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Drivers of human–black caiman (*Melanosuchus niger*) conflict in Indigenous communities in the North Rupununi wetlands, southwestern Guyana

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Abstract

Recovering populations of large carnivores impact the people that live alongside them, sometimes leading to conflict and lethal retaliation. One such carnivore, the black caiman (*Melanosuchus niger*) has been implicated in the destruction of fishing equipment, depredation of livestock and pets, and attacks on humans. In order to understand how various stakeholder groups are affected by the negative impacts of living alongside caiman, and their resulting attitudes and behaviors towards caiman, we conducted semistructured interviews in seven Indigenous communities in southwestern Guyana from November 2017 to October 2019. We used logistic and ordinal regression to identify demographic indicators of fishing behavior and factors that are associated with negative attitudes and antagonistic behavior. Loss of pets in addition to an effect of gender, rather than competition overfishing resources (as hypothesized) may drive conflict between Indigenous communities and black caiman. We propose site differences, such as ecotourism may affect attitudes about and behavior towards caiman. The presence of impacts on communities and retaliatory behavior indicates that human–wildlife and wildlife–human impacts involving black caiman may be a concern for the recovery of the species' populations, and the communities that coexist with them.

KEYWORDS

attacks, black caiman, crocodilians, fisheries, human–wildlife coexistence, human–wildlife conflict, livelihoods, Rupununi, subsistence

1 | INTRODUCTION

The widespread historical, and largely unsustainable, trade in crocodilian skins dramatically reduced the populations of many crocodilian species, some of which are only now recovering following conservation interventions (Plotkin et al., 1983; Thorbjarnarson, 2010). These species' recovery may impact the communities that live alongside them, affecting the acceptability of the species' conservation, even in communities with a culture of respect and acceptance of crocodilians (e Jr. et al., 2013; Sideleau et al., 2017). Crocodilians are known to destroy fishing equipment, depredate livestock and pets, and take human lives (Dufour, 1990; Pooley, 2015; Sideleau et al., 2017; Sideleau & Britton, 2013), resulting in retaliatory and peremptory persecution (Combrink et al., 2011). Managing the issues that emerge as a result of wildlife presence and/or behavior, better known as human–wildlife conflicts, is complicated by the interwoven nature of human and wildlife interests, particularly resources. Crocodilian and human dependence on water sources serves as a backdrop to many human–crocodilian conflicts (Wallace et al., 2011, Pooley, 2021). Water is an essential resource for North Rupununi communities who rely on rivers and ponds as a source of food, livelihoods, and cultural importance. (Finn & Jackson, 2011; Kareemulla et al., 2009). Therefore, conflict with crocodilians is especially difficult to resolve in communities that do not have regular access to alternative water sources, such as wells and catchments (Scott & Scott, 1994; Uluwaduge et al., 2018). Conflicts can also be exacerbated where fish are both an important and limited resource for both human populations and crocodilians (Dufour, 1990; Pooley et al. 2021).

Black caiman (*Melanosuchus niger*) are the largest aquatic carnivores in South America, persist mainly in remote aquatic systems (Thorbjarnarson, 2010), and have been implicated in conflict related to water use and fishing (Peres & Carkeek, 1993; Haddad & Fonseca, 2011; Pooley et al. 2021). Black caiman in Guyana are sympatric with the many relatively remote and growing Indigenous communities that are reliant on natural resources for subsistence and commercial use (Read et al., 2010). Although they are responsible for fewer attacks on people than some other crocodilian species (CrocBITE, 2013; Sideleau & Britton, 2013), crocodilian attacks may be underreported due to black caiman populations occurring alongside relatively remote Indigenous communities. Still, there are recorded incidents of black caiman attacks, including fatalities, throughout their range (Hall, 1991; Haddad & Fonseca, 2011; CrocBITE, 2013; Pooley et al. 2021).

Apart from sparse records of attacks on humans, there is little literature on human–caiman conflict, especially within Guyana (CrocBITE, 2013; Hall, 1991). Guyana represents the northernmost limit to the black caiman's range and populations here also faced intense and widespread hunting for their skins (Plotkin et al., 1983). The trade on caiman skins was legally restricted within Guyana after 1965 (de Klemm & Navid, 1989; Plotkin et al., 1983), and resulting in the Essequibo, Kuyuwini, Kassikaityu, Rupununi, Rewa, Siparuni, and upper Berbice rivers becoming hubs for recovering populations of this species (Ingwall, 2013; Taylor et al., 2016; Spellen, 2021).

In the Rupununi wetlands of southwestern Guyana, fishing is especially important to the subsistence and commercial livelihoods of resident Indigenous Makushi communities (Ozanne et al., 2014). The combination of recovering black caiman populations and widely reported local declines in fish populations (Ingwall, 2013) are driving an increasing perception of competition with caiman over fish resources (Harris et al., 2022). The resulting impacts on community members' livelihoods, in addition to their lives and/or well-being, may also be exacerbated by overfishing (Scott & Scott, 1994), and therefore may threaten both the food security of Makushi communities, as well as the recovery of a conservation dependent species (Ross, 2000). Left unchecked, overfishing may have ripple effects on food security that may, in turn, drive further conflict and antagonistic behaviors towards black caiman, thus threatening the viability of a significant population still in recovery.

