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Influence of diet overlap and nest-site aggression on human–black caiman conflict in Guyana

Arianne-Elise Harris ^{a,b}, Gyanpriya Maharaj ^{a,b}, Matthew Thomas Hallett ^{c,d,e,f}, Meshach Andres Pierre ^{g,h}, Christell Chesney ^{a,b}, and Alyssa Melville ^g

^aBiology Department, University of Guyana, Turkeyen Campus, Georgetown, Guyana; ^bCentre for the Study of Biological Diversity, University of Guyana, Georgetown, Guyana; ^cDepartment of Wildlife Ecology & Conservation, University of Florida, Gainesville, Florida, USA; ^dTropical Conservation and Development Program; ^eCenter for Latin American Studies, University of Florida; ^fConservation Department, Jacksonville Zoo & Gardens; ^gCaiman House, Guyana; ^hDepartment of Sociology and Criminology & Law, University of Florida, Gainesville, Florida, USA

ABSTRACT

The black caiman (*Melanosuchus niger*) is the largest aquatic predator in the Amazon freshwater bioregion. Their destruction of fishing gear, consumption of fish and turtles, and infrequent attacks on humans, pets, and livestock are drivers of conflict with riverine communities. Attitudes toward black caiman can motivate negative human–caiman interactions across their range. In this article, we explored the importance of understanding attitudes toward the presence of black caiman populations. We surveyed four villages situated along the Rupununi River in the North Rupununi Guyana. Analysis indicated that negative attitudes were influenced by seasonality, sex, and village. Results offered additional insights into human–wildlife interactions and the dynamics of living alongside a protected large predator in Guyana. We recommend further research into the linkage between black caiman behavioral ecology and incidences of conflict.

KEYWORDS

Black caiman; conflict; attitudes; Rupununi; Guyana

Introduction

Attitudes toward wildlife are used to understand human–wildlife conflict because they influence how people respond to a species' presence (Dickman, 2010). Attitudes refer to the evaluation (favorable or unfavorable) of a behavior of interest and can be formed from personal experiences, values, and knowledge (Figure 1). Together with subjective norms and perceived behavioral control, attitudes shape an individual's behavioral intention and behavioral response according to the Theory of Planned Behavior (Armitage & Christian, 2003; Ajzen & Fishbein, 1975).

Relative to human–wildlife conflict, attitudes toward threatening wildlife impact the behavioral response (e.g., retaliation). Property ownership, income, and personal safety may influence beliefs held about a predator, and increased persecution and/or retaliatory killings may follow-suit (Kellert, 1985).

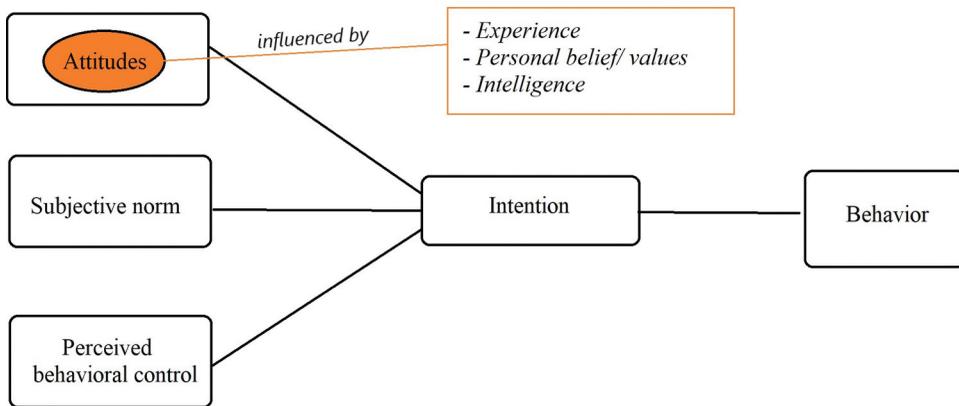


Figure 1. Theory of planned behavior (Ajzen 1991).

In Guyana, the black caiman (*Melanosuchus niger*) is the largest crocodylian and freshwater predator (Da Silveira & Thorbjarnarson, 1999). Listed as “Conservation Dependent” by the IUCN red list, successful conservation efforts and declining demand for caiman leather products led to the recovery of black caiman populations. The impact that increasing black caiman numbers have on riverine communities is an often overlooked aspect of species recovery. The North Rupununi wetlands of southwestern Guyana host the country’s largest black caiman population of black caiman. Despite an understanding of caiman ecology (Taylor et al., 2016; Vergne et al., 2011) and benefits to the ecotourism industry (Rosenblatt et al., 2021) in the region, research on human–caiman interactions is limited.

