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"Paiche reigns!" species introduction and indigenous fisheries in the Bolivian Amazon

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Abstract

Species introduction, combined with changing access rules, increasing demand, and new road and dam infrastructure, are contributing to remarkable changes in Bolivian Amazon fisheries. This paper examines community responses to the appearance of a commercially valuable introduced fish species, *Arapaima cf. gigas* ("paiche") in the Bolivian Amazon. Until the end of the 20th century, fisheries in this region were relatively low intensity, focused in rivers on a small number of native large-sized species by an urban-based commercial fishing fleet, and in floodplain lakes on a high diversity of native medium-sized species for subsistence by rural indigenous communities. In the seventies, *Arapaima cf. gigas* was introduced from Peru and has since invaded a significant portion of the Madre de Dios and Beni basins in northern Bolivia. This species now represents up to 80 % of commercial catches for the region. Occupying primarily floodplain lakes, many of which are located within indigenous territories, it has created economic opportunities and stimulated conflicts. The evolution of fisheries in one indigenous Tacana community is described, and the perspectives of local fishers are explored. Results suggest that while the new resource has strengthened incipient community-level organization, the current capture strategies and management mechanisms may not be conducive to sustainability or equitable distribution of returns. Commercial fisheries targeting a set of native species have been replaced by a single-species fishery in this community, raising questions about how the changes both in the resource-base and associated livelihood strategies are impacting system resilience. Ecosystem impacts of the introduction remain unclear. *Paiche* is viewed both as a potential threat and an opportunity by indigenous fishers. The management of this introduced species for a maximum social benefit and minimal environmental damage are topical concerns for communities and government actors and should be treated carefully considering local and broader, regional-scale implications.

Keywords: Artisanal fisheries; Bolivian Amazon; Introduced species; *Arapaima cf. gigas*; Adaptation; Resilience

Main text

Introduction

Globally, fisheries are increasingly vulnerable to a multitude of threats, resulting in an interest in fostering adaptation among fishing peoples (FAO 2007; Daw et al. 2009). Introduced species are considered one of the prime factors that contribute to the decline of native species and significant negative impacts on fishery-related livelihoods globally (Clavero and García-Berthou 2005; Shackleton et al. 2007). However, where communities have been able

to make use of non-native aquatic species, these can sometimes also present a new, economically valuable resource, as is the case of a variety of introduced fish species in the reservoirs and rivers of south-central Brazil (Hoeinghaus et al. 2009), and the Nile perch in Lake Victoria (Mkumbo and Marshall 2015). The Nile perch, in particular, has supported remarkable economic development in central African lakes after its introduction in the late 1970s (Mkumbo and Marshall 2015), though its negative environmental impacts and inequitable social benefits have long been criticized (see for example Von Kaufmann 2007; Balirwa et al. 2003). This paper presents a case where introduced species are providing economic opportunity, and explores adaptation strategies and resilience capacity by local fishers.

Resilience and adaptation are key concepts in understanding and addressing the challenges that introduced species present to small-scale fisheries. The resilience concept (Holling 1973) describes a cycle whereby ecosystems, human systems (communities) and management systems absorb unexpected shocks and perturbations without collapsing or otherwise entering an intrinsically undesirable state (Berkes and Folke 1998). In other words, resilience is the capacity of a whole system to respond to disturbance and shocks, while maintaining essential functions (Walker et al. 2004; Folke et al. 2005; Folke 2006). In a fishery, resilience is pertinent for management institutions, fishing communities, value chain, and the ecosystem in which the fish live (Charles 2005). There is a growing interest in enhancing the resilience in fisheries (Allison et al. 2007). In this context, adaptation is based primarily on groups managing the fisheries resource system by intentionally or unintentionally moving thresholds within the system (Walker et al. 2004). In the case of species introduction, adaptation in fisheries includes not only thresholds related to the relationship between resource users and resources in an existing and potentially 'knowable' system, but also new interactions and thresholds with unpredictable outcomes resulting from the external driver. It is important to consider the wide consequences of disturbances and adaptation to external drivers on fisher well-being and to better understand how these strategies are implemented and feed back into the resilience of fisheries as a social-ecological system (Coulthard 2012); these elements are critical to informing effective resource management planning.

Arapaima cf. gigas (*paiche* in the study area; *pirarucú* in Brazil; hereafter referred to as *paiche* in the text), the world's largest scaled freshwater fish, is native to the middle and lower portions of the Amazon Basin, where it has been largely overfished, but is not native to the Bolivian Amazon. *Paiche* was introduced to the upper Amazon headwaters of Peru in the 1960s (Carvajal-Vallejos et al. 2011), and first appeared in the Bolivian fisheries approximately 20 years ago. Currently it dominates the commercial catch in the northern Amazon region of Bolivia overall (Coca Méndez et al. 2012). Knowledge to date on the biological and ecological impacts of *paiche* introduction is presented in Miranda-Chumacero et al. (2013). The contributions of *paiche* to indigenous fisheries varies significantly at the local, or community level, and is likely influenced by a number of factors including access to floodplain lakes where *paiche* is present and abundant, adequate technology (gear and knowledge), connectivity to markets, and the mix of livelihood activities. Overall, high species diversity continues to be a key feature, both for subsistence and more recent commercial fishing in indigenous communities in the region surrounding Trinidadico. In a recent study by Argote et al. (2014), a total of 67 species were recorded in the fisheries catch for seven indigenous communities (including the study community of Trinidadico) over a one-month period. Native species landings were dominated by Characiformes,

Siluriformes, and Perciformes, with medium-sized catfish and piranhas of particular importance. It is not yet known if, or how, *paiche* affects the native fish communities in the region.