Resolving and mitigating these issues will become more necessary as both human and caiman populations continue to grow, but doing so is complicated by the multi-dimensional nature of human–wildlife conflicts (Dickman, 2010). It is important, therefore, to understand not just what the impacts from conflict are, but whether these affect attitudes and behavior (Frank et al., 2019; John et al., 2014; Marchini & Macdonald, 2012; Pooley et al. 2017; Redpath et al. 2015). Additionally, community members are not homogeneously affected by conflict, as gender, age, and occupation have all been identified as determining factors of the number incidences of conflict, as well as the attitudinal and behavioral response (Gore & Kahler, 2012; Ogra, 2009). To have effective, targeted conservation, it is not only important to identify the issues, and relevant stakeholder groups, but to understand what specific factors shape the attitudes and the resulting actions that they take (Dickman et al., 2013).

Fishers are consistently involved in and affected by, conflict with crocodilian species (Amarasinghe et al., 2015; Das & Jana, 2017; Santiapillai & de Silva, 2001). In order to understand how fishers, and other stakeholder groups, are affected by the negative impacts of living alongside black caiman, their resulting attitudes, and drivers of antagonistic behaviors towards caiman, we conducted semistructured interviews in seven Indigenous communities in the North Rupununi wetlands of southwestern Guyana from November 2017 to October 2019.

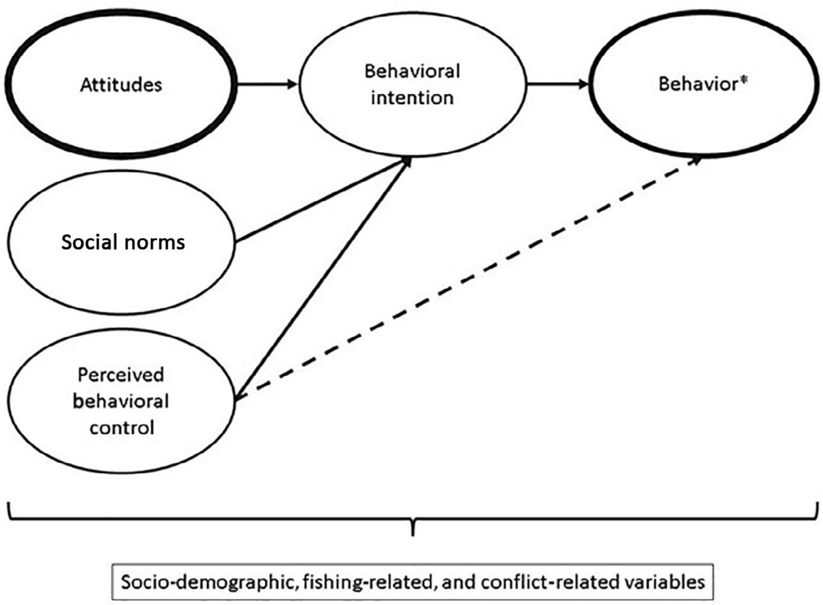

FIGURE 1 Theoretical framework featuring Ajzen's (1991) *Theory of planned behavior* model with operationalized constructs in bold.

1.1 | Hypotheses

a. Indicators of fishing behavior are predicted by socioeconomic variables.
b. Attitudes towards caiman are predicted by socioeconomic-based and impact-based variables.
c. Past antagonistic behavior towards caiman is predicted by socioeconomic-based and impact-based predictors.

2 | METHODS

2.1 | Study area

The Rupununi region of southwestern Guyana gains its name from the Rupununi river and the seasonally flooded wetland and savanna complex that black caiman inhabit and Indigenous communities depend for their livelihoods (Ingwall, 2013). The North Rupununi wetlands are regarded as a habitat of high ecological and cultural importance (Darwin Initiative Guyana Partnership, 2006), as they are home to >400 species of freshwater fish (de Souza et al., 2012), and many threatened species, such as arapaima (*Arapaima arapaima*), giant river otter (*Pteronura brasiliensis*), lowland tapir (*Tapirus terrestris*), and jaguar (*Panthera onca*; Darwin Initiative Guyana Partnership, 2006; Figure 1).

The North Rupununi wetlands are sparsely populated, and its predominantly Makushi inhabitants maintain primarily subsistence lifestyles dependent on farming, fishing, and hunting. As riverine communities interact with black caiman more regularly, we selected study sites (villages) based on their proximity to the Rupununi river. We conducted surveys in Yupukari (N3° 39′ 45.4″ W59° 21′ 17.7″), Katoka (N3° 33′ 18.8″ W59° 17′ 43.8″), and Massara villages (N3° 53′ 10.6″ W59° 18′ 10.1″) from November 2017 to January 2018 (Period 1); Yakarinta (N3° 53′ 53.5″ W59° 15′ 06.0″), Kwatamang (N3° 56′ 37.1″ W59° 05′ 58.3″), and Rewa villages (N3° 52′ 58.6″ W58° 48′ 12.4″) in July 2018, (Period 2); and Apoteri village (N4° 01′ 58.8″ W58° 34′ 58.8″) in October 2019 (Period 3; Figure 2). Yupukari and Rewa villages both feature community-owned ecotourism facilities, with Yupukari specifically focusing on caiman-based ecotourism.

This research was approved by and complied with the requirements of the Government of Guyana's Environmental Protection Agency (EPA; Permit no: 111617BR030), and Ministry of Amerindian Affairs, with permission granted by respective Indigenous village leaders and the North Rupununi District Development Board (NRDDB; see Supplementary Material S1 for examples of documentation for permission to conduct research).

