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MS Environmental Biology Capstone Project

Richard Patsilevas Jr.
Regis University

MS ENVIRONMENTAL BIOLOGY
CAPSTONE PROJECT

by

Richard H. Patsilevas Jr.

A Project Presented in Partial Fulfillment
of the Requirements for the Degree
Masters of Science
in Environmental Biology

REGIS UNIVERSITY
May, 2021

MS ENVIRONMENTAL BIOLOGY
CAPSTONE PROJECT

by

Richard H. Patsilevas Jr.

has been approved

May, 2021

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CHAPTER 1. LITERATURE REVIEW

A Combination of Methods is Needed to Accurately Detect Burmese Pythons in Southern Florida.

Introduction

Florida has the most introduced and invasive species in the United States (Engeman & Avery, 2016). A large proportion of these invasions include reptiles and amphibians because Florida's warm, year-round temperatures provide adequate habitat for invasions of reptiles that rely on their external environment for thermoregulation (Engeman et al., 2011). These animals are introduced to Florida in multiple ways, including major ports for wildlife distribution both legal and illegal, Florida's captive wildlife industry, where owners release the invasive species into the wild, and being in an area where severe hurricanes can accidentally release reptiles into the wild through building destruction (Engeman & Avery, 2016). By the time managers and researchers realize these invasive species are a problem, threatening ecosystems and native wildlife, it is usually too late to effectively respond as the populations are too large to effectively control (McNeely, 2013).

A serious threat to the native wildlife of south Florida is the Burmese python (*Python bivittatus*). Its large size and capability of eating many native animals, including endangered species, has caught the attention of managers and the media. These snakes and other invasive reptiles in Florida are predators that can have a large impact on the native wildlife, especially rare species, such as the Florida panther (Engeman et al., 2011). Burmese pythons most likely will not move north due to the warm temperatures they require in south Florida, but still leave the troubling task of how to manage them (Engeman et al., 2011).

Like most snakes, the Burmese python is cryptic, which makes it difficult to study. To monitor the Burmese python for mitigation, population data is important. Recently, investigators have struggled with low precision in population and detection estimates due to low recapture rates, variation in capture rates, and biased sources claiming there are low Burmese python population densities when their methods are not accurate, all of which can cloud results (Dorcas & Willson, 2009). Imprecise detections cause problems for managers making decisions about how to control python populations because they cannot accurately assess population size. In this paper I review methods being used to assess python location and detection in south Florida. The methods investigated are surveys done by foot, trapping, telemetry, and eDNA. A combination of these methods needs to be implemented in invasive Burmese python research. If possible, the best approach would be to use telemetry and eDNA for optimal results.

Surveys by Foot

Because of the Burmese python's cryptic nature, many different methods and strategies have been used to try and determine Burmese python population sizes in southern Florida. The most basic methods are common**,** yet not very effective, surveys completed by foot. These surveys can be done in multiple ways including human visual surveys, citizen science, and even the use of python detection dogs (Avery et al., 2014). When conducting visual surveys, researchers walk around visually searching for the pythons. Most snakes are found on canal levees or roads, which consist of an exceedingly small area of southern Florida and the everglades (Avery et al., 2014). This is because most of the Burmese python's habitat is in inaccessible terrain where walking is impossible. Citizen searches can be useful to have more people searching for pythons and identifying where pythons may be, but ultimately are ineffective. Due to the difficulty of detecting these snakes with the naked eye, in a 40-hour work week a single person would be expected to find one snake (Falk, Snow, & Reed, 2016). This means in a whole year if an individual is extremely successful, they would find 52 snakes. In one study, human participants searched a 31m x 25m natural enclosure for Burmese pythons. The results indicated that on average each individual was successful <1% of the time. These numbers could be even lower in the wild (Aver et al., 2014).

With the exceedingly low success of visual observations found in visual/citizen surveys it is possible that dogs, who have heightened senses compared to humans, could be useful. Dogs have an amazing sense of smell; this leads them to be used frequently for detection purposes in law enforcement and wildlife management. A pilot study was completed in 2011 by using black Labrador retrievers to assist in controlled canal python searches (Avery et al., 2014). The dogs found a total of 19 pythons with a 92% success rate, 30% higher than humans. The dogs completed searches 2.5 times faster than humans did. The drawback to using detection dogs, however, is that they can only search for 5 miles per day before they start overheating due to the intense heat in southern Florida. Researchers have concluded that dogs should be used to assist human visual surveys as they as more successful than humans. The common drawback among dogs and humans is being limited to only searching roads and canal levees (Avery et al., 2014). Ultimately, visual surveys result in low detection rates and have to be conducted in limited areas.

Constrictor Trapping

Trapping is sometimes used as an alternative to visual surveys because it allows researchers to access more difficult areas, such as places that can only be reached by airboat. Few studies have evaluated the success of trapping large constrictors, but the initial findings give some insight on the efficacy of trapping for Burmese pythons. Reed and colleagues (2011) completed the first live trapping study of any introduced large constrictor species. Baiting attractant traps with live laboratory rats was used to evaluate capture rates and use the capture rates as a proportion of possible pythons in the area (Reed et al., 2011). Reed and colleagues (2011) baited traps every night from August 3 to November 13 and throughout the entire study there was a trapping success rate of only 0.5% per night. Although this is only one study, these findings show that using attractant traps may not be beneficial in controlling or eradicating any of the large constrictor species in the everglades, let alone the cryptic Burmese python (Reed et al., 2011).

Radio Telemetry

A major limitation to visual surveys is the difficulty of detecting Burmese pythons in remote locations outside of roads and canal levees. To give researchers a better idea where to conduct any form of python detection, it is important to know where the pythons are. Knowing how Burmese pythons are using and dispersing through their habitat gives viable information on how to control their population (Hart et al., 2015). Researchers can gain this information by using telemetry data. In radio telemetry, a researcher will place a radio tag on an individual which will report back radio signals to show the animal's location. There was very little knowledge on free ranging snakes until radio telemetry came to use in the 1970's, which made monitoring snakes much easier for managers and researchers (Újvári & Korsós 2000). This older method of collecting data allows managers and researchers to understand the pythons' movements, home ranges, and habitat use patterns. It may be an older method, but it will be of great use in Burmese python research, providing exact locations of where the snakes are.

Telemetry was first used on Burmese pythons in 2005, when University of Florida researchers captured 17 adult Burmese pythons and implanted them with very high frequency (VHF) transmitters. The researchers tracked pythons by foot daily, for multiple days. After this initial period, the researchers tracked the pythons once a week by plane to not interfere with their movement patterns (Harvey et al., 2008). Harvey and colleagues (2008) used some of these snakes as “Judas Snakes” that lead observers to other snakes, which are then captured (Harvey et al., 2008). This helps researchers locate snakes and discover if others are in that specific area.

More thorough studies needed to be completed to further improve the knowledge of Burmese python habitat use. Hart et al. (2015) designed a multi-year radio telemetry study to characterize Burmese python movement patterns, fully discover their home range, and classify their habitat use. Their results demonstrated that python home ranges are larger in the introduced southern Florida range than in their natural home range, and that they prefer to disperse under relatively dry conditions (Hart et al., 2015). When performing future research, biologists can now use these data to show them where to conduct future studies.

eDNA Methods

When designing research studies to determine occupancy rates and detection rates of the Burmese python, the common techniques of trapping and visual surveys are not efficient enough due to low occupancy and detection rates. Researchers are using a relatively new method known as environmental DNA (eDNA). This method is completed by using Polymerase Chain Reactions (PCR) to detect Burmese pythons from water-based DNA (Piaggio et al., 2014). To conduct this molecular technique, researchers collect water samples, which should contain environmental DNA such as skin particles or bodily fluids from the python. The samples are then run through PCR, which amplifies small portions of DNA (Hunter et al., 2019). The first study conducted using eDNA was completed in a captive setting to see if it was possible to conduct this kind of molecular research using water samples (Piaggio et al., 2014). To test for eDNA, researchers amplified mitochondrial DNA cytochrome b genes using primers that were previously applied to low quality Burmese python DNA. All 5 sites that pythons were known to inhabit, had eDNA in them (Piaggio et al., 2014). These findings show that it is possible to use eDNA to detect Burmese pythons.

