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Abstract

Classical management has not been able to stop the 65% decrease in fishery production during the last 40 years in the Magdalena-Cauca River Basin. To analyze the effects of selective fishing of multiple species and small scale fisheries we addressed temporal changes at fishing level and the response of fishermen. The fishery reduced production and CPUE (catch per unit effort standardized), decreased the large sizes and growth rates of *Prochilodus magdalenae* and *Pseudoplatystoma magdaleniatum*, changed the abundance of trophic levels (decreased carnivores and increase of detritivores, omnivores), and increased exploitation rates. The fishermen have responded by implementing self-control measures, diversifying fishing gear and mesh size, including new species and sizes in the catch with a higher *cpue* (catch per unit effort) of small sized fish, adjusting the fishing effort to the abundance. We conclude that selective fishing has had ecological effects and fishermen have empirically self-regulated to optimize the cost-benefit ratio of their activity, developing a fishery that is more in line with ecosystemic structures. We address the balanced harvest strategy as a management alternative.

Keyword: Overfishing, Trophic structure, Management strategies, Catch per unit effort, Size structure

43 Introduction

44 Overfishing has been considered one of the main causes of fish stock depletion, and therefore
45 the most important factor to control (Kolding and van Zwieten 2011; Mosepele 2014). Allan et
46 al. (2005) warn that fish in rivers experience countless other direct and indirect pressures, such as
47 environmental degradation, a factor identified by Maestre et al. (2012) for the estuarine zone of
48 the Magdalena River Basin - Cauca (Colombia). However, classical management schemes
49 disregard the impact of environmental degradation on fisheries (Berkes et al. 2003) by
50 implementing measures aimed at guaranteeing selective fishing via the regulation of mesh size
51 and the sizes of mature species (Law 2000; Garcia et al. 2012; Tesfaye et al. 2016). This has led
52 to indications that so-called unselective fisheries are responsible for depleting populations
53 (Kolding et al. 2016c). In our case, classical management (closed season, regulation of sizes and
54 fishing gear) has not been able to stop the 65% decrease in fishery production during the last 40
55 years (L. Franco, Fundación Humedales, Bogotá, Colombia, personal communication, 2020).
56 We therefore question its effectiveness, especially so when other researchers alert us to the
57 effects of classical management on population, community, ecosystem dynamics and their
58 ecosystem services (Misund et al. 2004; Garcia et al. 2012; Belgrano and Fowler 2013; Kolding
59 et al. 2016b; Zhou et al. 2019). Selective fishing produced by classic management approaches
60 changes the size structure of populations and effects on the trophic cascade (Shackell et al. 2010;
61 Kolding et al. 2011; Kolding and van Zwieten 2011). Disturbances in the trophic cascade disrupt
62 life histories of the species (Law 2000; Conover and Munch 2002; van Wijk et al. 2013; Heino et
63 al. 2015) and ultimately reduce productivity and stock abundance (Zimmermann and Jørgensen
64 2017).

The effect of selective fishing is generally not studied as it is considered common to many of the world's artisanal fisheries where stock depletion is often attributed to non-selective fisheries and does not warrant any verification (Kolding et al. 2016c). However, studies have established that selective harvesting of large fish has unintended adverse effects for equitable conservation and sustainable use of biological diversity (Garcia et al. 2012; Jacobsen et al. 2014; Kolding et al. 2014). For example, alterations in the structure of fish communities leads to overfishing, forcing a decrease in the biomass of apical predators (large sizes) and an increase in smaller fish (prey) which are subject to lower predation mortality (Coll et al. 2010; Kolding and van Zwieten 2011; Law et al. 2013). These alterations are called trophic cascades (Frank 2005; Andersen and Pedersen 2010) as it is the abundance of predators that regulates the density of their prey and not the other way around (Belgrano and Fowler 2013). Another problem is that it favors the production of slower-growing genotypes (Conover and Munch 2002) which leads to a reduction in body size (Shackell et al. 2010) and directs fishing towards smaller individuals; i.e., overfishing for growth. On the other hand, Kuparinen et al. (2016) indicate that to make up for the loss of their large reproducers, species have altered their life histories resulting in earlier maturity, eroding not only the fish biomass, but reducing the viability to recover from environmental disturbances, thus generating recruitment overfishing.

Overfishing could also be a consequence of conventional management, which seeks to protect juveniles by concentrating catches on adult individuals (Jacobsen et al. 2014), regulating mesh size in fishing nets so only sexually mature individuals are captured (Tesfaye et al. 2016). However, the effects of this may be objectionable as it may interfere with population, community, ecosystem dynamics, and services (Kolding et al. 2016c, Zhou et al. 2019). Thus,

87 harvesting only adult fish does not necessarily prevent the effects of fishing, it sometimes even
88 exacerbates them. However, controlling selectivity can bring about positive effects in some
89 cases, as noted by Silvano et al. (2017) who recommend management measures intended to
90 replace small mesh gillnets with intermediate mesh size gillnets. Silvano and Begossi (2001) also
91 explain that the seasonal variation in the fishing strategy dilutes fishing pressure among several
92 fish species throughout the year, and may help to maintain fish stocks .

93 According to Misund et al. (2004) and Kolding and van Zwieten (2011), the adoption of
94 regulatory measures showed discrepancies between the objectives of maintaining biodiversity
95 and fish yield (García et al. 2012; Kolding et al. 2014). Kolding et al. (2016a) believe that a more
96 balanced harvesting regime would increase yields substantially, proposing a reduction in fishing
97 pressure on large predators and the distribution of fishing mortality among various groups and
98 sizes.

99 Fishing in the Magdalena-Cauca River basin is open access and common property. Small
100 boats (4 - 9 m) are used, mainly made of wood (66%) with small propulsion mechanisms
101 (wooden oars or 15 hp motors) and low-tech gear (Garzón and Gutiérrez 2013; López-Sánchez
102 2016). The fishery uses multiple gears and catches multiple species, whether in the river, stream,
103 or floodplain, depending on the time of year (dry or rainy season) (Garzón and Gutiérrez 2013;
104 The Nature Conservancy TNC et al. 2015). Fishermen can fish alone or in groups (3-4 people).
105 Fishing has been providing employment for more than 30,000 families, covering 60% of basic
106 needs, and its greatest value has been its contribution to the food security (TNC et al. 2015). The
107 per capita consumption of fish has been estimated at between 28 and 36 kg·person·year⁻¹
108 Historically, the fishery has been based on the extraction of migratory species such as

Prochilodus magdalenae, *Pseudoplatystoma magdaleniatum*, *Sorubim cuspicaudus*, *Pimelodus yuma* and *Pimelodus grosskopfii*. An average of 63000 t·yr⁻¹ was produced in the 1970s and 30697 t·yr⁻¹ between 2010-2015 (Barreto 2017). Colombian legislation regulates catches by fixing a minimum catch length, based on the standard length at first sexual maturity and on specific characteristics of fishing gears. In view of the reduction in fishery production, the fishers have empirically ignored the established regulations that restrict the use of non-selective gear, and are therefore identified as the cause of the decrease in fishery production. However, these impacts of fisheries have not been studied in Colombia.