2.2 | Sampling

The project team comprised of a local primary investigator and research assistants from regions 4, 6, and 8 of Guyana. We interviewed one participant per household for a minimum sample of 35 households in each community. We obtained hand-drawn village maps from the village leaders or community health workers within the community and marked households on the map as they were surveyed (Bernard 2011). We visually identified gaps and targeted to ensure that we captured a spatially

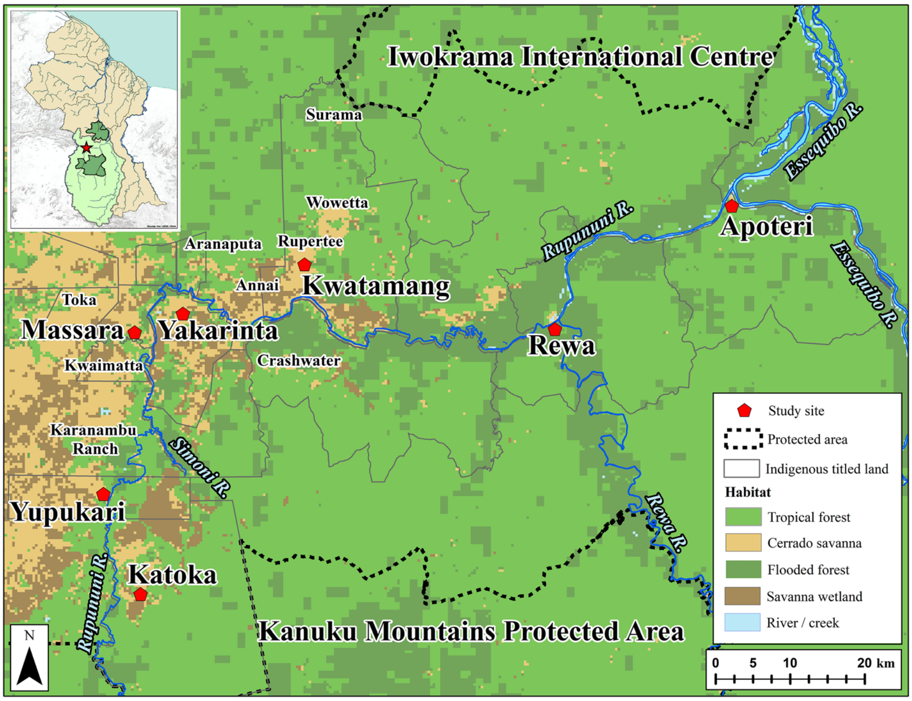

FIGURE 2 Map showing Guyana and the study sites

representative sample of village households. Participation was voluntary and written consent was required before the interview could be conducted.

Semistructured interviews were led by a single interviewer and conducted in private with a single participant. The questions examined attitudes towards caiman, fishing activity, the frequency, location, and type of interactions with black caiman, and benefits gained from ecotourism (see Supplementary Material S1). During the first survey period, participants were not prompted with responses or shown the survey sheet, and questions were designed to avoid leading responses (Bryman, 2012). We used both closed and open-ended questions to collect the quantitative and qualitative data used in our analyses (Bryman, 2012). We used the responses from the first survey period to create a more detailed and quantitative closed-ended survey, which we employed in the remaining communities (Bryman, 2012). Team members obtained verbal consent before each interview to use a digital audio recorder to record the interviews, which were later transcribed by members of the team. Community assistants translated interviews conducted in the Makushi language. The principal investigator coded the data from the open-ended questions once sufficient sample size was achieved.

2.3 | Data analysis

We collapsed categories with insufficient responses, as these were unsuitable for quantitative analysis ($n \leq 10$; Field et al., 2012), selected preliminary candidate variables for the proposed models based on a priori expectations of their importance to the response variable based on literature and on the information from the initial qualitative interview period (Zuur et al., 2010), and tested these initial candidate variables for association to determine whether there was potential multicollinearity (Zuur et al., 2010). We also used variance inflation factors (VIF) and VIR tolerance (1/VIF), to examine models post-hoc for evidence of multicollinearity (Field et al., 2012). We considered VIF $\geq$10 and 1/VIF $\leq$0.2 unsuitable for the models (Menard, 2002; Myers, 1990). For the nominal variable "site," we selected Yupukari village as the reference category, as there is caiman-based ecotourism present within the village.

We ran the generalized linear and logistic regression models in R 4.1.0 (R Core Team, 2021), and ordinal logistic regression models using the package *ordinal* (Christensen, 2019), tested for the assumptions of normality of the distribution of residuals and homogeneity of variance for the generalized linear models by examining diagnostic plots, and applied a log transformation (Field et al., 2012) for the continuous response variable "fish catch in weight" because the data showed a non-normal distribution. We used diagnostic plots to test the proportional odds assumption of the ordinal regression model (Liu & Zhang, 2018; see Supplementary Material S1), the convergence test to determine model fitness (Christensen, 2019), and calculated

TABLE 1 Summary statistics of the dataset (standard deviation [SD]) in a social survey of 288 individuals across 5 villages in Guyana regarding attitudes and behavior towards black caiman (*Melanosuchus niger*)

