vila, 1971) and there are reports of a distribution from sea level to 2500 masl (Amaya and Guerra, 1976).

In Peru, it constitutes a species of great biological, economic, social, and cultural importance; considered the only hydrobiological resource of the rivers of the south coast that supports an important commercial fishery, exhibiting greater abundance and production in the Majes-Camaná river (Yepez, 2009; Wasiw and Yepez, 2016).

In order to ensure the sustainability of the resource, regulatory measures have been established for the fishery: fishing permissions and methods, Minimum Capture Size (MCS = 7 cm), areas (first 5 km from the river mouth) and periods of fishing restriction (breeding season, between December 21 and March 31) (Peru, 2001, 2007, 2018).

However, currently there is an intense extraction that violates regulatory measures, mainly due to the high commercial demand for the resource and the free access to the river ecosystem, which, being open and large, hinders the control actions and the information fishing collection (Yepez, 2009).

To this pressure are added habitat alterations due to processes related to the use of water (construction of hydraulic structures) and the perennial contribution of pollutants of domestic, agricultural, and mining origin. These factors have caused a decrease in the size of the populations of this crustacean, in contrast to the greater abundance and captures generated in past decades; exhibiting low or no availability in some rivers and smaller basins of the western slope (Yepez, 2009; Wasiw and Yepez, 2016).

The lower availability of the resource affects the behavior of the fisherman, causing him to make decisions in the short term about what, how, how much, when, and where to fish, since each fisherman works to improve their individual economic situation, so it is important to know the economic status of fishermen and their behavior in the face of dynamic changes in the fishery (Rueda and Defeo, 2003).

In this sense, the present study aimed to analyze the variation in space (altitudinal) and time (monthly) of the catches and the effort applied throughout a year of free fishing in the river with the highest extraction in Peru; in turn, characterize the profitability of the fishing activity from a cash flow of costs and income received by fishermen. This contributes to a better understanding of the current state of the river prawn fishery as a basis for future scenarios, in addition to providing information for the development of fishing management plans of the resource.

MATERIAL AND METHODS

The scope of study is located in the lower-middle basin of the Majes-Camaná river in Arequipa - Peru. Four altitudinal strata were selected with an amplitude of 200 meters above sea level from the mouth of the river (at sea level) (Figure 1). Within each stratum, a sampling station and another reference station were established based on the area of jurisdiction of the prawn fishermen associations present (registered in the regional direction of production-Arequipa). The periodicity of data collection was monthly (second weekend) throughout the free fishing period (April to December) of 2019 (Peru, 2018).

In each station, information was collected *in situ* of the fishing operations carried out by the fishermen of each association. Fishing data referring to the fishing zone, method of capture, time of the fishing task and the weight of the extracted resource were considered. In turn, through surveys of the fishermen themselves, information was recorded regarding the fishing regime (number of monthly tasks), the sale prices of the resource, and operational expenses incurred in the fishery.

The CPUE (catch per unit of effort), expressed by the ratio of catch (kg)/effort (h), was multiplied by the average price (P, soles kg^{-1}; 1 US$ = 3.5 soles S/.) of the resource extracted according to the size of the individuals (large, medium and/or small), to obtain economic productivity per hour of fishing (PHF, soles h^{-1}). The number of average monthly fishing operations (O) was estimated from the multiplication of the number of daily operations by the fishing days per week extrapolated to the number of days of the month.

Monthly income per fisher (MIf) resulted from: MIf = Cf x O x P, where: Cf = average monthly catch per fisher (kg/month); O = number of monthly fishing operations; and P = average sale price (soles kg^{-1}). The total annual income (IT) results from the sum of the monthly incomes.

Direct costs (DC) were established from the sum of the initial investment costs (Io) and operating costs (OC) that result from the product of the costs incurred in each fishing operation by the number of average monthly operations (O). Indirect costs (IC) were the costs incurred in maintaining the assets, multiplied by their annual frequency. The total annual cost (TC) results from the annual sum of the DC and IC.

To demonstrate the statistical difference between the values of catch (kg), effort (h), costs (soles), price (soles kg^{-1}) and income (soles/month) by altitude stratum and month, the "stats" package of the R software was used. The assumptions of normality were validated with the Shapiro-Wilk test (shapiro.test function); subsequently, the Kruskal-Wallis test (kruskal.test function) was realized. Results were considered statistically significant at the 95% confidence level (p <0.05).

