

Behavioral Responses of American Crocodiles (*Crocodylus acutus*) to Conspecific, Crocodilian, and Hominid Juvenile Distress Calls in Cuajiniquil, Costa Rica

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ABSTRACT:

The following study analyzes the responses of American Crocodiles (*Crocodylus Acutus*) to distress call recordings of juvenile conspecifics, Spectacled Caimans, humans, and a control white noise. Understanding how crocodiles respond to each of these sounds provides insight into protective and predatory instincts. This knowledge is vital to better understand crocodile behavior, specifically in Cuajiniquil, where crocodiles fulfill many roles: protective parents, apex predators, and prey of humans. To assess how these roles apply to conspecific and allopatric distress calls, I tested 32 crocodiles with distress call recordings. I played one of the four recordings for one minute for each crocodile, observing their movement and behavioral responses. Additionally, I conducted additional behavioral observations by playing the American Crocodile juvenile distress call for three to five minutes. While analyzing the results, which included immediate responses to the sound and movement data, a mix of protective and predatory behavioral patterns emerged in response to the American Crocodile recording. Though further research is required, data suggests that crocodiles are uninterested in the caiman recording, and interested in the human recording. The crocodiles' response data from the white noise playback suggested disinterest.

Respuestas protectoras y depredadoras de los cocodrilos americanos (*Crocodylus acutus*) a llamadas de angustia juveniles del mismo especie y variedad de respuestas a llamadas de angustia juveniles humanas y de caimanes**RESUMEN:**

El siguiente estudio analiza las respuestas de los cocodrilos americanos (*Crocodylus acutus*) a grabaciones de llamadas de angustia de menores de su misma especie, de caimanes de anteojos, de humanos y a un ruido blanco como control. Comprender cómo responden los cocodrilos a cada uno de estos sonidos proporciona información sobre sus instintos protectores y depredadores. Este conocimiento es esencial para entender mejor el comportamiento de los cocodrilos, específicamente en Cuajiniquil, donde realizan diversos roles: padres protectores, depredadores ápice y presas de los humanos. Para evaluar cómo se aplican estos roles a las llamadas de angustia de individuos de la misma especie y de especies alopátricas, probé a 32 cocodrilos con grabaciones de llamadas de angustia de menores. Hice una de las cuatro grabaciones durante un minuto para cada cocodrilo, observando sus movimientos y respuestas de comportamiento. Además, realicé observaciones de comportamiento adicionales reproduciendo la llamada de auxilio de angustia de un cocodrilo americano durante tres a cinco minutos. Mientras analizaba los resultados, que incluían respuestas inmediatas al sonido y datos de movimiento, surgió una combinación de patrones de comportamiento protectores y depredadores en respuesta a la grabación de cocodrilos americanos. Aunque se requiere más investigación, los datos sugieren que los cocodrilos muestran desinterés por la grabación de caimanes y cierto

interés por la grabación de humanos. Los datos de la reproducción del ruido blanco indicaron desinterés.

INTRODUCTION:

Crocodylians have complex and intricate communication methods, and crocodiles specifically are considered the most vocal of all reptiles. Crocodylians use a variety of physical, olfactory, and acoustic methods to communicate. Head pushing, inflated posture, and tail wagging are used to demonstrate aggression (Brien et al., 2013), juveniles chirp and scream to communicate distress and danger, and bellowing (deep, loud calls) are complex mating rituals employed during the breeding season (Reber, 2020). Crocodiles are also known to be excellent parents, often protecting their offspring for months after hatching. Female crocodiles as well as dominant male crocodiles protect their eggs and hatchlings (Lenin, 2020). Juvenile crocodiles chirp to their mothers when they are ready to hatch, and emit distress calls when in danger, causing a mother or siblings to come to their aid (Ramireddy, 2019).

In addition to complex intraspecies communication, crocodiles have been observed to respond to sounds made by other species and even by inanimate objects such as gunshots and motors (Wermuth and Ross, 2024). One study showed that Nile Crocodiles understood and responded to Spectacled Caiman communication due to similar frequency slopes in their vocalizations, even though they are in different families, Crocodylidae and Alligatoridae. Juvenile Nile Crocodiles and juvenile Spectacled Caimans have the same acoustic code, meaning they can understand one another's calls. In the study, juvenile Nile Crocodiles moved towards a speaker whether the speaker was playing conspecific or Spectacled Caiman distress calls. (Mathevon et al., n.d.).

Another study showed Nile Crocodiles understanding and responding to distress calls from juveniles of phylogenetically different class: hominids. Researchers played calls of infant bonobos, chimpanzees, and humans from speakers at the Crocoparc Zoo in Morocco. The calls were recorded in a variety of scenarios, and therefore displayed different levels of distress and arousal. The results showed that the Nile Crocodiles respond to these calls. They did not seem to differentiate based on species, but rather were attracted to the calls that displayed higher levels of arousal and distress. Responses varied; some crocodiles approached on the surface of water, others swam underwater, some came very close to the speaker and stopped, and several attempted to bite the speaker. Researchers concluded that these responses point to a predatory response, although some individuals responded in a parental care context (Thévenet et al., 2019).