We are aware that the main current factor of pressure on fishery production is the environmental degradation reported for the basin by Restrepo and Restrepo (2005); Garzón and Gutiérrez (2013); Angarita et al. (2018); however, this study was conducted in view of the need for research that questions the effects of selective fishing. The first hypothesis is that selective fishing had ecological impacts on fish populations, affecting the dynamics of fish production in the Basin, and the second is that fishermen responded successfully to changes in fishery production. To this end, we have paid special attention to temporal changes, at fishing level (yield and catch per unit effort standardized -CPUE-), and the response of fishermen to these changes (number of gear types, complementary economic activities, and fishing effort), and regarding fish communities (size structure and trophic dynamics), species (population dynamics). We also address the balanced harvest strategy as a management alternative.

Materials and Methods

Sampling area

The Magdalena-Cauca River basin (257 400 km²) is located in the extreme north of South America and includes the Magdalena and the Cauca rivers, the most important Andean rivers in the region (Figure 1). The basin has a wide altitudinal distribution (from 3685 m to sea level) and includes all the diverse ecosystems of the Andean and Caribbean regions (Otero et al. 2003). It is comprised of 151 sub-basins – 42 of which are second-order streams – (Restrepo et al. 2006), which provide a diversity of environments, migratory routes for fish and alternative uses of fishery resources.

In recent years, the fishery landed about 30,000 t per year (Barreto 2017) and has been characterized by the use of a wide variety of fishing gears and methods to harvest fish resources represented by 52 freshwater species, most of them native (85%), and three of them, endemic. Also five exotic species occur. Thirty-one percent of the fished species are migratory, and 16 species (43.7%) have been classified with some level of threat (Mojica et al. 2012).

To collect prospective information of biological and fishery data, the entire basin was studied, establishing 40 sampling points in local landing areas. Sampling points were distributed as five in the upper basin, 19 in the middle basin, and 16 in the lower basin (Figure 1).

Data

The study collected (a) data on fisheries, including information on catch per unit of effort (*cpue*) and individual fish weight, and (b) biological data regarding size composition. The fisheries data spanned the years 1977-1989 and 2003-2015, while the biological data included the periods 1977-1989, 2003-2011 and 2009-2015. The sampling schemes methodology was based on Chapman (1976) whereby, via monthly stratified random sampling at landing points,

sampling at least 30% of the canoes that arrived at the port during a 24-hour period. The data on fishing canoes were collected for 10 days·month⁻¹. For the detailed analysis of the stock, we built a database with 261 004 length records [standard length (cm)] for the species *P. magdalenae*, *P. magdaleniatum*, *S. cuspidatus*, *P. yuma* and *P. grosskopfii*. For the composition analysis of the catch, we built a database including 47 species with 17,535 records (Table A1). Finally, for the *cpue* analysis (kg·canoe·day⁻¹), we built a database with 8,703 records.

To determine the dynamics of the fishing gears, workshops with fishermen were held between February and April 2017, following Escobar and Bonilla-Jiménez (2009) recommendations to work with focus groups (number of persons, previous and operational logistics, group techniques, etc.). To validate and adjust questions a pilot test was run in August 2016. Thereafter, we held a total of 6 workshops, one in each representative locality from each of the basin's sub-regions (6) with the participation of 12 to 15 fishermen of various ages, as recommended in the methodology. The outcome was a list of fishing gears introduced every decade between 1970-2015, including areas where they were employed, fishing seasons and complementary economic activities other than fishing. The number of gear types and complementary economic activities registered, corresponded to the value reported by the fishermen during the respective decade.

Data analysis

Annual fishery production estimated by Barreto (2017) from 1975 to 2015 was plotted and the dynamics of standardized relative abundance was analyzed by decades (CPUE). To standardize the CPUE, we used the methodology described by Sparre and Venema (1997) which determines an annual relative CPUE considering the sampled effort (canoe·day⁻¹). CPUE was estimated by

tabulating the catch average over 24 hours per fishing canoe ($\text{kg} \cdot \text{canoe} \cdot \text{day}^{-1}$), a measure established in the 1970s, at the beginning of fishery assessments (Valderrama and Zárate 1989).

To evaluate whether selective fishing had ecological effects on fish populations, we considered four factors: size, trophic groups, catch composition, and population dynamics.

To determine the changes in the size structure of the two main species in the catch (*P. magdalenae* and *P. magdaleniatum*), we constructed frequency histograms of the number of individuals by size ranges for the years 1984 and 2015.

To determine the changes for each trophic group in the catch, we established the contribution of each species to each trophic level, based on the total catch per species in the basin reported by Barreto (2017). Using secondary information, we defined the trophic level of each species within the following categories: detritivores, herbivores, omnivores, carnivores, and piscivores. We compared the contribution of each trophic level for the following periods: 1975-1984; 1985-1992, and 1993-2015 using the non-metric multidimensional scaling technique (NMDS), followed by similarity analysis (ANOSIM) (Clarke 1993). To assess representativity of the NMDS we estimated the stress value and compared it with values of the stress formula (Clarke et al. 2014)

For a historical comparison of the contribution to the capture of the main species (those that contribute more than 70% to the annual capture), we conducted a Chi-squared non-parametric test. Likewise, to establish whether there were changes, the species were listed by groups of years: 1975-1989, 1990-1999, 2000-2009 and 2010-2015. To estimate growth parameters, we used the monthly standard length frequency using the FISAT II program (Gayanilo et al. 2005)

and followed the routines of Powell-Wetherall, Gulland, and Holt, and the growth function of von Bertalanffy. To calculate the total mortality (Z), we used the linearized catch curve methods designed by Jones and van Zalinge, Beverton and Holt, and Ault and Erhardt. The estimation of natural mortality (M) was defined from the median of the values obtained by methods including Tanaka (1960), Taylor (1960), Rikhter and Efanov (1976), and Pauly (1980). Fishing mortality was calculated based on the difference between total mortality (Z) and natural mortality (M). Furthermore, the correlation between fishing mortality and total mortality ($F \cdot Z^{-1}$) established the exploitation rate (E). Faced with limited historical information on the species, our results were limited to comparing the population parameters of *P. magdaleniatum* and *P. magdalenae* over time. *P. magdaleniatum* is a slow-growing demersal species with lower natural mortality (M) compared to *P. magdalenae* which is a fast-growing benthopelagic species with a higher natural mortality rate.