As years have gone by, more Burmese python researchers are using this eDNA technique more frequently. Researchers are using eDNA in the same way during all studies by collecting water samples, but PCR is frequently changing to cut back errors in the procedure. For example, two decades ago, a new technique was discovered called quantitative Polymerase Chain Reaction (qPCR). qPCR allows for amplification and quantification of DNA molecules (Pabinger et al., 2014). Focusing on eDNA, Hunter et al. (2015) used qPCR replicates to account for errors in Burmese python detection. They discover that three qPCR replicates were needed to accurately detect Burmese python eDNA in each water sample (Hunter et al., 2015). They used a multi-scale occupancy model to estimate probabilities of eDNA occurrence and detection and used Bayesian methods of analysis to fit them with python eDNA. With this technique Hunter and colleagues completed the first estimates of snake occurrences throughout southern Florida, resulting in occupancy models that have a 91% detection probability.

Another form of PCR amplification known as droplet digital PCR (ddPCR) can be used in Burmese python research. This technique detects small traces of DNA by counting molecules by separating diluted nucleic acids (Floren et al., 2015). Droplet digital PCR is thought to be the best tool for dealing with inhibitors in the water system and can allow detection down to a single molecule (Orzechowski et al., 2019). Orzechowski and colleagues (2019) investigate if pythons occupied areas with wading birds more often than areas without wading birds. They obtained water samples and performed ddPCR on them. The tests displayed that 10 out of 15 samples from areas with wading birds had python eDNA, while areas without had 4 out of 15 samples with eDNA (Orzechowski et al., 2019). This shows that using eDNA with ddPCR is a viable research option for conducting studies on Burmese pythons.

Analysis

Population analysis on cryptic species can be extremely difficult because of low levels of detection. However, population estimates of cryptic species can be improved by using detection and site occupancy models. Researchers can complete site occupancy models as they successfully model populations of cryptic species and might be the only effective models for these cryptic populations (Durso, Willson, & Winnie, 2011). These models should include a null (constant) model, models where proportion of sites occupied is held constant, models where detection probability is held constant, and a global model where site occupancy and detection probability include two uncorrelated variables.

Durso et al. (2011) completed the first study of site occupancy on rare and cryptic aquatic snake species. They set up 20 minnow traps throughout their study area and calculated the site occupancy and detection estimates from their results using the program PRESENCE. With this program they conducted a Principal Component Analysis for each species of snake with their six site covariates (Durso et al., 2011). They estimated detection probability at 3-46% and occupancy at 12-96% while also calculating the effort necessary to declare absence of a species with statistical confidence. They state that it is necessary to incorporate these data when doing large-scale monitoring for secretive species (Durso et al., 2011).

Best Method Options

Many methods for detection of cryptic species like Burmese pythons are ineffective because of the methods low detection and capture rates. This is true for surveys done by foot and trapping attempts on Burmese pythons. However, eDNA is increasingly implemented for its promising results. Researchers are progressing with how they use eDNA with qPCR and ddPCR. With qPCR, researchers can use replicates to account for errors in detection of Burmese python eDNA, giving accurate results (Hunter et al., 2015). ddPCR can detect a single molecule, which assists in dealing with inhibitors within the water system (Orzechowski et al., 2019). Researchers can use telemetry data to guide where exactly they should conduct their eDNA research. Researchers should combine telemetry work with any of the other techniques discussed in this literature review, so that managers can accurately assess python occupancy, detection, and populations. The most efficient technique among them all, would be using telemetry combined with eDNA methods. This will allow researchers and managers to make the best decisions possible for how to control the invasive python population in southern Florida. Coming up with the best methods possible is important for managers as these Burmese pythons are detrimental to the ecosystems they are inhabiting.

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CHAPTER 2. GRANT PROPOSAL

The Invasive Burmese Python's (*Python bivittatus*) Distribution and Density in South Florida

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October 18, 2020

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Section 1. Abstract

Invasive species management is an especially important topic for managers dealing with conservation issues in south Florida. The Burmese python, a large constricting snake species

from Asia, is a top priority for management. These snakes are detrimental to wildlife within south Florida, including threatened and endangered species. Although Burmese pythons are a top priority, there are many difficulties that come along with trying to control this species. Currently, we do not know the snake's population size and distribution throughout the state of Florida, nor where they will occur seasonally. This is primarily due to the complications of detecting this species. I plan to bridge this knowledge gap by conducting a telemetry and environmental DNA (eDNA) study. The telemetry portion of this study will obtain an accurate home distribution of this species across the wet and dry seasons in Florida. The eDNA aspect of this study aims to obtain more accurate information on the snake's population sizes based on detection and occurrence of eDNA in water samples. This improved knowledge will allow managers to implement appropriate management plans for the snakes based on the population size, ultimately assisting in improving ecosystems that are disturbed by this snake's presence.

Section 2. Objectives, Hypotheses, Anticipated Value, Literature Review

Objectives

This study will provide important information on the distribution and density of Burmese pythons (*Python bivittatus*) throughout south Florida using a combination of telemetry and eDNA. Also, it will provide new information on the seasonal distribution and density of Burmese pythons. These data will provide managers with critical knowledge for suppressing the distribution of non-native Burmese pythons throughout south Florida.

Questions and Hypotheses

Q1: Are Burmese pythons inhabiting areas beyond their introduced range?

H1: Burmese pythons do not inhabit areas outside of their introduced range, due to the decreasing temperatures further north in Florida.

Q2: Is the Burmese python's distribution and density consistent throughout the year?

H2: Burmese python density will vary seasonally.

Anticipated Value

The findings of this study will provide important information on the distribution and density of the Burmese python. The Burmese python is an invasive species that is detrimental to native wildlife throughout south Florida, some of which are rare and endangered (Mazzoti et al., 2011). To assess the invasion, control the python population, and protect native species, getting accurate seasonal distributions and densities must be a top priority for managers. In this study, I will investigate potential home ranges for the Burmese pythons, showing where they primarily inhabit each season. I will also measure density to give an accurate description of the Burmese python density in these areas. The information from this study will fill knowledge gaps on distribution throughout various seasons in Florida and will provide accurate densities to go with those distributions. Ultimately, if managers are not looking in the correct areas, and underestimating the number of pythons in those areas, they will not be able to develop the best solutions possible for mitigating the invasion of Burmese pythons.

Literature Review

With over 40 species of invasive reptiles, the state of Florida has the most established invasive reptiles in the United States (Mazzoti et al., 2011). Most of the places that Florida's invasive reptile species inhabit are manmade habitats such as canals or backyards. Some species do not follow that pattern and cause damage to natural habitats throughout Florida (Mazzoti et al., 2011). Of these invaders, one of the most serious threats to the native wildlife of south Florida is the Burmese python. Because of its large size and capability of eating many native animals, including endangered species such as the Florida panther, the Burmese python has become a major ecological concern (Engeman et al., 2011).

Climatic factors often limit the geographic range of invasive species (McDowell et al., 2014). Although climate cannot always be used to indicate a species' distribution throughout a landscape, studies have examined the distribution of the Burmese python based on its native climate which is typically hot and humid rainforest areas but can extend into more temperate zones (Dorcas et al., 2011). However, these climate-based studies in Florida have had varying results (Mazzoti et al., 2011). Florida's climate is split into two seasons, a wet season, from June through September, which usually has warm temperatures ranging from 69 to 90 °F and a dry season, October through May, which normally has cooler temperatures ranging from 56 to 86 °F. A random cold spell in Florida gave researchers a chance to investigate if Burmese pythons could survive in colder Florida climates. The researchers found that 9 out of 10 snakes surveyed during the cold event died from the cold temperatures (Mazzoti et al., 2011). These results led researchers to believe that Burmese pythons' introduced range will be limited by cold temperatures in the north. But this still leaves the troubling task of how to manage them with no exact idea of the python's range and the inaccurate detection estimates (Engeman et al., 2011).