Variable type	Variable	Values	Summary statistics (frequencies or mean [SD])	Number of missing values (% missingness)
Attitude	Attitude	Negative	62.0%	4.9
		Neutral	21.9%	
		Positive	16.1%	
Past antagonistic behavior	Past antagonistic behavior	No	65.6%	1.0
		Yes	34.4%	
Site (Village)	Site (Village)	Yupukari	13.5%	0
		Apoteri	12.5%	
		Kwatamang	11.5%	
		Katoka	16.0%	
		Massara	20.8%	
		Rewa	10.1%	
		Yakarinta	15.6%	
Gender	Gender	Male	36.0%	0.7
		Female	64.0%	
Age (years)	Age (years)	—	Mean (SD): 39.8 (16.4)	0
			Range: 16 ≤ 90	
Household size	Household size	—	Mean (SD): 5.6 (2.7)	0.3
			Range: 1 ≤ 19	
Education level	Education level	Primary/lower	73.1%	4.5
		Seconary/higher	26.9%	
Fishing effort	Fishing effort	Less than a day	79.9%	8.3
		Day or longer	20.1%	
Fish catch (kg)	Fish catch (kg)	—	Mean (SD): 17.2 (34.8)	21.5
			Range: 0.8 ≤ 441	
Fishing frequency	Fishing frequency	Monthly/lower	25.1%	1.7
		Weekly/higher	74.9%	
Whether or not they sell fish	Whether or not they sell fish	No	53.7%	1.6
		Yes	46.3%	
Net damage	Net damage	No	19.4%	0
		Yes	80.6%	
Attack on domestic animal	Attack on domestic animal	No	39.3%	6.2
		Yes	60.7%	
Attack on human animal	Attack on human animal	No	27.6%	3.1
		Yes	72.4%	

effect sizes (standardized *beta*) using the package *sjPlot* (Lüdecke, 2021).

To account for missing data, we imputed 30 iterations of imputed datasets using the R package mice. This was to account for processes that we hypothesized affected the missingness (e.g., *not answered*, *refused to answer*, and/or otherwise *unknown* survey responses) that are present in social survey data (Burns, 2011; Rubin, 1976). Further detail on the imputed data and methods used to do so are in our Supplementary Material S1. The final model structures are below:

TABLE 2 Results of the models for attitudes and previous behavior as predicted by fishing behavior, demographics, and impacts

	Attitudes		Antagonistic behavior	
Estimates	**Listwise deletion**	**Multiple imputation**	**Listwise deletion**	**Multiple imputation**
(Intercept (clm) [Negative | Neutral])	−1.437	−1.292	—	—
(Intercept (clm) [Neutral | Positive])	−0.186	0.066	—	—
(Intercept [glm])			−3.935	
Village				
Yupukari (Reference)	—	—	—	—
Apoteri	−1.808** [−2.960 to −0.728]	−1.729*** [−2.731 to −0.726]	1.015+ [−0.143 to 2.233]	0.857 [−0.193 to 1.944]
	$p = 0.001$**		$p = 0.092$+	$p = 0.114$
Kwatamang	−0.667 [−1.730 to 0.374]	−0.963+ [−1.926 to −0.000]	−0.124 [−1.498 to 1.187]	−0.627 [−1.867 to 0.548]
	$p = 0.212$	$p = 0.050$+	$p = 0.855$	$p = 0.305$
Katoka	−2.085*** [−3.180 – −1.047]	−1.746** [−2.706 – −0.785]	−0.567 [−1.789–0.619]	−0.757 [−1.898–0.348]
	$p = 0.000$***	$p = <0.001$**	$p = 0.352$	$p = 0.184$
Masara	−1.633*** [−2.598 to −0.702]	−1.526 ** [−2.421 to −0.631]	0.313 −0.732 to 1.377]	0.183 [−0.796 to 1.176]
	$p = 0.001$***	$p = 0.001$ **	$p = 0.558$	$p = 0.716$
Rewa	−1.108* [−2.193 to −0.056]	−0.935+ [−1.924 to 0.055]	0.567 [−0.680 to 1.826]	0.411 [−0.738 to 1.565]
	$p = 0.041$*	$p = 0.064$+	$p = 0.372$	$p = 0.483$
Yakarinta	−1.359* [−2.434 – −0.321]	−1.201* [−2.187 – −0.215]	0.524 [−0.610–1.682]	−0.007 [−1.073–1.063]
	$p = 0.011$	$p = 0.017$	$p = 0.368$	$p = 0.990$
Age	−0.018+ [−0.038 to 0.002]	−0.017+ [−0.035 to 0.000]	0.003 [−0.019 to 0.025]	0.005 [−0.014 to 0.024]
	$p = 0.083$+	$p = 0.056$+	$p = 0.782$	$p = 0.580$
Gender				
Female (Reference)	–	–	–	–
Male	0.989** [0.306–1.704]	1.153** [0.499–1.807]	1.953*** [1.148–2.844]	1.847 *** [1.116–2.649]
	$p = 0.005$***	$p = 0.001$**	$p = 0.000$***	$p < 0.001$***
Whether or not participant knew or heard of someone who had been attacked by a caiman				
No (Reference)	—	—	—	—
Yes	−0.702+ [−1.498–0.087]	−0.782* [−1.508 – −0.056]	0.312 [−0.598–1.238]	0.311 [−0.524–1.161]
	$p = 0.081$+	0.035*	$p = 0.503$	$p = 0.467$
Whether or not participant lost a pet to a caiman				
No (Reference)	—	—	—	—

TABLE 2 (Continued)

