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Factors Influencing Acceptance of Hippopotamus at a Large Reservoir in Nigeria

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Abstract: In a world increasingly affected by human presence and activities, achieving human–wildlife coexistence has become the goal of many wildlife conservation programs. Coexistence requires an understanding of factors that contribute to human tolerance and acceptance of problematic wildlife. In four communities in Nigeria, we used structured and semi-structured interviews to explore local people's acceptance of the river hippopotamus (*Hippopotamus amphibius*) at a large reservoir with high human impact and where other conspicuous, damage-causing species are absent. We collected data two years apart to evaluate whether acceptance changed over time. Acceptance was low among respondents (21%). Logistic-regression results showed that attitudes, beliefs related to benefits and risks, behaviors toward hippos, study period, and income source significantly influenced acceptance of hippos. Results from Woolf tests showed that hippo-caused human fatalities most notably modified the observed decline in acceptance between study years. The potential significant impact of rare, yet severe events (in this case, human fatalities) on acceptance of wildlife and thus human–wildlife coexistence was supported in this study, one of few focused on hippo-human relations. For conservation and development interventions to be effective at this site, they should, at a minimum, improve human safety around hippos, emphasize current and potential benefits of hippos, create avenues for off-farm income, and reduce crop losses owing to hippos.

Keywords: attitudes; beliefs; conservation; fatality; *Hippopotamus amphibius*; human–wildlife coexistence; human–wildlife conflict; human–wildlife interactions; tolerance

Citation: Baker, L.R.; Radda, I.A.; Teneke, V.N.; Kadala, E.; Sturdivant, R.X.; Madwatte, G.A. Factors Influencing Acceptance of Hippopotamus at a Large Reservoir in Nigeria. *Conservation* **2022**, *2*, 662–681. https://doi.org/10.3390/conservation2040043

Academic Editors: Luca Luiselli, Giovanni Amori and Daniele Dendi

Received: 24 August 2022
Accepted: 21 October 2022
Published: 27 October 2022

1. Introduction

When the interests of humans and wildlife clash, subsequent negative outcomes for people or wildlife have been widely referred to as human–wildlife conflict [1]. This framing focuses on the adverse effects of wildlife on people and vice versa. Wildlife presents a threat to human livelihoods or safety by damaging agricultural crops, causing livestock or human casualties, destroying property, or transmitting disease [2,3]. At the same time, human activities may result in wildlife population declines and extirpations, species extinctions, geographic range contraction, social and behavioral changes, and habitat loss and degradation [4]. Additionally, supposed human–wildlife conflicts often stem from conflicts among human interest groups [1,5–7]. Conservation managers are therefore constantly challenged to better understand and manage the human dimensions of wildlife conservation.

Promoting coexistence between wildlife and people has become a central tenet of conservation efforts [8]. This is increasingly difficult given intensifying global human impact [9] and, subsequently, increased contact between wildlife and people, especially in shared landscapes outside of protected areas [10]. It also requires an understanding that coexistence may look quite different in different contexts [11], is dynamic [12], and does not equate to zero negative interactions between wildlife and people [13,14]. Realizing coexistence may depend, in large part, on the degree of tolerance or acceptance that people have for wildlife [13,15–17]. Although the terms coexistence, tolerance, and acceptance are increasingly applied in research on human–wildlife interactions, clear definitions and consistent usage of these terms are scarce [18].

Glikman and colleagues [11] classified tolerance as the most passive state and noted that it may be imposed, whereas acceptance involves recognition of a species' value. They considered tolerance to be a precursor to acceptance, which in turn was a precursor to coexistence. Consequently, research that aims to contribute to coexistence should understand the factors that influence tolerance and acceptance of wildlife at particular sites and in particular situations [19]. In general, people harbor negative attitudes and are more intolerant or nonaccepting where wildlife species (1) instill fear [20,21], (2) threaten human lives [22,23], and (3) depredate crops or livestock to the extent that livelihoods are adversely affected [24–28]. Where intolerance or nonacceptance exists, governments, private individuals, community groups, and others often negatively respond to wildlife using legal or illegal lethal and non-lethal methods [29,30].

Common measures of tolerance include attitudes, beliefs, and behaviors (actual or intentioned) [31], which in turn may be influenced by such factors as socio-demographic characteristics [32]. Common measures of acceptance include wildlife acceptance capacity, which is the socially acceptable maximum number of a population [33], or preferred trend in population size [15]. Insights from psychology are increasingly used to understand drivers of tolerance and acceptance of wildlife [17,31,34]. Psychological models of human behavior (e.g., hazard acceptance and theory of reasoned action/planned behavior) indicate that acceptance will be greater where people perceive benefits and relatively low risks from wildlife, have trust in management authorities, and believe they have some personal control in dealing with risks from wildlife [31]. Perceptions of benefits, risks, and control vary by species of concern, with larger and more dangerous taxa often eliciting stronger reactions [35].

In Africa, research on human–wildlife conflict and coexistence has largely focused on conspicuous taxa, notably large carnivores [16,22,26,36], elephants [37–40], primates [25,27,41–43], and problematic species (usually one or more of the above taxa) within a particular site (e.g., national park or game reserve) [44,45]. Like the African elephant (*Loxodonta africana*), the river, or common, hippopotamus (*Hippopotamus amphibius*) is a large mega-herbivore that can cause widespread farm damage [46–48]. Although farmers generally consider elephants a more serious agricultural pest than hippos [49,50], this may stem from hippos limiting their terrestrial movements to settlements and farms near water [50,51]. Hippos are also considered aggressive and dangerous, and for people attacked by hippos, there is a high likelihood of death [52]. Despite this, the literature on human-hippo interactions is relatively thin compared with the literature covering other problematic African taxa [47,52].

The relative neglect of hippos by the scientific and conservation community is unfortunate as negative interactions with people, including retaliatory killings of hippos, are a key contributor to the species' conservation status as Vulnerable [53]. In Mozambique, Dunham et al. [46] found that people most often killed hippos, elephants, and crocodiles in response to conflict situations, such as wildlife-caused human casualties or crop damage. Notably, the ratio of animals killed relative to the number of people affected by a species was highest for hippos (2.7:1) compared with other wildlife [46]. Threats to hippos are amplified in West Africa due to the region's low hippo population densities and high human population densities [53]. In Africa's most populous country, Nigeria, hippos appear to fare better in dammed reservoirs along rivers than in official protected areas [54]. However, outside

protected sites, hippos are especially vulnerable to harassment and hunting. In mid-2022, social media reports showed Nigerian military forces shooting and then celebrating near an injured hippo, presumably killed for meat and sport based on video footage [55,56].

To ultimately improve human-hippo relations in Nigeria, we sought to understand factors that influence acceptance of hippos by local communities at a large dam reservoir, as well as identify research needs and prospective conservation interventions. The situation at the focal site is uncommon in that (1) no other conspicuous, crop-damaging wildlife species, such as baboons or elephants, still occur in the area; (2) the reservoir supports the livelihoods of thousands of residents living around it; and (3) the reservoir harbors one of the largest populations of hippos in the country and is therefore of conservation importance [54,57]. Because we collected data two years apart, we also evaluated whether measured variables had a significant impact on acceptance of hippos over time. In particular, we were interested in the effect of rare, high-severity events (specifically, human fatalities that occurred between study periods).