The *paiche* invasion is occurring in the context of a rapidly changing social environment of land reforms, increasing urban and rural populations and expanding road access in Bolivia's northern Amazon region. These intersect with an increasing indigenous ownership, political decentralization, and a largely undocumented and unmanaged fishery. This complex context circumscribes the potential adaptation strategies and capacity for resilience displayed among fishing communities in the region. Indigenous groups have traditional access rights to natural resources, recently recognized by the national government, and a vested interest in their sustainable use. However, they face significant challenges in developing and implementing resource management strategies, including low technical and financial capacity and weak monitoring capacity. A better understanding of the range of social and biological impacts of the *paiche* introduction, and of local priorities and underlying values concerning aquatic resource exploitation and conservation, could provide useful insights as to how local fisheries have adapted to change, and inform appropriate development strategies.

This study presents some local views about the social and ecological impacts of *paiche*, and its role in fishery development of one community, including perspectives from some of the most successful *paiche* fishers in the region thus far. It explores how people in an indigenous community perceive and act in response to an external driver, in the context of changing governance frameworks at different scales, and identifies the factors which contribute to adaptation and resilience in the local fisheries system.

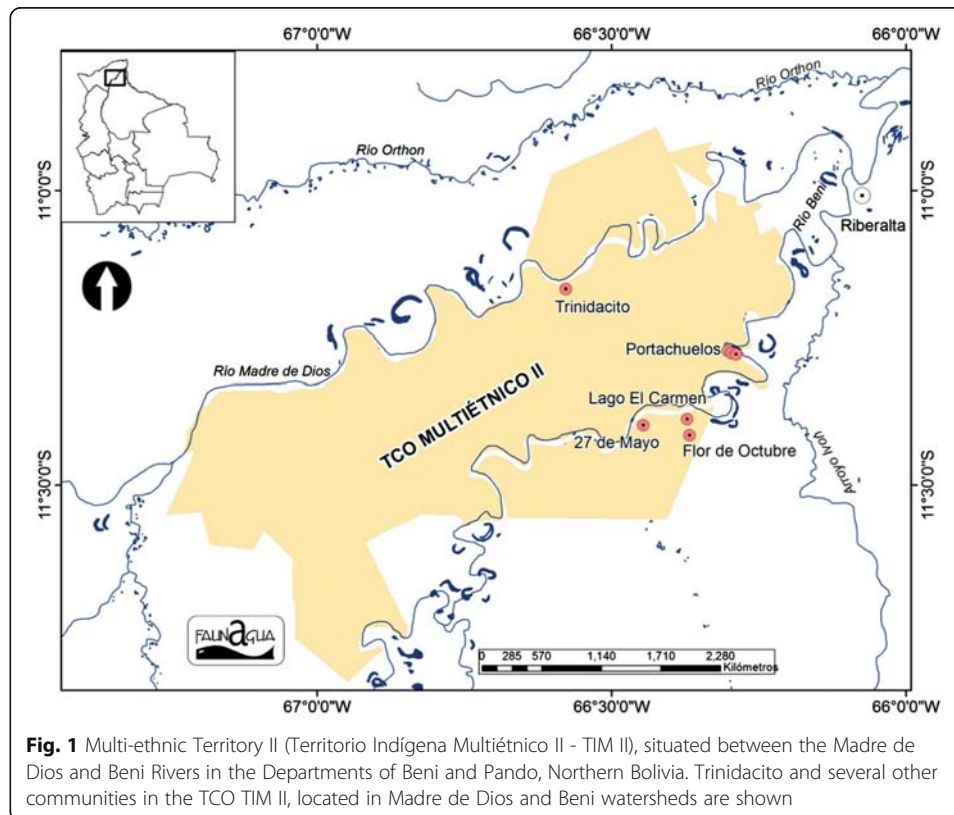
Methods

Study area

The northern portion of the Bolivian Amazon is an area of about 100,000 km², and includes the departments of Pando, Beni (Vaca Diez province) and a portion of La Paz (Iturralde province). An estimated three-quarters of this is upland tropical forest (Ibisch et al. 2003), but over 16 eco-regions are reported (Paramo 2005). The rivers, headwaters of the Amazon Basin, are home to a high diversity of fish species (Carvajal-Vallejos et al. 2014), and are considered of high ecological significance (Ibisch et al. 2003).

Indigenous communities in the Bolivian Amazon are largely organized in Communal Territories of Indigenous People (locally "Tierras de Comunidades de Origen" or TCOs), mostly located in forested areas, often close to rivers or lakes, with limited access to regional urban centres by unimproved roads or fluvial transport. In the region, these territories cover over 6921 km², with an estimated total population of 69,000 (Soria 2011). Livelihoods and subsistence are based on small-scale agriculture, fishing, hunting, and gathering of forest products, according to local availability of resources.