Estimates	Attitudes		Antagonistic behavior	
	Listwise deletion	Multiple imputation	Listwise deletion	Multiple imputation
Yes	−0.566+ [−1.232–0.082] $p = 0.089$+	−0.535 [−1.130–0.060] $p = 0.078$+	1.128** [0.377–1.919] $p = 0.004$**	1.008 ** [0.339–1.706] $p = 0.004$**
No. of observations	236	288	244	288
AIC	440.2	513.4	286.3	336.9
Log-likelihood	−201.082	−236.262	−125.126	−149.155
F	–	–	2.599	
Multiple pseudo R^2	0.402 (Nagelkere's)	0.191 (Nagelkere's)	0.251 (Tjur's)	0.230 (Tjur's)

$^{+}p < 0.1$;
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

a. Fishing Models

i. Fishing Catch – Demographic variables
ii. Fish Size – Demographic variables
iii. Effort spent fishing – Demographic variables

a. Attitude and antagonistic behavior models

i. Attitudes – Demographic variables + Fishing variables + Conflict-related variables
ii. Past antagonistic behavior – Demographic variables + Fishing variables + Conflict-related variables

3 | RESULTS

We conducted 292 interviews across seven indigenous communities, with 153 interviews in the first data collection period, 103 in the second, and 36 in the third. One survey site, Karanambu Ranch, featured insufficient responses for the analysis ($n = 4$) and was removed from the dataset. Of the participants surveyed, 64% were male and 36% were female, 80.6% had experienced net damage due to black caiman, 60.7% had lost livestock or a pet (such as a dogs, cows, or horses), and 72.4% knew someone who had been attacked by a black caiman (Table 1). Participant attitudes were predominantly negative (62%) on a scale ranging from positive, neutral, to negative (Table 1), except for Yupukari where 40% of respondents reported positive attitudes, as opposed to 31.4% negative, and 28.6% neutral. Participants expressed views such as "caiman are dangerous (negative)," "I don't feel any way (neutral)," and "caiman protect the water (positive)" (see Supplementary Material S1). Overall, 34.4% of total respondents reported having engaged in antagonistic behaviors towards black caiman in the past (shooting at a black caiman with arrows or firearms).

Overall, there was strong evidence of the effect of survey site and, gender on fishing behavior (Table 2). Respondents in Katoka and Rewa were significantly less likely to sell fish (Katoka, $p = 0.01$, $\beta = -1.20$, 95% CI = −2.16 to −0.29; Rewa, $p = 0.003$, $\beta = -1.66$, 95% CI = −2.80 to −0.60) out to commercial markets than those from Yupukari. Respondents in Apoteri, Rewa, and Yakarinta were significantly more likely to fish weekly or more frequently (Apoteri, $p = 0.021$, $\beta = 1.69$, 95% CI = 0.36–3.30; Rewa, $p = 0.011$, $\beta = 2.80$, 95% CI = 1.00–5.76; Yakarinta, $p = 0.004$, $\beta = 1.84$, 95% CI = 0.66–3.16) than respondents in Yupukari. Male participants were significantly more likely to catch more fish ($p = 0.001$, $\beta = 0.35$, 95% CI = 0.15–0.56), fish more frequently ($p < 0.001$, $\beta = 1.63$, 95% CI = 0.93–2.38), and sell fish ($p = 0.006$, $\beta = 0.80$, 95% CI = 0.24–1.37). Older respondents were more likely to fish for day or longer ($p = 0.047$, $\beta = 0.02$, 95% CI = 0.00–0.04) and fish more frequently ($p = 0.013$, $\beta = 0.03$, 95% CI = −0.05 to 0.01). Those with larger households caught more fish ($p = 0.048$, $\beta = 0.04$, 95% CI = −0.00 to 0.07) and fished more frequently ($p = 0.024$, $\beta = 0.15$, 95% CI = −0.02 to −0.29). Respondents with a secondary or higher education level were less likely to spend a day or longer fishing ($p = 0.043$, $\beta = -0.96$, 95% CI = −1.99 to −0.09) and fished less frequently ($p = 0.019$, $\beta = -0.90$, 95% CI = −1.65 to −0.15).

Contrary to our hypothesis, there was little evidence that fishing frequency affected participant attitudes towards black caiman ($p = 0.270$, $\beta = -0.39$, 95% CI = −1.09 to 0.30). Similarly, there was little evidence that participant attitudes were affected by whether they had experienced damage to fishing equipment by black caiman ($p = 0.33$, $\beta = -0.32$, 95% CI = −0.97 to 0.33). Participant's attitudes towards black caiman were affected by whether they knew or heard of someone who had been attacked by black caiman ($p = 0.04$, $\beta = -0.78$, 95% CI = −1.51 to -0.06). There was weak evidence that participant attitudes were affected by whether they had lost a domestic animal to a caiman or not ($p = 0.08$, $\beta = -0.54$, 95% CI = −1.13 to −0.06).

Likewise, fishing frequency did not predict variation in past antagonistic behavior towards black caiman ($p = 0.84$, $\beta = -0.08$, 95% CI = −0.90 to 0.74). Additionally, there was little evidence of the effect of site on antagonistic behavior after controlling for hypothesized variables, with no sites presenting p values below 0.1 or 0.05. Instead, there was strong evidence that gender ($p < 0.001$, $\beta = 2.01$, 95% CI = 1.22–2.88) and the loss of pets ($p = 0.007$, $\beta = 0.93$, 95% CI = 0.26–1.63) was associated with antagonistic behavior. Male respondents were significantly more likely to have attacked a black caiman in the past ($p < 0.001$, $\beta = 2.01$, 95% CI = 1.22–2.88). Finally, there was little evidence of association between attitudes and past antagonistic behavior towards caiman ($p < 0.001$, $X^2 = 2.64$, df = 2).