This research illustrates the complexities and the value of identifying key predictors of human acceptance toward dangerous and destructive wildlife, such as hippos. Our findings can help promote human–wildlife coexistence by contributing to the understanding and mitigation of negative human-hippo interactions and informing the development of conservation programs for environments heavily altered by human presence, notably outside protected areas.

2. Materials and Methods

2.1. Study Area

We conducted this study in four communities situated around the Kiri Dam reservoir in Adamawa State, northeastern Nigeria (Figure 1). Located about 25 km upriver from the Benue–Gongola confluence, Kiri Dam is an earth-filled embankment, about 1.3 km long and 20 m high [58]. Completed in 1982, the dam was built to irrigate a sugarcane plantation, but it also supports irrigation and fisheries for settlements around the reservoir. Originally, the reservoir covered a surface area of 107 km^2 [58]; over time siltation has significantly reduced both surface area and depth [59].

The dam project displaced more than 20,000 people. Some villages were wholly or partially submerged, and residents were resettled along or just beyond the reservoir's edge [60]. The dam also led to immigration. During construction some laborers settled in the area because of available fertile land, and fishers attracted by minimal competition in the newly created reservoir established small settlements. Present human settlements rely on reservoir water for dry-season farming, fishing, and watering livestock. The site occurs in a semi-arid region comprised of natural woodland savanna, which has been widely affected by deforestation and conversion to grazing land and farmland.

As a permanent water source, Kiri reservoir supports relatively high densities of both hippos and people. Hippo abundance here is among the highest across Nigeria. A 2018–2019 study estimated at least 56 individuals, the largest recorded population based on available data [54]. A 2021 census using drones led to an estimate of about 70 hippos (researchers are still analyzing these data) [57]. Human population densities (people/km^2) recorded in the year 2000 were 306 at Kiri Dam, 102 at Dadin Kowa Dam in Gombe State, and 48 at Kainji Dam in Niger State in northwestern Nigeria. The latter two dams have much larger reservoirs: Dadin Kowa covers 300 km^2 (Figure 1), and Kainji covers 1260 km^2 [61]. Consequently, the smaller Kiri reservoir supports a higher density of people.

Residents of the communities in this study are primarily farmers and fishers and generally impoverished, which is reflective of the region as a whole. Northeastern Nigeria is the poorest region in the country in terms of household wealth [62]. Among Nigeria's 36 states and the Federal Capital Territory, Adamawa State ranks 30th in percentage of households with an improved source of drinking water, and more than half (51%) of the female population has received no education [62].

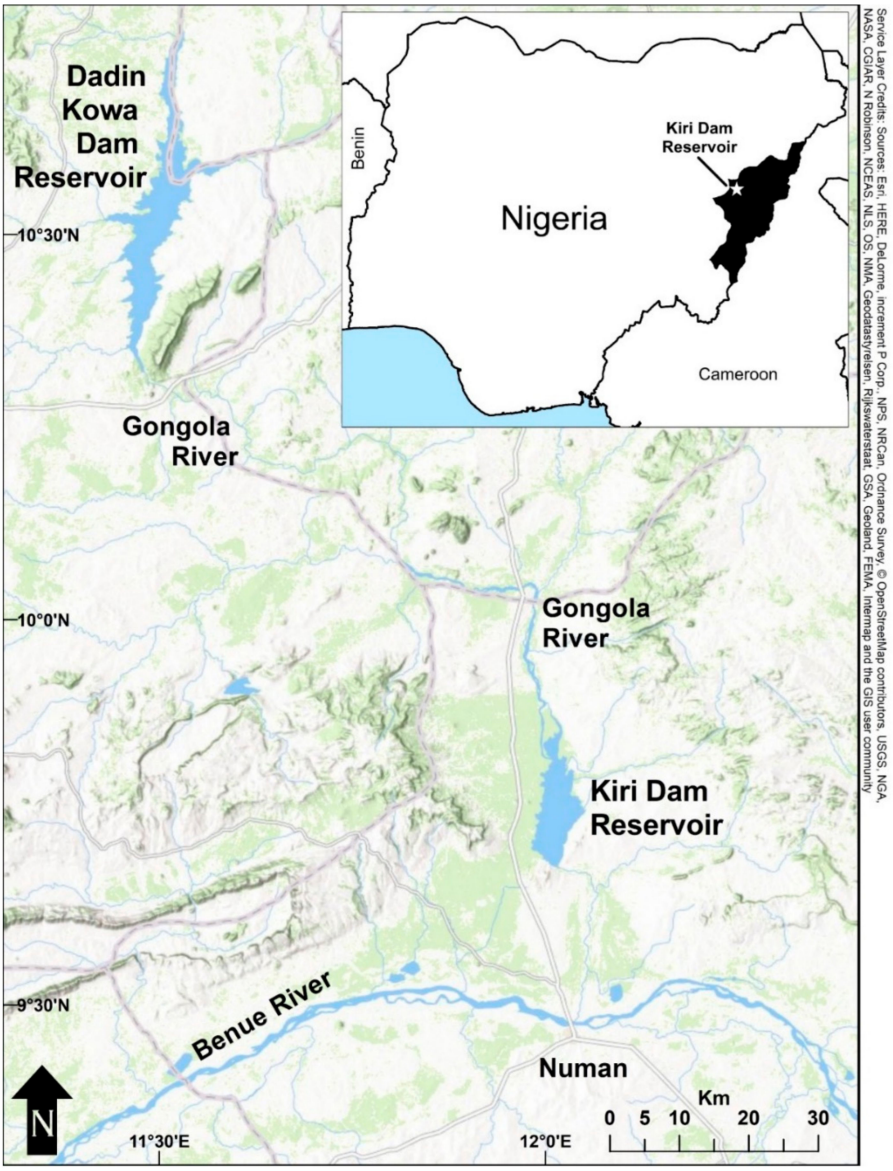

Figure 1. Kiri Dam is located at the confluence of the Benue and Gongola Rivers in Adamawa State, and downriver of Dadin Kowa Dam in Gombe State, in northeastern Nigeria.

2.2. Measurement

We collected data in October 2015 in two communities (Kiri and Baban Daba) and September–November 2017 in four communities (Kiri, Baban Daba, Talum, and Old Banjiram) (Table 1, Figure 2). The largest site, Kiri, is most developed; the smallest and least developed, Baban Daba, is a fishing settlement established after the dam was completed. We did not purposefully re-sample households in Kiri and Baban Daba. We added sites in the second period to improve coverage of the study area. We selected Talum and Old Banjiram because they were relatively close to the water, had reported hippo-related disturbance, and expanded our coverage of the western side of the reservoir.