The financial economic evaluation was carried out by means of annual cash flows (EF), considering an average prawn fisherman as a project in each altitudinal stratum with a horizon of 5 years of constant future (without changes in the prices of the product, of the inputs, the magnitudes of catches and fishing effort and so on) and with own capital. According to: FE = IT-CT (Sapag Chain, 2011).

The opportunity cost of capital (Kp) is the percentage that is left to earn (resignation) by not investing in the next best alternative (Seijo et al., 1998) and was of 9.07% estimated through the minimum acceptable rate of return (MARR) for the artisanal fishery in Peru, according to Berrú (2016). The opportunity

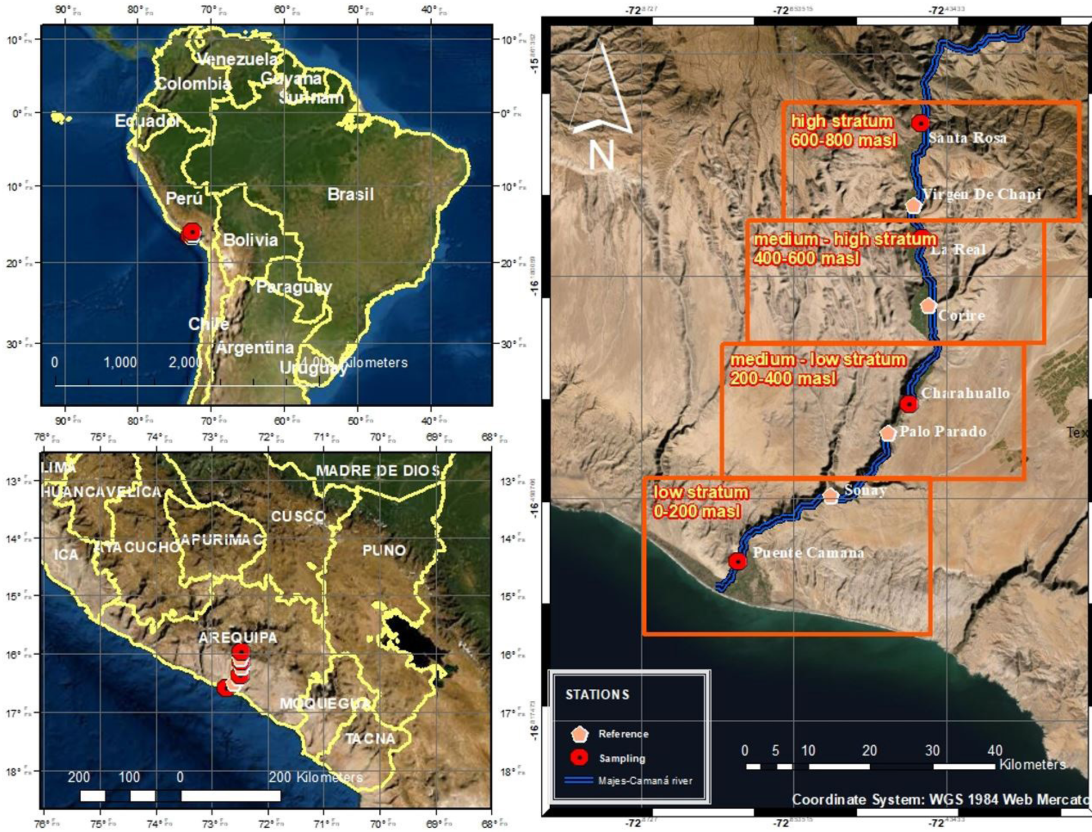

Figure 1. Sampling stations by altitude stratum on the area of jurisdiction of the prawn fishermen associations in Majes–Camaná river (masl = meters above sea level).

cost was used as a discount rate (d) or update in the profitability analysis using economic indicators such as the Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost ratio (B/C) and Discounted Payback Period (DPB), following the methodology described by Sapag Chain (2011).

RESULTS

Catch and fishing effort

During the free fishing period (April to December) 203 fishing operations were recorded, with an average of 23 operations per month (they were not always the same fishermen), there was a greater use of the "diving with artificial light" method, an effective manual collection method for conditions of good visibility. The catch ranged from 0.7 (April) to 9.3 (December) kg/operation for the upper stratum. On the other hand, the effort trend, expressed in effective hours of fishing, remained in the range of 1.5 to 2.1 h (Figure 2).