Like most snakes, the Burmese python is cryptic, which makes it difficult to study. To monitor Burmese python populations for mitigation, accurate data are crucial. Investigators have struggled with low precision in population and detection estimates due to low recapture rates and variation in capture rates. Due to these issues some sources claim there are low Burmese python population densities when their methods are not accurate, all of which can cloud results (Dorcas & Willson, 2009). Imprecise detections cause problems for managers on how to control python populations because they cannot accurately assess population size. The use of eDNA and radio telemetry will assist managers in detection and assessing distribution of Burmese pythons throughout Florida.

eDNA is showing promising results in detecting Burmese pythons. This method is completed by using polymerase chain reaction (PCR) to detect Burmese pythons from water-based DNA (Piaggio et al., 2014). To do this molecular technique, researchers collect water samples, which should contain eDNA such as skin particles or bodily fluids from the python. The samples are then run through PCR, which amplifies small portions of DNA (Hunter et al., 2019). This method circumvents some of the difficulties of density detection in this species. Telemetry data can guide where the eDNA research should be conducted. Radio telemetry is where a researcher places a radio tag on an individual which will report back radio signals showing the animal’s locations (Újvári & Korsós 2000). This telemetry method was unavailable to herpetologists until the 1970’s, but since then has been useful in understanding how snakes are using habitats (Újvári & Korsós 2000). With this distribution information, researchers and managers can have more accurate distribution and density data of the Burmese python in Florida. This improved knowledge will provide managers with specific areas in which they can focus their management efforts.

The invasive Burmese python is causing severe disturbances to Southern Florida. Currently, there is a knowledge gap in the density of Burmese python concentrations. Researchers also do not have an exact representation of the python's distribution throughout Florida due to the challenges of detecting where the Burmese pythons should be within the state's climate. Few studies have examined how python populations are distributed throughout the different seasonal temperatures in Florida. The information gained from this study is an important step for researchers and scientists. It will decrease the knowledge gap that researchers and managers have in both distribution and population density of the pythons. This information is necessary to be able to develop effective strategies for managing this invasive issue.

Section 3. Methods

Study Species

The study species in this project is the invasive Burmese python, a large constricting species from Asia. This species can range from 2 feet at birth up to 20 feet as a maximum length adult (Johnson, 2020). They have a yellowish tan to light brown coloring. Their backs and sides have separate dark brown blotches surrounded with a black outline. When upside down, Burmese pythons are unmarked down the center of their belly. The Burmese python can be found primarily around water but has also been known to adapt to forest habitats and open habitats. These snakes primarily feed on small mammals such as raccoons, deer, bobcats, alligators, and birds (Johnson, 2020). These snakes can even prey upon the highly endangered Florida panther as they are known to eat leopards in their native habitat in Asia.

Study Site

This study will be conducted in southwestern Florida. There will be two initial starting points to find Burmese pythons, which will then be prepped to have telemetry tags put on. The first starting point is in a southern area of Everglades National Park in Monroe County, which is the Southwest established county (Figure 1). The second starting point will be at a northern point of Collier County, which is the Northwest established county (Figure 1). Within these areas I will search various habitats such as marshes, swamps, canals, and forested areas. These are all expected habitats to find Burmese pythons according to Florida University**'s** department of Wildlife Ecology & Conservation (Johnson, 2020). The field study will go from mid-August 2021 until mid-February 2022. This period spans from halfway through the wet season through halfway through the dry season.

Telemetry Methods

To assess the distribution of pythons across south Florida I will use radio telemetry data. To obtain these data I will use a protocol similar to Hart et al. (2015). At each of the northern and southern starting locations five pythons will be captured by road, levee, and canal visual surveys. Once a python is captured, I will record its location via GPS. I will then take basic snake measurements such as length and girth, then place the snake in a snake bag within a large plastic container. I will bring each python to a lab and a veterinarian will implant the radio transmitters; two pythons will have an additional GPS attached. The veterinarian will anesthetize the pythons during the implantation procedure, and I will monitor them for 24 hours. After the snake is cleared it will be brought back to approximately 100m from where it was captured. Finally, I or my assistants will monitor Burmese pythons by foot for the first couple of days, then I will monitor them aerially every other week. These data will give me enough information to confidently state where the Burmese pythons are residing.

eDNA Methods

To assess the density of Burmese pythons in their respective areas, I will use a protocol following Hunter et al. (2015). Genomic DNA will be isolated from Burmese python skin samples and other constrictors. This will be done using the Qiagen DNeasy Blood and Tissue kit and their protocols. I will collect 100 water samples, from various areas at each site. I will then filter and extract DNA from the filtered samples. I will then run qPCR TaqMan assays using developed primers and probes. I will run triplicate qPCRs to analyze technical replicates and lower the probability of a detection error.

Statistical Analysis

I will complete two different kinds of statistical analyses for this study, an occupancy and detection analysis for the eDNA portion of the study, and distribution analysis for the telemetry portion. These analyses will be completed for each of the two seasons. For the occupancy analysis, I will fit multi-scale occupancy and detection models using the Bayesian Monte Carlow Markov Chain algorithm (MCMC) (Hunter et al., 2015). These models will estimate a latent site-level probability of eDNA occupancy, an average conditional probability of eDNA occurrence in a single sample, and the conditional probability of detecting eDNA in each PCR replicate. I will run 1000 iterations of each MCMC model (Ozechowski et al., 2019). For these occupancy and detection analyses I will use R software. For the distribution analysis, I will display home occupancy ranges in maps, using ArcGIS.

Potential Negative Impacts:

Any negative impacts should be minimal when conducting this study. Handling the snakes could upset them causing them to act out, which in return could be problematic for the handlers and the snake. To mitigate the chances of this happening, I will train all my assistants in proper snake handling techniques. There is also always a danger when an animal is anesthetized, but the risk should be low with licensed veterinarians performing the implantation. There will be minimal disturbances to the environment during fieldwork.

Project Timeline

Date	Activity	Deliverables
Mid-Aug. 2021- mid Oct. 2021	Find snakes, fit for telemetry data, start collecting telemetry data	Snakes to follow
Late Oct. 2021 – early Nov. 2021	Collect eDNA data from snake habitat (season 1)	Have samples to run in the laboratory
Early Nov. 2021 – mid Feb. 2022	Run eDNA samples in laboratory	Provide information on occupancy of snakes
Mid-Feb. 2022 – early Mar 2022	Collect eDNA data from snake habitat (season 2).	Have samples to run in the laboratory
Early Mar. 2022 – End of Mar. 2022	Run eDNA samples in laboratory	Provide information for occupancy analysis of snakes
Early Apr. 2022 – End of Apr. 2022	Complete data analysis	Have information for results section of document
End of Apr. 2022 – Early Jun. - 2022	Draft, edit, and complete report	Final Report

Section 4. Budget

Item	**Justification**	**Cost per unit**	**Quantity**	**Total**
Holohill SI-2 (11g) Radio Transmitter	To tag pythons	$300	10	$3000
A-R-600A 216-222Mhz USA Model Telemetry receiver	Detect and follow tagged pythons	$499	1	$499
Quantum 4000e medium backpack	GPS locations for selected pythons	?	2	?
Plane ticket to and from Florida	To get to Florida	$225	2	$450
Helicopter survey	To follow radio transmitted snakes	$260/hour	Approximately 14	$3640

Rental Pickup truck	To get to initial site	$32/day	14	$448
Campground stay	Place to stay during fieldwork	$90/night	14	$1260
Total Resource Expenditures				$9,297

I will request funds for the eDNA portion of this study from a different funding agency. I am waiting for a response on the price of the Quantum 4000e medium backpack.