Additionally, biologist Frank Joyce shared a story with me about a caiman responding to a distress call from a different species. In 1982, he observed a Central American Bullfrog, (*Leptodactylus savagei*) emit a distress call upon capture. These amphibians produce a "loud, spine-chilling scream" that is said to mimic the sound of a crying baby (Leenders, 2016). Joyce watched as a caiman approached the screaming *Leptodactylus savagei* in response to the loud, wailing distress call.

There is clear evidence of crocodiles responding to conspecific calls as well as calls of other species, and specifically responding to juvenile distress calls. While American Crocodiles, *Crocodylus acutus*, are known to exhibit complex communication behaviors, their responses to other species' vocalizations is relatively understudied compared to other crocodylians. My study will focus on American Crocodiles in hopes of discovering more about their responses to juvenile distress calls of various species. As mentioned above, crocodiles are unbelievable parents and predators with complex communication tactics. I assessed these characteristics by

playing juvenile distress call recordings of different species. The recordings I used were: American Crocodile (*Crocodylus acutus*), Spectacled Caiman (*Caiman crocodilus*), human (*Homo sapiens*), and white noise as a control.

I played the distress calls of baby American Crocodiles to ascertain if crocodiles had a response, and if that response was predatory or protective. Crocodilians show very strong parental care, and the crocodile recordings I used are from 1-month old juveniles. Crocodiles of this age are still cared for by their mothers. As it is not nesting season, I wondered if there is an inherent parental instinct, or if baby crocodiles are considered prey outside of nesting season.

Research shows that the calls of juvenile Spectacled Caimans and juvenile Nile Crocodiles have similar frequencies, and therefore, Nile crocodile mothers respond to the distress calls of both species (Mathevon et al., n.d.). I tested the juvenile Spectacled Caiman call to see if American Crocodiles react the same way, or if they would discern between the two calls and respond differently.

I tested the calls of human infants to see if American Crocodiles respond to the sound of a distressed baby. Humans have been attacked by crocodiles in Cuajiniquil, and so observing if there is a response to this distress call is very pertinent. Additionally, there is past research with Nile Crocodiles showing responses to both monkey and human babies crying (Thévenet et al., 2019).

White noise was the control recording, which I used to determine if the crocodiles respond to all types of loud noise, or if they can distinguish between loud noise and calls of animals. White noise was the control because it has no repeated sound pattern or frequency, and therefore is less likely to be confused with an animal call.

My central question is “What are the responses of American Crocodiles to the distress calls of juvenile American Crocodiles, juvenile Spectacled Caimans, and human infants?” To gain insight on what distinguishes a predatory versus a protective response, I interviewed Miriam Boucher, a crocodilian researcher who specializes in American Crocodile acoustics. She explained that a protective response is indicated by the crocodile swimming directly, head-on to whatever they want to guard or protect (Figure 1 and Appendix 2). However, a predatory or curious response is designated by an “investigative cruise,” during which the crocodile swims or stays parallel to whatever has intrigued them (Figure 1 and Appendix 3). This allows them a greater field of vision as they determine what they are looking at (Boucher, 2024). Boucher’s explanations formed the basis for my predictions (Table 1).

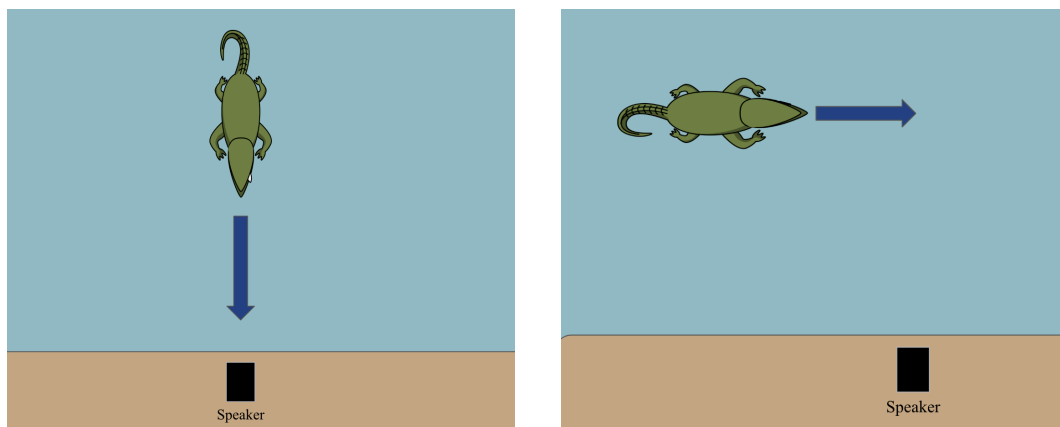


Figure 1. Protective response to an object of interest characterized by perpendicular motion towards object (left) and predatory response to an object of interest characterized by parallel motion towards object (right)

Table 1: Predictions on responses from American Crocodiles to various distress calls

Predicted Responses of American Crocodiles to Distress Call Playbacks	
Distress Call Playback	Predicted Response
American Crocodile	Mostly protective responses, some predatory responses.
Spectacled Caiman	Predatory response.
Human Infant	Predatory response.
White Noise (Control)	No response.

My predictions are based on the idea that American Crocodiles show strong parental care towards their babies, although they also prey on them after a certain amount of time. I predicted that the Spectacled Caiman and human infant calls would be perceived as prey. Additionally, I predicted that the white noise would not elicit a response because it does not have a frequency or pattern that mimics a distress call.

