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Fisheries of the scavenger species *Calophysus macropterus*: a case study in the Bolivian Amazon

Pesca de la especie carroñera *Calophysus macropterus*: un estudio de caso en la Amazonía Boliviana

RESEARCH ARTICLE
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ABSTRACT

Bolivian Amazon small-scale fisheries traditionally focus on large migratory fish species. However, in the last decade there has been a trend of increased landings of low-value medium-sized migratory species, such as blanquillo, *Calophysus macropterus*. This scavenger species is captured using chicken and bovine waste as bait, and occasionally carcasses from wild species. This study explores the boom of this specialized fishery in Puerto Villarroel, a small harbor on the Ichilo River, using a combination of historical landing data, fisheries statistics obtained by participatory fisheries monitoring, fish market studies and interviews with local key stakeholders. Additionally, mercury contamination of fish meat was evaluated. Blanquillo fishing started in 2008 and boomed around 2015, representing 30% of landings, after which it decreased to fluctuate around 15%. The capture and landing data suggest that this species is mainly captured by non-organized fishers. The market studies conducted between 2015 and 2018 in Cochabamba city and in lowland middle towns showed that on average more than 20% of consumption of Amazon river fish consisted of blanquillo meat. Mercury is accumulated in the muscle tissue at concentrations near the official limit established by WHO for human

consumption, whereas in 15% of fish the concentrations exceeded this limit. The paper pieces together the evolution of the blanquillo fishery in Bolivia, and looks at different aspects, including the diversity of fishers involved, possible impacts on other vulnerable species and public health, and potential impacts and effectiveness of different public policy approaches. In conclusion, the present study shows there is an overall need for more consistent and inclusive fisheries regulations in the Bolivian Amazon, as a way to protect aquatic fauna, avoid environmental contamination and secure human health.

Keywords: Catfish, mercury, fishing, fish markets, fisheries management.

RESUMEN

Las pesquerías a pequeña escala de la Amazonía boliviana se centran tradicionalmente en las grandes especies de peces migratorios. Sin embargo, en la última década ha habido una tendencia al aumento de los desembarques de especies migratorias de tamaño medio y bajo valor, como el blanquillo, *Calophysus macropterus*. Esta especie carroñera se captura utilizando como cebo desechos de pollo y bovino, y ocasionalmente cadáveres de especies silvestres. Este estudio explora el auge de esta pesquería especializada en Puerto Villarroel, un pequeño puerto en el río Ichilo, utilizando una combinación de datos históricos de desembarque, estadísticas pesqueras obtenidas mediante el monitoreo participativo de pesquerías, estudios de mercado de pescado y entrevistas con actores clave locales. La pesca del blanquillo comenzó en 2008 y tuvo un auge alrededor de 2015, representando el 30% de los desembarques, luego de lo cual disminuyó para fluctuar alrededor del 15%. Los datos de captura y desembarque sugieren que esta especie es capturada principalmente por pescadores no organizados. Los estudios de mercado realizados entre 2015 y 2018 en la ciudad de Cochabamba y en ciudades intermedias en los llanos mostraron que, en promedio, más del 20% del consumo de pescado del río Amazonas consistía en carne de blanquillo. El mercurio se acumula en el tejido muscular de blanquillo en concentraciones cercanas al límite oficial establecido por la OMS para el consumo humano. El documento reúne la evolución de la pesquería de blanquillo en Bolivia y analiza diferentes aspectos, incluida la diversidad de pescadores involucrados, los posibles impactos en otras especies vulnerables y la salud pública, y los posibles impactos y la eficacia de diferentes enfoques de políticas públicas.

Palabras clave: Siluriformes, mercurio, pesca, mercados de pescado, gestion pesquera.

INTRODUCTION

It is widely recognized that small-scale inland fisheries contribute significantly to poverty reduction and food security (Funge-Smith & Bennett 2019). Case studies conducted in the Amazon basin showed that fish are the most important protein source in rural diets, sustain local livelihoods, and supply urban markets (Almeida *et al*. 2001, Isaac & Almeida 2011, Coomes *et al*. 2010, Begossi *et al*. 2019). However, notwithstanding this general academic recognition, there is still an underestimation by decision makers of the wide-ranging and multiple services provided by fish and fisheries to human welfare. Inland fisheries contributions to society are generally overlooked or not diagnosed. This leads to deficient planning and poor decisions, therefore jeopardizing the fisheries sector and often pushing fishers into marginal positions (Cook *et al*. 2016; Doria *et al*. 2017). However, within this adverse scenario, Amazon fisheries have been shown to have an extraordinary ability to adapt to new challenges, explore new stocks and adopt new fishing practices (Goulding *et al.* 2018).

Commercial fisheries landings in the Amazon are historically multi-species, with a focus on large catfish and characid species (Castello *et al.* 2011, Castello *et al*. 2013, Ruffino 2014). In the Bolivian Amazon, landings before 2010 were dominated by five large species, three of which are carnivorous catfish and two are frugivorous characids, together comprising more than 80% of reported catch (Miranda-Chumacero *et al*. 2011, Doria *et al.* 2018). In this respect, Bolivian commercial fisheries were characterized by Van Damme *et al.* (2011) as underdeveloped, although the same authors recognized significant underreporting due to a deficient knowledge of the contribution of subsistence fisheries.

In the last decades these economically high-valued species were gradually complemented or replaced in commercial landings by smaller and lower-market-value detritivorous and herbivorous species (Heilpern *et al.* 2022). In most Amazon countries these smaller species occupy now the larger part of the catches (Garcia *et al*. 2008; Doria *et al.* 2018). In Bolivia, improved survey efforts during the last decade showed a clear trend towards increased landings of low-value medium-sized migratory species, mainly small characids and curimatids, supplying markets in the lowlands (Coca Méndez *et al*. 2012, Argote Soliz *et al*. 2017). Many of these species occupy lower positions in the food web than the traditional species, with an exception being *Calophysus macropterus*, or blanquillo, a short-lived siluriform species with omnivorous to scavenging habits (Pérez & Fabré 2009, Valente-Aguiar *et al*. 2020). The fisheries of this small migratory species emerged in the Mamoré River basin, in the last decade, adapting fishing methods practiced in Brazil and Colombia, and was driven by the growing demand of the national market for low-priced fish. Blanquillo fishing differs from the traditional multi-specific fisheries in using a method designed specifically for scavenger species, employing bait of poultry and bovine meat waste and, occasionally, carcasses of wild animals (Estupiñan *et al*. 2003; Iriarte & Marmontel 2013a, b; Botero-Arias *et al.* 2014, Brum *et al.* 2015; Franco *et al.* 2016).