Due to data did not meet the normality assumptions, the Kruskal-Wallis test demonstrated that there are statistically significant differences ($p < 0.05$) in the average weight values grouped by month, but not by altitude stratum ($p = 0.94$).

The comparison of effort grouped by month and stratum did not show statistically significant differences ($p = 0.61$ and $p = 0.26$ respectively).

CPUE and PEH

The CPUE showed a similar trend to the catch, with higher values for all strata in November and December. The maximum value of relative abundance of 4.8 kg h^{-1} was determined in December for the high and medium-high strata (Figure 3).

The average price of the resource (soles kg^{-1}) was directly proportional to altitude, denoting a stable trend from the beginning of the fishing period (April) to June in the low stratum (22.5 soles kg^{-1} or 6.4 US$ kg^{-1}) and August for upper strata (35.0 soles kg^{-1} or 10 US$ kg^{-1}). Later it presented a marked decrease associated with the increase in the availability of the resource, registering lower values for December with prices that varied from 10.0 to 14.5 soles kg^{-1} (2,9 a 4 US$ kg^{-1}) for the low and high strata respectively (Figure 3).

The economic productivity curve per hour of fishing (PHF) shows a similar trend to the CPUE and was directly associated with price variations, the lowest profitability value was estimated for the low stratum in April with 17.8 soles h^{-1} (5 US$ h^{-1}) and the highest in the high stratum in December with 69.8 soles h^{-1} (20 US$ h^{-1}) (Figure 3).

Monthly Income per Fisherman (MIf)

The monthly income received by an average fisherman, derived from the sale of the resource, varied from 964 soles/month (275 US$/month) for the low stratum in April and 6,760 soles/month (1,931 US$/month) for the high stratum in December, where despite the low price, was higher monthly catches and fishing operations (Figure 4).

The price and income per fisherman demonstrated significant differences (p <0.05) between the months and altitude stratums.

Investment, reinvestment, and operation costs

The investment costs refer to the acquisition of attire (suit and lighting equipment) and fishing gear. An average cost per fisher of 1,142.3 soles (US$ 325) is reported, where the "Atarraya" represented 44.7% followed by the diving jacket that constituted

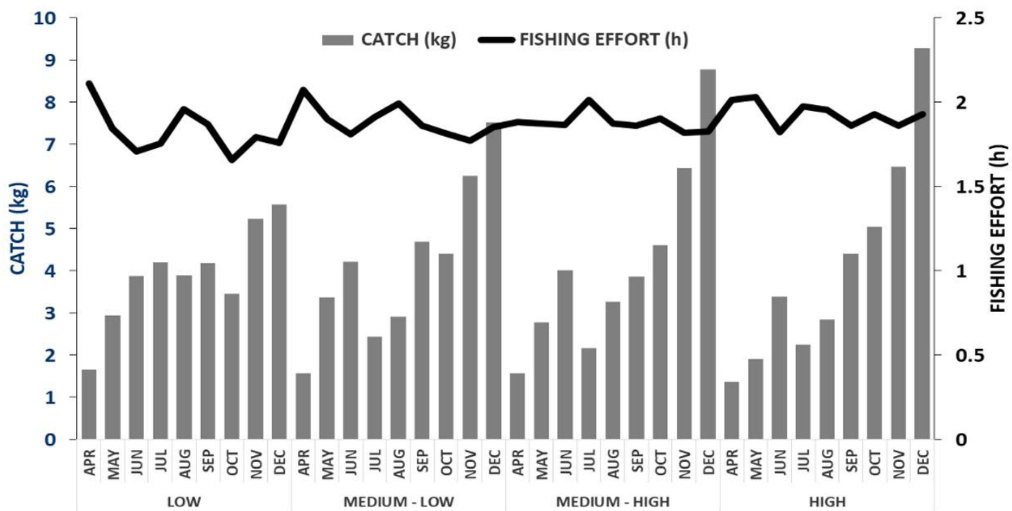

Figure 2. Spatial-temporal variation in catch (kg) and fishing effort (h) of the **prawn** fishery of the Majes-Camaná river (2019).