Appendix:

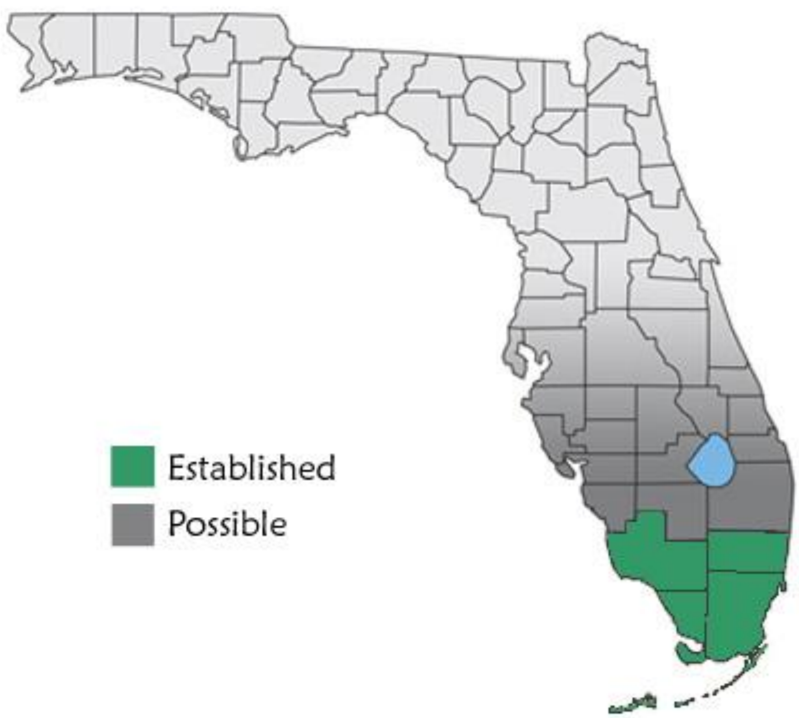

Figure 1: A map of the established and possible regions that the Burmese python may inhabit; retrieved from University of Florida department of Wildlife Ecology & Conservation

Section 5. Qualifications of Researcher

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Education

Master of Science: Environmental Biology May 2021
Regis University, Denver, CO

Bachelor of Science: Biology Pre-Medical/Veterinarian/Dental May 2017
Minor: Psychology
Waynesburg University, Waynesburg, PA

Relevant Work Experience

Conservation Education Specialist
Pittsburgh Zoo & PPG Aquarium, Pittsburgh PA Oct 2017 - Jul 2019

- Provided care for over 35 species of animals ranging from reptiles, amphibians, birds, mammals to invertebrates.
- Documented and recorded certain animal behaviors such as open mouth breathing in a certain snake
- Medicated animals using various techniques depending on the animal and situation
- Trained interns on proper techniques for handling, restraining, and husbandry of the animals
- Taught interactive Wonders of Wildlife classes to children and adults
- Part of a crew who performed animal amphitheater presentations to over 25,000 total guests throughout the summer

Research Experience

Do Seasonal Trail Closures Have an Impact on the Habitat Use of Local Ungulate Species in the Eagle Holy Cross Ranger District?
Rocky Mountain Wild, Denver CO Dec 2020 - May 2021

- Worked through the process of creating a multi-year research project with Rocky Mountain Wild
- Independently created annotated bibliography on relevant literature related to the topic
- Created the project methods/protocols
- Was in communication with the United States Forest Service regarding the project

Bison (*Bison bison)* Conservation Status and Recommendations for Denver Mountain Parks
Regis University, Denver CO Aug 2020 - Dec 2020

- Independent literature search on individual topic for project (health and genetics)
- Assessed and scored the conservation status of Denver Mountain Park's bison herds
- Provided recommendations for bison management to increase conservation status of the herds
- Worked with a group of students to write up a combined report on all topics of the herds

Do Macroinvertebrates Indicate Restoration Success in Semi-Arid Fresh Water Pools?

Evidence from the Mora River Watershed, New Mexico
Regis University, Denver CO Aug 2019 - Apr 2020

- Gathered and analyzed environmental and invertebrate data on ephemeral and perennial pools on the Rio Mora NWR to assist refuge managers on their restoration successes
- Designed research protocol, conducted statistical analysis, and presented findings to refuge managers
- Presented research findings at 2020 Front Range Student Ecology Symposium

The Use of Tongue-flicking May be a Good Indicator to Predict Feeding Behaviors for the Vipers at the Pittsburgh Zoo & PPG Aquarium
Pittsburgh Zoo & PPG Aquarium, Pittsburgh PA Nov 2018 - May 2021

- Wrote research proposal for the Pittsburgh Zoo, so the project could be approved
- Analyzed viper feeding behaviors in their captive environment
- Compared the rate of tongue flicks to striking behaviors
- Properly conducted research around potentially dangerous animals
- Worked effectively on my own and in a diverse group
- Created a scientific manuscript for the Pittsburgh Zoo & PPG Aquarium

Detection of Repeated Sequence Motifs in the Phospholipase A2 Gene
Family of Venomous Snakes
Waynesburg University, Waynesburg PA Feb 2016 - Apr 2017

- Aligned and analyzed rapid adaptive evolution of the phospholipase A2 gene family in various venomous snakes through MEGA software and analyzed through MEME software.
- Presented 3-semester research findings at the Western Pennsylvania Undergraduate Research Symposium

Academic Achievements

- 2020 Front Range Ecology Graduate Symposium Research Poster 2nd place Award 2020
- Gamma Sigma Epsilon National Chemistry Honor Society 2017
- Biology Club – President 2017
- Dean's List 2016 - 2017

Skills

- Animal handling
- Statistical analysis in R
- Geospatial analysis in ArcGIS and QGIS
- Microscopy light and dissection
- Knowledge of field techniques related to capturing and monitoring reptiles and amphibians
- Outdoor navigation via GPS
- Wildlife identification
- Organization and data management
- Leadership, problem-solving skills, and multi-tasking skills
- Communication through reports, presentations, formal and informal conversations

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CHAPTER 3. JOURNAL MANUSCRIPT

The Use of Tongue-flicking may be a Good Indicator to Predict Feeding Behaviors for the Vipers at the Pittsburgh Zoo & PPG Aquarium

Abstract

Squamates, and snakes in particular can sense their external environment via chemical cues. This chemosensory apparatus is used in many behaviors, especially those related to foraging, but few studies, if any have explored the relationship between pre-strike behaviors and feeding behaviors in a captive setting. This led me to ask the question whether tongue-flicking behavior can be indicative of striking behaviors in captive vipers at the Pittsburgh Zoo & PPG Aquarium. I answered this question by observing 9 different snakes across 6 species during their feeding times and seeing whether tongue-flicking rates were correlated at all to if a snake will strike and the latency of the strike. I discovered that as rate of flicks increased, the probability of a strike went up and as rate of flick increased the time of strike went down. This knowledge provides the keepers with insight on whether they should hold the prey in front of the snake for an extended period of time or just set the prey down and let the snake consume the prey at a later time. This may be the first study to quantitatively show the association between pre-strike tongue flicking and striking behavior.

Introduction

Squamate reptiles (lizards and snakes) rely on their ability to sense chemicals for many different reasons, including to help choose a mate and to recognize if a predator or prey is nearby (Baeckens et al. 2017). Additionally, there is a relationship between diet and chemosensory responses for various squamates (Cooper, 2007). Snakes are commonly studied to understand these relationships because many snakes have specific diet requirements compared to lizards, which are generally omnivores. Snakes detect chemicals by flicking their tongues and delivering the chemicals to the fenestra vomeronasalis, a pair of ducts that lead to the vomeronasal organ (Miller and Gutzke 1999). The vomeronasal organ is part of the accessory olfactory system (D'Aniellio et al. 2017). Both venomous and non-venomous snakes use the vomeronasal organ, and it allows the snake to know what is in the environment.