MATERIALS AND METHODS:

I took preliminary observations on 14 October, 2024, in Cuajiniquil, Costa Rica, to ensure that I would be able to find American Crocodiles in the area. I observed two American Crocodiles in the mangroves. After returning to Cuajiniquil on 18 November, 2024, I observed crocodiles in the Rio Cuajiniquil mangroves during low tide. I studied crocodiles at four sites along the Rio Cuajiniquil mangroves (Appendix 4), and one site at Baylis Puente, a bridge over the Rio Cuajiniquil (Appendix 5). Additionally, crocodiles were observed at Tomas Bay, the site of a mariculture project where the Rio Murcielago feeds into the ocean (Appendix 6). The fourth sighting location was in a small pond at the entrance to Playa 4x4 (Appendix 7).

I tested the crocodiles during low tide, playing the recordings from a range of 5 meters to 75 meters away. After finding a crocodile, I had a partner play one of the three juvenile distress call playbacks, or the control sound: American Crocodile, Spectacled Caiman, human infant, or white noise control. I played only one recording per crocodile to avoid testing multiple stimuli on one test subject. As each recording played, I trained my binoculars on the crocodile to observe any movement or response, and started a voice recording to document observations. At night, a flashlight was also trained on the crocodile. I observed each crocodile for ten minutes, noting any behavioral responses, whether they were acoustic, behavioral, or another type of response. I also noted lack of response, the location, the time of day, the tide level, the distance the crocodile was from myself, which sound was played, and any other pertinent information. After ten minutes, I sometimes played the conspecific juvenile distress call for three to five minutes to obtain additional behavioral data. These observations were based on the assumption I was visible to each crocodile that I tested. I conducted two days of preliminary observations, and ten days of

data collection. I performed chi-squared tests to determine if the factors I examined were associated.

RESULTS:

Over the course of 12 days, I tested 32 crocodiles by playing distress calls. I tested 12 crocodiles with the American Crocodile distress call, eight with the Spectacled Caiman distress call, six with the human infant distress call, and six with the white noise control sound. My sample sizes were uneven because sometimes crocodiles were viewed in groups of two to four, and every crocodile in the group was tested with the same sound to avoid a crocodile hearing multiple playbacks. Results were divided into several categories: immediate responses, movement responses, average movement distance, and stationary, submersion, and resurfacing behaviors.

Immediate response results refer to the crocodiles' immediate responses to a distress call playback (Figure 1). The "Stationary, Parallel (No Change)" response means that the crocodile remained in the exact position it was originally viewed in. "Parallel" refers to the crocodiles' snout and body being parallel to the speaker (Appendix 3), and perpendicular refers to the crocodiles' snout and body directly facing the speaker (Appendix 2).

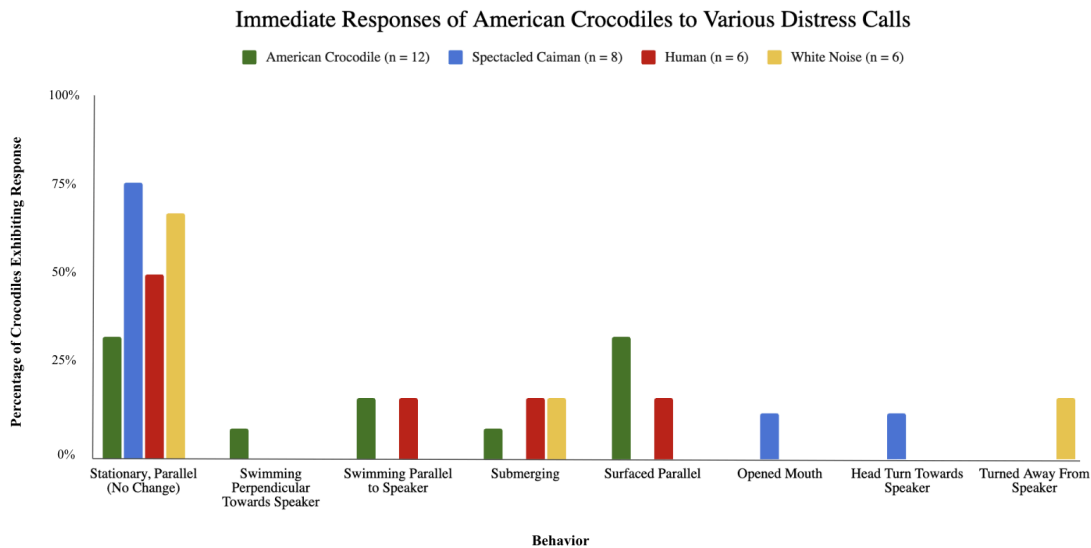


Figure 2. Immediate responses of American Crocodiles to three distress calls and one control sound (Based on "Stationary, Parallel" data, chi-squared test = 3.89, calculated p-value = 0.273568. Based on "Surfaced Parallel" data, chi-squared test = 5.45, calculated p-value = 0.0195)

Movement responses were tracked to quantify interest in the recording over the ten-minute observation period. "Moves Closer, Parallel" refers to a crocodile swimming closer to the speaker in a parallel position either from the left or right, while "Moves Farther, Parallel" refers to the crocodile swimming further away from the speaker in a parallel position either to the left or right. "Moves Closer, Perpendicular" refers to the crocodile swimming directly towards

the speaker (Appendix 2), whereas “Moves Farther, Perpendicular” refers to the crocodile swimming directly away from the speaker.