While recovery of this species is a success story, the lack of focus on coexistence and conflict threatens to undermine conservation efforts. As aquatic predators, dietary overlap and the competition for fish resources between black caiman and commercial anglers can lead to negative attitudes among communities that depend on fisheries for their livelihoods (Rosas-Ribeiro et al., 2012). Nest-site aggression increases along river banks and ponds in the dry season, coinciding with optimal fishing in the region. Dietary overlap and nest-site aggression represent threats to fish resources and human safety, potentially driving conflict between anglers and black caiman populations (Engel et al., 2014; Marchini & Macdonald, 2012).

Using semi-structured interviews, this study examined the impact of dietary overlap and nest-site aggression on attitudes and behavioral intention of four riverine communities of the North Rupununi wetlands. The goal was to inform management strategies focused on protecting North Rupununi biodiversity while maintaining villager livelihoods.

Method

Study Area

The North Rupununi administrative district (Region 9, SW Guyana, South America) has an 800,000-ha wetland connecting the Rio Branco and Essequibo watersheds; the area is bordered by a large, intact tropical forest. The district has populations of threatened

predators such as black caiman, giant river otters (*Pteronura brasiliensis*), and jaguars (*Panthera onca*). The North Rupununi wetlands are subject to two rainy seasons (May–September and December–January), supporting a diverse fish assemblage of >400 species with a high level of endemism (Mistry et al., 2008; De Souza et al., 2012, 2020). Although the North Rupununi wetlands are not protected by law, the North Rupununi District Development Board (NRDDDB) is a community organization representing the region’s 20 indigenous communities, who oversee the North Rupununi wetlands and village livelihoods. This article focused on four riverine communities of the North Rupununi (figure 2)–*Yakarinta*, *Kwatamang*, *Rewa*, and *Apoteri*. These communities are primarily indigenous *Makushi* people who maintain traditional livelihoods, including subsistence fishing, farming, and hunting (Hallett et al., 2019).

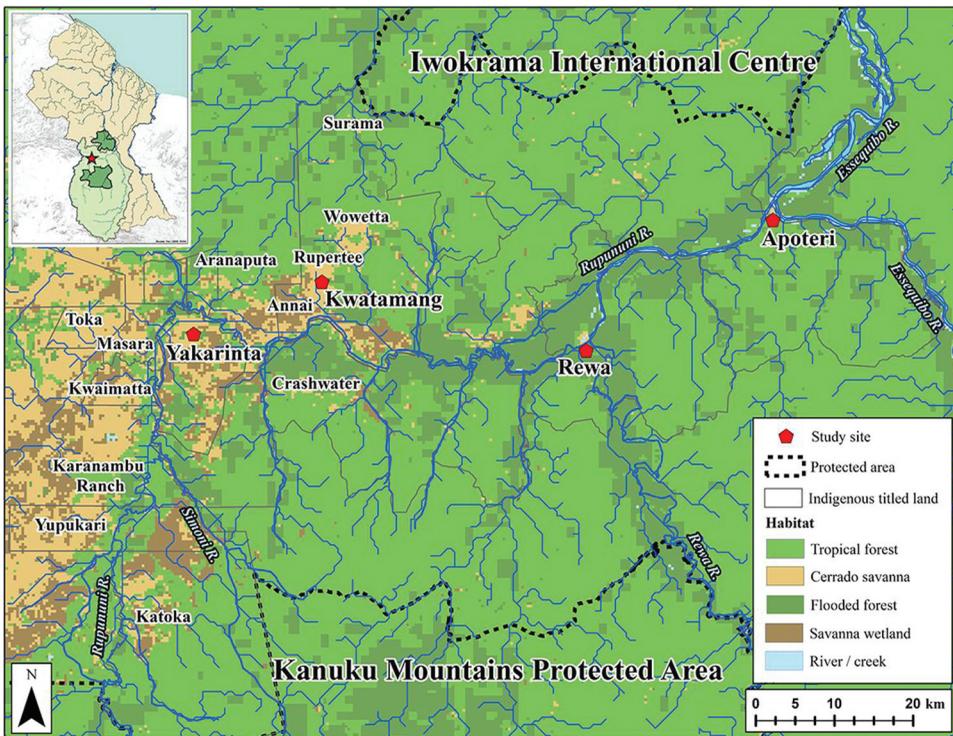


Figure 2. Map showing location of villages along the North Rupununi River, Guyana.

Survey Design

Data were collected using a semi-structured interviews. We used available maps of villages and attempted to collect a representative sample (Bernard, 2017). We interviewed one adult per household once given written consent. We conducted a minimum of 30 households per village (Draugalis et al., 2008).

