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Perceptions and reality in fisher coexistence with aquatic predators in the Peruvian Amazon

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Abstract

Humans and large aquatic predators compete for fish and negative interactions are widely reported as 'human–wildlife conflicts'. When aquatic predators are perceived to damage fisheries or fishing equipment, lethal control can occur. The perceptions and reality of damage are infrequently compared, but this relationship is key to determining how negative outcomes can be mitigated. We examine coexistence between people and six large aquatic piscivores (two caiman, two dolphins, two otters) in Amazonian Peru. We determine the extent of damage to fishing equipment caused by each species and compare this to the amount of damage perceived by fishers. Giant otter populations have recently recovered in some areas, so we expected different perceptions relating to experiences with otters. We trained fishers to complete fishing registers ($n = 278$, 1173 h of fishing) to record damage to nets by wildlife. We interviewed 302 people from three sites to determine perceptions of damage by predators, and attitudes towards giant otters. Rates of damage to nets reflected the presence and populations of different aquatic predators at each site, but when present, dolphins and caimans damaged nets more than otters, which rarely damaged nets. People living where giant otters had recently recovered perceived higher relative levels of damage to nets by them and had more negative attitudes about them, compared to people from areas where giant otters had been present for longer, aquatic predators were more abundant, and community resource management was longer-established. Better knowledge and more experience with a species may lead to more accurate perceptions of damage and increased tolerance. Where humans and animals compete for natural resources, conflict mitigation rarely includes better resource management. If tolerance of predators is greater where predators are common, and resources have not been overexploited, resource management may yield greater gains for stakeholders than other commonly prescribed forms of mitigation.

Introduction

Many wildlife species cause damage and economic loss to humans around the world (Nyhus, 2016). The extent or financial value of this damage is not always quantified, but these negative interactions can lead to the lethal control of the species responsible (Guerra, 2019). Where the species involved are not of conservation concern, such actions may be seen as pest control, but where threatened or declining species are involved, the control or conservation of these species may become a conservation-conflict between human stakeholders. These interactions are often portrayed as 'human–wildlife conflicts'. Negative interactions between aquatic predators and fisheries are frequent and widespread, but publications on aquatic human–wildlife conflict have not seen the exponential rise as noted for terrestrial systems (Guerra, 2019). Conflicts with freshwater aquatic predators are underreported (Cook *et al*., 2022), yet more than a third (37.5%) of crocodilians, cetaceans and otter species were frequently documented as 'in conflict' with humans (Cook *et al*., 2022).

Some of the largest crocodilians, saltwater crocodiles (*Crocodylus porosus*) and Nile crocodiles (*Crocodylus niloticus*), are frequently negatively perceived, either because of potential human attack (e.g. Caldicott *et al*., 2005; Wallace, Leslie, & Coulson, 2012), or for damage to fishing equipment (Aust *et al*., 2009). In Amazonia, three species of caimans (*M. niger*, *C. crocodilus* and *C. yacare*) break

commercial fishers' gill-nets leaving them unusable and reportedly cause injuries or deaths to people on occasion (Peres & Carkeek, 1993; Zucco & Tomás, 2004; Haddad & Fonseca, 2011; De Campos Neto, Stolf, & Haddad Jr, 2013; Balaguera-Reina & Velasco, 2019). Amazon river dolphin (*Inia geoffrensis*), hereafter Amazon dolphin, and tucuxi dolphins (*Sotalia fluviatilis*) in Brazilian rivers are considered competitors for fish resources by fishers, and cause damage though accidental entanglement in fishing gear (Da Silva & Best, 1996; Alves, Zappes, & Andriolo, 2012). Similarly, Ganges river dolphins (*Platanista gangetica gangetica*) in South Asian waterways interact negatively with fisheries (Paudel & Koprowski, 2020). Fisher-dolphin interactions in other freshwater dolphin species are rarely reported, but this may reflect the very low populations of these Endangered or Critically Endangered species (Cook *et al*., 2022). Negative human-otter interactions are well reported globally. Eurasian otters (*Lutra lutra*) damage fish farms (e.g. Bodner, 1995; Myšiak et al., 2013), and fisheries in Europe (Kruuk, 1995) while in Thailand, the Eurasian otter and sympatric Indian smooth-coated otter (*Lutrogale perspicillata*) damage fisher's nets (Kruuk, 1995). In Cambodia, the Indian smooth-coated otter and Hairy-nosed otter (*Lutra sumatrana*) are perceived as competitors by people that rely on fishing for income (Nop, 2007). Spotted-necked otters (*Lutra maculicollis*) interact with fishers in Rwanda taking 15% of fish from their nets and are considered pests (Lejeune, 1989; Larivière, 2002). The Neotropical otter (*Lontra longicaudis*) has also been reported damaging fishing nets from artisan fishers (Barbieri *et al*., 2012) and attacking fish traps in Brazil (Castro *et al*., 2014), while fishers have often reported giant otters (*Pteronura brasiliensis*) damaging fisheries and nets (Gomez & Jorgenson, 1999; Recharte, Bowler, & Bodmer, 2008; Lima, Marmontel, & Bernard, 2014a) although some authors have pointed out limited overlap between the diets of otters and fisher's most targeted fish species (Rosas-Ribeiro, Rosas, & Zuanon, 2012).

It is not always clear how attitudes correlate with the actual behaviour of people towards predators, but negative perceptions can lead to retaliation and lethal control (Dickman *et al*., 2014). When damage by a wild species is not measured, it is the perceived value of losses, rather than actual damage, that will influence peoples' attitudes and their degree of tolerance towards the species (Guerra, 2019). Perceptions are driven by a range of factors in addition to the rates and cost of damage. Cultural beliefs, socio-demographic factors and ecological knowledge are widely acknowledged to shape perceptions (Dickman, 2010; Nyhus, 2016), and in marine ecosystems, socioeconomic characteristics influence fishermen's attitudes (see Engel *et al*., 2014; Pont *et al*., 2016; Ramos *et al*., 2023). Because there are wider drivers of perceptions and attitudes, the perception of damage and costs may not align with reality, and there appears to be a tendency for perceptions of loss to be greatly exaggerated (e.g. de Oliveira *et al*., 2020). Where experience and ecological knowledge is a factor, negative perceptions of wildlife may be particularly exaggerated where species populations are newly recovered, bringing them into contact with humans that are not accustomed to them (Stoldt *et al*., 2020), or the ecological impacts that they have (Carswell, Speckman, & Gill, 2015; Cummings, Lea, & Lyle, 2019).