The study was carried out in the TCO known as "Multi-ethnic Indigenous Territory II" (hereafter referred to as TCO TIM II), located between the Madre de Dios and Beni rivers close to their confluence (67°0'0", 66°0'0" W, 11°30'0", 11°0'0"), and overlapping partly with both the Beni and Pando Departments (Fig. 1). The rivers approximate the borders of the TCO TIM II, and are used extensively for transport and fishing (by urban-based commercial fishers). Road access in the region was very limited, with improvements starting in 2007, and recurring interruptions due to seasonal rains and



floods. This area forms an extensive lowland floodplain system, at altitudes less than 300 m above sea level, intersected by numerous oxbow lakes (a shallow lake formed in a meander cut off by the drift of the main river in the floodplain) and with a pluviseasonal tropical climate whose dry season extends from May to September (Navarro and Maldonado 2005).

TCO TIM II is comprised of communities belonging to three distinct indigenous groups (Esse Eja, Tacana, Cavineño). This study focuses on the Tacana community of Trinidacito, located close to the banks of the Madre de Dios River, in an upland location (Fig. 1). Trinidacito is notable for its productive and locally managed commercial *paiche* fishery. The nearest urban centre is Riberalta, a regional river port city at the confluence of the Madre de Dios and Beni Rivers. This is the location of regional fish markets and exporters to national and international markets, and at the same time is the national centre for processing and export of wild-harvested Brazil nuts (*Bertholletia excelsa*) - the main contributor to the regional economy.

Surveys

Information was collected from published sources and reports on the general history of indigenous groups and fishing activity in the region. This was complemented by detailed interviews with people locally identified in Trinidacito as the oldest or most knowledgeable with respect to community and fishing history. Interviewees were selected by a combination of purposeful sampling of community and fishing leaders (direct observation), and an exponential, non-discriminative snowball method (Berg 1988); respondents were asked the question, “who are the most active and experienced fishers

in the community?" A total of 16 men and one woman were interviewed between August 2011 and June 2013. In many cases, fishers' wives also participated in and contributed to the interviews. Data were transcribed and organized using NVivo 10 software, according to key themes, historic timelines, consensus regarding events and perspectives, etc. Drawing on methods from human ecology, an adapted process of progressive contextualization (Vayda 1983) was used in the analysis of interview data to organize the story of fisheries participation, *paiche* introduction and the local responses. Findings were compared with data available from comparable studies in other parts of the Amazon Basin.

Results

Historical perspective

Rights to natural resources were historically concentrated in large rubber-tapping estates known as *barracas*, held by a very small group of elites (Garland and Silva-Santiesteban 2004; Pacheco 2003). Following the Second World War, the *barracas* underwent reorganization towards other extractive activities, notably Brazil nut harvesting (Cardona 2012). Beginning in the 1990s, decentralization of government, re-assignment of land rights, and establishment of indigenous territories (Indigenous Community Territories - TCOs) all contributed to the development of modern indigenous settlement and livelihoods in the region. Current fisheries result from the combination of both historically practiced traditional subsistence activity and new commercial opportunities.

The recognition of communal rights for exclusive access and traditional use of natural renewable resources located within the TCO territories was included in the national land reform of 1996 (Garland and Silva-Santiesteban 2004). However, the rules defining and permitting commercial activity and individual extractive activity within this framework are not clear. Specific regulations on natural resource exploitation and sustainable management at the level of the TCOs continue to evolve, including for fisheries, as their commercial potential is increasingly recognized. A new national fisheries law proposal, which involved a high level of consultation with fishers in its development, is currently pending approval and will provide additional clarity on resource access rules.

There is very little documentation for commercial fisheries in northern Bolivia prior to the 1980s, but fishing activity likely began to increase during the slow end (1970s–1990s) of the rubber industry (Cardona 2012). At this time, a variety of communities (indigenous and campesino) living on *barracas* abandoned them to create new settlements and pursue previously disallowed independent agro-extractive livelihoods (Henkemans 2001). More communities were located in proximity to urban centres and people increasingly participated in the regional market economy (Pacheco 2003). The remaining *barraca* estates continued to dominate the landscape, mainly through the Brazil-nut industry, and controlled access to fisheries in many of the lakes and smaller streams until well into the 1990s (Cardona 2012). Between 1980 to mid-1990s, the focus of commercial fisheries in the region was the larger-bodied catfish and other high-value fish in the main rivers, carried out mostly by small to medium sized boats (Van Damme et al. 2011). The floodplain lakes were used by local communities for subsistence, while commercial fishing was carried out by urban-based boats, as they travelled along the main rivers and fished opportunistically in accessible lakes to supplement their catch from the river. These boats also

purchased fish from the communities or traded in exchange for supplies. A new network of river traders emerged as the *barracas* system of community supply stores declined and road access continued to be very limited (Henkemans 2001). These new changes likely contributed to the formation of *habilito* relationships in the community-based fisheries, in which intermediaries provide credit for operational costs of harvesting in return for exclusive right to market the fish catch. This continues as a dominant factor in most of the commercial fisheries in the region.

In general, the participation of indigenous fishers in commercial activity in this region was relatively limited in terms of overall production volume, increasing rapidly only in the past 10 years. Prior to the emergence of the *paiche* fishery, commercial fisheries in the region focused on the exploitation of a handful of large-sized species in rivers and lakes such as *Colossoma macropomum* (local name *pacú*), *Pseudoplatystoma* spp. (local name *surubí*) and *Zungaro zungaro* (local name *chanana*) (Van Damme et al. 2011).