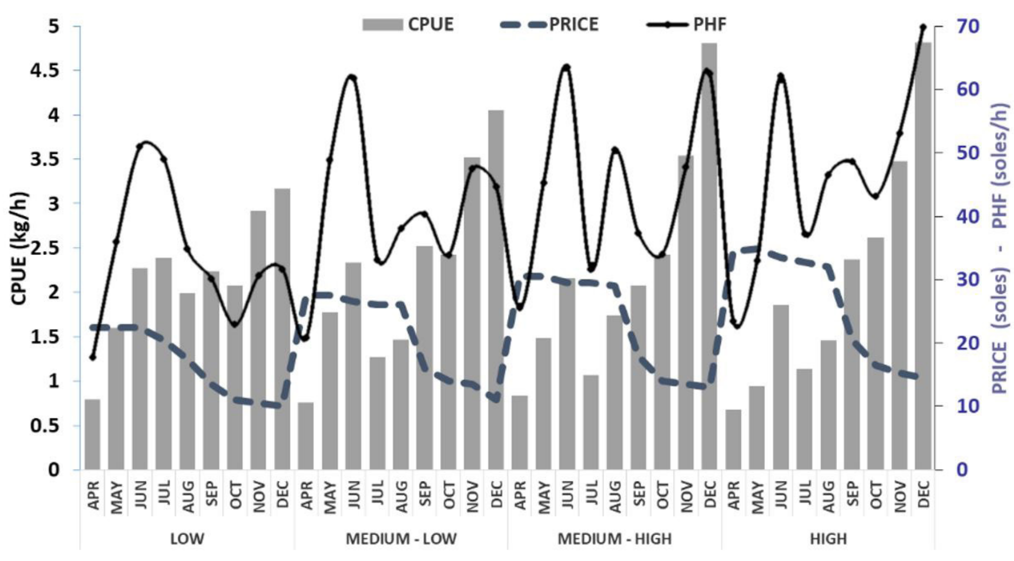

Figure 3. Spatial-temporal variation of CPUE (kg h^{-1}), price (soles kg^{-1}) and economic productivity per hour of fishing (soles h^{-1}) of the prawn fishery of the Majes-Camaná river (2019).

37.8% of the total investment. Moreover, the battery (6v), the mask, the flashlight, the water shoes and the chinguillo (mesh bag) recorded a joint percentage of 17.6%. The average (annual) costs grouped by altitude stratum did not show statistically significant differences ($p = 0.96$).

The costs per operation were 14.9 soles/operation (4.3 US$/operation), an amount mainly constituted by the previous inputs (coca leaves, pisco or alcohol and cigarettes) used as a stimulant to combat the cold and fatigue typical of manual fishing. The value of the total annual cost exerted by the replacement of instruments due to their use and wear was 744.9 soles (US$ 213), being the Atarraya the item with the highest reinvestment cost (48.9%) which has an average durability of 1.4 years, finally, the annual cost for the maintenance of the work tools was 50.0 soles (US$ 14.3) (Table 1).

Economic simulation model for the prawn fishery

Favorable profitability values were determined for an average fisherman from the different strata evaluated, considering a simulation of 5 years of useful life, at a discount or update rate of 9.07% and without any type of financing.

A positive net present value (NPV) was estimated and directly proportional to altitude, with a utility of S/. 57,608 (US$ 16,460) for the lower stratum and S/. 90,254 (US$ 25,787) for the upper stratum. The internal rate of return (IRR) showed a similar pattern with values between 1,356% for the low stratum and 2,094% for the high stratum.

The benefit/cost ratio (B/C) presented values higher than 1 in all strata and increased with altitude, varying from 3.4 (low stratum) to 5.3 (high stratum). Thus, for each monetary unit (sol or dollar) invested by the fishermen of the low stratum they will obtain a profit of 2.4 soles (or 0.7 dollars) (apart from recovering the investment), compared to the high stratum whose economic benefit per sun invested was 4.3 soles (1.2 dollars). The discounted payback period (DPB) showed an inversely proportional trend with altitude, being less than the year of activity. Fishermen from the low stratum recover their initial investment after 35.5 days (0.10 years) of work and those from the high stratum after 22.8 days (0.06 years) (Table 2).