The extensive river basin and associated wetlands of Amazonia host several large piscivorous predators, active commercial fisheries, and a human population dependent on subsistence fishing. In the western Brazilian Amazon, the black caiman is the most problematic species, followed by the Amazon dolphin, giant otter and tucuxi dolphin (Cook *et al*., 2022). However, all these species vary greatly in their distribution and habitat use within the Amazon region and negative interactions will be specific to the wildlife at each locality. For example, Amazon river dolphins are most common on larger rivers with abundant oxbow lakes, and where there is extensive seasonally flooding forest (Gomez-Salazar *et al*., 2012; Belanger *et al*., 2022), while black caiman have historically been heavily hunted, and their populations are now often concentrated in protected areas and very remote river systems (Marioni *et al*., 2021). One aquatic predator, the giant otter, has recently undergone significant changes in distribution across Amazonia. The IUCN still lists the species as Endangered and report overall declining populations through the destruction of their habitats (Groenendijk *et al*., 2015), but in the last two decades, populations of giant river otters have been recovering through most of Amazonia, inside and outside protected areas (e.g. Groenendijk & Hajek, 2006; Recharte & Bodmer, 2010; Groenendijk *et al*., 2014; Lima, Marmontel, & Bernard, 2014b; Pimenta *et al*., 2018). As a result, interactions with people have become more frequent (Recharte, Bride, & Bowler, 2015). Fishers perceive competition with giant otters due to overlap between commercial and subsistence fish species, and those consumed by otters (Carter & Rosas, 1997; Gomez & Jorgenson, 1999). They blame giant otters for reduced catches of fish and for damaging fishing nets (Lima, Marmontel, & Bernard, 2014a; Recharte, Bride, & Bowler, 2015), and in some cases express a desire to cull giant otter populations (Recharte, Bowler, & Bodmer, 2008).

Here, we compare actual levels of net damage caused by six species of large aquatic predators with perceptions of the damage caused in three communities with different population histories for the study animals. Additionally, to examine the effects of familiarity on negative outcomes, we compare attitudes and tolerance towards giant otters at different stages of population recovery at each of the three sites. We hypothesise that where giant otters have recently recovered, perceptions of net damage might exceed actual levels relative to other species that are better known to residents and affect attitudes towards the species.

Materials and methods

Study areas

This study was carried out in three protected areas in the north-eastern Peruvian Amazon, in the political district of Loreto (Fig. 1) between September 2014 and May 2017.

This large region of indigenous territories and protected areas is encountering significant threats from hydroelectric dam and road building (Roucoux *et al.*, 2017).

We collected data in four communities (28 de Julio, Alfonso Ugarte, Santa Elena and Intuto) on the boundary of the Pucucuro National Reserve (hereafter Pucacuro), two communities (Nueva Vida and Puerto Huaman) on the boundary of the Maijuna Kichwa Regional Conservation Area (MKRCA), and one community (San Martin de Tipishca) in the Pacaya-Samiria National Reserve (hereafter Pacaya Samiria) (Table 1).

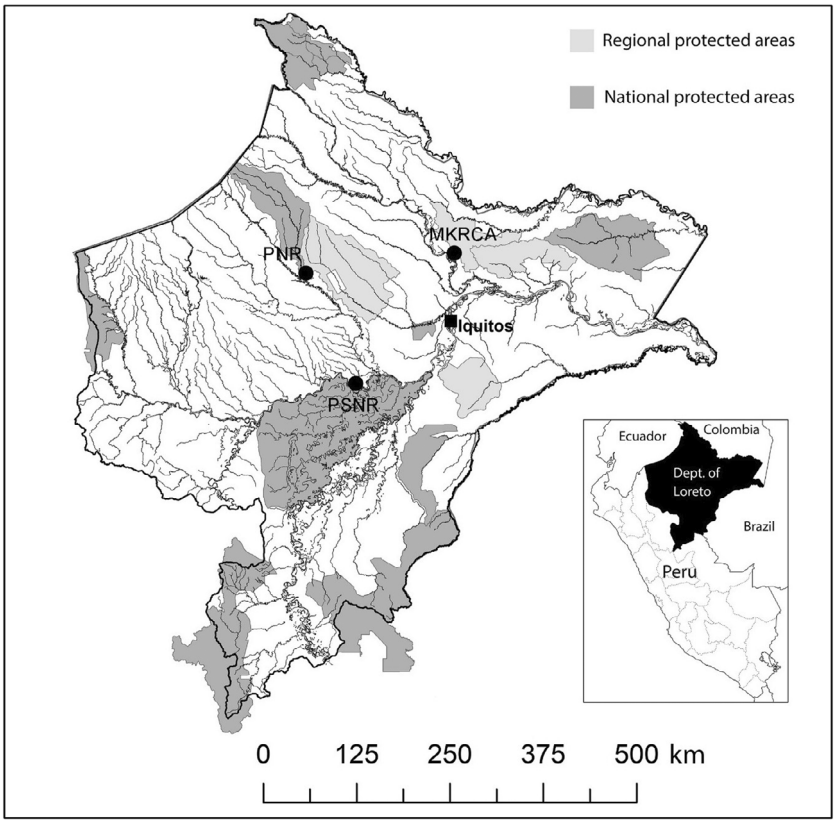

Figure 1 Communities surveyed for perceptions of damage by aquatic predators in Pucacuro National Reserve (PNR), Pacaya-Samiria National Reserve (PSNR) and the Maijuna Kichwa Regional Conservation Area (MKRCA).

Table 1 Characteristics and species of large aquatic piscivore present at three study areas in the Peruvian Amazon

	Pacaya Samiria	Pucacuro	MKRCA
Year established as protected areas	1972	2005	2015
Area (ha)	2 080 000	637 954	391 040
Main river	Marañon	Tigre	Napo
Ethnicity of indigenous communities	Kucama-Kucamilla	Kichwa	Maijuna-Kichwa
Study villages for interviews	San Martin de Tipishca	28 de Julio, Alfonso Ugarte, Intuto, Santa Elena	Nueva Vida, Puerto Huaman
Tourism	Yes	No	No
Species present			
Giant otters	Yes	Yes	No
Neotropical otter	Yes	Yes	Yes
Amazonian river dolphin	Yes	Yes	Yes
Tucuxi dolphin	Yes	Yes	Yes
Black caiman	Yes	Yes	No
Common caiman	Yes	Yes	Yes
Methods used			
Interviews	Yes	Yes	Yes
Fishing registers	Yes	Yes	No

Sources: SERNANP (2009), SERNANP (2013), Gilmore (2010).