Because these snakes use tongue flicking and picking up chemicals as a strategy to hunt, they are well adapted and the use of their vomerolefactory system has become their most important sense (Baeckens et al. 2017). As interest piques and the snake detects scent particles, it will repeatedly flick its tongue to get more cues. Thus, the frequency of flicking may correlate to the type of food that is in the snake's proximate vicinity. If it is prey that the snake is interested in it will flick more, compared to a prey it is not interested in (Baeckens et al. 2017).

Because predators commonly prey on potentially dangerous animals, many predators have evolved behaviors that allow for them to hunt and feed, while being relatively unharmed (Farrell et al., 2018). Like many other predators, certain snakes have developed their own feeding behaviors. Various venomous snakes from the family Viperidae are known for committing a quick strike, envenomating their prey, and then backing away (Higham et al., 2017; Saviola et al., 2013). This allows vipers to acquire their meal with little to no risk of being bitten or scratched by their prey, a vital point for survival (Saviola et al. 2013). Afterwards, the snake must then relocate their meal, which is especially useful because they will take little damage to their body when committing to a strike. This could also mean that the viper may not find their next meal because they let it run away to die (Saviola et al. 2013). Most vipers use a typical strike and release technique as explained previously, however some do not. The dangerous prey hypothesis predicts that if an animal knows the danger level of its prey, it will decide whether to strike and release, or to hold onto the prey (Glaudas et al. 2017). These snakes in the wild are attempting to strike at dangerous prey, which is why they use the strike and release technique quite frequently.

In a captive setting the snakes may realize there is little threat from the prey, and there is no need for them to search for their food. The realization of there being little threat to themselves may cause the snake to strike and not release the prey (Glaudas et al. 2017). This knowledge allows for a focus in this study on the snake's interest level of feeding, without deciding if the prey can harm the snake or not. Although, this information could be useful for management in captive vipers, there are few studies that have examined whether tongue-flicking behavior will allow a zookeeper to tell the striking tendencies of a snake. Zookeepers have many duties throughout the day including basic welfare such as cleaning enclosures, feeding/nutrition, enrichment, veterinary appointments for their animals, public interaction, and record keeping. If zookeepers have an idea of whether a snake will strike, they may decrease their total time spent feeding each individual, ultimately providing more time to complete other husbandry duties for these snakes and other animals that the zookeepers oversee.

The goal of this study is to determine whether tongue flicking behavior is indicative of striking behavior in captive vipers. All snakes are housed in the World of Discovery building at the Pittsburgh Zoo & PPG Aquarium. I analyzed the extent of tongue-flicking a snake exhibits to assist the keepers assessing in whether the snake will strike at the prey. I hypothesized that tongue-flicking rate and the probability of striking at a prey item are positively correlated because tongue-flicking signals greater interest in a food item. I predict that snakes with higher tongue-flicking rates will be more likely to strike at their prey than snakes that have lower tongue-flicking rates. I also predict that snakes with higher tongue-flicking rates will have a shorter latency to strike than snakes with low tongue-flicking rates. This information will give the zookeepers a better idea of whether a snake will likely strike their prey or not, allowing for optimal care of these vipers and other animals that these keepers are responsible for at the Pittsburgh Zoo & PPG Aquarium due to the extra time the keepers will have in their day.

Methods

Study Site & Species Description

All observations for feeding behaviors in this study were taken between December of 2018 and June of 2019. The snakes chosen for this study were viper species in the World of Discovery Building at the Pittsburgh Zoo & PPG Aquarium. A total of nine individuals representing six snake species were analyzed during this study. Four snakes were from North America, *Crotalus adamenteus* (eastern diamondback rattlesnake), *Crotalus atrox* (western diamondback rattlesnake), *Crotalus horridus* (Timber rattlesnake), and *Crotalis viridis* (prairie rattlesnake). Two snakes were from South America, these species are: *Lachesis muta muta* (bushmaster) and *Crotalus durissus terrificus* (Pacific rattlesnake). One enclosure housed two individuals of *Crotalis durissus terrificus* (1 and 2), which were recorded separately in this study. The snakes being fed each day were chosen by the keeper feeding for that day. The snakes were fed thawed rats each feeding day. Recordings were taken under normal zoo feeding procedures, no feeding routines were changed for this study.

Non-Feeding Variable Protocol

Each day non-feeding variables that could influence snake feeding behaviors were recorded. There were two categorical variables which were recorded: the occupancy in the World of Discovery Building and the keeper performing the feeding for the day. Due to people coming in and out and only one person recording data, getting the exact number of occupants at any given time was not possible. To counter this limitation, at the beginning of the daily feeding session if there were very few people in the area it was recorded as empty, if there were large groups of individuals it was recorded as busy. The keeper that was feeding that day was recorded. Each keeper was given a number, assigned as either a zero or one to be used for data analysis. In addition, the last time a certain snake was fed was documented, reported in days ranging from 14-21 days. I also documented the outside temperature for that day. Before the feedings started, a temperature was recorded in Fahrenheit from the weather channel application for the Pittsburgh Zoo & PPG Aquarium's general area and then converted to Celsius.

Tongue Flicking Observation Protocol

Each day approximately 45 minutes before feeding would occur, a baseline tongue flick frequency for each snake was recorded when no food was present in the snake exhibits. Once in front of the exhibit, a 90 second timer was started after writing down what snake was about to be observed. For the next 90 seconds the number of times the snake would flick its tongue was recorded. This was recorded as flick frequency under normal conditions.

As the keeper opened the door and presented the rat to the snake with feeding tongs, a stopwatch was started the moment the rat crossed over the exhibit door area. After the stopwatch started, every tongue-flick the snake made was counted. The flicks were counted until either the snake struck, or 90 seconds was reached. If a snake struck the rat, then the time of strike was recorded. If after a certain time the keeper felt that the snake was not going to strike at the rat, the keeper would lay the rat down in the exhibit for the snake to possibly consume at a later time in the day. The steps above were then repeated for the feeding of each snake. After all data was taken, the number of flicks were turned into rates by dividing the flicks by the amount of time observed. This turned into a normal rate of flicking (ROFN) and rate of flicking when a rat is present (ROFR).

Data Analysis

To determine a relationship between strikes and rate of flicks, general linear mixed effect models with a binomial error structure were run using the *glmer* function in the *lme4* package in R (Bates et al. 2015; R Core Team, 2019). To determine the best model to be used for analysis, I did a manual stepwise addition of predictor variables to find the model with the lowest AIC value. The possible predictor variables added were which keeper was doing the feeding, time since last feeding, normal rate of flicking, rate of flicking when a rat is present, the visitor occupancy in the building, and the outdoor temperature. To determine a relationship between rate of tongue-flicks and time of strike general linear mixed effect models were run with a poisson error structure. I used the same potential predictor variables and model selection approach as the strike and rate of flick models.

Results

The best model fit with striking behavior as a binary response included rate of flick when rats were present (ROFR), the keeper, the time since last feed, rate of flick under normal conditions (ROFN), and the amount of visitors present as predictors of the probability of striking at a prey item while also accounting for the random effect of each snake. This model was chosen because it possessed the lowest AIC value of all models (79.1) with a ΔAIC value of 1.3. The AIC values range from 79.1 for the best model to 82.6 for the highest AIC model. This model shows that as tongue flicking increases there is an increase in the odds of a strike occurring (figure 1a), specifically, for every 1/10 unit increase in the rate of flicks when a rat is present there is 185% increase in the odds of a strike occurring at a prey item ($p < 0.001$, 95% CI: 77% increase - 500% increase). Whenever the keeper changes there is a 3% increase in the odds of a strike occurring at a prey item, but this was not significant ($p = 0.964$, 95% CI: 77% decrease – 384% increase). For every day since the snakes last ate, there is a 19% decrease in the odds of a snake striking at a prey item, although this was not significant ($p = 0.201$, 95% CI: 44% decrease - 10% increase). For every 1/10 unit change in the normal rate of flick there is a 17% decrease in the odds of a snake striking at a prey item, but this was not significant ($p = 0.790$, 95% CI: 80% decrease – 223% increase). When there is a change in visitors from empty to busy, there is an 82% decrease in the odds of a strike occurring at a prey item ($p = 0.030$, 95% CI: 97% decrease - 24% decrease).