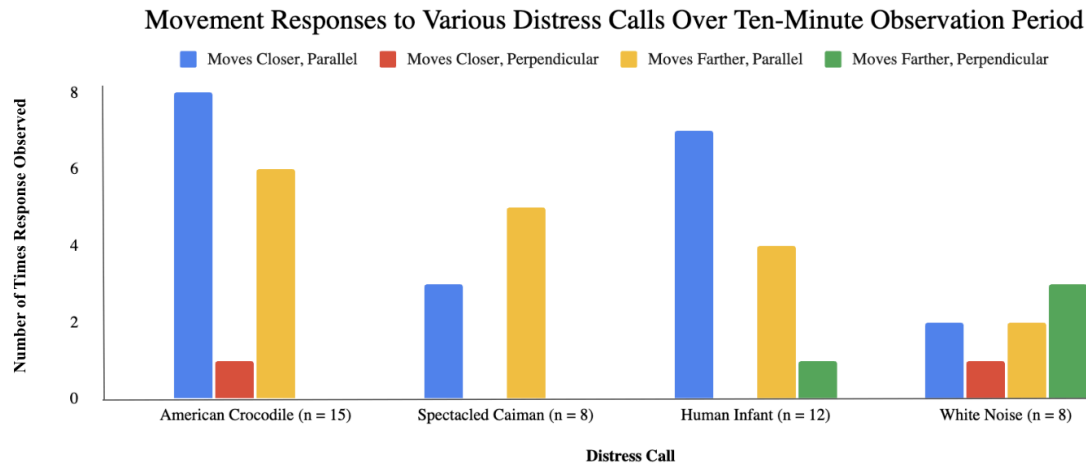


Figure 3. Total behavioral movement responses to four playbacks over a ten-minute observation period (chi-squared test = 1.91, calculated p-value = 0.591059 based on moving closer v.s. moving farther, not differentiating between parallel v.s. perpendicular movement)

It is also important to consider the average distance the crocodiles moved in each direction. This was quantified by totaling the average distance, in meters, that crocodiles moved for each of the four playbacks (Table 2).

Table 2: Average movement distances of American Crocodiles in response to distress calls (n = sample size of parameter combination)

Average Movement Distance and Type for Distress Calls and Control Sound

Type of Movement	American Crocodile Average Distance (m)	Spectacled Caiman Average Distance (m)	Human Average Distance (m)	White Noise Average Distance (m)
Moves Closer, Parallel	5.6 (n = 8)	5.33 (n = 3)	5.7 (n = 7)	0.75 (n = 2)
Moves Closer, Perpendicular	17 (n = 1)	0 (n = 0)	0 (n = 0)	1 (n = 1)
Moves Farther, Parallel	3.72 (n = 6)	4.2 (n = 5)	7.75 (n = 4)	6.5 (n = 2)
Moves Farther, Perpendicular	0 (n = 0)	0 (n = 0)	4 (n = 1)	5 (n = 3)

The lack of movement is also important. I analyzed the percentage of crocodiles that had no directional movement when the sound was played and for the ten-minute observation period following (Table 3). “Facial or Vertical Movement, No Directional Movement” means that the crocodile did not move towards or away from the speaker, but does not account for bodily movement such as facial movement, submerging, or resurfacing. The second column, labeled “Stationary,” means that the crocodile did not make any movement for the entire ten-minute observation period.

Table 3: Percentages of American Crocodiles that did not exhibit directional movement, percentages that remained stationary, and percentages that showed directional movement, over the ten-minute observation period (chi-squared test = 6.57, calculated p-value = 0.087045 based on no directional movement v.s. directional movement)

Breakdown of Lack of Directional Movement, Stationary Behavior and Movement

Playback Stimulus	Facial or Vertical Movement, No Directional Movement	Stationary	Directional Movement
American Crocodile (n = 12)	2 (16.66%)	2 (16.66%)	8 (66.66%)
Spectacled Caiman (n = 8)	4 (50%)	2 (25%)	2 (25%)
Human Infant (n = 6)	0 (0%)	1 (16.66%)	5 (83.33%)
White Noise (n = 6)	3 (50%)	1 (16.66%)	2 (33.33%)

Other noticeable behavioral responses included “Submerging,” which is defined as moving below the water’s surface, and “Resurfacing,” which is defined as reappearing after submersion (Table 4).

Table 4: Submersion and resurfacing responses for four different playbacks over a ten-minute observation period (chi-squared test = 0.5629, calculated p-value = 0.904873 based on surfacing v.s. resurfacing behavior)

Number of Submerging and Resurfacing Responses for Distress Calls and Control

Behavior	American Crocodile (n = 24)	Spectacled Caiman (n = 26)	Human Infant (n = 14)	White Noise (n = 19)
Submerging	15	14	8	12
Resurfacing	9	12	6	7

Another important result is that over the 32 crocodile samples, there were five instances of “Appearing,” which means that the crocodile appeared after the recording was played. Of these five instances, four occurred in response to the American Crocodile juvenile distress call, and one occurred in response to the human infant distress call.