In other Amazonian countries, blanquillo fishing was discouraged due to its potential impact on native wildlife, such as freshwater dolphins and caimans, which were used frequently as bait. In Brazil, a five-year moratorium was established (2015-

2019) (Instrução Normativa Interministerial no. 6, July 17th, 2014), and later renewed for three subsequent years (Jul 2020-Jun 2023, Instrução Normativa n°17 of 10 July 2020; jul 2021-jun 2022, Portaria SAP/MAPA no. 271 of 01 July 2021; jun 2022-jul 202, Portaria SAP/MAPA 1082 of 02 July 2022) justified by the negative impact of this fishery on the Amazon river dolphin *Inia geoffrensis*, used as bait (Trujillo *et al.* 2020). In Colombia blanquillo fishing was banned permanently after 2017 due to the methylmercury levels in its meat, representing a risk to human health (Nuñez-Avellaneda *et al*. 2014; Mosquera-Guerra *et al.* 2017). Blanquillo fishing is not prohibited at national level in Bolivia, although its capture and commercialization in the department of Cochabamba were *de facto* forbidden by regional authorities as of 2012. In January 2021, an agreement between the Department of Agriculture Services (SEDAG-Cochabamba) and affiliated fishers was signed on the maximum amount of *C. macropterus* catch per fishing trip (100 kg), the exclusive use of fish offal as bait and the total prohibition of using waste of domestic avian or mammal species. A new regional law promulgated in 2021 prohibited *C. macropterus* fishing, but enforcement is weak.

Management of *C. macropterus* fisheries is particularly challenging because of the suggested risks to human health associated with its consumption, and its potential impact on wildlife conservation. Considering the signs of an increase in the capture of the species in the Bolivian Amazon, it is imperative to understand the economic and social reasons for its success, and use this information to formulate and enforce specific fisheries policies, combined with aquatic wildlife conservation and the prevention of human health risks, and based on the best scientific information available. The specific objectives of this study were to: (a) identify trends in the contribution of this species to fish catches and landings in the study area during the last two decades; (b) establish the importance of blanquillo in urban markets in Cochabamba city and lowland middle towns; (c) identify some of the social and economic factors that support the production chain of the species; (d) explore the risk of consumption of blanquillo meat for human health. We also briefly discuss the possible impact of *Calophysus* fishing on aquatic wildlife in the study area, and especially on the Bolivian freshwater dolphin *Inia geoffrensis boliviensis*, based on published literature. Finally, we explore how Bolivia has taken up this fishery management challenge in the last decade and propose future fisheries regulations.

MATERIAL AND METHODS

Study area

The Bolivian Amazon, with a surface area of approximately 718 137 km^2, comprises 65.4% of the surface area of Bolivia. With exception of the Acre River, the Amazon forms part of the upper Madeira River basin, and is drained by four main rivers: Madre de Dios, Mamoré, Beni and Iténez (or Guaporé). The lowland sections of these rivers are intensively used for commercial fishing, whereas the main urban fish markets, in Santa Cruz, La Paz and Cochabamba, are located in the headwaters of these rivers (Van Damme *et al*., 2011).

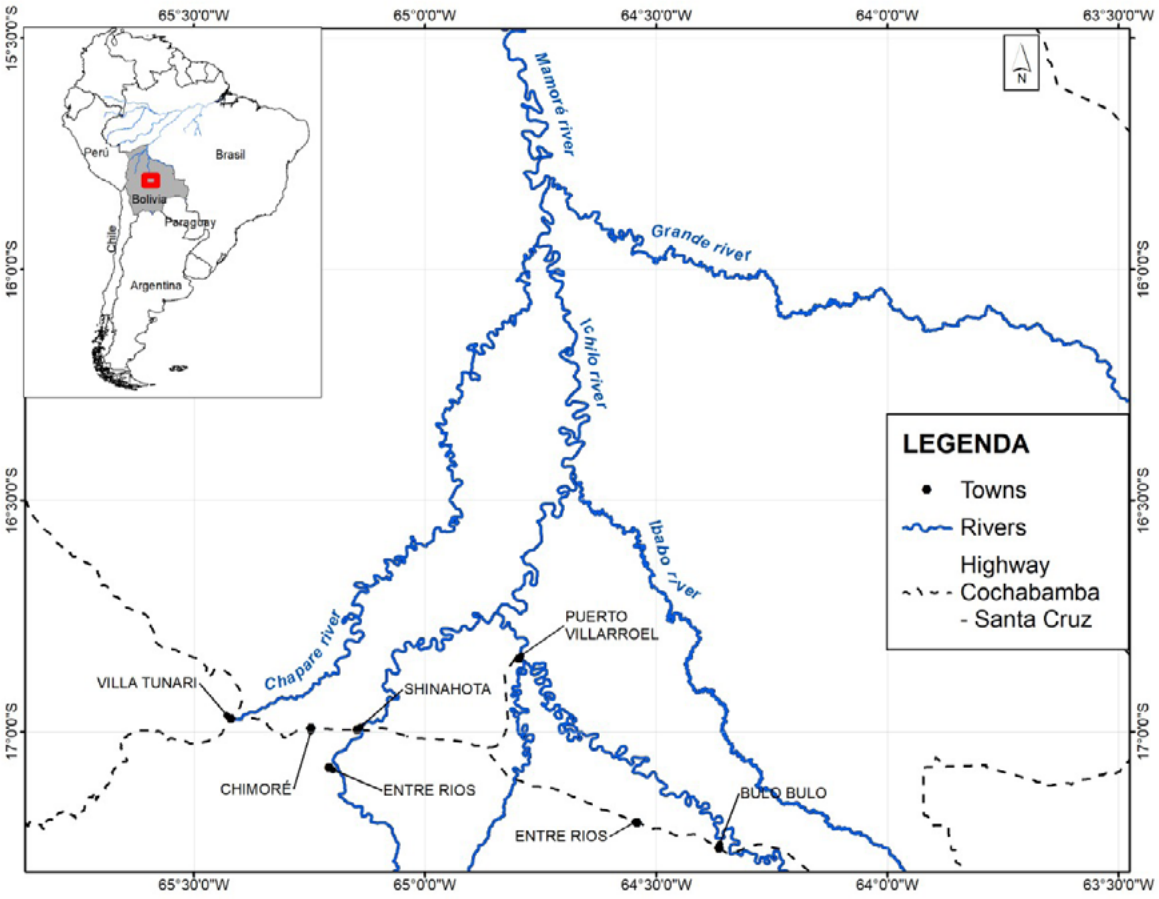

FIGURE 1. Study area indicating Puerto Villarroel landing site and fish markets

Considering the de facto prohibition of blanquillo fishing and the consequent difficulty to obtain reliable data on fisheries practices, a multidisciplinary approach combining different survey techniques was applied. The present study on commercial fisheries was conducted in Puerto Villarroel, a small fish landing site in the upper Ichilo River, a headwater of the Mamoré River (Figure 1). This riverine locality has a population of approximately 8000 habitants (INE 2020). The fishing area comprises the main river channel and oxbow lakes along the Ichilo River, up to its confluence with the Grande River.