Survey questions were designed to evaluate the correlation between personal beliefs and respondent attitudes toward black caiman. Surveys were broken down into three sections: attitudes toward diet overlap (ADO), attitudes toward nest-site aggression (ANA), and conflict occurrence (CO). ADO questions focused on respondent fishing frequency, fish

species preferred by black caiman and commercial anglers, and the perceived dietary overlap between villagers and black caiman. ANA questions focused on knowledge of when and where black caiman nest and what time of year black caiman are perceived to be more aggressive. A scale (0 – negative, 1 – neutral, and 2 – positive) regarding how respondents felt about each behavior was asked at the end of both sections. The CO section evaluated whether respondents experienced conflict with black caiman and what type of conflict event occurred.

We conducted data analyses with the Proportional Odds Model in the R package “ordinal” under the “CLM” function, which utilizes Cumulative Link analysis for ordinal regression (Christensen, 2015). Our ordered independent variable (η_{ij}) was in conflict with black caiman. Our dependent variables “ θ_j ” and “ β ” represented respondent attitudes, measured on the scale: negative < neutral < positive, and covariates of interest. Covariates included sex, age, village, and the question on dietary overlap. Model legitimacy was tested using the Hessian condition of the convergence properties. The Hessian condition is a value used in cumulative link models to explain the ratio of smallest to largest eigenvalues. Typically, a small condition ($<10^4$) is a good assurance that a well-defined optimum has been reached. Condition $>10^4$ indicates that the convergence criterion was not satisfied and the model needs more information to form a definitive conclusion on the association (Christensen, 2015; Thacker, 1989). Given the sampling strategy, our results cannot be generalized beyond the survey sites. When compared to the census data (see supplementary 1: <https://doi.org/10.5281/zenodo.5846719>), more men were interviewed, and thus, our findings may not reflect female attitudes. Permission was obtained from the leaders (*toshaos*) and village councils of participating communities, as well as the Ministry of Indigenous People’s Affairs and the Guyana Environmental Protection Agency (Permit No.: 111617BR03).

Results

We collected 143 responses across all four villages. Of the respondents, 65% were male, 32% were female, and 3% were unrecorded. Fifty-one percent of respondents indicated that they use the river to fish weekly, 29% daily, 10% monthly, 4% seasonally, 3% yearly, and 3% do not use the river for fishing. In terms of diet overlap, 25% stated that black caiman are an opportunistic species whose impact is spread over a variety of fish species (see supplementary 2: <https://doi.org/10.5281/zenodo.5846719>), while 19% specifically highlighted *Cichla ocellaris*, 12% *Prochilodus rubrotaeniatus*, and 9% *Pygocentrus sp.*

Fifty-four percent of respondents believed that black caiman have a negative impact on the amount of fish that they catch, 29% did not believe that they do, and 17% remained unsure. Two-thirds (65%) held negative attitudes toward black caiman because of their impact on fish resources, 20% were neutral, and 15% maintained positive attitudes despite the perceived diet overlap.

Respondents differed in their seasonal association with black caiman aggressive behavior. Forty-one percent associated heightened aggression with the dry season, 30% with the rainy season, 8% with both seasons, and 21% were not sure. Three-quarters (78%) noted that black caiman nest in the dry season along ponds that are often targeted by anglers, while 19% were not sure, and 2% linked nesting to the wet season. In terms of attitudes toward nest-site aggression, 73% of respondents reported negative attitudes, 16% were neutral, and 11% maintained positive attitudes. More than half (61%) of respondents reported

experiencing some form of conflict with black caiman (e.g., destroyed fishing nets, depredation of livestock/pets, and attacks on humans) compared to 39% which reported never experiencing these events. Respondents highlighted that attacks on humans were rare though they have heard stories of such occurring in nearby villages.

CLM estimates for attitudes toward dietary overlap were negative ($p = .069$) with a -0.700 unit decrease in predicted respondent attitude, given that all other variables are held constant, and the respondent answered “yes” to conflict (Table 1). In terms of attitudes toward nest-site aggression, the conflict coefficient estimate was negative (Table 2), but not statistically significant ($p = .120$), given that all other variables are held constant, and the respondent answered “yes” to conflict. Both ADO and ANO models suggest that negative attitudes were most prevalent in *Kwatamang* village ($p = .023$), with an expected $+1.69$ unit increase in predicted respondent attitude toward dietary overlap and a $+1.43$ unit increase in respondent attitude toward nest-site aggression, respectively, given that all other variables remain constant. The Hessian condition of the convergence properties for both models was $<10^4$; thus, model predictions were accepted.