Arapaima cf. gigas (paiche), a new resource

The regional fisheries picture changed dramatically from the 1990s onward, due in large part to new fisheries based on the introduced *paiche*, currently making up over 60 % of total landings (by weight) for the Riberalta region, 40 % of indigenous commercial landings in the region (Coca Méndez et al. 2012), and 82 % of landings in Trinidadcito (Argote et al. 2014). *Paiche* may also represent a number of new threats to the native fish resources (Van Damme et al. 2014).

Until very recently, *paiche* meat was sold in the national urban fish markets only as fillets of *surubí* catfish; while texture, taste and appearance of the two fish are distinct, consumers are not well-informed and do not usually discriminate between these species (Van Damme, personal observation). For the past three years, it has begun to appear in upscale restaurants and is now sold in some fish markets as *paiche*. While the main markets are regional urban centres in Bolivia (La Paz, Santa Cruz, Riberalta, Cobija) significant amounts of *paiche* are also sold fresh or salted to intermediaries who export it illegally across the border from Guayaramerín to Brazilian markets (Coca Méndez et al. 2012) where it is highly valued.

Local actor perspectives in Trinidadcito

Trinidadcito is a Tacana community, established in the early 20th century as a *barraca* for rubber extraction. It was governed by a local boss who lived in the community. A variety of *caciques* (local people appointed to leadership and regulatory roles) directed and financed fisheries activities until the community became involved with the indigenous movement around the time of the regional indigenous census in the early 1990s. The community was included in the creation of the TCO TIM II, following the Instituto Nacional de Reforma Agraria (INRA) law in 1996. The community is approximately 90 years old, among the oldest modern settlements in Pando Department, with 350 residents from 73 families. The main livelihood activities include seasonal harvest of Brazil nuts (January–March), fishing, agriculture and occasional participation in gold mining activity on the Madre de Dios River (Ledezma, unpublished data 2011). The community has one health post, one school, and unpaved road access to Riberalta (since 2006–7), one cellphone communication tower, recent wells for potable water (2013), and several gas-powered generators that are used sporadically.

Compared to other communities in the study region, Trinidacito has a relatively long history of local participation in commercial fishing activity. According to interviews, the formation of the oxbow lake Lago Mentiroso, currently the main fishing location for the community (Argote et al. 2014) and one of the most productive lakes in the region (Carvajal-Vallejos, unpublished data), was accelerated with the help of human modification (channel-cutting) by crew from one of these commercial boats around 1925. Consequently, it continues to have relatively high connectivity to the main stem of the river, facilitating entry of boats and, as a result, emergence of conflicts. Participation in commercial fishing activity is reported to have begun approximately 50 years ago, with a low level of organization and uncontrolled access by outsiders. For two decades (1960–70s) there was sporadic, uncontrolled entry into local lakes for commercial fishing by fishers from Riberalta and nearby communities. At this time, the lake fishery was based on the native species, mostly *pacú* and *pacupeba* (*Mylossoma* spp.), and fish were sold to medium-sized commercial boats (two person crew, and holding capacity of up to 10 tonnes) that were frequently travelling on the Madre de Dios River, carrying supplies and product to and from the *barracas*, occasionally fishing in the river and lakes, or trading goods for fish from local residents. Several of the older fishers describe fishing in cooperation with urban-based partners or investors during this time. Hook and line was the gear most frequently used, those who could afford them also used gill nets (500–1000 m in length). Interviewees reported very high abundance of fish during this period (for example, catches of 90–100 *pacú* (8–10 kg size) per 300 m of gill net). Less commercially desirable fish, such as *corvina* (*Plagioscion squamosissimus*) for example, were used locally for subsistence or discarded as by-catch (to “not waste salt”). The price at this time was very low, at Bs. 2 per kg of salt-dried fish (roughly equivalent to US \$0.10).

At the same time as the regional population grew, the demand for fish increased, rubber-tapping activities declined, local interest in commercial fishing grew, and conflicts arose among rural indigenous and urban-based fishers. In the 1980s, triggered by destructive fishing practices of outside parties, the community organized into an association and lobbied successfully for exclusive access to the lagoon in exchange for a concession fee paid to the regional government, which initiated community management. Concession fees were commonly used in the region in the 1980s and 1990s for licenses to exploit different forest-based products, including rubber, Brazil nuts, hardwoods, etc. Interviewees describe a significant effort over time to organize and protect resource access rights. The founding president of the fishing union reports that a concession of Bs. 700 (between US \$16.00 and US \$35.00 at the time) was collected from the fishers' annual royalties and paid to the National Centre for Fisheries Development (CDP) for five years, from 1980–1984. A later president states that a concession of Bs. 1000 per year (approximately US \$ 294.00 at the time) was also paid to the municipality for a period of two years in the early 1990s, around the time that interest in fishing the *paiche* began to develop. With the exclusive rights guaranteed through this concession, the community was able to legally control the incursion of outside fishers by confiscating their gear and imposing fines. One male fisher comments,

“Those outsiders, those fishermen, how do you call them, the ‘professionals’ from Riberalta, were always coming in and plundering us...Problems arrived to them with

all of this. They were fined and all of those things...we would confront them and take all the material they had. To get it back, they had to pay us a fine.”