The Pucacuro National Reserve (PNR)

The Pucacuro National Reserve was declared in 2014 in one of the regions with the highest biodiversity in the world (Ridgely & Guy, 1989; Voss & Emmons, 1996; SERNANP, 2013; Perez-Peña *et al*., 2014). There are no communities inside the reserve, but eight communities are situated outside of the protected area, seven of which belong to the Kichwa indigenous group. Livelihoods here are based around farming and hunting, although fishing is a daily activity providing one of the main sources of dietary protein. Several species of fish are commercially exploited including ornamental fish such as Arowana (*Osteoglossum bicirrhosum*), and important food fish like catfish (Siluriformes) and giant Arapaima (*Arapaima gigas*) (Perez-Peña *et al*., 2014). Pucacuro had yet to develop tourism.

All six large predators were present in the reserve, but the giant otter had only recently returned to the area after a long absence that exceeded the memory of most inhabitants. Family groups of giant otters were newly confirmed during wildlife monitoring by park guards in 2013 (Ruck *et al*., 2014) and were being regularly encountered by fishers by the time of our interviews.

Maijuna-Kichwa regional conservation area (MKRCA)

The MKRCA is situated between the Napo River close to Iquitos, and the Algodon River close to the Colombian border on its northern side. It was declared a Regional Conservation Area in 2015 (SPDA, 2015). The main livelihood activities in the MKRCA are hunting, fishing, swidden-fallow agriculture and the collection of forest products like palm fruits (Gilmore, Endress, & Horn, 2013). The communities Nueva Vida and Puerto Huaman on the Yanayacu River are relatively close to the city of Iquitos, but are not visited by tourists (Gilmore, Endress, & Horn, 2013).

Amazon river dolphins, common caiman and Neotropical otters were frequent close to the communities, while tucuxi dolphins rarely entered the narrow river channels. Black caiman and giant otters were thought to have been absent from the site for several decades although occasional sightings by residents at nearby localities are possible (Bravo, 2010).

Pacaya-Samiria National Reserve (PSNR)

The Pacaya Samiria National Reserve, located between the Marañon and Ucayali Rivers, is one of the largest protected areas of the Peruvian Amazon. It was classified as a National Reserve in 1982 (SERNANP, 2009). People in the community of San Martin de Tipishca within the reserve have livelihoods based on agriculture, palm fruit extraction, managed hunting and fishing, and small-group tourism (SERNANP, 2009; Gomez-Salazar *et al*., 2012).

All six large predators were present in the reserve. The giant otter had been close to extinct in the reserve for many years, during which time it was unknown to most inhabitants (Recharte & Bodmer, 2010). However, the species recovered between 2000 and 2010 and was established throughout the reserve by the time of our interviews (Recharte, Bride, & Bowler, 2015).

Data collection and analysis

Fishing registers

To explore the actual net damage caused by aquatic predators, we recruited six fishers in Santa Elena (Pucacuro) and six in San Martin de Tipishca (Pacaya Samiria) to record net damage and negative interactions with aquatic fish predators alongside existing fishing registers of fish catches and weights during their normal fishing activities. We were unable to implement fishing registers in the MKRCA. Fishers were trained to fill-in a datasheet and record the number of times actual damage was caused by each aquatic predator species or by fish. Registers were kept for a representative sample of the communities' normal fishing activity across different parts of their territories. Fishers identified predator species visually. Caiman species were recorded together, because fishers did not always see enough of the animal to identify it to species level, and fish were recorded by family as broadly identified by the fishers using common names. Fishers were unable to record the fish lost to predators. Fishers also recorded dates, number of fishing hours during the day and night (defined by the position of the sun above or below the horizon), the amount of fish caught, size of the net used and the size of every instance of damage. To compare the amount of damage caused by each species, we used the total length of damage caused per 100 h of fishing per 100 m of net. Fishers completed 278 damage registers across 68 days, totalling 1173 h of fishing (667 h during the day, 506 h at night). Nets used were 20–50 m long, 2 m deep nylon gill nets with a 5.1 cm mesh and floats on the top edge. These nets target a broad range of species. Nets were set at river or lake margins where they typically reached close to the bottom of the water. Catches were processed for consumption or sale, depending on the volume and species composition of the catch.

We used descriptive statistics and a non-parametric Kruskal–Wallis test to compare the amount of net damage due to each species. We used binomial regression to determine whether the total hours of fishing or total fish captured predicted the occurrence of damage by predators.

Interviews

Leaders from each community granted permission to carry out research. In Pucacuro, initial interviewees were selected from a list of people in the community held by the SERNANP reserve management team, and in Pacaya Samiria and MKRCA the head of each community identified families available for interview. We used a 'snowball' method (Bernard, 2006) to find additional interviewees. Interviewees were given explanations of the research prior to requesting consent and could withdraw from the interview at any time. In each community, we interviewed two representative adults

per household (over 18 years old). One male and one female were selected where available. Although fishing is predominantly carried out by men in the region, most women also fish to some extent and are highly involved in the preparation of catches and the repair of nets (Recharte, Bride, & Bowler, 2015). In these activities, they observe and discuss damage. Since perceptions are formed through knowledge transfer as well as experience (Braga-Pereira *et al.*, 2022), women represented an important demographic to this study. All Ethics approval was granted by the University of Stirling Ethics Committee and approved by the Peruvian protected areas authority (SERNANP) and locally by community leaders.

Face-to-face structured interviews with closed and open-ended answers were used. We asked respondents in Spanish about (1) their socio-demographic background, (2) their perception of damage to fisheries and nets by aquatic predators; and (3) their attitudes and tolerance towards the aquatic predators. Attitude was defined as 'a *disposition or tendency to respond with some degree of favour or not to a psychological object'* (Kansky & Knight, 2014).

Perceptions of damage by aquatic predators

To compare perceptions of damage by aquatic mammals, we asked interviewees to rank the species that '*steal most fish*' and '*damage nets most*' from six aquatic predators and a control species; the vegetarian capybara (*H. hydrochaeris*). We used the mean Weighted Rank Index (WRI) score to compare species and areas (Nepal & Weber, 1993; Gillingham & Lee, 2003), where

$$\mathrm{WRI} = \sum_i^n \left(\frac{\mathbf{1}}{\boldsymbol{R}\mathrm{i}}\right)/\boldsymbol{N}$$

correspond to: n, number of respondents ranking species; R, rank of the *ith* order; N, total number of respondents in the sample.