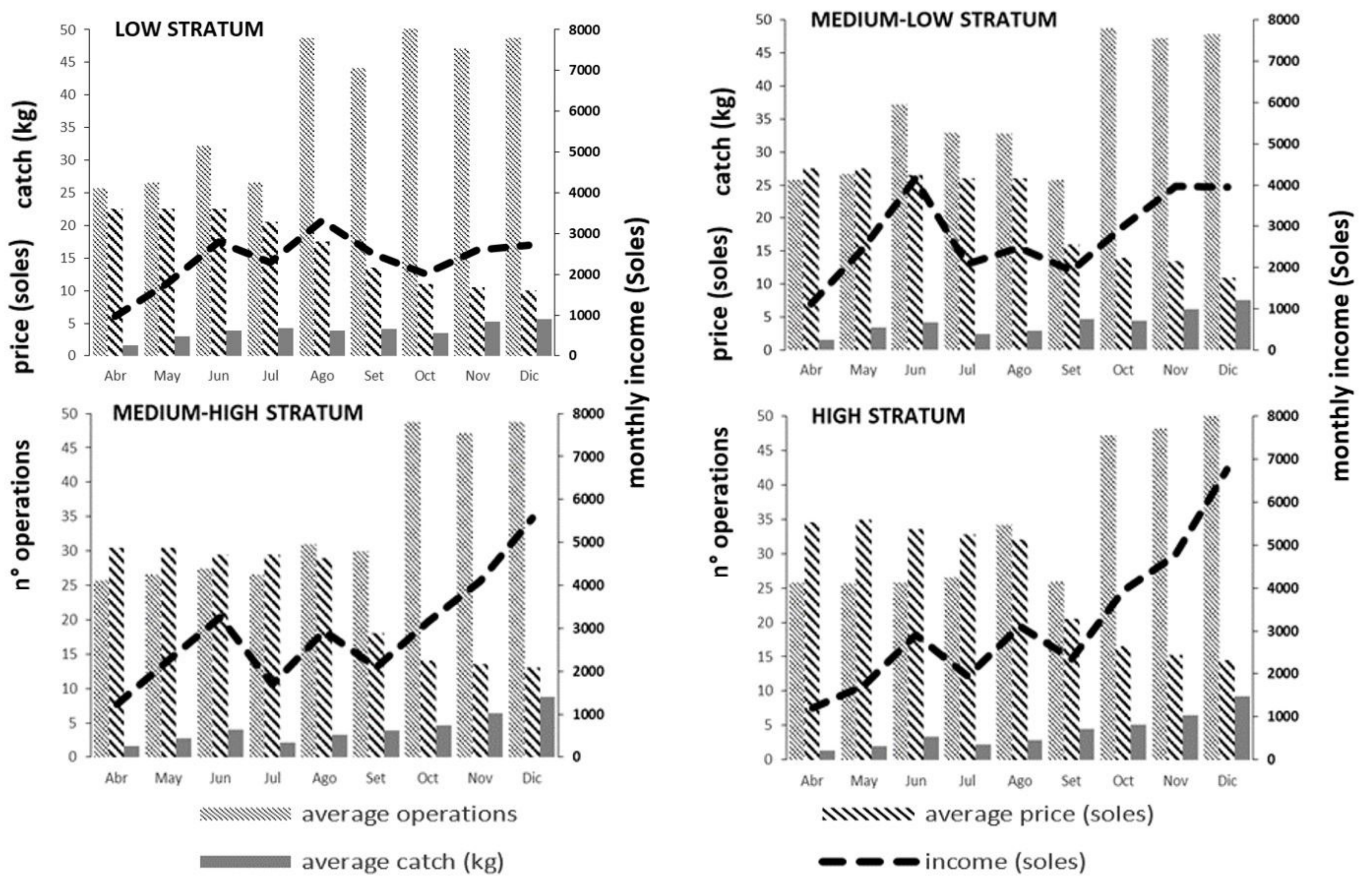

Figure 4. Spatio-temporal variation of the monthly income per fisher (soles/month) and CPUE (kg h^{-1}) of the prawn from the Majes-Camaná river (2019).

Table 1. Valuation of investment, reinvestment, and operation costs (soles) in the extractive activity of Camarón from the Majes-Camaná river (2019).