In addition to playing one sound for each crocodile, on six crocodiles, I performed additional behavioral tests to observe reactions to the juvenile American Crocodile noise (Figure 3). These additional tests were prompted by one procedural test where a crocodile appeared from the terrestrial mangroves, likely drawn in by the juvenile crocodile call. After playing the procedural noise and observing for ten minutes, I began playing the American Crocodile noise, either completely continuously or nearly-continuously for three to five minutes.

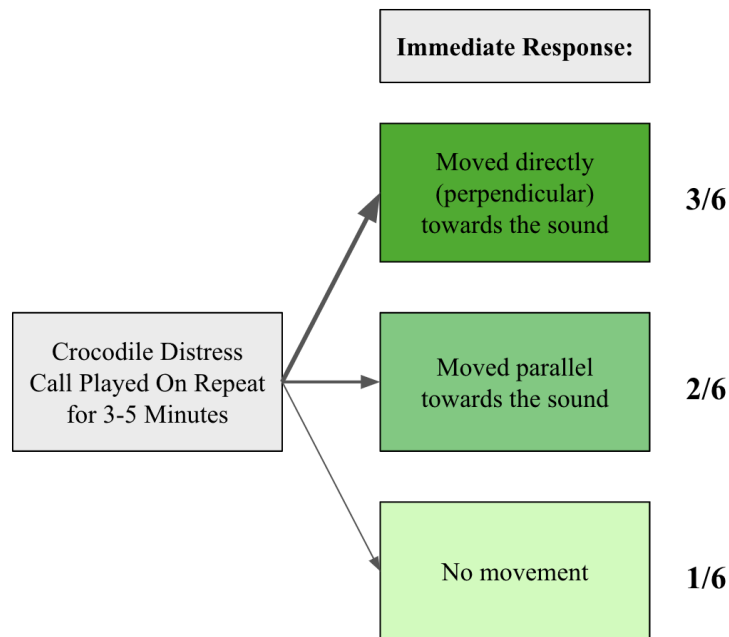


Figure 4. Immediate responses of American Crocodiles to additional conspecific distress call testing

Movement responses over the course of 5 to 10 minutes for these additional behavioral observations were also analyzed and graphed (Figure 4).

Movement Responses to Juvenile American Crocodile Distress Calls During Additional Behavioral Observation

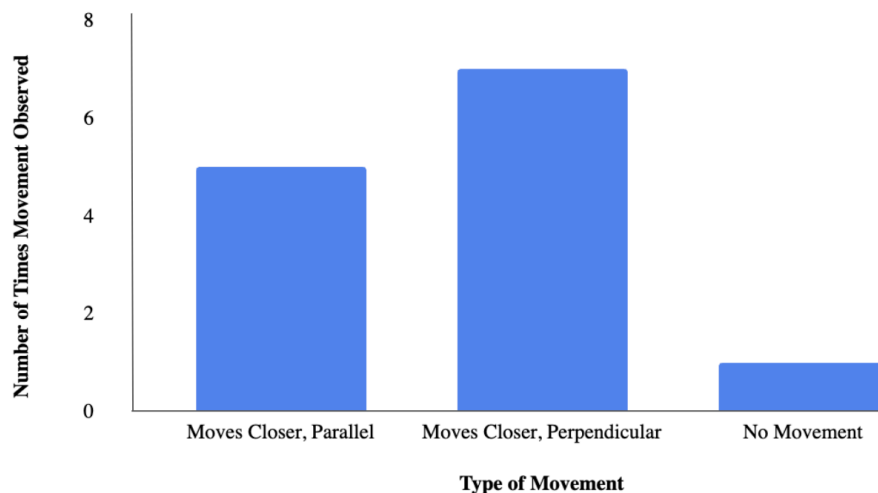


Figure 5. Total behavioral movement responses during additional behavioral observation while playing juvenile American Crocodile distress calls for three to five minutes

DISCUSSION:

For immediate responses to the conspecific distress call, the tested crocodiles only remained stationary 33.3% of the time, the lowest percentage out of the four recordings (Figure 2). Another 33.3% of the time, the crocodile appeared, or “Surfaced Parallel” as the sound was played, displaying interest by seeking the source (Figure 2). This is especially significant as crocodiles can interpret sounds while underneath the water, although it is unknown whether they hear the sound or can feel the frequency vibrations (Boucher, 2024), and is statistically significant as the calculated p-value equals 0.0195 (Figure 2).

In one instance, the juvenile crocodile distress call was played with no crocodiles in view. While the sound played, a three-meter adult crocodile emerged from land, jumped into the water, swam directly towards the speaker for 20 meters. The crocodile only shifted to a parallel, investigative cruise after it realized my presence. Swimming directly, or perpendicular, towards an object of interest, in this case, the speaker, suggests a protective response in American Crocodiles to the juvenile conspecific distress call (Boucher, 2024).

This result is further supported by the additional behavioral observations with conspecific distress calls (Figures 4 and 5). Out of six trials where juvenile crocodile distress calls were played repeatedly for three to five minutes, five times the crocodile moved immediately towards the speaker (Figure 4). Three of these movements were perpendicular to the speaker (Figure 4). Additionally, perpendicular swimming towards the sound was observed seven times overall (Figure 5). This suggests an innate protective response. It is not currently nesting season in Cuajiniquil, so there are no juvenile crocodiles and female crocodiles do not have hatchlings to protect. Therefore, a protective response in November shows that this behavior is instinct rather than being specific to a crocodiles’ own hatchlings.