To establish the fishermen's response to the dynamics of fishery production, we evaluated: gear, relative abundance by size, fishing effort, and complementary economic activities.

To compare the *cpue* ($\text{kg} \cdot \text{canoe} \cdot \text{day}^{-1}$) by fish size between 2010 and 2015, we used the data relating to the cast net *atarraya* (the most traditional gear in the artisanal fishery) with mesh sizes of 6, 7 and 8 cm. To estimate the correlation between the dependent variable (*cpue*) and the independent variable (standard length), we used the indirect probabilistic method, employing the standard length range of Kolding et al. (2003).

Based on the workshops, and to determine the response of fishermen, we correlated the number of types of fishing gear per decade used and yield (1970-2015) (Barreto 2017) with a

confidence level of $p < 0.05$. To find the best data adjustment, we applied polynomial regression. We also established the percentage increase in terms of the diversity of fishing gear correlated to fishery yield.

We developed a linear regression ($p < 0.05$), between fishing effort (canoe-day⁻¹) as the dependent variable and total catch-month⁻¹ (kg) as the independent variable in the middle Magdalena region between 2013-2015. We constructed a list of all economic activities complementary to fishing between 1970-2015 and related them to the decade to which they were reported by fishermen.

Results

The yield from the Magdalena-Cauca River basin revealed decreasing peaks in the 1975 - 1984 period (51 964 t average), followed by a short-term recovery from 1985 to 1991 (52 831 t on average), and finally, a period of low records with small fluctuations tending towards the stability in the 1992 - 2015 period (30 772 t yearly on average) (Figure 2). At the same time, LnCPUE decreased over time, indicating a progressively lower fish abundance with significant differences between different periods (Chi-squared = 74,136, $p < 0.001$) (Figure 3). Thus, in the 70s, CPUE was 27 kg·canoe·day⁻¹ decreasing by 30% in the following decade. The lowest values were registered between 2007 and 2011 –2.5 times less than in the 1970s, with a small 13% increase between 2012 and 2015– indicating a possible increase in fish abundance. The *a posteriori* tests, showed significant differences between all the periods ($p < 0.05$).

When comparing the size structure of the two main species in the catches, we found that in the most recent years (2010 -2015), a significant portion of the large size fraction was lost (Figure 4, black bars) with a displacement of the size structure towards smaller fish. This

condition was the result of pressure directed since the 1970s towards the capture of large individuals (sexually mature) through the government's establishment of regulatory catch sizes as follows: *P. magdaleniatum*, from 80 cm onwards (Figure 4 a,b), and *P. magdalenae* from 25 cm onwards (Figure 4 c, d), truncating the size structure of each of these species.

The effect of the decrease in large individuals was also reflected in changes in the trophic structure of the fish community. Since the 1970s, the trophic levels of the species caught varied over time. Detritivorous species maintained fish yield (Figure 5), and when comparing current groups, the highest trophic level (piscivores) decreased by 28%, while the lowest trophic level (detritivores) increased by 8%. The intermediate groups showed the greatest changes. The biomass contribution of carnivores decreased by 51%, and in omnivores, it increased by 62%. Furthermore, it was during the recovery-decrease phase of the fishery from 1985 to 1992, that trophic changes at almost all levels were observed (Figure 5). NMDS confirmed that the biomass contribution of the different functional groups formed three clusters with an excellent representation of the complexity of the data (stress value: 0,03) (Figure 6). They were significantly different from each other ($R=0.67$) according to the ANOSIM test.

During the study periods, the composition of the catch did not show substantial changes over time (Chi-squared = 2.492; $p > 0.05$), with the continuous presence of nine species that contributed the most to the biomass of the catch (Table 1). However, the records indicated that as abundance decreased, there was a greater diversity of less commercially important small and medium-sized species entering the fishery. In 2015 up to 49 species were recorded (Table 2).

Selective fishing forced demographic changes in "individual" growth in each of the species, which we support with the decrease in their growth rates between the time periods evaluated (Table 3). This result is related to the selective elimination of fast-growing individuals within the respective cohorts of each species according to the selectivity of the gear and catch size regulations. Likewise, the results found for exploitation rates (E) reflected the vulnerability of the populations under exploitation. During the 2010-2015 period, all five species evaluated showed signs of high exploitation ($E > 0.8$) (Table 3).

Faced with the decrease in fishery production, fishermen adjusted to the new level of abundance (30,836 t average between 1993-2015) and species sizes, incorporating a total of 23 types of fishing gears between active and passive (Table 4), which were modified over time, diversifying the mesh or hook size for a total of 87 varieties of gears (Table A2). The fishermen modified most of the types of fishing gear, decreasing the mesh or hook sizes over time to adjust to the species' sizes. Mesh sizes were reduced in 32% of the cases (considered illegal gears), and 18% of fishing gears with larger mesh sizes were no longer subsequently used in the fishery. Cast nets (drop nets) with mesh sizes larger than 8 cm ceased to be used in the 1980s, and were replaced by those with mesh sizes smaller than 4 cm in the 1990s. In the 1980s, purse seines (e.g., *chinchorro* with mesh size larger than 8 cm), disappeared from fishery, and gillnets – known as trammel nets – were reduced from an 8 cm mesh size in the 1980s to half that size (i.e., 4 cm) in the 90s (Table A2).

This variety of gears was a result of the artisanal fishermen's response to changes in fishery production, so that while they reduced catches of larger species, they were catching smaller and smaller species to maintain acceptable yields. The variety of gears increased in time as fishery

yields decreased (Figure 7); increasing up to 40% during the period of most significant yield decrease (1975-1984), reducing to a 14% rate of increase when yields were more stable (1993-2015). They have also developed fishing patterns according to the environments (river, stream and swamp) and the hydrological period (Table 4).

Using the cast net *atarraya* showed the potential to catch a great diversity of species (36) and sizes (10-108 cm Ls), with the smallest individuals or the smallest species contributing the highest abundances to the catches (between 10 and 28 cm Ls). These decreased as the size increased ($R^2 = 0.87$) (Figure 8).