We also asked about the perception of the relative cost of repairing broken fishing nets attributed to single events involving each animal species; all the answers were converted from Peruvian Soles to American Dollars ($) at the rate prevailing in 2017. We used a one-way ANOVA to compare the perceptions of costs checking the assumption of normality with the Shapiro–Wilk test.

Attitudes and tolerance towards a recovering aquatic predator

To compare knowledge, opinions, perceptions, attitudes and tolerance for a species at different stages of recovery, we asked a series of questions about giant otters that could be answered 'yes', 'no' or 'I don't know' (Table 2). We compared the proportion of respondents in agreement ('yes' answers) with each question at each site using Kruskal-Wallis tests.

To understand why people would kill giant otters, we asked interviewees if they knew somebody that had killed or tried to kill a giant otter, and if so, why they had done so. This open-ended question was not used for empirical analysis.

Socio-demographic factors and attitudes

Overall attitudes were scored using questions 1–3 and 5–7, for which answers could be categorised as positive, negative or neutral. Because not agreeing with a statement does not necessarily indicate an opposite view, we scored '1' for agreeing with a positive statement and '0' for disagreeing or responding, 'I don't know'. For negative questions, we scored '-1' for agreeing or '0' for disagreeing or 'I don't know'. Summing these scores produced an overall attitude score for each respondent, with positive values representing more positive responses, and negative values more negative responses. Because these scores are based on a limited range of specific questions, they cannot be used to determine overall positive or negative attitudes towards giant otters. Rather, we use them to examine the influence of socio-demographic factors on the probability of a respondent returning overall negative responses to our specific set of questions (Table 2).

To determine whether socio-demographic factors were associated with positive or negative attitudes towards giant otters, we used a Generalised Linear Model with logit link function GLZM(b) to assess which factors were associated with overall attitudes. We used (1) geographical area, Pucacuro National Reserve (PNR), Pacaya-Samiria National

Table 2 Questions on perceptions and attitudes towards giant otters (*Pteronura brasiliensis*) at communities surveyed for damage by aquatic predators in Pucacuro National Reserve (PNR), Pacaya-Samiria National Reserve (PSNR) and the Maijuna Kichwa Regional Conservation Area (MKRCA), in the Peruvian Amazon

	Do you agree with the following statements?	Yes	No	I don't know
1	I like to have giant otter living close to my community			
2	I am scared of giant otters			
3	The only way to have more fish is if all the giant otters disappear from the area			
4	There more giant otters now than 10 years ago			
5	There are a lot of fish in the river for the giant otter and for us			
6	Should animals that break nets be killed?			
7	Have you ever killed or tried to kill a giant otter?			
8	Is killing giant otters permitted?			

Reserve (PSNR) and the Maijuna Kichwa Regional Conservation Area (MKRCA); (2) Gender (scored as male or female since only these responses were given); and (3) education level (none, primary only, secondary or higher) as explanatory variables. We used Pearson χ^2 to test for overdispersion. Wald χ^2 was used to test the significance of each factor using a two-tailed $P < 0.05$. We did not test for interactions between the variables because the sample was too small for robust assessment of interactions.

Results

Interactions with large aquatic predators

Net damage occurred on 172 (61%) of 278 fishing sessions recorded in participatory fishing registers in Pacaya Samiria and Pucacuro. Eighty-three (48%) of these events were caused by dolphins, caiman and otters, 3 (2%) by unknown causes, and 86 (50%) by fish, largely piranhas (Serrasalmidae) that bit holes when they attacked other fish trapped in the nets, or by suckermouth catfish (Loricariidae) with ridged fins that make them inextricable from the net without damage. Of the 83 events caused by large aquatic predators, most were caused by Amazon river dolphins ($n = 51$), followed by caiman ($n = 23$), for which the species could not be determined, giant otters ($n = 7$) and Tucuxi dolphins ($n = 2$). Neotropical otters were never recorded damaging nets. Rates of damage varied between the two reserves. Incidents of net damage were three times more frequent in Pacaya Samiria compared to Pucacuro (incidence rate ratio: 3.08, 95% CI: 1.82–5.45, $P < 0.0001$) (Fig. 2), but the proportion of incidents of damage caused by each species was similar at each site. Different species caused different amounts of damage per event. Caimans were occasionally caught in the nets at Pucacuro, leading to a small number of events with extensive net damage (Fig. 2b).

The effects of fishing time and rates of fish capture on net damage

Rates of net damage were similar during the day and night, even for nocturnal species (Fig. 3). Nightly hours fishing and fish capture weights were entered into a binomial logistic regression to predict damage (yes/no) to nets. The logistic regression model ($\chi^2 = 11.14$, d.f. = 2, $P < 0.05$) explained 11% (Nagelkerke $R^2 = 0.11$) of the variance of net damage and correctly classified 60% of the fishing trips in relation to net damage. Larger catches of fish slightly increased the likelihood of net damage (odds ratio = 1.04; 95% CI = 1.02–1.06; $P \leq 0.001$), but the duration of a fishing session had no effect on damage (odds ratio = 0.96, 95% CI = 0.89–1.63; $P = 0.24$).