Cost type	Item	Minimal cost (soles)	Maximum cost (soles)	Average cost (soles)	Desvest cost (soles)	%	Total cost (soles)
Investment	Atarraya	250.0	750.0	510.0	216.2	44.6	**1142.3**
	Diving jacket	390.0	500.0	431.3	35.2	37.8	
	Battery 6v	55.0	60.0	57.9	2.5	5.1	
	Mask	40.0	70.0	52.5	9.3	4.6	
	Flashlight	35.0	45.0	40.0	4.1	3.5	
	Water shoes	25.0	35.0	29.4	3.2	2.6	
	Chinguillo (mesh bag)	20.0	25.0	21.3	2.3	1.9	
Operation	Previous inputs	8.0	15.0	10.5	2.7	70.5	**14.9**
	Transport	0.0	3.0	2.0	1.1	13.4	
	Flashlight focus	1.3	1.7	1.5	0.1	10.1	
	Battery charge	0.5	1.5	0.9	0.3	6.0	
			Lifespan (months)	**Lifespan (years)**	**Annual cost (soles)**	**%**	**Total cost per year (soles)**
Replacement	Atarraya	510.0	16.8	1.4	364.3	48.9	**744.9**
	Diving jacket	431.3	27.8	2.3	186.5	25.0	
	Battery 6v	57.9	16.9	1.4	41.2	5.5	
	Mask	52.5	45.0	3.8	14.0	1.9	
	Flashlight	40.0	36.0	3.0	13.3	1.8	
	Water shoes	29.4	3.0	0.3	117.5	15.8	
	Chinguillo (mesh bag)	21.3	31.5	2.6	8.1	1.1	
Maintenance	Diving jacket (patched)	13.8	8.3	0.7	20.0	6.6	**50.0**
	Atarraya (repair)	5.0	2.0	0.2	30.0	9.9	

Table 2. Altitudinal variation of the values of economic profitability indicators for the fishery of the Majes-Camaná river prawn (2019).

Stratum	VPN (soles)	IRR (%)	ratio B/C	Payback (years)	Payback (days)
Low	S/. 57,608.37	1356%	3.43	0.10	35.48
Medium - low	S/. 75,660.94	1764%	4.42	0.07	27.14
Medium - high	S/. 80,611.21	1876%	4.77	0.07	25.50
High	S/. 90,253.53	2094%	5.25	0.06	22.81

DISCUSSION

The river prawn fishery is artisanal and intended for direct human consumption, it is developed during the night by manual extraction carried out by prawn fishermen who use "lung diving with artificial light" as their main fishing method. During events of cloudiness of the river, diving loses effectiveness and is replaced by the "Atarraya" (circular network).

The significant differences in the catches (kg) between the months are possibly associated with the seasonal variation of the river regime, where for the last quarter there is a lower flow and water mirror that leads to a smaller area of dispersion of the resource and better accessibility for its capture, an event similar to that reported in Amazon River fisheries (Wasiw et al., 2012; Dias et al., 2020). In turn, the average catches show a slight increase with altitude, however the differences between strata do not they are statistically significant.

The fishing effort, defined as the time that the fisherman spends in the water, is set by the fisherman and presented a stable pattern of approximately 2 hours of fishing activity, so it did not show marked variations per month and stratum. Price and income were higher in the last quarter of the year and for high strata, possibly due to greater availability (seasonal) and size of the resource respectively; the latter is directly proportional to altitude, as reported by Viacava et al. (1978).

The costs incurred in the fishery are miniscule in contrast to the on-board fisheries Zamora-Bornachera et al. (2007), for the

Colombian Caribbean fishery, report an investment cost of US$ 2,140, equivalent to 7,500 soles. In the same way Berrú (2016), for the "Navajuela" (*Tajelus dombeii*) fishery in Ancash-Peru, reports an investment amount of 21,114 soles (US$ 6,030) associated with the boat, motor, and fishing gear (nets, hooks, compressors), components that generate annual reinvestment and replacement costs of 2,066 and 1,336 soles (US$ 590 and 380) respectively. Mariategui (2009), for the Giant Squid (*Dosidicus gigas*) fishery, the main artisanal fishery in Peru, reports expenses per day of 250 soles (US$ 70), these operating costs include fuel, boat rental, food, and ice to preserve the fish product.