Another adaptation made by the fishermen was related to fishing effort and abundance. According to Figure 9, there is a linear relationship between effort and catch. That is, abundance regulated the number of canoes that went out to fish (daily fishing effort), allowing us to establish, on average, 341 kg·month⁻¹ per canoe (ranging between 144-804 kg·month⁻¹). This would be equivalent to establishing that on average a fisherman catches 1 t·year⁻¹, considering that a canoe can carry between 1 and 4 fishermen, depending on the gear used.

Another adjustment that they employed was that of diversifying their sources of income. In the 1970s, fishing was the economic activity par excellence for the fishermen, supported by agriculture to complete the food security of their family nucleus. However, in the following decades, the dedication changed and although fishing remained the main economic activity, fishermen diversified their complementary economic activities into 12 different categories (Table 5).

Discussion

Our findings revealed that having developed a selective fishery, initially intended for the extraction of the largest individuals of the fish community, contributed to reducing fishery production and CPUE that we identified as pressure indicators. Table 6 presents the trends of these indicators such as the loss of the fractions of large fish and the reduction in growth rates for *P. magdaleniatum* and *P. magdalenae*, changes in the abundance of trophic levels (decrease of piscivores / carnivores and increase of detritivores / omnivores), and evidence of high exploitation rates ($E > 0.8$). Faced with these indicators, fishermen have responded successfully, adapting and adjusting to the changes in the new scenarios of fishery production by implementing measures such as the diversification of fishing gear (progressive reduction of mesh size or hook size) with the capture of new species and smaller sizes, which generated a slight increase in CPUE; a strategy that conserved the structure of the fish community. This strategy also regulated the fishing effort and fishermen responded by incorporating new economic activities (mining, day labor, construction, and guardianship, among others).

Even though catch composition in terms of the contribution of the most important species has remained stable, the decrease in fishery yield and CPUE reflect a reduced abundance of the resource. However, in recent years (2012 to 2015), a slight increase in CPUE has been observed and considering that the number of fishermen has remained relatively constant over time (Kapetsky 1978; Medio Ambiente 2017), we can assume that these facts configure a new scenario, where self-regulated fishermen contribute to stabilizing the activity according to new levels of fishery production. This slight increase in CPUE was the result of the diversification of the mesh size and variety of fishing gear, although this has resulted in a greater presence of smaller standard lengths that support fishery yield, since they are the most productive and generate the highest CPUE. Indeed, Wolff et al. (2015) indicate that this is due to the fact that

smaller fish are more abundant, grow faster, have higher biomass, and a higher general rate of renewal in the system. These results are in line with those obtained by Kolding et al (2016c) who assessed the African Lake Kariba fishery finding that that the highest yields and lowest structural impact on the ecosystem are obtained by targeting small individuals in the community.

The reaction of fishermen to declining abundance has been explained by Kolding et al. (2016c) as logical and necessary. We believe that these are adaptive responses that are not related to a destructive attitude towards their own resource base and we agree with Berkes and Pockock (1981) when they indicate that the motivation for self-regulation does not stem from altruism or environmental idealism; rather, self-regulation is intricately tied in with the long-term maintenance of good catches and good income.

This adaptation was empirical and its results are comparable with other cases in the tropics where various patterns of community management explained the variation in fish sizes (Campos-Silva and Peres 2016) or in others, where formal co-management actions have, at least partially, contributed to increased fish abundance and fishing yields (Silvano et al. 2014). It is assumed that fishermen respond more readily to daily signals of abundance of the resource than to a search for unsustainable levels of catches, contributing positively to fishing, in contrast to the constant impact of environmental degradation on fishery resources as has been demonstrated for the basin (S. Hernández-Barrero, M. Valderrama Barco, C. G. Barreto Reyes, L. Sierra Sierra, J. Páramo, W. Stotz *in prep*). We believe that the fishery behaves as a predator-prey system that fluctuates, but where predators (fishermen) are ultimately limited by the productivity and abundance of prey. This is also reported by Kolding and van Zwieten (2011) who considered that this conditioning, in African fisheries, suggests that the fishing effort exerted in these systems is

limited by the productivity of the ecosystem through individual catch rates, in contrast with the assumption of "the tragedy of the commons" (Hardin 1968), where an effort of unlimited growth would degrade productivity. This is a common condition for many artisanal fisheries that have been assessed (Du Feu et al. 1997; Blanchard et al. 2005; Jawad 2006; Welcomme et al. 2010; Ogundiwin 2014; Dienye and Olopade 2017), where fishermen make continuous modifications and improvements (Dienye and Olopade 2017) and which should consequently be considered as "learning organizations" that adapt to new circumstances (Kolding et al. 2014). It is for this reason that fishermen have also adapted by seeking different economic alternatives to diversify their economic sources and thus reduce their direct dependence on fishing.

Nevertheless, Silvano et al. (2017) have established that the intensive use of some types of gear, such as gillnets, could increase the risk of the regional extirpation of a specific population and impair the provision of ecosystem services by targeting fish. However, we believe that communities are able to respond by making changes in the time and location of activities, by using different species, and by developing or using new technologies, as also considered by Huntington et al. (2017).

In contrast to the purposes of classical management, selective fishing has affected fish communities and the life history of the species alike. We demonstrate that targeted fishing for large individuals has resulted in the truncation of the size structure of the two most important species –*P. magdalenae* and *P. magdaleniatum*–. This decrease had already been recorded in the basin, particularly for *P. magdalenae*, a species currently represented in the catches by a single age group, and, similarly for *P. magdaleniatum*, whose average age at capture changed from 8 years (89 cm in 1973) to 4 years (61 cm in 2013) (Valderrama et al. 2015). The loss of adult

individuals would translate into loss of spawning biomass for the *P. magdalenae* and *P. magdaleniatum* populations and therefore limitations in the number of recruits with collateral effects on the respective abundance of their populations and on the number of recruits, associated with recruitment overfishing, which has also been found by other researchers such as Hutchings et al. (2012); Siskey et al. (2016); Fogarty and Siskey (2019) for other fish species.