Table 1. Cumulative Link Model “CLM” output. Model formula: attitude_feeding ~ conflict + gender + age + village + influence on catch. Model threshold was flexible. Hessian condition = $1.5e+05$. Number of Observations = 131. Estimates with asterisks indicate significant p -value (* = .05, ** = .005).

Dependent variable	Coefficient estimate	Standard error
Conflict	-0.700^*	0.386
Age	-0.019	0.013
Gender = male	0.735^*	0.445
Kwatamang	1.700^{**}	0.751
Rewa	1.453^*	0.755
Yakarinta	1.469^{**}	0.735
Dietary overlap = “not sure”	-0.148	0.536

Table 2. Cumulative Link Model “CLM” output summary. Model Formula: attitude_nesting ~ conflict + gender + age + village + influence on catch. Model threshold was flexible. Hessian condition = $1.5e+05$. Number of Observations = 131. Estimates with asterisks indicate significant p -value (* = .05, ** = .005).

Dependent variable	Coefficient estimate	Standard error
Conflict	-0.656	0.423
Age	-0.011	0.014
Gender = male	0.881^*	0.489
Kwatamang	1.435^{**}	0.629
Rewa	1.452	0.722
Yakarinta	0.799	0.628
Dietary overlap = “not sure”	-0.940	0.599
Dietary overlap = “yes”	-0.892^*	0.457

Discussion

Attitudes Toward Nest-Site Aggression

Black caiman mate at the beginning of the dry season (September/October) and construct their nests in December/January when dropping water levels have created dry banks along rivers and ponds where females construct their nest mounds (Villamarín et al., 2011; Villamarín-jurado & Suárez, 2007). Females choose locations set near permanent water bodies to ensure access to food for themselves and their hatchlings (Banon et al., 2019). Permanent pools, ponds, and lakes represent relatively easy access to fish for both caiman and commercial anglers. While 78% of respondents knew that black caiman nest in dry season, only 41% agreed black caiman were more aggressive while nesting. While attitudes toward nesting behavior were largely negative, our models suggested that nest-site aggression alone was not a statistically significant driver of human-caiman conflict. Previous experience with caiman conflict and a negative attitude toward nest-site aggression did not result in a significantly lower chance of a respondent having a positive attitude.

Adult female black caiman lay 30–60 eggs, which they may actively guard against predators for 60–90 days during incubation and an additional 365–548 days for hatchling pods in the water bodies (Caut et al., 2019). This level of maternal investment (up to 700 days) means that a given adult female may breed every 2–3 years (Caut et al., 2019; Da Silveira et al., 1997). In a growing black caiman population like the one found in the North Rupununi wetlands, this means that females displaying increased aggression related to the guarding of nests and hatchlings are nearly constant. This increased aggression around nesting seems to be either relatively low or sufficiently spread out across the system as it was not a significant driver of negative attitudes and related conflict. While the data did not support our assumption of negative attitudes due to increased threat to safety resulting from nest-site aggression, our models indicated that diet overlap, village, and gender may have a greater influence over the overall negative attitudes toward and resulting conflict with black caiman in the North Rupununi wetlands.

Attitudes Toward Diet Overlap

Fishes in the North Rupununi wetlands undertake seasonal migrations in response to changing water levels, with residents depending on these movements to meet daily protein requirements and provide income (Mistry et al., 2004; De Souza et al., 2012). Most respondents engaged in subsistence commercial fishing on at least a weekly basis and believed that diet overlap with black caiman is driving competition for fish resources, which is ultimately resulting in largely negative attitudes held toward the region's largest aquatic predator. Black caiman are known opportunistic predators, but they do also play an important regulatory role in freshwater ecosystems by preying on large, predatory fish species and smaller caiman (Peres & Carkeek, 1993). Left unchecked, predatory species can create an imbalance in species pool diversity, adding pressure to fish protein availability (Lasmar et al., 2014; Rosas-Ribeiro et al., 2012). Despite the ecological benefits, most respondents still reported negative attitudes toward black caiman, indicating that personal belief toward dietary overlap may be fueling how respondents view the large predator.