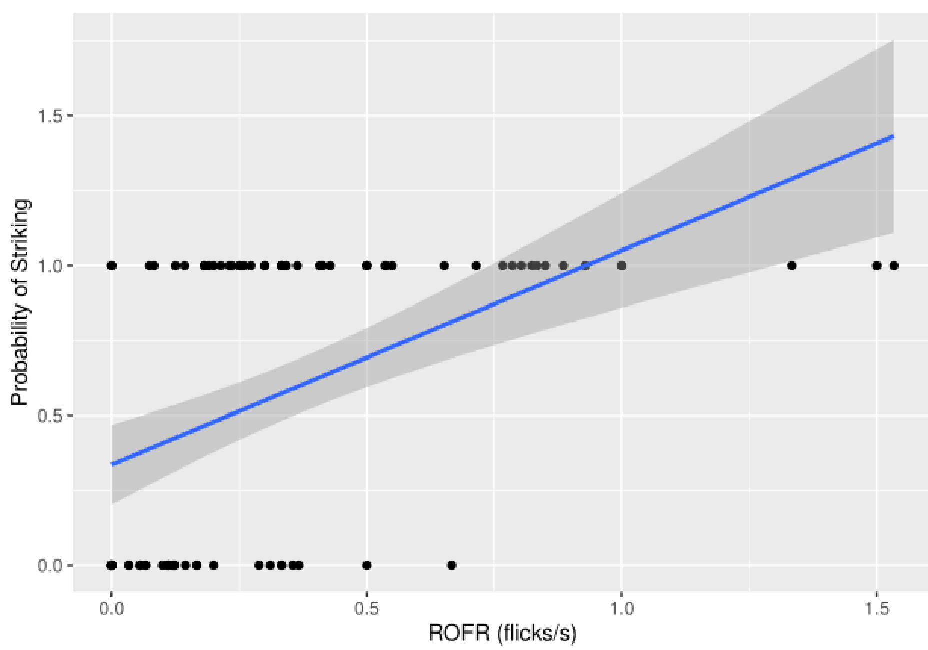

Figure 1a: Relationship between rate of flicks and probability of strike from the best-fitting model. The blue line represents the relationship between the probability of striking and the ROFR. The gray shading is the 95% confidence interval of the relationship.

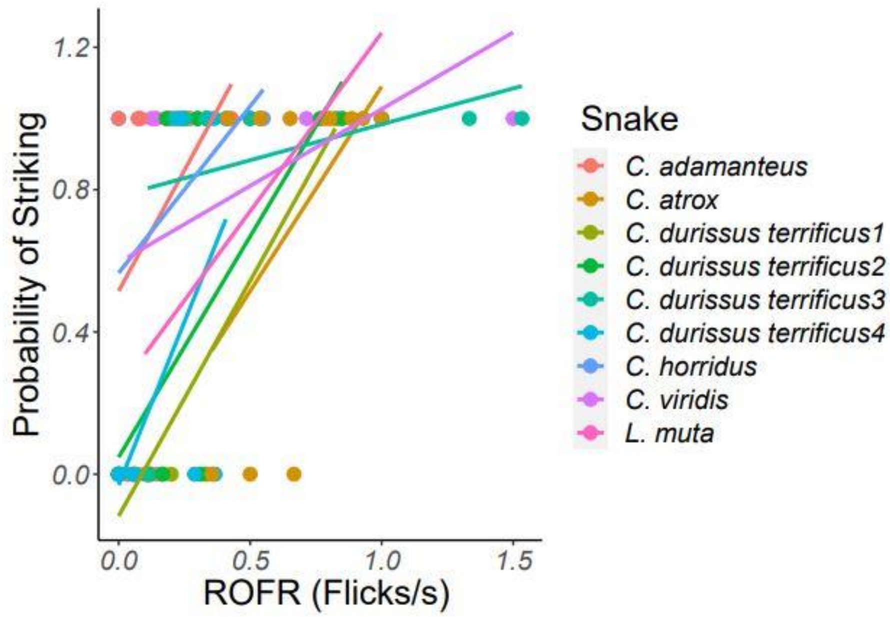

Figure 1b: Relationship between rate of flicks and probability of striking from the best-fitting model for each snake. Each line shows the general relationship between the amount of tongue-flicking to if a snake will strike or not. Each snake has its own dot and line color as seen on the legend to the right of the graph. The colored line represents the relationship between the Probability of Striking and the ROFR for that specific snake.

The latency to strike at prey as a response was best predicted by the same predictors as the probability of a strike occurring, including ROFR, the keeper, the time of last feeding, the ROFN, and the amount of visitors as predictors while also accounting for the random effect of each snake. To select the best model, I used the model with the lowest AIC value (477.9) with a ΔAIC of 0.7. The AIC values ranged from 446.6 to 509.1. This model shows that as the rate of tongue-flicking increases, there is a slight decrease on the time of strike (Figure 2a). For every 1/10 unit increase in the ROFR the time to strike at a prey item decreased by 10% ($p < 0.001$, 95% CI: 13% decrease - 7% decrease). Whenever the keeper changes there is a 1% decrease in the odds of the TOS increasing, although this was not significant ($p = 0.872$, 95% CI: 16% decrease - 15% increase). There is a 5% increase in the time of strike occurring for every 1 increase in days since the snake was last fed ($p = 0.001$, 95% CI: 2% increase – 8% increase).

For every 1/10 unit increase in baseline tongue-flicking there is a 3% increase in the time of strike occurring, although this was not significant ($p < 0.452$, 95% CI: 41% decrease - 215% increase). Whenever the building is primarily empty there is a 107% increase in the time of strike occurring ($p < 0.001$, 95% CI: 5% decrease - 12% increase). All effects are reported when all other variables are held constant.

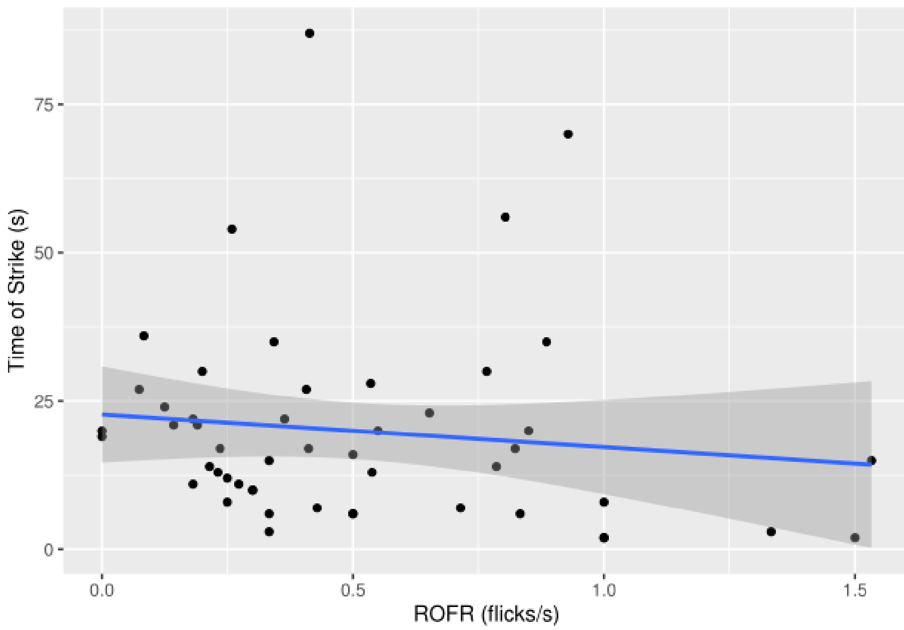

Figure 2a: Relationship between time of strike and rate of tongue flicks from the best-fitting model. Each dot displays an individual feeding event. The blue line is the relationship between the time of strike and the ROFR. The gray shading around the blue line is the 95% confidence interval of the relationship.