Paiche appeared around Trinidadcito sometime in the late 1980s (reportedly seen in Lago Mentiroso as early as 1984) but was not commercially exploited until at least 1990 when a small group of outside fishers (possibly from Brazil) were observed catching and transporting the *paiche* fresh on ice. Within a few years (1992), a group of three local male fishers began catching *paiche* and selling it salt-dried to two buyers from Riberalta, for Bs. 2.50–3 per kg (US \$ 0.67–US \$ 0.81 at the time). Other buyers on the Brazilian border (Guayamerín) subsequently began paying Bs. 5 per kg (US \$ 1.35 at the time). At this time, *paiche* was in high demand and extremely over-exploited in Brazil.

Likely triggered by this demand and responding to a new national legislation for regularizing associations, the local fishing association was registered in 1994 as a working union, with 14 original members. This union grew to more than 40 active members, described as very well organized and effective at regulating the activity, collecting fees and distributing permits. An unprecedented increase in *paiche* fishing and an accompanying decline in the abundance of native species were observed. *Paiche* production peaked for several years; one younger male fisher who arrived in 2001 comments that at this time there were many more *paiche* in the lake, and more people in the fishery (as high as 60 active members).

In the early 2000s, some regulation of commercial fisheries at the Department level occurred, following a similar model to that established by the CDP in the 1990s, and including an agreement for permanent exclusive use of the lake. This is documented in the written records of the fishing union (2004–2009) (Herrera et al. unpublished observations), and included a requirement for an expedition permit (*faena*), valid for 30-day periods. Additionally, fishers paid a royalty, based on the total catch volume, (approx. 10 % of the sale value, or 0.20 Bs./k (US \$ 0.05 at the time)). Similar to the earlier arrangement with the CDP, registration and fee collection for permits and royalties was carried out by a locally appointed monitor for the union who received a percentage of the royalties as a salary, and delivered the rest to the departmental office, located in Riberalta. This system was seen as effective and positive by many fishers interviewed. According to one male fisher,

“In the past there were norms...one had to have a license, permission to enter the lake. Because in these licenses it said even in which boat one would be fishing. How many kilos, with what material. These licenses were used for one entry for fishing, nothing more. A permit, as you could call it. If you wanted to go in again, you needed another permit...I authorized people and gave them the papers...and there was another paper where kilos were recorded...”

Overlapping with this time period and jurisdiction, the creation of the TCO TIM II reserve in the 2000s led to a new process of negotiating, whereby agreements for each of its 34 communities were made to guarantee their access to traditional resources and land. Within the framework of TCO regulations, Trinidadcito secured exclusive rights to Lago Mentiroso, due to the history of use and existing agreement with Pando Department. Resulting from this, the royalty payment was to be transferred to the local community association (who would pay a portion to the TCO TIM II government) and a third fee, monthly

membership dues for the fishing union (Bs. 10 or US \$ 2.70 at that time) was also instituted, though there was a period of confusion regarding the payment of fees, and legitimacy of the different agencies to collect them.

In 2010, the union was re-registered as a productive association, to align with changing TCO regulations and national laws governing productive associations and professional unions. During this time, the fisheries office distributing permits moved significantly further away to the Department capital of Cobija and the collection of permit and royalty fees became more sporadic, with payment of fees becoming highly dependent on local enforcement. At the time of interviews, a recent change in association leadership and doubts about paying the fees to municipal government meant that none of these fees had been paid in at least a year. The framework for resource management is in transition as the TCO government becomes more active in its governance and establishing regulations and resource management provisions. In the meantime, the enforcement officer is no longer active, resulting in an increase in unregulated fishing activity without payment of royalties, a renewed invasion by outside urban-based fishers and an increased call for seasonal closures. The local fishers report dissatisfaction with the current lack of regulation on the fishery:

“Nowadays people work without any documentation, no permits...Who authorizes the entry in the lake? In the past...the lake itself belonged to the community, but those who were doing the work of the fishery were unionized with all the appropriate documentation ...this was done so no one outside the community could come in, so there was work for people from here. So no one pirated. Now...anyone can come in...”

In 2007, road access to the community was improved, enabling faster transport to Riberalta (2 h) and a change in the *habilito* dependence, and fostering independence. Several fishers purchased motorcycles, and began transporting fresh fish directly to Riberalta markets in search of a better price. However, due to the high costs of credit and supplies required for paiche fishing, this also included setting up new networks of *habilito* with Riberalta buyers. Some buyers arrived by car and fishers reported that the main vehicle bought and carried 400 to 450 kg of *paiche* per trip, on average 3 times per week. Local estimates place the total number of *paiche* fished at 70–80 fish weekly (1000–1500 kg/week) during the peak production time of March – April (the beginning of the fishing season, after the Brazil-nut harvest). By 2012, *paiche* was almost exclusively transported to Riberalta by motorcycle and sold fresh, directly to large-scale intermediaries. Women in Riberalta, employed by these intermediaries, process and package the meat into large filets before its shipment by air to national markets.

Currently, the entire commercial fishery in Trinidacito is directed to *paiche*, while other smaller-bodied native species are reported to be fished for family consumption only, as secondary income for food, clothing, etc. “to sustain the family through the year”. Brazil nut harvesting continues to be a more profitable economic activity overall, providing the bulk of family income, used for improving housing or purchasing transportation.