We assessed acceptance of hippos based on an individual's preference for the presence or absence of hippos at the reservoir. Based on prior knowledge of the site, we did not use more common measures (such as wildlife acceptance capacity [33] or preferred trend in population size [15]). We expected that respondents would offer widely variable population-size estimates and state overwhelmingly a preference for a much smaller or non-existent population. We were also careful to avoid questions that might suggest a locally desired outcome from our study (e.g., removal of some hippos). For this study,

we settled on acceptance over tolerance because local communities at Kiri reservoir are relatively powerless to manage or respond to problem hippos and thus "tolerate" them out of necessity.

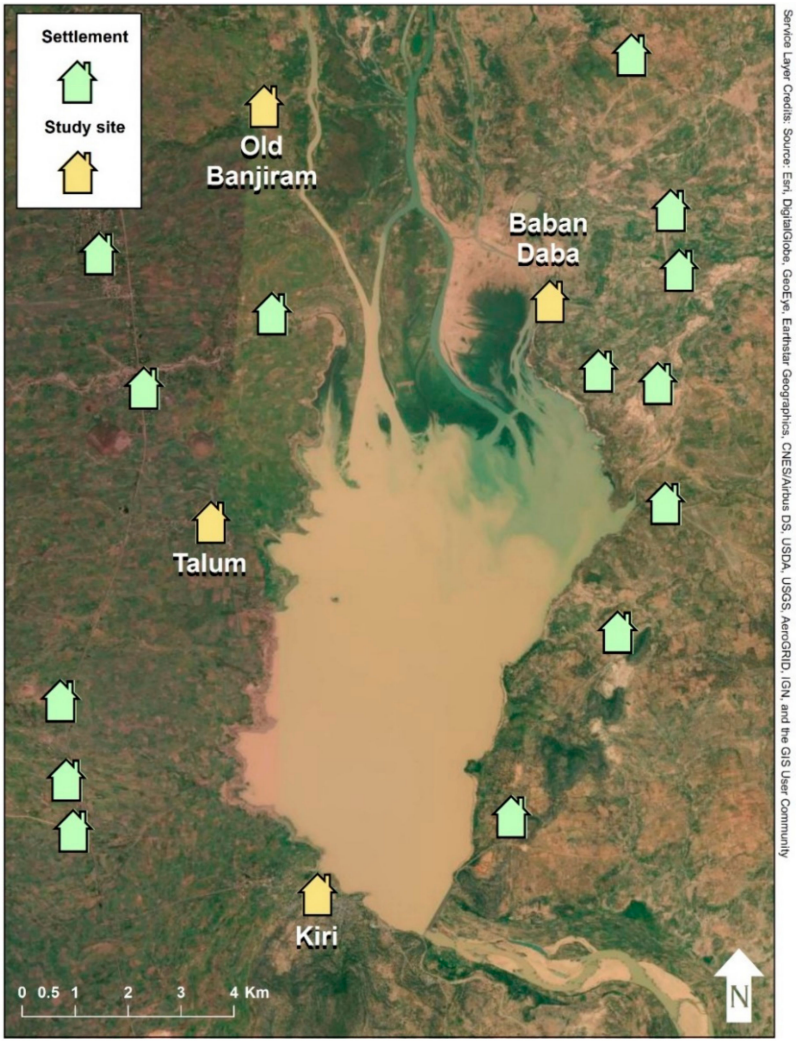

Figure 2. The four communities included in this study were Kiri (largest), Baban Daba (smallest), Talum, and Old Banjiram.

We used a mixed-methods approach involving face-to-face qualitative interviews and structured questionnaires. In the first study period, we conducted in-depth, semi-structured interviews with three government officials (two from the Adamawa State Wildlife Department and one from the Upper Benue River Basin Authority) and one *Sarkin Ruwa*, an indigenous title holder who oversees water resources and fisheries. Data from these interviews informed the content of a questionnaire, which we tested and adjusted for content and length before administering the final version. We endeavored to conduct interviews of a locally suitable length (i.e., to limit how long respondents were away from potential income-earning activities and help ensure responses toward the end of interviews were not hurried or abbreviated).

Table 1. Timeline of surveys, hippo-caused human fatalities, and reprisal action at Kiri Dam reservoir from 2012–2017. Although unverified officially, local reports indicate that other fatalities likely occurred between 1982 (when the dam was completed) and 2012; these reports did not appear in the government record. Since this study concluded, one fatality occurred at Baban Daba (August 2022). All fatalities occurred on water.

Date	Event	Reprisal	Community
May 2012	Human fatality—1 adult male killed while fishing at night	1 hippo killed on government directive	Baban Daba
October 2015	Survey period 1		Kiri; Baban Daba
November 2015	Human fatality—1 male youth killed while in transit in a canoe	None	Kwadadai
April 2016	Human fatality—2 adult males killed while fishing at night	1 hippo killed on government directive	Old Banjiram
September–November 2017	Survey period 2		Kiri; Baban Daba; Talum; Old Banjiram
September 2017	Human fatality—1 adult male drowned after canoe was overturned by a hippo	None	Baban Daba [a]
October 2017	Human fatality—1 adult male killed while fishing	None	Talum [b]

[a] Research here was completed by October 28, thus this fatality occurred just prior to the survey.
[b] Research here was completed by September 30, thus this fatality occurred after the survey. Research at Old Banjiram, which is relatively near Talum, was conducted a couple of days after this fatality.

Including closed and open-ended questions, the questionnaire collected data on socio-demographic characteristics, farming practices, benefits and risks associated with hippos, stated prior behaviors upon encountering hippos, knowledge of legal protection and conservation of hippos, and views about hippo protection (Supplementary Materials). We did not investigate previous or intended behaviors regarding local people harassing or killing hippos given the likelihood of inaccurate reporting. Kiri residents were largely aware of wildlife laws protecting hippos, and government wildlife officers were members of the data-collection team in the second study period.

Our sampling unit was an individual household. For Kiri and Talum, we used stratified random sampling. We divided Kiri by its 12 wards and Talum by its 4 wards and then randomly selected households. The number of households selected from each ward was relative to the total number of households in the ward, thus sampling was proportionate. For the other communities, we randomly selected individual households from the estimated total number of households. Sample size across both survey periods was 258 (Table 2). In addition to the qualitative interviews conducted in 2015, we conducted two such interviews in 2017 (with a community leader from Kiri and a *Sarkin Ruwa* from a smaller settlement).

For the questionnaire, we interviewed adults (18 years and above) who were either the male household head or his wife at their homes. When an adult member of a selected household was unavailable, we attempted to visit again. If after a second visit, we did not meet any adult in the household, we randomly selected another household. We administered questionnaires in the Hausa language, either directly or with an interpreter, after obtaining verbal informed consent. For questions about benefits and risks of living near hippos, we did not suggest options. For example, if a respondent answered "yes" when asked if there were any benefits or advantages to having hippos at Kiri reservoir, we then asked that person to identify one or more benefits without suggesting relevant possibilities. For some questions, the questionnaire form listed likely responses (gleaned from prior qualitative data and the pilot test) to allow for quicker recording of data.