4 | DISCUSSION

Human–crocodilian conflict is a conservation issue of interest to practitioners worldwide, but little has been published about human–black caiman conflict, particularly within Guyana (Pooley et al. 2021). Our results indicate that conflict exists within the North Rupununi wetlands of Guyana, and that the loss and injury of domestic animals and people, rather than negative attitudes towards black caiman, perceived competition over fish resources, may drive retaliatory and peremptory killing of black caiman. Although we were able to determine demographic predictors of fishing behavior, and potentially subgroups of fishers, evidence suggested that these have little influence on negative attitudes and antagonistic behavior towards caiman in the North Rupununi.

Nonquantified differences may explain the variation in attitudes and past antagonistic behavior between survey sites, including the presence of ecotourism and previous experience with conservation activities and research. Reported rates of antagonistic behavior were relatively low across all sites when compared with CrocBITE (2013) records, though it is possible that these were underreported due to the sensitive nature of the questions (Nuno & St. John F.A.V., 2015).

4.1 | Modeling approach

Initial regression models both featured loss in model R^2 and gains in log-likelihood, indicating that model parsimony was achieved with respect to "site" via a tradeoff between false overfitting due to missing data and gains/losses in true variance of parameters, which resulted in false gains in p-value precision (van Buuren 2018). The imputed antagonistic behavior model, when controlling for all other factors, differed from the complete-case analysis model by featuring "site" as non-significant in the imputed model. Once missing data were accounted for, the statistical power increased, thus passing the threshold to detecting an effect by masking the effect of missing data. After accounting for missing data, only having lost pets or livestock and being male came out as significant predictors of antagonistic behavior. This conclusion should be considered speculative at this point, as further testing is needed to confirm whether this exploratory observed relationship is evident through a plausible causal mechanism.

4.2 | Competition over fish resources

Household size and education level predicted fishing frequency, suggesting that participants with less access to alternative sources of income and larger families rely more heavily on fish resources for subsistence. While our a priori assumption was that Makushi communities' reliance on fishing for livelihoods would lead to increased perceptions of black caiman as a threat, fishing frequency did not have a significant effect on participants' attitudes or antagonistic behavior. This result was surprising, as black caiman are known to be destructive for fisheries (Peres & Carkeek, 1993). Community members may

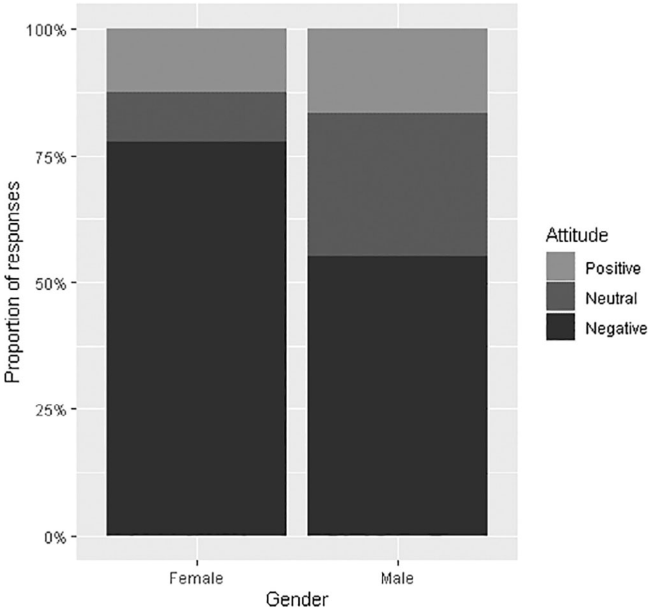

FIGURE 3 Distribution of participant attitudes by sex.

instead consider overfishing, rather than black caiman, as responsible for reduction in fish resources (Ingwall, 2013). The introduction and proliferation of monofilament lines and nets occurred within the lifetime of many participants, raising concern over the reduction in fish stocks in the region (Ingwall, 2013). Furthermore, other piscivorous species sympatric to black caiman, such as giant river otters (Rosas-Ribeiro et al., 2012), may add to the frustration over competition and destruction of fishing equipment. Variation in attitudes could be influenced by other indicators of fishing behavior.

4.3 | Gender

Gender affects both attitudes and behavior towards wildlife (Kellert & Berry, 1987). We found that while most respondents felt negatively towards black caiman, female respondents were proportionally more prone to negative attitudes than male respondents (Figure 3). However, our results showed that male respondents were more likely to retaliate to black caiman presence. The observed differences between the genders' attitudes towards black caiman may be explained by risk perceptions of carnivores (Alexander et al., 2015; Wallace et al., 2011). Professions or gender roles that require increased time spent on the water generally faced higher mortality from crocodilians (Das & Jana, 2017; Sideleau et al., 2017). Reports of black caiman attacks within Guyana have mostly involved males (87.5% male, $n = 7$; CrocBITE, 2013), and similarly throughout the black caiman range (85.9% male, $n = 85$; CrocBITE, 2013). Male respondents' skew towards positive attitudes towards caiman, while also disproportionately having acted antagonistically towards a black caiman in the past is plausibly explained by traditional community gender roles. In traditional Makushi society, male spend more time fishing and may therefore directly encounter caiman regularly, resulting in higher instances of retaliatory attacks to caiman by male fishers. Over time, these fishermen may develop an understanding that although caiman are dangerous, the frequency of attacks to encounters is very low. Women, on the other hand, may spend less time on the river and instead hear about caiman secondhand through tales of conflict events shared between community members, leading to heuristic bias and higher perceived risk associated with the presence of black caiman (Marchini & Macdonald, 2012; Tversky & Kahneman, 1974). Our results imply support for the hypothesis that gendered perceptions of risk and control contributed to the formation of negative attitudes (Johansson & Karlsson, 2011; Zajac et al., 2012).