Size-selective fishing has also brought about changes in the life history of *P. magdaleniatum* and *P. magdalenae* (altering their individual growth). This information could provide some guidance as to what might be happening to the species in the basin that share similar life histories. This targeting of the same cohort would favor the capture of fast-growing individuals that were then replaced by slower-growing ones. Although we did not carry out genetic studies, Rochet and Benoît (2012) report that selective fishing would also be promoting genetic changes with an evolution towards smaller sizes and slower growth, which is counterproductive for the populations. Law (2000), Hutchings (2002), Kolding and van Zwieten (2011) and Kuparinen et al. (2016) indicate that changes in life history resulting in earlier maturation and less investment in the gonads bring a number of disadvantages related to losses at the following levels: survival, successful fertilization, courtship, ability to acquire and defend nesting sites, and egg quality among others. However, we must not ignore the fact that there are other—no less important—environmental factors. The country's development of hydroelectric power showed a growth rate of 220% between 1975-1984 and 1992-2015 with 35 reservoirs, storing 17.2 Mm³ of water (Jiménez-Segura et al. 2014; Angarita et al. 2018). Reservoirs fragment the river, interrupting the reproductive migrations (Jimenez -Segura et al. 2014) and attenuate the river's hydrological regimes (Angarita et al. 2018) and therefore influence the growth rate of fish species, considering

that Valderrama and Petrere (1994) established that there is a close relationship between the amplitude of high water hydrological periods and the *P. magdalenae* growth rate. Another factor of pressure that could affect fish reproduction is the presence of mercury (Mancera-Rodríguez and Álvarez-León 2006). This heavy metal becomes incorporated in the fish populations' food chains affecting their reproductive health (Crump and Trudeau 2009, Kjelland et al. 2015). The basin houses over 40 thousand ha of gold mining. According to a study by the United Nations Office on Drugs and Crime -UNODC- and Ministry of Justice and Law (2016), for every 1 kg of gold produced in one of the main gold producing localities of the basin (Nechi) potentially 5 kg of mercury are discharged. According to the Sistema de Información Minero Energético (SIMCO) (<https://www1.upme.gov.co/InformacionCifras/Paginas/Boletin-estadistico-de-ME.aspx>) and Lozano and Pulido (1986) gold production grew by 50% between 1975-1984 and 1992-2015.

Considering the above, signs of overfishing of the ecosystem and overfishing by recruitment intensified by a degraded environment caused by anthropogenic activities, were reflected in the high exploitation rates of the species evaluated ($E > 0.8$). This does not surprise us and has overshadowed the fishermen's self-regulatory actions.

Colombia's Conventional management has been based on the formulation of regulations only supported by biological theories, such as propagation and growth theory, which tacitly accept that the concept of growth overfishing that legitimizes the capture of large and mature individuals to protect the smaller ones. This denies the life history of fish as it examines their survival as if they were mammals (Kolding and van Zwieten (2011). This generalized situation arose from the limited knowledge about the life history and the potential fecundity of most of the

species, a fact that has led to the adoption of management measures without sufficient evaluation.

The changes in the trophic structure in the fish communities—illustrated by decreased contribution to the production of higher trophic levels (piscivores) compensated by the increase in the detritivorous and omnivorous trophic levels—reflects what is known as trophic cascades (Shackell et al. 2010). Changes which affect internal dynamics and ecosystem functioning are responsible for maintaining its stability and resilience (Kolding et al. 2011; Kolding and van Zwieten 2011). The reduction in the size of predators and the dynamics of the lower trophic levels imply that the ecosystem may be less energy efficient in relation to its historical state according to Shackell et al. (2010). Our findings therefore indicate symptoms of ecosystem overfishing. However, although selective fishing has largely conditioned this situation, the basin's environmental degradation contributes to the alteration of aquatic quality and productivity, forcing an increase in detritivores through changes in sediment flow or, on the contrary, forcing a decrease in piscivores and carnivores through the bioaccumulation of mercury used in gold mining.

To avoid the effects induced by selective fishing Kuparinen and Festa-Bianchet (2017) propose to limit the fishing mortality of larger individuals, to avoid running counter to the natural mortality pattern. Implementing this management measure would be simpler than the complicated size limit regulations, where the challenges would be more closely related to the need to change the perception of people traditionally conditioned to accept the legally determined minimum sizes. This invitation would imply contemplating an approach towards a more balanced catch (Garcia et al. 2016; Kolding et al. 2016b; Zhou et al. 2019). We support the

concept of balanced catches as a management alternative based on the findings of this study including: A stable fishery production since 1992; fishermen who have managed to self-regulate; and the development of a fishery based on a wide range of species, sizes and fishing patterns, challenging classical management. As a result, the evolution of the fishing pattern observed is an empirical example of a more balanced harvest, carried out by both fishermen and merchants who have incorporated the supply of both high- and low-value species in the national market, as shown by fishery marketing statistics (De La Hoz, et al. (2017). Currently, the greatest limitations we are likely to face are political and cultural, since there is a great ethical weight attached to the protection of juveniles. As indicated by Zhou et al. (2019), balanced harvesting is not a purely scientific issue, but also involves a legal and social choice.

We are not unaware of the theoretical and empirical gaps that still exist and for which the balanced harvest model has been criticized. This is the case for Froose et al. (2016) who indicate that the size structure model is unrealistic with respect to life history (small size biomass), response to fishing ($F=M$), and economics (uniform cost of fishing and the same price for all species and sizes. It is also important to consider the indication that in some cases of tropical fisheries, mesh sizes need to be increased in order to guarantee a sustainable catch (Silvano et al. 2017). This contrasts with studies that state that in developing countries, the fishing activity is sustainable, despite the use of small mesh sizes (Wolff et al. 2015). The topic is complex and presents challenges for further research and formulation of tools to develop control regulations for balanced harvesting (e.g., Kolding and van Zwieten 2011; Garcia et al. 2012; Law et al. 2016; Kolding et al. 2016a; Law et al. 2016). In this respect, we must learn from fishermen who have demonstrated greater consistency in the face of dynamic fishing, fish, and their constantly changing environment. Successful cases of balanced (usually unplanned) harvesting in African

fisheries such as in Bangweulu Swamps, Lake Kariba (Zhou et al. 2019) and the southern coast of Kenya (Tuda et al. 2016) encourage us to continue on this path to finding alternative ways to maintain ecosystem structure and function. In short, we consider that balanced harvesting is a strategic mechanism, which, as stated by Kolding et al. (2016a), is not intended to replace conventional management, but to provide a means to help reconfigure it, in a more complete ecosystem-based framework, using the new harvesting regulations and performance criteria.

While environmental degradation has now been catalogued as the main driver of change in terms of fishery production, we conclude that selective fishing has also contributed to ecological effects on fish communities while fishermen have adapted to natural daily dynamics and empirically self-regulated in order to optimize the cost-benefit ratio of their activity. This study has therefore produced information on the effect of management measures and it contributes to modifying the negative image of fisherman by developing a fishery that is more in line with the structure of the ecosystem. We thereforw encourage ecosystem-based management, which allows a sustainable use of fish stocks in the Magdalena-Cauca River basin within safe ecological limits.

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Table 1. Historical composition (in percentage) of fishery yield in the Magdalena-Cauca River basin. Data from 1977 to 1985 is from Valderrama and Zárate (1989), and from 1985 to 2015 was obtained from the authors' personal database. *this species is included in others.