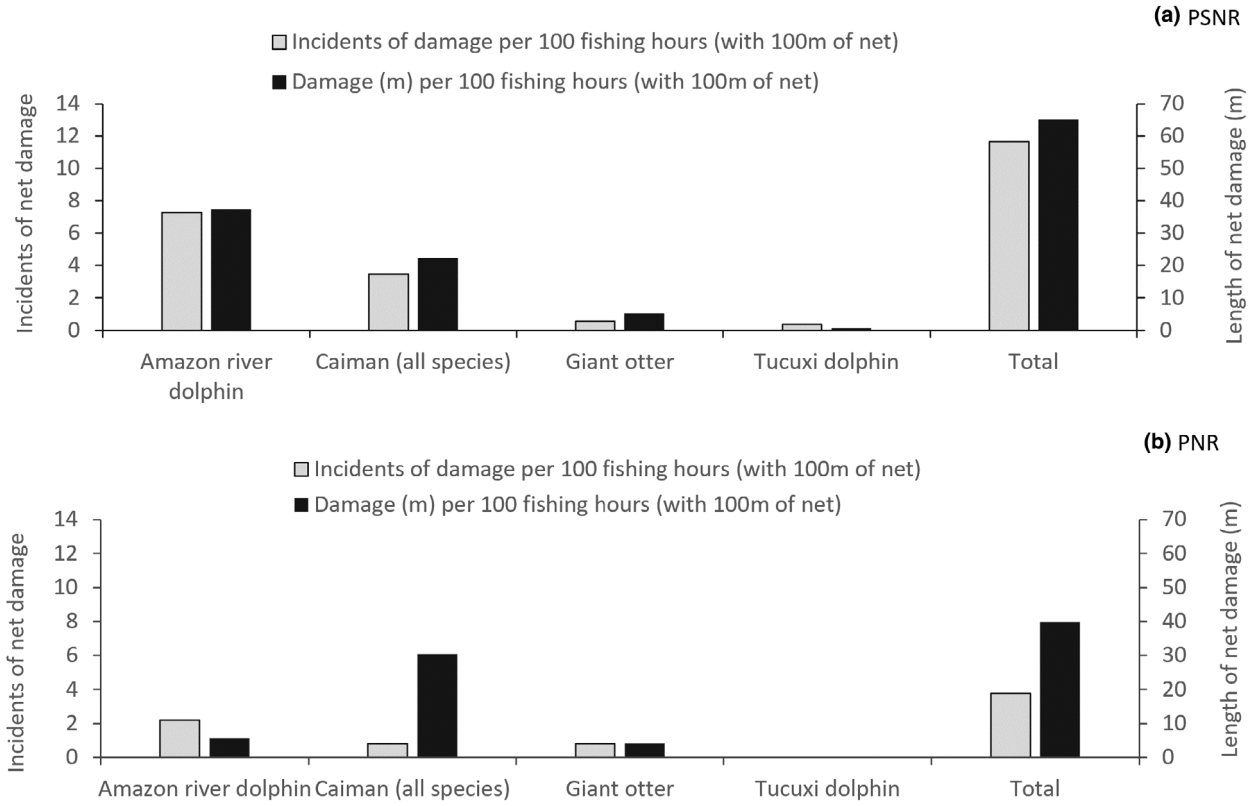

Figure 2 Damage to fishing nets per 100 fishing hours by aquatic predators during fishing trips by fishers in Loreto, Peru in (a) the Pacaya-Samiria National Reserve, Peru. (b) Pucacuro National Reserve, Peru.

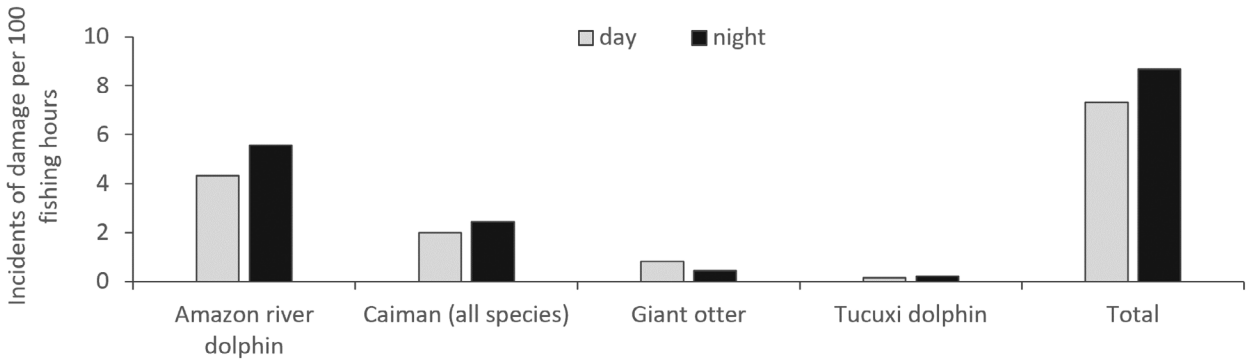

Figure 3 Rates of net damage by aquatic predators during day and night during fishing trips by fishers in the Pucacuro and Pacaya-Samiria National Reserves, Peru.

Perceptions of damage caused by aquatic predators

We interviewed 302 people in total, 155 male and 147 female, 172 (57%) from Pucacuro, 80 (26.5%) from Pacaya Samiria and 50 (16.6%) from MKRCA. The average age of the interviewees was 41 years (mean = 40.68, SD: 13.49), and the average family size was five (mean = 5.2, SD: 2.4). While the main economic activity for most people was farming (91.7%, $N = 277$), 162 (53.6%) of respondents also mentioned fishing as one of their most important activities for earning money. Thirty-seven (12.3%) listed it as their main economic activity.

Net damage was reported by 100% of respondents, including those that did not fish personally. In these cases, damage to family members nets was reported. When we asked which animals fishers thought stole most fish from nets, and which caused most damage to fishing nets, the responses varied between communities from the different protected areas. While Amazon dolphin and giant otter were consistently considered among the most harmful in all three areas, caiman were considered more harmful by fishers in Pacaya Samiria compared to the other two areas; in MKRCA the neotropical otter was perceived as taking most fish and damaging most nets (Fig. 4).

Damage to nets is associated with several costs that can be hard to quantify. As well as the monetary value of the net, there is a reduction in the efficacy of the net while damaged, and time and resources are used in repairing nets. Most respondents ($N = 278$) told us that they paid for materials to repair the nets, 13% ($N = 42$) said they organised communal gatherings for repairing nets.

There were 24 respondents that did not answer the question or said that they would not repair the net, using damaged nets until they were replaced. Interviewees were asked to estimate the cost of repairing the net from a single 'damage event' caused by each species that broke it. The mean perceived cost of events was greatest for black caiman at $12.68 and lowest for tucuxi dolphin at $8.62. However, although there were differences between the perceived costs of damage between species (one-way ANOVA, F (5,1225) = 4.36, $P < 0.001$), the observed effect size f is small (0.13), and only the differences between black caiman and tucuxi dolphin ($P < 0.001$) and between black caiman and Neotropical otter ($P = 0.022$) were significant (Tukey HSD).

Attitudes and tolerance towards a recovering aquatic predator

The majority of respondents in Pacaya Samiria and Pucacuro (81.2 and 72.1%, respectively) said there were more giant otters now than 10 years ago, but fewer than half of respondents from MKRCA (44%) believed that giant otter population was increasing. At the time of interviews giant otter populations had not reached the vicinity of the community surveyed in the MKRCA and were only observed in the reserve by people who travelled far from the community. Seventy percent of respondents from Pacaya Samiria and 25.6% from Pucacuro said they liked living close to the giant otters, compared to 50% of the respondents from the MKRCA, where giant otters are rare (Gilmore, 2010). When asked about the impact of giant otters on fish populations, there were differences between communities; 61% of respondents in Pucacuro, and 40% in MKRCA thought that removing giant otters from the protected area would lead to increased fish populations. In Pacaya Samiria, this was much lower, with only 25% of people agreeing with that statement. Most people in all areas thought that there were plenty of fish for both their communities and the giant otters. Less than half of interviewees agreed with the statement 'I feel scared of giant otters' (Fig. 5).