Table 2. Estimated number of households and final sample sizes for each community in this study.

Community	Estimated Number of Households	Survey Year	Sample Size
Kiri	554	2015	55
		2017	52
Baban Daba	74	2015	14
		2017	37
Talum	76	2017	47
Old Banjiram	102	2017	53
Total	806		258

2.3. Analyses

We evaluated the influence of several predictor variables on acceptance of hippos (Table 3). We initially conducted univariate analyses (crosstabulations and logistic regression modeling) to assess which variables influenced acceptance at the $p \leq 0.05$ level. Overwhelming negative responses from one community (Old Banjiram) led to inflated standard errors and potentially biased coefficient estimates; therefore, we combined Old Banjiram and Talum in the "community" variable because these communities are geographically near and share similar characteristics. For the binary dependent variable (acceptance), one respondent was indifferent. We included this case to summarize sociodemographic characteristics and farming practices of the study population (n = 258), but excluded it from subsequent analyses. Final sample sizes for several analyses varied due to missing responses.

For two binary predictors, benefits and attitudes, seven and four respondents, respectively, were unsure. We further evaluated these 11 cases based on other responses from their interviews and consequently classified them as negative responses. After identifying 11 significant predictor variables in univariate analyses, we checked for multicollinearity and removed one of a set of correlated variables, based on tetrachoric correlations, from further analysis. For example, nearly all respondents who planted rice did so close to the reservoir (χ^2 = 137.45, df = 1, $p < 0.001$); therefore, our analysis included rice (types of crops grown) and excluded "rice crops grown near reservoir".

We used a final list of eight predictors in the multivariate analysis (Table 3), in which we applied a purposeful model-building approach in logistic regression analyses [63]. To account for non-nested model comparisons, we selected the final model based on change in Akaike's Information Criterion (AIC) [64]. We tested the ability of the final model to discriminate using a receiver operating characteristic (ROC) curve, with classification metrics and a cut-off point of 0.4 [63].

Because the study periods were two years apart, we included study year as a variable in our analyses. This was relevant because hippos caused the deaths of three people within the interim period and two deaths during the second study period (Table 1). To evaluate whether these deaths, or other factors, may have influenced a change in acceptance over time, we conducted univariate analyses using study year as a predictor with acceptance as the dependent variable. Then, in separate analyses, we controlled for these five variables of interest: benefits, risks (crop damage, disruption of fishing activities, and human injuries or deaths), and attitudes. Using Woolf tests of homogeneity [65], we determined whether each variable led to a significant increase or decrease in the odds of preferring the presence of hippos at Kiri reservoir (i.e., whether the variable was an effect modifier). If effect modification was absent, we tested for confounding by comparing the adjusted odds ratio (OR_{adj}) for each of the five variables to the OR for study year alone. We considered a percent change in ORs of 10% or higher to indicate confounding [66,67]. If confounding was indicated, we used Mantel-Haenszel tests with pooled ORs [68] to test if there was a significant effect controlling for the confounding predictor. We conducted the above steps twice: for the two communities surveyed in both study years and for all four communities.

This allowed us to assess whether any observable change in acceptance over time was disproportionately influenced by the inclusion of two new communities.

Table 3. Variables used to evaluate human-hippo relations at Kiri Dam reservoir, Adamawa State, Nigeria. Variables included in the multivariate analysis are starred (*).

Variable	Assessment
Acceptance	Preference for the presence of hippos
Socio-demographics	Community of residence * Age Gender Religion Indigene of community Education Number of living children Number of people in household Sources of income *
Study period	Year of study *
Farming practices	Types of crops grown * Crops grown near reservoir Type of crops grown near reservoir Season of severest crop damage by hippos
Beliefs	Beliefs about population trend (in past 5 years) Benefits due to hippos * Risks (problems) due to hippos *
Behaviors	Reactions to encountering hippos on land/water *
Attitudes	Hippos should/should not be protected *
Personal control	Awareness of law against killing wildlife Permission needed to kill hippo Consequences for killing hippo without permission

3. Results

3.1. Acceptance

Most respondents in this study (203; 79%) found the presence of hippos at Kiri reservoir unacceptable. This group included all respondents from Old Banjiram, 86% from Baban Daba, 70% from Talum, and 69% from Kiri.

3.2. Socio-Demographics

Respondents were primarily male (184; 71%), likely a consequence of social norms, and indigenes (190; 74%) (i.e., born in one of the four focal sites). Average age was 40 years (SD = 15.8; range = 18–90). Respondents practiced Christianity (162; 63%) or Islam (95; 37%). Respondents had about 8 people, on average, residing in their household (SD = 4.5; range = 1–31). Nearly one-third of respondents had no formal education (78; 30%). Others (n = 180) had begun primary school but did not finish (20; 11%) or had completed primary school only (52; 29%), junior secondary school only (28; 16%), or senior secondary school (56; 31%). About 13% of respondents had attained tertiary-level education.

Main sources of income reported by 251 respondents were farming (223; 89%), fishing (110; 44%), petty trading (60; 24%), and skilled work (e.g., carpentry, tailoring, driving) (35; 14%). Most respondents relied on multiple income sources, of which one was usually farming (e.g., 95% of fishers had farms). Fifty-seven respondents (23%) relied solely on farming. Types of work also differed by gender. Significantly more men reported earning income from farming (78%; χ^2 = 29.71, df = 1, $p < 0.001$) and fishing (96%; χ^2 = 57.27, df = 1, $p < 0.001$), while significantly more women engaged in petty trading (67%; χ^2 = 58.96, df = 1, $p < 0.001$). Skilled workers were also more often men (83%; χ^2 = 2.34, df = 1, p = 0.13).

3.3. Farming Practices

Farmers (n = 223) grew mostly maize (200; 90%), guinea corn (sorghum) (176; 79%), and rice (171; 77%). Other crops included bean, soya bean, sesame, potato, tomato, millet, onion, and okra. Most respondents (204; 91%) had farms located close to the reservoir for convenient access to water. Crops proximate to water were predominantly rice (160; 78%) and maize (131; 64%). Respondents reported that hippos damage and eat these two crops, as well as beans, significantly more often than hippos damage other crops. The majority of respondents (206; 82%) noted that crop damage was most severe during the rainy season (May–October).

3.4. Beliefs: Hippo Population Trend

Most respondents believed that the Kiri hippo population had increased in the 5 years prior to their interview date. The percentage of those who thought the population had increased was nearly identical in both study periods: 96% in year 1 and 95% in year 2. Data from qualitative interviews provided additional context about population trends at the reservoir: There was general agreement that hippo sightings and human-hippo encounters along the Gongola River were rare prior to damming the river. Local people used to rush to the riverside just to observe a hippo. The hippo population at Kiri began to expand in the 1990s, which coincided with the onset of complaints about hippos from local communities to wildlife officials.