A prior study of fisher behaviour and catch composition identified three fishing types in the area. The first type (A in Table 1) is practiced by commercial fishers living in Puerto Villarroel, engaged in fishing during the official fishing season, which lasts eight months a year. They are owners of boats, canoes, ice boxes for onboard storage of fish, engines (gasoline and diesel motors), fishing gear, accessories, tools and other equipment. They mostly catch large high-valued fish species. Most of the fishers practicing type A-fishing are affiliated with local fisher organizations, and generally comply with the regulations established by the public authority for fisheries, which registers their official catch at landing points. Type B-fishing (Table 1) is practiced mainly by commercial fishers possessing canoes and basic

fishing gear catching smaller quantities of large and/or medium-sized fish. Some of these complement their catches with blanquillo. Most of their fish landings are registered by the regional authorities (see below). The third type (type C in Table 1) is practiced mainly by occasional or part-time fishers, mostly living outside Puerto Villarroel, fishing individually or in small groups, not complying with, or not aware of, fishing regulations. Most of these fishers capture blanquillo in the shallow parts of the river, at night, using bovine or chicken meat waste or, occasionally, carcasses from wild mammals, caimans and fish, as bait. Fishers using this technique have a minimum value of capital invested in goods for fishing production, since they only have canoes, and sell the blanquillo they capture at dawn without using ice for conservation. Although they are informal, many register their catch in the regional office in order to legally transport it to Cochabamba city or lowland towns. However, some fishers probably do not report their catch, using other forms of transport, and evading official controls.

TABLE 1. Types of fishing and fishers in Puerto Villarroel.

Main fishing types	Description of fishers	Profile	Registration of catches or landings
A	Traditional fishers with large fishing boats (locally denominated *ponton*)	On average crew of four fishers; ice boxes of max. 1500 kg; undertake long fishing trips (±12 days), almost exclusively fishing large-sized fish	The majority is affiliated to fisher organizations and participate actively in daily monitoring of their catch. Their landings are also registered by regional authorities.
B	Traditional fishers with small fishing boats (canoes, *chalupas*)	On average crew of two or three fishers; ice boxes of max. 300 kg; undertake short fishing trips (according to interviews 2-5 days) capturing both large-sized and medium-sized fish, sometimes complemented with blanquillo	Few of them are affiliated to fisher organizations. Most if not all of their catches are registered by regional authorities. Few participate in the daily monitoring of catches
C	*Blanquillo* fishers using canoes or working from the shore	On average crew of two fishers; occasional oportunistic fishers realizing short fishing trips (max. two days) only fishing blanquillo; rarely use ice for fish conservation.	Not organized and not affiliated with fisher organizations. Some of their landings are registered by regional authorities, but none during the annual fisheries ban between November and February.

Participative monitoring

Fishers practicing type A-fishing from both fisher organizations participate actively in the daily monitoring of fish catch. This monitoring system of catches, described in detail by Van Damme *et al*. (2019), was set up with more than 50 different fishers participating during variable time periods over a total time span of 15 years, with data collected from an average annual number of 9.9 (± 3.9; range

4-17) commercial fishery boats participating in fish records between 1998 and 2007, and 8.7 (± 2.5, range 6-11) boats between 2015 and 2019. In 2018 and 2019, the number of participating fishers increased to 30, due to a strengthened commitment for participation in monitoring by the members of the fisheries organizations. Data for the period 2009-2014 were not available since the monitoring was temporally interrupted due to failure in funding and follow-up. Overall, captured fish were monitored daily on board during 925 fishing trips over the 15-year monitoring period, 666 between 1998 and 2008, and 259 from 2015 to 2019. Data were only available from beginning of March to end of October each year, due to the annual closed season imposed by the regional government in the other four months, considered spawning period for the commercial species. During the fisheries ban most commercial fishers were dedicated to alternative activities, principally timber extraction. A form filled by trained fishers during each trip provided daily catch data by species, individual fish weight, as well as information on fishing gear, fishing location and crew members. Such form generally covered fishing trips of four to 20 days with a crew of two to four, and seldom six or eight, fishers. In total, over the entire sampling period, 20 species were registered (not considering species which represented <0.1% of total biomass), which for the sake of the present analysis were divided in three groups: the scavenger species blanquillo, large-sized species, and medium-sized and/or low-valued species (Table 2).

Official landing data

Official landing data for Puerto Villarroel were obtained from SEDAG-Cochabamba for 2000-2008 and 2011-2016, with an interruption of data collection in 2009 and 2010, due to administrative decisions. The efficiency of this monitoring system improved along the study period: before 2009 only 30% of the catch was

TABLE 2. Fish species recorded in the catches registered through participative monitoring, in the landings recorded by authorities and in fish markets. In each group the species are ordered alphabetically. P.Vill.= Puerto Villarroel.

Groups	Species	Local names	Catch P.Vill.	Landings P.Vill.	Markets middle towns	Markets Cochabamba city
Group 1. Large-sized species	*Brachyplatystoma filamentosum*	Bacalao	X	X	X	
	Brachyplatystoma platynemum	Barbachata	X	X	X	
	Brachyplatystoma rousseauxii	Plateado	X	X	X	
	Colossoma macropomum	Pacú	X	X	X	X
	Leiarius marmoratus	Tujuno			X	
	Phractocephalus hemioliopterus	General	X	X		
	Piaractus brachypomus	Tambaquí	X	X	X	X
	Pseudoplatystoma fasciatum	Surubí	X	X	X	X
	Pseudoplatystoma tigrinum	Simicuyo	X	X	X	X
	Sorubimichthys planiceps	Chicotillo	X	X		
	Zungaro zungaro	Muturo	X	X	X	X

Groups	Species	Local names	Catch P.Vill.	Landings P.Vill.	Markets middle towns	Markets Cochabamba city
Group 2. Medium-sized species	*Ageneiosus inermis*	Seferino			X	
	Brycon amazonicus	Yatorana			X	
	Hoplias malabaricus	Bentón			X	
	Hypophthalmus edentates	Vela	X	X	X	
	Mylossoma spp.	Pacupeba	X	X	X	
	Pinirampus pirinampus	Barbachata			X	
	Plagioscion squamosissimus	Corvina	X	X		
	Potamorhina sp., *Psectrograster* sp.	Sabalina	X			
	Potamotrygon sp.	Raya			X	
	Prochilodus nigricans	Sabalo	X	X	X	X
	Pterodorus granulosus	Reque			X	
	Pygocentrus nattereri	Piraña	X	X	X	X
	Raphyodon vulpinus	Machete				
	Salminus brasiliensis	Dorado			X	
	Serrasalmus spp.	Piraña	X	X		
Group 3. *C. macropterus*	*Calophysus macropterus*	Blanquillo	X	X	X	X
Number of species			20	18	21	8

identified to species level and attributed to one of the three fish groups; after 2010, more than 90% of the landings was assigned to the appropriate category. Notwithstanding the mentioned limitations, these data allowed the identification of trends in blanquillo landings in the Ichilo River. Landings were recorded by an official, who divided the catch in three groups (Table 2). The first two fish groups form part of the multi-species fisheries making almost exclusively use of fishing nets, whereas the latter, denominated as blanquilleo (blanquillo fishing) locally, is part of this specialized fisheries in which bait is used. In type C-fishing, the weight of blanquillo and the other species was often recorded separately, but not always (as was the case in 14% of the records which contained blanquillo data). The number of days for which landing records were available varied from year to year. Landing data were not available for November to February of each year, during the annual fisheries ban. Landings were not recorded every day during the 8-month period during which fishing was allowed. For the entire study period between 2011 and 2018, records were available for 1 144 of the total number of landing days (1 470), or 78% recording efficiency. However, the landings were monitored at least 12 days each month. The mean number of days per month with records available was 24 (±7).