Less than a third of respondents (28.8%) from Pacaya Samiria agreed with the statement that animals that broke nets should be killed, compared to much higher proportions in communities in Pucacuro (57.6%) and MKRCA (66%) (Kruskal-Wallis: $\chi^2 = 23.23$; $P < 0.001$).

There was a significant difference in the proportion of people self-reporting that they had killed giant otters in Pacaya Samiria, Pucacuro and MKRCA (Kruskal-Wallis: $\chi^2 = 23.93$; $P < 0.001$), with a minority of the respondents (1.2%) from Pacaya Samiria admitting to killing one compared to 23.3% in Pucacuro and 32% MKRCA (Fig. 6).

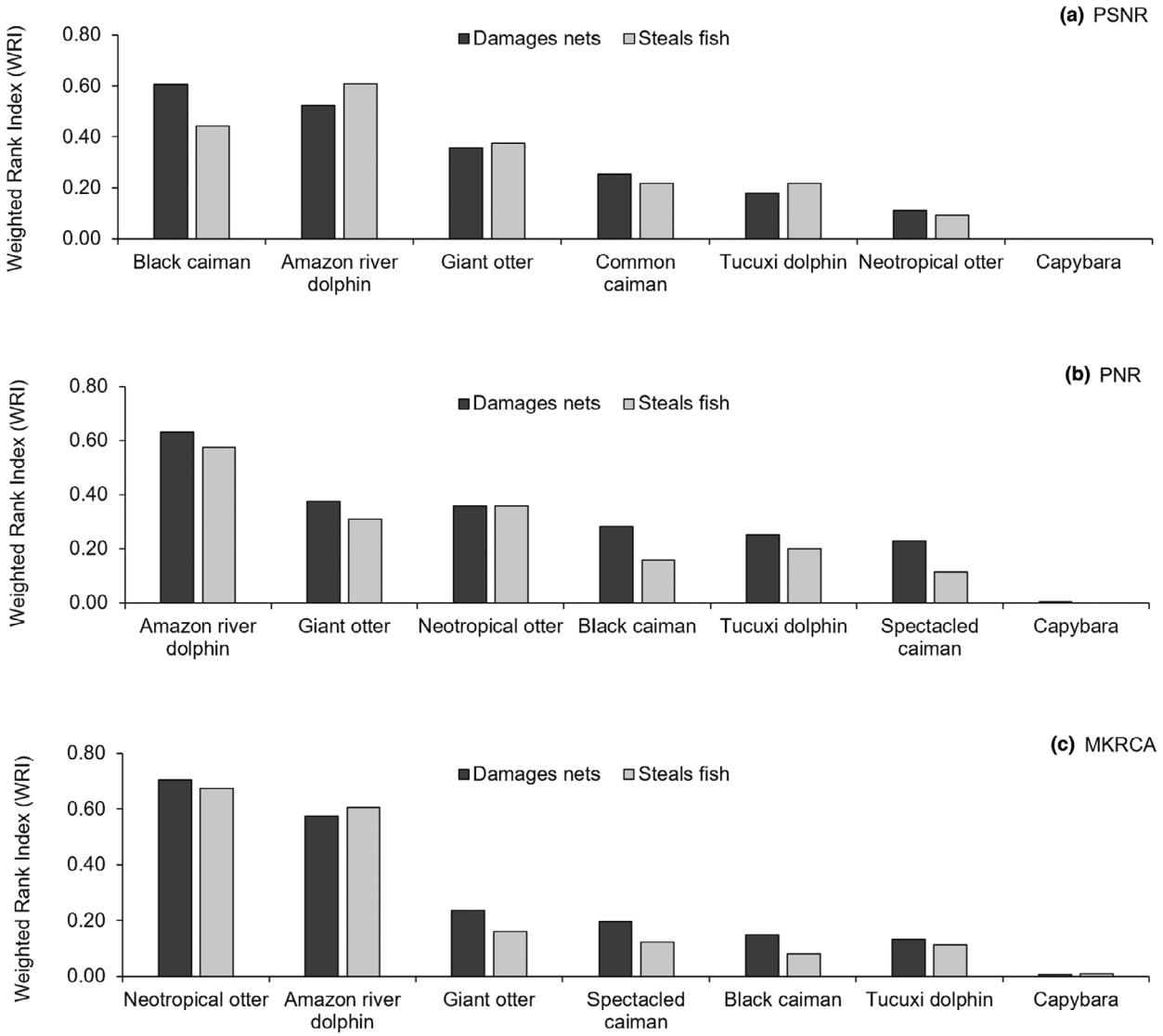

Figure 4 Perceptions of loss of fish and damage to nets by the aquatic predators in the Peruvian Amazon; black caiman *Melanosuchus niger*, common caiman *Caiman crocodilus*, Amazon river dolphin *Inia geoffrensis*, tucuxi dolphin *Sotalia fluviatilis*, giant otter *Pteronura brasiliensis* and neotropical otter *Lontra longicaudis*. From interviewees in the communities of; (a) Pacaya-Samiria National Reserve (PSNR) $N = 80$, (b) Pucacuro National Reserve (PNR) $N = 172$, and (c) Maijuna-Kichwa Regional Conservation Area (MKRCA) $N = 50$. Scored using the Weighted Rank Index (WRI) for each species and presented in order of rank for the most net damage. Capybara (*Hydrochoerus hydrochaeris*) was included as a control.

There was significant difference between the communities (Kruskal-Wallis: $\chi^2 = 43.26$; $P < 0.001$) where respondents said that they knew that killing giant otters was illegal; most respondents in Pacaya Samiria (93.8%) and Pucacuro (65.1%) were aware, but in MKRCA fewer (40.0%) knew about this legislation.

Of 302 respondents 34% ($N = 103$) said they knew someone that had previously hunted giant otter. Of these, 50 (49%) people said it was because of damage to nets, 26 (25%) respondents said they wanted to sell the skin, 16 (16%) said to keep the young as a pet, while 10 (10%) gave diverse other reasons.

Socio-demographic factors and attitudes

Binary logistic regression was used to see how attitude scores were influenced by geographical area, gender, or educational level. Our model explained a significant amount of the variation on whether respondents gave overall negative responses to our questions about giant otters (GLZM(b): Likelihood $\chi^2_2 = 34.65$, $N = 302$, $P < 0.0001$).