3.5. Beliefs: Risks and Benefits

Nearly all respondents (255; 99%) reported problems or risks resulting from living near hippos at Kiri, notably that hippos damaged crops (248; 98%). Other risks were that hippos injured or killed people (199; 78%), disrupted fishing activities in general (135; 53%), damaged fishing nets (54; 21%), damaged boats (19; 7%), injured or killed livestock (14; 6%), and scared or chased people (12; 5%). With one exception, the percentage of respondents who noted that hippos harmed people varied little by village: Kiri (73%), Baban Daba (75%), Talum (78%), and Old Banjiram (92%).

Several respondents described close calls with hippos on water, often remarking that their boats were damaged or destroyed and that they were forced to "run for their lives". Such incidents exacerbated the fears and frustrations of fishers, boat transporters, and their families. In Old Banjiram, a 35-year-old mother from a household of 15 grew anxious whenever her husband did not return from fishing by a certain time; she feared hippos had killed him. According to a *Sarkin Ruwa*, because hippos had become more disruptive and dangerous, he now prayed before entering water. Fear had led some fishers to consider abandoning this livelihood activity altogether. Not all hippos were considered dangerous, however, and some fishers had learned to identify aggressive and non-aggressive animals, the latter of which reportedly posed little to no risk. Fishing was also purportedly safer with motorized boats, which are uncommon at the reservoir, because they allowed for speedier movement and hippos were wary of them. However, one respondent suggested that hippos were losing their fear of motorized boats, likely due to repeated exposure over time.

Monetary benefits associated with hippos (e.g., through ecotourism or trophy hunting proceeds) are presently unavailable at this site, and few respondents reported non-monetary benefits (43; 17%). Within this group, hippos had educational value (i.e., for children to know what a hippo is and see it in future) (18; 42%), improved fishing (13; 30%), and attracted visitors to the reservoir (12; 28%). While fishers at Kiri generally recognized that hippo dung is linked to "more fish", one *Sarkin Ruwa* noted that if you cannot get close enough to fish safely, there is really no benefit. Other reported benefits of hippos included making Kiri famous and securing fishing equipment at night (i.e., people were afraid to enter water to steal equipment because hippos may be nearby).

Hippos also have value in local culture and customary practices. Hippo skin, for example, is crafted into traditional whips used by indigenous rulers' guards to maintain

order and convey their rank. Indigenous rulers also display hippo skulls as a symbol of their community and authority. A few respondents reported medicinal uses of hippos: The skin can treat earaches, and the fatty oil can treat broken bones. In Kiri, a 46-year-old male respondent associated several benefits with hippos, including that hippos protect people from evil animals such as *ragon ruwa* (a large catfish). Other local beliefs in Kiri maintain that the spirits of people live in hippos, crocodiles, or other wild animals, making it a taboo to kill or eat these animals. This belief—purportedly now rare—is present in other communities in the region.

3.6. Behaviors

When asked about prior typical reactions to encountering hippos when on land or in a boat, most respondents fled or moved away (209; 82%) and/or confronted hippos by scaring or chasing them (117; 46%). Eighty-four respondents (33%) engaged in either behavior depending on the situation: typically, confronting hippos when on land (e.g., hippos in your farm) and fleeing from hippos when on water. Common methods of scaring hippos included shining flashlights, making loud noises (e.g., banging on zinc), shouting, and throwing stones.

3.7. Attitudes

Three-quarters of respondents (196; 76%) did not support the protection of hippos at Kiri reservoir. Explanations largely associated negative attitudes with crop damage and risk to human safety. Even where respondents recognized one or more positive aspects of hippos, most attitudes were biased by the problems hippos caused. A 40-year-old male farmer from Talum captured this sentiment: "I love [the hippos'] presence here, but cannot bear their number and activities".

3.8. Personal Control

Under normal circumstances, the government does not issue hunting licenses for hippos. Most respondents (234; 91%) were aware of the illegality of killing hippos and widely reported (241; 94%) that authorities must give permission for or oversee any proposed actions against disruptive hippos. Most of this latter group (220; 91%) also noted that consequences, such as being arrested or paying a fine, would ensue if permission was not obtained. As such, local people were restricted to more arduous personal tasks to chase away hippos, such as guarding farms at night, and some respondents appealed that the government should legally permit them to kill problem hippos. Our data indicated that unsanctioned hunts of hippos may have occurred at Kiri, though such incidents, if true, would have been rare.

Responses regarding from whom to seek permission or report a disturbance varied, but most common answers were local or state government officials, community leaders, and local or regional indigenous rulers. Data from qualitative interviews indicated that the relationship among authorities with regard to management of water resources and hippos should be clarified and strengthened to promote better collaboration. "Traditional rulers feel the animals belong to them", according to one state official.

3.9. Multivariate Analysis

The eight predictors used in the multivariate analysis were study year, community of residence, income source (skilled work), farming practices (type of crops–rice), beliefs about benefits (yes/no), beliefs about risks (hippos harm/kill people), behaviors (flee from hippos), and attitudes (protection for hippos). The best model included six variables (Table 4). Respondents who were more accepting of hippos also believed that hippos should be protected, believed there were benefits to having hippos at the reservoir, did not mention that hippos harmed or killed people, did not report fleeing when encountering hippos, were interviewed in the first study period, and earned some of their income from skilled work. This final model had high discriminatory ability (Supplementary Materials).

Table 4. Coefficients of predictors in the best model of acceptance of hippopotamus (AIC = 89.78).

Variable	β [a]	SE	95% CI		*p*
			Lower	Upper	
Attitudes (pro-protection)	5.267	0.846	3.608	6.925	<0.001
Beliefs–benefits (yes)	4.224	0.949	2.364	6.085	<0.001
Beliefs–risks (human casualties)	–1.402	0.679	–2.733	–0.072	0.02
Behaviors (flee from hippos)	–1.693	0.733	–3.129	–0.256	0.02
Study period (second year)	–1.538	0.725	–2.959	–0.118	0.03
Income source (skilled work)	1.439	0.688	0.090	2.788	0.04

[a] Parameter estimates refer to the likelihood that respondents were accepting (preferred the presence) of hippos in the reservoir.

3.10. Change-Over-Time Analysis

Respondents from the second study period were significantly less accepting of hippos than those from the first period. Our comparison of Woolf and Mantel-Haenszel results for all four communities (full data set) with results for just the two communities included in both study years yielded a similar unadjusted relationship between study year and acceptance. Therefore, the addition of the two communities did not alter the fundamental relationship, and the full data set improved power.

For analyses using all four communities, the odds of preferring the presence of hippos significantly reduced, by about 56%, between study periods (OR = 0.44; 95% CI = 0.22, 0.88; $p = 0.01$; Fisher's exact). Woolf tests for effect modification showed that no variables of interest—benefits, risks (disruption of fishing activities and human injuries/deaths), and attitudes—significantly affected the relationship between acceptance and study year (Table 5). We could not conduct tests for the fifth variable of interest, risks–crop damage, because nearly all respondents claimed hippos destroyed farms. The most noteworthy modification of the effect of time on acceptance of hippos occurred with human casualties (Figure 3). For those who did not remark that hippos killed or harmed people, the OR for preferring the presence of hippos by year was 1.02—essentially no change in acceptance between study years. However, for those who said that hippos killed or harmed people, the OR was 0.38. Therefore, the odds of accepting hippos decreased by more than 60% between study years in this group. While not statistically significant ($p = 0.16$), the effect of human fatalities was large.