According to local fishers, both native species and the *paiche* have decreased in abundance. According to the oldest male fishers in the community, a great deal more effort is now required to catch the native fish. The reduced effectiveness of hook and line has motivated some to use gillnets, including seine nets, which catch fish indiscriminately, one of the causes of “ending with everything.” The *pacú* and *surubí* fish are considered

top commercial species in other nearby communities; in Trinidadito these other species are utilized for subsistence and very occasionally for commerce.

“The *paiche* reigns! I would like only that they close this side [of the lake], locking it up, wrapping it up for two years. So that the countless thousands of kilos of fish will come here again. I haven’t fished those thousands of kg anymore. Just me! And we were 40 fishermen. He who fished least, weekly, arrived with 300 kg salt-dried, imagine the decline. He who fished least. It was a fantasy!”

“Heavily, they have diminished, in the case of the *pacú* at least. Back then, we caught *pacú* without need of gillnets. We’d catch 10-12-15 *pacus* in the day, just with fruit. Now there aren’t any. Since the presence of the *paiche*. There are a lot of *paiche*!”

In addition to access issues, the unequal distribution of benefits from the *paiche* fishery is one of the main conflicts. Overall, there is some debate at the community level over what to do with *paiche*, since it is seen as a revenue generator for only a few people, even though it is a communal resource. Some suggest re-establishing payments to the community association and creating more widely beneficial value-added processing activities. The recently amended TCO regulation (2013) now permits commercial fishing activity for a subset of communities through their local associations. Prior to this, only forestry and harvesting of forest products (under community management plans) were permitted. Individual economic opportunities are still not clearly recognized within this framework.

Trinidadito is the only community within the TCO TIM II with established local norms regulating the fishing activity, including specific rules for the exploitation of *paiche*. These include mandatory membership in the commercial fishing union/association, mandatory participation in monthly meetings, reporting of catch data, payment of royalty fees (until recently), and observation of fishery closures. Fisheries closures are determined according to perceived best seasonal periods for *paiche* exploitation, in coordination with other extractive and agricultural activities. Restrictions on gear-type inhibit gillnet use, unless for communal harvests (native species) for social or ceremonial purpose. A system of fines and exclusion set by the community leaders is applied for non-compliance with the regulations. There is some indication of a rule allowing temporary closures when it is perceived that the catch levels are declining. There are no rules or social norms regarding minimum size, or fishing *paiche* during the reproductive phase.

When asked about permitting the use of gillnets in the community (a practice commonly observed, but widely and emphatically prohibited) respondents’ opinions were divided. Gillnets are prohibited by both the TCO and community regulations, but over half the fishers were observed to be using them, as evidenced by the fisheries monitoring data.

“It is prohibitively [sic] prohibited, the use of gillnets. They aren’t allowed in the regulation...for the TCO. They are prohibited...everyone knows they are prohibited. Prohibitively! [sic].”

“No...it scares the fish, and the gillnets destroy everything. Even the cats fall in them! They pull up everything, even the anacondas!”

“It would be good to allow them to some degree, in a controlled manner, maybe twice a month or something.”

The reasons for not using gillnets include “fish learning to avoid capture” or being scared off, rather than potential over-exploitation. The clandestine use of gillnets is a secondary conflict which includes equipment robbery, from within the community and from outsiders, or ‘borrowing’ and leaving material somewhere else. Several fishers report having *paiche* gillnets stolen from their hidden storage locations close to the lake.

Other fishers commented on insufficient legislation or higher-level norms governing the fisheries activity, but reiterated the importance of local regulation and rules at the community level.

“Nowadays we don’t have norms, as you’d call them...there is no legislation... people are like this, some want them, others are not interested.... But we have [local] rules of course. For example, one has to obey the rules. One has to accept to be organized, to be an associate in order to fish. If there is a monthly membership fee, to pay it. One has to have permission.... One has to be affiliated and in good standing and accept all the conditions that are put in place by the internal rules... [The rules were made when] it was observed that rules were missing. But even rules don’t necessarily mean ‘responsibility’, as many people know, for example these fishermen and salt-dryers who catch *corvina* [less commercially important] and throw it away....because they don’t want to waste salt on it...”

In Trinidadico, *paiche* has seldom been incorporated in the local diet, although several families reported occasionally eating it as *chicharron* (fried in cubes), or beginning to include parts in soup. One respondent remarked that this resulted from copying ‘as we saw the rich ones do’. All interviewees indicated that *paiche* is important for economic activity; many also suggested that since its arrival the abundance of smaller-bodied native species has decreased.

“Well, the *paiche*, despite being an introduced species in the country of Bolivia, the *paiche* has come to bring us many sources of work to the communities and the fishermen who are also from outside. It is a very profitable source...It’s good...We have maintained it for years, by fishing in a sustainable way....with our more traditional materials from here....hooks and lines.”

“For me, *paiche* is good, that’s it...because you can even eat it, it’s good for selling, everything.”

“For me, it would be much better for there to be *paiche*. It’s what sustains, like I said. It never disappears completely, good fish, it can always be fished.”

Only two fishers indicated that *paiche* should be reduced or exterminated, to eliminate predation on the native species that are locally important for subsistence. However, these same two respondents are young, full-time professional *paiche* fishers, with limited experience fishing the native species, and could be looking for increased opportunity to fish *paiche*.