Attitudes toward black caiman feeding did not vary by season, despite the fact that fish availability is greater in the dry season. We infer that villager frustration with the ever present and growing population of black caiman is constant but may increase with the need to increase fishing effort and switch fishing strategies. The most common complaint from respondents was that black caiman destroy nets in their attempt to opportunistically remove fish. Although we provide no complimentary statistic in this study, increased reliance on monofilament nets is common in the North Rupununi during the wet season when fish are not congregated in dry season pools that can be targeted by hook and line (Mistry et al., 2004; De Souza et al., 2012). This explains the correlation between negative attitudes and those that have experienced conflict. While perceived competition over fish resources may be ever present, actual observed competition via destruction of the primary tools for fishing only increases negative attitudes. This perceived undermining of both current and future catch success threatens both the economic and subsistence livelihoods and influences personal beliefs toward the large predator. Respondents implied that it is these tangible events of conflict that are the primary driver of retaliatory attacks on black caiman in the Rupununi.

Respondents identified that the true cost of human–caiman conflict was primarily damage to fishing equipment and rarely personal injury or death (though the latter has occurred). Given the value placed on freshwater fish, conflict resulting in the destruction of fishing equipment is likely the primary driver of negative respondent attitudes toward black caiman feeding and nesting since both behaviors coincide with fishing activities in the North Rupununi wetlands. Gender was also noted as slightly significant in our feeding model. We inferred this to be the result of fishing being done by men primarily and more men participating in our survey.

Our results reiterated that drivers of attitudes and actions are often context-specific, even down to relatively small spatial scales (village-level) within perceivably homogeneous study populations. For example, all of the sites in our sample were made up of riverine communities composed prominently of indigenous Makushi people within a relatively small area (1,500 km²). However, even within this population, respondents from Kwatamang village were increasingly negative compared to the other communities. We can only speculate that this negative response may be due to a higher proportion of men interviewed and a higher dependency on commercial fishing in Kwatamang due to the village's strategic location along the Georgetown-Lethem highway. Kwatamang has lower forest cover (and hence less access to game and productive farming grounds) than other communities.

We do not dismiss the influence that ecotourism may have on attitudes and resulting conflict. When combined, positive and neutral attitudes accounted for ~45% of our respondents, indicating some benefit of black caiman presence on these North Rupununi villages. Rewa village is home to a community-run eco-lodge, and both Yakarinta and Apoteri villages benefit from privately owned eco-lodges in close proximity. The economic benefit from ecotourism may explain this positive outlook due to the appeal large, charismatic predators have to ecotourists. Although perceived dietary overlap was a driving factor for negative attitudes, 46% of respondents did not perceive or were unsure of black caiman as competition for fish resources. This response might be linked to an ecological understanding of large predator presence while also adding to the economic benefit of ecotourism. The ability to observe black caiman may help anglers understand when and where fish populations move and also drive tourism revenues (Rosenblatt et al., 2021). Despite our results highlighting negative attitudes towards a growing black caiman population, we

speculate that increasingly positive attitudes in communities receiving the direct (employment) and indirect (purchasing of produce) economic benefits provided by ecotourism is an indicator that this development activity may be successfully offsetting the cost to subsistence and commercial fishing, thus promoting coexistence with black caiman populations in the North Rupununi.

Conclusion

Attitudes toward black caiman behaviors in the North Rupununi are largely negative and correlated with the importance of subsistence and commercial fishing to the livelihoods of *Makushi* communities. Seasonal variation in caiman behavior and fishing strategies may have important effects on how riverine villages in Guyana respond to the large predator. However, North Rupununi ecotourism may counteract these negative attitudes due to the economic benefit black caiman presence provides to villages with eco-lodges. Additional research on feeding patterns and selection of nesting locations of black caiman in Guyana is needed. This may help in identifying high-impact sites where human–caiman conflict occurs while providing potential tourism “hotspots” for black caiman sightings and conservation. Such research would be of interest to key stakeholders such as The North Rupununi District Development Board which presides over North Rupununi community matters. Furthermore, in-depth surveys regarding North Rupununi attitudes toward black caiman co-existence would prove beneficial for larger social science research which seeks to incorporate the Theory of Planned Behavior. This approach can help boost our knowledge on the human aspect of conflict, whereby attitudes can be linked to other aspects of the Theory of Planned behavior, in an effort to understand how co-existing villages interact with a predator species.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

The supplemental material that supports the findings of this study is openly available on GitHub at <https://doi.org/10.5281/zenodo.5846719>. Data and code used can be provided upon request to the corresponding author.

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ORCID

Arianne-Elise Harris  <http://orcid.org/0000-0002-5364-4550>
 Gyanpriya Maharaj  <http://orcid.org/0000-0002-1373-9862>
 Matthew Thomas Hallett  <http://orcid.org/0000-0002-3168-8536>
 Meshach Andres Pierre  <http://orcid.org/0000-0001-8055-9944>
 Christell Chesney  <http://orcid.org/0000-0001-8593-7772>
 Alyssa Melville  <http://orcid.org/0000-0002-6213-8377>

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