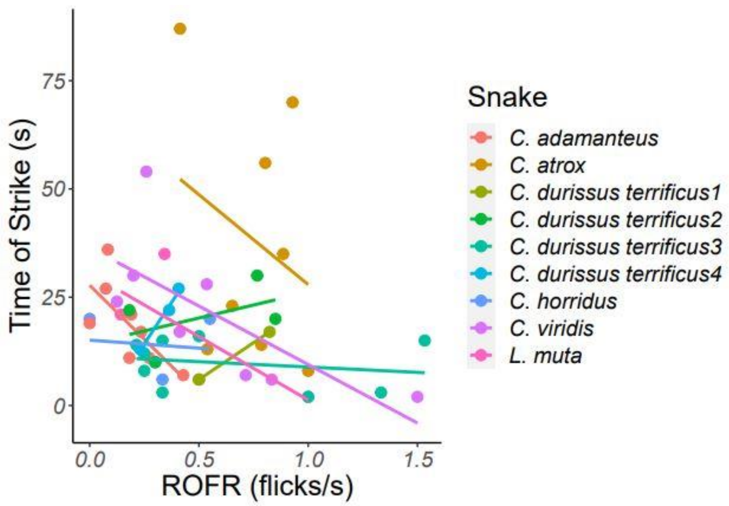

Figure 2b: Relationship between time of strike and rate of tongue flicks from the best-fitting model for each individual. Each snake has its own color for each dot and line. Each dot represents an individual feeding event. Each line shows the relationship between the time of strike and the ROFR for each snake.

Discussion

In this study I set out to answer the question of whether a zookeeper can determine if a snake will strike based on its tongue-flicking behavior. I quantified this behavior as two different responses (striking and time of strike), that provided similar results. Striking had a very strong, significant relationship to tongue-flicking, while time of strike had a significant, but not as strong relationship to tongue-flicking. The rate of tongue-flicking may be a great indicator on whether a snake will strike, as there was a very strong relation. But if a keeper looks at the rate of tongue-flicking they may have a difficult time telling how long it will be before a snake strikes at the prey item. Generally, although there may be variation between snakes, the more tongue-flicking the snake does, the less latency there is for a strike. Based on these results, it leads me to believe that snakes may be using their tongues to determine whether they will strike, but also that other senses may also be used to decide how quickly to strike.

I predicted that a greater rate of tongue flicking would lead to a greater probability of a strike occurring because vipers detect external olfactory cues using this behavior. Generally, my statistical findings are in line with this prediction, and as the rate of flicks increased the odds of a strike occurring dramatically increased. To my knowledge, this is the only study investigating this specific association. The results from this research may only be based on one study but may provide important knowledge for the husbandry and behavioral ecology fields. To further our understanding of this relationship, it would be beneficial if other research projects continue to investigate this relationship between tongue-flicking and striking behaviors.

The time of strike had a relatively weak effect compared to if a strike would occur. I believe this is happening because the snakes may be supplementing their olfactory senses using their eyes and possibly their infrared detectors (loreal pits) to find and assess prey items, rather than just their vomeronasal organ. Typically, studies analyzing tongue-flicking look at scent trailing and how snakes track down their prey such as how odor concentration can impact trailing behavior or rattlesnakes (Smith et al., 2005). It is common for snakes to strike at prey moving around them (Burghardt & Denny, 1983; Shine & Sun, 2003). If the viper has picked up the chemical cue that a prey item is in the area and sees that prey item enter its enclosure it may strike quickly from its instinct without many flicks. At times zookeepers may move the prey item around, to elicit a response from the snake due to the movement of the prey, imitating it being alive. A previous study has shown that pit-vipers prefer to strike at prey items which could be live prey (based on thermal and movement cues) rather than dead items (Shine & Sun, 2003). If the viper species at the Pittsburgh Zoo & PPG Aquarium see the prey and know the scent of the prey, they may not need additional information and decide to strike shortly after detecting their prey. These reasons may be why there are such different variations among snakes in regard to strike latency.

There may also be some limitations in this study that might be leading to tongue-flicking not having as strong of an effect on time of strike. These snakes were fed a rat during every feeding session. The vomeronasal organ is the primary way that snakes obtain chemical information. Different stimuli can lead to different responses depending on the snake species snakes (de Cock Buning, 1983; Schivik & Clark, 1997). But these snakes are collecting the same information every time due to being fed the same prey item. If a different prey item was presented, we may see different tongue-flicking rates and variations in time of strike due to the variation in their diet. It has been shown that some lizard attacks on prey are dependent on the stimuli and prey presented (Recio et al., 2020). This has also been discussed in garter snakes, that elicit different responses to cotton swabs being presented to them depending on what scent is on the swab (Fuchs & Burghardt, 1971). These previous results lead me to believe that with diet variation zookeepers may see different responses to prey items than observed in this study.

The knowledge gained from this study can be used by zookeepers to increase the welfare of the animals at the Pittsburgh Zoo & PPG Aquarium. As time goes on, zookeepers are looking for the best possible way to provide optimal care for their animals. The information here allows zookeepers to determine early on if there will be a strike or not. If a snake is exhibiting a large amount of tongue flicking, for these specific snakes, it may mean that the snake is going to strike and that the faster the rate is, the better there is a chance of a strike occurring. This knowledge can lead the keepers to continue holding the prey item out because eventually the snake is going to strike, but how soon that strike will occur, may not be known. With this study looking at tongue-flicking to indicate feeding responses, I have discovered valuable knowledge for pre-strike behavior rather than post-strike behavior in an applied, animal husbandry setting.

Acknowledgements

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CHAPTER 4.

Rattlesnake Roundups: Could Educational Roundups be the new Future for the Town of Sweetwater, Texas?

Introduction

Rattlesnake roundups are large annual events that draw spectators from all around the world. The world's largest rattlesnake roundup occurs every March in Sweetwater, Texas. The town of Sweetwater typically has a population of 11,000, but during the roundup the town's population explodes to 40,000 (Sweetwater Jaycees). This weekend-long event has many festivities that capture the local culture: a miss snake charmer pageant, a carnival, a cookoff, and the gun, knife, and coin show (Sweetwater Jaycees). Then there is the main event, the roundup itself, where hunters bring the snakes they caught to the roundup where the snakes are thrown into a pit together. They are then moved to the milking pit, where the snake venom is collected for future use in antivenom. After that, the snakes go to a research station where they are measured, sexed, and weighed. Finally, they end up in the skinning pit where they are beheaded and skinned, and their skin is turned into various items (National Geographic, 2010).

This rattlesnake roundup causes a conflict between herpetologists and conservationists, the hunters of Sweetwater, and the general population of humans that live in or near rattlesnake habitat. Sweetwater's roundup started in 1958 and is a part of the town's culture, while also bringing in a significant amount of money for the community. Animal rights activists and scientists object that roundups use unethical methods of capturing the snakes and harm rattlesnake populations. I believe this culture of killing rattlesnakes needs to change. I propose to resolve these conflicts by implementing a no-kill roundup. Sweetwater can celebrate their local culture, but instead of killing the snakes, use the festivities as an opportunity for education and conservation.

Figure 1: Example of a Rattlesnake pit from the 2019 Sweetwater Texas Rattlesnake roundup, (Villegas, 2019.)