4.4 | Depredation of domestic animals

The difference between the variables that statistically predicted of attitudes and retaliatory behavior may be due to differences in both the frequency of attacks on humans and losses of domestic animals, and differences in the impact of these events on community members. Loss of pets and livestock occurs much more frequently in participants' lives (one participant, for instance, reported losing 40 pets) than attacks on humans. Indigenous Makushi people depend on both wildlife and domestic animals for subsistence and livelihoods. Dogs are commonly used for both hunting and home security, in addition to other personal benefits, such as companion animals (Whitaker, 2016). On average, 25% (range = 2%–61%) of households around the Kanuku Mountains Protected Area hunt for subsistence and commercial purposes (Hallett et al., 2019). Thus, the loss of both large and small domestic animals may be perceived as a loss of protein sources, potential income, with the loss of a dog further impacting households due to impacts to hunting practice and perceptions of personal safety and security of ones' property (Whitaker, 2016). The loss of hunting dogs is especially damaging to subsistence households during the rainy season and other periods of low fish availability (Read et al., 2010). Our data show that the loss of pets or livestock to caiman not only contributes to negative attitudes towards the species but was also the only significant predictor of retaliatory or peremptory killing of caiman. The significant connection to antagonistic behaviors means that depredation of pets and livestock may be an urgent issue to address in mitigating human–caiman conflict in the North Rupununi wetlands.

4.5 | Context relevance

Site or village is an interesting variable that proved to be a significant predictor of attitudes towards caiman and fishing behavior, but not antagonistic behavior. While we have ruled out fishing frequency as a possible predictor of negative attitudes and actions, there are still a number of factors at play at the site level that must be considered, ranging from access to transportation and to economic centers, wealth, and the presence of alternative sources of income, such as ecotourism. Attitudes towards caiman were overwhelmingly negative across the study areas, except in Yupukari village where the proportion of respondents with positive attitudes was nearly double that of any other community in the study area. While other communities are home to ecotourism lodges or benefit from tourism indirectly, Yupukari village is home to Caiman House, an ecolodge that has built its product specifically around caiman-based research. It was here that researchers found that the value of caimans for ecotourism was 29%–47% higher than what could be earned for other uses (Rosenblatt et al., 2021). It is also possible, however, variation at the site level reflects the interwoven nature of community members' attitudes within the social network of their communities (Bodin, 2017). Other dimensions of human behavior, such as emotional responses, perceived behavioral control, social norms (Ajzen, 1991) need to be explored to determine whether other underlying social factors contribute to human–black caiman conflict in this context.

Both applied conservation and conservation science can build further on the need for context-relevance for the management of human–wildlife conflicts through the exploration and employment of context-relevant methods of inquiry, as well as assessments of the most effective available methods for management methods (Pooley et al. 2021; IUCN 2020). This is particularly relevant within multiuse landscapes such as the North Rupununi wetlands, which have become an important and understudied context within which conservation occurs (König et al., 2020). Our results support the IUCN's (2020) statement that human–wildlife conflicts, including those involving crocodilians such as black caiman, need context specificity to be understood—and context-specific solutions to be resolved.

4.6 | Limitations and applications for applied research

Our nonprobabilistic sampling approach limited the generalizability of our results (Bryman, 2012) and potentially introduced human bias in the selection of households. The use of a "village map" is neither wholly random nor replicable, and therefore may not be completely representative of the community. This, however, reflected the difficulties of conducting social research in remote villages for which data, such as the location of houses and the number of village members, were not available prior to arriving in the field. Participant unwillingness to implicate themselves in antagonistic behaviors towards a protected species may also have resulted in underreporting or the presentation of false information (Nuno & St. John F.A.V., 2015).

As human–wildlife conflicts are a subsection of wider human–wildlife interactions, all embedded within complex and multi-faceted socioecological systems (Carter et al., 2012, 2017), they are inherently difficult to study, as they require nuanced perspectives, and the potential for convoluted causal mechanisms that cross the physical and social world. In this case, our data support the growing recognition of the complex relationship between attitudes and behaviors that go far beyond the simple models that form the conceptual basis of many studies of the human dimensions of wildlife management, such as value–attitude–behavior (Fulton et al., 1996) and the theory of planned behavior (Ajzen, 1991). In practice, human–wildlife conflict is much more complex and may be better suited instead leaning towards more interdisciplinary approaches (Bennett et al., 2017; Moon & Blackman 2014; IUCN 2020). Nevertheless, even in the absence of data and information on socio-ecological systems issues, such as human–black caiman conflict, the urgency of many wildlife conservation needs often requires decision-making, despite the presence of knowledge gaps.

Human–wildlife conflict is multidimensional, and many other factors can be at play, even between or within relatively small communities of the same Indigenous group and within the same landscape. We recommend that further research in this landscape should consider human–wildlife conflict within the context of other species. Black caiman conflict does not exist within a vacuum, and the relative importance of impacts from other species, such as giant river otters, jaguars, pumas (*Puma concolor*), green anacondas (*Eunectes murinus*), birds of prey, and other carnivores may better determine how to effectively allocate limited conservation resources.