Scientific name	1977-1985	1985-1992	1993-2015
<i>Pseudoplatystoma magdaleniatum</i>	22.9	13.5	14.9
<i>Sorubim cuspicaudus</i>	4.8	3.0	5.1
<i>Prochilodus magdalenae</i>	35.5	53.1	40.7
<i>Pimelodus grosskopfii</i>	*	1.6	5.7
<i>Ageneiosus pardalis</i>	3.1	2.0	2.2
<i>Brycon moorei</i>	*	0.2	1.6
<i>Megaleporinus muyscorum</i>	*	1.0	2.0
<i>Pimelodus yuma</i>	5.3	10.2	13.7
<i>Plagioscion magdalenae</i>	8.0	4.7	3.9
Others	20.4	10.7	10.3
*this species is included in others	100.0	100.0	100.0

778 Table 2. List of species appearing in the catches since 1975 and the incorporation of other
 779 species to the Magdalena-Cauca River basin fishery over time. The table shows the total number
 780 of species by time period.

Scientific name	1975 - 1989	1990 - 1999	2000 - 2009	2010 - 2015
<i>Triportheus magdalenae</i>	x	x	x	x
<i>Pseudoplatystoma magdaleniatum</i>	x	x	x	x
<i>Sorubim cuspidatus</i>	x	x	x	x
<i>Prochilodus magdalenae</i>	x	x	x	x
<i>Cynopotamus magdalenae</i>	x	x	x	x
<i>Ageneiosus pardalis</i>	x	x	x	x
<i>Brycon moorei</i>	x	x	x	x
<i>Pimelodus yuma</i>	x	x	x	x
<i>Plagioscion magdalenae</i>	x	x	x	x
<i>Sternopygus aequilabiatus</i>	x	x	x	x
<i>Megaleporinus muyscorum</i>	x	x	x	x
<i>Pseudopimelodus spp</i>		x	x	x
<i>Piaractus brachypomus</i>		x	x	x
<i>Pimelodus grosskopfii</i>		x	x	x
<i>Panaque cochliodon</i>		x	x	x
<i>Caquetaia kraussii</i>		x	x	x
<i>Oreochromis niloticus</i>		x	x	x
<i>Oreochromis sp</i>		x	x	x
<i>Hoplias malabaricus</i>		x	x	x
<i>Ichthyoelephas longirostris</i>		x	x	x
<i>Megalops atlanticus</i>		x	x	x
<i>Curimata mivartii</i>		x	x	x
<i>Ctenolucius hujeta</i>			x	x
<i>Sturisomatichthys spp</i>			x	x
<i>Xyliphius magdalenae</i>			x	x
<i>Sternopygus aequilabiatus</i>			x	x
<i>Hypostomus hondae</i>			x	x
<i>Chaetostoma spp</i>			x	x
<i>Andinoacara latifrons</i>			x	x
<i>Geophagus steindachneri</i>			x	x
<i>Salminus affinis</i>			x	x
<i>Potamotrygon magdalenae</i>			x	x
<i>Astyanax magdalenae</i>			x	x
<i>Cyphocharax magdalenae</i>			x	x
<i>Spatuloricaria gymnogaster</i>			x	x
<i>Colossoma macropomum</i>			x	x
<i>Notarius bonillai</i>			x	x
<i>Dasylicaria spp</i>			x	
<i>Pangasionodon hypophthalmus</i>				x
<i>Chaetostoma thomsoni</i>				x
<i>Leporinus striatus</i>				x
<i>Ancistrus spp</i>				x
<i>Rhamdia guatemalensis</i>				x
<i>Centrochir crocodili</i>				x
<i>Leporellus vittatus</i>				x
<i>Kronoheros umbrifer</i>				x
<i>Brycon henni</i>				x
<i>Trachelyopterus insignis</i>				x
<i>Cetopsis othonops</i>				x
Unidentified				x
Number of species	11	22	38	49

Table 3. Population parameters for the main species in the Magdalena-Cauca River basin in two periods (L_{∞} = asymptotic length cm Standar lenght, K = annual growth rate, Z = total annual mortality rate, M = annual natural mortality rate, F = annual fishing mortality rate, E = annual exploitation rate %).

	1984-1986	L_{∞}	K	Z	M	F	E
<i>Pseuplatystoma magdaleniatum</i>		145.80	0.26	1.043	0.480	0.563	0.540
<i>Prochilodus magdalenae</i>		54.84	0.62	4.575	1.610	2.965	0.648
	2011-2015						
<i>Pseuplatystoma magdaleniatum</i>		149.53	0.22	2.379	0.317	2.062	0.867
<i>Prochilodus magdalenae</i>		57.75	0.23	2.405	0.380	2.025	0.842
<i>Sorubim cuspicaudus</i>		157.46	0.18	3.267	0.457	2.810	0.860
<i>Pimelodus grosskopfii</i>		53.00	0.33	5.57	0.699	4.871	0.875
<i>Pimelodus yuma</i>		43.05	0.64	5.045	0.836	4.210	0.834

795 Table 4. Type and variety of fishing gear used in the Magdalena-Cauca River basin from 1970 to 2015. Database was collectively
 796 compiled with 90 fishermen from the upper, middle, and lower basin.

Fishing gear	Fishing gear principle	Type of fishing gear	1970-1980	1981-1990	1991-2000	2001-2015	Zones of use	Seasons of use
Active	Drop nets	Cast net atarraya	4	3	4	5	Rivers/River channels/Foodplains	Throughtout year
		Cast net chile	2	2	1	1	Rivers/River channels/Foodplains	Throughtout year
		Cast net bocachiquera			1	1	River channels/Foodplains	High water/rising water
		Cast net lancera		2	2	2	Rivers (running waters)	High water
	Purse seine	Chinchorra	2	4	4	3	Rivers (shore)/Foodplains	Low water or in transition
		Chinchorro	2	4	4	4	Rivers (shore)	Low water or in transition
	Trawl net	Tranquilla	1	2	2	3	Rivers	Low water
		Hand trawl	2	1	1	1	Rivers	High water
		Light rastra	1	2	1	2	Rivers/River channels	All year round
		Heavy rastra		1	1	2	Rivers/River channels	All year round
	Lift nets	Congolo		1	2	1	Rivers	Low water
	Spears and harpoons	Harpoon	1	1	1	1	Rivers/River channels/Foodplains	Low water
		Arrow	1	1			Rivers/River channels/Foodplains	Hight water/Low water
Passive	Gill net (fixed/floating)	Slider			5	4	Rivers	Low and rising waters
		Trawl-raspachín			2	2	Rivers	Low water
		Trasmallo		4	2	7	Rivers/River channels/Foodplains	All year round
		Mallón		2	2	2	Rivers	Throughtout year (night)
		Paco paco		1	2	2	Rivers (swirls)	High water
		Trampero			1	1	Rivers	All year round
		Volador			2	2	Rivers deep zone	Rising water
	Lines	Hand-rod line (hook)	9	11	12	13	Rivers/River channels/Foodplains	All year round
		Calandrio	1	2	3	4	Rivers/River channels/Foodplains	High water/rising water
	Traps	Nasa (Fish trap)	1	1	1	1	Rivers/Foodplains	All year round
Total			27	45	56	64		

Table 5. Complementary activities conducted by fishermen in the Magdalena-Cauca River basin over time.