For those who stated that hippos disrupted fishing activities, the percent who preferred the presence of hippos declined between study periods, but by a small amount (31.9% to 21.6%) (Figure 3). For those who did not remark that hippos disrupted fishing activities, the drop in acceptance for hippos was greater (33.3% to 12.2%). Although this effect was insignificant ($p = 0.28$), small sample sizes in some categories may have been a factor. For example, only 19 respondents who did not remark that hippos disrupted fishing activities were more accepting of hippos (7 in 2015 and 12 in 2017).

Table 5. According to Woolf, Mantel-Haenszel, and pooled odds ratios (ORs) results, while no variables of interest significantly affected the relationship between acceptance of hippos and study year, confounding was notably indicated for "hippos provide benefits" and, to a lesser degree, "hippos kill or harm people" and "hippos should be protected".

	Woolf Test			Mantel-Haenszel Test				Pooled ORs	
Variable	χ^2	df	*p*	OR_{adj}	95% CI Lower	95% CI Upper	*p*	OR_{unadj}/OR_{adj} Ratio	Confounding Bias Indicated
Benefits	0.00	1	1.00	0.228	0.100	0.521	<0.001	1.921	Yes
Fishing disruption	1.16	1	0.28	0.465	0.244	0.886	0.02	0.942	No
Human casualties	1.97	1	0.16	0.554	0.281	1.091	0.08	0.791	Moderate
Attitudes	0.16	1	0.69	0.539	0.210	1.384	0.19	0.813	Moderate

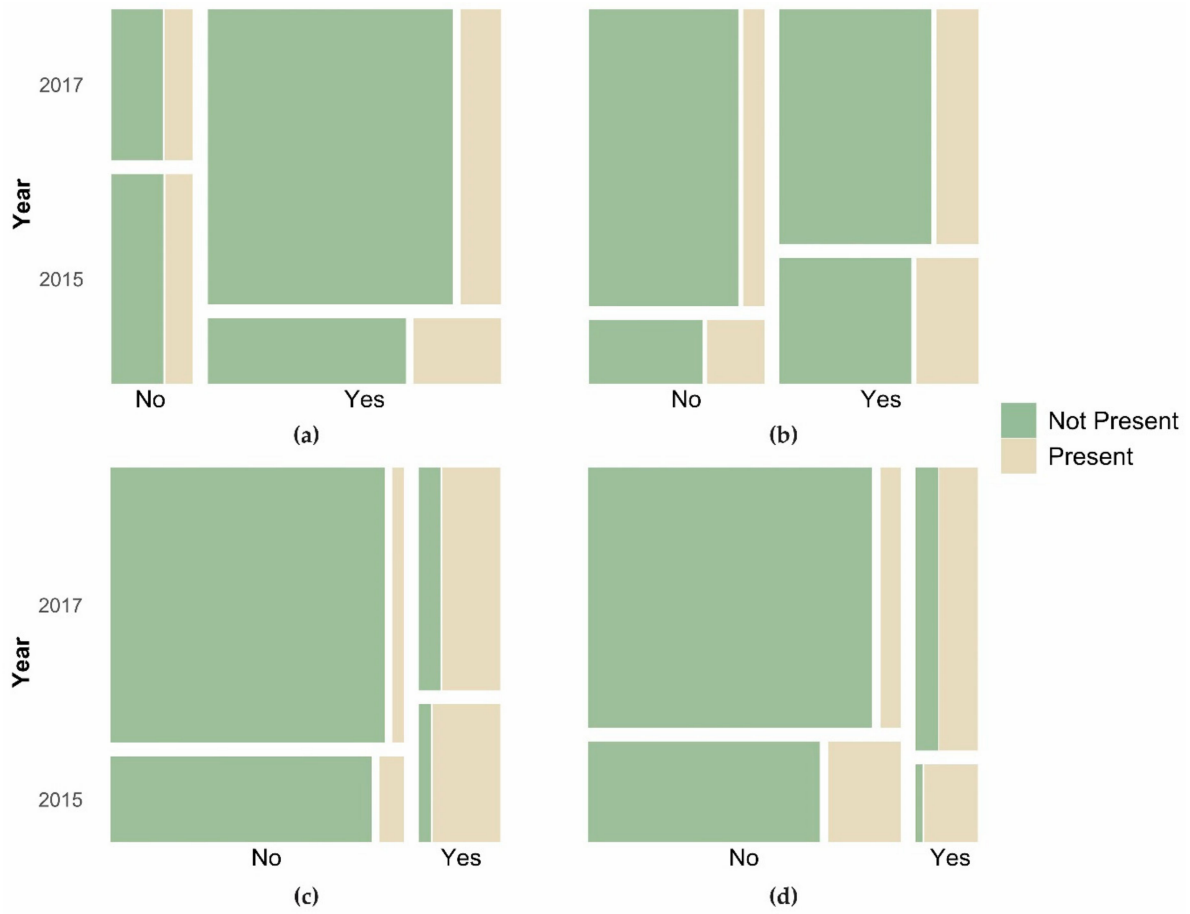

Figure 3. Relationship between year and acceptance of hippos based on whether respondents noted that hippos (**a**) caused human casualties, (**b**) disrupted fishing activities, (**c**) should be protected, and (**d**) provided one or more benefits.

The ratio of unadjusted to adjusted ORs indicated the presence of confounding, particularly by benefits, where the percent change in ORs was 92% (Table 5). To a lesser degree, human casualties (change of 21%) and attitudes (change of 19%) also confounded. Mantel-Haenszel tests of the pooled OR_{adj} showed that after controlling for confounding, there was a significant change in odds by year. This result aligned with the multivariate model in which year was a significant predictor when variables such as benefits and human deaths were included.

Considering only the two communities surveyed in both years (Baban Daba and Kiri), the odds of preferring the presence of hippos reduced between study periods by about 46% (OR = 0.54; 95% CI = 0.25, 1.19; $p = 0.10$; Fisher's exact). Compared to results from the full data set, the effect was slightly reduced and insignificant, although a smaller sample size may explain this outcome. Results of Woolf tests led to the same overall findings as with the full data set: no significant effect modification in the relationship between study year and acceptance, but the variable human casualties was again noteworthy. For respondents who did not remark that hippos killed or harmed people, the OR for preferring the presence of hippos by year was 0.96—very little change in acceptance between study periods. For those who mentioned human casualties as a disadvantage, the OR was 0.49. Although not significant ($p = 0.47$), the odds of accepting hippos in this group decreased by 47% between study years. According to Mantel-Haenszel results for Baban Daba and Kiri, confounding again existed primarily by benefits, where the percent change in ORs was 81%, and by attitudes, with a change of 31%.