Market analysis

A fish market study was conducted in Cochabamba. This city of over 600 000 habitants is located 600 km west of Puerto Villarroel, at 2 750 masl in the high Andes, (Figure 1). Seven urban markets were visited twice, in 2015 and in 2018 (Table 3). Fish markets in three middle-sized towns (Ivirgarzama, Entre Rios, Villa Tunari) in the lowlands, 40 to 80 km of the landing site were also evaluated. These towns represent approximately 50% of the urban population of six lowland towns of the Cochabamba department (Figure 1). Fish markets in Entre Rios and Villa Tunari were visited in 2017, and in Ivirgarzama in 2018. Market data were collected through a structured interview conducted with fish meat retailers in the fish markets and permanent selling points, not including supermarkets and restaurants. Overall, 52% of all the retailers in fish markets were interviewed (Table 3), and all of these were womenThe data collected in the survey were: a) number of days per week and number of weeks a year fish of different species is sold regularly; b) quantities sold per day (kg/day) and/or per week for each species; c) average annual sale prices (Bs/kg) for each species between April and October, and maximum sale prices (Bs/kg) during the Eastern period, generally in March; d) average prices (Bs/kg) paid to salesmen; and e) place of origin of the fish. Only Amazon fish were considered, excluding the introduced species *Arapaima gigas*, which originates from the northern Bolivian Amazon (Riberalta town). Farmed fish (*Colossoma macropomum, Piaractus brachypomus*) were also excluded from the data set, as well as sábalo (*Prochilodus lineatus*) originating from the Pilcomayo River in Bolivia or from the La Plata River basin in Argentina (Navia *et al*. 2019). The fish sold were divided over the three groups referred to in Table 2. All prices were adjusted to 2018 prices using official inflation rates and converted to US$ using an exchange rate of 7 Bs/1 US$.

TABLE 3. Number of inhabitants (INE 2012), fish markets and sample size in Cochabamba city and in lowland towns included in the market surveys 2015-2018

City/town	Nbr. of inhabitants in the urban area	Number of markets	Fish markets	Number of retailers	% retailers intervie-wed	Survey year
Cochabamba	630 587	7	25 de Mayo, 6 de Agosto, Calatayud, Ingavi, Lanza Brazil, Pulacayo, América	15	39	2015
		7	Zona Sud Sarco, Pulacayo, Calatayud, América, Católica, Lanza Brazil, Rotonda Laguna	24	57	2018
Entre Rios	13 736	1	Avenida Principal	6	75	2017
Ivirgarzama	33 338	1	Waca Playa	7	50	2018
Villa Tunari	62 454	1	Abasto 19 de Agosto	4	80	2017

Interviews

In 2017, 24 (all male) fishers in Puerto Villarroel were interviewed on fishing methods used in the fishing area, using the snowball-methodology to identify key persons and responsive fishers. This non-probability sampling methodology (Bailey

1982) allowed to identify and interview both fishers who are members of the established fishing organizations and illegal fishers. Research design safeguards were implemented to protect the confidentiality of the participants in the interviews.

Mercury analysis

To estimate the human risk of blanquillo consumption, individual fish (N=25) from the Ichilo River were collected for mercury analysis. Four to five grams of muscle from the dorsal region were collected and frozen until analysis. Atomic fluorescence was used for the Hg-analysis, using norms EPA 245.2, including chemical digestion and readings of fluorescence. All analyses were conducted in the Laboratory of Environmental Quality, UMSA, La Paz. The concentrations are given in mg Hg per wet weight (WW) of tissue, and were compared with the maximum acceptable concentrations for consumption proposed by the World Health Organization (0.5 mg/kg WW), and endorsed by most countries (Kimáková *et al.* 2018).

RESULTS

Capture data obtained by participative monitoring

The mean catches per fishing trip recorded by participative monitoring varied between 215 and 839 kg along the study period (Table 4). The average duration of the trips was between 8.8 and 14.5 days. Total annual recorded catch in Puerto Villarroel fluctuated between 8 and 92 tons (Figure 2). The contribution of blanquillo to the catches in the first sampling period (up to 2008) was low, averaging only 0.08% of total catch, but it increased to 2.6% in the last year of this period, when it reached 455 kg. The percentage contribution of blanquillo to the catch in the period 2015-2019 represented 1.1% on average, with the highest percentage contributions in 2016 (1.4%) and 2019 (1.7%).

TABLE 4. Catch data in Puerto Villarroel from 1998 to 2008 (11 years) and from 2015 to 2019 (five years)

Year	Number of trips	Mean catch/ trip (kg)	Duration of trip (days)	% of fishing trips which landed *C. macropterus* as bycatch	Total annual catches of *C. macropterus* (kg)
1998	96	415 ± 318	13.1 ± 5.2	4.2	16
1999	62	238 ± 223	11.7 ± 6.4	4.8	8
2000	50	457 ± 344	14.5 ± 5.3	4.0	8
2001	58	400 ± 335	12.1 ± 5.5	0.0	0
2002	38	215 ± 150	14.0 ± 5.7	2.6	2
2003	59	367 ± 402	10.3 ± 3.6	0.0	0
2004	109	225 ± 162	12.9 ± 5.2	1.8	114
2005	94	258 ± 262	12.1 ± 3.9	0.0	0
2006	44	524 ± 602	11.7 ± 3.3	0.0	0
2007	53	643 ± 625	10.6 ± 4.8	34.0	106

Year	Number of trips	Mean catch/ trip (kg)	Duration of trip (days)	% of fishing trips which landed *C. macropterus* as bycatch	Total annual catches of *C. macropterus* (kg)
2008	25	658 ± 282	12.5 ± 2.7	8.0	455
2015	21	561 ± 485	12.6 ± 4.3	9.5	160
2016	32	712 ± 551	12.7 ± 5.2	3.1	100
2017	41	777 ± 544	13.6 ± 12.8	0.0	0
2018	108	839 ± 748	8.8 ± 4.5	12.0	1 417
2019	104	823 ± 586	11.7 ± 7.0	29.8	1 444

Landing data

Historical landing data obtained from the regional office of SEDAG-Cochabamba showed the low contribution of blanquillo in 2005 (2.1%) and 2006 (1.7%), a gradual increase of this species in the landings of 2007 (4.4%) and a sudden increase in 2008 (14.4%). The species gained importance in the landings during the second recording period, with significant contributions in 2011 (35%) and 2012 (32%), followed by a drop in 2013 and 2014, a recovery in 2015, and a second drop in 2016 (Figure 3). During this second period of six years, 20.2% of the landings consisted exclusively of blanquillo, whereas 3.7% and 0.9% was blanquillo landed together with large species and small species, respectively (Figure 4). About 5% were landings of blanquillo combined with other species but without separating the weight of each contributing species group.