4.7 | Applications for mitigation and management

Our data suggest that black caiman may be low-level irritation for village residents of the North Rupununi wetlands, with infrequent escalations in tensions related to specific events. Limited competition over fish stocks already in decline due to overfishing, periodic destruction of fishing nets, and rare attacks on humans likely contribute to the largely negative attitudes towards black caiman that are held across the region, but only the direct loss of a valued resource like pets and livestock showed a clear relationship with antagonistic behavior. Addressing gendered risk perceptions through women's empowerment activities (Gore & Kahler, 2012), adopting hunter-education programs that seek to shift away from indiscriminate shooting of animals for "target practice" and towards more responsible behavior (Decker & Purdy, 1986), developing education programs that reinforce the ecological importance of top carnivores (Marchini & Macdonald, 2020), and improving management of inland fisheries (Cook et al., 2022) all are worthwhile pursuits that have shown to play a role in reducing human–carnivore conflict and undoubtedly would have broader benefits to people and wildlife. However, in this case, improving pet care and livestock management may represent the most efficient strategy for mitigating severe human–caiman conflicts and safeguarding this recovering population of black caiman in the North Rupununi wetlands.

While dogs are valued in the Rupununi for their support of hunting and home security, the majority are left unconstrained to hunt and scavenge for their food when not actively engaged in a hunt. Free-roaming dogs are known to transmit diseases, hybridize with wild canids, and reduce populations of game species, but are also more susceptible to depredation by wild carnivores (Hughes & Macdonald, 2013). In this case, improvements in the health and welfare of dogs via providing proper food and water and containing dogs within close proximity to a primary dwelling would likely eliminate the risk of depredation by caiman. Likewise, livestock (cows, horses, pigs, sheep, and chickens are the most common) are also most often managed in free-roaming groups that may or may not be returned to safe structures (corals, coops) to overnight (site dependent), they are rarely provided with food and mineral supplements, and do not have access to artificial water sources (Hallett et al., 2022). More intensive livestock management practices that confine livestock to areas "safe" from carnivores would require significant monetary investment in order to meet the animals' needs from artificial sources (supplementary feed and minerals, shade structures, wells to supply water) and is well beyond the current capacity of livestock producers in the region. However, riparian fencing that excludes livestock from natural water sources is one option that may be feasible to pursue on its own and these fences have been shown to positively affect water quality (Grudzinski et al., 2020) and would likely dramatically reduce the risk of depredation by caiman. Changes to the current strategies for managing of dogs and livestock would likely reduce the type of human–caiman conflict that we identified as the primary driver of retaliatory and peremptory killing but would require shifts in culture that could be supported by educational and social marketing campaigns, but also investments from government and conservation organizations to improve access to supplies and equipment.

In terms of management of, and coexistence with, the growing black caiman population in the North Rupununi wetlands, we recommend the co-development management plans that incorporates input from relevant stakeholders but supports local implementation by Indigenous communities. Community-driven management has been shown to combat the helplessness reported by many communities in dealing with conflict when the responsibility for management is centralized with government authorities (Amit & Jacobson, 2017; Raihan Sarker & Røskaft, 2010). Instead, management plans should capitalize on previously identified best practices for developing community-owned solutions (Berardi et al., 2015)—solutions that are generated through a participatory, just, and inclusive process that is open to a diverse array of flexible and adaptable management options that incorporate social capital and socio-ecological perspectives, includes youth, ensures stewardship of resources into the future, and promotes communities taking a leadership role in their own development (Mistry et al., 2016). Conflicts with black caiman in North Rupununi communities are primarily handled by the elected village leader (*toshaos*) and their appointed village council, but questions persist about whether authority lies with relevant government agencies. Management actions should reinforce local ownership over resources and empower village residents to inform local decision-making about conflict with black caiman, including determining when lethal management techniques are necessary.

5 | CONCLUSION

Our study supports the hypothesis that coexistence proves to likely be a complex and multi-faceted concept: separate but linked to human–human conflicts; and human–wildlife and wildlife–human impacts. Emergent literature suggests that human–wildlife conflict itself, negative attitudes and undesirable behaviors towards carnivores (those seemingly contrary to conservation goals from the perspective of conservation bodies), may be an inevitable reality due to the complex and interwoven nature of human cognition (Frank et al., 2019; Hill, 2021; Pooley, Siroski, et al., 2021). Although, when taken to one extreme, this implies a reality in which human behavior that negatively impacts wildlife is an intractable and insolvable issue. Rather, when examined through the lens that Pooley, Bhatia, and Vasava (2021), and other scholars within the emerging field of human–wildlife coexistence encourage in their work (Madden, 2004; Pooley, Bhatia, & Vasava, 2021), co-existence may not only be possible even while there are present issues involving wildlife and local stakeholders, but that the most effective management actions may be those that respectfully balance and compromise between all stakeholders needs and realities, and the resulting decisions that are based in their own realities. This precludes collaboration and does not exclude the consideration of management options from broader afield even in the presence of only limited scientific evidence of their effectiveness. Interventions such as Pooley et al.'s (2021) suggestion of employing safety devices should be considered. Our results indicate that human–black caiman conflict in the North Rupununi can be resolved, although further research is warranted, particularly from the paradigm of co-existence.

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DATA AVAILABILITY STATEMENT

The data and code used for the analysis will be published in long-term online data and code repositories.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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