Discussion

The introduced *paiche* has significantly impacted local resource and governance systems since its appearance in Bolivia, in particular for the indigenous community of Trinidadico.

This research provides insights into adaptations to introduced species, which we describe as they relate to 3 focus areas: local organization in response to the external driver of *paiche*, its contribution to diversified livelihood strategies and implications for resource sustainability, and the influence of conflicts.

External drivers and local organization

The evolution of the local fishery management system in Trinidadcito has had several stages, responding to triggers from external pressures (conflicts with outside fishers and new species), developing within a changing environment of regulatory authority, and grounded in both historical formal relationships and local practice. This corresponds to the release, re-organization and exploitation components of the “Holling cycle” (Walker et al. 2004). The local fishery evolution shows evidence of adaptation as the community self-organized and learned to make use of the new resource. The community is now strongly engaged in commercial fisheries exploitation, based almost exclusively on *paiche*, with some local management, though conservation or sustainability practices for this are less evident than economic ones. However, while signs of over-exploitation of the native *pacú* and *pacupeba* fishery were becoming apparent in Trinidadcito in the 1990s, the *paiche* fishery was building, thus avoiding the phases of overt collapse and re-organization that could have been expected of the native fish fishery. The relatively large scale of the *paiche* exploitation and regulatory uncertainty after the collapse of the CDP and the creation of the TCO TIM II, triggered re-organization and a strengthened local union – primarily to secure continued exclusive community access to the resource, and regulate distribution of *paiche* fishing rights. Most recently, the new road access, a shift to fresh fish, and renewed uncertainty of upper level authority have created new value chains and possibly is triggering a new phase of institutional re-organization. Institutional experience at the community level, possibly building on the history and social learning of rigid organization from the rubber era, contributed considerably to the success of formal steps of organization. For example, interviewees in Trinidadcito identified the lack of a local regulatory officer as a key factor contributing to deteriorating conditions. Overlapping jurisdictions and unclear authority of different governance actors during the transition to TCO governance also appear to be causes for local concern.

Livelihoods diversification, conservation and sustainability

The *paiche* introduction has provided Trinidadcito an opportunity for livelihood diversification (to include a new species and fishery), which can be a resilience-building mechanism (Allison and Ellis 2001; Marschke and Berkes 2006). Indigenous fisheries of the TCO TIM II in the Northern Bolivian Amazon are part of a multi-faceted livelihood that has evolved from a history of subsistence hunting and gathering to include more income-generating, commercial extractive activities including rubber, Brazil nuts, and most recently, fishing. This ability to diversify and adapt to resource availability is an important part of resilience in the face of multiple stressors. Livelihoods continue to be based on seasonal cycles of agriculture and Brazil nut harvest, with fisheries for subsistence and commerce playing an increasingly important role for many communities, though in general considered of a secondary supportive role. In some cases, such as Trinidadcito, commercial fisheries have increased because of the availability and profitability of the *paiche* fishery,

but continue to be practised as a seasonal activity, interspersed with Brazil nut harvesting, and still considered a secondary source of income, which may enable more flexibility and ability for small adjustments - for example to lower fishing effort when scarcity becomes apparent. This contrasts significantly with other fishing communities in the same reserve who do not have access to the same mix of livelihood activities as Trinidadito, and have a lower abundance of *paiche* in their lakes. For example, in the more recently settled, flood-vulnerable communities of El Sur (located near the Beni River, TCO TIM II) landings include a diversity of medium-bodied native species and significantly less *paiche*. Most community members are engaged in commercial fishing year-round, with fishing constituting a 'safety-net' to deal with other shocks of life on the floodplain. Fishing as a 'buffer' is an adaptation mechanism, which these communities utilize to increase their resilience to external stressors. This is also consistent with results from the Peruvian Amazon (see Coomes et al. 2010) and the observation of highly heterogeneous fisheries in small communities of the Brazilian Amazon (Castello et al. 2013).

The current Trinidadito model is an interesting example of a single-species commercial fishery, despite high diversity of native species in the region. Currently, there is clear evidence that Trinidadito fishers are targeting *paiche* exclusively for their commercial fishery, with occasional opportunistic capture of other species for subsistence or sometimes for sale. This represents a significant shift in their fishery, and its implications for fishing effort, resource sustainability, or long term resilience are not clear. There is insufficient data available to determine the abundance of the native fish species in the lagoons surrounding Trinidadito and whether this has been affected by the *paiche* or fishing pressure.

Significant changes are evident in biological and social aspects of the fishery, demonstrating social innovation and adaptation, as well as a mismatch between expressed conservation interests and a lack of evidence of accompanying stewardship behaviours. The catch composition in the overall region has shifted considerably; fishing effort in Trinidadito is almost exclusively dedicated to *paiche* harvest. While local knowledge of the autochthonous species and interest in conservation were evident, these were not connected with associated stewardship behaviours to protect threatened stocks. For example, serious reductions of fish stocks of *pacú*, *pacupeba*, and *paiche* were referred to, though these are not evident from the sparse fishing data. Perception on the cause of these reductions was not clear, though local overfishing is considered a very likely factor. Interviewees also expressed concern about overfishing and waste (such as discarded by-catch for species such as *corvina*), and are asking for more restrictive management, both for sustainability and to reduce waste, but are not necessarily practicing conservation in their fishing methods.