The increase in CPUE throughout the year is associated with the greater availability (abundance) of the resource in the last quarter, in agreement with that described by Viacava et al. (1978), Yepez (2009), and Wasiw and Yepez (2016). However, it is necessary to clarify that the magnitudes of the recorded catches are closely associated with the ability of the fisherman, acquired through continuous practice.

The value of prawn is high compared to other invertebrates. Berrú (2016) reported for *T. dombeii* values of 1.4 to 1.9 soles kg^{-1} and incomes between 2,191 and 5,109 soles (US$ 625 and 1460), which were distributed among fishermen, resulting in an approximate income of 420 and 1,000 soles/fisherman (US$ 120 and 285). Monthly income per prawn fisherman at the time of greatest availability of the resource, can exceed ca. 630% the minimum living wage (930 soles or US$ 265).

Due to the low costs and high income inherent to prawn farming, all profitability indicators were very favorable in contrast to other artisanal fisheries. Berrú (2016), for the "navajuela" fishery with a (more favorable) scenario of 5 years, without financing and where the owner of the vessel participated as a fisherman, reports a maximum NPV of 29,330 soles (US$ 8,380), IRR of 53.84%, B/C = 1.22 and PRD of 1.84 years. Zamora-Bornachera et al. (2007) report positive NPV values for the Colombian Caribbean fisheries, however the economic profitability per fisherman is very low and does not reach, in most cases, the minimum legal monthly wage. Campos et al. (2007), for a profitability analysis of tilapia cultivation in net tanks, report an IRR of 57%, B/C = 3.34 and PRD of 1.71 years. Gelli et al. (2020) studied the economic viability of the *Kappaphycus alvarezii* seaweed used as a leaf biofertilize, the results, in the scenario of medium price, were positive with an IRR of 38.99% and a recovery rate of 2.7 years.

Despite the high profitability of the prawn fishery, it is the "gatherers" (primary buyers) and the "retailers" (sellers of national markets), who perceive the greatest economic benefits in the fishery value chain since they determine the daily price of the resource. Situation similar to that reported by Panayotou (1982), Castilla and Defeo (2001), Zamora-Bornachera et al. (2007) and Berrú (2016), where economic pressures for daily subsistence, high financial dependence due to the absence of means of production and market dynamics, keep fishermen subordinate to the economic decisions imposed by those who buy their fish production.

Wasiw and Yepez (2016) report a negative trend (2005 - 2017) in the values of population indices of resource concentration in Peruvian prawn rivers. This reduction in availability leads to lower catches, which has a negative impact on the income or profits of the agents that carry out their fishery, which, with the expectation of obtaining greater economic benefits, generate greater pressure on the vulnerable resource.

The increase in fishing effort on the resource affects the yields of the different users of the fishery. Seijo et al. (1998) indicates that for open access fisheries, such as river fisheries, the optimal allocation of fishery resources fails, due, among other factors, to the occurrence of high exclusion costs, so that a fisher does not benefit in postponing the catch in the hope of obtaining larger and more valuable prawn in the future, because another fisherman may catch them in the same period. As long as, the resource continues to be exploited excessively, populations will continue to decline.

Galarza and Kamiche (2016) argue that the recognition of artisanal and small-scale fishing in society in general, associate with provision of food, employment, and foreign exchange in recent times, has led to the implementation of various government actions to try to incorporate it as a strategic activity for the economic development of the countries and raise the standard of living of fishermen and their communities.

Due to the good profitability of the prawn fishery, the extractive activity should be aimed at the fishermen's associations constituting micro/small companies, registered and with legal status established in the country, which would allow them not only to formalize the activity, but also to have access to credit opportunities and/or apply for financing of innovation projects offered by the government, private sector and international agents, oriented to the development of productive, organizational and business capacities of the producers.

CONCLUSION

The fishing yield expressed in CPUE ($kg\ h^{-1}$) increased throughout the free fishing period. The economic profitability indicators NPV, IRR, B/C were directly proportional to altitude and showed high profitability for fishermen who exercise the activity, this profitability is associated with low investment, reinvestment, and operation costs. The high demand for the resource leads to higher sale prices (compared to other resources) which in turn causes higher income to fishermen, which are mainly associated with the availability of the resource (it is higher in the last quarter of the year) than it is under constant fishing pressure under a continuously degraded environment.

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