Over the entire second period, blanquillo fishing peaked in September and October (Figure 5), but there were large interannual variations. Lowest blanquillo records were registered in June-August, when higher landings of other species were

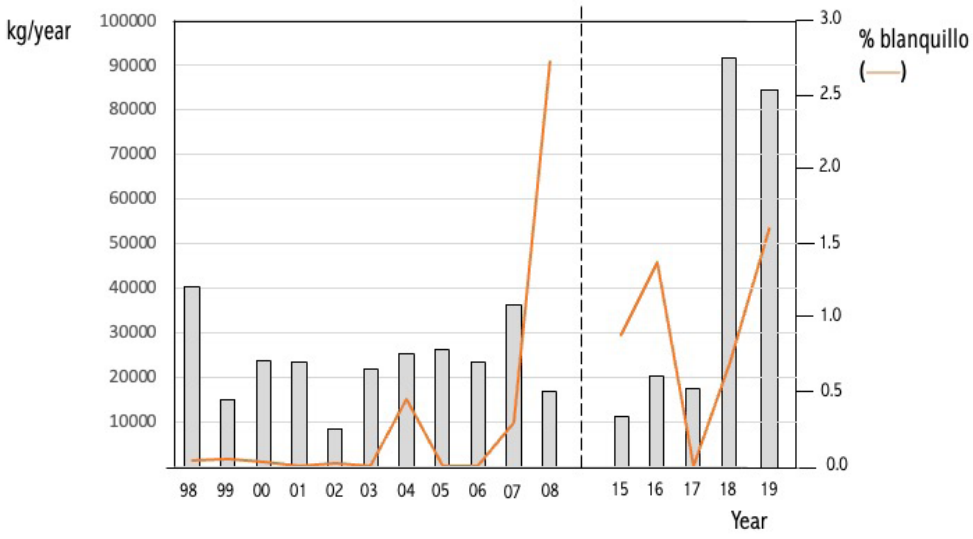

FIGURE 2. Total annual catch including all species (kg) and proportion of blanquillo (%) in Puerto Villarroel recorded through participative monitoring of fish catches onboard of type A-fishing boats

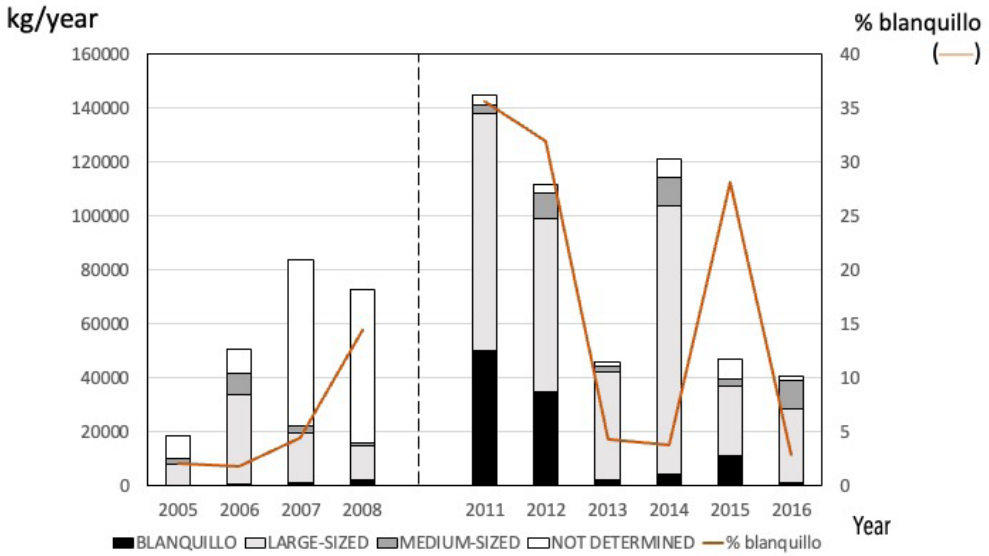

FIGURE 3. Evolution of the contribution of large-sized species, medium-sized species and blanquillo to total landings in Puerto Villarroel (Ichilo River) between 2005 and 2016.

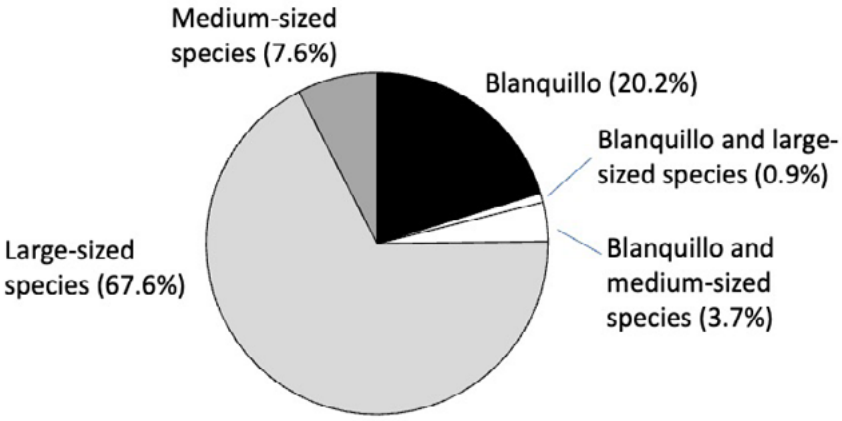

FIGURE 4. Composition of landings in Puerto Villarroel (2011-2016). Landings of mixtures of blanquillo and other species without identification of the volume of each fish group were not included.

obtained, coinciding with the piracema (upstream movement of migratory fish species). According to the interviewees, the blanquillo fishery continued during the closed season, when it replaced completely the traditional multi-species fisheries and represented the single fish source. However, data for this period are not available.

From 2011 to 2016, annual average landings of fishers practicing both type A- and B- fishing (N=1175), catching only the traditional species, were between 184 and 257 kg, whereas for those A and B fishers catching also blanquillo the landings (N=113) in these same years were on average 21% higher, between 190 and 372 kg. On the other hand, the landings of fishers of type C (blanquillo fishers) in these years were between 94 and 209 kg (Table 5).

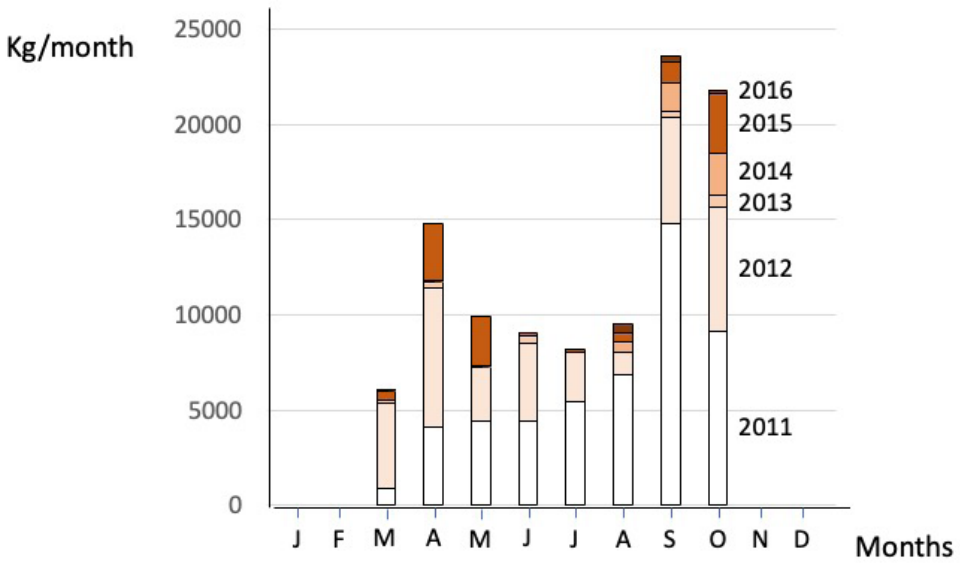

FIGURE 5. Monthly landings of blanquillo in Puerto Villarroel between 2011 and 2016.