4. Discussion

This study presented the unique opportunity to investigate human–wildlife relations involving a single conspicuous and problematic species in an environment heavily affected by people. Acceptance of hippos at Kiri reservoir in northeastern Nigeria was not complicated by the presence of, or impacts caused by, other conspicuous or damage-causing wildlife (e.g., elephants and crocodiles [69,70]). Our results showed that attitudes, beliefs related to benefits and risks, behaviors upon encountering hippos, study period, and income source significantly predicted human acceptance of hippos, which was, as expected, low among respondents. Farming practices and crop damage, although not statistically significant variables in our analysis, will nonetheless be important factors in reducing negative hippo-human interactions at this site. Here, we discuss our main findings and their conservation implications.

4.1. Predictors of Acceptance

Socio-demographic characteristics may be important determinants of attitudes toward wildlife and thus contribute to tolerance, acceptance, and ultimately coexistence (for example, age [32,71], gender [72,73], and level of education [32,74]). Of the measured socio-demographic variables in this study, only income source (skilled work) significantly influenced acceptance. Although most of those who engaged in skilled activities also had farms, individuals and households with multiple sources of income, notably off-farm sources, are generally more resilient to wildlife crop damage [75]. They also are likely to have fewer direct encounters with hippos.

We found support for the influence of attitudes on acceptance, as reported elsewhere [36,76]. Our attitudinal measure showed that acceptance of hippos was higher among respondents who supported the protection of hippos. At Kiri, hippos are legally protected (through state wildlife laws), and most respondents were aware of this, as well as the need to obtain permission to act against problematic animals. As a result, local circumstances require Kiri residents to be tolerant of hippos. Unlike other parts of Nigeria where wildlife poaching is common (including in some protected areas) [77–79], reports of local people harming hippos at Kiri were non-existent during our study periods, even though complaints about hippos were widespread. We viewed non-support for hippo protection partly as a desire to freely "deal with" problematic animals because of concern over lack of government intervention, therefore gaining more control over the risks posed by hippos. Even if communities were empowered in this way, however, such freedom may not result in significant hippo deaths. Hippos are often not easily killed, and unless supported by others with greater means, Kiri residents generally lack the financial resources to engage equipped hunters.

Fear of hippos, widely reported by respondents in this study, may also deter people from acting on their own. Fear was a key factor in deterring Tanzanians from hunting lions, even though people commonly considered lions to be problematic [80]. In this study, we found that local people who reportedly fled upon encountering hippos on land or water were less accepting of hippos. Hippos are dangerous animals, so fleeing is a sensible reaction. We also interpreted this reaction as an indicator of fear for personal safety, which can lead to negative views toward wildlife [20] and ultimately result in preference for lethal control of potentially dangerous species [19].

Beliefs about other risks posed by wildlife, real or perceived, such as property or farm damage, may be particularly salient in affecting views toward wildlife; in other cases, perceptions of benefits and positive impacts of wildlife may be especially important. At Kiri reservoir, acceptance of hippos was significantly influenced by beliefs about benefits and risks. Respondents who believed that hippos provided at least one benefit or presented a risk to human safety were more or less accepting, respectively, of hippos. Respondents in this study who recognized benefits were few, but given that monetary benefits from hippos (e.g., through ecotourism) are unavailable at Kiri, this result was somewhat encouraging. Respondents especially recognized educational and attraction values of hippos,

as well as ecological value (hippo dung = increased fish abundance). Perceptions of benefits appear critical in improving tolerance and acceptance of problematic species (e.g., large carnivores) [15,17,81,82].

4.2. Human Fatalities

Wildlife-caused human casualties pose high costs (e.g., significantly greater than farm or livestock damages in India [83]) and can have a particularly powerful and negative impact on human–wildlife relations [23]. Our data from Kiri reservoir supported the substantial effect of human fatalities on acceptance of hippos and as the largest modifier of the effect on acceptance over time.

Based on the timing and number of human fatalities caused by hippos in relation to the dates of this study (Table 1), we expected and found that when asked about the risks of living near hippos, relatively more respondents in the second survey period remarked that hippos kill people. Additionally, we cannot discount that these fatalities may have influenced the observed decline over time in the number of respondents who recognized benefits of hippos and thought hippos deserved protection. We are unaware of other significant changes at the reservoir between study periods (e.g., large increase in hippo abundance or crop damage by hippos) that might further explain these declines.

Insight may be gleaned from a 2007 study in eight communities and settlements around Kiri reservoir. It found that of 48 respondents, 19 (39%) preferred the conservation of hippos; 21 (44%) preferred hippos be killed; and 8 (17%) had mixed feelings toward hippos [84]. To manage hippo-related problems, most respondents (46%) suggested the establishment of a protected area over other options (killing some, killing all, chasing them away, or paying compensation) [84]. Crop damage by hippos was the No. 1 reported complaint (by 52% of respondents), but only two respondents mentioned attacks on humans. Although we can draw only limited comparisons with this study, its findings indicate more positive attitudes toward hippos at Kiri reservoir at that time.

In our study, human fatalities may largely explain the particularly hostile attitudes toward hippos at Baban Daba and Old Banjiram. While respondents across all four communities universally condemned crop damage by hippos, human fatalities had dissimilar effects. Hippos caused the death of a resident of Baban Daba more than 3 years before the first study period (Table 1). During the second study period, hippos caused a person from Baban Daba to drown. Research here occurred just one month after this incident. Similarly, in 2016 (1.5 years before the second study period), hippos killed two people at Old Banjiram in a gruesome manner (dismemberment), per official reports. Then, just days before we began research at Old Banjiram, hippos caused the death of a Talum resident. We had completed our research in Talum by then. So although this fatality could not have affected responses at Talum, it may have affected responses at Old Banjiram, which is relatively near and on the same side of the reservoir. For Old Banjiram respondents, the Talum fatality may have dredged up memories of the previous year's deaths.

Wildlife attacks on humans can have severe and lasting psychological and emotional impacts for survivors and the families of those affected [85]. Although neither Talum nor Kiri had a similar experience reflected in our data, it is unclear if, or how, attacks elsewhere affected residents in these communities and other reservoir communities not included in our study. Future research should explore the extent to which social networks may affect local people's fear of and negative beliefs about hippos, as this would inform conservation and outreach efforts [86].

4.3. Limitations

Our results should be considered in the context of this study's limitations, such as a sample biased toward men. Men are more directly involved in negative interactions with hippos (e.g., most women do not fish at Kiri, yet they are active in fish processing). Although there was no effect of gender in our final model of acceptance, we recognize that women can be significantly, if indirectly, affected by human–wildlife interactions [87,88].

Differential impacts of these interactions on gender would be important to explore at Kiri reservoir in future.

Our results also may have been affected by a smaller sample size in the first survey period relative to the second period (27% vs. 73% of the total sample) and the addition of two communities in the second period. Although we found that the latter did not alter the basic relationship between study year and acceptance of hippos, without prior data from Old Banjiram and Talum, we cannot ascertain if the observed decline in acceptance might have been weaker or stronger. Given the wholly negative responses from Old Banjiram, however, the likelihood seems low that in 2015, prior to any human deaths at this site, 100% of respondents would have been unaccepting of hippos.