Geographical area (GLZM(b): Wald $\chi^2_2 = 13.60$, $N = 302$, $P = 0.001$), gender (GLZM(b): Wald $\chi^2_2 = 9.31$, $N = 302$, $P = 0.002$) and educational level (GLZM(b): Wald $\chi^2_2 = 6.72$, $N = 302$, $P = 0.035$) all had a significant effect on

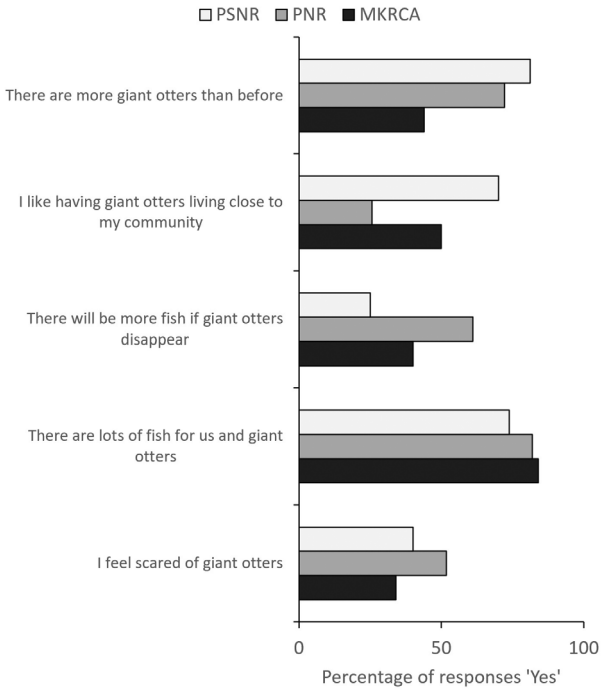

Figure 5 Opinions and perception towards giant otters (*Pteronura brasiliensis*) in three sites in Loreto, Peru: Pucucuro National Reserve (PNR) ($N = 172$), Maijuna Kichwa Regional Conservation Area (MKRCA) ($N = 50$) and Pacaya-Samiria National Reserve (PSNR) ($N = 80$).

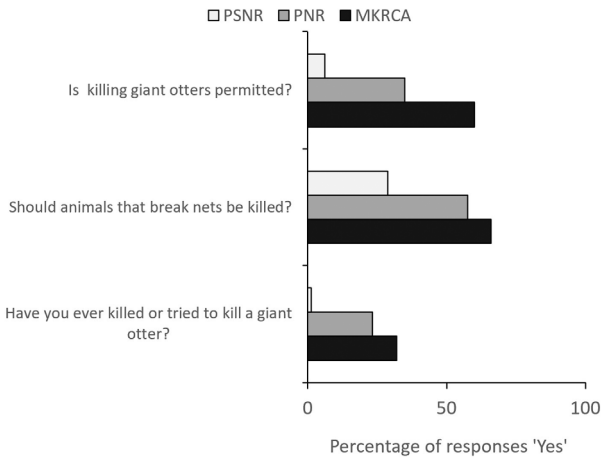

Figure 6 Self-reported knowledge, attitudes and actions relating to retaliation towards giant otters and other net damaging animals in the three study areas: (a) Pacaya Samiria ($N = 80$), (b) Pucacuro ($N = 172$), and (c) MKRCA ($N = 50$).

the probability of returning overall negative responses to attitudinal questions about giant otters.

Respondents from Pucucuro were 3.7 times more likely to give more negative responses overall than people from Pacaya Samiria (Exp(B) = 3.67, 95% CI: 1.68–8.02), while those from MKRCA were 1.4 times more likely to give negative responses overall than people from Pacaya Samiria (Exp(B) = 1.43, 95% CI: 0.51–4.01). Women were more than twice as likely to give more negative responses than men (Exp(B) = 2.47, 95% CI: 1.38–4.42), and those who completed more time in school were less likely to give negative responses (secondary levels compared to primary only, Exp(B) = 2.33, 95% CI: 1.21–4.49; secondary levels compared to no education, Exp(B) = 1.44, 95% CI: 0.57–3.59).

Discussion

Incidents of net damage by aquatic predators were three times more frequent in Pacaya Samiria compared to Pucacuro. At both sites, Amazon dolphins and caiman most often damaged nets and there were relatively low levels of damage by either of the two otter species or tucuxi dolphins. At Pacaya Samiria, dolphins caused damage three times as frequently and caiman four times as frequently than at Pucacuro. Although the length of net damaged per 100 fishing hours by caiman at Pucacuro was slightly higher than at Pacaya Samiria, this was driven by two rarer incidents at Pucacuro in which caiman became entangled, damaging very large sections of net. Such an encounter with either caiman species can often render an entire net unusable (Peres & Carkeek, 1993; this study). We have no reason to suspect that these major events are more frequent relative to minor incidents at either site – fishers report similar incidents at Pacaya Samiria, but they did not occur while participants were keeping registers.

Differences in rates of damage are likely driven by animal abundance for each species. Pacaya Samiria has high populations of both dolphin species relative to other sites, often attributed to the abundant lakes and high proportion of seasonally flooding '*varzea*' forest at the site (Gomez-Salazar *et al.*, 2012; Belanger *et al.*, 2022). Similarly, Pacaya Samiria has larger numbers of large adult black caiman, which are becoming increasingly rare outside protected areas (Marioni *et al.*, 2021), and common caiman are more abundant at Pacaya Samiria compared to Pucacuro, perhaps attributable to habitat and the longer history of community management of the reserve (Gomez, 2015; Hernández, 2016).

Perceptions of net damage varied between reserves, in most cases matching up with what we recorded in net damage registers and corresponding with the wildlife present at each site. Amazon dolphins were ranked highly for damage at all three sites, perceived in first or second place as animals that broke nets with the highest frequency and stole the most fish from nets. This reflects reality in Pacaya Samiria and Pucacuro, in that dolphins were the most frequent damagers of nets at both sites. Black caiman ranked highly in Pacaya Samiria, but not at other sites, reflecting the higher population in this reserve relative to other sites. However, we could not determine how much of the actual damage reported in registers was done by black or common caiman, so it is difficult to compare the perceptions of damage by black caiman with reality. Amazon dolphins clearly caused more incidents of damage than all caiman species together. This could be seen as a discrepancy between perceptions

and reality, but if the occurrence of occasional major damage events by caiman in Pacaya Samiria has a similar effect on the total net damage caused by caiman, as it did in registers for Pucacuro, then caiman could indeed be causing more damage than Amazon dolphins when averaged out over longer periods.