TABLE 5. Monthly landings of blanquillo in Puerto Villarroel between 2011 and 2016.

Year	Type A and Type B fishing, landing only traditional species		Type A and Type B fishing, landing traditional species and blanquillo		Type C fishing landing only blanquillo	
	Number of landings	Landings/ trip (kg)	Number of landings	Landings /trip (kg)	Number of landings	Landings/ trip (kg)
2011	412	184 ± 156	188	190 ± 163	249	131 ± 112
2012	319	191 ± 170	123	221 ± 174	187	122 ± 94
2013	166	243 ± 203	24	194 ± 113	7	109 ± 83
2014	406	257 ± 205	33	372 ± 276	14	209 ± 136
2015	117	186 ± 163	54	335 ± 318	42	146 ± 105
2016	164	221 ± 194	10	236 ± 222	7	94 ± 50

Market data

The number of species commercialized in fish markets is negatively related with the distance to the landing point. Between 12 and 16 species were commercialized in Ivirgarzama, Entre Rios and Villa Tunari, but only six species arrived at the markets of Cochabamba (Table 6). However, blanquillo was sold in all the markets visited between 2015 and 2018.

Table 6 shows the contribution of the different species groups to the overall estimated sales in these five localities. In all localities, high-priced large species were the main marketed fish group, occupying more than 45% of total weight. Blanquillo represented 18.4-20.8% of total weight marketed in Cochabamba in 2015 and 2018 respectively, and between 4.0 and 10.3% in the lowland towns (Table 6). The price per kg of blanquillo (range 2.3-3.4 US$) was similar to the price of other medium-sized species (range 1.7-4.0 US$), and lower than the price of large-sized species (range 2.5-5.1 US$). The price of blanquillo was slightly higher in Cochabamba than in the lowland towns.

TABLE 6. Average values of prices and annual fish sales by species in Cochabamba city and three lowland towns in the Bolivian Amazon. The annual fish sales were estimated by extrapolating daily sales reported by the retailers.

City/town	Cochabamba						Entre Rios			Villa Tunari			Ivirgarzamaa		
Survey year	2015			2018			2017			2017			2018		
Species group	Weight (t/ year)	%	Price (US$/ kg)	Weight (t/ year)	%	Price (US$/ kg)	Weight (t/ year)	%	Price (US$/ kg)	Weight (t /year)	%	Price (US$/ kg)	Weight (t/ year)	%	Price (US$/ kg)
Large-sized species	408	61.7	4.3-5.1	218	54.2	3.9-5.0	34	75.8	3.1	60	58.7	3.4	23	57.9	2.5
Medium-sized species	122	19.9	2.6	101	25.0	4.0	8	17.9	2.1	32	36.7	2.1	13	31.8	1.7
Blanquillo	122	18.4	3.4	84	20.8	3.1	3	6.4	2.3	4	4.6	2.6	4	10.3	2.3

Interviews

The interviewees mentioned the use of two fishing techniques to catch blanquillo. Before 2015, fishers used the "corral", wooden cages immersed in shallow water, a method probably copied from Brazil. In this case, a fisherman positions himself on top of a wooden box at door height and holds a piece of bait with his hand, dropping it in the water inside the corral to attract the fish. Besides blanquillo, two other species are captured in small quantities, *Pimelodus blochii* and *Cetopsis* spp., which are both discarded. After several blanquillos enter the corral the door is closed and the fish is removed by hand and gutted. This fishing method was invariably applied at a shallow depth, close to the river bank. As the years passed, blanquillo fishing evolved, improving efficiency and reducing costs. Fishing 2016 onwards was done also applying a fairly easy procedure: the viscera of chickens together with the remains of bovine viscera and fat were tied together on a short stick and placed below the water surface. The fish are immediately caught lifting the stick quickly out of the water and into the canoe. Other fishers caught the fish by hand holding the decomposing meat between their legs, a method also described by Iriarte & Marmontel (2013a).

Formerly, most of the fishers used what is locally known as ¨hot bait¨, which are either chicken or bovine viscera, bought at slaughterhouses, or carcasses of wild animals such as capibara (*Hydrochoerus hydrochaeris*), caimans (*Caiman yacare*) and, eventually, dolphins (*Inia g. boliviensis*). Four of 24 interviewed fishers confirmed that dolphin meat was occasionaly used before 2015. According to the interviewees, the blanquillo capture success is positively related with the degree of bait decomposition and its fat content. Bovine or chicken viscera are mostly obtained from the localities of Bulo Bulo, Ivirgarzama or Shinahota (Figure 1) and from there shipped to Puerto Villarroel or transported by land. Fishing is carried out generally at night, as blanquillo is nocturnal. Fishers who are frequently engaged in blanquillo fishing mention that hot bait became difficult to obtain after 2015, due to controls by the municipal administrative authorities that exist in slaughterhouses,

and increasing prices. For example, a bucket of chicken viscera known as "gallinacea" weighing approximately 20 kg ranged between 14 and 43 US$ in 2017, whereas in 2014 the cost was only 4 US$.

As a response to governmental restrictions and regulations and the high costs, after 2015 blanquillo was increasingly caught with so-called "cold bait" or fish offal, consisting of the discarded heads and viscera of large catfish, mainly *Pseudoplatystoma* spp., *Phractocephalus hemioliopterus* and *Zungaro zungaro*, and of *Colossoma macropomum* or *Piaractus brachypomus,* which are considered to have a high fat content. The use of fish offall became commonplace in 2016 and outweighted the use of hot bait. Moreover, fish caught with hot bait in 2017 was often rejected by the salesmen and retailers because the fish meat thus obtained quickly acquires an unpleasant odor. Fishers and merchants mention that the use of fish offall reduces pollution in the rivers since the fat content of this bait is lower, and bait remains (heads) are buried or left on the banks of the rivers, where they are consumed by scavenging birds such as vultures.

Mercury analysis

The mean weight of the blanquillo sampled for mercury analysis was 566 (± 265) g (range 320-1150 g) and total length was 40 (± 4) cm (range 35-49 cm). Total mercury concentrations detected in muscle tissue were between 0.03 and 1.3 mg/kg ww (mean 0.31 ± 0.31 mg/kg ww). Five individuals (equivalent to 20% of the sample) showed mercury concentrations above the limits recommended by the WHO (0.5 mg/kg ww).