During two trials, the crocodile immediately swam parallel to the sound (Figure 4). Additionally, parallel swimming towards the noise was observed five times overall (Figure 5). Parallel swimming, or an “investigative cruise,” is typical predatory behavior (Boucher, 2024). From this, I can extrapolate that the American Crocodiles also displayed predatory responses to juvenile conspecific distress calls.

In one scenario, two crocodiles were moving downstream, away from the human infant playback, and when the American Crocodile distress call was played, they immediately turned and moved approximately 30 meters upstream towards the speaker. One moved completely parallel to the speaker, and the other switched between parallel and perpendicular swimming. This evinces a specific interest in the juvenile conspecific distress call compared to the human infant distress call. Only once during the additional juvenile conspecific trials did a crocodile exhibit no movement, and the crocodiles never moved away from the speaker (Figure 5). Not only does this demonstrate both predatory and protective behavior towards baby crocodiles in distress, it also points to potential improvement in my procedure. Whereas perpendicular swimming was only observed once (6.6%) during my procedure, in which the recording was played for one minute, it was observed 53.8% of the time when the noise was played for three to five minutes (Figure 5). This implies that a longer recording may be necessary to elicit consistent responses from an American Crocodile. Longer recordings may more closely mimic the duration of real juvenile conspecific distress calls, especially since hatchlings vocalize until they receive protection from their mother (Chabert et al., 2015). If a distress call suddenly stopped after one

minute as opposed to continuing for three to five, the adult crocodile may assume the hatchling was no longer in danger and therefore alter its response.

Observing both protective and predatory behavior in response to the juvenile conspecific distress calls prompts a further extension regarding sex. Female crocodiles protect their hatchlings for months, while male crocodiles rarely participate in this part of parenthood (Lenin, 2020). It would be interesting to determine if predatory responses are associated with males, while females exhibit protective responses as they typically care for young. This species does not have gender dimorphism, so this study would require examination of the cloaca to determine sex (Ziegler and Olbort, n.d.).

The immediate responses of American Crocodiles to the juvenile Spectacled Caiman distress call showed that 75% of crocodiles did not respond (Figure 2). They remained stationary and parallel to the speaker, with only their head above water. This is known as the “minimum exposure” posture, in which a crocodilian is able to keep all important sensory organs above water while concealing the rest of its body (Crocodile Specialist Group, n.d.). This position can imply two things: either a crocodile that is relaxed and uninterested in the sound that is being played, or a crocodile that is observing potential prey and waiting to make a move (Crocodile Specialist Group, n.d.).

It is difficult to determine the reasoning behind crocodiles remaining stationary in immediate response to the Spectacled Caiman distress call. The two other immediate responses included the crocodile opening its mouth or turning its head towards the noise (Figure 2). These reactions imply interest in the sound being played, although they only occurred once each, and therefore more testing is necessary to reveal any patterns. Over the ten-minute observation period, five of eight times the crocodile moved away from the speaker when the juvenile Spectacled Caiman distress call was played, showing disinterest in the recording (Figure 3). Additionally, 62.5% of all crocodiles tested with this noise showed no directional movement, and 25% of crocodiles did not show any movement, including facial expressions, submersion, or resurfacing (Table 3). The chi-squared test produced a p-value of 0.087045 for this data, which is indicative of an association between the distress call and movement. While there may be some predatory interest, overall the crocodiles displayed disinterest in the Spectacled Caiman distress call. This data refutes my original prediction that the crocodiles would respond predatorily to the juvenile Spectacled Caiman distress call. It also does not align with the Mathevon’s study in which Nile Crocodiles responded to Spectacled Caiman distress calls (Mathevon, 2024). This suggests differences in acoustics and distress call responses between Nile Crocodiles and American Crocodiles.

One explanation for my results is that there is little territorial overlap between caimans and crocodiles in Cuajiniquil. I observed no Spectacled Caimans in Cuajiniquil over my 12-day testing period in areas where American Crocodiles were found, and biologist Frank Joyce stated that he has only seen them farther upriver, in areas with higher concentrations of freshwater. Therefore, most American Crocodiles may be unfamiliar with the Spectacled Caiman distress call. Although more trials are needed to conclusively determine the common response to Spectacled Caiman playbacks, my current data points to disinterest in the distress call.

The immediate responses to the human infant distress call show that 50% of the time the crocodile remained stationary in minimum exposure position, 16.7% of the time submerged, 16.7% of the time swam parallel, and 16.7% of the time appeared from underwater when the sound was played (Figure 2). The chi-squared test produced a p-value of 0.273568, suggesting that there is no correlation between the playback and immediate responses. The results of

movement over a ten-minute observation period displayed the crocodiles moving parallel towards the speaker seven times, and moving away from the speaker five times for the human infant distress call (Figure 3). This points to almost equal instances of interest and disinterest, but is inconclusive due to a calculated p-value of 0.591059. The average movement directly away from the speaker was 7.75 meters, a distance that was greater than movement away for any of the other recordings (Table 2). This distance points to intentional, rather than random movement, and could be inferred as either fear of the human infant distress call or disinterest. I remain unsure about the American Crocodiles' response to the human infant playback. Their immediate responses displayed a mix of interest and disinterest, and further trials are necessary to obtain significant data. However, it is important not to discredit responses such as the crocodile swimming parallel to the speaker and appearing when the sound was played, behaviors that imply predatory interest or investigation.