Complementary economic activity	1950	1960	1970	1980	1990	2000	2010	2015
Agriculture	x	x	x	x	x	x	x	x
Mining				x	x	x	x	x
Minor species farming				x	x	x	x	x
Other					x	x	x	x
Construction						x	x	x
Fish trader						x	x	x
Farm laborer						x	x	x
Own business						x	x	x
Research projects						x	x	x
Boatman							x	x
Custodian							x	x

810 Table 6. Trends in fishing and biological parameters evaluated as a result of selective fishing in the Magdalena-Cauca River Basin.

Parameter	Indicator	1975-1984	1985-1992	1993-2015	1975-1984	1985-1992	1993-2015
Fishery production	t·year ⁻¹				reduction	transitory increase	stabilization
Relative abundance	CPUE (kg·canoe·day ⁻¹)				reduction	reduction	slight increase
Fishers	number	=	=	=	constant	constant	constant
Species size structure	Longitud estandar (cm)				broad size range		narrow size range
Biomass contribution of main species to the catches	% per species	=	=	=	constant	constant	constant
Species diversity in the catches	number of species in time				11	22	49
Trophic dynamics	% average biomass per trophic level over time	omnivores	omnivores	omnivores	43% detritivores 0% herbivores 9% omnivores	59% detritivores 0% herbivores 14% omnivores	47% detritivores 1% herbivores 24% omnivores
		piscivores/ carnivores	piscivores/ carnivores	piscivores/c arnivores	26 % carnivores	11% carnivores 15% piscivores	13 % carnivores 15% piscivores
					21% piscivores		
Population dynamics (main species)	exploitation rate (E)				optimal exploitation		overexploitation
	growth rate (k)				<i>P. magdaleniatum</i> , k= 0.26 <i>P. magdalenae</i> , k=0.62		<i>P. magdaleniatum</i> , k= 0.22 <i>P. magdalenae</i> , k=0.23
Use of varieties gear	number of gear types per time				27-45	56	64
Size and relative abundance (castnet)	Size (cm) per <i>cpue</i> (kg·canoa·día ⁻¹)						< size > <i>cpue</i>
Fishing effort and local capture (Magdalena mid river basin)	canoe·day ⁻¹ and kg·month ⁻¹						canoes number varies with abundance of fishes
Income activities alternative to fishing	number				3	4	11

812 Figure captions

813 Figure 1. Location of landing points in the Magdalena-Cauca River basin where biological and
814 fishing information was collected. The study covered upper, middle, and lower basin; black
815 points correspond to primary data obtained in this research, and white points correspond to
816 secondary data used. Map was created in ArcGis 10.3 software. Source: The base map was
817 created with the public available data of the Instituto Geográfico Agustín Codazzi [June 2018]
818 <https://www.igac.gov.co/es/ide/datos-e-informacion/cartografia>. 1: 100,000 scale cartography
819 was used. Geographic coordinates for the sampling stations and the additional records where
820 sourced from own data, Valderrama and Zárate (1989) and Barreto (2017).

821 Figure 2. Trends and periods of fishery yield in the Magdalena-Cauca River basin from 1975 to
822 2015. Source: Figure was created using data of Barreto (2017).

823 Figure 3. Median trend of the CPUE ($\text{kg} \cdot \text{canoe} \cdot \text{day}^{-1}$) in time in the Magdalena-Cauca River
824 basin.

825 Figure 4. Changes in the size structure of *Pseudoplatystoma magdaleniatum* (a-b) and
826 *Prochilodus magdalenae* (c-d) populations in the Magdalena-Cauca River basin over time. The
827 parts in white reflect the individuals to be protected according to the Colombian fishing
828 regulations governing the basin, while the parts in black show the sizes that can be targeted.

829 Figure 5. Trophic structure of harvested fish communities related to their contribution to fishery
830 yield. The years are grouped based the evolution phases of fishery yield: 1975-1985 decreasing
831 phase; 1986-1991 recovery phase, and 1992-2015 stability trend. Herbivorous species between
832 1993-2015 contributed with less than 200 t.

Figure 6. Non-metric multidimensional scale plot (NMDS) for periods of years, grouped by clusters. Stress value= 0.03. Overall R: 0.67, significance level: 0.1%.

Figure 7. Number of fishing gear types per decade, between 1975 and 2015, reported by fishermen in the Magdalena-Cauca River Basin. The three periods that show the historical evolution of fishery production are presented. The resulting polynomial regression of the number of gears in time was $N^{\circ} \text{ gears} = -0.0286t^2 + 2.3257t + 17.36$; $R^2 = 0.9989$.

Figure 8. Size distribution (Standard length -cm-) and relative abundance (*cpue* -kg·canoe·day⁻¹-) of all species captured with the cast net *atarraya* with 6, 7 and 8 cm mesh size during the 2010-2015 period. Linear regression was performed through the probabilistic function (*p*) between the log-transformed relative abundance (LN *cpue*) and the length ranges between 10-108 cm Standard Length. The correlation coefficient R^2 is shown. The number of observations was 5752.

Figure 9. Total effort density (canoe-day⁻¹) in relation to catches (kg-month⁻¹) between 2013-2015 in the middle Magdalena region. The resulting linear regression of the number of canoes per day was $N^{\circ} \text{ canoes} = 0.0018_{\text{catch}} + 2.2759$; $R^2 = 0.79$.