DISCUSSION

This study shows that catch data obtained by participative monitoring reflect mostly fishing of large highly valued species (type A), whereas the official landings record all fishing types, including the blanquillo fisheries. The integrated methodological approach adopted, combining onboard registration of catches with landing records and a market study, allowed for a more accurate description of some of the key actors in the food chain of this Amazon fish species.

Blanquillo fishing in the Bolivian Amazon started probably around 2008, almost a decade after its first appearance in Brazil (Estupiñan *et al*. 2003; Gómez *et al*. 2008; Brum *et al.* 2015, Iriarte & Marmontel 2013a). The introduction of this new fishing technique in Bolivia was probably copied from neighboring countries and from then on exploitation was fueled by a steadily growing local and regional demand for low-value fish meat. These fisheries boomed in the second decade of this century responding specifically to the demand for low-priced fish in Cochabamba city, known for its low fish consumption figures (Wiefels 2019) and high unsatisfied demand for fish meat. The increase was also driven by an impoverished fisheries sector in a region with little other labor opportunities besides harvesting of aquatic and forest resources (fish, timber), accessible using the river as single transport route

towards the northern Bolivian Amazon. It apparently involves the recent inclusion of peri-urban town dwellers who have limited employment opportunities. Blanquillo fishing also appeared in an adverse political context with a deficient fisheries regulation system and weak law enforcement. Another factor is the annual closure of fishing implemented by regional authorities during the high-water season, which encourages fishers to catch fish without having to use large easy-to-control fishing boats. This type of fishery ban aims at protecting fish during their reproduction phase, but curiously enough can have negative impacts on fish resource and habitat conservation (Van Damme *et al*. 2011, Correa *et al*. 2014). In the study area, it temporally interrupts family income, and has led to the incursion of fishers in two informal and/or illegal activities: blanquillo fishing (present study) and timber extraction.

In Colombia, blanquillo became a substitute for the former popular, but now overfished, capaz fish *Pimelodus grosskopfil* (Mosquera-Guerra *et al*. 2017), whereas in the Peruvian Amazon it was the decline of the long-distance migratory gilded catfish (*Brachyplatystoma rousseauxii*) yields that caused the increased capture of blanquillo (Garcia *et al.* 2016). Although Van Damme *et al*. (2019) described the collapse of gilded catfish populations in the study area, caused by the interruption of their migration routes by downstream Jirau and Santo Antônio dams (Hahn *et al*. 2020), there was no evidence of a causal or perceived relationship between the decrease of gilded catfish and the increase in blanquillo fishing.

Blanquillo is an abundant and widely distributed species in the Bolivian Amazon. However, throughout the study period the species hardly appeared in the catches recorded by type-A commercial fishers; some underreporting of this illegal catch may have occurred. Moreover, the landing data show there is an obvious difference between fishers. For some type-B fishers commercial fishing for blanquillo is probably considered as an emergency catch in case of unsuccesful yield of the traditional species during a fishing trip. At least 25% of the blanquillo landed during the study was captured in combination with medium-sized species. However, the larger part of the blanquillo (70%) is caught by type-C fishers specialized in blanquilleo. Blanquillo fishing experienced a boom because it provides some comparative advantages for these fishers. They are more informal and non-associated, fish closer to the landing site and during shorter time intervals (maximum two days) than the multispecies fisheries. Blanquillo fishing also has a more predictable success, being determined mainly by bait quality, and less so by the climatic and hydrological conditions affecting catch per effort using gillnets and hooks in the multispecies fishery. These factors explain why this type of fishing has grown quickly after its initial introduction as an attractive supplement to, or replacement of, traditional fishing, as occurred in Brazil (Iriarte & Marmontel 2013a). Despite being an illegal activity, the blanquillo landings appear in the official landing records because the salesmen need the SEDAG-receipt to be able to pass transport control and commercialize the catch, and because local authorities are permissive in their control. The best fishing season for scavenger species, according to the interviewees, is from October to February, when landings are not recorded at all due to the official fishery ban. This may partly explain why the reported landings are still well below the figures recorded in markets, which moreover receive fish from non-traditional landing sites.

After 2012, there was a significant drop in recorded blanquillo landings. This can have two reasons. Either the fishers did lose interest in blanquillo fishing, responding to the *de facto* fishing prohibition of this species enacted at the end of 2012, or they still caught the fish but used alternative market strategies. After a short recovery of the blanquillo fisheries in 2014 and 2015, probably responding to a relaxed fishing control, another significant drop was observed in 2016, probably as a result of the only existent written reference to the prohibition of blanquillo transport (and thus also fishing) by the regional authorities, which came along with a stricter control. However, notwithstanding these fisheries bans, the market studies showed that blanquillo was still sold in urban markets of Cochabamba city in 2015, and was also very popular in the fish markets of intermediate cities in 2017.

Blanquillo fishing is problematic and debated internationally for various reasons: A first often quoted argument is the possible risk of its consumption to human health (Mosquera-Guerra *et al*. 2017). High mercury concentrations in the blanquillo meat, often above the WHO-limit for safe consumption (0.5 mg/kg), were recorded in Colombia (Salinas *et al*. 2014, Nuñez-Avellaneda *et al.* 2014, Mosquera-Guerra *et al*. 2017) and Brazil (Beltrán-Pedreros *et al*. 2011). Although it is generally described as an omnivorous species (Garcia *et al*. 2016; Froese & Pauly 2019), blanquillo has distinct scavenger habits feeding on carcasses of other species (Pérez & Fabré 2009, Valente-Aguiar *et al.* 2020), and thus might biomagnify mercury (Castro *et al*. 2016). These findings were used as an argument to prohibit its capture or consumption in some Amazonian countries or regions. In Colombia, marketing of blanquillo meat, much of which originates from Brazil, was prohibited (Trujillo *et al*. 2020). In southern Peru, its capture was forbidden in the upper Madre de Dios River basin, a gold exploitation area, because of the risk for human health due to high concentrations of Hg found in its meat. On the other hand, although blanquillo was shown to accumulate high concentrations of Hg in the Brazilian Amazon well above the WHO-limit (Beltrán-Pedreros *et al*. 2011, Bastos *et al*. 2015), this was not used as argument to forbid its fishing and/or consumption. In the present study, mercury exceeded WHO limits in only 15% of blanquillo individuals. Its consumption so far was not considered a risk for human health by the national authorities. Moreover, the meagre application of standard protocols for data collection and disperse interpretation of mercury data in Amazon countries, as well as the absence of a basin-wide policy on the fishing of scavenger species, makes the formulation of local recommendations on blanquillo consumption more difficult.