Background Information on Rattlesnake Roundups

For many years rattlesnake roundups have been community events and doubled as community fundraisers (Adams & Thomas, 2008). Rattlesnake roundups began west of the Mississippi River in Oklahoma during the late 1930's with the primary goal of eradicating the western diamondback rattlesnake (*Crotalus atrox*). Areas east of the Mississippi River started similar events for the eastern diamondback rattlesnake (*Crotalus adamanteus*) in Alabama around the late 1950s (Means, 2009). Currently, there are only four states that allow "killing" rattlesnake roundups to occur: Alabama, Georgia, Oklahoma, and Texas. The Sweetwater roundup event is on its 63rd consecutive year and has not declared that they will be switching to a no-kill roundup anytime soon. This event and all that it includes is deeply ingrained in the culture of the town (NPR, 2020).

Due to the controversy over the harm that these events may be having on rattlesnakes, and some unethical approaches to catching the snakes, many states have switched from roundups to wildlife festivals. Some of these events have a key focus on education, such as the wildlife festival in Claxton, Georgia (Villegas, 2019). At Claxton's festival, the event is focused on all forms of wildlife rather than focusing specifically on snakes. They have raptor shows, snake tagging demonstrations, and even dog handler shows that the public can attend. Other events have decided to go a different route, in Pennsylvania, some events still decide to hold roundups, but they are no-kill roundups that focus on education and research. One town that does this is the Noxen, Pennsylvania. This event serves as a large fundraiser for the Noxen volunteer fire department (Noxen PA, 2021) Many places are switching to festivals and no-kill roundups and are still successful events.

Stakeholders

Herpetologists/Conservationists

Many research and conservation groups such as the Center for Biological Diversity are fighting against rattlesnake roundups hoping that they are either terminated or do not allow the roundups to kill the snakes. Quantitative population effects on rattlesnakes from roundups are relatively unknown, however, there is evidence that these roundups may impact rattlesnake life histories. A study on eastern diamondback rattlesnakes investigated the impacts on the eastern diamondback's populations from four different towns rattlesnake roundups and found that the mean weight of the heaviest snakes turned in had decreased up to 21% over the past 50 years (Means, 2009). As snakes grow their entire life, this statistic shows that the largest snakes are younger than they used to be, which can affect breeding, as eastern diamondbacks reach sexual maturity around the age of 3 and clutch size is said to be correlated with body size. If the average snake size is decreasing, this threatens the whole population, as snakes will, on average, produce smaller clutches (Means, 2009).

A common technique used to catch rattlesnakes for roundups is known as gassing, where snake hunters pour gasoline through a tube into rattlesnake dens. When the fumes reach the rattlesnakes, they leave their dens in a daze, allowing for rattlesnake hunters to catch the snakes (Center for Biological Diversity, 2017). Not only does this have an effect on the snakes the hunters are going after, but also impacts other animals that may be around the gassing area. For western diamondback rattlesnakes, gassing also harms invertebrates and burrowing owls (Center for Biological Diversity, 2017). For rattlesnakes in the eastern portion of the United States, this leads to negative impacts on gopher tortoises, as sometimes rattlesnakes decide to den in the tortoise burrows (Speake & Mount, 1973).

Roundup participants and the Sweetwater Community

The annual Sweetwater roundup represents more than just an event for the community; it is a part of their culture and history. Back when the event began in 1958, the main focus was attempting to eradicate rattlesnakes in the area. Today, the town no longer tries to eradicate the snakes, aiming instead to check their population (National Geographic, 2010). Some members have even said that they do not wish to eradicate the rattlesnakes but to teach people to live around them (NPR, 2020). Whatever the motivation, the roundups represent a large source of revenue and opportunity to the community: approximately 8.3 million dollars (NPR, 2020).

The revenue does not just go into local businesses for private use; the money is invested into the community. Sweetwater uses the proceeds to provide Thanksgiving and Christmas dinners for families that cannot afford them, host toy drives, and even provide college scholarships for town residents, thus providing the residents opportunities that they may not have otherwise coming from the small town of Sweetwater (NPR, 2020). The town and rattlesnake hunters would prefer to keep this roundup here, because getting rid would impede on their culture and possibly the economic benefits the town gets from the event.

Humans in Rattlesnake Areas

Snakes are one of the most common fears among humans (Souchet & Aubret, 2016). As a previous employee of the Pittsburgh Zoo & PPG Aquarium, there have been many times that I have showed a snake to an individual and they reacted in fear, running away from the snake, or screaming because they instinctively fear it. Other individuals may dislike snakes because they view snakes as pests. There are also multiple times that I have heard individuals state that the only good snake is a dead snake. This shows me that there is a miscommunication between snakes and people, that some humans do not understand the importance of snakes to the ecosystem. One way that snakes benefit ecosystems is by secondary seed dispersal. They disperse these seeds by consuming rodents who have previously eaten seeds, promoting plant dispersal (Reiserer et al., 2018). Another import point that humans may not understand, is that snakes do not want to harm them. The most common behavioral response is for snakes to hide or move away. If a snake does bite an individual, it is likely defending itself and viewing a human as a predator trying to harm it (Gibbons & Dorcas, 2002). To put this into context, in the United States there are around 7,000-8,000 annual human envenomation's, and on average only 5 lead to deaths (Center for Disease Control, 2018).

In Georgia a petition had over 5,000 signatures from individuals wanting the Whigham Georgia roundup to switch to wildlife events promoting education about rattlesnakes. When the Claxton Georgia event switched from killing snakes to having educational presentation, among other festivities, there were still approximately 15,000 people that attended (Center for Biological Diversity). This shows that people want to learn about rattlesnakes. These kinds of events can provide important information for people that spend time in rattlesnake country and make them feel safe while enjoying the outdoors.

Proposed Solution

Accounting for all stakeholders, my proposed solution involves education, science, and still allowing snake hunters to capture snakes, but not to kill them. This solution is similar to the Georgia and Pennsylvania conversions, but will have some different aspects that allow Sweetwater's roundup to be one of a kind. The town of Sweetwater can still hold rattlesnake events, but they will entail a much different itinerary than usual. The success of rattlesnake roundups switching to wildlife events which promote education, this leads me to believe that Sweetwater Texas can accomplish this and be successful. For them to still hold the title as the largest event in the world of this kind, they will need to have some festivities that others do not have.

The rattlesnake hunters can still capture the snakes, but they will not kill them. Whenever they capture a snake, they will mark/tag the snake and obtain a GPS coordinate to where that snake was captured. This will allow the snakes to be brought back to the location where they were found. There will be no gassing of the snakes, this will cause hunters to have to find different ways to capture the snakes without harming the snakes, or other wildlife. This may require participants to capture snakes when they are outside of their den. Whenever the snakes are brought back to the event area, the snakes can be used for educational purposes. The town can team up with herpetologists and wildlife experts to show people all about rattlesnakes and other wildlife. Visitors who come to this event can be up close to snakes, among other animals, that are living, and learn that they can feel safe around them. Many other aspects of the festival can still continue as normal, there can still be cookoffs and coin shows among other activities, such as bringing in various groups to educate visitors on different forms of wildlife. This will allow the town to still create revenue, create an educational environment, and no snakes will be harmed in the process. This method may lose a portion of revenue from killing the snakes, but educational additions to the roundup will help bring in revenue that will be lost. With other towns successfully changing their ways, I believe this is the best possible solution for Sweetwater that has the potential to please all stakeholders.

Conclusion

Rattlesnake roundups have been around for many years. Typically, these events have been known for harming and killing snakes. Changing the focus of these events is necessary because of the unethical approaches of capturing and killing the snakes and possible effects they can have on populations. Some states have been successful in switching from kill-events to creating educational events. I believe that if Sweetwater Texas makes this shift, that they will still be successful at creating revenue, while keeping their culture of capturing these snakes. This will create a fun and educational environment for the local community and tourists alike and has a chance to be a very successful event.

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