Another potential influence on respondents' views in the second study period was that two of the four observers were state wildlife officials. These observers' professional affiliation may have led some respondents to answer dishonestly [89], such as reporting less favorable views of hippos to encourage an official response (e.g., removal of one or more hippos), or reporting more favorable views due to fear over potential repercussions (e.g., mistrust in the assurance of anonymity) or a desire to be viewed favorably by the interviewer. Presently, other than lethal control of problematic hippos, a rare occurrence, state authorities do not formally intervene at Kiri on behalf of residents.

4.4. Conservation Implications

At Kiri reservoir, human-hippo relations would benefit from conservation and development interventions that promote human safety around hippos, awareness of the current and potential benefits of hippos, livelihood diversification through off-farm activities, and mitigation of and compensation for farm damage. We do not propose this as an exclusive list. To guide these and other interventions, additional research is needed to help us better understand hippo-human relations at this site. Of interest would be hippo behavior and ecology, hippo crop-foraging patterns, effect of hippos on fishing practices, and seasonal variation in human-hippo interactions. Rigorous qualitative research on the socio-cultural aspects of human-hippo relations would also be beneficial [13], including further exploration of cultural beliefs and practices related to hippos. Socio-political aspects of human-human relations regarding hippos and water resources (e.g., dynamics among communities, government officials, and indigenous authorities) deserve greater attention. One relevant question would be how human-hippo and human-human relations about hippos might change in future as water volume continues to decline, resulting in an even more crowded reservoir.

Where human safety is threatened and costly, increasing tolerance and acceptance of wildlife will require a reduction in human casualties [83]. This could mean developing community awareness programs and materials that examine risky human behaviors, risky situations, and hippo behavior. Because all known fatalities at Kiri occurred on water, such programs should especially engage fishers and boat transporters. Awareness programs should not, however, solely highlight the dangers of hippos, as this may enhance perceptions of risk and fear and reduce acceptance [17].

Awareness programs should emphasize the benefits of wildlife. Although there are no direct monetary benefits derived from hippos at Kiri, the recognition of other benefits (e.g., ecological and educational) significantly influenced the acceptance of hippos. Similarly, Inskip and colleagues [15] found that local people who believed the presence of tigers protected the Sundarbans also had higher tolerance for tigers; this belief was more important in affecting tolerance than a belief in tigers as important for tourism. Although few respondents recognized the celebrity that hippos brought to Kiri reservoir, such recognition could be leveraged in conservation programs. Pride in a local wildlife population can have positive impacts on human attitudes toward both problematic [25] and dangerous [19] species. For example, members of the Australian public who expressed pride in local shark populations were generally against lethal control of sharks [19].

Hippo tourism has been proposed for Kiri, and while benefits from wildlife tourism can improve tolerance and acceptance of wildlife [16,24,72], we caution against this approach as the sole or primary means for improving human-hippo relations at this site for several reasons. First, Kiri occurs in a geographic region that has been disadvantaged by political insecurity since Boko Haram emerged more than a decade ago. Although Kiri is not within the main conflict zone, fear of travel to this region is likely to limit the number of potential tourists and the sustainability of an ecotourism program. Second, although Kiri boasts a sizeable hippo population and diverse birdlife, it cannot compete with the biodiversity and scenery of other regional attractions (e.g., Yankari Game Reserve and Gashaka Gumti National Park). Third, there is no guarantee that benefits from hippo tourism will improve acceptance of hippos [71], especially if crop damage and human casualties are not mitigated. Finally, careful consideration of benefit-sharing mechanisms and the potential for social inequality within and among communities from ecotourism programs would be particularly important for this site.

Although not measured in this study, financial losses from wildlife-caused damage to crops and fishing boats and equipment may pose significant hardship, especially for poor households in low-income countries [37,41,69,90]. Income from farming was not a significant predictor of acceptance of hippos in this study; however, nearly 9 in 10 respondents were farmers, so any effect may have been undetectable in statistical tests. Because of limited natural grass forage around the reservoir, crop foraging by hippos will continue, and so mitigation will be required. Compensation or insurance schemes may help offset hardship resulting from damage to crops, damage to fishing boats/gear, medical bills, or burial expenses, but limited state resources will be an obstacle to their viability and effectiveness.

Most Kiri farmers planted rice and maize near the reservoir, and they reported greater damage to these two crops than to others. In this study, we did not determine whether crop type or location played a more important role in hippo crop foraging. Rice and maize, being most proximate to the reservoir, may simply be more accessible to hippos as they emerge to feed. Similarly, Kendall [50] found that Tanzanian farmers living around Ruaha National Park reported no obvious favorite crop of hippos, but that farms closest to the Great Ruaha River and to places where hippos emerge from and return to the river were most often damaged. Although this would imply crop location is more important than crop type, Eltringham [91] suggested that rice, being closely related to the natural grass forage of hippos, may be preferred relative to other available crops. Mkanda and Kumchedwa [92] found that hippos in Malawi similarly preferred rice and local maize even though the latter was more widespread and favored hybrid maize among the three crops even though it was cultivated the least. Similar investigations at Kiri would help guide mitigation interventions.

One advantage to the situation at Kiri is that conservation interventions can be adapted to hippos because of the absence of other large, damage-causing species. One disadvantage is that water levels fluctuate seasonally and with closures/openings of the dam spillway gates, and farmers plant near or at the edge of the water year-round. Thus, some proven mitigation measures for crop foraging by wildlife, such as access prevention (fencing and trenches), will be viable only if there is a buffer zone around the water. In addition to crop-damage control, diversifying farming systems and livelihoods through off-farm activities may help buffer Kiri farmers against losses from wildlife-caused crop damage and other environmental problems, such as climate change [75].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/conservation2040043/s1, Figure S1: ROC Curve and Document: Questionnaire.

Author Contributions: Conceptualization, L.R.B. and I.A.R.; methodology, L.R.B. and I.A.R.; investigation, L.R.B., I.A.R., V.N.T., E.K. and G.A.M.; formal analysis, L.R.B. and R.X.S.; writing—original draft preparation, L.R.B.; writing—review and editing, all authors; supervision, L.R.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the American University of Nigeria Institutional Review Board (AUN-17-09-02).

Informed Consent Statement: Authors obtained verbal informed consent from respondents and provided respondents a copy of the consent script in English and Hausa languages.

Data Availability Statement: Not applicable.

Acknowledgments: Appreciation goes to the Adamawa State communities of Kiri, Baban Daba, Talum, and Old Banjiram and their leaders. We thank the Adamawa State Ministry of the Environment and Natural Resources Development, especially late Wildlife Calvin Haskainu, Nayumi Matthew, and Sanusi Audu. We are grateful to Simon Pooley and four anonymous reviewers for helpful comments on the manuscript, Blake Loosley for statistical input, and the American University of Nigeria (AUN) and AUN Department of Natural and Environmental Sciences for support.

Conflicts of Interest: The authors declare no conflict of interest.

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