There are three further problems with blanquillo fishing, often quoted in literature, and particularly relevant in the study area. The first is the water pollution caused by introducing domestic animal waste in the water, releasing liquid and solid organic residues (Beltrão *et al.* 2017). This environmental risk identified in some Brazilian water bodies was evaluated as argument against blanquillo fishing by Botero-Arias *et al.* (2014). According to these authors the decomposing bait can negatively affect water quality, and can pose a risk for river dwellers who consume the river water for drinking, as was described by Beltrão *et al*. (2017) in Brazil. Bolivian legislation prohibits the introduction of animal waste in open water courses (Environmental Law No. 1333 of the 27th of March 1992, Arts. 39 and 107, and the Normative on Management of Solid waste Art. 91), but there are no specific regulations on the

use of bait. In the present study, one of the proposals of fishers to use fish offal as alternative bait, and in this way avoid total prohibition of the activity, is precisely the lower water contamination using this type of bait.

Another possible risk associated with the fishing and consumption of blanquillo is related with the rapid decomposition of the meat when captured using bait, also reported in Brasil (Brum *et al.* 2015). Blanquillo fish meat is often rejected in the studied markets by the authorities verifying food quality, either the National Service for Health and Food Safety SENASAG, or municipal authorities. In the study area, the high temperatures (28-30 °C) and the high humidity (>90%) prevailing throughout the year affect negatively blanquillo conservation. Fishers capture relatively large amounts of blanquillo in a short time and during the day, generally delaying the gutting. The consumption by blanquillo of decomposing bait with high fat content, combined with a deficient cold chain and high solar radiation, induces quick fermentation in the fish stomachs and negatively affects meat quality. Because blanquillo consumption puts at risk the health of final consumers, the competent public authority has discouraged the marketing of meat of this species at regional level. However, the low level of enforcement due the lack of a formal prohibition, and the high economic return obtained by fishers and salesmen explain the general failure of this type of prohibition.

A final problem has led to fierce debate amongst the industrial fishing sector and conservationists. According to the latter, the blanquillo fishing technique has a negative impact on aquatic fauna (dolphins, caimans, capibaras) occasionally used as bait in Bolivia (Escobar *et al*. 2020) and in other Amazon countries (Estupiñan *et al*. 2003; Loch *et al*. 2009; Botero-Arias *et al*. 2014; Brum *et al*. 2015; Iriarte & Marmontel 2013a, Franco *et al*. 2016). However, although some interviewed fishers confirm the occasional use of dolphin meat as bait, in the present study area it has been difficult to evaluate the impact of blanquillo fishing on aquatic wildlife because of the evasive behaviour of fishers, who hide their catch or bait used. Also, the combined use in the field of different baits, such as domestic waste, fish offall and occasional wild meat, makes it easier to camouflage illegal practices, making control more difficult. In Brazil, Colombia and in southern Peru blanquillo fishing and/or consumption has been forbidden during variable time intervals due to its supposed or demonstrated impact on aquatic wildlife. In Brazil, the main data source sustaining the five-year fishing moratorium originated in the Mamirauá Reserve where Da Silva *et al*. (2011) estimated an annual loss by blanquillo fishing of 1 650 dolphins, and Mintzer *et al*. (2013) and Da Silva *et al*. (2018) showed a significant decrease in natural population size in this area. However, the extrapolation of these data to the overall Brazilian Amazon was questioned by Beltrão *et al*. (2017) and Pimenta *et al*. (2018), both emphasizing the high level of uncertainty on the real number of dolphins sacrificed in blanquillo fishing. In Bolivia, there is no official data on the use of dolphin bait, and the National and Regional Authorities failed to show evidence when it was called by public opinion to gather evidence.

These precedents show that the problematics of fishing scavenger species extends far beyond the challenge of merely protecting aquatic wildlife used occasionally as bait. Besides this risk factor, both human health affectation and environmental contamination should be considered in an integrated way for the management of

these fisheries. In contrast with the Amazonian multispecies fisheries which are traditionally managed through a combination of fishing gear restrictions, closed seasons, access restrictions and fishing agreements (Ruffino 2014), blanquillo fisheries need different management strategies. They are monospecific, focus on a low-value species, use a specialized fishing technique, and are practiced in a remote area by individual non-organized fishers. Fishers landing only one species may be more reluctant to accepting management rules, and have little motivation or possibility to shift towards other species. Because they belong to the poorer social strata, the prohibition of the capture of their target species might have significant social consequences. These specialized fishers are not embedded in traditional fisher society, generally do not participate in co-management initiatives, are difficult to track and often suffer a lack of alternative income sources, in contrast with legally established fishers which have more capital and can adapt more easily to changing management rules (see Iriarte & Marmontel 2013a, Brum *et al.* 2015).

One of the key points in socio-ecological terms is the heterogeneity observed among fisher groups, each using different fishing practices, having different motivations, and showing different degrees of compliance with regulations. The blanquillo fishers are 'outsiders' of sort, yet their actions affect how fishing in general is perceived by the general public and by the public stakeholders, and having consequences for the broader group of formal fishers. These marginal fishers, who are responsible for 20% of total catch and more than 90% of blanquillo catch, agree to enter into discussion with other organized fishers, but there are also many challenges to overcome before molding this type of interactions in a more formal agreement eventually mediated by the public stakeholder.

Precautionary measures for the conservation of Amazonian dolphins and their use as bait generally fall within the realms of restrictive legislation and law enforcement, alternative bait use, or incentives for economic alternatives (Mintzer *et al.* 2018). In the study area, a restrictive top-down approach is commonplace, but is based on weakly founded arguments such as low fish quality and the supposed negative impact on dolphin populations and enforcement has been limited by the lack of a formal legal instrument. As an alternative, local fishers argue that blanquillo fisheries might be converted to an environmentally friendly practice, through the introduction of best practices during fishing, refrigeration, transport and commercialization, as well as introducing fisheries quota, regulation of the type of bait to be used, and control of illegal fishing. However, this transition would ask a joint colaborative effort by public stakeholders and local actors. The change from hot bait (domestic meat waste) to ¨cold¨ fish offal has also been proposed by the fisher organizations, and was recently (2021) agreed upon in a governance framework, but requires an additional commercial transaction between recognized fishers and the transport of this offal over relatively long distances to users, making it not economically attractive and socially exclusive.

The main challenge is to integrate the monospecific and multispecies fishery management strategies in one overall ecosystem-based approach (Goulding *et al*. 2018), viewing the fishery as a socio-ecological system (Ostrom 2009, Fulton 2021) coupled with a co-management strategy which might complement the traditional top-down management. This approach should not only focus on the posible negative

side-effects of illegal fishing practices, but also on the human dimension and the social outcomes of fishery regulations. Ecosystem-based fisheries management, in combination with agreed fishery regulations, alternative economic incentives and educational programs might trigger the change of the blanquillo fishery to other sustainable higher income activities. The active involvement of the fisher organizations, which have shown some potential in internal control of fisheries activities, might be a key element in this strategy.

In conclusion, the present study shows there is an overall need for more consistent and inclusive fisheries regulations in the Bolivian Amazon, as a way to protect aquatic fauna, avoid environmental contamination and secure human health. A precautionary approach and a stepwise prohibitive legislation, supported by the legally established fishery organizations, may avoid further escalating of blanquillo fisheries and unpredictable consequences for wildlife and human welbeing. In this framework, fishery management decisions will have to be taken under conditions of uncertainty and should be based on the best scientific evidence and on cooperation within an appropiate fisheries governance framework.

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