These inconclusive results refute my prediction that the human infant distress call would elicit predatory responses. It also conflicts with Thévenet's study showing that Nile Crocodiles respond predatorily to human infants' wails (Thévenet, 2023). One explanation for my results is that the American Crocodiles in Cuajiniquil are hunted by humans. It is possible that poaching has established fear of humans in some of Cuajiniquil's crocodile population. Therefore, the crocodiles may be interested in humans as potential prey, but also can see humans as dangerous to their survival. This dynamic may affect the consistency of the results to the human infant distress call, especially if some crocodiles have experienced threatening interactions with humans while others have not.

For immediate responses to the white noise recording, 66.6% of American Crocodiles did not respond to the noise and maintained the minimum exposure position (Figure 2). In one instance (16.7%), the crocodile turned away from the speaker and swam in the opposite direction, a response that was unique to the white noise recording (Figure 2). This collection of behavioral responses points to a lack of interest in the recording being played, although further testing is necessary due to a calculated p-value of 0.273568. To further support this claim, over the ten-minute observation period, all four directional movements responses were nearly equal, which suggests random movement, rather than intentional movement towards or away from the speaker (Figure 3). Nearly equal amounts of directional movement were not observed for any of the three distress call playbacks. Additionally, when the crocodile did move parallel towards the speaker for the white noise playback, the average distance was 0.75 meters (Table 2). For the other three distress calls, the average movement parallel ranged from 5.33 to 5.7 meters (Table 2). For perpendicular movement towards the speaker, the average white noise distance was 1 meter, while the average conspecific distress call movement was 17 meters (Table 2). This implies that any movement towards the speaker for the white noise was far less intentional than it was for the three distress calls. Additionally, 66.66% of crocodiles tested with the white noise showed no directional movement over the course of ten minutes, which suggests a disinterest in investigating (Table 3). The chi-squared test produced a p-value of 0.087045, which suggests an association between movement responses and the white noise recording. The three datasets in combination display a lack of interest and response to the white noise control recording, which aligns with my original prediction.

Submerging and resurfacing behaviors were collected for each recording (Table 4). Literature states that the submersion has lots of causes: predation (Grigg et al., 1985), resting (San Diego Zoo Wildlife Alliance Library Staff, 2024), and thermal regulation (C., 2020). Resurfacing implies that the crocodile either wants to assume minimum exposure position

(Crocodile Specialist Group, n.d.), is done resting (San Diego Zoo Wildlife Alliance Library Staff, 2024), or no longer needs to thermoregulate (C., 2020). Because there are multiple reasons why crocodiles submerge or resurface, I cannot extract conclusions from this data. Additionally, the chi-squared test produced a p-value of 0.904873, showing that there is no correlation between distress call and submersion/resurfacing behaviors. Further research with a focus on submersion and resurfacing patterns in relation to movement, behavior, and the amount of time after a recording is played is necessary to draw conclusions.

Some sources of error include the crocodiles' awareness of my presence. Crocodilians have exceptional vision, with a highly specialized retina that includes a foveae along the back of the eye. The foveae is parallel to the horizon, allowing them to pick out far-off details without moving closer. This adaptation allows them to quickly recognize movement and potential prey on the horizon line (Nagloo et al., 2016). These highly specialized eyes likely allowed the crocodiles to see me during the day. At night I had to shine a flashlight on the crocodiles to keep track of them, making them aware of my presence. In one instance, I played a recording while hiding behind a sandbank. The crocodile emerged from the woods, unable to see me. It swam directly towards the speaker, however, as soon as it moved far enough to see me in its line of vision, it began swimming slower, stopped, and turned parallel. This suggests that some crocodiles may alter their behavior in the presence of humans. A solution for this problem would be to set up speakers that play the recordings automatically at regular intervals, or to hide behind a sheet and wait for crocodiles to appear. This would produce more realistic results without human interference.

Further extensions include determining the sex of the crocodiles, as female crocodiles and male crocodiles fulfill different roles in parenthood. Males mate with females, but females care for hatchlings for months after birth (Lenin, 2020). It would be insightful to see if female crocodiles are more likely to exhibit protective behavior, while males are more likely to display predatory tendencies towards conspecific juvenile distress calls. Additionally, repeating this experiment during the nesting season would provide insight on whether the responses to the conspecific distress call would change in the presence of hatchlings. I theorize that with real hatchlings present, there would be even more instances of protective behavior. Finally, repeating the experiment with a focus on crocodiles of different ages (juvenile, subadult, and adult) could be insightful. Juvenile siblings (Ramireddy, 2019) as well as mother crocodiles (Lenin, 2020) often respond protectively to hatchlings' distress calls, yet hatchlings are prey for other adult crocodiles. Testing crocodiles of different ages would provide insight on how different distress calls are perceived over the course of an American Crocodiles' lifespan. This experiment could be executed by paying close attention to crocodile size and appearance, and getting closer to crocodiles to determine age.

In conclusion, the most significant piece of information obtained from this study was that American Crocodiles respond both predatorily and protectively to juvenile conspecific distress calls. This suggests that in addition to viewing juveniles as prey, an innate protective instinct exists. This study is important as it offers behavioral insight into an understudied species whose population is increasing and becoming more prominent in parts of Costa Rica such as Cuajiniquil and the Nicoya Peninsula.