Current fishing practices in Trinidadito are likely unsustainable. Although prohibited by local regulations, non-selective gillnets are widely used. In addition, new fishing gears to catch *paiche* have been developed - for example the *arma blanca* (see Fig. 2) is a particularly destructive strategy for this fish species because it targets individuals that are protecting their offspring, making the young individuals more vulnerable to predators (Castello, McGrath and Beck 2011; see also Imbiriba 1994). Unlike examples from indigenous fisheries of the Brazilian Amazon (e.g. Amaral 2005), traditional methods such as harpoons, arrows, and poisons are largely absent. There were common references in interviews to fish learning to avoid fishing gear, particularly gillnets. While this



Fig. 2 Fishing gear 'arma blanca' invented and used for paiche fishing in Trinidadcito, TCO TIM II

argument may be a prelude to the introduction of more efficient gear with the first signs of overfishing, our interviews indicate some evidence that *paiche* will actively avoid areas being fished by gillnets (or other gear). On an annual basis, there is a peak of *paiche* catches at the start of each season, even though the fish being caught are at least several years old and largely resident in the lakes being fished. While the predatory nature of these fishing strategies were marginally mentioned in some interviews, this was often tempered by the perception of abundance of this fish and the identification of it as something introduced, or not belonging, and possibly threatening the native stocks, despite it now forming the basis for the entire fishery. Management mechanisms such as minimum size restrictions, and seasonal closures for fish reproductive periods, cited in other areas as critical elements supporting *paiche* recruitment and abundance (Castello 2004), are not yet used or considered in this region for *paiche*. This may be due to a lack of clarity surrounding whether sustaining introduced populations should be a goal as there currently is no overall local perception of resource scarcity, and local knowledge of best conservation practices for this species may be limited. This may change if the local *paiche* resource does become substantially reduced.

Conflicts

Trinidadcito is one of earliest indigenous communities to develop a commercial fishery in the region, initially responding to a strong market for native fish, facilitated by its proximity to the Madre de Dios river, the proximate location of a large, deep, productive floodplain lake (Lago Mentiroso), and increasing connectivity with regional markets in Riberalta. User conflicts have been exacerbated by the presence of this highly valued resource within indigenous territories; the unequal distribution of benefits from fisheries is an ongoing concern for all of the fisheries in the region. This included conflicts with outside fishers that triggered early self-organization and a lobby by the community to department-level authorities to gain exclusive community access to the resource. Two main persistent conflicts referred to in the interviews were those between local and outside fishers, and the relationship between the fishers and intermediaries (*habilito*).

The first of these, conflict over access, has triggered stronger levels of community organization that undoubtedly helped the development of the community overall, highlighting the potential positive spin-offs of conflict as a stimulus for change and improved resilience. Similar conflicts in other communities in the TCO TIM II did not appear to be so dramatic, and did not trigger similar levels of community organization.

The second source of conflict, *habilito*, a social contract in fisheries where credit is provided to fishers in exchange for exclusive right to the fish catch, is a dominant factor in most of the commercial fisheries in the region. This relationship is generally not favourable for the fishers, and is based on a long history of similar arrangements for extractive workers in this area for rubber, Brazil nut, and mining activities. In general, *habilito* enables a relative monopoly of some aspect of the value chain by the intermediary, for example transport, ice, or market access. To some extent, this element was challenged in Trinidadico with new road access and the profitability of *paiche*, which allowed fishers to transport their catch to urban markets directly by motorcycle and to experiment with the establishment of a local processing plant in the community. It remains to be seen if the new value chain links created through these changes are better than the earlier *habilito* system, or if new *habilito* arrangements will be created.

Conclusion

Introduced species may represent both new opportunities and challenges to fishing communities that influence their well-being and resilience. For example, the introduced Nile Perch in Lake Victoria constituted about 66 % of the total catch at its peak in 1990 (Mkumbo and Marshall 2015), but its introduction has been described as a socio-environmental failure from the perspective of impacts on local human communities (Von Kaufmann 2007), presumably with attendant reduced resilience. The *paiche* fishery in Bolivia, perhaps most advanced in Trinidadico, has shown some evolutionary steps reflecting the Holling cycles of resilience thinking (Holling 1973; Walker et al. 2004). These steps have been fostered by community cohesion, created through conflicts over access and the distribution of benefits, but tempered by historical social capital from the rubber-tapping era of both positive organizational capacity and fiscally-oriented monitoring mechanisms that vary in effectiveness. An evolving local organization adapting to a changing resource base and external pressures has been able to demonstrate strengths and deficits in expanding community-based fishery management and fisheries practices. While fishers maintain a diversified seasonal livelihood strategy, they have also increased single species exploitation instead of a traditional focus on small-bodied native species. While the fishery is still too young to assess how long-term resilience and well being will be affected by the introduction of *paiche*, information reported here will help inform multiple scales of regulatory and development strategies to foster positive outcomes for indigenous communities that may take advantage of the new opportunity *paiche* presents.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

AM and FMCV designed and implemented the study, performed data analysis and writing. AA participated in data collection and analysis and made contributions to the writing. TKR, PVD and JC participated in data analysis, writing and editing. All authors read and approved the final manuscript.

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