853 Table A1 Length and catch data records for fish species in the Magdalena-Cauca River basin.

Scientific name	Length Record	Catch Record
<i>Aequidens pulcher</i>		2
<i>Ageneiosus pardalis</i>		846
<i>Ancistrus centrolepis</i>		293
<i>Astyanax fasciatus</i>		6
<i>Brycon henni</i>		3
<i>Brycon moorei</i>		490
<i>Caquetaia kraussii</i>		180
<i>Caquetaia umbrifera</i>		5
<i>Chaetostoma marginatum</i>		116
<i>Chaetostoma thompsonii</i>		27
<i>Cochlodon spp</i>		69
<i>Colossoma macropomum</i>		1
<i>Ctenolucius hujeta</i>		15
<i>Curimata mivartii</i>		368
<i>Cynopotamus magdalenae</i>		220
<i>Cyphocharax magdalenae</i>		133
<i>Geophagus steindachneri</i>		4
<i>Hoplias malabaricus</i>		172
<i>Hypostomus hondae</i>		249
<i>Ichthyoelephas longirostris</i>		353
<i>Leporellus vittatus</i>		2
<i>Leporinus striatus</i>		8
<i>Megaleporinus muyscorum</i>		768
<i>Megalops atlanticus</i>		6
<i>Oreochromis niloticus</i>		48
<i>Oreochromis sp</i>		5
<i>Pangasionodon hypophthalmus</i>		2
<i>Piaractus brachypomus</i>		136
<i>Pimelodus grosskopfii</i>	20872	642
<i>Pimelodus yuma</i>	26691	280
<i>Plagioscion magdalenae</i>		377
<i>Potamotrygon magdalenae</i>		15
<i>Prochilodus magdalenae</i>	130361	3861
<i>Pseudopimelodus c.f. bufonius</i>		97
<i>Pseudoplatystoma magdaleniatum</i>	53400	3762
<i>Rhamdia quelen</i>		1
<i>Salminus affinis</i>		261
<i>Sorubim cuspicaudus</i>	29680	3008
<i>Spatuloricaria gymnogaster</i>		282
<i>Sternopygus aequilabiatatus</i>		25
<i>Sternopygus macrurus</i>		140
<i>Sturisoma panamense</i>		46
<i>Triporthus magdalenae</i>		91
<i>Xyliphius magdalenae</i>		32
Others		88
Total number of records	261004	17535

854

855 Table A2. Types of fishing gear according to its mesh size (cm) and hook size (#) for each
 856 decade. Collective construction with fishermen from the upper, middle, and lower basin of the
 857 Magdalena-Cauca River basin. ** fishing gear that decreased mesh size over time. † fishing gear
 858 that was never used again.

Variety of fishing gear	70-80	81-90	91-00	01-15
hook-wire				x
hook # 2	x	x	x	x
hook # 3	x	x	x	x
hook # 4	x	x	x	x
hook # 5	x	x	x	x
hook # 6	x	x	x	x
hook # 7	x	x	x	x
hook # 8	x	x	x	x
hook # 9	x	x	x	x
hook # 10		x	x	x
hook # 11		x	x	x
hook # 12	x	x	x	x
rod			x	x
harpoon	x	x	x	x
cast net 4 cm	**		x	x
cast net 5 cm	**			x
cast net 6 cm	x	x	x	x
cast net 7 cm	x	x	x	x
cast net 8 cm	x	x	x	x
cast net for catfish 8 cm	†	x		
cas net bocachiquera 7 cm			x	x
cas net malluda lancera 8 cm		x	x	x
cas net malluda lancera 10 cm		x	x	x
hand trawl 4 cm	**		x	x
hand trawl 6 cm	†	x		
hand trawl 8 cm	†	x		
calandrio # 2 catfish	**		x	
calandrio # 3	**	x	x	x
calandrio # 5				x
calandrio # 6				x

calandrio # 7		x	x	x	x
cast net chile 4 cm		x	x	x	x
cast net chile 6 cm	†	x	x		
purse seine chinchorra 4 cm		x	x	x	x
purse seine chinchorra 4 cm	**		x	x	x
purse seine chinchorra 6 cm	**		x	x	x
purse seine chinchorra 7 cm	†**			x	
purse seine chinchorra 8 cm	†	x	x		
purse seine chinchorro 5 cm	**		x	x	x
purse seine chinchorro 6 cm		x	x	x	x
purse seine chinchorro 8 cm		x	x	x	x
purse seiner chinchorro small catfish			x	x	x
lift net 6 cm	†			x	
lift net 4 cm			x	x	x
gill net slider 4 cm	**				x
gill net slider 6 cm				x	x
gill net slider 7 cm				x	x
gill net slider 8 cm				x	x
gill net slider caliber 10				x	
gill net slider caliber 4				x	
arrow	†	x	x		
gill net mallón 20 cm	†		x		
gill net mallón 16 cm			x	x	x
gill net mallón 14 cm	**				x
gill net mallón 12 cm	†**			x	
trap		x	x	x	x
gill net paco paco 5p	**			x	x
gill net paco paco 8p			x	x	x
trawl net raspachin 5 cm				x	
trawl net raspachin 6 cm				x	x
trawl net raspachin 8 cm					x
trawl net ligh rastra 8 cm	**				x
trawl net light rastra 12 cm	†**		x	x	
trawl net light rastra 14 cm	†**		x		
trawl net light rastra 16 cm	**				x
trawl net light rastra liviana 24 cm	†	x			
trawl net heavy rastra 8 cm	**				x
trawl net heavy rastra pesada 10 cm	**				x
trawl net heavy rastra 12 cm	†		x	x	
gill net trampero				x	x

trawl net tranquila 7 cm	**				X
trawl net tranquila 6 cm	† **		X		
trawl net tranquila 8 cm		X	X	X	X
trawl net tranquila 10 cm				X	X
gill net trasmallo 12 cm	†		X	X	
gill net trasmallo 4 cm	**				X
gill net trasmallo 6 cm	**				X
gill net trasmallo 7 cm			X		
gill net trasmallo 8 cm			X		
gill net trasmallo catfish 8 cm	**				X
gill net trasmallo catfish 10 cm	**				X
gill net trasmallo catfish 12 cm	**				X
gill net trasmallo catfish 14 cm	**				X
gill net trasmallo catfish 16 cm			X	X	X
gill net volador 12 cm	**				X
gill net volador 14 cm				X	
gill net volador 16 cm				X	X

859

Location of landing points in the Magdalena-Cauca River basin where biological and fishing information was collected. The study covered upper, middle, and lower basin; black points correspond to primary data obtained in this research, and white points correspond to secondary data used. Map was created in ArcGis 10.3 software. Source: The base map was created with the public available data of the Instituto Geográfico Agustín Codazzi [June 2018] <https://www.igac.gov.co/es/ide/datos-e-informacion/cartografia>. 1: 100,000 scale cartography was used. Geographic coordinates for the sampling stations and the additional records where sourced from own data, Valderrama and Zárate (1989) and Barreto (2017).

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