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APPENDIX:

Date	Time of Day	Location	Size Estimate (m)	Age
11/19/24	Midday	Fallen Tree	?	?
11/19/24	Midday	Laguna	2	Adult
11/19/24	Midday	Class Beach	3	Adult
11/19/24	Midday	Class Beach	2	Adult
11/19/24	Midday	Class Beach	2.5	Adult
11/20/24	Midday	Fallen Tree	?	?
11/21/24	Midday	Tomas Bay	3m	Adult
11/21/24	Midday	Tomas Bay	?	?
11/21/24	Midday	Tomas Bay	?	?
11/21/24	Night	Baylis Puente	0.5	Baby
11/21/24	Night	Baylis Puente	1	Juvenile
11/21/24	Night	Baylis Puente	1	Juvenile
11/21/24	Night	Class Beach	3	Adult
11/21/24	Night	Class Beach	?	?
11/22/24	Midday	Laguna	?	?
11/22/24	Midday	Class Beach	3	Adult
11/22/24	Night	Class Beach	1	Juvenile
11/24/24	Dusk	Class Beach	2.5	Adult
11/24/24	Night	Baylis Puente	0.33	Baby
11/25/24	Night	Class Beach	1.5	Subadult
11/25/24	Night	Class Beach	?	?
11/25/24	Night	Class Beach	3	Adult
11/25/24	Night	Class Beach	?	?
11/25/24	Night	Tomas Bay	1	Juvenile
11/25/24	Night	Tomas Bay	1	Juvenile
11/25/24	Night	Tomas Bay	3.5	Adult

11/25/24	Night	Tomas Bay	2	Adult
11/25/24	Night	Tomas Bay	3	Adult
11/25/24	Night	Tomas Bay	2	Adult
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/25/24	Night	Tomas Bay	?	?
11/26/24	Night	Delta	?	?
11/26/24	Night	Class Beach	1.5	Subadult
11/26/24	Night	Class Beach	1.5	Subadult
11/26/24	Night	Class Beach	2	Adult
11/26/24	Night	Baylis Puente	?	?
11/26/24	Night	Baylis Puente	?	?
11/27/24	Night	Tomas Bay	?	?
11/27/24	Night	Tomas Bay	?	?
11/27/24	Night	Tomas Bay	?	?
11/27/24	Night	Tomas Bay	?	?
11/28/24	Night	Baylis Puente	1	Juvenile
11/28/24	Night	Baylis Puente	2	Adult
11/28/24	Night	Class Beach	?	?
11/28/24	Night	Class Beach	3.5	Adult
11/28/24	Night	Class Beach	?	?
11/28/24	Night	Class Beach	?	?
11/28/24	Night	Pond	0.5	Juvenile
11/29/24	Night	Class Beach	?	?
11/29/24	Night	Class Beach	2	Adult
11/29/24	Night	Class Beach	?	?

Appendix 1: American Crocodiles (*Crocodylus acutus*) seen in Cuajiniquil during the study



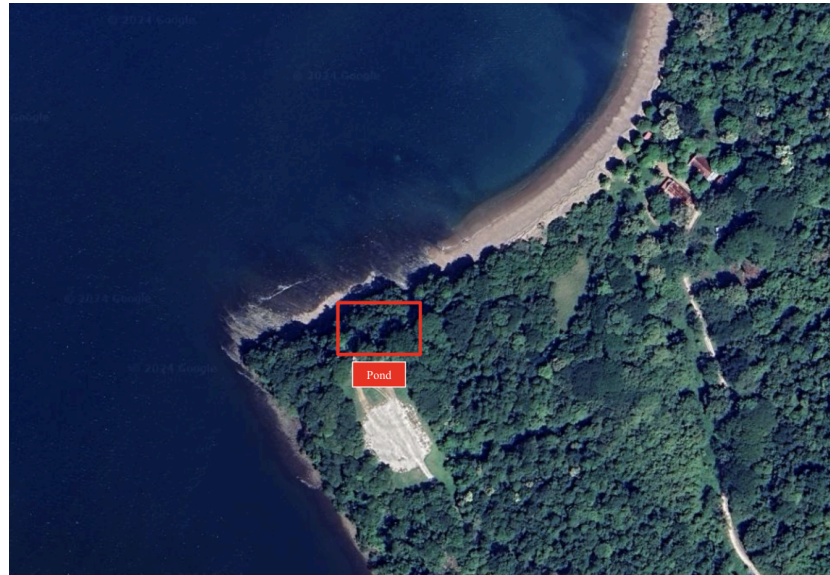
Appendix 2: American Crocodile swimming perpendicular to object of interest



Appendix 3: American Crocodile swimming parallel to object of interest



Appendix 4: Crocodile sighting locations along the mangrove ecosystem of Rio Cuajiniquil**Appendix 5:** Sighting location at Baylis Puente along the Rio Cuajiniquil**Appendix 6:** The mariculture project at Tomas Bay, another sighting location



Appendix 7: The pond at Playa 4x4, the final sighting location

Appendix 8: [Datasheet](#) of raw American Crocodile observation data, including specific movements with timestamps, as well as procedure and observations from November 18, 2024 to November 29, 2024