In the MKRCA, the neotropical otter was the perceived as the most damaging. Although we do not have net damage registers for these communities, the rarity or absence of other species at the site can potentially explain these perceptions. The river channel near the MKRCA communities is relatively small, so Amazon dolphins are relatively infrequent and highly seasonal, while tucuxi dolphins are very infrequent. Giant otters and black caiman were not present close to the communities at the time of our surveys and would only have been encountered by community members further afield (Gilmore, 2010). Even common caiman were only present as occasional small specimens, likely a result of high hunting pressure (Gilmore, 2010). Neotropical otters are relatively small, solitary, and naturally occur at low densities (Rheingantz, Santiago-Plata, & Trinca, 2017), so we do not expect rates of damage to be high. Rather, we suspect that the overall rates of damage by other aquatic predators is much lower at MKCRA than at the other sites, leaving the Neotropical otter as the highest ranked for perceived damage.

At Pacaya Samiria and Pucacuro, perceptions of damage to nets by giant otters did not always match up with registers. Otters were ranked as more damaging for fishing nets than were both species of caiman at Pucacuro, but not at Pacaya Samiria. In reality, damage was infrequent by comparison to caiman at both sites. Respondents from Pucacuro were also much more likely to give more negative responses to attitudinal questions than people from Pacaya Samiria. At Pacaya Samiria, people have coexisted with larger numbers of predators, and more frequent net damage, for longer periods of time, and yet view them more positively in our interviews. Where species are infrequently encountered and therefore less well known, perceptions may not reflect reality and tend to be more negative (Lescureux *et al*., 2011; Wieczorek Hudenko, 2012; Dickman & Hazzah, 2016). In Pacaya Samiria, where perceptions more closely reflected reality, fishers have been coexisting with giant otters for longer, around a decade sooner than the recovery of the otters in Pucacuro in the early 2010s (Ruck *et al*., 2014; Recharte, Bride, & Bowler, 2015), not long before surveys were conducted. Giant otters are diurnal and highly visible, eating their catches above the water, which may give the impression of greater predation than more cryptic species. We suggest that the lack of familiarity at Pucacuro may have inflated perceptions of the risk of damage by giant otters as their populations recovered, driving more negative attitudes, while greater experience may better inform fishers from Pacaya Samiria on the likelihood of net damage and fish consumption by these predators. More prevalent negative attitudes towards these predators in women may also be driven by lower levels of experience with them. Such discrepancies in perception and reality may be broadly typical of attitudes towards recently recovered predators and highlights a need for close examination wherever species recovery brings large predators into contact with people.

In addition to perceptions of damage being more realistic in Pacaya Samiria relative to Pucacuro and the MKRCA, there also seems to be greater tolerance of aquatic predators. Less than a third of respondents (28.8%) from Pacaya Samiria agreed with the statement that animals that broke the nets should be killed, compared with 57.6% in Pucacuro and 66% in MKRCA. This could reflect a difference in knowledge of the law, other benefits from wildlife, or the results of conservation activity in the more established reserve (Recharte, Bride, & Bowler, 2015). Or, it could be that increased experience with these predatory species could mitigate the effects of damage and competition and increase tolerance towards predatory species. While the recovery of giant otters across many Amazonian regions (Groenendijk *et al*., 2021) means that negative perceptions with potentially lethal outcomes could increase across the entire Amazon region, the suggestion that familiarity can reduce negative sentiment is encouraging. However, it should also be noted that the increased familiarity in Pacaya Samiria comes alongside an established and largely successful community-managed fishery with better fish catches and associated economic benefits (Bodmer, Puertas, & Fang, 2009; Bodmer *et al*., 2014). As a new National Reserve, Pucacuro is still developing community fisheries management practices. The relationship between the perceptions of wildlife conflict and trends in resource availability appears to be somewhat neglected in the literature (e.g. Nyhus, 2016) and in aquatic ecosystems research tends to be focused on the effect that the animal in conflict has on fisheries, rather than how declines through other mechanisms might impact perceptions of predators (Guerra, 2019). Good fisheries management, leading to positive changes in fish populations, could change perceived and actual levels of net damage and competition between people and aquatic predators, while familiarity with predators will reduce discrepancies between perceived and actual levels of damage.

Mitigation suggested for net damage often includes increased rates of collection of fish from the nets to avoid attracting predators (Akpona *et al*., 2015). Informal conversations with fishers during our research suggested that fishers in Pacaya Samiria, Pucacuro already mitigate higher levels of net damage at night with more frequent net checking to reduce incidents with aquatic predators. This practice may explain why the difference between net damage at day and night is minimal in our registers, even though some principle damagers of nets, the black and common caiman, are largely nocturnal. Other forms of mitigation for damage to fisheries by aquatic predators in Amazonia, are unproven. Compensation schemes in large, remote and economically poor areas are unlikely to be viable. Tourism has been wildly proposed as a form of mitigation for negative experiences with large predators and other problematic wildlife globally (Kiss, 2004) and may play a role at some sites (Recharte, Bride, & Bowler, 2015). However, benefits from tourism reach a limited number of localities in Amazonia (Alverson *et al*., 2008;

Recharte, Bride, & Bowler, 2015) and generally reach small proportions of the local communities (Goodwin & Roe, 2001).

Where tourism cannot reach, altering perceptions may be one of the few applicable methods for mitigating the effects of damage by aquatic predators, but the best methods for enabling perceptual change remain to be established. While perceptions of predators were better in the most established protected areas within our study, these could be influenced by positive experiences with the predators themselves, by conservation actions, or by better overall catches of fish resulting from established community fisheries management. What is clear, however, is that perceptions of damage were closer to reality, and attitudes towards aquatic predators better, in the more established reserve, with a longer track record of community management of fisheries and wildlife populations (Bodmer, Puertas, & Fang, 2009; Bodmer *et al.*, 2014). Possibly improving perceptions and attitudes to species commonly considered 'in conflict' with human interest goes hand in hand with managing the natural resources predators and humans are competing for (Treves *et al.*, 2006). Community-based conservation solutions are proving to have the most success in species population recovery in Amazonia (Campos-Silva *et al.*, 2017), and local ecological knowledge is increasingly acknowledged as a key tool in conservation (Braga-Pereira *et al.*, 2022). Perhaps local empowerment and community management are also the key to improving perceptions and tolerance of large predators.

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Author contributions

MR, PL and MB conceived and planned the experiments. MR carried out the experiments. MR, DM, PL and MB analysed the results. MR and MB prepared the figures, MR, PL, SJV and MB contributed to the interpretation of the results. MR took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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